भारत की राष्ट्रीय भवन निर्माण संहिता 2005

National Building Code of India 2005

भारतीय मानक ब्यूरो

BUREAU OF INDIAN STANDARDS

भारत की राष्ट्रीय भवन निर्माण संहिता 2005

NATIONAL BUILDING CODE OF INDIA 2005

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BUREAU OF INDIAN STANDARDS

SP 7 : 2005

FIRST PUBLISHED 1970
FIRST REVISION 1983
SECOND REVISION 2005

© BUREAU OF INDIAN STANDARDS

ICS 0.120; 91.040.01
ISBN 81-7061-026-5

PRICE Rs. 7 550.00

PUBLISHED BY BUREAU OF INDIAN STANDARDS, MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG, NEW DELHI 110 002, PRINTED AT SUNSHINE PROCESS, C-105/5, NARAINA INDUSTRIAL AREA, PHASE I, NEW DELHI 110 028 (INDIA).

FOREWORD

Construction programmes are interwoven in a large measure in all sectors of development, be it housing, transport, industry, irrigation, power, agriculture, education or health. Construction, both public and private, accounts for about fifty percent of the total outlay in any Five Year Plan. Half of the total money spent on construction activities is spent on buildings for residential, industrial, commercial, administrative, education, medical, municipal and entertainment uses. It is estimated that about half of the total outlay on buildings would be on housing. It is imperative that for such a large national investment, optimum returns are assured and wastage in construction is avoided.

Soon after the Third Plan, the Planning Commission decided that the whole gamut of operations involved in construction, such as, administrative, organizational, financial and technical aspects, be studied in depth. For this study, a Panel of Experts was appointed in 1965 by the Planning Commission and its recommendations are found in the 'Report on Economies in Construction Costs' published in 1968.

One of the facets of building construction, namely, controlling and regulating buildings through municipal byelaws and departmental handbooks received the attention of the Panel and a study of these regulatory practices revealed that some of the prevailing methods of construction were outmoded; some designs were overburdened with safety factors and there were other design criteria which, in the light of newer techniques and methodologies, could be rationalized; and building byelaws and regulations of municipal bodies which largely regulate the building activity in the country wherever they exist, were outdated. They did not cater to the use of new building materials and the latest developments in building designs and construction techniques. It also became clear that these codes and byelaws lacked uniformity and they were more often than not 'specification oriented' and not 'performance oriented'.

These studies resulted in a recommendation that a National Building Code be prepared to unify the building regulations throughout the country for use by government departments, municipal bodies and other construction agencies. The then Indian Standards Institution (now Bureau of Indian Standards) was entrusted by the Planning Commission with the preparation of the National Building Code. For fulfilling this task a Guiding Committee for the preparation of the Code was set up by the Civil Engineering Division Council of the Indian Standards Institution in 1967. This Committee, in turn, set up 18 specialist panels to prepare the various parts of the Code. The Guiding Committee and its panels were constituted with architects, planners, materials experts, structural, construction, electrical illumination, air conditioning, acoustics and public health engineers and town planners. These experts were drawn from the Central and State Governments, local bodies, professional institutions and private agencies. The first version of the Code was published in 1970.

After the National Building Code of India was published in 1970, a vigorous implementation drive was launched by the Indian Standards Institution to propagate the contents and use of the Code among all concerned in the field of planning, designing and construction activities. For this, State-wise Implementation Conferences were organized with the participation of the leading engineers, architects, town planners, administrators, building material manufacturers, building and plumbing services installation agencies, contractors, etc.

These Conferences were useful in getting across the contents of the Code to the interests concerned. These Conferences had also helped in the establishment of Action Committees to look into the actual implementation work carried out by the construction departments, local bodies and other agencies in different States. The main actions taken by the Action Committees were to revise and modernize their existing regulatory media, such as, specifications, handbooks, manuals, etc, as well as building byelaws of local bodies like municipalities at city and town levels, zilla parishads, panchayats and development authorities, so as to bring them in line with the provisions contained in the National Building Code of India. In this process, the Indian Standards Institution rendered considerable support in redrafting process.

Since the publication in 1970 version of the National Building Code of India, a large number of comments and useful suggestions for modifications and additions to different parts and sections of the Code were received as a result of use of the Code by all concerned, and revision work of building byelaws of some States. Based on the comments and suggestion received the National Building Code of India 1970 was revised in 1983.

Some of the important changes in 1983 version included : addition of development control rules, requirements for greenbelts and landscaping including norms for plantation of shrubs and trees, special requirements for low income housing; fire safety regulations for high rise buildings; revision of structural design section based on new and revised codes, such as Concrete Codes (plain and reinforced concrete and prestressed concrete), Earthquake Code, Masonry Code; addition of outside design conditions for important cities in the country, requirements relating to noise and vibration, air filter, automatic control, energy conservation for air conditioning; and guidance on the design of water supply system for multi-storeyed buildings.

The National Building Code of India is a single document in which, like a network, the information contained in various Indian Standards is woven into a pattern of continuity and cogency with the interdependent requirements of Sections carefully analyzed and fitted in to make the whole document a cogent continuous volume. A continuous thread of 'preplanning' is woven which, in itself, contributes considerably to the economies in construction particularly in building and plumbing services.

The Code contains regulations which can be immediately adopted or enacted for use by various departments, municipal administrations and public bodies. It lays down a set of minimum provisions designed to protect the safety of the public with regard to structural sufficiency, fire hazards and health aspects of buildings; so long as these basic requirements are met, the choice of materials and methods of design and construction is left to the ingenuity of the building professionals. The Code also covers aspects of administrative regulations, development control rules and general building requirements; fire protection requirements; stipulations regarding materials and structural design; rules for design of electrical installations, lighting, air conditioning and lifts; regulation for ventilation, acoustics and plumbing services, such as, water supply, drainage, sanitation and gas supply; measures to ensure safety of workers and public during construction; and rules for erection of signs and outdoor display structures.

Some other important points covered by the Code include 'industrialized systems of building' and 'architectural control'. The increase in population in the years to come will have a serious impact on the housing problem. It has been estimated that the urban population of India will continue to increase with such pace as to maintain the pressure on demand of accommodation for them. Speed of construction is thus of an utmost importance and special consideration has to be given to industrialized systems of building. With increased building activity, it is also essential that there should be some architectural control in the development of our cities and towns if creation of ugliness and slum-like conditions in our urban areas is to be avoided.

Since the publication of 1983 version of National Building Code of India, the construction industry has gone through major technological advancement. In the last two decades, substantial expertise has been gained in the areas of building planning, designing and construction. Also, lot of developments have taken places in the techno-legal regime and techno-financial regime, apart from the enormous experience gained in dealing with natural calamities like super cyclones and earthquakes faced by the country. Further, since the last revision in 1983 based on the changes effected in the Steel Code, Masonry Code and Loading Code as also in order to update the fire protection requirements, three amendments were brought out to the 1983 version of the Code. Considering these, it was decided to take up a comprehensive revision of the National Building Code of India.

The changes incorporated in the present Code, which is second revision of the Code, have been specified in the Foreword to each Part/Section of the Code. Some of the important changes are:

a) A new Part 0 'Integrated Approach — Prerequisite for Applying the Provisions of the Code' emphasizing on multi-disciplinary team approach for successfully accomplishing building/development project, has been incorporated.

b) New chapters on significant areas like structural design using bamboo, mixed/composite construction and landscaping have been added.

c) Number of provisions relating to reform in administration of the Code as also assigning duties and responsibilities to all concerned professionals, have been incorporated/modified. Also detailed provisions/ performance to ensure structural sufficiency of buildings, have been prescribed so as to facilitate implementation of the related requirements to help safely face the challenges during natural disasters like earthquake.

d) Planning norms and requirements for hilly areas and rural habitat planning, apart from detailed planning norms for large number of amenities have been incorporated.

e) Fire safety aspects have been distinctly categorized into fire prevention, life safety and fire protection

giving detailed treatment to each based on current international developments and latest practices followed in the country.

f) Aspects like energy conservation and sustainable development have been consistently dealt with in various parts and sections through appropriate design, usage and practices with regard to building materials, construction technologies and building and plumbing services. Renewable resources like bamboo and practices like rain water harvesting have been given their due place.

g) The latest revised earthquake code, IS 1893 (Part 1) : 2002 'Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings', has been incorporated, due implementation of the provisions of which in applicable seismic zone of the country, needs to be duly adhered to by the Authorities.

The Code now published is the third version representing the present state of knowledge on various aspects of building construction. The process of preparation of the 2005 version of the Code had thrown up a number of problems; some of them were answered fully and some partially. Therefore, a continuous programme will go on by which additional knowledge that is gained through technological evolution, users' views over a period of time pinpointing areas of clarification and coverage and results of research in the field, would be incorporated in to the Code from time to time to make it a living document. It is, therefore, proposed to bring out changes to the Code periodically.

The provisions of this Code are intended to serve as a model for adoption by Public Works Departments and other government construction departments, local bodies and other construction agencies. Existing PWD codes, municipal byelaws and other regulatory media could either be replaced by the National Building Code of India or suitably modified to cater to local requirements in accordance with the provisions of the Code. Any difficulties encountered in adoption of the Code could be brought to the notice of the Sectional Committee for corrective action.

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Joint Director (Civil Engineering)

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Ad-hoc Group for Part 0 of NBC, CED 46:AG

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Panel for Administration, Development Control Rules and General Building Requirements, CED 46:P1

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Panel for Fire Protection, CED 46:P2

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Panel for Building Materials, CED 46:P3

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Panel for Loads, Forces and Effects, CED 46:P4

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Structural Engineering Research Centre (CSIR), Chennai	SHRI C. V. VAIDYANATHAN SHRI K. MANI (*Alternate*)
The Institution of Engineers (India), Kolkata	SHRI P. P. DHARWADKAR
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In personal capacity (*Emeritus Scientist, Structural Engineering Research Centre, Madras CSIR Campus, Taramani, Chennai 600 113*)	DR T. V. S. R. APPA RAO
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Panel for Soils and Foundations, CED 46:P5

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Panel for Timber, CED 46:P6

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Panel for Masonry, CED 46:P7

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Panel for Plain, Reinforced and Prestressed Concrete, CED 46:P8

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Gammon India Ltd, Mumbai	SHRI S. A. REDDI
Hindustan Prefab Limited, New Delhi	SHRI HAZARI LAL SHRI M. KUNDU (*Alternate*)
Larsen and Toubro Ltd, ECC Construction Group, Chennai	SHRI K. P. RAGHAVAN SHRI S. KANAPPAN (*Alternate*)
Ministry of Road Transport and Highways, New Delhi	SHRI T. B. BANERJEE SHRI SATISH KUMAR (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	DR ANIL KUMAR SHRI H. K. JULKA (*Alternate*)
Research, Designs and Standards Organization (Ministry of Railways), Lucknow	SHRI R. K. GUPTA SHRI J. P. DAS (*Alternate* I) SHRI A. K. GUPTA (*Alternate* II)
Structural Engineering Research Centre (CSIR), Chennai	DR N. LAKSHMANAN SHRI H. G. SREENATH (*Alternate*)
Tandon Consultants, New Delhi	SHRI MAHESH TANDON
The Institution of Engineers (India), Kolkata	SHRI S. S. CHAKRABARTY

Panel for Steel, CED 46:P9

Organization	*Representative(s)*
MECON Ltd, Ranchi	SHRI A. BASU (***Convener***)
Central Public Works Department, New Delhi	CHIEF ENGINEER SUPRINTENDING ENGINEER (P & A) (*Alternate*)
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI D. K. DINKER COL V. K. TYAGI (*Alternate*)
Indian Institute of Technology, Chennai	DR V. KALYANARAMAN
Institute for Steel Development and Growth, Kolkata	DR T. K. BANDYOPADHYAY SHRI ARIJIT GUHA (*Alternate* I) SHRI P. L. RAO (*Alternate* II)
Kalpataru Power Transmission Ltd, Gandhinagar	SHRI M. C. MEHTA SHRI B. K. SATISH (*Alternate*)
M. N. Dastur and Co Ltd, Kolkota	SHRI SATYAKI SEN SHRI TAPAN KUMAR BHAUMIK (*Alternate*)

Organization	*Representative(s)*
Research, Designs and Standards Organization (Ministry of Railways), Lucknow	SHRI R. K. GUPTA SHRI D. K. SINGH (*Alternate*)
SPECO Engineering Pvt Ltd, New Delhi	SHRI ONKAR SINGH
Structural Engineering Research Centre (CSIR), Chennai	DR S. SEETHARAMAN SHRI S. ARUL JAYACHANDRAN (*Alternate*)
The Institute of Engineers (India), Kolkata	SHRI R. P. GUPTA

Panel for Prefabrication and Systems Buildings, CED46:P10

Organization	*Representative(s)*
Larsen and Toubro Ltd, Chennai	SHRI A. RAMAKRISHNA (***Convener***) SHRI K. V. RANGASWAMI (*Alternate*)
B. G. Shrike Construction Technology Pvt Ltd, Pune	SHRI G. R. BHARITKAR SHRI R. P. JAKHALEKAR (*Alternate*)
Central Building Research Institute (CSIR), Roorkee	SHRI B. N. HIRA SHRI D. K. GAUTAM (*Alternate*)
Central Public Works Department, New Delhi	CHIEF ENGINEER (NDZ-III) SHRI A. K. GARG (*Alternate*)
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	COL R. N. MALHOTRA SHRI P. K. GUPTA (*Alternate*)
Hindustan Prefab Limited, New Delhi	SHRI HAZARI LAL SHRI M. KUNDU (*Alternate*)
Institute for Steel Development and Growth, Kolkata	DR T. K. BANDYOPADHYAY SHRI ALOK BAISHYA (*Alternate*)
Lloyd Insulations (India) Ltd, New Delhi	SHRI MOHIT KHANNA SHRI K. K. MITRA (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	SHRI H. K. JULKA SHRI SATISH SHARMA (*Alternate*)
Shirish Patel and Associates Consultants Pvt Ltd, Mumbai	SHRI SHIRISH B. PATEL SHRI P. H. SRINIVASACHAR (*Alternate*)
Structural Engineering Research Centre (CSIR), Chennai	SHRI H. G. SREENATH SHRI R. JAYARAMAN (*Alternate*)
System Building Technologists, New Delhi	SHRI G. B. SINGH
The Indian Institute of Architects, Mumbai	SHRI S. R. SIKKA
The Institution of Engineers (India), Kolkata	DR R. K. BHANDARI SHRI P. B. VIJAY (*Alternate*)

Panel for Constructional Practices and Safety, CED 46:P11

Organization	*Representative(s)*
In personal capacity (*103, Charak Sadan, Vikaspuri, New Delhi 110 018*)	SHRI P. KRISHNAN (***Convener***)
Adlakha and Associates, New Delhi	SHRI PRAMOD ADLAKHA
Builders Association of India, Mumbai	SHRI RAJ PAL ARORA
Central Building Research Institute (CSIR), Roorkee	SHRI N. K. SHANGARI SHRI B. S. GUPTA (*Alternate*)
Central Public Works Department, New Delhi	SHRI R. P. BHARDWAJ
Construction Industries Development Council, New Delhi	SHRI P. R. SWARUP SHRI SUNIL MAHAJAN (*Alternate*)
Director General of Factory Advice Service and Labour Institute (Ministry of Labour), Mumbai	SHRI S. K. DUTTA SHRI I. ROYCHOWDHURI (*Alternate*)

Organization	*Representative(s)*
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI DINESH SIKAND SHRI A. K. SINGH (*Alternate*)
Engineers India Limited, New Delhi	SHRI M. P. JAIN SHRI A. K. TANDON (*Alternate*)
Gammon India Ltd, Mumbai	SHRI K. N. CHATTERJEE SHRI S. C. SARIN (*Alternate*)
Indian Plywood Industries Research and Training Institute, Bangalore	SHRI H. GURUVA REDDY SHRI M. PAVAN KUMAR (*Alternate*)
Larsen and Toubro Ltd, Chennai	SHRI R. P. SAKUNIA
National Building Construction Corporation, New Delhi	SHRI B. PRASAD SHRI N. P. AGARWAL (*Alternate*)
School of Planning and Architecture, New Delhi	DR V. THIRUVENGADAM
The Indian Institute of Architects, Mumbai	SHRI KAILASH CHANDRA JAITIA SHRI C. M. SAPRA (*Alternate*)
The Institution of Engineers (India), Kolkata	SHRI H. P. JAMDAR SHRI K. B. RAJORIA (*Alternate*)

Panel for Lighting and Ventilation, CED 46:P12

Organization	*Representative(s)*
Central Building Research Institute (CSIR), Roorkee	SHRI V. K. MATHUR (***Convener***) DR ISHWAR CHAND (*Alternate* I) SHRI SHREE KUMAR (*Alternate* II)
All India Institute of Hygiene and Public Health, Kolkata	DR GAUTAM BANERJEE
Bureau of Energy Efficiency (Ministry of Power), New Delhi	REPRESENTATIVE
Central Public Works Department, New Delhi	CHIEF ENGINEER (E) II SUPERINTENDING ENGINEER (E) P (*Alternate*)
Council of Architecture, New Delhi	PROF VINOD KUMAR GUPTA
Director General Factory Advice Service and Labour Institute (Ministry of Labour), Mumbai	SHRI S. K. DUTTA SHRI I. ROYCHOWDHURI (*Alternate*)
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI S. K. MAHESHWARI SHRI A. C. VERMA (*Alternate*)
Indian Society for Lighting Engineers, New Delhi	SHRI P. K. BANDYOPADHYAY
Ministry of Non-Conventional Energy Sources, New Delhi	SHRI BIBEK BANDYOPADHYAY
Municipal Corporation of Greater Mumbai, Mumbai	SHRI P. G. CHAVAN SHRI R. K. RAHATE (*Alternate*)
National Physical Laboratory (CSIR), New Delhi	DR H. C. KANDPAL
Philips India Ltd, Mumbai	SHRIMATI SUDESHNA MUKHOPADHYAY SHRI S. P. TAMBE (*Alternate*)
School of Planning and Architecture, New Delhi	PROF ARVIND KISHAN
The Indian Institute of Architects, Mumbai	PROF ASHOK B. LALL
The Institution of Engineers (India), Kolkata	PROF C. S. JHA

Panel for Electrical Installations, CED 46:P13

Organization	*Representative(s)*
In personal capacity (*EA 345, Maya Enclave, New Delhi 110 064*)	SHRI J. N. BHAVANI PRASAD (***Convener***)
Bureau of Energy Efficiency (Ministry of Power), New Delhi	REPRESENTATIVE
Central Electricity Authority, New Delhi	CHIEF ENGINEER (DP & D) DIRECTOR (UT) (*Alternate*)
Chief Electrical Inspectorate, Tamil Nadu	SHRI S. SUBRAMANIAN SHRI M. KAMAL BATCHA (*Alternate*)

Organization	*Representative(s)*
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI AJAY SHANKAR SHRI SHIV OM PRAKASH (*Alternate*)
Engineers India Ltd, New Delhi	SHRI A. ANANTHANARAYAN SHRI N. SETHI (*Alternate*)
Fairwood Consultants Pvt Ltd, New Delhi	SMT SHRUTI GOEL
Siemens Ltd, Chennai	SHRI HEMANT TUNGARE SHRI AJIT DESHPANDE (*Alternate*)
The Institution of Engineers (India), Kolkata	PROF SAMIRAN CHOUDHARY LT GEN S. K. JAIN (*Alternate*)

Panel for Air Conditioning and Heating, CED 46:P14

Organization	*Representative(s)*
Spectral Services Consultants Pvt Ltd, New Delhi	DR PREM C. JAIN (***Convener***) SHRI ASHISH RAKHEJA (*Alternate*)
Airtron Consultants, Bangalore	SHRI R. V. SIMHA
Air Treatment Engineering Pvt Ltd, Chennai	SHRI K. P. S. RAMESH
Blue Star Limited, Mumbai	SHRI JITENDRA MORESHWAR BHAMBURE
Bureau of Energy Efficiency (Ministry of Power), New Delhi	REPRESENTATIVE
Central Building Research Institute (CSIR), Roorkee	DR ISHWAR CHAND SHRI B. M. SUMAN (*Alternate*)
Central Public Works Department, New Delhi	SHRI S. R. SUBRAMANIAN SHRI S. P. BARANWAL (*Alternate*)
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI NARENDRA KUMAR SHRI R. A. DUBEY (*Alternate*)
Hi-Tech Consultant, New Delhi	SHRI N. S. HUKMANI
Indian Institute of Technology, New Delhi	DR R. S. AGARWAL
Indian Society for Heating, Refrigeration and Air-Conditioning Engineers, New Delhi	SHRI N. S. HUKMANI
Sterling India Consulting Engineers, New Delhi	SHRI G. C. MODGIL
Suvidha Engineers India Ltd, Noida	SHRI ALOK C. TANDON
The Institution of Engineer (India), Kolkata	SHRI PRADEEP CHATURVEDI
Voltas Limited, New Delhi	SHRI S. M. KULKARNI SHRI ATUL MALIK (*Alternate*)
In personal capacity (*K-43, Kailash Colony, New Delhi 110 048*)	SHRI M. M. PANDE

Panel for Acoustics, Sound Insulation and Noise Control, CED 46:P15

Organization	*Representative(s)*
Suri and Suri Consulting Acoustical Engineers, New Delhi	SHRI GAUTAM SURI (***Convener***)
All India Radio, New Delhi	SHRI DEEPAK MEHROTRA SHRI S. MUTHUSWAMY (*Alternate*)
Central Building Research Institute (CSIR), Roorkee	SHRI R. K. SRIVASTAVA SHRI R. L. DHABAL (*Alternate*)
Central Public Works Department, New Delhi	SHRI K. A. ANANTHANARAYANAN SHRI N. NAGARAJAN (*Alternate*)
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	BRIG S. K. SHARMA SHRIMATI ANURADHA BHASIN (*Alternate*)
Indian Institute of Science, Bangalore	PROF M. L. MUNJAL
Indian Institute of Technology, Chennai	PROF S. NARYANAN DR A. RAMACHANDRAIAH (*Alternate*)
Indian Institute of Technology, Kharagpur	DR A. R. MOHANTY

Organization	*Representative(s)*
Lloyd Insulations (India) Pvt Ltd, New Delhi	SHRI N. SRINIVAS SHRI B. S. JAMWAL (*Alternate*)
National Physical Laboratory (CSIR), New Delhi	DR V. MOHANAN DR OMKAR SHARMA (*Alternate*)
School of Planning and Architecture, New Delhi	PROF (DR) SHOVAN K. SAHA
The Indian Institute of Architects, Mumbai	SHRI INDRANATH BASU
The Institution of Engineers (India), Kolkata	SHRI K. V. CHAUBAL SHRI P. K. ADLAKHA (*Alternate*)

Panel for Installation of Lifts and Escalators, CED 46:P16

Organization	*Representative(s)*
KONE Elevators India Ltd	SHRI A. SANKARAKRISHNAN (***Convener***) SHRI L. N. VENKATRAMAN (*Alternate* I) SHRI S. EMANUEL RAJASEKARAN (*Alternate* II)
Central Public Works Department, New Delhi	SHRI J. K. CHAUDHURY SHRI A. S. LUTHRA (*Alternate*)
Chief Electrical Inspectorate, Government of Delhi, New Delhi	SHRI K. L. GROVER SHRI A. K. AGGARWAL (*Alternate*)
Chief Electrical Inspectorate, Govt of Tamil Nadu, Chennai	SHRI S. SUBRAMANIAN SHRI M. KAMAL BATCHA (*Alternate*)
Delhi Development Authority, New Delhi	SHRI S. K. SINHA SHRI N. K. GUPTA (*Alternate*)
ECE Industries Ltd, Ghaziabad	SHRI P. K. BANKA SHRI JAGAT MOHAN (*Alternate*)
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI RAMA NATH SHRI M. L. BANSAL (*Alternate*)
Otis Elevator Company (India) Ltd, New Delhi	SHRI V. S. MOHAN SHRI S. P. RAO (*Alternalte* I) SHRI ANURAG MANGLIK (*Alternate* II)
Public Works Department, Government of Maharashtra, Mumbai	SHRI A. M. THATTE SHRI S. D. MAHAJAN (*Alternate*)
Schindler India Pvt Ltd, Mumbai	SHRI RONNIE DANTE SHRI T. A. K. MATHEWS (*Alternate*)
The Institution of Engineers (India), Kolkata	SHRI JAGMAN SINGH DR R. K. DAVE (*Alternate*)
In personal capacity [*4, Vidharbha Samrat Co-operative Housing Society, 93 C, V. P. Road, Vile Parle (West), Mumbai 400 056*]	SHRI A. S. HERWADKAR

Panel for Plumbing Services, CED 46:P17

Organization	*Representative(s)*
Deolalikar Consultants Pvt Ltd, New Delhi	SHRI S. G. DEOLALIKAR (***Convener***)
Birhan Mumbai Licenced Plumbers Association, Mumbai	PRESIDENT SHRI H. G. GANDHI (*Alternate*)
Central Building Research Institute (CSIR), Roorkee	SHRI SURESH KUMAR SHARMA SHRI AJAY SINGH (*Alternate* I) SHRI R. S. CHIMOTE (*Alternate* II)
Central Ground Water Board, New Delhi	DR SALEEM ROMANI SHRI S. K. SHARMA (*Alternate*)
Central Pollution Control Board, New Delhi	DR A. B. AKOLKAR DR M. SUNDAREVADIVAL (*Alternate*)
Central Public Works Department, New Delhi	SHRI H. S. DOGRA SHRI A. K. SINHA (*Alternate*)
Delhi Development Authority, New Delhi	SHRI S. P. RUSTOGI SHRI G. K. SETHI (*Alternate*)

Organization	*Representative(s)*
Delhi Jal Board, New Delhi	SHRI SUBHASH CHANDER
Engineer-in-Chief's Branch, Army Headquarters, New Delhi	SHRI JITENDRA SINGH SHRI SURYA PRAKASH (*Alternate*)
Indian Plumbing Association, New Delhi	SHRI SUDHAKARAN NAIR SHRI P. RAMACHANDRAN (*Alternate*)
Indraprastha Gas Ltd, New Delhi	SHRI PEEYUSH TRIPATHI SHRI C. S. SAGAR (*Alternate*)
Municipal Corporation of Delhi, Delhi	ENGINEER-IN-CHIEF SHRI M. M. DAS (*Alternate*)
Municipal Corporation of Greater Mumbai, Mumbai	SHRI T. V. SHAH SHRI V. R. PEDHNEKAR (*Alternate*)
National Environmental Engineering Research Institute (CSIR), Nagpur	DR APURBA GUPTA SHRI P. S. KELKAR (*Alternate*)
Spectral Services Consultants Pvt Ltd, New Delhi	SHRI SANDEEP GOEL
The Indian Institute of Architects, Mumbai	SHRI UDAY PANDE
The Institution of Engineers (India), Kolkata	SHRI P. C. TYAGI
In personal capacity (*B/58A, Gangotri Enclave, Alaknanda, New Delhi 110 019*)	SHRI J. D' CRUZ
In personal capacity (*Principal Advisor, School of Environment Management, Guru Gobind Singh Indraprastha University, Keshmere Gate, Delhi 110 006*)	DR D. K. CHADHA
In personal capacity (*610, Technology Apartments, 24, Patparganj, Delhi 110 092*)	SHRI SUBIR PAUL

Panel for Landscaping, Signs and Outdoor Display Structures, CED 46:P18

Organization	*Representative(s)*
In personal capacity (*5, Sunder Nagar, New Delhi 110003*)	DR J. R. BHALLA (***Convener***)
Central Public Works Department, New Delhi	SHRI ARVIND KANSAL SHRI A. N. DEVIKAR (*Alternate*)
Council of Architecture, New Delhi	KUMARI VINITA C. K. VIJAYAN
Delhi Urban Arts Commission, New Delhi	SHRI H. K. YADAV SHRI DINA NATH (*Alternate*)
Housing and Urban Development Corporation, New Delhi	SHRI R. K. SAFAYA
Institute of Town Planners, India, New Delhi	DR S. K. KULSHRESTHA
Municipal Corporation of Delhi, Delhi	SHRI S. S. HADKE SHRI S. RAMESH (*Alternate*)
Municipal Corporation of Greater Mumbai, Mumbai	SHRI M. S. GHAG SHRI R. K. RAHATE (*Alternate*)
National Institute of Design, Ahmedabad	SHRI ANANDO DUTTA SHRI J. G. SEVAK (*Alternate*)
Selvel Publicity and Consultants Pvt Ltd, Mumbai	SHRI K. S. NICHOLSON
Shaheer Associates, New Delhi	PROF M. SHAHEER
Town and Country Planning Organization, New Delhi	SHRI J. B. KSHIRSAGAR SHRI Y. RAMESH (*Alternate*)
The Indian Institute of Architects, Mumbai	SHRI MAHESH PALIWAL
The Institution of Engineers (India), Kolkata	PROF JITENDRA SINGH
In personal capacity (*D-198, Defence Colony, New Delhi 110024*)	SHRI RAVINDRA BHAN

Member Secretary
SHRI SANJAY PANT
Joint Director (Civil Engineering)

Joint Member Secretary
SHRI S. K. VERMA
Deputy Director (Civil Engineering)

In this Code, where reference is made to 'accepted standards' in relation to material specification, testing or other related information or where reference is made to 'good practice' in relation to design, constructional procedures or other related information, the Indian Standards listed at the end of the concerned Parts/Sections may be used to the interpretation of these terms.

At the time of publication, the editions indicated in the above Indian Standards were valid. All standards are subject to revision and parties to agreements based on the Parts/Sections are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of each Part/Section, the number appearing in the first column indicates the number of the reference in that Part/Section. For example:

a) accepted standard [3(1)] refers to the standard given at serial number 1 of the list of standards given at the end of Part 3, that is IS 8888 (Part 1) : 1993 'Guide for requirements of low income housing: Part 1 Urban area (*first revision*)'.

b) good practice [6-5A(22)] refers to the standard given at serial number 22 of the list of standards given at the end of sub-section 5A of Part 6, that is IS 4926 : 2003 'Code of practice for ready-mixed concrete (*second revision*)'.

c) accepted standard 7(9) refers to the standard given at serial number 9 of the list of standards given at the end of Part 7, that is IS 2925 : 1984 'Specification for industrial safety helmets (*second revision*)'.

d) accepted standard [8-5(4)] refers to the standard given at serial number 2 of the list of standards given at the end of Section 5 of Part 8, that is IS 14665 (Part 3/Sec 1 and 2) : 2000 'Electric traction lifts: Part 3 Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts'.

e) good practice [9-2(3)] refers to the standard given at serial number 3 of the list of standards given at the end of Section 2 of Part 9, that is IS 8198 (Part 5) : 1984 'Code of practice for steel cylinders for compressed gases: Part 5 Liquefied petroleum gas (LPG) (*first revision*)'.

INFORMATION FOR THE USERS

For the convenience of the users, this publication is also available in the following five groups of the National Building Code of India 2005 each incorporating the related Parts/Sections dealing with particular area of building activity:

Group 1	**For Development, Building Planning and Related Aspects**	Part 0:	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 2:	Administration
		Part 3:	Development Control Rules and General Building Requirements
		Part 4:	Fire and Life Safety
		Part 5:	Building Materials
		Part 10:	Landscaping, Signs and Outdoor Display Structures
			Section 1 Landscape Planning and Design
			Section 2 Signs and Outdoor Display Structures
Group 2	**For Structural Design and Related Aspects**	Part 0:	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 6:	Structural Design
			Section 1 Loads, Forces and Effects
			Section 2 Soils and Foundations
			Section 3 Timber and Bamboo
			3A Timber
			3B Bamboo
			Section 4 Masonry
			Section 5 Concrete
			5A Plain and Reinforced Concrete
			5B Prestressed Concrete
			Section 6 Steel
			Section 7 Prefabrication, Systems Building and Mixed/Composite Construction
			7A Prefabricated Concrete
			7B Systems Building and Mixed/ Composite Construction
Group 3	**For Construction Related Aspects including Safety**	Part 0:	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 7:	Constructional Practices and Safety
Group 4	**For Aspects Relating to Building Services**	Part 0:	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 8:	Building Services
			Section 1 Lighting and Ventilation
			Section 2 Electrical and Allied Installations
			Section 3 Air conditioning, Heating and Mechanical Ventilation
			Section 4 Acoustics, Sound Insulation and Noise Control
			Section 5 Installation of Lifts and Escalators
Group 5	**For Aspects Relating to Plumbing Services including Solid Waste Management**	Part 0:	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 9:	Plumbing Services
			Section 1 Water Supply, Drainage and Sanitation (including Solid Waste Management)
			Section 2 Gas Supply

The information contained in different groups will essentially serve the concerned professionals dealing in the respective areas.

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NATIONAL BUILDING CODE OF INDIA

PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

BUREAU OF INDIAN STANDARDS

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FOREWORD

In order to provide safe and healthy habitat, careful consideration needs to be paid to the building construction activity. Building planning, designing and construction activities have developed over the centuries. Large number of ancient monuments and historical buildings all over the world bear testimony to the growth of civilization from the prehistoric era with the extensive use of manual labour and simple systems as appropriate to those ages to the present day mechanized and electronically controlled operations for designing and constructing buildings and for operating and maintaining systems and services. In those days those buildings were conceptualized and built by master builders with high levels of artisan skills. Technological and socio-economic developments in recent times have led to remarkable increase in demand for more and more sophistication in buildings resulting in ever increasing complexities. These perforce demand high levels of inputs from professionals of different disciplines such as architecture, civil engineering, structural engineering, functional and life safety services including special aspects relating to utilities, landscaping, etc in conceptualization, spatial planning, design and construction of buildings of various material and technology streams, with due regard to various services including operation, maintenance, repairs and rehabilitation aspects throughout the service life of the building.

This Code, besides prescribing the various provisions, also allows freedom of action to adopt appropriate practices and provides for building planning, designing and construction for absorbing traditional practices as well as latest developments in knowledge in the various disciplines as relevant to a building including computer aided and/or other modern sensors aided activities in the various stages of conceptualization, planning, designing, constructing, maintaining and repairing the buildings. India being a large country with substantial variations from region to region, this Code has endeavoured to meet the requirements of different regions of the country, both urban and rural, by taking into consideration factors, such as, climatic and environmental conditions, geographical terrain, proneness to natural disasters, ecologically appropriate practices, use of eco-friendly materials, reduction of pollution, protection and improvement of local environment and also socio-economic considerations, towards the creation of sustainable human settlements.

This Part of the Code dealing with 'integrated approach' is being included for the first time. It gives an overall direction for practical applications of the provisions of different specialized aspects of spatial planning, designing and construction of buildings, creation of services, and proposes an integrated approach for utilizing appropriate knowledge and experience of qualified professionals right from the conceptualization through construction and completion stages of a building project and indeed during the entire life cycle. The 'integrated approach' should not only take care of functional, aesthetic and safety aspects, but also the operational and maintenance requirements. Also, cost optimization has to be achieved through proper selection of materials, techniques, equipment installations, etc. Further, value engineering and appropriate management techniques should be applied to achieve the aim set forth for the purpose of construction of a building fully meeting the specified and implied needs of spatial functions, safety and durability aspects, life and health safety, comfort, services, etc in the building.

The aim of the 'integrated approach' is to get the maximum benefit from the building and its services in terms of quality, timely completion and cost-effectiveness. In the team approach which is an essential pre-requisite for integrated approach, the aim clearly is to maximize the efficiency of the total system through appropriate optimization of each of its sub-systems. In other words, in the team, the inputs from each of the professional disciplines have to be so optimized that the total system's efficiency becomes the maximum. It may be re-emphasized that maximizing the efficiencies of each sub-system may not necessarily assure the maximization of the efficiency of the total system. It need hardly to be stated that specified or implied safety will always get precedence over functional efficiency and economy. Further, progressive approach such as that relating to the concept of intelligent buildings would be best taken care of by the 'integrated approach' as laid down in this Part.

Quality systems approach and certification thereunder covering the various dimensions brought out above may go a long way in achieving the above goal of real integrated approach.

NATIONAL BUILDING CODE OF INDIA

PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

1 SCOPE

This Part covers guidelines to be followed for judicious implementation of the provisions of various Parts/ Sections of the Code.

2 TERMINOLOGY

2.0 For the purpose of this Part, the following definitions and those given in Part 1 'Definitions' shall apply.

2.1 Authority Having Jurisdiction — The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.2 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, *VERANDAH*, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents/ *SHAMIANAHS/PANDALS*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions shall not be considered as building.

2.3 Owner — Person or body having a legal interest in land and/or building thereon. This includes free holders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

NOTE — For the purpose of the Code, the word 'owner' will also cover the generally understood terms like 'client', 'user', etc.

3 GENERAL

3.1 Buildings, shall be classified as Residential, Educational, Institutional, Assembly, Business, Mercantile, Industrial, Storage and Hazardous in groups and sub-division as classified in Part 4 'Fire and Life Safety'.

For further sub-classification of buildings and various related provisions thereof with respect to administration; development control rules and general building requirements; building materials; fire and life safety; structural design; constructional practices and safety; building and plumbing services; and landscaping, signs and outdoor display structures, other parts/sections of the Code may be referred to.

3.2 The scope of various Parts/Sections of the Code which cover detailed provisions on different aspects of development of land/building construction activity, are given in Annex A, with a view to providing an overview for the users of the Code.

4 TEAM APPROACH

A land development/building project comprises the following major stages:

a) Location/siting,
b) Conceptualization and planning,
c) Designing and detailing,
d) Construction/execution, and
e) Maintenance and repair.

Each stage necessarily requires professionals of many disciplines who should work together as a well coordinated team to achieve the desired product delivery with quality, in an effective manner.

Appropriate multi-disciplinary teams need to be constituted to successfully meet the requirements of different stages. Each team may comprise need based professionals out of the following depending upon the nature, magnitude and complexity of the project:

a) Architect,
b) Civil engineer,
c) Structural engineer,
d) Electrical engineer,
e) Plumbing engineer,
f) Fire protection engineer,
g) HVAC engineer,
h) Environment specialist,
j) Town planner,
k) Urban designer,
m) Landscape architect,
n) Security system specialist,
p) Interior designer,
q) Quantity surveyor,
r) Project/construction manager, and
s) Other subject specialist(s).

planning; aesthetics; fire and life safety; structural adequacy; plumbing services; lighting and natural ventilation; electrical and allied installations; air conditioning, heating and mechanical ventilation; acoustics, sound insulation and noise control; installation of lifts and escalators; building automation; data and voice communication; other utility services installations; landscape planning and design; urban planning; etc need to be kept in view right at the concept stage. The project requiring such multi-disciplinary inputs need a co-ordinated approach among the professionals for proper integration of various design inputs. For this, and to take care of the complexities of multi-disciplinary requirements, a design team of professionals from required disciplines shall be constituted at the appropriate stage. Here, it is desirable that the multi-disciplinary integration is initiated right from the concept stage. The team shall finalize the plan. The composition of the team shall depend on the nature and magnitude of the project. Design is an evolutionary and participatory process, where participation of owner constitutes a very important input at all stages, and the same shall be ensured by the design team.

To ensure proper implementation of the design, the design team, may be associated during the construction/ execution stage.

4.2 Project Management and Construction Management Teams

The objective of project management or construction management is primarily to achieve accomplishment of project in accordance with the designs and specifications in a stipulated time and cost framework, with a degree of assurance prior to commencement and satisfaction on accomplishment.

For large projects, separate teams of experienced professionals from the required disciplines may be constituted for project management and for construction management depending upon the complexities of the project. However, for smaller projects these teams may be combined. The teams shall be responsible for day-to-day execution, supervision, quality control, etc and shall ensure inter-disciplinary co-ordination during the construction stage. The team shall be responsible to achieve satisfactory completion of the project with regard to cost, time and quality. Some members of the design team may also be included in the project management team and/or associated actively during the project execution stage. It is important that leaders and members of project management/construction management teams, experience and expertise in these fields.

4.3 Operation and Maintenance Team

Operation, maintenance and repairs also require a multi-disciplinary approach to ensure that all the requirements of the users are satisfactorily met. During maintenance and repairs, the jobs requiring inter-disciplinary co-ordination have to be executed in such a manner as not only to cause least inconvenience to the user but also to ensure that there is no mismatch or damage to the structure, finishings, fittings and fixtures. For carrying out routine maintenance/repair jobs, utilization of the services of trained technicians preferably having multi-disciplinary skills should be encouraged.

Special repairs, rehabilitation and retrofitting are specialized jobs which demand knowledge of the existing structure/installations. Association of concerned specialists may be helpful for these works.

The Operation and Maintenance Team may also be known as Asset Management or Estate Management Team.

5 PLANNING, DESIGNING AND DEVELOPMENT

5.1 The main functions of design team (*see* **4.1**) constituted for the planning, designing and development, are as under:

a) Formalization of design brief in consultation with the owner.
b) Site investigation/survey.
c) Preparation of alternative concept designs.
d) Selection of a concept in consultation with and with the consent of owner.
e) Sizing the system.
f) Development of design, covering :
    1) Integration of architecture, structure and services,
    2) Synthesis of requirements of each discipline, and
    3) Interaction with each other and with the owner.
g) Preparation of preliminary designs and drawings and obtaining owner's approval.
h) Preparation of preliminary cost estimates for approval of owner.
j) Preparation of work-breakdown structure and programme for pre-construction activities.
k) Assisting client to obtain approvals of the Authority.
m) Preparation of detailed specification and

construction working drawings with integration of engineering inputs of all concerned disciplines.

n) Preparation of detailed design of each discipline for various services.

p) Peer review/proof checking of the drawings/ designs in case of important projects, depending upon their complexity and sensitivity.

q) Preparation of detailed cost estimate.

r) Obtaining final approval of client.

s) Preparation of bill of quantities, specifications and tender documents.

5.2 The following considerations, as may be applicable to the project, may be considered during planning, notwithstanding other relevant aspects specifically prescribed in concerned parts/sections of this Code; these considerations in general are with the objective of addressing to the important issues like environmental protection, energy conservation, cultural issues, creating barrier free built-environment, safety aspects, etc, all of these leading towards sustainable development, and have to be applied with due regard to the specific requirements of size and type of project:

a) Geoclimatic, geological and topographical features.

b) Varied sociological pattern of living in the country.

c) Effective land use to cater to the needs of the society in a most convenient manner.

d) Modular planning and standardization to take care of future planning giving due consideration to the specified planning controls.

e) Emphasis on daylight utilization, natural ventilation, shielding, and window area and its disposition; daylighting to be supplemented with an integrated design of artificial lighting.

f) Optimum utilization of renewable energy sources duly integrated in the overall energy system design; with consideration of active and passive aspects in building design including thermal performance of building envelope.

g) Rain water harvesting, and use of appropriate building materials considering aspects like energy consumption in production, transportation and utilization, recyclability, etc for promoting sustainable development.

h) Requisite mandatory provisions for handicapped persons.

j) Acoustical controls for buildings and the surroundings.

k) Promotion of artwork in buildings, specially buildings of importance.

m) Due cognizance of recommendations of the Archeological Survey of India with regard to national monuments and construction in archeologically important sites.

n) Due cognizance of relevant provisions of applicable coastal zone regulation act.

p) Conservation of heritage structures and areas.

q) Environmental and social impact analysis.

r) Design of services with emphasis on aspects of energy efficiency, environment friendliness and maintainability.

s) Integrated waste management.

t) Voice and data communication, automation of building services, and intelligent building; use of security and surveillance system in important and sensitive buildings, such as, access control for the people as well as for vehicle.

u) Interlinking of fire alarm system, fire protection system, security system, ventilation, electrical systems, etc.

v) Analysis of emergency power, standby power requirement and captive power systems.

w) Cost optimization through techniques like value engineering.

y) Adoption of innovative technologies giving due consideration to constructability and quality aspects.

z) Instrumentation of buildings and monitoring and use of information so generated to effect improvements in planning and design of future building projects.

6 CONSTRUCTION/EXECUTION (ACTUALIZATION)

6.1 The main functions of the teams (*see* **4.2**) constituted for Project Management/Construction Management may be, to :

a) specify criteria for selection of constructors;

b) specify quality control, quality audit system and safety system;

c) short-list constructors;

d) have pre-bid meetings with the intending constructors;

e) receive and evaluate tenders;

f) select constructors;

g) execution and supervision;

h) monitor quality, time and cost control;

j) prepare/certify the completion (as-built) drawings; and

k) ensure availability of operation manuals for field use.

6.2 Apart from the specific provisions laid down in the concerned Parts/Sections of the Code, the following considerations, as may be applicable to the project concerned, shall be given due attention:

a) Adopting scientific principles of construction management, quality management, cost and time control.

b) Engagement of executing and supervising agencies, which meet the specified norms of skills, specialization, experience, resourcefulness, etc for the work.

c) Ensuring inter-disciplinary co-ordination during construction.

d) Contract management and techno-legal aspects.

e) Completion, commissioning and trial run of installations/equipments and their operation and maintenance through the suppliers/other teams, where necessary.

f) Make available shop drawings as well as as-built drawings for the building and services.

g) Arrange all maintenance and operation manual from the concerned suppliers/ manufacturers.

6.3 The team of professionals (*see* **4.2**) shall work and monitor the project activities for successful construction/execution of the project with regard to cost, time, quality and safety.

7 OPERATION AND MAINTENANCE

7.1 The team of professionals (*see* **4.3**) shall set up a system of periodic maintenance and upkeep of constructed buildings.

7.2 The operation and maintenance team shall be responsible for preparation/application of operation and maintenance manual, and draw maintenance schedule/frequencies and guidelines for maintenance personnel. Apart from the specific provisions laid down in concerned Parts/Sections of the Code, the following, as may be applicable to the project concerned shall additionally be taken into account:

a) Periodic validation of buildings by competent professionals through inspection of the buildings in respect of structural safety and safety of electrical and other installations and ensuring that all fire safety equipments/ systems are in proper working condition.

b) Preparation of preventive maintenance schedules for all installations in the building and strictly following the same; the record of the preventive maintenance to be properly kept.

c) Ensuring inter-disciplinary co-ordination during maintenance and repairs; deployment of trained personnel with multi-disciplinary skills to be encouraged.

d) Condition survey of structures and installations, identification of distress of various elements and initiating plans for rehabilitation/retrofitting well in time.

7.3 The proposals for rehabilitation/retrofitting should be prepared after detailed investigations through visual inspection, maintenance records and testing as required and got executed through specialized agencies under the guidance and supervision of competent professionals.

ANNEX A

(*Clause* 3.2)

BRIEF DETAILS OF THE COVERAGE OF VARIOUS PROVISIONS UNDER DIFFERENT OTHER PARTS/SECTIONS OF THIS CODE

A-1 PART 1 DEFINITIONS

It lists the terms appearing in all the Parts/Sections of the Code. However, some common definitions are reproduced in this Part also.

A-2 PART 2 ADMINISTRATION

It covers the administrative aspects of the Code, such as applicability of the Code, organization of building department for enforcement of the Code, procedure for obtaining development and building permits, and responsibility of the owner and all professionals involved in the planning, design and construction of the building.

A-3 PART 3 DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS

It covers the development control rules and general building requirements for proper planning and design at the layout and building level to ensure health safety, public safety and desired quality of life.

A-4 PART 4 FIRE AND LIFE SAFETY

It covers the requirements for fire prevention, life safety in relation to fire, and fire protection of buildings. The Code specifies planning and construction features and fire protection features for all occupancies that are necessary to minimize danger to life and property.

A-5 PART 5 BUILDING MATERIALS

It covers the requirements of building materials and components, and criteria for accepting new or alternative building materials and components.

A-6 PART 6 STRUCTURAL DESIGN

This Part through its seven sections provides for structural adequacy of buildings to deal with both internal and external environment, and provide guidance to engineers/structural engineers for varied usage of material/technology types for building design.

A-6.1 Section 1 Loads, Forces and Effects

It covers basic design loads to be assumed in the design of buildings. The live loads, wind loads, seismic loads, snow loads and other loads, which are specified therein, are minimum working loads which should be taken into consideration for purposes of design.

A-6.2 Section 2 Soils and Foundations

It covers structural design (principles) of all building foundations, such as, raft, pile and other foundation systems to ensure safety and serviceability without exceeding the permissible stresses of the materials of foundations and the bearing capacity of the supporting soil.

A-6.3 Section 3 Timber and Bamboo

A-6.3.1 *Section 3A Timber*

It covers the use of structural timber in structures or elements of structures connected together by fasteners/ fastening techniques.

A-6.3.2 *Section 3B Bamboo*

It covers the use of bamboo for constructional purposes in structures or elements of the structure, ensuring quality and effectiveness of design and construction using bamboo. It covers minimum strength data, dimensional and grading requirements, seasoning, preservative treatment, design and jointing techniques with bamboo which would facilitate scientific application and long-term performance of structures. It also covers guidelines so as to ensure proper procurement, storage, precautions and design limitations on bamboo.

A-6.4 Section 4 Masonry

It covers the structural design aspects of unreinforced load bearing and non-load bearing walls, constructed using various bricks, stones and blocks permitted in accordance with this Section. This, however, also covers provisions for design of reinforced brick and reinforced brick concrete floors and roofs. It also covers guidelines regarding earthquake resistance of low strength masonry buildings.

A-6.5 Section 5 Concrete

A-6.5.1 *Section 5A Plain and Reinforced Concrete*

It covers the general structural use of plain and reinforced concrete.

A-6.5.2 *Section 5B Prestressed Concrete*

It covers the general structural use of prestressed concrete. It covers both work carried out on site and the manufacture of precast prestressed concrete units.

A-6.6 Section 6 Steel

It covers the use of structural steel in general building construction including the use of hot rolled steel sections and steel tubes.

A-6.7 Section 7 Prefabrication, Systems Building and Mixed/Composite Construction

A-6.7.1 *Section 7A Prefabricated Concrete*

It covers recommendations regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transport and erection of prefabricated concrete elements for use in buildings and such related requirements for prefabricated concrete.

A-6.7.2 *Section 7B Systems Building and Mixed/ Composite Construction*

It covers recommendations regarding modular planning, component sizes, joints, manufacture, storage, transport and erection of prefabricated elements for use in buildings and such related requirements for mixed/composite construction.

A-7 PART 7 CONSTRUCTIONAL PRACTICES AND SAFETY

It covers the constructional planning, management and practices in buildings; storage, stacking and handling of materials and safety of personnel during construction operations for all elements of a building and demolition of buildings. It also covers guidelines relating to maintenance management, repairs, retrofitting and strengthening of buildings. The objective can be best achieved through proper coordination and working by the project management and construction management teams.

A-8 PART 8 BUILDING SERVICES

This Part through its five elaborate sections on utilities provides detailed guidance to concerned professionals/ utility engineers for meeting necessary functional requirements in buildings.

A-8.1 Section 1 Lighting and Ventilation

It covers requirements and methods for lighting and ventilation of buildings.

A-8.2 Section 2 Electrical and Allied Installations

It covers the essential requirements for electrical and allied installations in buildings to ensure efficient use of electricity including safety from fire and shock. This Section also includes general requirements relating to lightning protection of buildings.

A-8.3 Section 3 Air Conditioning, Heating and Mechanical Ventilation

This Section covers the design, construction and installation of air conditioning and heating systems and equipment installed in buildings for the purpose of providing and maintaining conditions of air temperature, humidity, purity and distribution suitable for the use and occupancy of the space.

A-8.4 Section 4 Acoustics, Sound Insulation and Noise Control

It covers requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

A-8.5 Section 5 Installation of Lifts and Escalators

It covers the essential requirements for the installation, operation, maintenance and also inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb-waiter) and escalators so as to ensure safe and satisfactory performance.

A-9 PART 9 PLUMBING SERVICES

This Part through its two sections gives detailed guidance to concerned professionals/plumbing engineers with regard to plumbing and other related requirements in buildings.

A-9.1 Section 1 Water Supply, Drainage and Sanitation (Including Solid Waste Management)

It covers the basic requirements of water supply for residential, business and other types of buildings, including traffic terminal stations. This Section also deals with general requirements of plumbing connected to public water supply and design of water supply systems.

It also covers the design, layout, construction and maintenance of drains for foul water, surface water and sub-soil water and sewage; together with all ancillary works, such as connections, manholes and inspection chambers used within the building and from building to the connection to a public sewer, private sewer, individual sewage-disposal system, cess-pool, soakaway or to other approved point of disposal/ treatment work. It also includes the provisions on solid waste management.

A-9.2 Section 2 Gas Supply

It covers the requirements regarding the safety of persons and property for all piping uses and for all types of gases used for fuel or lighting purposes in buildings.

A-10 PART 10 LANDSCAPING, SIGNS AND OUTDOOR DISPLAY STRUCTURES

A-10.1 Section 1 Landscape Planning and Design

It covers requirements of landscape planning and design with the view to promoting quality of outdoor built environment and protection of land and its resources.

A-10.2 Section 2 Signs and Outdoor Display Structures

It covers the requirements with regard to public safety, structural safety and fire safety of all signs and outdoor display structures including the overall aesthetical aspects of imposition of signs and outdoor display structures in the outdoor built environment.

NATIONAL BUILDING CODE OF INDIA

PART 1 DEFINITIONS

BUREAU OF INDIAN STANDARDS

FOREWORD

Each Part or Section of the National Building Code gives the definitions of the special terms used in it. These definitions may be found in the clause 'Terminology' normally placed immediately after the 'Scope' in each Part/Section. However, users may find this part very convenient for reference as it gives the alphabetically arranged list of terms defined in all the parts along with the location of the definition.

NATIONAL BUILDING CODE OF INDIA

PART 1 DEFINITIONS

1 SCOPE

This Part lists the terms appearing in all the Parts/ Sections of the National Building Code of India. The terms have been arranged in their alphabetical order. The Part(s)/Section(s) in which these terms are appearing, have been indicated against the terms.

However, some common definitions are reproduced in this part also; the definitions being placed immediately below the term concerned.

A

Abandoned Sign — Part 10/Section 2

Access — Part 3

Access Panel — Part 9/Section 1

Accessory — Part 8/Section 2

Accessory Use — Part 2, Part 3

Any use of the premises subordinate to the principal use and customarily incidental to the principal use.

Advertising Sign — Part 10/Section 2

Air Change per Hour — Part 8/Section 1

Air Conditioning — Part 8/Section 3

Air Gap — Part 9/Section 1

Air-Break — Part 9/Section 1

Alteration — Part 2, Part 3

A change from one occupancy to another, or a structural change, such as an addition to the area or height, or the removal of part of a building, or any change to the structure, such as the construction of, cutting into or removal of any wall, partition, column, beam, joist, floor or other support, or a change to or closing of any required means of ingress or egress or a change to the fixtures or equipment.

Alternating Current Variable Voltage (ACVV) Control — Part 8/Section 5

Alternating Current Variable Voltage Variable Frequency (ACVVVF) Control — Part 8/Section 5

Altitude (θ) — Part 8/Section 1

Ambient Noise — Part 8/Section 4

Anatomical Purpose Definitions for Engineers — Part 6/Section 3B

Apparatus — Part 8/Section 2

Appliance — Part 8/Section 2

Appliance Valve — Part 9/Section 2

Approved — Part 2, Part 3, Part 10/Section 2

Approved by the Authority having jurisdiction.

Area of Special Control — Part 10/Section 2

Atmospheric Pressure — Part 8/Section 3

Audible Frequency Range — Part 8/Section 4

Authority Having Jurisdiction — Part 2, Part 3, Part 6/Section 7B, Part 9/Section 1, Part 9/Section 2, Part 10/Section 2

The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

Automatic Fire Detection and Alarm System — Part 4

Automatic Operation — Part 8/Section 5

Automatic Sprinkler System — Part 4

Available Head — Part 9/Section 1

Avenue — Part 10/Section 1

A-Weighted Sound Pressure Level, L_{pA} — Part 8/ Section 4

A-Weighted Sound Pressure, p_A — Part 8/Section 4

Axial Flow Fan — Part 8/Section 1

Azimuth (ϕ) — Part 8/Section 1

B

Back Fill — Part 6/Section 2

Back Siphonage — Part 9/Section 1

Back to Back Cluster — Part 3

Back Up — Part 9/Section 1

Backflow Prevention Device — Part 9/Section 1

Backflow — Part 9/Section 1

Background Noise — Part 8/Section 4

Balcony — Part 3

Baluster — Part 8/Section 5

Balustrade — Part 8/Section 5

Bamboo — Part 6/Section 3B

Bamboo Borer (Bamboo GHOON) — Part 6/Section 3B

Bamboo Clump — Part 6/Section 3B

Bamboo Culm — Part 6/Section 3B

Bamboo Mat Board — Part 6/Section 3B

Banner — Part 10/Section 2

Banner Sign — Part 10/Section 2

Barrel — Part 9/Section 1

Base — Part 9/Section 1

Basement or Cellar — Part 3

Basic Module — Part 6/Section 7A, Part 6/Section 7B

Basic or Ultimate Stress — Part 6/Section 3, Part 6/Section 3B

Batter Pile (Raker Pile) — Part 6/Section 2

Battery of Fixtures — Part 9/Section 1

Beam, Built-Up-Laminated — Part 6/Section 3
Beam, Glued-Laminated — Part 6/Section 3
Bearing Capacity, Safe — Part 6/Section 2
Bearing Capacity, Ultimate — Part 6/Section 2
Bearing Pile — Part 6/Section 2
Bearing Pressure, Allowable (Gross or Net) — Part 6/Section 2
Bearing Pressure, Allowable — Part 6/Section 2
Bearing Pressure, Safe — Part 6/Section 2
Bed Block — Part 6/Section 4
Bedding — Part 9/Section 1
Benching — Part 9/Section 1
Bond — Part 6/Section 4
Bored Cast in-situ Pile — Part 6/Section 2
Bored Compaction Pile — Part 6/Section 2
Bored Pile — Part 6/Section 2
Bottom Car Clearance — Part 8/Section 5
Bottom Car Runby — Part 8/Section 5
Bottom Coutnerweight Runby — Part 8/Section 5
Boucherie Process — Part 6/Section 3B
Branch — Part 9/Section 1
Branch Soil Pipe (BSP) — Part 9/Section 1
Branch Soil Waste Pipe (BSWP) — Part 9/Section 1
Branch Ventilating Pipe (BVP) — Part 9/Section 1
Branch Waste Pipe (BWP) — Part 9/Section 1
Break-in — Part 8/Section 4
Breaking Strength — Part 6/Section 3B
Break-out — Part 8/Section 4
Brightness Ratio or Contrast — Part 8/Section 1
Broad Band Noise — Part 8/Section 4
Buffer — Part 10/Section 1, Part 8/Section 5
Building (House) Drain — Part 9/Section 1
Building (House) Drain-Combined — Part 9/Section 1
Building (House) Drain-Sanitary — Part 9/Section 1
Building (House) Drain-Storm — Part 9/Section 1
Building (House) Sewer — Part 9/Section 1
Building (House) Sub-Drain — Part 9/Section 1
Building (House) Trap — Part 9/Section 1
Building — Part 2, Part 3, Part 4

Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, verandah, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents/temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

Building, Height of — Part 2, Part 3, Part 4

The vertical distance measured, in the case of flat roofs from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of last livable floor of the building adjacent to the external walls; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof, and in the case of gables facing the road, the mid-point between the eaves level and the ridge. Architectural features serving no other function except that of decoration shall be excluded for the purpose of measuring heights.

Building Line — Part 2, Part 3, Part 10/Section 2

The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme. The building line may change from time-to-time as decided by the Authority.

Buildings Related Illnesses (BRI) — Part 8/Section 3
Bunched — Part 8/Section 2

C

Cabin — Part 3
Cable — Part 8/Section 2
Cable Armoured — Part 8/Section 2
Cable, Crossed Linked Insulated — Part 8/Section 2
Cable, Flexible — Part 8/Section 2
Cable, Lead-Covered — Part 8/Section 2
Cable, Metal-Sheathed — Part 8/Section 2
Cable, PVC-Insulated — Part 8/Section 2
Cable, PVC-Sheathed — Part 8/Section 2
Cable, Tough Rubber-Sheathed (Cable, TRS) — Part 8/Section 2
Cable, Weatherproof — Part 8/Section 2
Cable, XLPE — Part 8/Section 2
Call Indicator — Part 8/Section 5
Candela (cd) — Part 8/Section 1
Canopy — Part 3
Canopy Sign — Part 10/Section 2
Car Bodywork — Part 8/Section 5
Car Door Electric Contact — Part 8/Section 5
Car Platform — Part 8/Section 5
Car Switch Operation — Part 8/Section 5
Carframe — Part 8/Section 5
Carpet Area — Part 3

Ceiling Rose — Part 8/Section 2

Cell — Part 6/Section 3B

Cellular Concrete — Part 6/Section 7B, Part 6/ Section 7A

Cellulose — Part 6/Section 3B

Central Field — Part 8/Section 1

Centre Internode — Part 6/Section 3B

Centrifugal Fan — Part 8/Section 1

Cesspool — Part 9/Section 1

Chair — Part 9/Section 1

Channel — Part 9/Section 1

Characteristic Load — Part 6/Section 3B

Characteristic Strength — Part 6/Section 3B

Check — Part 6/Section 3

CHHAJJA — Part 3

Chimney — Part 3

Chowk or Courtyard — Part 3

Chowk, Inner — Part 3

Chowk, Outer — Part 3

Chute — Part 9/Section 1

Circuit — Part 8/Section 2

Circuit Breaker — Part 8/Section 2

Circuit Final, Sub — Part 8/Section 2

Cistern — Part 9/Section 1

Clay — Part 6/Section 2

Clay, Firm — Part 6/Section 2

Clay, Soft — Part 6/Section 2

Clay, Stiff — Part 6/Section 2

Cleaning Eye — Part 9/Section 1

Clear Design Sky — Part 8/Section 1

Clear Waste Water — Part 9/Section 1

Clearance — Part 8/Section 5

Cleat — Part 8/Section 2

Cleavability — Part 6/Section 3B

Cleavage — Part 6/Section 3B

Climber (Creeper/Vine) — Part 10/Section 1

Closed Clusters — Part 3

Closed Sign — Part 10/Section 2

Cluster — Part 3

Cluster Court Town House — Part 3

Cluster Plot — Part 3

Collapse — Part 6/Section 3B

Collection Chamber — Part 9/Section 1

Column — Part 6/Section 3B

Column, Pier and Buttress — Part 6/Section 4

Columnar — Part 10/Section 1

Combination Sign — Part 10/Section 2

Combustible Material — Part 4, Part 10/Section 2

The material which either burns itself or adds heat to a fire, when tested for non-combustibility in accordance with accepted standard [4(1)].

Common Rafter — Part 6/Section 3B

Communication Pipe — Part 9/Section 1

Components — Part 6/Section 7A, Part 6/Section 7B

Composite Members — Part 6/Section 7A, Part 6/ Section 7B

Compression Wood — Part 6/Section 3

Conductor of a Cable or Core — Part 8/Section 2

Conductor, Aerial — Part 8/Section 2

Conductor, Bare — Part 8/Section 2

Conductor, Earthed — Part 8/Section 2

Conductor, Insulated — Part 8/Section 2

Connection — Part 9/Section 1

Connector — Part 8/Section 2

Connector Box or Joint Box — Part 8/Section 2

Connector for Portable Appliances — Part 8/Section 2

Conservation (Preservation) — Part 10/Section 1

Consumer — Part 9/Section 1

Consumer's Pipe — Part 9/Section 1

Consumer's Terminals — Part 8/Section 2

Contaminants — Part 8/Section 1

Contour — Part 10/Section 1

Contour Interval — Part 10/Section 1

Contour Line — Part 10/Section 1

Control — Part 8/Section 5

Conventional Symbols — Part 8/Section 2

Conversion — Part 2

Cooking Alcove — Part 3

Cord, Flexible — Part 8/Section 2

Core of a Cable — Part 8/Section 2

Counterweight — Part 8/Section 5

Cover — Part 9/Section 1

Covered Area — Part 3, Part 4

Ground area covered by the building immediately above the plinth level. The area covered by the following in the open spaces is excluded from covered area:

a) garden, rockery, well and well structures, plant nursery, waterpool, swimming pool (if uncovered), platform round a tree, tank, fountain, bench, *CHABUTARA* with open top and unenclosed on sides by walls and the like;

b) drainage culvert, conduit, catch-pit, gully pit, chamber, gutter and the like;

c) compound wall, gate, unstoreyed porch and portico, slide, swing, uncovered staircases,

ramp areas covered by *CHHAJJA* and the like; and

d) watchman's booth, pumphouse, garbage shaft, electric cabin or sub-stations, and such other utility structures meant for the services of the building under consideration.

NOTE — For the purpose of this part, covered area equals the plot area minus the area due for open spaces in the plot.

Crookedness — Part 6/Section 3B

Cross Wall — Part 6/Section 3B

Cross-Connection — Part 9/Section 1

Cross-Sectional Area of Masonry Unit — Part 6/Section 4

Cross-Talk — Part 8/Section 4

Crown of Trap — Part 9/Section 1

'Cul-de-Sac' Cluster — Part 3

Curtain Wall — Part 6/Section 4

Curvature — Part 6/Section 3B

Customer's/Consumer's Connection — Part 9/Section 2

Cut-off Level — Part 6/Section 2

Cut-out — Part 8/Section 2

D

Damp Situation — Part 8/Section 2

Daylight Area — Part 8/Section 1

Daylight Factor — Part 8/Section 1

Daylight Penetration — Part 8/Section 1

Dead — Part 8/Section 2

Dead Knot — Part 6/Section 3

Decay or Rot — Part 6/Section 3

Decayed Knot — Part 6/Section 3

Decibels — Part 8/Section 4

Deciduous Tree — Part 10/Section 1

Deep Manhole — Part 9/Section 1

Definitions of Defects in Bamboo — Part 6/Section 3B

Definitions of Defects in Timber — Part 6/Section 3

Deflector Shieve — Part 8/Section 5

Delamination — Part 6/Section 3B

Density — Part 3

Depth of Manhole — Part 9/Section 1

Detached Building — Part 3

Development — Part 2, Part 3

'Development' with grammatical variations means the carrying out of building, engineering, mining or other operations in, or over, or under land or water, or in the use of any building or land, and includes redevelopment and layout and subdivision of any land; and 'to develop' shall be construed accordingly.

Dewpoint Temperature — Part 8/Section 3

Diameter — Part 9/Section 1

The nominal internal diameter of pipes and fittings.

Diameter of Knot — Part 6/Section 3

Diaphragm, Structural — Part 6/Section 3B

Dilution Ventilation — Part 8/Section 1

Direct Earthing System — Part 8/Section 2

Direct Solar Illuminance — Part 8/Section 1

Direct Tap — Part 9/Section 1

Direction Sign — Part 10/Section 2

Discolouration — Part 6/Section 3, Part 6/Section 3B

Discrimination (Over-Current Discrimination) — Part 8/Section 2

Distance Area of Resistance Area (for Earth Electrode only) — Part 8/Section 2

Distribution Board — Part 8/Section 2

Door — Part 8/Section 5

Door Closer — Part 8/Section 5

Door Operator — Part 8/Section 5

Door, Centre Opening Sliding — Part 8/Section 5

Door, Mid-Bar Collapsible — Part 8/Section 5

Door, Single Slide — Part 8/Section 5

Door, Swing — Part 8/Section 5

Door, Two Speed Siding — Part 8/Section 5

Door, Vertical Bi-parting — Part 8/Section 5

Door, Vertical Lifting — Part 8/Section 5

Double Button (Continuous Pressure) Operation — Part 8/Section 5

Downcomer — Part 4

Downtake Tap — Part 9/Section 1

Drain — Part 2, Part 3, Part 9/Section 1

A conduit, channel or pipe for the carriage of storm water, sewage, waste water or other water-borne wastes in a building drainage system.

Drain Ventilating Pipe (DVP) — Part 9/Section 1

Drainage — Part 2, Part 9/Section 1

The removal of any liquid by a system constructed for the purpose.

Drainage Work — Part 9/Section 1

Driven Cast in-situ Pile — Part 6/Section 2

Driven Precast Pile — Part 6/Section 2

Drop Connection — Part 9/Section 1

Drop Manhole — Part 9/Section 1

Dry Bulb Temperature — Part 8/Section 1

Dry Riser — Part 4

Dry-Bulb Temperature — Part 8/Section 3

Drying Degrades in Round Bamboo — Part 6/Section 3B

Duct System — Part 8/Section 3
Duration of Load — Part 6/Section 3
Dwelling Unit/Tenement — Part 3

E

Earth — Part 8/Section 2
Earth Continuity Conductor — Part 8/Section 2
Earth Electrode — Part 8/Section 2
Earth Fault — Part 8/Section 2
Earth Leakage Circuit Breaker System — Part 8/Section 2
Earthing Lead — Part 8/Section 2
Edge Distance — Part 6/Section 3
Effective Height — Part 6/Section 4
Effective Length — Part 6/Section 4
Effective Opening — Part 9/Section 1
Effective Temperature (ET) — Part 8/Section 1
Effective Thickness — Part 6/Section 4
Efficiency of a Pile Group — Part 6/Section 2
Egress — Part 10/Section 1
Electric Sign — Part 10/Section 2
Electrical and Mechanical Interlock — Part 8/Section 5
Electro-Mechanical Lock — Part 8/Section 5
Electronic Devices — Part 8/Section 5
Elevation — Part 10/Section 1
Emergency Lighting — Part 4
Emergency Lighting System — Part 4
Emergency Stop Push or Switch — Part 8/Section 5
Enclosed Distribution Board — Part 8/Section 2
End Distance — Part 6/Section 3, Part 6/Section 3B
End Splitting — Part 6/Section 3B
Enthalphy — Part 8/Section 3
Equivalent Continuous A — Weighted Sound Pressure Level, $L_{Aeq,T}$ — Part 8/Section 4
Equivalent Sound Absorption Area of a Room, A — Part 8/Section 4
Escalator — Part 8/Section 5
Escalator Installation — Part 8/Section 5
Escalator Machine — Part 8/Section 5
Escape Lighting — Part 4
Evaporative Air Cooling — Part 8/Section 3
Evergreen — Part 10/Section 1
Exhaust of Air — Part 8/Section 1
Exit — Part 3
Exotic — Part 10/Section 1
Exposed Metal — Part 8/Section 2
Exterior Sign — Part 10/Section 2
External Faces of Cluster — Part 3
External Reflected Component (ERC) — Part 8/Section 1

F

Façade Level — Part 8/Section 4
Factor of Safety (with Respect to Bearing Capacity) — Part 6/Section 2
Factor of Safety — Part 6/Section 2
Feed Cistern — Part 9/Section 1
Fencing — Part 10/Section 1
Finger Joint — Part 6/Section 3
Finished Grade — Part 10/Section 1
Fire Damper — Part 8/Section 3
Fire Door — Part 4
Fire Exit — Part 4
Fire Lift — Part 4
Fire Load — Part 4
Fire Load Density — Part 4
Fire Resistance Rating — Part 4
Fire Resistance, Criteria of — Part 4
Fire Resisting Wall — Part 4
Fire Separating Wall — Part 4
**Fire Separation* — Part 3, Part 4

The distance in metres measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of street or other public space to the building for the purpose of preventing the spread of fire.

Fire Separation Wall — Part 8/Section 3
Fire Stop — Part 4
Fire Survival Cable — Part 8/Section 2
Fire Tower — Part 4
Fitting, Lighting — Part 8/Section 2
Fittings — Part 9/Section 1

Fittings shall mean coupling, flange, branch, bend, tees, elbows, unions, waste with plug, *P* or *S* trap with vent, stop ferrule, stop tap, bib tap, pillar tap, globe tap, ball valve, cistern storage tank, baths, water-closets, boiler, geyser, pumping set with motor and accessories, meter, hydrant, valve and any other article used in connection with water supply, drainage and sanitation.

Fixture Unit — Part 9/Section 1
Fixture Unit Drainage — Part 9/Section 1
Flame Retardant Cable — Part 8/Section 2
Flameproof Enclosure — Part 8/Section 2
Flatten Bamboo — Part 6/Section 3B
Float Operated Valve — Part 9/Section 1
Floor — Part 3

* Definitions are different.

The lower surface in a storey on which one normally walks in a building. The general term 'floor' unless specifically mentioned otherwise shall not refer to a 'mezzanine floor'.

Floor Area Ratio (FAR) — Part 3, Part 4

The quotient obtained by dividing the total covered area (plinth area) on all floors by the area of the plot:

$$\text{FAR} = \frac{\text{Total covered area of all floors}}{\text{Plot area}}$$

Floor Levelling Switch — Part 8/Section 5
Floor Selector — Part 8/Section 5
Floor Stopping Switch — Part 8/Section 5
Flushing Cistern — Part 9/Section 1
Foliage — Part 10/Section 1
Footing — Part 6/Section 2
Formation — Part 9/Section 1
Foundation — Part 6/Section 2
Foundation, Raft — Part 6/Section 2
Free-Field Level — Part 8/Section 4
Freestanding Sign — Part 10/Section 2
French Drain or Rubble Drain — Part 9/Section 1
Frequency — Part 8/Section 4
Fresh Air or Outside Air — Part 8/Section 1
Frost Line — Part 9/Section 1
Full Culm — Part 6/Section 3B
Fuse — Part 8/Section 2
Fuse-Element — Part 8/Section 2

G

Gallery — Part 3
Garage, Private — Part 3
Garage, Public — Part 3
Gas Fitter — Part 9/Section 2
Geared Machine — Part 8/Section 5
Gearless Machine — Part 8/Section 5
General — Part 6/Section 2, Part 10/Section 2
General Ventilation — Part 8/Section 1
General Washing Place — Part 9/Section 1
Geyser — Part 9/Section 1
Glare — Part 8/Section 1
Global Warming Potential (GWP) — Part 8/Section 3
Globe Temperature — Part 8/Section 1
Goods Lift — Part 8/Section 5
Grade — Part 10/Section 1
Gradient — Part 10/Section 1
Grading — Part 10/Section 1
Grasses — Part 10/Section 1
Gravel — Part 6/Section 2
Ground Sign — Part 10/Section 2
Groundcover — Part 10/Section 1
Group Automatic Operation — Part 8/Section 5
Group Housing — Part 3
Group Open Space — Part 3
Grout — Part 6/Section 4
Guide Rails — Part 8/Section 5
Guide Rails Fixing — Part 8/Section 5
Guide Rails Shoe — Part 8/Section 5
Gully Chamber — Part 9/Section 1
Gully Trap — Part 9/Section 1

H

Habitable Room — Part 3
Hard Landscape — Part 10/Section 1
Hardy Plant — Part 10/Section 1
Harmonics — Part 8/Section 2
Haunching — Part 9/Section 1
Hedge — Part 10/Section 1
Heel Rest Bend or Duck-Foot Bend — Part 9/Section 1
Hemi Cellulose — Part 6/Section 3B
Herb — Part 10/Section 1
High Altitudes — Part 9/Section 1
High Rise Building — Part 4
Highway Authority — Part 9/Section 1
Hollow Unit — Part 6/Section 4
Horizontal Exit — Part 4
Horizontal Pipe — Part 9/Section 1
Hospital Lift — Part 8/Section 5
Hot Water Tank — Part 9/Section 1
Humidification — Part 8/Section 1
Humidity, Absolute — Part 8/Section 1
Humidity, Relative — Part 8/Section 1
Hydronic Systems — Part 8/Section 3

I

Identification Sign — Part 10/Section 2
Illuminance — Part 8/Section 1
Illuminated Sign — Part 10/Section 2
Impact Sound Pressure Level, L_i — Part 8/Section 4
Increments — Part 6/Section 7A, Part 6/Section 7B
Independent Cluster — Part 3
Indoor Air Quality (IAQ) — Part 8/Section 3
Indoor Ambient Noise — Part 8/Section 4
Inflammable — Part 8/Section 2
Informational Sign — Part 10/Section 2
Ingress — Part 10/Section 1
Inlet Hopper — Part 9/Section 1
Inner Diameter — Part 6/Section 3B

Insertion Loss (L_{IL}) — Part 8/Section 4
Inside Location — Part 6/Section 3, Part 6/Section 3B
Inspection Chamber — Part 9/Section 1
Installation (Electrical), of Buildings — Part 8/Section 2
Insulated — Part 8/Section 2
Insulation (Electrical) — Part 8/Section 2
Insulation, Basic — Part 8/Section 2
Insulation, Double — Part 8/Section 2
Insulation, Reinforced — Part 8/Section 2
Insulation, Supplementary — Part 8/Section 2
Interceptor — Part 9/Section 1
Interceptor Manhole or Interceptor Chamber — Part 9/Section 1
Interlocking Cluster — Part 3
Internal Faces of Cluster — Part 3
Internal Reflected Component (IRC) — Part 8/Section 1
Invert — Part 9/Section 1, Part 10/Section 1

J

Joint — Part 6/Section 3B, Part 6/Section 4
Joist — Part 6/Section 3B
Junction Pipe — Part 9/Section 1

K

Kerb — Part 10/Section 1
Kerb-Stone — Part 10/Section 1
Knot — Part 6/Section 3
Knot Hole — Part 6/Section 3

L

Lagging — Part 9/Section 1
Laminated Veneer Lumber — Part 6/Section 3
Landing — Part 8/Section 5
Landing Call Push — Part 8/Section 5
Landing Door — Part 8/Section 5
Landing Zone — Part 8/Section 5
Lateral Support — Part 6/Section 4
Leaf — Part 6/Section 4
Ledge or TAND — Part 3
Length of Internode — Part 6/Section 3B
Levelling Device, Lift Car — Part 8/Section 5
Levelling Device, One-Way Automatic — Part 8/Section 5
Levelling Device, Two-Way Automatic Non-Maintaining — Part 8/Section 5
Levelling Device, Two-Way Automatic Maintaining — Part 8/Section 5
Levelling Devices — Part 8/Section 5
Levelling Zone — Part 8/Section 5
Licensed Plumber — Part 9/Section 1
Lift — Part 3, Part 8/Section 5

An appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car platform.

Lift Car — Part 8/Section 5
Lift Landing — Part 8/Section 5
Lift Machine — Part 8/Section 5
Lift Pit — Part 8/Section 5
Lift Well — Part 8/Section 5
Lift Well Enclosure — Part 8/Section 5
Lifting Beam — Part 8/Section 5
Light Output Ratio (η) — Part 8/Section 1
Lighting — Part 8/Section 1
Lignin — Part 6/Section 3B
Linked Switch — Part 8/Section 2
Live Knot — Part 6/Section 3
Live or Alive — Part 8/Section 2
Load Bearing Wall — Part 6/Section 4
Loaded Edge Distance — Part 6/Section 3
Loaded End or Compression End Distance — Part 6/Section 3B
Local Exhaust Ventilation — Part 8/Section 1
Location — Part 6/Section 3
Locations, Industrial — Part 8/Section 2
Locations, Non-Industrial — Part 8/Section 2
Loft — Part 3
Loose Grain (Loosened Grain) — Part 6/Section 3
Loose Knot — Part 6/Section 3
Lumen (lm) — Part 8/Section 1
Luminance (At a Point of a Surface in a Given Direction) (Brightness) — Part 8/Section 1
Luminous Flux (ϕ) — Part 8/Section 1

M

Main Soil Pipe (MSP) — Part 9/Section 1
Main Soil Waste Pipe (MSWP) — Part 9/Section 1
Main Ventilating Pipe (MVP) — Part 9/Section 1
Main Waste Pipe (MWP) — Part 9/Section 1
Maintenance Factor (d) — Part 8/Section 1
Make-up Air — Part 8/Section 1
Make-up Ground — Part 6/Section 2
Manhole — Part 9/Section 1
Manhole Chamber — Part 9/Section 1
Mansard — Part 10/Section 2
Marquee Sign — Part 10/Section 2
Masonry — Part 6/Section 4

Masonry Unit — Part 6/Section 4
Matchet — Part 6/Section 3B
Mats — Part 6/Section 3B
Means of Egress — Part 4
Mechanical Ventilation — Part 8/Section 1
Meridian — Part 8/Section 1
Mezzanine Floor — Part 3
Miniature Circuit Breaker — Part 8/Section 2
Modular Co-ordination — Part 6/Section 7A, Part 6/Section 7B
Modular Grid — Part 6/Section 7A, Part 6/Section 7B
Module — Part 6/Section 7A, Part 6/Section 7B
Mortise and Tenon — Part 6/Section 3B
Mould — Part 6/Section 3
Mound — Part 10/Section 1
Multimodule — Part 6/Section 7A, Part 6/Section 7B
Multiple Earthed Neutral System — Part 8/Section 2
Multi-Under-Reamed Pile — Part 6/Section 2

N

Native — Part 10/Section 1
Natural Grade — Part 10/Section 1
Natural Ventilation — Part 8/Section 1
Negative Skin Friction — Part 6/Section 2
Net Section — Part 6/Section 3B
Neutral Conductor — Part 8/Section 2
Node — Part 6/Section 3B
Noise — Part 8/Section 4
Noise Exposure Forecast (NEF) — Part 8/Section 4
Noise Rating (NR) — Part 8/Section 4
Noise Reduction Co-efficient (NRC) — Part 8/Section 4
Non-Selective Collective Automatic Operation — Part 8/Section 5
Non-Service Laterine — Part 9/Section 1
Normalized Impact Sound Pressure Level, L_n — Part 8/Section 4
North and South Points — Part 8/Section 1

O

Occupancy or Use Group — Part 2, Part 3, Part 4

The principal occupancy for which a building or a part of a building is used or intended to be used; for the purposes of classification of a building according to occupancy, an occupancy shall be deemed to include the subsidiary occupancies which are contingent upon it.

Occupier — Part 2
Octave Band — Part 8/Section 4
**Offset* — Part 6/Section 2, Part 9/Section 1
Oil Buffer — Part 8/Section 5
Oil Buffer Stroke — Part 8/Section 5
Open Clusters — Part 3
Open Sign — Part 10/Section 2
Open Space — Part 3
Open Space, Front — Part 3
Open Space, Rear — Part 3
Open Space, Side — Part 3
Operating Device — Part 8/Section 5
Operation — Part 8/Section 5
Operational Construction/Installation — Part 2
Orientation of Buildings — Part 8/Section 1
Outdoor Furniture — Part 10/Section 1
Outer Diameter — Part 6/Section 3B
Outside Location — Part 6/Section 3A, Part 6/Section 3B
Over Speed Governor — Part 8/Section 5
Overhead Beams — Part 8/Section 5
Owner — Part 2, Part 3, Part 10/Section 2

Person or body having a legal interest in land and/or building thereon. This includes free holders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/lessee till the allotment/lease subsists.

Ozone Depletion Potential (ODP) — Part 8/Section 3

P

Panel Wall — Part 6/Section 4
Parapet — Part 3, Part 10/Section 2
Parking Space — Part 3
Partition — Part 3
Partition Wall — Part 6/Section 4
Passenger Lift — Part 8/Section 5
Peat — Part 6/Section 2
Percentile Level, $L_{AN,T}$ — Part 8/Section 4
Period of Supply — Part 9/Section 1
Peripheral Field — Part 8/Section 1
Permanent Load — Part 6/Section 2
Permissible Stress — Part 6/Section 3, Part 6/Section 3B
Permit — Part 2
Pile Foundation — Part 6/Section 2

* Definitions are different.

Pilot — Part 9/Section 2

Pink Noise — Part 8/Section 4

Pipe System — Part 9/Section 1

Pipe Work — Part 9/Section 1

Pitch Pocket — Part 6/Section 3

Plenum — Part 8/Section 3

Plinth — Part 3

The portion of a structure between the surface of the surrounding ground and surface of the floor, immediately above the ground.

Plinth Area — Part 3, Part 4

The built up covered area measured at the floor level of the basement or of any storey.

Plug — Part 8/Section 2

Plumbing System — Part 9/Section 1

Plumbing — Part 9/Section 1

Point (in Wiring) — Part 8/Section 2

Porch — Part 3

Portable Sign — Part 10/Section 2

Position and/or Direction Indicator — Part 8/Section 5

Positive Ventilation — Part 8/Section 1, Part 8/Section 3

Potable Water — Part 9/Section 1

Prefabricate — Part 6/Section 7 A, Part 6/Section 7B

Prefabricated Building — Part 6/Section 7A, Part 6/Section 7B

Premises — Part 9/Section 1

Pressure Regulator — Part 9/Section 2

Pressurization — Part 4

Pressurization Level — Part 4

Principal Rafter — Part 6/Section 3B

Projecting Sign — Part 10/Section 2

Propeller Fan — Part 8/Section 1

Psychrometric Chart — Part 8/Section 3

Psychrometry — Part 8/Section 3

Puff Ventilation — Part 9/Section 1

Pure Tone — Part 8/Section 4

Purge — Part 9/Section 2

Purlins — Part 6/Section 3B

Q

Qualified Installing Agency — Part 9/Section 2

R

Rated Load (Escalator) — Part 8/Section 5

Rated Load — Part 8/Section 5

Rated Speed (Escalator) — Part 8/Section 5

Rated Speed — Part 8/Section 5

Rating Level, L_{Ar}, T_r — Part 8/Section 4

Recirculated Air — Part 8/Section 3

Reflected Glare — Part 8/Section 1

Reflection Factor (Reflectance) — Part 8/Section 1

Refrigerant — Part 8/Section 3

Registered Architect, Engineer, Structural Engineer, Supervisor, Town Planner — Part 2

Regulatory Sign — Part 10/Section 2

Relative Humidity — Part 8/Section 3

Residual Current Circuit Breaker — Part 8/Section 2

Residual Head — Part 9/Section 1

Retiring Cam — Part 8/Section 5

Return Air — Part 8/Section 3

Reveal — Part 8/Section 1

Reverberation Time, T — Part 8/Section 4

Rheostatic Control — Part 8/Section 5

Riser — Part 9/Section 2

Road — Part 2, Part 3

Road Line — Part 2, Part 3

Roof Battens — Part 6/Section 3B

Roof Exits — Part 4

Roof Sign — Part 10/Section 2

Roof Skeleton — Part 6/Section 3B

Room Height — Part 2, Part 3

The vertical distance measured from the finished floor surface to the finished ceiling surface. Where a finished ceiling is not provided, the underside of the joists or beams or tie beams shall determine the upper point of measurement for determining the head room.

Room Index (k_r) — Part 8/Section 1

Roping Multiple — Part 8/Section 5

Row Housing/Row Type Building — Part 3

S

Saddle — Part 9/Section 1

Safety Gear — Part 8/Section 5

Sanctioned Plan — Part 2

Sand — Part 6/Section 2

Sand, Coarse — Part 6/Section 2

Sand, Fine — Part 6/Section 2

Sand, Medium — Part 6/Section 2

Sandwich Panels — Part 6/Section 7A, Part 6/Section 7B

Sandwich, Structural — Part 6/Section 3

Sanitary Appliances — Part 9/Section 1

Sap Stain — Part 6/Section 3

Sapwood — Part 6/Section 3

Scaffold — Part 6/Section 3B

Screen — Part 10/Section 1

Section 5

Self Compacting Concrete — Part 6/Section 7A, Part 6/ Section 7B

Semi-Detached Building — Part 3

Service — Part 8/Section 2

Service Laterine — Part 9/Section 1

Service Lift (Dumb-Waiter) — Part 8/Section 5

* *Service Pipe* — Part 9/Section 1, Part 9/Section 2

Service Road — Part 2, Part 3

Service Shut-Off Valve (Isolation Valve) — Part 9/ Section 2

Set-back Line — Part 2, Part 3

A line usually parallel to the plot boundaries and laid down in each case by the Authority, beyond which nothing can be constructed towards the site boundaries.

Sewer — Part 9/Section 1

Shade Factor — Part 8/Section 3

Shake — Part 6/Section 3

Shallow Foundation — Part 6/Section 2

Shear Connectors — Part 6/Section 7A, Part 6/ Section 7B

Shear Wall — Part 6/Section 4

Sheave — Part 8/Section 5

Shrub — Part 10/Section 1

Sick Building Syndrome (SBS) — Part 8/Section 3

Sign — Part 10/Section 2

Sign Area — Part 10/Section 2

Sign Copy — Part 10/Section 2

Sign Face — Part 10/Section 2

Sign Structure — Part 10/Section 2

Signal Operation — Part 8/Section 5

Signs — Part 10/Section 2

Silt — Part 6/Section 2

Single Automatic Operation — Part 8/Section 5

Single-Speed Alternating Current Control — Part 8/ Section 5

Site (Plot) — Part 2, Part 3, Part 4

A parcel (piece) of land enclosed by definite boundaries.

Site, Corner — Part 3

Site, Depth of — Part 3

Site, Double Frontage — Part 3

Site, Interior or Tandem — Part 3

Sky Component (SC) — Part 8/Section 1

Sky Sign — Part 10/Section 2

Slack Rope Switch — Part 8/Section 5

Slop Hopper (Slop Sink) — Part 9/Section 1

Slope of Grain — Part 6/Section 3

Smoke Damper — Part 8/Section 3

Soakaway — Part 9/Section 1

Socket-Outlet — Part 8/Section 2

Soffit (Crown) — Part 9/Section 1

Soft Landscape — Part 10/Section 1

Soft Rock — Part 6/Section 2

Soil Appliances — Part 9/Section 1

Soil Pipe — Part 9/Section 1

Soil Waste — Part 9/Section 1

Soil, Black Cotton — Part 6/Section 2

Soil, Coarse Grained — Part 6/Section 2

Soil, Find Grained — Part 6/Section 2

Solar Load — Part 8/Section 1

Solid-State d.c. Variable Voltage Control — Part 8/ Section 5

Sound — Part 8/Section 4

Sound Exposure Level, L_{AE} — Part 8/Section 4

Sound Knot — Part 6/Section 3

Sound Power — Part 8/Section 4

Sound Power Level (L_w) — Part 8/Section 4

Sound Pressure Level, L_p — Part 8/Section 4

Sound Pressure, p — Part 8/Section 4

Sound Receiver — Part 8/Section 4

Sound Reduction Index, R — Part 8/Section 4

Sound Source — Part 8/Section 4

Spaced Column — Part 6/Section 3

Spectrum — Part 8/Section 4

Speech Interference Level (SIL) — Part 8/Section 4

Split — Part 6/Section 3

Splits — Part 6/Section 3B

Spot Elevation — Part 10/Section 1

Spray-Head System — Part 8/Section 1

Spread Foundation — Part 6/Section 2

Spring Buffer — Part 8/Section 5

Spring Buffer Load Rating — Part 8/Section 5

Spring Buffer Stroke — Part 8/Section 5

Stack Effect — Part 8/Section 1

Stack Pressure — Part 4

Staircover (or Mumty) — Part 3

Standardized Impact Sound Pressure Level, L_{nT} — Part 8/Section 4

Standardized Level Difference, D_{nT} — Part 8/Section 4

Static Pressure — Part 8/Section 3

Stop Tap — Part 9/Section 1

* Definitions are different.

Stop-Cock — Part 9/Section 1

Storage Tank — Part 9/Section 1

Storey — Part 3

The portion of a building included between the surface of any floor and the surface of the floor next above it, or if there be no floor above it, then the space between any floor and the ceiling next above it.

Storey, Topmost — Part 3

Street — Part 2, Part 3

Any means of access, namely, highway, street, lane, pathway, alley, stairway, passageway, carriageway, footway, square, place or bridge, whether a thoroughfare or not, over which the public have a right of passage or access or have passed and had access uninterruptedly for a specified period, whether existing or proposed in any scheme and includes all bunds, channels, ditches, storm-water drains, culverts, sidewalks, traffic islands, roadside trees and hedges, retaining walls, fences, barriers and railings within the street lines.

Street Furniture — Part 10/Section 1

Street Level or Grade — Part 2, Part 3

The officially established elevation or grade of the centre line of the street upon which a plot fronts and if there is no officially established grade, the existing grade of the street at its mid-point.

Street Line — Part 2, Part 3, Part 10/Section 2

The line defining the side limits of a street.

Structural Element — Part 6/Section 3

Structural Grades — Part 6/Section 3

Structural Purpose Definitions — Part 6/Section 3, Part 6/Section 3B

Structural Timber — Part 6/Section 3

Structure Borne Noise — Part 8/Section 4

Structure, Permanent — Part 6/Section 3

Structure, Temporary — Part 6/Section 3

Sub-Soil Water — Part 9/Section 1

Sub-Soil Water Drain — Part 9/Section 1

Sub-Zero Temperature Regions — Part 9/Section 1

Supply Air — Part 8/Section 3

Supply and Return Air Grilles and Diffusers — Part 8/Section 3

Supply Pipe — Part 9/Section 1

Supports — Part 9/Section 1

Surface Cracking — Part 6/Section 3B

Surface Water — Part 9/Section 1

Surface Water Drain — Part 9/Section 1

Suspension Ropes — Part 8/Section 5

Swale — Part 10/Section 1

Switch — Part 8/Section 2

Switch Disconnector Fuse — Part 8/Section 2

Switch Disconnectors — Part 8/Section 2

Switchboard — Part 8/Section 2

Switchgear — Part 8/Section 2

System — Part 6/Section 7A, Part 6/Section 7B,

Systems of Drainage — Part 9/Section 1

T

Taper — Part 6/Section 3B

Temporary Sign — Part 10/Section 2

Terminal Slow Down Switch — Part 8/Section 5

Terminal Stopping Device Final — Part 8/Section 5

Terminal Stopping Switch Normal — Part 8/Section 5

Termites — Part 6/Section 3

Thermal Energy Storage — Part 8/Section 3

Thermal Transmittance — Part 8/Section 3

Third Octave Band — Part 8/Section 4

Threshold Limit Value (TLV) — Part 8/Section 1

Threshold of Hearing — Part 8/Section 4

Tight Knot — Part 6/Section 3

Tissue — Part 6/Section 3B

To Abut — Part 3

To Erect — Part 2, Part 3

Top Car Clearance — Part 8/Section 5

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* Definitions are different.

NATIONAL BUILDING CODE OF INDIA

PART 2 ADMINISTRATION

BUREAU OF INDIAN STANDARDS

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FOREWORD

A need for codifying and unifying administrative provisions in different development control rules and building byelaws had been felt, particularly in regard to the applicability of the Code, desirable qualifications for the enforcing Authority and the representative of the owner and responsibilities and duties of the Authority and the owner.

It is expected that the town and country planning department will co-ordinate the administrative provisions of this Part and the same given in the State Town and Country Planning Acts.

This Part recommends the setting up of a 'Board of Appeal'. The 'Board of Appeal' gives the owner/architect/ engineer an opportunity to defend the schemes which are based on conventional or new methods of design and construction or using new materials, which have been otherwise rejected by the Authority.

This Part also emphasizes the need for setting up an Arts Commission for metropolitan areas to safeguard existing aesthetics in the event of new schemes proposed for buildings of public importance or buildings coming up in an important area near historic/monumental buildings. The Commission can assist the civic authorities in reviewing plans for development from the stand point of assuring good taste and regard for often threatened natural beauties. The Commission can serve as a means whereby by the government and public bodies and individuals could get advice on artistic questions in connection with building schemes.

The first version of this Part was brought out in 1970, which was subsequently revised in 1983. As a result of implementing 1970 version of this Part in rewriting building byelaws and development control rules of some municipal corporations and municipalities, some useful suggestions were emerged. These were incorporated in the first revision to the extent possible. The significant changes in 1983 version of this Part included the new administrative provisions related to development control rules, additional information to be furnished/indicated in the building plan for multi-storeyed and special buildings and modified provisions regarding submission of building plans by Government Departments to the Authority.

In this second revision, number of modifications have been incorporated based on the experience gained over the years specially in view of different techno-administrative and techno-legal regime encountered in various situations faced. Specially the provisions of this Part have been thoroughly reviewed in the context of the natural calamities faced by the country, such as the devastating earthquake in Gujarat in the year 2001, and provisions have been accordingly modified to further ensure structural adequacy of the buildings. In this context, structural design of buildings in accordance with the provisions of the Code and construction and supervision thereof by competent professionals to ensure structural safety have been given due importance in this revision. Other significant modifications incorporated include:

a) Modifications in the definitions of certain terms;
b) Inclusion of the concept of team of building officials;
c) Inclusion of provision of single window approach for permit for all services;
d) Inclusion of provisions regarding computerization of approval processes for building permits;
e) Inclusion of provision to certify safety of buildings against natural disaster by engineer/structural engineer and owner;
f) Inclusion of provision of two stage permit for high rise residential buildings and special buildings;
g) Provisions regarding inspection of completed and occupied building by the Authority from safety point of view have been made comprehensive;
h) Inclusion of provision empowering engineers/architects for sanctioning plans of residential buildings up to 500 m^2;
j) Provisions for architectural control to effectively take care of the urban aesthetics, have been modified; and
k) Inclusion of landscape architect and urban designer among the registered professionals for the concerned applicable works.

The Sectional Committee responsible for revision of the Code has examined the use of the words 'surveyor/ building surveyor/supervisor', etc under various building bye-laws with varying qualifications in different states. It has been decided not to use the generic word 'surveyor' or such other words. The Sectional Committee has, on the other hand recommended association of various professionals for various job responsibilities depending upon their qualifications/competence.

Also, it is noted that the words 'licencing/licensed, etc' are in use by local bodies in different states. The Sectional Committee, however, decided for use of words 'registration/registered, etc' for the same, which may now be adopted uniformly. The registration requirements of professionals are given in Annex A.

NATIONAL BUILDING CODE OF INDIA

PART 2 ADMINISTRATION

SECTION 1 GENERAL

1 SCOPE

This Part covers the administrative aspects of the Code, such as applicability of the Code, organization of building department for enforcement of the Code, procedure for obtaining development and building permits, and responsibility of the owner.

NOTE — This Code is called the National Building Code of India, hereinafter referred to as 'the Code'.

2 TERMINOLOGY

2.0 For the purpose of this part, the following definitions shall apply.

2.1 Accessory Use — Any use of the premises subordinate to the principal use and customarily incidental to the principal use.

2.2 Alteration — A change from one type of occupancy to another, or a structural change, such as an addition to the area or height, or the removal of part of a building, or any change to the structure, such as the construction of, cutting into or removal of any wall, partition, column, beam, joist, floor or other support, or a change to or closing of any required means of ingress or egress or a change to the fixtures or equipment.

2.3 Approved — Approved by the Authority having jurisdiction.

2.4 Authority Having Jurisdiction — The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.5 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, verandah, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents/ *SHAMIANAHS*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

2.6 Building, Height of — The vertical distance measured, in the case of flat roofs from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of last livable floor of the building adjacent to the external walls; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof, and in the case of gables facing the road, the midpoint between the eaves level and the ridge. Architectural features serving no other function except that of decoration shall be excluded for the purpose of measuring heights.

2.7 Building Line — The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme. The building line may change from time-to-time as decided by the Authority.

2.8 Conversion — The change of occupancy or premises to any occupancy or use requiring additional occupancy permit.

2.9 Development — 'Development' with grammatical variations means the carrying out of building, engineering, mining or other operations in, or over, or under land or water, or in the use of any building or land, and includes redevelopment and layout and subdivision of any land; and 'to develop' shall be construed accordingly.

2.10 Drain — A conduit or channel for the carriage of storm water, sewage, waste water or other water-borne wastes in a building drainage system.

2.11 Drainage — The removal of any liquid by a system constructed for the purpose.

2.12 Occupancy or Use Group — The principal occupancy for which a building or a part of a building is used or intended to be used; for the purposes of classification of a building according to occupancy, an occupancy shall be deemed to include the subsidiary occupancies which are contingent upon it.

2.13 Occupier — Occupier includes any person for the time being, paying or liable to pay rent or any portion of rent of the building in respect of which the ward is used, or compensation or premium on account of the occupation of such building and also a rent-free tenant, but does not include a lodger, and the words 'occupy' and 'occupation' do not refer to the lodger.

An owner living in or otherwise using his own building shall be deemed to be the occupier thereof.

2.14 Operational Construction/Installation — A construction/installation put up by Government Departments for operational purposes (*see* **12.1.1.1**).

2.15 Owner — Person or body having a legal interest in land and/or building thereon. This includes free holders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

2.16 Permit — A permission or authorization in writing by the Authority to carry out work regulated by the Code.

2.17 Registered Architect, Engineer, Structural Engineer, Supervisor, Town Planner, Landscape Architect, Urban Designer — A qualified architect, engineer, structural engineer, supervisor, town planner, landscape architect or urban designer who has been registered by the Authority or by the body governing such profession and constituted under a statute, as may be applicable. The registration requirements of these professionals shall be as given in Annex A.

NOTES

1 Unless specified otherwise, the word 'engineer' shall mean 'civil engineer' or 'architectural engineer'.

2 The word 'licencing/licensed, etc' if used by the Authority in the above context shall be deemed to mean 'registration/ registered', etc.

2.18 Road — *See* **2.25**.

2.19 Road Line — *See* **2.27**.

2.20 Room Height — The vertical distance measured from the finished floor surface to the finished ceiling surface. Where a finished ceiling is not provided, the underside of the joists or beams or tie beams shall determine the upper point of measurement for determining the head room.

2.21 Sanctioned Plan — The set of plans and specifications submitted in connection with a building or development and duly approved and sanctioned by the Authority.

2.22 Service Road — A road/lane provided at the rear or side of a plot for service purposes.

2.23 Set-back Line — A line usually parallel to the plot boundaries and laid down in each case by the Authority, beyond which nothing can be constructed towards the site boundaries.

2.24 Site (Plot) — A parcel (piece) of land enclosed by definite boundaries.

2.25 Street — Any means of access, namely, highway, street, lane, pathway, alley, stairway, passageway, carriageway, footway, square, place or bridge, whether a thoroughfare or not, over which the public have a right of passage or access or have passed and had access uninterruptedly for a specified period, whether existing or proposed in any scheme and includes all bunds, channels, ditches, storm-water drains, culverts, sidewalks, traffic islands, roadside trees and hedges, retaining walls, fences, barriers and railings within the street lines.

2.26 Street Level or Grade — The officially established elevation or grade of the centre line of the street upon which a plot fronts and if there is no officially established grade, the existing grade of the street at its mid-point.

2.27 Street Line — The line defining the side limits of a street.

2.28 To Erect — To erect a building means:

a) to erect a new building on any site whether previously built upon or not;

b) to re-erect any building of which portions above the plinth level have been pulled down, burnt or destroyed.

2.29 Unsafe Building — Buildings which are structurally and constructionally unsafe or insanitary or not provided with adequate means of egress or which constitute a fire hazard or are otherwise dangerous to human life or which in relation to existing use constitute a hazard to safety or health or public welfare, by reason of inadequate maintenance, dilapidation or abandonment.

3 APPLICABILITY OF THE CODE

3.1 All Parts of the Code and their sections shall apply to all buildings described in **3.2** to **3.8**, as may be applicable.

3.2 Where a building is erected, the Code applies to the design and construction of the building.

3.3 Where the whole or any part of the building is removed, the Code applies to all parts of the building whether removed or not.

3.4 Where the whole or any part of the building is demolished, the Code applies to any remaining part and to the work involved in demolition.

3.5 Where a building is altered (*see* **12.4** and **12.4.1**), the Code applies to the whole building whether existing or new except that the Code applies only to part if that part is completely self-contained with respect to facilities and safety measures required by the Code.

3.6 Where the occupancy of a building is changed, the Code applies to all parts of the building affected by the change.

3.8 Existing Buildings/Development

Nothing in the Code shall require the removal, alteration or abandonment, nor prevent continuance of the use or occupancy of an existing building/development, unless in the opinion of the Authority, such building/development constitutes a hazard to the safety of the adjacent property or the occupants of the building itself.

4 INTERPRETATION

4.1 The heading which appears at the beginning of a clause or sub-clause of the Code shall be deemed to be a part of such clause or sub-clause respectively.

4.2 The use of present tense includes the future tense, the masculine gender includes the feminine and the neuter, the singular number includes the plural and the plural includes the singular. The word 'person' includes a corporation as well as an individual; writing includes printing and typing and 'signature' includes thumb impression made by a person who cannot write if his name is written near to such thumb impression.

5 ALTERNATIVE MATERIALS, METHODS OF DESIGN AND CONSTRUCTION, AND TESTS

5.1 The provisions of the Code are not intended to prevent the use of any material or method of design or construction not specifically prescribed by the Code, provided any such alternative has been approved.

5.2 The Authority may approve any such alternative provided it is found that the proposed alternative is satisfactory and conforms to the provisions of relevant parts regarding material, design and construction and that material, method, or work offered is, for the purpose intended, at least equivalent to that prescribed in the Code in quality, strength, compatibility, effectiveness, fire and water resistance, durability and safety.

5.3 Tests

Whenever there is insufficient evidence of compliance with the provisions of the Code or evidence that any material or method of design or construction does not conform to the requirements of the Code or in order to substantiate claims for alternative materials, design or methods of construction not specifically prescribed in the Code, the Authority may require tests sufficiently in advance as proof of compliance. These tests shall be made by an approved agency at the expense of the owner.

5.3.1 Test methods shall be specified by the Code for the materials or design or construction in question. If For methods of test for building materials, reference may be made to Part 5 Building Materials.

5.3.2 Copies of the results of all such tests shall be retained by the Authority for a period of not less than two years after the acceptance of the alternative material.

SECTION 2 ORGANIZATION AND ENFORCEMENT

6 DEPARTMENT OF BUILDINGS

6.1 The department of buildings shall be created by the Authority and a team of building officials shall be appointed to carry out work of such department.

6.2 Appointment of Team of Building Officials

The team of building officials shall be appointed by the Authority. The team shall comprise officials drawn from concerned disciplines such as engineer, architect, town planner, landscape architect and urban designer as may be decided by the Authority. For scrutiny of layout plans of plots of one hectare and above in metro cities and two hectares and above in other places, town planner shall be part of the team of building officials. For plots of five hectares and above, landscape architect shall also be part of the team. An urban designer shall also be required to be the part of team of building officials for examining proposals on integrated urban design and development for residential/business/institutional and assembly building.

NOTE — Metro cities are cities with population more than 1 000 000.

6.3 Organization

In the department of buildings, such number of officers, technical assistants, inspectors and other employees shall be appointed to assist the team of building officials as shall be necessary for the administration of the Code and as authorized by the Authority.

6.4 Delegation of Powers

The Authority may designate one of the building officials who shall exercise all the powers of the team of building officials. The work of the team of building officials may be outsourced to competent professional/agency/group as may be deemed necessary.

6.5 Qualification of Building Officials

The qualification of building officials scrutinizing the plans and carrying out inspection of buildings shall not in any case be less than those prescribed in Annex A.

6.5.1 In small local bodies having insufficient resources to appoint such officials with the above

6.6 Qualifications of Assistant

No person shall be appointed as Assistant unless he has got the qualifications prescribed in Annex A for a registered Supervisor.

6.7 Restriction on Employees

No official or employee connected with the department of buildings except one whose only connection is that of a member of the Board of Appeals, established under **8** shall be engaged directly or indirectly in a work connected with the furnishing of labour, materials or appliances for the construction, alteration or maintenance of a building, or the preparation of plans or of specifications thereof unless he is the owner of building; nor shall such official or employee engage in any work which conflicts with his official duties or with the interests of the Department.

6.8 Records

Proper records of all applications received, permits and orders issued, inspections made shall be kept and copies of all papers and documents connected with the administration of its duties shall be retained and all such records shall be open to public inspection at all appropriate times.

7 POWER AND DUTIES OF TEAM OF BUILDING OFFICIALS

7.0 The team of building officials shall enforce all the provisions of the Code and shall act on any question relative to the mode or manner of construction and the materials to be used in the erection, addition, alteration, repair, removal, demolition, installation of service equipment and the location, use, occupancy and maintenance of all buildings except as may otherwise be specifically provided.

7.1 Application and Permits

The team of building officials shall receive all applications and issue permits (*see* **12.10**) for the erection and alteration of buildings and examine the premises for which such permits have been issued and enforce compliance with the Code.

7.2 Building Notices and Orders

The team of building officials shall issue all necessary notices or orders to remove illegal or unsafe conditions, to require the necessary safeguards during construction, to require adequate exit facilities in existing buildings and to ensure compliance with all the requirements of safety, health and general welfare of the public as included in the Code.

advance notice, the team of building officials or its duly authorized representative may enter at any reasonable time any building or premises to perform any duty imposed upon him by the Code.

7.4 Inspection

The team of building officials shall make all the required inspections or it may accept reports of inspections of authoritative and recognized services or individuals; and all reports of inspections shall be in writing and certified by a responsible officer of such authoritative service or by the responsible individual or engage any such expert opinion as he may deem necessary to report upon unusual technical issues that may arise, subject to the approval of the Authority.

7.5 Construction Not According to Plan

Should the team of building officials determine at any stage that the construction is not proceeding according to the sanctioned plan or is in violation of any of the provisions of the Code, or any other applicable Code Regulation, Act or Byelaw, it shall notify the owner, and all further construction shall be stayed until correction has been effected and approved.

7.5.1 Should the owner fail to comply with the requirements at any stage of construction, the Authority shall issue a notice to the owner asking explanation for non-compliance. If the owner fails to comply within 14 days from the date of receiving the notice, the Authority shall be empowered to cancel the building permit issued and shall cause notice of such cancellation to be securely pasted upon the said construction, if the owner is not traceable at his address given in the notice. Pasting of such a notice shall be considered sufficient notification of cancellation to the owner thereof. No further work shall be undertaken or permitted upon such construction until a valid building permit thereafter has been issued. If the owner, in violation of the notice for cancellation, continues the construction, the Authority may take all necessary means to stop such work and further appropriate actions including demolitions. The owner shall, however, have right to appeal against cancellation of permit, to the board of appeal, within a stipulated period, as may be decided by the Authority.

7.6 Modification

Wherever practical difficulties are involved in carrying out any provision of the Code, the team of building officials may vary or modify such provisions upon application of the owner or his representative provided the spirit and intent of the Code shall be observed and public welfare and safety be assured. The application

for modification and the final decision of the team of building officials shall be in writing and shall be officially recorded with the application for the permit in the permanent records of the Department of Building Inspection.

7.7 Occupancy Violations

Wherever any building is being used contrary to provisions of the Code, the team of building officials may order such use discontinued and the building or portion thereof, vacated by the notice served on any person, causing such use to be discontinued. Such person shall discontinue the use within 10 days after receipt of such notice or make the building or portion thereof, comply with the requirements of the Code.

8 BOARD OF APPEALS

In order to determine the suitability of alternative materials or methods of design or construction and to provide for reasonable interpretation of the provisions of the Code or in the matter of dispute relating to an ongoing construction vis-a-vis the sanctioned plan, a Board of Appeals consisting of members who are qualified by experience and training and to pass judgement upon matters pertaining to building construction, shall be appointed by the Authority. A representative of the team of building officials shall be an *ex-officio* member and shall act as secretary to the Board. The Board shall adopt reasonable rules and regulations for conducting its investigations and shall render all decisions and findings in writing to the team of building officials with a duplicate copy to the appellant and may recommend such modifications as are necessary.

9 VIOLATIONS AND PENALTIES

9.1 Offences and Penalties

9.1.1 Any person who contravenes any of the provisions of the Code or any requirements of obligations imposed on him by virtue of the Code, or who interferes with or obstructs any person in the discharge of his duties, shall be guilty of an offence and the Authority shall levy suitable penalty or take other actions as per the Code (*see also* **7.5** and **15**).

NOTE — The penalty may be in the form of collection of arrears of tax.

9.1.2 The buildings/developments violating any applicable statutory rules shall be demolished/brought within the limits as prescribed in such rules at the expense of the owner. The buildings coming up in the vicinity of an aerodrome in violation of the height restriction laid down by the Directorate General of Civil Aviation shall be accordingly demolished/brought within the limits prescribed by DGCA rules.

9.1.3 The registered architect, engineer, structural engineer, supervisor, town planner, landscape architect, urban designer and utility service engineer (*see* Annex A) responsible for the services rendered for supervision of the construction/development and for the completion certificate; in the event of violation of the provisions of the Code, shall be liable to penalties as prescribed by the Authority including cancellation of registration done by it or make such recommendation to the statutory body governing such profession.

9.2 Further Obligation of Offender

The conviction of any person for an offence under the provision of **9.1** shall not relieve him from the duty of carrying out the requirements or obligations imposed on him by virtue of the provisions of the Code; and if such requirements or obligations are not complied with in accordance with an order made under provisions of **9.1**, the Authority under the provisions of the Code may, if necessary and advisable, enter upon the premises in respect of which a conviction has been made and carry out at the expense of the convicted person, the requirements or obligations referred to in the said order and the expense, if not paid on demand, may be recovered with cost in a court.

9.3 Conviction No Bar to Further Prosecution

The conviction of any person under the provisions of this part for failing to comply with any of the said requirements or obligations shall not operate as a bar to further prosecution under this part for any subsequent failure on the part of such person to comply.

10 POWER TO MAKE RULES

The Authority may make rules for carrying out the provisions and intentions of the Code provided that any rule shall not be in direct/indirect conflict or nullify/dilute any of the provisions of the Code.

SECTION 3 PERMIT AND INSPECTION

11 DEVELOPMENT/BUILDING PERMIT

11.1 Permit Required

No person shall carry out any development, erect, re-erect or make alterations or demolish any building or cause the same to be done without first obtaining a separate permit for each such development/building from the Authority. No permits shall, however, be required for works referred to in **12.1.1.1** and **12.4.1.**

11.1.1 The development/building permit shall take into cognizance the provisions under the relevant Town Planning Act/Development Act/Municipal Act/any other applicable statutes for layout, building plans, water supply, sewerage, drainage, electrification, etc, as provided in the said Act/statute. Also, if so directed

by the Authority, the permit shall take care of the need for landscape development plan incorporating rain-water harvesting proposals in the layout and building plans.

11.1.2 Specific approvals shall be obtained from Civil Aviation Authorities, Fire Services Department (in case the building proposed is 15 m and above), Pollution Control Board, designated authorities under Factories Act/Cinema Regulation Act, Urban Arts Commission, designated Coastal Regulation Zone Authority, Archeological Survey of India, Heritage Committee and any such other authority as may be applicable.

11.1.3 In order to facilitate clearance from above bodies with the concept of single window clearance approach and thereby final approval by the Authority within the stipulated time frame, the Authority may constitute a Development/Building Permit Approval Committee consisting of representative of the team of building officials, representatives of all bodies/ organizations from whom clearance for development/ building permit clearance is required.

Recommendations from such Committee shall be summarily utilized by the team of building officials in sanctioning process. The Committee may meet once in 15/30 days depending upon the work load. The first response/invalid notice/non-compliance intimation shall be issued by the Authority to the owner within 30 days of submission of the plans to the Authority.

11.1.4 The Authority shall permit a registered architect/engineer to approve the building proposals including plans, and certify completion of building for issue of related regulatory building permits and occupancy certificate for residential buildings designed by self or otherwise, on plot size up to 500 m^2. The responsibility of compliance with respect to provisions of Code shall rest with the registered architect/engineer. However, the plans shall be required to be submitted to the Authority for information and record.

NOTE — Where the experience clearly shows that satisfactory building permit activities are being carried out through the above empowerment of professionals, the Authority may extend such provision for larger areas and other building occupancies.

11.2 Pre-Code Development/Building Permit

If any development/building, permit for which had been issued before the commencement of the Code, is not wholly completed within a period of three years from the date of such permit, the said permission shall be deemed to have lapsed and fresh permit shall be necessary to proceed further with the work in accordance with the provisions of the Code.

12 APPLICATION FOR DEVELOPMENT/ BUILDING PERMIT

12.1 Notice

Every owner who intends to develop, erect, re-erect or make alterations in any place in a building shall give notice in writing to the Authority of his said intention in the prescribed form (*see* Annex B) and such notice shall be accompanied by plans and statements in triplicate as required under **12.2** and **12.3** except for special buildings (high rise, non-residential) where additional copies may be submitted as desired by the Authority. The Authority shall permit submission of plans/documents in electronic form in addition to hard copy. The Authority should also progressively computerize the approval process.

12.1.1 Regarding submission of plans by Government Departments, the procedure shall be as given in **12.1.1.1** and **12.1.1.2**.

12.1.1.1 The operational construction/installation of the Government, whether temporary or permanent, which is essential for the operation, maintenance, development or execution of any of the following services may be exempted from the point of view of the byelaws:

a) Railways;
b) National highways;
c) National waterways;
d) Major ports;
e) Airways and aerodromes;
f) Posts and telegraphs, telephones, wireless, broadcasting, and other like forms of communications;
g) Regional grid for electricity;
h) Defence; and
j) Any other service which the Central/State Government may, if it is of opinion that the operation, maintenance, development of execution of such service is essential to the life of the community, by notification, declare to be a service for the purpose of this clause.

In case of construction/installation where no approvals are required, the concerned agencies which are exempted from seeking approval shall submit the drawings/plans/details for information and records of the Authority before construction/installation.

12.1.1.2 However, the following construction of the Government departments do not come under the purview of operational construction for the purpose of exemption under **12.1.1.1**:

a) New residential building (other than gate lodges, quarters for limited essential operational

staff and the like), roads and drains in railway colonies, hospitals, clubs, institutes and schools, in the case of railways; and

b) A new building, new construction or new installation or any extension thereof in the case of any other services.

12.2 Information Accompanying Notice

The notice shall be accompanied by the key plan, site plan, building plan, services plans, specifications structural sufficiency certificate and certificate of supervision as prescribed in **12.2.2** to **12.2.8**.

12.2.1 *Sizes of Drawing Sheets and Recommended Notation for Colouring Plans*

12.2.1.1 The size of drawing sheets shall be any of those specified in Table 1.

Table 1 Drawing Sheet Sizes

(*Clause* 12.2.1.1)

Sl No.	Designation	Trimmed Size mm
(1)	(2)	(3)
i)	A0	841 × 1 189
ii)	A1	594 × 841
iii)	A2	420 × 594
iv)	A3	297 × 420
v)	A4	210 × 297
vi)	A5	148 × 210

12.2.1.2 The plans shall be coloured as specified in Table 2.

12.2.2 *Key Plan*

A key plan drawn to a scale of not less than 1 in 10 000 shall be submitted along with the application for a development/building permit showing the boundary locations of the site with respect to neighbourhood landmarks. The minimum dimension of the key plan shall be not less than 75 mm.

12.2.3 *Site Plan*

The site plan sent with an application for permit shall be drawn to a scale of not less than 1 in 500 for a site up to one hectare and not less than 1 in 1 000 for a site more than one hectare and shall show:

a) the boundaries of the site and of any contiguous land belonging to the owner thereof;

b) the position of the site in relation to neighbouring street;

c) the name of the streets in which the building is proposed to be situated, if any;

d) all existing buildings standing on, over or under the site including service lines;

e) the position of the building and of all other buildings (if any) which the applicant intends to erect upon his contiguous land referred to in (a) in relation to:

Table 2 Colouring of Plans

(*Clause* 12.2.1.2)

Sl No.	Item	Site Plan			Building Plan		
		White Plan	Blue Print	Ammonia Print	White Plan	Blue Print	Ammonia Print
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Plot lines	Thick black	Thick black	Thick black	Thick black	Thick black	Thick black
ii)	Existing street	Green	Green	Green	—	—	—
iii)	Future street, if any	Green dotted	Green dotted	Green dotted	—	—	—
iv)	Permissible building lines	Thick dotted black	Thick dotted black	Thick dotted black	—	—	—
v)	Open spaces	No colour	No colour	No colour	No colour	No colour	No colour
vi)	Existing work	Black (outline)	White	Blue	Black	White	Blue
vii)	Work proposed to be demolished	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched
viii)	Proposed work (*see* Note 1)	Red filled in	Red	Red	Red	Red	Red
ix)	Drainage and sewerage work	Red dotted	Red dotted	Red dotted	Red dotted	Red dotted	Red dotted
x)	Water supply work	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin

NOTES

1 For entirely new construction this need not be done; for extension of an existing work this shall apply.

2 For land development, subdivision, layout, suitable colouring notations shall be used which shall be indexed.

1) the boundaries of the site and in case where the site has been partitioned, the boundaries of the portion owned by the applicant and also of the portions owned by others;
2) all adjacent street, buildings (with number of storeys and height) and premises within a distance of 12 m of the site and of the contiguous land (if any) referred to in (a); and
3) if there is no street within a distance of 12 m of the site, the nearest existing street;

f) the means of access from the street to the building, and to all other buildings (if any) which the applicant intends to erect upon his contiguous land referred to in (a);
g) space to be left about the building to secure a free circulation of air, admission of light and access for scavenging purposes;
h) the width of the street (if any) in front and of the street (if any) at the side or near the buildings;
j) the direction of north point relative to the plan of the buildings;
k) any physical features, such as wells, drains, etc; and
m) such other particulars as may be prescribed by the Authority.

12.2.4 *Sub-Division/Layout Plan*

In the case of development work, the notice shall be accompanied by the sub-division/layout plan which shall be drawn on a scale of not less than 1 : 500 containing the following:

a) Scale used and north point;
b) The location of all proposed and existing roads with their existing/proposed/prescribed widths within the land;
c) Dimensions of plot along with building lines showing the setbacks with dimensions within each plot;
d) The location of drains, sewers, public facilities and services, and electrical lines, etc;
e) Table indicating size, area and use of all the plots in the sub-division/layout plan;
f) A statement indicating the total area of the site, area utilized under roads, open spaces for parks, playgrounds, recreation spaces for parks, playgrounds, recreation spaces and development plan reservations, schools, shopping and other public places alongwith their percentage with reference to the total area of the site proposed to be subdivided; and
g) In case of plots which are subdivided in built-up areas in addition to the above, the means of access to the sub-division from existing streets.

12.2.5 *Building Plan and Details*

The plan of the buildings and elevations and sections accompanying the notice shall be drawn to a scale of 1 : 100. The plans and details shall:

a) include floor plans of all floors together with the covered area clearly indicating the size and spacings of all framing members and sizes of rooms and the position of staircases, ramps and liftwells;
b) show the use or occupancy of all parts of the buildings;
c) show exact location of essential services, for example, WC, sink, bath and the like;
d) include at least one elevation from the front showing height of building and rooms and also the height of parapet;
e) include at least one section through the staircase;
f) include the structural arrangements with appropriate sections showing type/ arrangement of footings, foundations, basement walls; structural load bearing walls, columns and beams, and shear walls; and arrangement/spacing of framing members, floor slabs and roof slabs with the material used for the same;
g) show all street elevations;
h) give dimensions of the projected portions beyond the permissible building line;
j) include terrace plan indicating the drainage and the slope of the roof; and
k) give indications of the north point relative to the plan.

NOTE — The requirement of 1 : 100 is permitted to be flexible for specific details needed for further illustration; and also for drawings for these in electronic form.

12.2.5.1 *Building plan for multi-storeyed/special buildings*

For all multi-storeyed buildings which are 15 m or more in height and for special buildings like educational, assembly, institutional, industrial, storage and hazardous and mixed occupancies with any of the aforesaid occupancies having covered area more than 500 m^2, the building sanction shall be done in two stages.

Stage 1: First stage for planning clearance

The following additional information shall be furnished/indicated in the building plan in addition to the items given in **12.2.5** as applicable:

a) Access to fire appliances/vehicles with details of vehicular turning circle and clear motorable accessway around the building;
b) Size (width) of main and alternative staircases along with balcony approach, corridor, ventilated lobby approach;
c) Location and details of lift enclosures;
d) Location and size of fire lift;
e) Smoke stop lobby/door, where provided;
f) Refuse chutes, refuse chamber, service duct, etc;
g) Vehicular parking spaces;
h) Refuse area, if any;
j) *Details of building services* — Air-conditioning system with position of fire dampers, mechanical ventilation system, electrical services, boilers, gas pipes, etc;
k) Details of exits including provision of ramps, etc, for hospitals and special risks;
m) Location of generator, transformer and switchgear room;
n) Smoke exhauster system, if any;
p) Details of fire alarm system network;
q) Location of centralized control, connecting all fire alarm systems, built-in-fire protection arrangements and public address system, etc;
r) Location and dimensions of static water storage tank and pump room along with fire service inlets for mobile pump and water storage tank;
s) Location and details of fixed fire protection installations, such as, sprinklers, wet risers, hose-reels, drenchers, etc; and
t) Location and details of first-aid fire fighting equipments/installations.

Stage 2: Second stage for building permit clearance

After obtaining the sanction for planning (Stage 1) from the Authority, a complete set of structural plans, sections, details and design calculations duly signed by engineer/structural engineer (*see* Annex A) along with the complete set of details duly approved in Stage 1 shall be submitted. The building plans/details shall be deemed sanctioned for the commencement of construction only after obtaining the permit for Stage 2 from the Authority.

12.2.6 *Services Plans*

The services plans shall include all details of building and plumbing services, and also plans, elevations and sections of private water supply, sewage disposal system and rainwater harvesting system, if any (*see* Part 8 'Building Services' and Part 9 'Plumbing Services').

12.2.7 *Specifications*

Specifications, both general and detailed, giving type and grade of materials to be used, duly signed by the registered architect, engineer, structural engineer or supervisor shall accompany the notice (*see* Annex B).

12.2.8 *Structural Sufficiency Certificate*

The plans shall be accompanied by structural sufficiency certificate in the prescribed form (*see* Annex C) signed by the engineer/structural engineer (*see* Annex A) and the owner jointly to the effect that the building is safe against various loads, forces and effects including due to natural disasters, such as, earthquake, landslides, cyclones, floods, etc as per Part 6 'Structural Design' and other relevant Codes. The engineer/structural engineer shall also have the details to substantiate his design.

12.2.9 *Supervision*

The notice shall be further accompanied by a certificate in the prescribed form (*see* Annex D) by the registered architect/engineer/structural engineer/supervisor/town planner (*see* Annex A) undertaking the supervision (*see* **9.3**).

12.3 Preparation and Signing of Plans

The registered architect/engineer/supervisor/town planner/landscape architect/urban designer/utility service engineer shall prepare and duly sign the plans as per their competence (*see* Annex A) and shall indicate his/her name, address, qualification and registration number as allotted by the Authority or the body governing such profession. The structural plans and details shall also be prepared and duly signed by the competent professionals like registered engineer/ structural engineer (*see* Annex A). The plans shall also be duly signed by the owner indicating his address. The type and volume of buildings/development work to be undertaken by the registered professionals may generally be as in Annex A.

12.4 Notice for Alteration only

When the notice is only for an alteration of the building (*see* **3.5**), only such plans and statements, as may be necessary, shall accompany the notice.

12.4.1 No notice and building permit is necessary for the following alterations, and the like which do not otherwise violate any provisions regarding general

building requirements, structural stability and fire and health safety requirements of the Code:

a) Opening and closing of a window or door or ventilator;
b) Providing intercommunication doors;
c) Providing partitions;
d) Providing false ceiling;
e) Gardening;
f) White washing;
g) Painting;
h) Re-tiling and re-roofing;
j) Plastering and patch work;
k) Re-flooring; and
m) Construction of sunshades on one's own land.

12.5 Fees

No notice as referred to in **12.1** shall be deemed valid unless and until the person giving notice has paid the fees to the Authority and an attested copy of the receipt of such payment is attached with the notice.

NOTE — The fees may be charged as a consolidated fee. In the event of a building/development permit is not issued, the fees so paid shall not be returned to the owner, but he shall be allowed to re-submit it without any fees after complying with all the objections raised by the Authority within a period of one year from the date of rejection after which fresh fees shall have to be paid.

12.6 Duration of Sanction

The sanction once accorded shall remain valid up to three years. The permit shall be got revalidated before the expiration of this period. Revalidation shall be subject to the rules then in force.

12.7 Deviations During Construction

If during the construction of a building any departure (excepting for items as given in **12.4.1**) from the sanctioned plan is intended to be made (*see* **7.5**), sanction of the Authority shall be obtained before the change is made. The revised plan showing the deviations shall be submitted and the procedure laid down for the original plan heretofore shall apply to all such amended plans except that the time limit specified in **12.10.2** shall be three weeks in such cases.

12.8 Revocation of Permit

The Authority may revoke any permit issued under the provisions of the Code, wherever there has been any false statement, misrepresentation of any material fact in the application on which the permit was based or violation of building permit or in case of noncompliance thereof, and shall state the reasons for revoking the permit.

12.9 Qualifications of Architects/Engineers/ Structural Engineers/Landscape Architect/Urban Designer/Supervisors/Town Planners/Services Personnel

Architects, engineers, structural engineers, landscape architect, urban designer, supervisors and town planners wherever referred in the Code, shall be registered by the Authority or the body governing such profession constituted under a statute, as competent to do the work for which they are employed. A guide for the equivalent technical qualifications and professional experience required for such registration with the Authority is given in Annex A. In case of building and plumbing services, qualifications for engineers for utility services shall be as given in **A-2.8**.

12.9.1 In case the registered professional associated with the preparation and signing of plans or for supervision, is being changed during any stage of building/land development process, the professional shall intimate the Authority in writing about the further non-association with the project.

12.10 Grant of Permit or Refusal

The Authority may either sanction or refuse the plans and specifications or may sanction them with such modifications or directions as it may deem necessary and thereupon shall communicate its decision to the person giving the notice (*see* Annex E).

12.10.1 The building plans for buildings identified in **12.2.5.1** shall also be subject to the scrutiny of the Fire Authority and the sanction through building permit shall be given by the Authority after the clearance from the Fire Authority (*see also* **11.1.3**).

12.10.2 If within 30 days of the receipt of the notice under **12.1** of the Code, the Authority fails to intimate in writing to the person, who has given the notice, of its refusal or sanction, the notice with its plans and statements shall be deemed to have been sanctioned; provided the fact is immediately brought to the notice of the Authority in writing by the person who has given notice and having not received any intimation from the Authority within fifteen days of giving such written notice. Subject to the conditions mentioned in this clause, nothing shall be construed to authorize any person to do anything in contravention of or against the terms of lease or titles of the land or against any other regulations, byelaws or ordinance operating on the site of the work.

12.10.3 In the case of refusal, the Authority shall quote the reason and relevant sections of the Code which the plans contravene. The Authority shall as far as possible advise all the objections to the plans and specifications in the first instance itself and ensure that no new

objections are raised when they are resubmitted after compliance of earlier objections.

12.10.4 Once the plan has been scrutinized and objections have been pointed out, the owner giving notice shall modify the plan to comply with the objections raised and re-submit it. The Authority shall scrutinize the re-submitted plan and if there be further objections, the plan shall be rejected.

13 RESPONSIBILITIES AND DUTIES OF THE OWNER

13.1 Neither the granting of the permit nor the approval of the drawings and specifications, nor inspections made by the Authority during erection of the building shall in any way relieve the owner of such building from full responsibility for carrying out the work in accordance with the requirements of the Code (*see* **9**).

13.2 Every owner shall:

a) permit the Authority to enter the building or premises for which the permit has been granted at any reasonable time for the purpose of enforcing the Code;

b) submit a document of ownership of the site;

c) obtain, where applicable, from the Authority, permits relating to building, zoning, grades, sewers, water mains, plumbing, signs, blasting, street occupancy, electricity, highways, and all other permits required in connection with the proposed work;

d) give notice to the Authority of the intention to start work on the building site (*see* Annex F);

e) give written notice to the Authority intimating completion of work up to plinth level;

f) submit the certificate for execution of work as per structural safety requirements (*see* Annex G); and give written notice to the Authority regarding completion of work described in the permit (*see* Annex H);

g) give written notice to the Authority in case of termination of services of a professional engaged by him; and

h) obtain an occupancy permit (*see* Annex J) from the Authority prior to any:

1) occupancy of the building or part thereof after construction or alteration of that building or part, or

2) change in the class of occupancy of any building or part thereof.

13.2.1 *Temporary Occupancy*

Upon the request of the holder of the permit, the Authority may issue a temporary certificate of occupancy for a building or part thereof, before the entire work covered by permit shall have been completed, provided such portion or portions may be occupied safely prior to full completion of building without endangering life or public welfare.

13.3 Documents at Site

13.3.1 Where tests of any materials are made to ensure conformity with the requirements of the Code, records of the test data shall be kept available for inspection during the construction of the building and for such a period thereafter as required by the Authority.

13.3.2 The person to whom a permit is issued shall during construction keep pasted in a conspicuous place on the property in respect of which the permit was issued:

a) a copy of the building permit; and

b) a copy of the approved drawings and specifications referred in **12**.

14 INSPECTION, OCCUPANCY PERMIT AND POST-OCCUPANCY INSPECTION

14.1 Generally all construction or work for which a permit is required shall be subject to inspection by the Authority and certain types of construction involving unusual hazards or requiring constant inspection shall have continuous inspection by special inspectors appointed by the Authority.

14.2 Inspection, where required, shall be made within 7 days following the receipt of notification, after which period the owner will be free to continue the construction according to the sanctioned plan. At the first inspection, the Authority shall determine to the best of its ability that the building has been located in accordance with the approved site plans. The final inspection of the completion of the work shall be made within 21 days following the receipt of notification [*see* **13.2**(f)] for the grant of occupancy certificate.

14.2.1 The owner/concerned registered architect/ engineer/structural engineer/town planner will serve a notice/completion certificate to the Authority that the building has been completed in all respects as per the approved plans. The deviations shall also be brought to the notice of the Authority (with relevant documents). The team of building officials or its duly authorized representative shall then visit the site and occupancy certificate shall be given in one instance.

14.2.2 The occupancy certificate should clearly state the use/type of occupancy of the building. However, the applicant can apply for change of use/occupancy permitted within the purview of the Master Plan/Zonal Plan/Building Byelaws, where so required.

14.3 When inspection of any construction operation reveals than any lack of safety precautions exist, the Authority shall have right to direct the owner to stop the work immediately until the necessary remedial measures to remove the violation of safety precautions are taken.

14.4 Periodic Occupancy Renewal Certificate

14.4.1 For buildings covered in **12.2.5.1** after completion of the building and obtaining the occupancy certificate, periodic inspections of buildings shall be made by the Fire Authority to ensure the fire safety of the building and compliance with the provisions of fire and life safety requirements (*see* Part 4 'Fire and Life Safey'). Periodic occupancy renewal certificate shall be made available by the Authority/Fire Authority which shall also include safekeep of fire fighting installations and equipments for such buildings.

14.4.2 All occupied building and buildings covered under **12.2.5.1** shall also be subjected to periodic physical inspection by a team of multi-disciplinary professionals of local Authority. The work by team of professionals may be outsourced by the Authority to competent professionals as may be deemed necessary. The team shall ensure the compliance of byelaws, natural lighting, ventilation, etc, besides structural and electrical safety. After checking, the team shall be required to give the certificate for above aspects. If any shortcoming/deficiencies or violations are noticed during inspection, the Authority shall ensure the compliance of these within a specified time frame of six months. If not complied with, the building shall be declared unsafe. The period of inspection shall usually be 3 to 5 years but in any case not more than 5 years.

15 UNSAFE BUILDING

15.1 All unsafe buildings shall be considered to constitute danger to public safety and shall be restored by repairs or demolished or dealt with as otherwise directed by the Authority (*see* **15.2** to **15.5**).

15.2 Examination of Unsafe Building

The Authority shall examine or cause to be examined every building reported to be unsafe or damaged, and shall make a written record of such examination.

15.3 Notice to Owner, Occupier

Whenever the Authority finds any building or portion thereof to be unsafe, it shall, in accordance with established procedure for legal notice, give to the owner and occupier of such building written notices stating the defects thereof. This notice shall require the owner or the occupier within a stated time either to complete specified repairs or improvements or to demolish and remove the building or portion thereof.

15.3.1 The Authority may direct in writing that the building which in his opinion is dangerous, or has no provision for exit if caught fire, shall be vacated immediately or within the period specified for the purpose; provided that the Authority concerned shall keep a record of the reasons for such action with him.

If any person does not comply with the orders of vacating a building, the Authority may direct the police to remove the person from the building and the police shall comply with the orders.

15.4 Disregard of Notice

In case the owner or occupier fails, neglects, or refuses to comply with the notice to repair or to demolish the said building or portion thereof, the Authority shall cause the danger to be removed whether by demolition or repair of the building or portion thereof or otherwise.

15.5 Cases of Emergency

In case of emergency, which, in the opinion of the Authority involves imminent danger to human life or health, the decision of the Authority shall be final. The Authority shall forthwith or with such notice as may be possible promptly cause such building or portion thereof to be rendered safe by retrofitting/strengthening to the same degree of safety or removed. For this purpose, the Authority may at once enter such structure or land on which it stands, or abutting land or structure, with such assistance and at such cost as may be deemed necessary. The Authority may also get the adjacent structures vacated and protect the public by an appropriate fence or such other means as may be necessary.

15.6 Costs

Costs incurred under **15.4** and **15.5** shall be charged to the owner of the premises involved. Such costs shall be charged on the premises in respect of which or for the benefit of which the same have been incurred and shall be recoverable as provided under the laws (*see* Note).

NOTE — The costs may be in the form of arrears of taxes.

16 DEMOLITION OF BUILDING

Before a building is demolished, the owner shall notify all utilities having service connections within the building, such as water, electric, gas, sewer and other connections. A permit to demolish a building shall not be issued until a release is obtained from the utilities stating that their respective service connections and appurtenant equipment, such as, meters and regulators have been removed or sealed and plugged in a safe manner.

17 VALIDITY

17.1 Partial Invalidity

In the event any part or provision of the Code is held to be illegal or void, this shall not have the effect of making void or illegal any of the other parts or provisions thereof, which may or shall be determined to be legal, and it shall be presumed that the Code would have been passed without such illegal or invalid parts or provisions.

17.2 Segregation of Invalid Provisions

Any invalid part of the Code shall be segregated from the remainder of the Code by the court holding such part invalid, and the remainder shall remain effective.

17.3 Decisions Involving Existing Buildings

The invalidity of any provision in any clause of the Code as applied to existing buildings and structures shall not be held to effect the validity of such section in its application to buildings hereafter erected.

18 ARCHITECTURAL CONTROL

18.1 Compliance with the provisions of the Code is adequate for normal buildings. But for major public building complexes or buildings coming up in an important area near historic/monumental buildings and areas of heritage, the aesthetics of the whole scheme may also have to be examined, *vis-a-vis* existing structures. In addition, any development which may mar the general characteristics and environment of historical, architectural or other monuments should also be subject to the provisions of this clause. This clause is intended to cover very few structures to come up in the vicinity of other declared/historically important structures, and the scrutiny shall be limited to the external architectural features only so as to ensure an aesthetic continuance of the existing structures with the new. The scrutiny shall not deal with the routine building plan scrutiny from other requirements of Code from the point of view of structural safety and functional requirements.

18.2 An Urban Arts Commission shall be established at the city/state level on issues related to urban aesthetics, through a statute. This statutory authority/ commission established by an Act of State Legislative Assembly, shall accord approval to all major buildings/ important development projects having bearing on the urban aesthetics, depending upon the importance of the area with respect to natural or built heritage or projects on plot areas above 1 hectare and located in specifically identified areas. The Urban Arts Commission shall act as guardian of urban architecture; mainly with regard to building form and envelope, the relationship between the building, and the ambient environment *vis-a-vis* other dependants should be seen in depth.

18.3 The Commission may work in the following manner:

a) The Commission may select only the important buildings as in **18.1** and examine the same. The person responsible for the schemes, say an architect or an engineer, may examine either alone or with the owner. A study of the plans, elevations, models, etc, should be made. The architect/engineer should explain in general terms the purposes which the building is to serve and the main conditions which have influenced him in preparing the design.

b) The Commission after full discussion, may communicate their decision in writing to the parties concerned. The Commission may recommend a change in the whole scheme or suggest modifications in the existing scheme, if so required.

18.4 The Urban Arts Commission should also be charged with advising the city government, on schemes which will beautify the city and add to its cultural vitality.

GUIDE FOR THE QUALIFICATIONS AND COMPETENCE OF PROFESSIONALS

A-1 ESSENTIAL REQUIREMENTS

A-1.1 Every building/development work for which permission is sought under the Code shall be planned, designed and supervised by registered professionals. The registered professionals for carrying out the various activities shall be: (a) architect, (b) engineer, (c) structural engineer, (d) supervisor, (e) town planner, (f) landscape architect, (g) urban designer, and (h) utility service engineer. Requirements of registration for various professionals by the Authority or by the body governing such profession and constituted under a statute, as applicable to practice within the local body's jurisdiction, are given in **A-2.1** to **A-2.5**. The competence of such registered personnel to carry out various activities is also indicated in **A-2.1.1** to **A-2.5.1**.

A-2 REQUIREMENTS FOR REGISTRATION AND COMPETENCE OF PROFESSIONALS

A-2.1 Architect

The minimum qualifications for an architect shall be the qualifications as provided for in the *Architects Act*, 1972 for registration with the Council of Architecture.

A-2.1.1 *Competence*

The registered architect shall be competent to carryout the work related to the building/development permit as given below:

a) All plans and information connected with building permit except engineering services of multistoreyed/special buildings given in **12.2.5.1**.

b) Issuing certificate of supervision and completion of all buildings pertaining to architectural aspects.

c) Preparation of sub-division/layout plans and related information connected with development permit of area up to 1 hectare for metro-cities and 2 hectare for other places.

d) Issuing certificate of supervision for development of land of area up to 1 hectare for metro-cities and 2 hectare for other places.

A-2.2 Engineer

The minimum qualifications for an engineer shall be graduate in civil engineering/architectural engineering of recognized Indian or foreign university, or the Member of Civil Engineering Division/Architectural Engineering Division of the Institution of Engineers (India) or the statutory body governing such profession, as and when established.

A-2.2.1 *Competence*

The registered engineer shall be competent to carryout the work related to the building/development permit as given below:

a) All plans and information connected with building permit;

b) Structural details and calculations of buildings on plot up to 500 m^2 and up to 5 storeys or 16 m in height;

c) Issuing certificate of supervision and completion for all buildings;

d) Preparation of all service plans and related information connected with development permit; and

e) Issuing certificate of supervision for development of land for all area.

A-2.3 Structural Engineer

The minimum qualifications for a structural engineer shall be graduate in civil engineering of recognized Indian or foreign university, or Corporate Member of Civil Engineering Division of Institution of Engineers (India), and with minimum 3 years experience in structural engineering practice with designing and field work.

NOTE — The 3 years experience shall be relaxed to 2 years in the case of post-graduate degree of recognized Indian or foreign university in the branch of structural engineering. In case of doctorate in structural engineering, the experience required would be one year.

A-2.3.1 *Competence*

The registered structural engineer shall be competent to prepare the structural design, calculations and details for all buildings and supervision.

A-2.3.1.1 In case of buildings having special structural features, as decided by the Authority, which are within the horizontal areas and vertical limits specified in **A-2.2.1**(b) and **A-2.4.1**(a) shall be designed only by structural engineers.

A-2.4 Supervisor

The minimum qualifications for a supervisor shall be diploma in civil engineering or architectural assistantship, or the qualification in architecture or

engineering equivalent to the minimum qualification prescribed for recruitment to non-gazetted service by the Government of India plus 5 years experience in building design, construction and supervision.

A-2.4.1 *Competence*

The registered supervisor shall be competent to carryout the work related to the building permit as given below:

a) All plans and related information connected with building permit for residential buildings on plot up to 100 m^2 and up to two storeys or 7.5 m in height; and

b) Issuing certificate of supervision for buildings as per (a).

A-2.5 Town Planner

The minimum qualification for a town planner shall be the Associate Membership of the Institute of Town Planners or graduate or post-graduate degree in town and country planning.

A-2.5.1 *Competence*

The registered town planner shall be competent to carryout the work related to the development permit as given below:

a) Preparation of plans for land sub-division/ layout and related information connected with development permit for all areas.

b) Issuing of certificate of supervision for development of land of all areas.

NOTE — However, for land layouts for development permit above 5 hectare in area, landscape architect shall also be associated, and for land development infrastructural services for roads, water supplies, sewerage/drainage, electrification, etc, the registered engineers for utility services shall be associated.

A-2.6 Landscape Architect

The minimum qualification for a landscape architect shall be the bachelor or master's degree in landscape architecture or equivalent from recognized Indian or foreign university.

A-2.6.1 *Competence*

The registered landscape architect shall be competent to carryout the work related to landscape design for building/development permit for land areas 5 hectares and above. In case of metro-cities, this limit of land area shall be 2 hectares and above.

NOTE — For smaller areas below the limits indicated above, association of landscape architect may also be considered from the point of view of desired landscape development.

A-2.7 Urban Designer

The minimum qualification for an urban designer shall be the master's degree in urban design or equivalent from recognized Indian or foreign university.

A-2.7.1 *Competence*

The registered urban designer shall be competent to carryout the work related to the building permit for urban design for land areas more than 5 hectares and campus area more than 2 hectares. He/She shall also be competent to carryout the work of urban renewal for all areas.

NOTE — For smaller areas below the limits indicated above, association of urban designer may be considered from the point of view of desired urban design.

A-2.8 Engineers for Utility Services

For buildings identified in **12.2.5.1**, the work of building and plumbing services shall be executed under the planning, design and supervision of competent personnel. The qualification for registered mechanical engineer (including HVAC), electrical engineer and plumbing engineers for carrying out the work of Air-conditioning, Heating and Mechanical Ventilation, Electrical Installations, Lifts and Escalators and Water Supply, Drainage, Sanitation and Gas Supply installations respectively shall be as given in Part 8 'Building Services' and Part 9 'Plumbing Services' or as decided by the Authority taking into account practices of the National professional bodies dealing with the specialist engineering services.

A-3 BUILDER/CONSTRUCTOR ENTITY

The minimum qualification and competence for the builder/constructor entity for various categories of building and infrastructural development shall be as decided by the Authority to ensure compliance of quality, safety and construction practices as required under the Code.

ANNEX B

(*Clause* 12.1)

FORM FOR FIRST APPLICATION TO DEVELOP, ERECT, RE-ERECT OR TO MAKE ALTERATION IN ANY PLACE IN A BUILDING

To

.....

.....

.....

Sir,

I hereby give notice that I intend to develop, erect, re-erect or to make alteration in the building No..... or to.....on/in Plot No.....in Colony/ Street .....*MOHALLA/BAZAR*/Road.....City .....and in accordance with the building code of .....Part II, Clauses .....and I forward herewith the following plans and specifications in triplicate duly signed by me and ..... the Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1], Registration No. ..... who will supervise its erection.

(Name in block letters)

1. Key plan
2. Site plans
3. Sub-division/layout plan
4. Building plans
5. Services plans
6. Specifications, general and detailed[2]
7. Title of ownership of land/building
8. Certificates for structural sufficiency and supervision

I request that the development/construction may be approved and permission accorded to me to execute the work.

Signature of Owner .....

Name of the Owner .....

(in block letters)

Address of Owner .....

.....

.....

.....

.....

Date: .....

---

[1] Strike out whichever is not applicable.

[2] A format may be prepared by the Authority for direct use.

ANNEX C

(*Clause* 12.2.8)

FORM FOR CERTIFICATE FOR STRUCTURAL DESIGN SUFFICIENCY

With respect to the building work of erection, re-erection or for making alteration in the building No.....or to.....on/in Plot No. .....Colony/ Street.....*MOHALLA/BAZAR*/Road .....City....., we certify that the structural plans and details of the building submitted for approval satisfy the structural safety requirements for all situations including natural disasters, as applicable, as stipulated under Part 6 Structural Design of the National Building Code of India and other relevant Codes; and the information given therein is factually correct to the best of our knowledge and understanding.

	Signature of owner with date	Signature of the Registered Engineer/ Structural Engineer with date and registration No.
Name:	.....	.....
Address:	.....	.....

ANNEX D

(*Clause* 12.2.9)

FORM FOR SUPERVISION

I hereby certify that the development, erection, re-erection or material alteration in/of building No..... or the .....on/in Plot No.....in Colony/ Street .....*MOHALLA/BAZAR*/Road..... City..... shall be carried out under my supervision and I certify that all the materials (type and grade) and the workmanship of the work shall be generally in accordance with the general and detailed specifications submitted along with, and that the work shall be carried out according to the sanctioned plans.

Signature of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

Name of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

(in block letters)

Registration No. of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

Address of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

.....

.....

.....

.....

Date: .....

[1] Strike out whichever is not applicable.

ANNEX E

(*Clause* 12.10)

FORM FOR SANCTION OR REFUSAL OF DEVELOPMENT/BUILDING PERMIT

To

.....

.....

.....

Sir,

With reference to your application .....dated .....for grant of permit for the development, erection, re-erection or material alteration in the building No. ..... or to.....on/in Plot No.....in Colony/ Street.....*MOHALLA/BAZAR*/Road.....City.....

I have to inform you that the sanction has been granted/refused by the Authority on the following grounds:

1.
2.
3.
4.
5.
6.

Office Stamp .....

Office (Communication) No. .....

Date: .....

Signature of the Authority .....

Name, Designation and Address of the Authority.....

.....

.....

ANNEX F

[*Clause* 13.2 (d)]

FORM FOR NOTICE FOR COMMENCEMENT

I hereby certify that the development, erection, re-erection or material alteration in/of building No. ..... or the.....on/in Plot No.....in Colony/Street.....*MOHALLA/ BAZAR*/Road.....City .....will be commenced on as per your permission, vide No.....dated.....under the supervision of .....Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1], Registration No.....and in accordance with the plans sanctioned, vide No.....dated.....

Signature of Owner .....

Name of Owner .....
(in block letters)

Address of Owner.....

.....

Date: .....

.....

[1] Strike out whichever is not applicable.

ANNEX G

[*Clause* 13.2(f)]

FORM FOR CERTIFICATE FOR EXECUTION OF WORK AS PER STRUCTURAL SAFETY REQUIREMENTS

With respect to the building work of erection, re-erection or for making alteration in the building No..... or to .....on/in Plot No.....Colony/Street .....*MOHALLA/ BAZAR*/Road .....City....., we certify:

a) that the building has been constructed according to the sanctioned plan and structural design (one set of drawings as executed enclosed), which incorporates the provisions of structural safety as specified in Part 6 'Structural Design' of the National Building Code of India and other relevant Codes; and

b) that the construction has been done under our supervision and guidance and adheres to the drawings and specifications submitted and records of supervision have been maintained.

Any subsequent changes from the completion drawings shall be the responsibility of the owner.

	Signature of owner with date	Signature of the Registered Engineer/ Structural Engineer with date and registration No.
Name:	.....	.....
Address:	.....	.....

ANNEX H

[*Clause* 13.2 (f)]

FORM FOR COMPLETION CERTIFICATE

I hereby certify that the development, erection, re-erection or material alteration in/of building No..... or the ..... on/in Plot No..... in Colony/Street ..... *MOHALLA/BAZAR/* Road.....City..... has been supervised by me and has been completed on .... according to the plans sanctioned, vide No. ..... dated ..... The work has been completed to my best satisfaction, the workmanship and all the materials (type and grade) have been used strictly in accordance with general and detailed specifications. No provisions of the Code, no requisitions made, conditions prescribed or orders issued thereunder have been transgressed in the course of the work. The land is fit for construction for which it has been developed or re-developed or the building is fit for use for which it has been erected, re-erected or altered, constructed and enlarged.

I hereby also enclose the plan of the building completed in all aspects.

Signature of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

Name of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

(in block letters)

Registration No. of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

Address of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1] .....

Date: .....

Signature of the Owner

[1] Strike out whichever is not applicable.

ANNEX J

[*Clause* 13.2(h)]

FORM FOR OCCUPANCY PERMIT

The work of erection, re-erection or alteration in/of building No.....or the.....on/ in Plot No.....in Colony/Street.....*MOHALLA/BAZAR*/Road..... City.....completed under the supervision of.....Architect/Engineer/Structural Engineer/Supervisor, Registration No.....has been inspected by me. The building can be permitted/ not permitted for occupation for .....occupancy subjected to the following:

1.
2.
3.

One set of completion plans duly certified is returned herewith.

Signature of the Authority .....

Office Stamp

Date: .....

NATIONAL BUILDING CODE OF INDIA

PART 3 DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Part covers development control rules, including such aspects as sub-division and layout rules, land use classifications, open spaces, area and height limitations, means of access, and parking spaces; this part also covers the general building requirements, such as the requirements of parts of buildings, provision of lifts, etc.

It is expected that for proper coordination and enforcement of the development control rules and general building requirements, the departments concerned, namely, the town planning department and the building department, will coordinate the total development and building activity at both organizational and technical levels.

Particular attention is invited to Table 3 on floor area ratio (FAR) limitations. It is emphasized that the floor area of a single storey building is limited in absolute terms by the type of construction and occupancy class. Also, the absolute floor areas for different types of construction and different occupancies have a definite ratio among them. The ratios as recommended in the American Iron and Steel Institute publication 1961 'Fire Protection Through Modern Building Codes' have been generally adopted in this Part and Table 3 has been developed on this basis. Table 3 is repeated in Part 4 'Fire and Life Safety' also for convenience of reading.

Limitation of areas and heights of buildings is achieved in this country by specifying it in terms of floor area ratio (FAR) or floor space index (FSI). The significance of the contribution of different types of construction giving different fire resistances has not been taken cognizance of in specifying FAR for different occupancies, in the present development control rules and municipal byelaws of the country. Table 3, therefore, gives the comparative ratios of FAR between types of buildings and occupancy classes and these have been specified mainly from the fire protection aspect of buildings. To arrive at the actual FAR for different buildings coming up in different areas, the Authority should further modify them, by taking into consideration other aspects like density of any area, parking facilities required, the traffic load (road width) and the services available. The heights of buildings shall also be regulated, keeping in view the local fire fighting facilities.

In some state byelaws, the FAR (or FSI) has been expressed in the form of percentage. However, the Committee responsible for preparation of this Code is of the opinion that, it being a ratio should be expressed only in the form of a ratio, as done in this Part.

It is particularly to be borne in mind by the Authority that the ratios are definitive and it can assess the particular FAR for a type of construction and for an occupancy and establish a new table, but retaining the comparative ratios as given in Table 3.

Keeping in view the enormous problems faced by the country with regard to the ever increasing squatter settlements/ pavement dwellers in urban areas (cities of all sizes), it is imperative that all the urban local bodies sooner or later evolve schemes for their rehabilitation. The resources are meagre and the problems are enormous. There has been a tendency on the part of a number of development agencies/local bodies to link space norms with affordability. Affordability is an important criterion but at the same time a public agency cannot ignore the basic minimum needs of the family to be housed (including the mental, physical and social health of the marginalized groups, which is linked with shelter). The local bodies shall have to evolve appropriate policies for their integration with the broad urban society and generate/allocate resources and more importantly adopt a planning process, which are people friendly. The Government of India has also formulated the National Slum Policy to this effect. Therefore, keeping in view the needs of low income housing, to cater to Economically Weaker Sections of Society (EWS) and Low Income Group (LIG), the requirements on planning, design of layout/shelter have been rationalized and the same are provided in this Part. This will contribute significantly in the massive housing programmes undertaken for the low income sector. This information is based on the provisions of IS 8888 (Part 1) : 1993 'Guide for requirements of low income housing: Part 1 Urban areas (*first revision*)'.

Further, city development process would need a dynamic approach to take care of urban renewal and also development needs in dense core areas of the cities. Innovative approaches in planning and design with participating models of public private-people's partnership become necessary to solve the emerging development needs. With

this in view, many city development agencies have evolved innovative planning and development tools like transferable development rights (TDR) where the developer would receive a portion of the development rights in a new location, keeping in view the constraints in the existing land area and the development potential. Such development rights can be transferred into outskirts or new developed areas where land availability is assured. This would encourage the professionals and developers to participate in urban renewal and at the same time ensure that the developments in both the inner core areas and new areas take place in an orderly and efficient manner. The TDR concept should be increasingly encouraged by the authority dealing with urban renewal, re-development projects including housing and re-development projects for slum including dwellers.

Urbanization in India is taking place at a rapid pace. With 5 million population in cities at the time of independence, it has already crossed 28 million (2001 census). It is likely to be 50 million by 2021. The number of cities and towns have been expanding and there are 5 161 cities and towns of various sizes. In the Indian practice cities over 50 lakhs population have been identified as mega-cities (6 in number) and cities over 10 lakhs (29 in number) population as metro-cities. These 35 cities above 10 lakhs population is likely to be above 70 by 2021. The other cities are either small or medium towns or cities with different population limits. Urbanization in each of above cities and towns (mega-cities, metro-cities, small and medium towns and cities) will be different in nature and the development challenges are also different keeping in view the extent of urbanization, industrialization, commercialization and the nature of transportation needs. Therefore, the Code provisions should be appropriately utilized depending upon the need of hierarchy of cities for which the administrative and technical requirements have been covered in the Code for various facets of the activity.

The first version of this Part was prepared in 1970. As a result of incorporation of this Part in the revised development control rules and building byelaws of some municipal corporations and municipalities, some useful suggestions had emerged. First revision of this part was brought out in 1983, where these suggestions were incorporated to the extent possible. The major modifications incorporated in the first revision included:

a) Addition of development control rules giving guidance on means of access, community spaces and other aspects required for planning layouts.

b) Addition of provisions regarding plot sizes and frontage for different types of buildings, such as detached, semi-detached, row type and special housing schemes.

c) Requirements of open spaces for other occupancies, such as educational, institutional, assembly, industrial buildings, etc, were included.

d) Provisions relating to interior open space were elaborated, including requirements for ventilation shaft.

e) Requirements of open spaces for group housing development were covered.

f) Requirements of off-street parking spaces were covered.

g) Requirements for greenbelts and landscaping including norms for plantations of shrubs and trees were covered.

h) Requirements of certain parts of buildings, such as loft, store room, garage, basement, chimney, parapet, cabin, boundary wall, wells, septic tanks, office-cum-letter box room, meter room were included.

j) Special requirements of low income housing were covered.

The term Development Control Rules used in this Part encompasses the related aspects comprehensively with a view to promoting orderly development of an area.

This second revision is being brought out to incorporate the modifications found necessary in light of the experience gained with the use of this Part. Significant modifications incorporated in this revision include:

a) Terminology given in this Part has been made exhaustive by incorporating definitions of additional terms used, such as, access, chimney, to erect, etc, and number of terms pertaining to cluster planning for housing.

b) Detailed planning norms/open spaces for various amenities such as educational facilities, health care facilities, socio-cultural facilities, distribution services, police, civil defence and home guards, and fire services have been included.

c) Off-street parking requirements have now been also included for cities with population (i) between 1 000 000 and 5 000 000, and (ii) above 5 000 000 (*see* Annex B).

d) Special requirements for low income housing given in the earlier version have been modified and updated (*see* Annex C) based on IS 8888 (Part 1) : 1993 'Guide for requirements of low income housing:

Part 1 Urban area (*first revision*)'. In these revised provisions, single room dwelling has been discouraged, guidelines for water seal latrine have also been incorporated, and cluster planning approach has been recommended.

e) Requirements for cluster planning for housing have been added (*see* Annex E), which are based on the guidelines given in IS 13727 : 1993 'Guide for requirements of cluster planning for housing'.

f) Special requirements for low income housing for rural habitat planning has been added (*see* Annex F).

g) Special requirements for development planning in hilly areas has been added (*see* Annex G).

h) The requirements for buildings and facilities for the physically challenged have been revised, with listing of additional categories of physically challenged; modifications in requirements of ramps, stairs, doors, handrails and controls; and incorporation of additional requirements regarding windows.

j) Also, the opportunity has been utilized to update the reference to Indian Standards.

NATIONAL BUILDING CODE OF INDIA

PART 3 DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS

1 SCOPE

This Part deals with the development control rules and general building requirements to ensure health and safety of the public.

2 TERMINOLOGY

2.0 For the purpose of this part, the following definitions shall apply:

2.1 Access — A clear approach to a plot or a building.

2.2 Accessory Use — Any use of the premises subordinate to the principal use and customarily incidental to the principal use.

2.3 Alteration — A change from one occupancy to another, or a structural change, such as an addition to the area or height, or the removal of part of a building, or any change to the structure, such as the construction of, cutting into or removal of any wall, partition, column, beam, joist, floor or other support, or a change to or closing of any required means of ingress or egress or a change to the fixtures or equipment.

2.4 Approved — Approved by the Authority having jurisdiction.

2.5 Authority Having Jurisdiction — The Authority which has been created by a statute and which for the purpose of administering the Code/Part may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.6 Back-to-Back Cluster — Clusters when joined back to back and/or on sides (*see* Fig. 1).

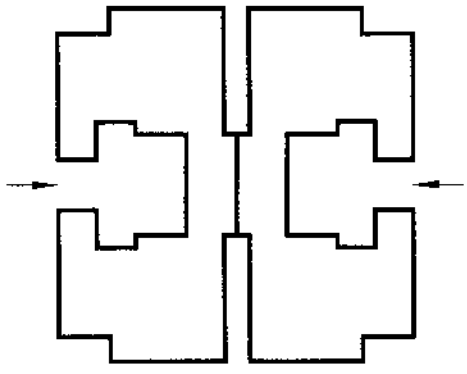


FIG. 1 BACK-TO-BACK CLUSTER

2.7 Balcony — A horizontal projection, with a handrail or balustrade or a parapet, to serve as passage or sitting out place.

2.8 Basement or Cellar — The lower storey of a building below or partly below ground level.

2.9 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, *VERANDAH*, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents, *SHAMIANAHS*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

2.10 Building, Height of — The vertical distance measured in the case of flat roofs, from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of last livable floor of the building adjacent to the external walls; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof; and in the case of gables facing the road, the mid-point between the eaves level and the ridge. Architectural features serving no other function except that of decoration shall be excluded for the purpose of measuring heights.

2.11 Building Envelope — The horizontal spatial limits up to which a building may be permitted to be constructed on a plot.

2.12 Building Line — The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme. The building line may change from time-to-time as decided by the Authority.

2.13 Cabin — A non-residential enclosure constructed of non-load bearing partition.

2.14 Canopy — A projection over any entrance.

2.15 Carpet Area — The covered area of the usable rooms at any floor level (excluding the area of the wall).

2.16 *CHHAJJA* — A sloping or horizontal structural overhang usually provided over openings on external walls to provide protection from sun and rain.

2.17 Chimney — An upright shaft containing one or more flues provided for the conveyance to the outer air of any product of combustion resulting from the operation of heat producing appliance or equipment employing solid, liquid or gaseous fuel.

2.18 Chowk or Courtyard — A space permanently

open to the sky, enclosed fully or partially by building and may be at ground level or any other level within or adjacent to a building.

2.19 Chowk, Inner — A chowk enclosed on all sides.

2.20 Chowk, Outer — A chowk one of whose sides is not enclosed.

2.21 Closed Clusters — Clusters with only one common entry into cluster open space (*see* Fig. 2).

2.22 Cluster — Plots or dwelling units or housing grouped around an open space (*see* Fig. 3).

Ideally housing cluster should not be very large. In ground and one storeyed structures not more than 20 houses should be grouped in a cluster. Clusters with more dwelling units will create problems in identity, encroachments and of maintenance.

2.23 Cluster Court Town House — A dwelling in a cluster plot having 100 percent or nearly 100 percent ground coverage with vertical expansion, generally limited to one floor only and meant for self use.

2.24 Cluster Plot — Plot in a cluster.

2.25 Cooking Alcove — A cooking space having direct access from the main room without any inter-communicating door.

2.26 Covered Area — Ground area covered by the building immediately above the plinth level. The area covered by the following in the open spaces is excluded from covered area (*see* Table 3):

a) Garden, rockery, well and well structures, plant nursery, waterpool, swimming pool (if uncovered), platform round a tree, tank, fountain, bench, *CHABUTRA* with open top and unenclosed on sides by walls and the like;

b) Drainage culvert, conduit, catch-pit, gully pit, chamber, gutter and the like;

c) Compound wall, gate, unstoreyed porch and portico, canopy, slide, swing, uncovered staircase, ramps areas covered by *CHHAJJA* and the like; and

d) Watchmen's booth, pumphouse, garbage shaft, electric cabin or sub-stations, and such other utility structures meant for the services of the building under consideration.

NOTE — For the purpose of this Part, covered area equals the plot area minus the area due for open spaces.

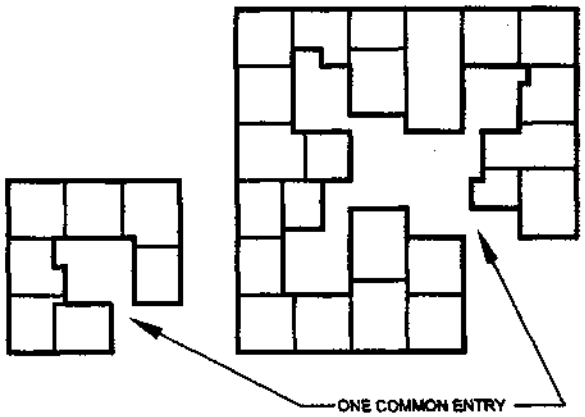


FIG. 2 CLOSED CLUSTER

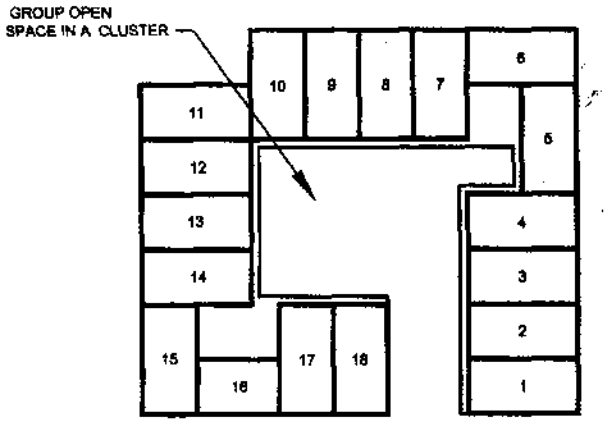


FIG. 3 CLUSTER

2.27 'Cul-de-Sac' Cluster

Plots/dwelling units when located along a pedestrianised or vehicular 'cul-de-sac' road (*see* Fig. 4).

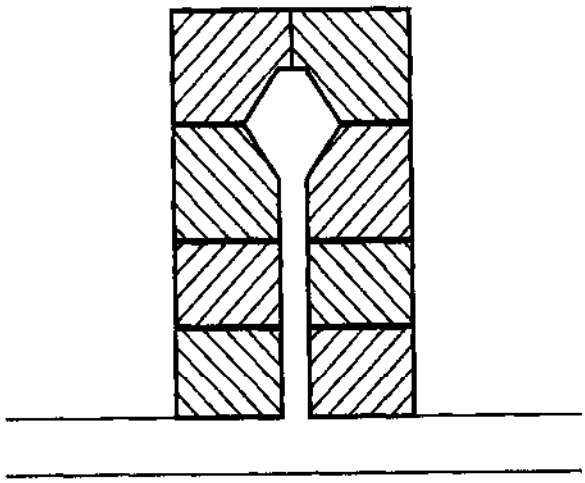


FIG. 4 CUL-DE-SAC CLUSTER

2.28 Density — The residential density expressed in terms of the number of dwelling units per hectare.

NOTE — Where such densities are expressed exclusive of community facilities and provision of open spaces and major roads (excluding incidental open spaces), these will be net residential densities. Where these densities are expressed taking into consideration the required open space provision and community facilities and major roads, these would be gross residential densities at neighbourhood level, sector level or town level, as the case may be. The provision of open spaces and community facilities will depend on the size of the residential community.

Incidental open spaces are mainly open spaces required to be left around and in between two buildings to provide lighting and ventilation.

2.29 Detached Building — A building detached on all sides.

2.30 Development — 'Development' with grammatical variations means the carrying out of building, engineering, mining or other operations, in, or over, or under land or water, on the making of any material change, in any building or land, or in the use of any building, land, and includes re-development and layout and subdivision of any land and 'to develop' shall be construed accordingly.

2.31 Drain — A conduit, channel or pipe for the carriage of storm water, sewage, waste water or other water borne wastes in a building drainage system.

2.32 Drainage — The removal of any liquid by a system constructed for the purpose.

2.33 Dwelling Unit/Tenement — An independent housing unit with separate facilities for living, cooking and sanitary requirements.

2.34 Escalator — A power driven, inclined, continuous stairway used for raising or lowering passengers.

2.35 Exit — A passage, channel or means of egress from any building, storey or floor area to a street or other open space of safety.

2.36 External Faces of Cluster — Building edges facing the cluster open spaces.

2.37 Fire Separation — The distance in metres measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of a street or other public space for the purpose of preventing the spread of fire.

2.38 Floor — The lower surface in a storey on which one normally walks in a building. The general term 'floor' unless specifically mentioned otherwise shall not refer to a 'mezzanine floor'.

2.39 Floor Area Ratio (FAR) — The quotient obtained by dividing the total covered area (plinth area) on all floors by the area of the plot:

$$\text{FAR} = \frac{\text{Total covered area of the floors}}{\text{Plot area}}$$

2.40 Gallery — An intermediate floor or platform projecting from a wall of an auditorium or a hall providing extra floor area, additional seating accommodation, etc. It shall also include the structures provided for seating in stadia.

2.41 Garage, Private — A building or a portion thereof designed and used for parking of private owned motor driven or other vehicles.

2.42 Garage, Public — A building or portion thereof, other than a private garage, designed or used for repairing, servicing, hiring, selling or storing or parking motor driven or other vehicles.

2.43 Group Housing — Housing for more than one dwelling unit, where land is owned jointly (as in the case of co-operative societies or the public agencies, such as local authorities or housing boards, etc) and the construction is undertaken by one Agency.

2.44 Group Open Space — Open space within a cluster.

Group open pace is neither public open space nor private open space. Each dwelling unit around the cluster open space have a share and right of use in it. The responsibility for maintenance of the same is to be collectively shared by all the dwelling units around.

2.45 Habitable Room — A room occupied or designed for occupancy by one or more persons for study, living, sleeping, eating, kitchen if it is used as a

corridors, cellars, attics, and spaces that are not used frequently or during extended periods.

2.46 Independent Cluster — Clusters surrounded from all sides by vehicular access roads and/or pedestrian paths (*see* Fig. 5).

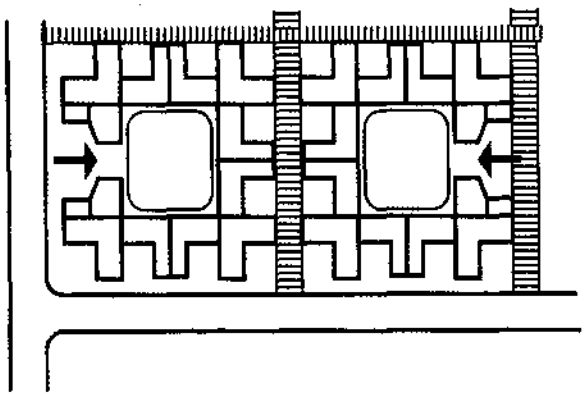


FIG. 5 INDEPENDENT CLUSTER

2.47 Interlocking Cluster — Clusters when joined at back and on sides with at least one side of a cluster common and having some dwelling units opening onto or having access from the adjacent clusters.

Dwelling units in such clusters should have at least two sides open to external open space. Houses in an interlocking cluster can have access, ventilation and light from the adjacent cluster and should also cater for future growth (*see* Fig. 6).

2.48 Internal Faces of Cluster — Building edges facing the adjacent cluster open space (as in case of interlocking cluster) of the surrounding pedestrian paths or vehicular access roads.

2.49 Ledge or *TAND* — A shelf-like projection, supported in any manner whatsoever, except by means of vertical supports within a room itself but not having projection wider than 1 m.

vertical or substantially vertical direction by means of a guided car or platform. The word 'elevator' is also synonymously used for 'lift'.

2.51 Loft — A structure providing intermediate storage space in between two floors with a maximum height of 1.5 m, without having a permanent access.

2.52 Mezzanine Floor — An intermediate floor between two floors of any storey forming an integral part of floor below.

2.53 Occupancy or Use Group — The principal occupancy for which a building or a part of a building is used or intended to be used; for the purposes of classification of a building according to occupancy; an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it.

2.54 Occupancy, Mixed — The occupancy, where more than one occupancy are present in different portions of the building.

2.55 Open Clusters — Cluster where cluster open spaces are linked to form a continuous open space (*see* Fig. 7).

2.56 Open Space — An area, forming an integral part of the plot, left open to the sky.

NOTE — The open space shall be the minimum distance measured between the front, rear and side of the building and the respective plot boundaries.

2.57 Open Space, Front — An open space across the front of a plot between the building line and front boundary of the plot.

2.58 Open Space, Rear — An open space across the rear of a plot between the rear of the building and the rear boundary of the plot.

2.59 Open Space, Side — An open space across the side of the plot between the side of the building and the side boundary of the plot.

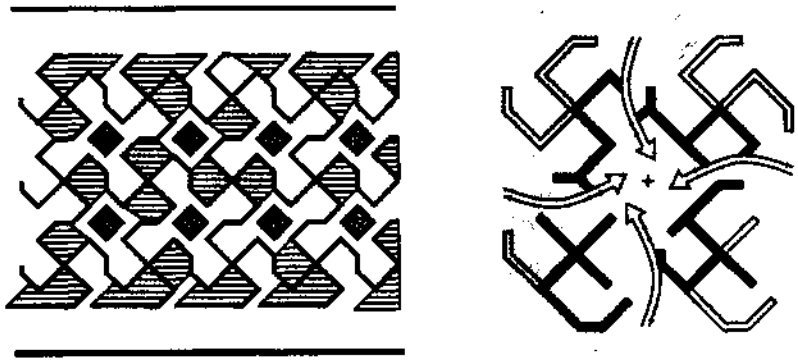


FIG. 6 INTERLOCKING CLUSTER

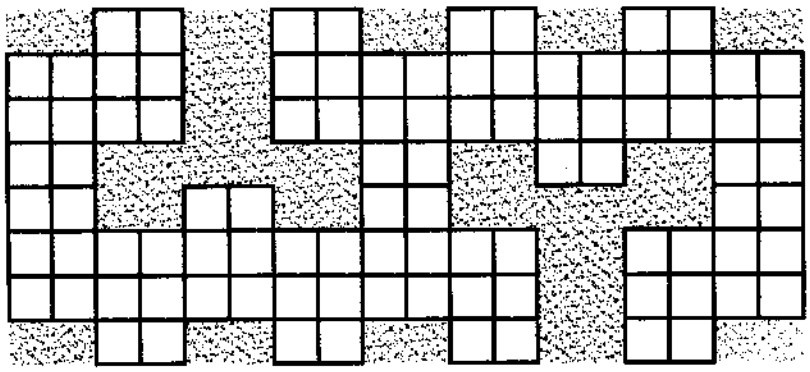


FIG. 7 OPEN CLUSTER

2.60 Owner — Person or body having a legal interest in land and/or building thereon. This includes free holders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

2.61 Parapet — A low wall or railing built along the edge of a roof or floor.

2.62 Parking Space — An area enclosed or unenclosed, covered or open, sufficient in size to park vehicles, together with a drive-way connecting the parking space with a street or alley and permitting ingress and egress of the vehicles.

2.63 Partition — An interior non-load bearing barrier, one storey or part-storey in height.

2.64 Plinth — The portion of a structure between the surface of the surrounding ground and surface of the floor, immediately above the ground.

2.65 Plinth Area — The built up covered area measured at the floor level of the basement or of any storey.

2.66 Porch — A covered structure supported on pillars or otherwise for the purpose of pedestrian or vehicular approach to a building.

2.67 Road — *See* **2.82**.

2.68 Road Line — *See* **2.84**.

2.69 Room Height — The vertical distance measured from the finished floor surface to the finished ceiling surface. Where a finished ceiling is not provided, the underside of the joists or beams or tie beams shall determine the upper point of measurement.

2.70 Row Housing/Row Type Building — A row of buildings, with only front, rear and interior open spaces where applicable.

2.71 Semi-Detached Building — A building detached on three sides.

2.72 Service Road/Lane — A road/lane provided adjacent to a plot(s) for access or service purposes as the case may be.

2.73 Set-Back Line — A line usually parallel to the plot boundaries and laid down in each case by the Authority, beyond which nothing can be constructed towards the plot boundaries.

2.74 Site (Plot) — A parcel (piece) of land enclosed by definite boundaries.

2.75 Site, Corner — A site at the junctions of and fronting on two or more intersecting streets.

2.76 Site, Depth of — The mean horizontal distance between the front and rear site boundaries.

2.77 Site, Double Frontage — A site, having a frontage on two streets, other than a corner plot.

2.78 Site, Interior or Tandem — A site access to which is by a passage from a street whether such passage forms part of the site or not.

2.79 Staircover (or *MUMTY*) — A structure with a roof over a staircase and its landing built to enclose only the stairs for the purpose of providing protection from weather and not used for human habitation.

2.80 Storey — The portion of a building included between the surface of any floor and the surface of the floor next above it, or if there be no floor above it, then the space between any floor and the ceiling next above it.

2.81 Storey, Topmost — The uppermost storey in a building whether constructed wholly or partly on the roof.

2.82 Street — Any means of access, namely, highway, street, lane, pathway, alley, stairway, passageway, carriageway, footway, square, place or bridge, whether a thoroughfare or not, over which the public have a right of passage or access or have passed and had access uninterruptedly for a specified period, whether existing or proposed in any scheme, and includes all bunds, channels, ditches, storm-water drains, culverts, sidewalks, traffic islands, roadside trees and hedges, retaining walls, fences, barriers and railings within the street lines.

2.83 Street Level or Grade — The officially established elevation or grade of the central line of the street upon which a plot fronts and if there is no officially established grade, the existing grade of the street at its mid-point.

2.84 Street Line — The line defining the side limits of a street.

2.85 To Abut — To abut on a street boundary such that any portion of the building is on the road boundary.

2.86 To Erect — To erect a building means:

a) to erect a new building on any site whether previously built upon or not; and

b) to re-erect any building of which portions above the plinth level have been pull down, burnt or destroyed.

2.87 Tower-like Structures — Structures shall be deemed to be tower-like structures when the height of the tower-like portion is at least twice the height of the broader base at ground level.

2.88 *VERANDAH* — A covered area with at least one side open to the outside with the exception of 1 m high parapet on the upper floors to be provided on the open side.

2.89 Volume to Plot Area Ratio (VPR) — The ratio of volume of building measured in cubic metres to the area of the plot measured in square metres and expressed in metres.

2.90 Water-Closet (WC) — A water flushed plumbing fixture designed to receive human excrement directly from the user of the fixture. The term is used sometimes to designate the room or compartment in which the fixture is placed.

2.91 Window — An opening to the outside other than a door, which provides all or part of the required natural light or ventilation or both to an interior space.

3 LAND USE CLASSIFICATION AND USES PERMITTED

3.1 Land Use Classification

The land use classification may be as indicated below:

Sl No.	*Use Zone (Level 1)*	*Use Zone (Level 2)*
(1)	(2)	(3)
i)	Residential (R)	Primary Residential Zone (R-1) Mixed Residential Zone (R-2) Unplanned/Informal Residential Zone (R-3)
ii)	Commercial (C)	Retail Shopping Zone (C-1) General Business and Commercial District/Centres (C-2) Wholesale, Godowns, Warehousing/Regulated Markets (C-3)
iii)	Manufacturing (M)	Service and Light Industry (M-1) Extensive and Heavy Industry (M-2) Special Industrial Zone Hazardous, Noxious and Chemical (M-3)
iv)	Public and Semi-Public (PS)	Government/Semi-Government/Public Offices (PS-1) Government Land (use determined) (PS-2) Educational and Research (PS-3) Medical and Health (PS-4) Social, Cultural and Religious (PS-5) Utilities and Services (PS-6) Cremation and Burial Grounds (PS-7)
v)	Recreational (P)	Playgrounds/Stadium/Sports Complex (P-1) Parks and Gardens — Public Open Spaces (P-2) Special Recreational Zone — Restricted Open Spaces (P-3) Multi-Open Space (Maidan) (P-4)

Sl No.	*Use Zone (Level 1)*	*Use Zone (Level 2)*
(1)	(2)	(3)
vi)	Transportation and Communication (T)	Roads (T-1) Railways (T-2) Airport (T-3) Seaports and Dockyards (T-4) Bus Depots/Truck Terminals and Freight Complexes (T-5) Transmission and Communication (T-6)
vii)	Agriculture and Water Bodies	Agriculture (A-1) Forest (A-2) Poultry and Dairy Farming (A-3) Rural Settlements (A-4) Brick Kiln and Extractive Areas (A-5) Water Bodies (A-6)
viii)	Special Area	Old Built-up (Core) Area (S-1) Heritage and Conservation Areas (S-2) Scenic Value Areas (S-3) Village Settlement (S-4) Other Uses (S-5)

NOTES

1 Areas of informal activities may be identified in the above land use categories at Level 2.

2 Mixed use zone may be identified at the development plan level, having more than one use zone with mixed activities of such use zones.

3 In all, there could be 35 use zones at the development plan level within eight land use categories at the perspective plan level as given in the above table.

4 Use premises for different activities could be provided at the project/action plan level or with the approval of the Authority as the case may be.

5 Use zone regulations for the use permissibility could be decided by the town planner depending upon the requirement/ feasibility.

3.2 The various building uses and occupancies (*see* 7) permitted on the various zones shall be as given in the Master Plan.

3.3 Uses to be in Conformity with the Zone

Where the use of buildings or premises is not specifically designated on the Development Plan or in the absence of Development Plan, shall be in conformity with the zone in which they fall.

3.4 Uses as Specifically Designated on Development Plan

Where the use of a site is specifically designated on the Development Plan, it shall be used only for the purpose so designated.

3.5 Non-conforming Uses

No plot shall be put to any use, occupancy or premises other than the uses identified in **3.1**, except with the prior approval of the Authority.

3.6 Fire Safety

Buildings shall be so planned, designed and constructed as to ensure fire safety and this shall be done as per Part 4 'Fire and Life Safety'.

4 MEANS OF ACCESS

4.1 Every building/plot shall abut on a public/private means of access like streets/roads duly formed.

4.2 Every person who erects a building shall not at any time erect or cause or permit to erect any building which in any way encroaches upon or diminishes the area set apart as means of access required in the Code. No buildings shall be erected so as to deprive any other building of the means of access.

4.3 Width of Means of Access

The residential plots shall abut on a public means of access like street/road. Plots which do not abut on a street/road shall abut/front on a means of access, the width and other requirements of which shall be as given in Table 1.

Table 1 Width and Length of Means of Access

(*Clause* 4.3)

Sl No.	Width of Means of Access	Length of Means of Access
	m	m
(1)	(2)	(3)
i)	6.0	75
ii)	7.5	150
iii)	9.0	250
iv)	12.0	400
v)	18.0	1 000
vi)	24.0	above 1 000

NOTE — If the development is only on one side of the means of access, the prescribed widths may be reduced by 1 m in each case.

In no case, development on plots shall be permitted unless it is accessible by a public street of width not less than 6 m.

4.3.1 *Other Buildings*

For all industrial buildings, theatres, cinema houses, assembly halls, stadia, educational buildings, markets, other buildings which attract large crowd, the means of access shall not be less than the following:

Width of Means of Access	*Length of Means of Access*
m	m
12.0	200
15.0	400
18.0	600
24.0	above 600

Further, in no case shall the means of access be lesser in width than the internal accessways in layouts and subdivision.

4.3.2 *Pathways*

The approach to the buildings from road/street/internal means of access shall be through paved pathway of width not less than 1.5 m, provided its length is not more than 30 m.

4.3.2.1 In the case of special housing schemes for low income group and economically weaker section of society developed up to two storeyed row/cluster housing scheme, the pedestrian pathway width shall be 3 m subject to provisions of **9.4.1**(a). The pedestrian pathway shall not serve more than 8 plots on each side of the pathway; the length of the pathway shall be not more than 50 m.

4.3.3 The length of the main means of access shall be determined by the distance from the farthest plot (building) to the public street. The length of the subsidiary accessway shall be measured from the point of its origin to the next wider road on which it meets.

4.3.4 In the interest of general development of an area, the Authority may require the means of access to be of larger width than that required under **4.3** and **4.3.1**.

4.3.5 In existing built-up areas in the case of plots facing street/means of access less than 4.5 m in width, the plot boundary shall be shifted to be away by 2.25 m from the central line of the street/means of accessway to give rise to a new street/means of accessway of 4.5 m width.

4.4 The means of access shall be levelled, metalled, flagged, paved, sewered, drained, chanelled, lighted, laid with water supply line and provided with trees for shade to the satisfaction of the Authority free of encroachment by any structure or fixture so as not to reduce its width below the minimum required under **4.3** and shall be maintained in a condition to the satisfaction of the Authority.

4.4.1 If any private street or any other means of access to a building is not levelled, metalled, flagged or paved, sewered, drained, channelled, lighted or laid with water supply line or provided with trees for shade to the satisfaction of the Authority, who may, with the sanction of the Authority, by written notice require the owner or owners of the several premises fronting or adjoining the said street or other means of access or abutting thereon or to which access is obtained through such street or other means of access or which shall benefit by works executed, to carry out any or more of the aforesaid requirements in such manner as he shall direct.

4.4.2 If any structure or fixture is set upon a means of access so as to reduce its width below the minimum required, the Authority may remove the same further and recover the expenses so incurred from the owner.

4.5 Access from Highways/Important Roads

No premises other than highway amenities like petrol pumps, motels, etc, shall have an access direct from highways and such other roads not less than 52 m in width, which the Authority with the approval of the Highway Authority shall specify from time-to-time. The Authority shall maintain a register of such roads which shall be open to public inspection at all times during office hours. The portion of such roads on which direct access may be permitted shall be as identified in the Development Plan. However, in the case of existing development on highways/other roads referred to above, the operation of this clause shall be exempted. These provisions shall, however, be subject to the provisions of the relevant State Highway Act, and National Highway Act.

4.6 For high rise buildings and buildings other than residential, the following additional provisions of means of access shall be ensured:

a) The width of the main street on which the building abuts shall not be less than 12 m and one end of this street shall join another street not less than 12 m in width;

b) The approach to the building and open spaces on all its sides up to 6 m width and the layout for the same shall be done in consultation with the Chief Fire Officer of the city and the same shall be hard surface capable of taking the mass of fire engine, weighing up to 45 tonnes. The said open space shall be kept free of obstructions and shall be motorable.

c) The main entrance to the plot shall be of adequate width to allow easy access to the fire engine and in no case shall it measure less than 6 m. The entrance gate shall fold back against the compound wall of the premises, thus leaving the exterior accessway within the plot free for movement of fire service vehicle. If the main entrance at the boundary wall is built over, the minimum clearance shall be 4.5 m. A turning radius of 9 m shall be provided for fire tender movement.

4.7 Cul-de-sacs giving access to plots and extending from 150 m to 275 m in length with an additional turning space at 150 m will be allowed only in residential areas, provided cul-de-sacs would be permissible only on straight roads and further provided the end of cul-de-sacs shall be higher in level than the level of the starting point of such dead end road. The turning space, in this case shall be not less than 81 m^2 in area, with no dimension less than 9 m.

4.8 Intersection of Roads

For intersection junctions of roads meeting at right angles as well as other than right angles, the rounding off or cut off or splay or similar treatment shall be done, to the approval of the Authority, depending upon the width of roads, the traffic generated, the sighting angle, etc, to provide clear sight distance.

4.9 The building line shall be set back at least 3 m from internal means of access in a layout of buildings in a plot subject to provisions of **8.2.1**.

5 COMMUNITY OPEN SPACES AND AMENITIES

5.1 Residential and Commercial Zones

In any layout or sub-division of land measuring 0.3 hectare of more in residential and commercial zones, the community open spaces shall be reserved for recreational purposes which shall as far as possible be provided in one place or planned out for the use of the community in clusters or pockets.

5.1.1 The community open spaces shall be provided catering to the needs of area of layout, population for which the layout is planned and the category of dwelling units. The following minimum provision shall be made:

a) 15 percent of the area of the layout, or

b) 0.3 to 0.4 ha/1 000 persons; for low income housing the open spaces shall be 0.3 ha/1 000 persons.

5.2 No recreational space shall generally be less than 450 m^2.

5.2.1 The minimum average dimension of such recreational space shall be not less than 7.5 m; if the average width of such recreational space is less than 24 m, the length thereof shall not exceed 2.5 times the average width. However, depending on the configuration of the site, commonly open spaces of different shapes may be permitted by the Authority, as long as the open spaces provided serve the needs of the immediate community contiguous to the open spaces.

5.2.2 In such recreational spaces, a single storeyed structure as pavilion or gymnasia up to 25 m^2 in area may be permitted; such area may be excluded from FAR calculations.

5.3 Each recreational area and the structure on it shall have an independent means of access. Independent means of access may not be insisted upon if recreational space is approachable directly from every building in the layout. Further, the building line shall be at least 3 m away from the boundary of recreational open space.

5.4 Industrial Zones

In the case of sub-division of land in industrial zones of area 0.8 hectare or more, 5 percent of the total area shall be reserved as amenity open space which shall also serve as a general parking space; when such amenity open space exceeds 1 500 m^2, the excess area could be utilized for the construction of buildings for banks, canteens, welfare centres and such other common purposes considered necessary for the industrial user, as approved by the Authority.

5.4.1 In all industrial plots measuring 1 000 m^2 or more in area, 10 percent of the total area shall be provided as an amenity open space to a maximum of 2 500 m^2. Such an amenity open space shall have a means of access and shall be so located that it could be conveniently utilized as such by the persons working in the industry.

5.5 Other Amenities

In addition to community open spaces, the layouts shall provide for the amenities as given in **5.5.1** to **5.5.6**. These provisions may be modified based on specific requirements, as decided by the Authority.

	Land Area Required, Min
a) ***Pre-Primary to Secondary Education***	
1) *Pre-primary, nursery school (1 for every 2 500 population)*	
i) Area per school	0.08 ha
ii) Location of pre-primary/nursery school	Near a park
2) *Primary school (class 1 to 5) (1 for every 5 000 population)*	
i) Strength of school — 500 students	
ii) Area per school	0.40 ha
a) School building area	0.20 ha
b) Play field area (with a minimum of 18 m × 36 m to be ensured for effective play)	0.20 ha
3) *Senior secondary school (class 6 to 12) (1 for every 7 500 population)*	
i) Strength of the school — 1 000 students	
ii) Area per school	1.80 ha
a) School building area	0.60 ha
b) Play field area (with a minimum of 68 m × 126 m to be ensured for effective play)	1.00 ha
c) Parking area	0.20 ha
4) *Integrated school without hostel facility (class 1 to 12) (1 for every 90 000 to 100 000 population)*	
i) Strength of the school—1 500 students	
ii) Area per school	3.50 ha
a) School building area	0.70 ha
b) Play field area	2.50 ha
c) Parking	0.30 ha
5) *Integrated school with hostel facilities (class 1 to 12) (1 for every 90 000 to 100 000 population)*	
i) Strength of school — 1 500 students	
ii) Area per school	3.90 ha
a) School building area	0.70 ha
b) Play field area	2.50 ha
c) Residential (including hostel area)	0.40 ha
d) Parking area	0.30 ha
6) *School for physically challenged (class 1 to 12) (1 for every 45 000 population)*	
i) Strength of school — 400 students	
ii) Area per school	0.70 ha
a) School building area	0.20 ha
b) Play field area	0.30 ha
c) Parking area	0.20 ha
b) ***Higher Education — General***	
1) *College (1 for every 125 000 population)*	
i) Student strength of college — 1 000 to 1 500 students	
ii) Area per college	5.00 ha
a) College building area	1.80 ha
b) Play field area	2.50 ha
c) Residential (including hostel area)	0.40 ha
d) Parking area	0.30 ha
2) *University campus/centre area*	10.00 ha
3) *New university area*	60.00 ha

	Land Area Required, Min
*c) **Technical Education***	
1) *Technical education centre (A) (1 for every 1 000 000 population to include 1 ITI and 1 polytechnic)*	
i) Strength of ITI — 400 students	
ii) Strength of polytechnic — 500 students	
iii) Area per technical education centre	4.00 ha
a) Area for ITI	1.60 ha
b) Area for polytechnic	2.40 ha
2) *Technical education centre (B) (1 for every 1 000 000 population to include 1 ITI, 1 technical centre and 1 coaching centre)*	
Area per technical education centre	4.00 ha
a) Area for ITI	1.60 ha
b) Area for technical centre	2.10 ha
c) Area for coaching centre	0.30 ha
*d) **Professional Education***	
1) *Engineering college (1 for every 1 000 000 population)*	
i) Strength of the college — 1 500 students	
ii) Area per college	6.00 ha
2) *Medical college (1 for every 1 000 000 population)*	
Area of site including space for general hospital	15.00 ha
3) *Other professional colleges (1 for every 1 000 000 population)*	
i) Area of site for students strength upto 250 students	2.00 ha
ii) Additional area of site for every additional 100 students or part thereof upto total strength of 1 000 students	0.50 ha
iii) Area of site for strength of college — From 1 000 to 1 500 students	6.00 ha

5.5.2 *Health Care Facilities*

	Land Area Required, Min
1) *Dispensary (1 for every 15 000 population)*	
Area	0.08 ha to 0.12 ha
2) *Nursing home, child welfare and maternity centre (1 for every 45 000 to 100 000 population)*	
i) Capacity 25 to 30 beds	
ii) Area	0.20 ha to 0.30 ha
3) *Poly-clinic with some observation beds (1 for every 100 000 population)*	
Area	0.20 ha to 0.30 ha
4) *Intermediate hospital (category B) (1 for every 100 000 population)*	
i) Capacity 80 beds (initially the provision may be for 50 including 20 maternity beds)	
ii) Total area	1.00 ha
a) Area for hospital	0.60 ha
b) Area for residential accommodation	0.40 ha
5) *Intermediate hospital (category A) (1 for every 100 000 population)*	
i) Capacity 200 beds (initially the provision may be for 100 beds)	
ii) Total area	3.70 ha
a) Area for hospital	2.70 ha
b) Area for residential accommodation	1.00 ha

i)	Capacity 500 beds (initially the provision may be for 300 beds)	
ii)	Total area	6.00 ha
	a) Area for hospital	4.00 ha
	b) Area for residential accommodation	2.00 ha
7)	*Multi-speciality hospital (1 for 100 000 population)*	
i)	Capacity 200 beds (initially the provision may be for 100 beds)	
ii)	Total area	9.00 ha
	a) Area for hospital	6.00 ha
	b) Area for residential accommodation	3.00 ha
8)	*Speciality hospital (1 for every 100 000 population)*	
i)	Capacity 200 beds (initially the provision may be for 100 beds)	
ii)	Total area	3.70 ha
	a) Area for hospital	2.70 ha
	b) Area for residential accommodation	1.00 ha

5.5.3 *Socio-cultural facilities*

		Land Area Required, Min
1)	*Community room (1 for every 5 000 population)*	
	Area	750 m^2
2)	*Community hall, mangal karyayala/kalyana mandapam/barat ghar/library (1 for every 15 000 population)*	
	Area	2 000 m^2
3)	*Recreational club (1 for every 100 000 population)* (*see also* **5.2, 5.2.1, 5.2.2** *and* **5.3**)	
	Area	10 000 m^2
4)	*Music, dance and drama centre (1 for every* 100 000 population)	
	Area	1 000 m^2
5)	*Meditation and spiritual centre (1 for every* 100 000 population)	
	Area	5 000 m^2
6)	*Socio-cultural centre (1 for every 1 000 000* population)	
	Area	15 ha

5.5.4 *Distribution Services*

		Land Area Required, Min
1)	*Petrol/diesel filling and servicing centre*	
	May be permitted in central as well as sub-central business district, district centres, community centres (only filling station), residential and industrial use zones in urban areas, along the national highways, state highways, villages identified as growth centres, freight complex and on proposed major roads.	
	Shall not be located on the road having right of way less than 30 m.	
	Shall be approved by the explosive/fire department.	
	Area/Size	
i)	Only filling station	30 m × 17 m
ii)	Filling-cum-service station	36 m × 30 m
iii)	Filing-cum-service station-cum-workshop	45 m × 36 m
iv)	Filling station only for two and three wheelers	18 m × 15 m
2)	*Compressed natural gas (CNG)/filling centre*	
	Permitted in all use zones (except in regional parks and Developed District Parks) and along the national highways, state highways and villages identified as growth centres, freight complex and on proposed major roads	

	Land Area Required, Min
Shall not be located on the road having right of way less than 30 m.	
Shall be approved by the explosive/fire department.	
Area/size for mother station (building component—control room/office/dispensing room, store, pantry and W.C.	1 080 m^2 (36 m × 30 m)
3) *LPG godowns/Gas godown 1 for every 40 000 to 50 000 population*	
The major concern for its storage and distribution is the location which shall be away from the residential areas and shall have open spaces all around as per the *Explosive Rules*.	
i) Capacity — 500 cylinders or 8 000 kg of LPG	520 m^2
ii) Area (inclusive of chowkidar hut)	(26 m × 20 m)
4) *Milk distribution (1 milk booth for every 5 000 population)*	
Area inclusive of service area	150 m^2

5.5.5 *Police, Civil Defence and Home Guards*

	Land Area Required, Min
1) *Police station (1 for every 90 000 population)*	
Area (inclusive of essential residential accommodation 0.05 ha additional to be provided for civil defence and home guards)	1.50 ha
2) *Police post (1 for every 40 000 to 50 000 population) (not served by a police station)*	
Area (inclusive of essential residential accommodation)	0.16 ha
3) *District office and battalion (1 for every 1 000 000 population)*	
i) Area for district office	0.80 ha
ii) Area for battalion	4.00 ha
iii) Total area	4.80 ha
4) *Police line (1 for every 2 000 000 population)*	
Area	4.00 to 6.00 ha
5) *District Jail (1 for every 1 000 000 population)*	
Area	10.00 ha
6) *Civil defence and home guards (1 for every 1 000 000 population)*	
Area	2.00 ha

5.5.6 *Fire*

	Land Area Required, Min
One fire station or sub-fire station within 1 km to 3 km (for every 200 000 population)	
i) Area for fire station with essential residential accommodation	1.00 ha
ii) Area for sub-fire station with essential residential accommodation	0.60 ha

5.5.7 *Telephone, Telegraphs, Postal and Banking Facilities*

	Land Area Required, Min
a) ***Telephone and Telegraphs***	
1) *Telephone exchange of 40 000 lines (1 for every 400 000 population)*	
Area	4.00 ha
2) *Telegraph booking counter (1 for every 100 000 population)*	
Floor area to be provided in community centre	200 m^2
3) *Telegraph booking and delivery office (1 for every 500 000 population)*	
Floor area to be provided in district centres	1 700 m^2

	Land Area Required, Min
b) ***Postal***	
1) *Post office counter without delivery (1 for every 15 000 population)*	
Floor area to be provided in local shopping centre	85 m^2
2) *Head post office with delivery office (1 for 250 000 population)*	
Area	750 m^2
3) *Head post office and administrative office (1 for 500 000 population)*	
Area	2 500 m^2
c) ***Banking***	
1) *Extension counters with ATM facility (1 for every 15 000 population)*	
i) Floor area for counters	75 m^2
ii) Floor area for ATM	6 m^2
2) *Bank with locker, ATM and other banking facilities (1 for 100 000 population)*	
Area	2 500 m^2

5.5.8 *Sports Activity*

	Land Area Required, Min
1) *Divisional sports centre (1 for 1 000 000 population)*	
Area	20.00 ha
2) *District sport centre (1 for 100 000 population)*	
Area	8.00 ha
3) *Neighbourhood play area (1 for 15 000 population)*	
Area	1.50 ha
4) *Residential unit play area (1 for 5 000 population)*	
Area	5 000 m^2

5.5.9 *Shopping*

	Land Area Required, Min
1) *Convenience shopping (1 for 5 000 population)*	
Area	1 500 m^2
2) *Local shopping including service centre (1 for 15 000 population)*	
Area	4 600 m^2
3) *Community centre with service centre (1 for 100 000 population)*	
Area	5.00 ha
4) *District centre (1 at district level/1 for 500 000 population)*	
Area	7.50 ha
5) *Local wholesale market (1 for 1 000 000 population)*	
Area	10.00 ha
6) *Weekly markets (1 to 2 locations for every 100 000 populations with 300 to 400 units per location)*	
Parking and other open spaces within the commercial centres could be so designed that weekly markets can operate in these areas during non-working hours.	
The area of informal sector should have suitable public conveniences and solid waste disposal arrangements.	
Area per location	0.40 ha
7) *Organized informal sector eating places (1 for 100 000 population)*	
Area	2 000 m^2

5.5.10 *Religious*

	Land Area Required, Min
1) *Religious campus (1 for 100 000 population)*	
Area	5.00 ha

5.5.11 *Electrical Sub-station*

	Land Area Required, Min
1) *11 kV Sub-station (1 for 15 000 population)*	
Area	500 m^2
2) *66 kV Sub-station (2 for 100 000 population)*	
Area for each Sub-station	6 000 m^2 (that is 60 m × 100 m)
3) *220 kV Sub-station (1 for 500 000 population)*	
Area	4.00 ha

5.5.12 *Transport*

	Land Area Required, Min
1) *Three wheeler and taxi stand (1 for 15 000 population)*	
Area	500 m^2
2) *Bus terminal (1 for 100 000 population)*	
Area	4 000 m^2
3) *Bus depot (1 for 500 000 population)*	
Area	2.00 ha

5.5.13 *Cremation/Burial Ground*

The site shall be identified in locations, which are not proximous to residential areas

	Land Area Required, Min
1) *Electric crematorium (1 for large size towns)*	
Area	2.00 ha
2) *Cremation ground (1 for 500 000 population)*	
Area	2.50 ha
3) *Burial ground (1 for 500 000 population)*	
Area	4.00 ha

5.5.14 *Dhobi Ghat*

	Land Area Required, Min
1) *Dhobi ghat with appropriate arrangements for water and drainage facilities and it shall be ensured that the water bodies are not polluted as a result of such activities (1 for 100 000 population)*	
Area	5 000 m^2

5.6 Every layout or sub-division shall take into account the provisions of development plan and if the land is affected by any reservation for public purposes, the Authority may agree to adjust the location of such reservations to suit the development.

6 REQUIREMENTS OF PLOTS

6.1 No building shall be constructed on any site, on any part of which there is deposited refuse, excreta or other offensive matter objectionable to the Authority, until such refuse has been removed therefrom and the

site has been prepared or left in a manner suitable for building purposes to the satisfaction to the Authority.

6.2 Damp Sites

Wherever the dampness of a site or the nature of the soil renders such precautions necessary, the ground surface of the site between the walls of any building erected thereon shall be rendered damp-proof to the satisfaction of the Authority.

6.3 Surface Water Drains

Any land passage or other area within the curtilage of a building shall be effectively drained by surface water drains or other means.

6.3.1 The written approval of the Authority shall be obtained for connecting any sub-soil or surface water drain to a sewer.

6.4 Distance from Electric Lines

No *VERANDAH*, balcony, or the like shall be allowed to be erected or re-erected or any additions or alterations made to a building within the distances quoted below in accordance with the current *Indian Electricity Rules* as amended from time-to-time between the building and any overhead electric supply line:

		Vertically m	*Horizontally* m
(1)	(2)	(3)	(4)
a)	Low and medium voltage lines and service lines	2.5	1.2
b)	High voltage lines up to and including 11 000 V	3.7	1.2
c)	High voltage lines above 11 000 V and up to and including 33 000 V	3.7	2.0
d)	Extra high voltage line beyond 33 000 V	3.7 (plus 0.3 m for every additional 33 000 V or part thereof)	2.0 (plus 0.3 m for every additional 33 000 V or part thereof)

6.5 Distance of site from the normal edge of water course/area may be specified by the Authority, keeping in view the normal maximum flood/tide level.

6.6 Size of Plots

6.6.1 *Residential*

Each plot shall have a minimum size/frontage corresponding to the type of development as given below:

Type of Development	*Plot Size* m^2	*Frontage* m
(1)	(2)	(3)
Detached building	Above 250	Above 12
Semi-detached building	125-250	8 to 12
Row type building	50-125	4.5 to 8

NOTE — For low income housing *see* **12.20**.

6.6.1.1 The minimum size of the site for group housing development shall be as given in the Master Plan and local development control rules.

6.6.2 *Industrial*

The size of the plot shall not be less than 300 m^2 and its width shall not be less than 15 m.

6.6.3 *Other Land Uses*

The minimum size of plots for buildings for other uses not covered under **5.5** shall be as decided by the Authority.

7 CLASSIFICATION OF BUILDINGS

7.0 Buildings are classified based on occupancy and types of construction.

7.1 For the purpose of the Code, the following shall be the occupancy classification and types of construction; for more detailed information, reference may be made to Part 4 'Fire and Life Safety'.

7.1.1 *Occupancy Classification*

a) Residential;
b) Educational;
c) Institutional;
d) Assembly;
e) Business;
f) Mercantile (will include both retail and wholesale stores);
g) Industrial (will include low, moderate and high fire hazards);
h) Storage; and
j) Hazardous.

7.1.2 *Types of Construction*

a) Type 1,
b) Type 2,
c) Type 3, and
d) Type 4.

8 OPEN SPACES (WITHIN A PLOT)

8.1 General

Every room intended for human habitation shall abut on an interior or exterior open space or an open *VERANDAH* open to such interior or exterior open space.

8.1.1 The open spaces inside and around a building have essentially to cater for the lighting and ventilation requirements of the rooms abutting such open spaces, and in the case of buildings abutting on streets in the front, rear or sides, the open spaces provided shall be sufficient for the future widening of such streets.

8.1.2 *Open Spaces Separate for each Building or Wing*

The open spaces shall be separate or distinct for each building and where a building has two or more wings, each wing shall have separate or distinct open spaces for the purposes of lighting and ventilation of the wings.

However, separation between accessory and main buildings more than 7 m in height shall not be less than 1.5 m; for buildings up to 7 m in height no such separation shall be required.

8.1.3 The open space shall be the minimum distance measured between the front, rear and side of the building and the respective plot boundaries. The front, rear and side of the building shall be the point of the building nearest to the boundary.

8.2 Residential Buildings

8.2.1 *Exterior Open Spaces*

8.2.1.1 *Front open space*

a) Every building fronting a street shall have a front space, forming an integral part of the site as below:

Sl No.	*Front Open Space, Min* m	*Width of Street Fronting the Plot* m
(1)	(2)	(3)
i)	1.5[1)]	Up to 7.5[1)]
ii)	3.0	7.5 to 18
iii)	4.5	18 to 30
iv)	6.0	Above 30

[1)] For buildings up to a maximum height 7 m.

NOTE — In case a building abuts two or more streets, the value of open paces is to be based on the average width of streets, subject to a minimum of 1.8 m for cases (ii), (iii) and (iv) above.

b) For streets less than 7.5 m in width, the distance of the building (building line) shall be at least 5 m from the centre line of the street (*see* **4.3.5**).

NOTE — This limiting distance has to be determined by the Authority for individual road/street widths taking into account the traffic flow.

8.2.1.2 *Rear open space*

a) Every residential building shall have a rear open space, forming an integral part of the site, of an average width of 3 m and at no place measuring less than 1.8 m, except that in the case of a back-to-back sites, the width of the rear open space shall be 3 m throughout. Subject to the condition of free ventilation, the open space left up to half the width of the plot shall also be taken into account for calculating the average width of the rear open space. For plots of depths less than 9 m, for buildings up to 7 m in height, the rear open space may be reduced to 1.5 m.

b) *Rear open space to extend the rear wall*

The rear open space shall be co-extensive with the entire face of the rear wall. If a building abuts on two or more streets, such rear open space shall be provided throughout the face of the rear wall. Such rear wall shall be the wall on the opposite side of the face of the building abutting on the wider street unless the Authority directs otherwise.

c) In case of corner plots less than 300 m^2 in area, the rear open space should be 2.4 m minimum.

8.2.1.3 *Side open space*

a) Every semi-detached and detached building shall have a permanently open air space, forming an integral part of the site as below:

1) For detached buildings there shall be a minimum side open space of 3 m on both the sides.

NOTE — For detached residential buildings up to 7 m in height on plots with a frontage less than 12 m (*see* **6.6.1**), one of the side open spaces may be reduced to 1.5 m.

2) For semi-detached buildings, there shall be a minimum side open space of 3 m on one side.

NOTE — For semi-detached buildings up to 7 m in height on plots with a frontage less than 9 m (*see* **6.6.1**), the side open spaces may be reduced to 1.5 m.

3) For row-type buildings, no side open is required.

b) In the case of semi-detached buildings, the open spaces provided on one side shall be as

in **8.2.1.3** (a) and all habitable rooms shall abut either on this side open space or front and rear open spaces or an interior open space (*see* **8.2.5**).

8.2.2 The provisions of **8.2.1.2** and **8.2.1.3** are not applicable to parking lock-up garages up to 3 m in height located at a distance of 7.5 m from any street line or front boundary of the plot.

8.2.3 The open spaces mentioned in **8.2.1.1** to **8.2.1.3** shall be for residential buildings up to a height of 10 m.

8.2.3.1 For buildings of height above 10 m, the open spaces (side and rear) shall be as given in Table 2. The front open spaces for increasing heights of buildings shall be governed by **9.4.1** (a).

Table 2 Side and Rear Open Spaces for Different Heights of Buildings

(*Clause* 8.2.3.1)

Sl No.	Height of Buildings	Side and Rear Open Spaces to be Left Around Building
	m	m
(1)	(2)	(3)
i)	10	3
ii)	15	5
iii)	18	6
iv)	21	7
v)	24	8
vi)	27	9
vii)	30	10
viii)	35	11
ix)	40	12
x)	45	13
xi)	50	14
xii)	55 and above	16

NOTES

1 For buildings above 24 m in height, there shall be a minimum front open space of 6 m.

2 Where rooms do not derive light and ventilation from the exterior open space, the width of such exterior open space as given in col 3 may be reduced by 1 m subject to a minimum of 3 m and a maximum of 8 m. No further projections shall be permitted.

3 If the length or depth of the building exceeds 40 m, add to col (3) 10 percent of length or depth of building minus 4.0 m.

8.2.3.2 For tower-like structures, as an alternative to **8.2.3.1**, open spaces shall be as below:

a) Up to a height of 24 m, with one set-back, the open spaces at the ground level, shall be not less than 6 m;

b) For heights between 24 m and 37.5 m with one set-back, the open spaces at the ground level, shall be not less than 9 m;

c) For heights above 37.5 m with two set-backs, the open spaces at the ground level, shall be not less than 12 m; and

d) The deficiency in the open spaces shall be made good to satisfy **8.2.3.1** through the set-backs at the upper levels; these set-backs shall not be accessible from individual rooms/flats at these levels.

8.2.4 The front open space would govern the height of the building (*see* **9.4**).

8.2.5 *Interior Open Spaces*

a) *Inner courtyard* — In case the whole of one side of every room excepting bath, WC and store room is not abutting on either the front, rear or side open spaces, it shall abut on an inner courtyard, whose minimum width shall be 3 m.

Further, the inner courtyard shall have an area, throughout its height, of not less than the square of one-fifth the height of the highest wall abutting the courtyard. Provided that when any room (excluding staircase bay, bathroom and water-closet) is dependent for its light and ventilation on an inner courtyard, the dimension shall be such as is required for each wing of the building.

Where only water-closet and bath room are abutting on the interior courtyard, the size of the interior courtyard shall be in line with the provision for ventilation shaft as given in **8.2.5** (b).

b) *Ventilation shaft* — For ventilating the spaces for water-closets and bath rooms, if not opening on to front, side, rear and interior open spaces, these shall open on the ventilation shaft, the size of which shall not be less than the values given below:

Height of Buildings	*Size of Ventilation Shaft*	*Minimum One Dimension of the Shaft*
m	m^2	m
(1)	(2)	(3)
Up to 10	1.2	0.9
12	2.8	1.2
18	4.0	1.5
24	5.4	1.8
30	8.0	2.4
Above 30	9.0	3.0

NOTES

1 For buildings of height above 30 m, a mechanical ventilation system shall be installed besides the provision of minimum ventilation shaft.

2 For fully air-conditioned residential buildings for lodging purposes, the ventilation shaft need not be insisted upon, provided the air-conditioning system works in an uninterrupted manner, also, provided there is an alternative source of power supply.

c) *Outer courtyard* — The minimum width of the outer courtyard (as distinguished from its depth) shall be not less than 2.4 m. If the width of the outer courtyard is less than 2.4 m, it shall be treated as a notch and the provisions of outer courtyard shall not apply. However, if the depth of the outer courtyard is more than the width, the provisions of **8.1.2** shall apply for the open spaces to be left between the wings.

8.2.6 *Joint Open Air Space*

Every such interior or exterior open air space, unless the latter is a street, shall be maintained for the benefit of such building exclusively and shall be entirely within the owner's own premises.

8.2.6.1 If such interior or exterior open air space is intended to be used for the benefit of more than one building belonging to the same owner, the width of such open air space shall be the one specified for the tallest building as specified in **8.2.3** abutting on such open air space.

8.2.6.2 If such interior or exterior open air space is jointly owned by more than one person, its width shall also be as specified in **8.2**, provided every such person agrees in writing to allow his portion of such joint open air space to be used for the benefit of every building abutting on such joint open air space and provided he sends such written consent to the Authority for record. Such common open air space shall thenceforth be treated as a permanently open air space required for the purposes of the Code. No boundary wall between such joint open air space shall be erected or raised to a height of more than 2.0 m.

8.3 Other Occupancies

8.3.1 Open spaces for other occupancies shall be as below:

a) *Educational buildings* — Except for nursery schools, the open spaces around the building shall be not less than 6 m.

b) *Institutional buildings* — The open spaces around the building shall be not less than 6 m.

c) *Assembly buildings* — The open space at front shall be not less than 12 m and the other open spaces around the building shall be not less than 6 m.

NOTE — However, if assembly buildings are permitted in purely residential zones, the open spaces around the building shall be not less than 12 m.

d) *Business, mercantile and storage buildings* — The open spaces around the building shall be not less than 4.5 m. Where these occur in a purely residential zone or in a residential with shops line zone the open spaces may be relaxed.

e) *Industrial buildings* — The open spaces around the building shall be not less than 4.5 m for heights up to 16 m, with an increase of the open spaces of 0.25 m for every increase of 1 m or fraction thereof in height above 16 m.

NOTE — Special rules for narrow industrial plots in the city, namely plots less than 15 m in width, and with appropriate set-backs from certain streets and highways, shall be applicable.

f) *Hazardous occupancies* — The open spaces around the building shall be as specified for industrial buildings [*see* **8.3.1** (e)].

8.4 Exemption to Open Spaces

8.4.1 *Projections into Open Spaces*

Every open space provided either interior or exterior shall be kept free from any erection thereon and shall be open to the sky, except as below:

a) Cornice, roof or weather shade not more than 0.75 m wide;

b) Sunshades over windows/ventilators or other openings not more than 0.75 m wide;

c) Canopy not to be used as a sit out with clearance of 1.5 m between the plot boundary and the canopy;

d) Projected balcony at higher floors of width not more than 1.2 m; and

e) Projecting rooms/balconies [*see* (d)] at alternate floors such that rooms of the lower two floors get light and air and the projection being not more than the height of the storey immediately below.

However, these projections into open spaces shall not reduce the minimum required open spaces.

8.4.1.1 *Accessory building*

The following accessory buildings may be permitted in the open spaces:

a) In an existing building, sanitary block of 2.4 m in height subject to a maximum of 4 m^2 in the rear open space at a distance of 1.5 m from the rear boundary may be permitted, where facilities are not adequate.

b) Parking lock up garages not exceeding 2.4 m in height shall be permitted in the side or rear open spaces at a distance of 7.5 m from any road line or the front boundary of the plot; and

c) Suction tank and pump room each up to 2.5 m^2 in area.

8.4.2 *Projection into Street*

8.4.2.1 In existing built-up or congested areas, no projection of any sort whatsoever, except sunshades (*see* **8.4.2.3**) extending more than 23 cm below a height of 4.3 m, shall project over the road or over any drain or over any portion outside the boundaries of the site, provided the projection arising out of the vertical part of the rain-water spouts projecting at the road level or the water pipe may be permitted in accordance with the drainage plan.

8.4.2.2 *Porticos in existing developed area*

Porticos in bazaar areas of existing developed areas may be permitted to project on road land subject to the following limitations:

a) Porticos may be allowed on such roads leaving a minimum clear space of 18 m between kerbs;
b) The porticos shall not be less than 3 m wide;
c) Nothing shall be allowed to be constructed on the portico which shall be used as an open terrace;
d) Nothing shall be allowed to project beyond the line of arcades; and
e) The space under the portico shall be paved and channelled according to the directions of the Authority.

8.4.2.3 *Sunshades over windows and ventilators*

Projections of sunshades over windows or ventilators in existing built-up or congested areas when permitted by the Authority shall fulfil the following conditions:

a) No sunshade shall be permitted over the road or over any drain or over any portion outside the boundaries of the site below a height of 2.8 m from the road level;
b) Sunshades provided above a height of 2.8 m from the ground level shall be permitted to project up to a maximum width of 60 cm, if the road over which they project exceeds 9 m in width; and
c) No sunshade shall be permitted on roads less than 9 m in width or on roads having no footpaths.

8.5 Limitations to Open Spaces

8.5.1 *Safeguard Against Reduction of Open Space*

No construction work on a building shall be allowed if such work operates to reduce an open air space of any other adjoining building, belonging to the same owner to an extent less than what is prescribed at the time of the proposed work or to reduce further such open space if it is already less than that prescribed.

8.5.2 *Additions or Extensions to a Building*

Additions or extensions to a building shall be allowed, provided the open spaces for the additions/extensions satisfy **8.2** after such additions/extensions are made.

9 AREA AND HEIGHT LIMITATIONS

9.1 General

The limitation of area and height of buildings of different occupancy classes and types of construction shall be achieved by specifying it in terms of FAR, which shall take into account the various aspects that govern in specifying FAR as given below:

a) Occupancy class;
b) Types of construction;
c) Width of street fronting the building and the traffic load;
d) Locality where the building is proposed and the density;
e) Parking facilities;
f) Local fire fighting facilities; and
g) Water supply and drainage facilities.

9.2 The comparative FAR's for different occupancies and types of construction are as given in Table 3 and the Authority shall select a basic FAR for one occupancy and a type of construction and arrive at the FAR values for other combinations taking into account the other local factors (*see* **9.1**).

9.2.1 *Unlimited Areas*

The minimum fire separation on all sides of buildings of unlimited areas (*see* Table 3) and of Type 1 construction shall be 9 m.

9.3 Street Width

The area limits shall apply to all buildings fronting on a street or public space not less than 9 m in width accessible to a public street.

9.4 Height Limit

The height and number of storeys shall be related to FAR and the provisions of **8**.

9.4.1 Where a building height is not covered by Table 3, the maximum height shall be limited according to the width of the street as follows:

a) The maximum height of building shall not exceed 1.5 times the width of road abutting plus the front open space;
b) If a building abuts on two or more streets of different widths, the building shall be deemed to face upon the street that has the greater width and the height of the building shall be

Table 3 Comparative Floor Area Ratios for Occupancies Facing One Public Street of at Least 9 m Width

(Clauses 2.26, 9.2 *and* 9.2.1)

Occupancy Classification	Type of Construction			
	Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)
Residential	UL	2.0	1.4	1.0
Educational	UL	2.0	1.4	1.0
Institutional	UL	1.5	1.0	0.8
Assembly	UL	1.0	0.7	0.5
Business	UL	2.9	2.3	1.6
Mercantile	8.0	1.8	1.4	1.0
Industrial	7.5	1.9	1.6	1.3
Storage (*see* Note 4)	6.0	1.5	1.3	1.0
Hazardous (*see* Note 4)	2.8	1.1	0.9	NP

UL — Unlimited

NP — Not Permitted

NOTES

1 This table has been prepared, taking into account the combustible content in the different occupancies as well as the fire resistance offered by the type of construction (*see* Part 4 'Fire and Life Safety').

2 This table shall be modified by the Authority, taking into account the other aspects as given below (*see* **9.1**):

a) Density in terms of dwelling units/hectare;

b) Traffic considerations;

c) Parking spaces;

d) Local fire fighting facilities; and

e) Water supply, drainage and sanitation requirements.

3 The FAR specified may be increased by 20 percent for the following:

a) A basement or cellar and space under a building constructed on stilts and used as a parking space, and air-conditioning plant room used as accessory to the principal use;

b) Electric cabin or sub-station, watchman's booth of maximum size of 1.6 m^2 with minimum width or diameter of 1.2 m, pumphouse, garbage shaft, space required for location of fire hydrants, electric fittings and water tank;

c) Projections and accessory buildings as specifically exempted (*see* **8.4.1**); and

d) Staircase room and lift rooms above the topmost storey, architectural features; and chimneys and elevated tanks of dimensions as permissible under the Code; the area of the lift shaft shall be taken only on one floor.

4 In so far as single storey storage and hazardous occupancies are concerned, they would be further governed by volume to plot area ratio (VPR), to be decided by the Authority.

regulated by the width of that street and may be continued to this height to a depth of 24 m along the narrower street subject to conformity of **8**; and

c) For buildings in vicinity of aerodromes, provisions of **9.5** shall apply.

9.4.2 *Height Exceptions*

9.4.2.1 *Roof structures*

The following appurtenant structures shall not be included in the height of the building unless the aggregate area of such structures, including penthouses, exceeds one-third of the area of the roof of building upon which they are erected:

a) Roof tanks and their supports (with support height not exceeding 1 m);

b) Ventilating, air-conditioning, lift rooms and similar service equipment;

c) Stair cover (*MUMTY*) not exceeding 3 m in height; and

d) Chimneys, parapet walls and architectural features not exceeding 1.2 m in height.

9.4.2.2 The building height for different occupancy types shall not exceed the maximum height prescribed in Part 4 'Fire and Life Safety'.

9.5 Restrictions in the Vicinity of Aerodromes

9.5.1 For buildings in the vicinity of aerodromes, the maximum height of such buildings shall be decided in consultation with the Civil Aviation Authorities. This shall be regulated by the rules for giving no objection certificate for construction of buildings in the vicinity of aerodromes of Directorate General of Civil Aviation, which are given in Annex A. However, the latest rules of Directorate General of Civil Aviation shall be followed in all cases of buildings coming up in the vicinity of an aerodrome.

9.5.1.1 For the purpose of **9.5.1** new buildings, structures which rise to 30 m or more in height and are to be located within 20 km of the aerodrome reference point, shall be constructed only if no objection certificate has been obtained from the Directorate General of Civil Aviation.

9.5.1.2 In the case of buildings to be erected in the vicinity of defence aerodromes, the maximum height of such buildings shall be decided by the Defence Authority.

9.5.2 This will apply specially to new constructions, overhead high voltage/medium voltage lines, telephones/telegraph lines, factories, chimneys, wire/TV antennas.

9.5.2.1 No new chimneys or smoke producing factories shall be constructed within a radius of 8 km from the aerodrome reference point (ARP).

9.5.2.2 Overhead high voltage/medium voltage lines or telephone/telegraph lines shall not be permitted in the approach/take-off climb areas within 3 000 m of the inner edge of these areas.

9.5.2.3 A 3 m margin shall be allowed in new constructions for wireless/TV antennas, cooling towers and *MUMTIES*.

9.5.3 Butcheries, tanneries and solid waste disposal sites shall not be permitted within 10 km from the aerodrome reference point.

9.6 Group Housing

9.6.1 Group housing development may be in low rise house clusters or multi-storeyed apartments for high density development.

9.6.2 No limit to floors and height shall be applicable, but the coverage and floor area ratio for various densities may be as given in Table 4 unless otherwise provided in the Master Plan and local development control rules.

Table 4 Floor Area Ratio and Coverage for Group Housing

(*Clause* 9.6.2)

Sl No.	Net Residential Density in Dwelling Units/ Hectare	Maximum Coverage in Percent	Floor Area Ratio
(1)	(2)	(3)	(4)
i)	25	25	0.50
ii)	50	30	0.75
iii)	75	33	0.90
iv)	100	35	1.00
v)	125	35	1.25
vi)	150	35	1.50
vii)	175	35	1.75

NOTE — The coverage shall be calculated on the basis of the whole area reserved for group housing.

9.6.3 The minimum size of the site for group housing multi-storeyed apartment shall be 3 000 m^2.

9.6.3.1 The number of dwelling units are calculated on the basis of the density pattern given in the Development Plan taking into consideration a population of 4.5 persons per dwelling unit.

9.6.3.2 The basement may vary between 33.33 to 50 percent of the plot area and is to be used for parking, servicing and for essential household storage without counting in FAR.

9.6.3.3 One car parking space for every two flats up to 90 m^2 floor area and one for every flat for 100 m^2 or more shall be provided.

9.6.4 With a view to providing adequate parking for occupancies and the vehicular load, appropriate off-street parking provisions have to be made in the building/on-site. This could also be permitted in basement areas and the footprint for the basement parking can exceed the ground coverage of the building subject to no basement building construction to cross the building line and all other safety features for structural, fire, health and public safety being ensured.

10 OFF-STREET PARKING SPACES

10.1 The off-street parking (on-site parking) spaces in a plot to be provided shall be in accordance with Annex B. The spaces given in Annex B shall be considered by the Authority in conjunction with the Development Rules, in force, if any.

10.2 The spaces to be left out for off-street parking as given in **10.3** to **10.6** shall be in addition to the open spaces left out for lighting and ventilation purposes as given in **15**.

10.2.1 Further 50 percent of the open spaces required around buildings under **8** may be allowed to be utilized for parking or loading or unloading spaces, provided a minimum distance of 3.6 m around the building is kept free from any parking, loading or unloading spaces subject to the provisions of Part 4 'Fire and Life Safety'.

10.3 Each off-street parking space provided for vehicles shall be as follows:

a) For car, the minimum parking space to be 3 m × 6 m when individual parking space is required and 2.75 m × 5 m when common parking space is required.

b) Space for scooter/two wheeler and bicycle to be not less than 1.25 m^2 and 1.00 m^2 respectively.

c) Area for each equivalent car space inclusive of circulation area is 23 m^2 for open parking, 28 m^2 for ground floor covered parking and 32 m^2 for basement.

10.4 For buildings of different occupancies, off-street parking space for vehicles shall be provided as stipulated below:

a) *Motor Vehicles* — Space shall be provided as specified in Annex B for parking motor vehicles (cars).

b) *Other Types of Vehicles* — For non-residential building, in addition to the parking areas provided in (a) above, 25 to 50 percent additional parking space shall be provided for parking other types of vehicles and the additional spaces required for other vehicles shall be as decided by the Authority, keeping in view the nature of traffic generated in the city.

10.5 Off-street parking space shall be provided with adequate vehicular access to a street; and the area of drives, aisles and such other provisions required for adequate manoeuvering of vehicle shall be exclusive of the parking space stipulated in these provisions.

10.6 If the total parking space required by these provisions is provided by a group of property owners for their mutual benefits, such use of this space may be construed as meeting the off-street parking requirements under these provisions, subject to the approval of the Authority.

10.7 In buildings of mercantile (commercial), industrial and storage type, in addition to the parking spaces provided, a space at the rate of 3.5 m × 7.5 m, shall be provided for loading and unloading activities, for each 1 000 m^2 of floor area or fraction thereof.

10.8 Parking spaces shall be paved and clearly marked for different types of vehicles.

10.9 Apart from parking at ground level, provision of underground or multistoreyed parking may be permitted. The parking of vehicles at different level may also be mechanized. In the case of parking spaces provided in basement(s), at least two ramps of adequate width and slope shall be provided, located preferably at opposite ends. In case of underground/multistoreyed parking, special measures with regard to fire safety shall be taken (*see* Part 4 'Fire and Life Safety').

11 GREENBELTS, LANDSCAPING AND WATER CONSERVATION

11.1 General

Greenbelts and landscaping including plantation of shrubs and trees help to certain extent in enhancing the environmental quality.

11.1.1 Planting of trees in streets and in open spaces should be done carefully to take advantage of both shades and sunshine without obstructing the flow of wind circulation and sight. Their advantage for abating glare and for providing cool and/or warm pockets in developed areas should also be taken.

11.2 Norms for Planting of Shrubs and Trees

11.2.1 Suitable provisions may be made for greeneries including plantation of shrubs and trees as a part of environmental protection in general. This aspect shall be taken care of from the initial stage of town and country planning, zoning and planning of development of particular area and group housing. Finally, this aspect shall also be taken into account in planning individual building of different occupancies.

11.2.2 The types of plants, the distance between trees/plants from the building and the distance between plants shall be carefully worked out keeping in view the structural safety and aesthetic requirements of buildings.

11.3 Trees shall be numbered area-wise, plot-wise and road-wise by the concerned authority and they shall be checked periodically.

11.4 Cutting and pruning of trees in public as well as private areas shall be suitably regulated. Trees shall be cut only after obtaining the permission of the Authority designated for this purpose.

11.5 The landscape planning and design shall be done in accordance with Part 10 'Landscaping, Signs and Outdoor Display Structures, Section 1 Landscape Planning and Design'.

11.6 Water Conservation and Augmentation

In view of critical shortage of water, conservation of water by rain water harvesting and by use of recycled water to the maximum extent possible will be required. In this regard the following provisions may be adopted.

11.6.1 The local authority preparing a town-planning scheme or a development plan should see that the local water bodies are preserved, and if dry, are activated by directing water-courses appropriately. If required, the same should be enlarged, deepened, etc.

11.6.2 The water body should be protected by ensuring that no permanent/temporary construction development takes place around it up to a distance of 50 m from the edge of the water body and the same shall be suitably landscaped. Further, the public shall have easy access to the water body.

11.6.3 The rain water run-off shall be suitably directed to Recharging Wells in plots belonging to the local authority and of appropriate design.

11.6.4 The local authority should encourage for collection of rain water from roofs and terraces and direct the same either to a storage tank or to a recharging well.

11.6.5 Buildings having central air-conditioning plants requiring water for cooling purposes may not be allowed to use fresh water for the purpose.

11.6.6 Commercial or residential multi-storey complexes may use recycled water for flushing of toilets. Separate storage tanks and separate distribution pipes shall be provided for the purpose.

12 REQUIREMENTS OF PARTS OR BUILDINGS

12.1 Plinth

12.1.1 *Main Buildings*

The plinth or any part of a building or outhouse shall be so located with respect to the surrounding ground level that adequate drainage of the site is assured. The height of the plinth shall be not less than 450 mm from the surrounding ground level.

12.1.2 *Interior Courtyards and Covered Parking*

Every interior courtyard shall be raised at least 150 mm

above the determining ground level and shall be satisfactorily drained.

12.2 Habitable Rooms

12.2.1 *Height*

The height of all rooms for human habitation shall not be less than 2.75 m measured from the surface of the floor to the lowest point of the ceiling (bottom of slab). In the case of pitched roof, the average height of rooms shall not be less than 2.75 m. The minimum clear head room under a beam, folded plates or eaves shall be 2.4 m. In the case of air-conditioned rooms, a height of not less than 2.4 m measured from the surface of the floor to the lowest point of air-conditioning duct or the false ceiling shall be provided.

12.2.1.1 The requirements of **12.2.1** apply to residential, business and mercantile buildings. For educational and industrial buildings, the following minimum requirements apply:

a)	Educational Buildings	Ceiling height 3.6 m for all regions; in cold regions, 3 m
b)	Industrial Buildings	Ceiling height 3.6 m, except when air-conditioned, 3 m (*Factory Act* 1948 and Rules therein shall govern such heights, where applicable).

12.2.2 *Size*

The area of habitable room shall not be less than 9.5 m^2, where there is only one room with a minimum width of 2.4 m. Where there are two rooms, one of these shall not be less than 9.5 m^2 and the other not less than 7.5 m^2, with a minimum width of 2.1 m.

12.3 Kitchen

12.3.1 *Height*

The height of a kitchen measured from the surface of the floor to the lowest point in the ceiling (bottom slab) shall not be less than 2.75 m, except for the portion to accommodate floor trap of the upper floor.

12.3.2 *Size*

The area of a kitchen where separate dining area is provided, shall be not less than 5.0 m^2 with a minimum width of 1.8 m. Where there is a separate store, the area of the kitchen may be reduced to 4.5 m^2. A kitchen, which is intended for use as a dining area also, shall have a floor area of not less than 7.5 m^2 with a minimum width of 2.1 m.

12.3.3 *Other Requirements*

Every room to be used as kitchen shall have:

a) unless separately provided in a pantry, means for the washing of kitchen utensils which shall lead directly or through a sink to a grated and trapped connection to the waste pipe;

b) an impermeable floor;

c) a flue, if found necessary; and

d) a window or ventilator or opening of size not less than as specified in **15.1.1** subject to increase in area of opening in accordance with Note 3 of **15.1.2**.

12.4 Bathrooms and Water-Closets

12.4.1 *Height*

The height of a bathroom or water-closet measured from the surface of the floor to the lowest point in the ceiling (bottom of slab) shall not be less than 2.1 m.

12.4.2 *Size*

The area of a bathroom shall not be less than 1.8 m^2 with a minimum width of 1.2 m. The floor area of water-closet shall be 1.1 m^2 with a minimum width of 0.9 m. If bath and water-closet are combined, its floor area shall not be less than 2.8 m^2 with a minimum width of 1.2 m.

12.4.3 *Other Requirements*

Every bathroom or water-closet shall:

a) be so situated that at least one of its walls shall open to external air;

b) not be directly over or under any room other than another water-closet, washing place, bath or terrace, unless it has a water-tight floor;

c) have the platform or seat made of water-tight non-absorbent material;

d) be enclosed by walls or partitions and the surface of every such wall or partition shall be finished with a smooth impervious material to a height of not less than 1 m above the floor of such a room;

e) be provided with an impervious floor covering, sloping towards the drain with a suitable grade and not towards *VERANDAH* or any other room; and

f) have a window or ventilator, opening to a shaft or open space, of area not less than 0.3 m^2 with side not less than 0.3 m.

12.4.4 No room containing water-closets shall be used for any purpose except as a lavatory and no such room shall open directly into any kitchen or cooking space by a door, window or other opening. Every room containing water-closet shall have a door completely closing the entrance to it.

12.5 Ledge or *TAND*/Loft

12.5.1 *Height*

The minimum head-room of ledge or *TAND*/loft shall be 2.2 m. The maximum height of loft shall be 1.5 m.

12.5.2 *Size*

A ledge or *TAND*/loft in a habitable room shall not cover more than 25 percent of the area of the floor on which it is constructed and shall not interfere with the ventilation of the room under any circumstances.

12.6 Mezzanine Floor

12.6.1 *Height*

It shall have a minimum height of 2.2 m.

12.6.2 *Size*

The minimum size of the mezzanine floor, if it is to be used as a living room, shall not be less than 9.5 m^2. The aggregate area of such mezzanine floor in a building shall in no case exceed one-third the plinth area of the building.

12.6.3 *Other Requirements*

A mezzanine floor may be permitted over a room or a compartment provided:

a) it conform to the standard of living rooms as regards lighting and ventilation in case the size of mezzanine floor is 9.5 m^2 or more (*see* **14.1.2**);

b) it is so constructed as not to interfere under any circumstances with the ventilation of the space over and under it;

c) such mezzanine floor is not sub-divided into smaller compartments;

d) such mezzanine floor or any part of it shall not be used as a kitchen; and

e) in no case shall a mezzanine floor be closed so as to make it liable to be converted into unventilated compartments.

12.7 Store Room

12.7.1 *Height*

The height of a store room shall be not less than 2.2 m.

12.7.2 *Size*

The size of a store room, where provided in a residential building, shall be not less than 3 m^2.

12.8 Garage

12.8.1 *Height*

The height of a garage shall be not less than 2.4 m.

12.8.2 *Size*

The size of garages shall be as below:

a) *Private Garage* — 3.0 m × 6.0 m, minimum; and

b) *Public Garage* — Based on the number of vehicles parked, etc (*see* **10**).

12.9 Basement

12.9.1 The basement shall not be used for residential purposes.

12.9.2 The construction of the basement shall be allowed by the Authority in accordance with the land use and other provisions specified under the Development Control Rules.

12.9.2.1 The basement to be constructed within the building envelope and subject to maximum coverage on floor 1 (entrance floor) may be put to only the following uses:

a) Storage of household or other goods of ordinarily non-combustible material;

b) Strong rooms, bank cellars, etc;

c) Air-conditioning equipment and other machines used for services and utilities of the building; and

d) Parking spaces.

12.9.3 The basement shall have the following requirements:

a) Every basement shall be in every part at least 2.4 m in height from the floor to the underside of the roof slab or ceiling;

b) Adequate ventilation shall be provided for the basement. The ventilation requirements shall be the same as required by the particular occupancy according to byelaws. Any deficiency may be met by providing adequate mechanical ventilation in the form of blowers, exhaust fans, air-conditioning systems, etc;

c) The minimum height of the ceiling of any basement shall be 0.9 m and the maximum, 1.2 m above the average surrounding ground level;

d) Adequate arrangements shall be made such that surface drainage does not enter the basement;

e) The walls and floors of the basement shall be watertight and be so designed that the effects of the surrounding soil and moisture, if any, are taken into account in design and adequate damp proofing treatment is given; and

f) The access to the basement shall be separate from the main and alternative staircase

providing access and exit from higher floors. Where the staircase is continuous in the case of buildings served by more than one staircase, the same shall be of enclosed type serving as a fire separation from the basement floor and higher floors. Open ramps shall be permitted if they are constructed within the building line subject to the provision of (d).

The exist requirements in basements shall comply with the provisions of Part 4 'Fire and Life Safety'.

12.10 Chimneys

The chimneys shall be built at least 0.9 m above flat roofs, provided the top of the chimneys is not below the top of the adjacent parapet wall. In the case of sloping roofs, the chimney top shall not be less than 0.6 m above the ridge of the roof in which the chimney penetrates.

12.11 Parapet

Parapet walls and handrails provided on the edges of roof terraces, balcony, *VARANDAH*, etc shall not be less than 1.0 m and not more than 1.2 m in height from the finished floor level.

12.12 Cabin

The size of cabins shall not be less than 3.0 m^2 with a minimum width of 1.0 m. The clear passages within the divided space of any floor shall not be less than 0.75 m and the distance from the farthest space in a cabin to any exit shall not be more than 18.5 m. In case the sub-divided cabin does not derive direct lighting and ventilation from any open spaces/ mechanical means, the maximum height of the cabin shall be 2.2 m.

12.13 Boundary Wall

12.13.1 The requirements of the boundary wall are given below:

a) Except with the special permission of the Authority, the maximum height of the compound wall shall be 1.5 m above the centre line of the front street. Compound wall up to 2.4 m height may be permitted if the top 0.9 m is of open type construction of a design to be approved by the Authority.

b) In the case of a corner plot, the height of the boundary wall shall be restricted to 0.75 m for a length of 10 m on the front and side of the inter-sections and the balance height of 0.75 m if required in accordance with (a) may be made up of open type construction (through railings) and of design to be approved by the Authority.

c) However, the provisions of (a) and (b) are not applicable to boundary walls of jails. In industrial buildings, electric sub-stations, transformer stations, institutional buildings like sanitoria, hospitals, industrial buildings like workshops, factories and educational buildings like schools, colleges, including hostels, and other uses of public utility undertakings and strategically sensitive buildings, a height up to 2.4 m may be permitted by the Authority.

12.14 Wells

Wells, intended to supply water for human consumption or domestic purposes, where provided, shall comply with the requirements of **12.14.1** and **12.14.2**.

12.14.1 *Location*

The well shall be located:

a) not less than 15 m from any ash pit, refuse pit, earth closet or privy and shall be located on a site upwards from the earth closet or privy;

b) not less than 18 m from any cess pit soakway or borehole latrine and shall be located on a site upwards from the earth closet or privy;

c) that contamination by the movement of sub-soil or other water is unlikely; and

d) not under a tree or otherwise it should have a canopy over it, so that leaves and twigs may not fall into the well and rot.

12.14.2 *Requirements*

The well shall:

a) have a minimum internal diameter of not less than 1 m;

b) be constructed to a height not less than 1 m above the surrounding ground level, to form a parapet or kerb and to prevent surface water from flowing into a well, and shall be surrounded with a paving constructed of impervious material which shall extend for a distance of not less than 1.8 m in every direction from the parapet from the kerb forming the well head and the upper surface of such a paving shall be sloped away from the well;

c) be of sound and permanent construction (*PUCCA*) throughout. Temporary or exposed (*KUTCHA*) wells shall be permitted only in fields or gardens for purposes of irrigation; and

d) have the interior surface of the lining or walls of the well be rendered impervious for a depth of not less than 1.8 m measured from the level of the ground immediately adjoining the well-head.

12.15 Septic Tanks

Where a septic tank is used for sewage disposal, the location, design and construction of the septic tank shall conform to requirements of **12.15.1** and **12.15.2** [*see also* Part 9 'Plumbing Services, Section 1 Water Supply, Drainage and Sanitation (Including Solid Waste Management)'].

12.15.1 *Location of the Septic Tanks and Subsurface Absorption Systems*

A sub-soil dispersion system shall not be closer than 18 m from any source of drinking water, such as well, to mitigate the possibility of bacterial pollution of water supply. It shall also be as far removed from the nearest habitable building as economically feasible but not closer than 6 m, to avoid damage to the structures.

12.15.2 *Requirements*

a) *Dimensions of septic tanks* — Septic tanks shall have a minimum width of 750 mm, a minimum depth of 1 m below the water level and a minimum liquid capacity of 1 m^3. The length of tanks shall be 2 to 4 times the width;

b) Septic tanks may be constructed of brickwork, stone masonry, concrete or other suitable materials as approved by the Authority;

c) Under no circumstances shall effluent from a septic tank be allowed into an open channel drain or body of water without adequate treatment;

d) The minimum nominal diameter of the pipe shall be 100 mm. Further, at junctions of pipes in manholes, direction of flow from a branch connection shall not make an angle exceeding 45° with the direction of flow in the main pipe;

e) The gradients of land drains, under-drainage as well as the bottom of dispersion trenches and soakways shall be between 1:300 and 1:400;

f) Every septic tank shall be provided with ventilating pipe of at least 50 mm diameter. The top of the pipe shall be provided with a suitable cage of mosquito-proof wire mesh.

The ventilating pipe shall extend to a height which would cause no smell nuisance to any building in the area. Generally, the ventilating pipe may extend to a height of about 2 m, when the septic tank is at least 15 m away from the nearest building and to a height of 2 m above the top of the building when it is located closer than 15 m;

g) When the disposal of septic tank effluent is to a seepage pit, the seepage pit may be of any suitable shape with the least cross-sectional dimension of 0.90 m and not less than 1.00 m in depth below the invert level of the inlet pipe. The pit may be lined with stone, brick or concrete blocks with dry open joints which should be backed with at least 75 mm of clean coarse aggregate. The lining above the inlet level should be finished with mortar. In the case of pits of large dimensions, the top portion may be narrowed to reduce the size of the RCC cover slabs. Where no lining is used, specially near trees, the entire pit should be filled with loose stones. A masonry ring may be constructed at the top of the pit to prevent damage by flooding of the pit by surface runoff. The inlet pipe may be taken down a depth of 0.90 m from the top as an anti-mosquito measure; and

h) When the disposal of the septic tank effluent is to a dispersion trench, the dispersion trench shall be 0.50 m to 1.00 m deep and 0.30 m to 1.00 m wide excavated to a slight gradient and shall be provided with 150 mm to 250 mm of washed gravel or crushed stones. Open jointed pipes placed inside the trench shall be made of unglazed earthenware clay or concrete and shall have a minimum internal diameter of 75 mm to 100 mm. Each dispersion trench shall not be longer than 30 m and trenches shall not be placed closer than 1.8 m.

12.16 Office-cum-Letter Box Room

In the case of multi-storeyed multi-family dwelling apartments constructed by existing and proposed Cooperative Housing Societies or Apartment Owners Associations, limited companies and proposed societies, an office-cum-letter box room of dimension 3.6 m × 3 m shall be provided on the ground floor. In case the number of flats is more than 20, the maximum size of the office-cum-letter box room shall be 20 m^2.

12.16.1 *Business Buildings*

Provision shall be made for letter boxes on the entrance floor as per the requirements of the postal department.

12.17 Meter Rooms

For all buildings above 15 m in height and in special occupancies, like educational, assembly, institutional, industrial, storage, hazardous and mixed occupancies with any of the aforesaid occupancies having area more than 500 m^2 on each floor, provision shall be made for an independent and ventilated meter (service) room, as per requirements of electric (service) supply undertakings on the ground floor with direct access from outside for the purpose of termination of electric

supply from the licensee's service and alternative supply cables. The door/doors provided for the service room shall have fire resistance of not less than two hours.

12.18 Staircase/Exit Requirements

12.18.1 The minimum clear width, minimum tread width and maximum riser of staircases for buildings shall be as given in **12.18.1.1** to **12.18.1.3** (*see also* Part 4 'Fire and Life Safety').

12.18.1.1 *Minimum width* — The minimum width of staircase shall be as follows:

a)	Residential buildings (dwellings) NOTE — For row housing with 2 storeys, the minimum width shall be 0.75 m.	1.0 m
b)	Residential hotel buildings	1.5 m
c)	Assembly buildings like auditoria, theatres and cinemas	2.0 m
d)	Educational building	1.5 m
e)	Institutional buildings	2.0 m
f)	All other buildings	1.5 m

12.18.1.2 *Minimum tread*

The minimum width of tread without nosing shall be 250 mm for residential buildings. The minimum width of tread for other buildings shall be 300 mm.

12.18.1.3 *Maximum riser*

The maximum height of riser shall be 190 mm for residential buildings and 150 mm for other buildings and these shall be limited to 12 per flight.

12.18.2 The minimum head-room in a passage under the landing of a staircase shall be 2.2 m. The minimum clear head-room in any staircase shall be 2.2 m.

12.18.3 *Exit Requirements*

All aspects of exit requirements for corridors, doors, stair cases, ramps, etc in respect of widths, travel distance shall be as per Part 4 'Fire and Life Safety'.

12.19 Roofs

12.19.1 The roof of a building shall be so designed and constructed as to effectively drain water by means of sufficient rain-water pipes of adequate size, wherever required, so arranged, jointed and fixed as to ensure that the rain-water is carried away from the building without causing dampness in any part of the walls, roof or foundations of the building or an adjacent building.

12.19.2 The Authority may require rain-water pipes to be connected to a drain or sewer to a covered channel formed beneath the public footpath to connect the rain-water pipe to the road gutter or in any other approved manner.

12.19.3 Rain-water pipes shall be affixed to the outside of the external walls of the building or in recesses or chases cut or formed in such external walls or in such other manner as may be approved by the Authority.

12.19.4 It is desirable to conserve rain water using suitable rain water harvesting techniques including by roof water collection. In this context, reference may be made to Part 9 'Plumbing Services, Section 1 Water Supply, Drainage and Sanitation (Including Solid Waste Management)'.

12.20 Special Requirements of Low Income Housing

Special requirements of low income housing shall be as given in Annex C. For detailed information in this regard, reference may be made to the accepted standards [3(1)].

12.21 Special Requirements for Physically Challenged

Special requirements for planning of buildings and facilities keeping in view the needs of the physically challenged, applicable particularly to public buildings meant for their use, are given in Annex D.

12.22 Special Requirements for Cluster Planning for Housing

Special requirements for cluster planning for housing shall be as given in Annex E.

12.23 Special Requirements for Low Income Habitat Planning in Rural Areas

Special requirements for low income habitat planning in rural areas shall be as given in Annex F.

12.24 Special Requirements for Development Planning in Hilly Areas

Special requirements for development planning in hilly areas is given in Annex G.

13 FIRE AND LIFE SAFETY

For requirements regarding fire and life safety for different occupancies, reference shall be made to Part 4 'Fire and Life Safety'.

14 DESIGN AND CONSTRUCTION

For requirements regarding structural design, reference shall be made to Part 6 'Structural Design' and for construction (including safety) reference shall be made to Part 7 'Constructional Practices and Safety'.

15 LIGHTING AND VENTILATION

15.1 For requirements regarding lighting and

ventilation for different uses and occupancies, reference shall be made to Part 8 'Building Services, Section 1 Lighting and Ventilation'.

15.1.1 *Lighting and Ventilation of Rooms*

Rooms shall have, for the admission of light and air, one or more openings, such as windows and ventilators, opening directly to the external air or into an open *VERANDAH*.

15.1.2 Notwithstanding the area of openings obtained through **15.1**, the minimum aggregate area (*see* Notes 1 to 3) of such openings, excluding doors inclusive of frames, shall be not less than:

a) one-tenth of the floor area for dry hot climate;
b) one-sixth of the floor area for wet hot climate;
c) one-eighth of the floor area for intermediate climate; and
d) one-twelfth of the floor area for cold climate.

NOTES

1 If a window is partly fixed, the openable area shall be counted.

2 No portion of a room shall be assumed to be lighted, if it is more than 7.5 m away from the opening assumed for lighting that portion.

3 The area of openings as given in (a) to (d) above shall be increased by 25 percent in the case of a kitchen [*see* 12.3.3(d)].

16 ELECTRICAL AND ALLIED INSTALLATIONS (INCLUDING LIGHTNING PROTECTION OF BUILDINGS)

For requirements regarding electrical installations in buildings including lightning protection of buildings, reference shall be made to Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

17 AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION

For requirements regarding design, construction and installation of air conditioning, heating and mechanical ventilation systems, reference shall be made to Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation'.

18 ACOUSTICS, SOUND INSULATION AND NOISE CONTROL

For requirements regarding the desired noise levels and sound insulation in different occupancies, reference shall be made to Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control'.

19 HEAT INSULATION

For calculation of solar radiation on buildings and recommended limits of thermal transmittance of roofs and walls for different parts of the country and heat transmission losses due to different constructions, reference may be made to good practice [3(2)].

20 INSTALLATION OF LIFTS AND ESCALATORS

Provision for lifts shall be made for buildings 15 m or more in height. For requirements regarding planning, designing and installation, etc of lifts and escalators, reference shall be made to Part 8 'Building Services, Section 5 Installation of Lifts and Escalators'.

21 PLUMBING SERVICES AND SOLID WASTE MANAGEMENT

For requirements regarding water supply, drainage and sanitation (including solid waste management) and gas supply, reference shall be made to Part 9 'Plumbing Services'.

ANNEX A

(*Clause* 9.5.1)

CIVIL AVIATION REQUIREMENTS FOR CONSTRUCTION IN THE VICINITY OF AN AERODROME

A-0 GENERAL

A-0.1 For the purpose of this Annex, the following definitions shall apply.

A-0.1.1 *Aerodrome Reference Point (ARP)* — This is a designated point, which is established in the horizontal plane at or near the geometric centre of the landing area.

A-0.1.2 *Approach Funnel* — *See* Fig. 8.

A-0.1.3 *Elevation or Reduced Level* — The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from the mean sea level.

A-0.1.4 *Transitional Area* — An area which is below a specified surface sloping upwards and outwards from the edge of the approach funnel and from a line originating at the end of the inner edge of each approach area, drawn parallel to the runway centre line in the direction of landing (*see* Fig. 8).

A-0.1.5 *Runway Strip* — *See* Fig. 8.

A-1 PROHIBITED AREA

A-1.1 No building or structure shall be constructed or erected, or no tree shall be planted, on any land within the limits specified in **A-1.2** and **A-1.3** in respect of the aerodromes listed in **A-3** and in respect of the aerodrome at Thiruvananthapuram.

A-1.2 For the Aerodromes (*see* A-3)

These requirements shall be applicable for the land enclosed in approach funnels of the runway with a maximum distance of 360 m measured from each runway and along the extended centre line of the runway. For the purpose of this clause, the requirements of approach funnel and an instrument runway shall be as given in **A-1.2.1** to **A-1.2.3**.

A-1.2.1 Approach funnel in the case of an instrument runway means the area in the shape of an isosceles trapezium having the longer parallel side 4 800 m long (2 400 m on either side of the extended centre line of the runway) and smaller parallel side 300 m long (150 m on either side of the extended centre line of the runway) where the smaller and longer parallel sides are placed at a distance of 60 m and 15 060 m, respectively, from the end of the runway and at right angles to the extended centre line.

A-1.2.2 In the case of a non-instrument runway, the approach funnel means the area in the shape of an isosceles trapezium having the longer parallel side 1 800 m long (900 m on either side of the extended centre line of the runway) and smaller parallel side 180 m long (90 m on either side of the extended centre line of the runway), where the smaller and longer parallel sides are placed at a distance of 60 m and 6 540 m, respectively, from the end of the runway and at right angles to the extended centre line. Thereafter, the trapezium is followed by a contiguous rectangular area of that width for the remainder of the length up to a distance of 15 060 m from the end of the runway.

A-1.2.3 An instrument runway is a runway served by visual and non-visual aid or aids providing at least directional guidance adequate for a straight in approach and intended for the operation of aircraft using instrument approach procedures.

A-1.3 For the Aerodrome at Thiruvananthapuram

These requirements shall be applicable for the land enclosed in approach funnels of all runways with a maximum distance of 304.80 m, measured from each runway and along extended centre line of the runway, and the land enclosed in a belt of 30.48 m width outside the operational boundary of the aerodrome. For the purpose of this clause, the requirements of approach funnel and operational boundary shall be as given in **A-1.3.1** and **A-1.3.2**.

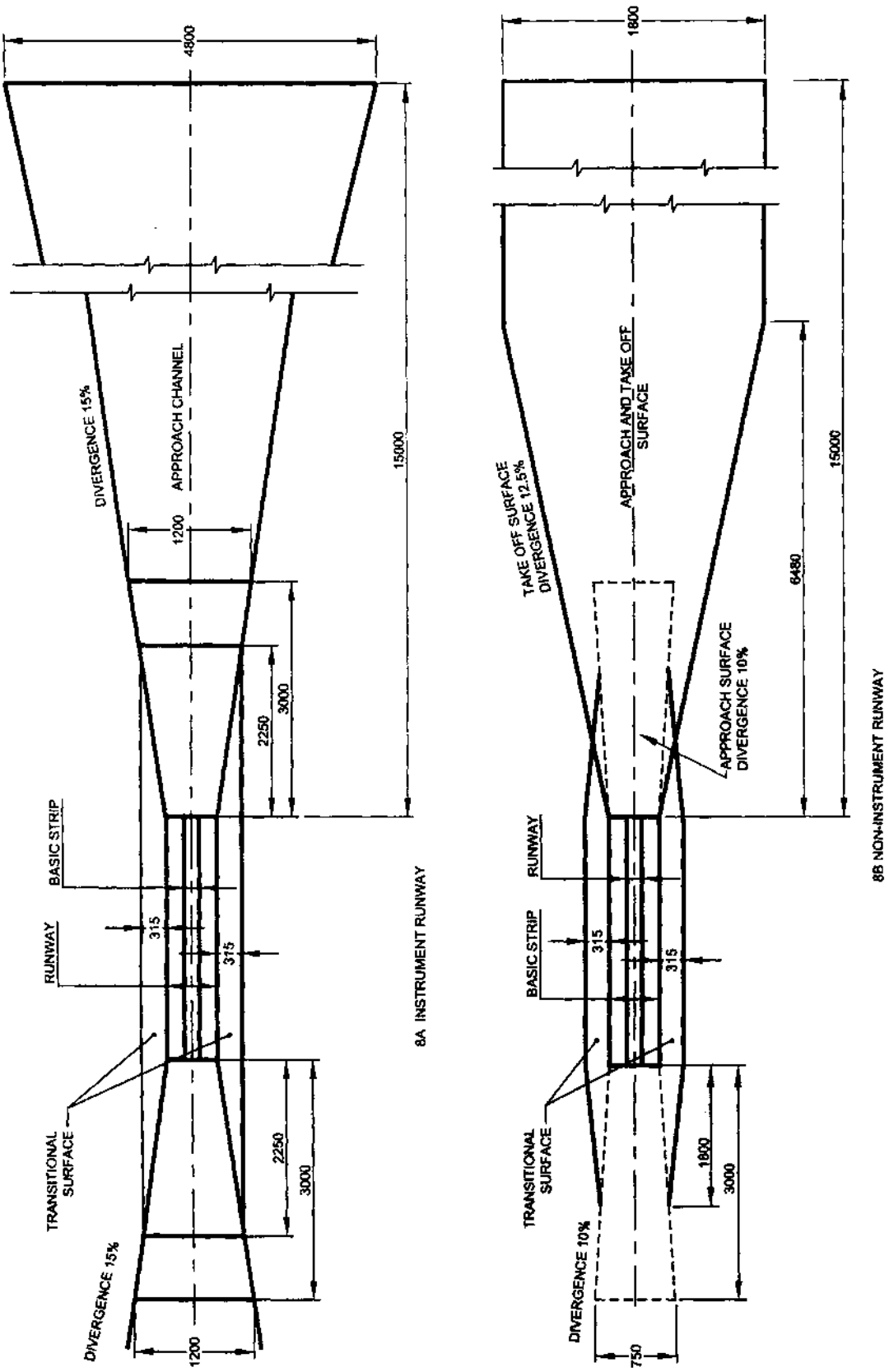
A-1.3.1 Approach funnel means the area in the shape of an isosceles trapezium having the longer parallel side of length 4 724.4 m (2 362.2 m on either side of the extended centre line of the runway) and smaller parallel side of 152.4 m (76.2 m on either side of the extended centre line of the runway) where the smaller and longer parallel sides are placed at a distance of 60.9 m and 15 301 m, respectively, from the end of the runway and at right angles to the extended centre line.

A-1.3.2 Operational boundary means an area enclosed between parallel lines at a distance of 152.4 m on either side of the centre line of the runways or 30.4 m from the boundary fencing of the aerodrome, whichever is greater.

A-2 HEIGHT RESTRICTION

A-2.1 For the Aerodromes (*see* A-3)

No building or structure higher than the height specified in Tables 5 and 6 shall be constructed or



All dimensions in metres.

FIG. 8 RUNWAY

erected, or no tree which is likely to grow or ordinarily grows higher than the height specified in the Tables 5 and 6, shall be planted, on any land within a radius of 20 km from ARP of the aerodromes listed in **A-3**, excluding the land covered by **A-1.2**.

Table 5 Height Restriction with Respect to Approach Funnels

(*Clauses* A-2.1 *and* A-2.1.1)

Sl No.	Area	Maximum Permissible Height Above the Elevation of the Nearest Runway End
(1)	(2)	(3)
i)	More than 360 m but not exceeding 510 m	6
ii)	More than 510 m but not exceeding 660 m	9
iii)	More than 660 m but not exceeding 810 m	12
iv)	More than 810 m but not exceeding 960 m	15
v)	More than 960 m but not exceeding 1 110 m	18
vi)	More than 1 110 m but not exceeding 1 260 m	21
vii)	More than 1 260 m but not exceeding 1 410 m	24
viii)	More than 1 410 m but not exceeding 1 560 m	27
ix)	More than 1 560 m	30

A-2.1.1 Table 5 gives the height restriction with respect to approach funnels and shall be applicable for the land enclosed in the approach funnels of all runways where distances are measured from each end of the runway, along extended centre line of the runway.

A-2.1.2 Table 6 gives height restriction with respect to transitional area and shall be applicable for the land enclosed in the transitional area of all runways at an aerodrome listed in **A-3** where distances are measured from the associated runway strip and the edge of the associated approach funnels, forming the inner boundary of the transitional area and along a line at right angles to the centre line of the runway.

A-2.2 For the Aerodrome at Thiruvananthapuram

No building or structure higher than the height specified in Table 7 shall be constructed or erected, or no tree which is likely to grow or ordinarily grows higher than the height specified in Table 7, shall be planted, on any level within a radius of 20 km from ARP of the aerodrome at Thiruvananthapuram, excluding the land covered by **A-1.3**.

Table 6 Height Restriction with Respect to Transitional Area

(*Clauses* A-2.1 *and* A-2.1.2)

Sl No.	Distance from the Inner Boundary of the Transitional Area Specified Above	Maximum Permissible Height Above the Elevation of the ARP
(1)	(2)	(3)
i)	Up to a distance of 21 m	—
ii)	More than 21 m but not exceeding 42 m	3
iii)	More than 42 m but not exceeding 63 m	6
iv)	More than 63 m but not exceeding 84 m	9
v)	More than 84 m but not exceeding 105 m	12
vi)	More than 105 m but not exceeding 126 m	15
vii)	More than 126 m but not exceeding 147 m	18
viii)	More than 147 m but not exceeding 168 m	21
ix)	More than 168 m but not exceeding 189 m	24
x)	More than 189 m but not exceeding 210 m	27
xi)	More than 210 m	30

Table 7 Height Restriction

(*Clause* A-2.2)

Sl No.	Area	Maximum Permissible Height Above Ground Level
(1)	(2)	(3)
i)	The area lying between the coastline and the Chakai canal other than specified in **A-1.3**	3
ii)	The area lying in a belt of 457.2 m width between the Eastern Bank of the Chakai canal and a line running parallel to this canal for the entire length	6
iii)	A parallel belt of 762 m width running East of area (ii) above	15.2
iv)	A parallel belt of 609.6 m width running East of area (iii) above	24.3
v)	Rest of the area extending up to 20 km from ARP	30.4

A-3 AERODROMES

A-3.1 A list of aerodromes indicating runway directions, runway elevations and ARP elevations is given in Table 8.

Table 8 Runway Directions, Runway End Elevations and ARP Elevations for Aerodromes

(*Clause* A-3.1)

Sl No.	Aerodrome	ARP Elevation m	Runway No.	Runway End Elevation
(1)	(2)	(3)	(4)	(5)
1.	Ahmadabad	55	14	54
			32	56
			05	54
			23	56
2.	Agartala	14	05	12
			23	14.5
			18	13.5
			36	13.5
3.	Akola	305	10	303
			28	303
4.	Amritsar	229	07	229
			25	230
			16	230
			34	229
5.	Aurangabad	581	09	582
			27	573.5
6.	Belgaum	758	08	755
			26	747
7.	Balurghat	24	09	24
			27	23
8.	Bangalore	888	09R	875
			27L	881
			09L	876
			27R	882.5
9.	Vadodara	37	04	36.5
			22	37.5
			09	36.5
			27	38.7
10.	Behala	2.6	18	3.5
			36	3.5
11.	Bhavnagar	5.4	07	11
			25	6
12.	Bhopal	523	06	522.5
			24	521
			12	521.5
			30	523
13.	Bhubaneshwar	44.5	05	33
			23	41.5
			14	38
			32	37
14.	Bhuj	78.5	05	81.5
			23	74.5
			11	79
			29	77.5
15.	Bilaspur	274	06	270
			24	282
			17	276
			35	269
16.	Chakulia	129	08	135
			26	132
			17	130
			38	27
17.	Chennai	10.5	07	12
			25	15.5
			12	9
			30	13
18.	Coimbatore	396	05	402
			23	391
19.	Cooch-Behar	41.5	04	41.5
			22	41.5
20.	Delhi (Palam)	227	10	219
			28	236.5
			09	220
			27	229
21.	Delhi (Safdarjung)	212	12	215
			30	212
22.	Dibrugarh	109.5	05	109
			23	109.5
23.	Gauhati	48	03	49
			21	48
24.	Gaya	110	10	108
			28	115.5
			01	109
			19	111
25.	Hyderabad	531	09	530
			27	522
			14	531
			32	528
26.	Indore	561	07	563.5
			25	559.5
27.	Jabalpur	495	06	480
			24	494.5
28.	Jaipur	385	15	389.5
			33	384.4
			09	383.7
			27	381.3
29.	Jhansi	236	15	236.5
			33	236.5
30.	Jharsuguda	228	06	228.20
			24	229.14
31.	Kailashadar	27.5	03	28.5
			21	27.5
32.	Kamalpur	39	01	45
			19	41
33.	Kandla	29	05	29
			23	29
34.	Kanpur	125	10	125
			28	124.5
35.	Keshod	49.5	05	50.5
			23	50.5
			18	50
			36	52
36.	Khajuraho	217.4	01	222
			19	210
37.	Kolhapur	607	07	609.6
			25	605.6
38.	Kolkata	5.3	01L	4.8
			19R	5
			01R	5
			19L	4.5

Table 8 — *Continued*

(1)	(2)	(3)	(4)	(5)
39.	Kota	273	08	272
			26	272
40.	Kulu	1084	16	1089
			34	1088
41.	Khowai	29	18	26
			36	27
42.	Lalitpur	367	10	368.5
			28	363
43.	Lilabari	100.2	04	101.5
			22	101.5
44.	Lucknow	122	09	122
			27	122
			01	122
			19	123
45.	Madurai	136.30	09	140
			27	130
			13	138.5
			31	136
46.	Malda	24	11	24
			29	23.5
47.	Mangalore	102	09	97
			27	89
48.	Mumbai (Juhu)	3	08	5
			26	2.5
			04	2.5
			22	2.5
			16	2.5
			34	2.5
49.	Mumbai (Santacruz)	8	09	4
			27	10
			14	11
			32	7.5
50.	Muzaffarpur	53	11	53
			29	53
51.	Mysore	715.5	05	720
			23	710
			09	717.5
			27	708
52.	Nagpur	308.5	09	309
			27	301
			14	315
			32	307
53.	Panagarh	73	15	71
			33	73
54.	Panna	425	17	435.80
			35	410.35
55.	Passighat	155.5	17	156.5
			35	153
56.	Patna	51	07	52
			25	52

Table 8 — *Concluded*

(1)	(2)	(3)	(4)	(5)
57.	Pantnagar	233	10	234
			28	234
58.	Porbandar	5	09	6.7
			27	4.5
59.	Port Blair	6	04	3.66
			22	17.8
60.	Raipur	313.6	06	309
			24	316
61.	Rajahmundry	45	05	34
			23	46
62.	Rajkot	134	05	133
			23	128.5
			14	130
			32	133.5
63.	Ranchi	646	13	654
			31	632.5
64.	Satna	319	11	316.5
			29	316
65.	Sholapur	418	15	478.5
			33	478
66.	Silchar	102	06	98.5
			24	107.5
67.	Tanjore	76	14	77
			32	70.5
			07	76.5
			25	74.5
68.	Tiruchchirappalli	85	15	84
			33	85
			09	88
			27	84
69.	Tirupati	103	08	106.4
			26	102
70.	Tulihal (Imphal)	774.5	04	773.5
			22	775
71.	Udaipur	509	08	511.5
			26	508
72.	Varanasi	80	09	80
			27	80
73.	Vijayawada	21	08	25
			26	21.5
74.	Vishakhapatnam	3	05	4
			23	2
			09	4
			27	2
			18	4
			36	4
75.	Warangal	285	15	290
			33	276.5
			09	289
			27	280.5

ANNEX B

(*Clause* 10.1)

OFF-STREET PARKING SPACES

The off-street parking spaces shall be as given below:

Sl No.	*Occupancy*	*One Car Parking Space for Every*				
		Population less than 50 000	Population 50 000 to 200 000	Population Between 200 000 to 1 000 000	Population Between 1 000 000 to 5 000 000	Population Above 5 000 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Residential	—	—	a) 2 tenements having built-up area 101 to 200 m^2	1 tenement of 100 m^2 built-up area	1 tenement of 75 m^2 built-up area
	a) Multi-family	—	—	b) 1 tenement of 200 m^2 built-up area		
	b) Lodging establishments, tourist homes and hotels, with lodging accommodation	12 guest rooms	8 guest rooms	4 guest rooms	3 guest rooms	2 guest rooms
ii)	Educational (*see* Note 1)	—	—	70 m^2 area or fraction thereof of the administrative office area and public service areas	50 m^2 area or fraction thereof of the administrative office area and public service areas	35 m^2 area or fraction thereof of the administrative office area and public service areas
iii)	Institutional (Medical)	20 beds (Private)	15 beds (Private)	10 beds (Private)	5 beds (Private)	2 beds (Private)
		30 beds (Public)	25 beds (Public)	15 beds (Public)	10 beds (Public)	5 beds (Public)
iv)	a) Assembly halls, cinema theatres	120 seats	80 seats	25 seats	15 seats	10 seats
	b) Restaurants	60 seats	40 seats	20 seats	10 seats	5 seats
	c) Marriage halls, community halls	600 m^2 plot area	400 m^2 plot area	200 m^2 plot area	50 m^2 plot area	25 m^2 plot area
	d) Stadia and exhibition centre	240 seats	160 seats	50 seats	30 seats	20 seats
v)	a) Business offices and firms for private business	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof	25 m^2 area or fraction thereof
	b) Public or semi-public offices	500 m^2 area or fraction thereof	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof

(1)	(2)	(3)	(4)	(5)	(6)	(7)
vi)	Mercantile (*see* Note 2)	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof	25 m^2 area or fraction thereof
vii)	Industrial	400 m^2 area or fraction thereof	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof
viii)	Storage	—	—	500 m^2 floor area or part thereof	250 m^2 area or fraction thereof	125 m^2 area or fraction thereof

NOTES

1 In the case of auditoria for educational buildings, parking space shall be provided as per Sl No. (iv)

2 For plots up to 50 m^2, as in the case of shops, parking spaces need not be insisted upon.

3 For other institutions, transport/communication centre, parking space requirement shall be assessed based on the proposed building.

ANNEX C

(*Clause* 12.20)

SPECIAL REQUIREMENTS FOR LOW INCOME HOUSING IN URBAN AREAS

C-1 GENERAL

C-1.1 These guidelines cover the planning and general building requirements of low income housing for houses having a maximum plinth area of 40 m^2 including future expansion. The requirement regarding layout planning of low income housing colonies are applicable to public and private agencies/ government bodies. The requirements on design and construction of buildings for low income housing in approved layouts are applicable to all private and public agencies.

C-1.2 In these planning standards, the general master plan requirement for community open spaces estimated at 0.3 ha for thousand persons is provided; road areas are worked out between 10 and 20 percent of the site area; one nursery school of 0.1 ha is provided for a population of 1 500 and shopping centres at 4 shops per thousand population are also covered.

C-1.3 It is emphasized that this type of development should apply to clusters of 400 dwelling units, so distributed in the development under consideration as to maintain the overall densities of the master plan for the area.

C-2 PLANNING

C-2.1 Type of Development

The type of development for low income housing shall be plotted developments as row housing/flatted development as row housing or group housing on cluster pattern.

C-2.2 Layout Pattern

C-2.2.1 In the land to be developed, at least 75 percent of the plots may be of the size less than or up to 60 m^2 per dwelling unit in metropolitan towns and 100 m^2 in other towns and hill areas. Remaining 25 percent of the plots may be more than 60 m^2, however, no plot shall be more than 200 m^2. In case of group housing or flatted development at least 75 percent units should have a plinth area (excluding external circulation such as stairs, lifts, lobbies, etc) up to or not exceeding 40 m^2 including future expansion.

C-2.2.2 The mix of plot of different sizes should have a wide range to accommodate the need of lower income group. The project may include more than one site provided they are in the same neighbourhood.

C-2.2.3 The layout should generally conform to the following land use:

	Land Under Each Use	
	General	Hill Area
Saleable		
i) Residential	50 percent, *Min*	35 percent
ii) Work places, schools, institutions, shops, community places, etc	20 percent, *Max*	15 percent
Non-Saleable		
Roads, pedestrian paths, drains, public and semi-public open spaces	30 percent, *Max*	50 percent

NOTES

1 Any neighbourhood development should have provision for

basic civic and community facilities, however, where such facilities are available in proximity the same could be considered and, in that case, the area under residential use could be increased correspondingly.

2 If land required under statutory provisions of master plan/ development plan is proportionately higher but serves larger city needs, re-adjustment of the recommended land use pattern can be considered. Such provisions should, however, be carefully reviewed by the planning authorities to keep them to the barest minimum levels.

C-2.3 Plot Area

C-2.3.1 *Plot Size*

The minimum plot size with ground coverage not exceeding 75 percent, shall not be less than 40 m^2 in small and medium town and not less than 30 m^2 in metropolitan cities. Plot sizes below 30 m^2 but not less than 15 m^2 may be permitted in case of cluster planning, however, in such cases the ground coverage and FSI shall be 100 percent and 2 percent respectively (*see also* Annex E for Special requirements for cluster planning for housing).

NOTES

1 In exceptional cases in metropolitan cities with population more than 1 million the size of plots may be brought down to 25 m^2 in cases of low income housing colonies located in congested areas as decided by the Authority. In mega-cities it may be further reduced to 15 m^2. In such cases where plot size is below 25 m^2, only cluster planning or group housing may be adopted.

2 A minimum of 25 percent of the plot size shall be left open without adversely affecting light and ventilation for habitable spaces and toilet. It shall not be made mandatory to leave set back on any side.

C-2.3.2 *Minimum Frontage*

The minimum frontage of the plot shall be 3.6 m in width.

C-2.4 Density

The density norms for plotted development and mixed development shall be as follows:

Type of Development	*Range of Densities (Gross)*
a) Plotted development	65-120 plots per hectare
b) Mixed development	
i) Small towns	75-100 dwelling units per hectare
ii) Cities	100-125 dwelling units per hectare
iii) Metropolitan Cities	125-150 dwelling units per hectare

C-2.4.2 In case of developments with per dwelling unit covered area of 15 m^2 maximum densities of 500 dwelling units per hectare shall be permissible.

C-2.5 Height of Building

The height of building shall not exceed 15 m.

NOTES

1 For buildings up to the height of 15 m, there is no need to provide lifts.

2 Housing for the low-income group shall preferably be up to a maximum of two storeys.

3 Buildings for housing beyond 15 m in height should be resorted to in exceptional circumstances and it should be governed by provisions laid down in this Code.

C-2.6 Cluster Planning

For size of open cluster and open space, set backs, vehicular access and pedestrian paths in cluster planning, the provisions given in Annex E shall apply.

C-3 GENERAL BUILDING REQUIREMENTS

C-3.1 General

The requirements of parts of buildings shall be as given in **C-3.2** to **C-3.9**.

C-3.2 Plinth

The minimum height of plinth shall be regulated on the basis of environmental and topographical condition and higher plinth height may be required in areas prone to flooding.

C-3.3 Size of Room

C-3.3.1 *Habitable Room*

Every dwelling unit to be provided should have at least two habitable rooms. Even if one room house is provided initially it should be capable of adding a new second room in future. However, in case single room tenements are required to be provided where future additions are not possible, the carpet area of multipurpose single room should be at least 12.5 m^2. Such one room dwelling units with 12.5 m^2 carpet area of habitable space is permitted only in case of on site rehabilitation of slum dwellers. In a house of two rooms, first room shall not be less than 9.0 m^2 with minimum width of 2.5 m and second room shall not be less than 6.5 m^2 with a minimum width of 2.1 m provided the total area of both the rooms is not less than 15.5 m^2. In incremental housing the bigger room shall always be the first room.

C-3.3.1.1 To facilitate incremental housing in case of flatted development or otherwise, habitable space at mezzanine level may be permitted. The minimum size of such a mezzanine floor should not be lesser than 6.5 m^2 and such a floor should occupy not more than 50 percent of the room area of which it is a part. Such a mezzanine floor should have appropriate openings to facilitate light and ventilation as per **C-3.6**. Minimum

clear height below and above the mezzanine floor should be 2.4 m and 2.1 m respectively.

As far as possible mezzanine floor should have direct ventilation from the external face of the building. Where this is not possible ventilation through main room may be allowed provided total area of openings in the main room is provided taking into consideration area of mezzanine floor.

Such mezzanine floor may be accessible through the main room by a ladder, whose minimum angle with vertical plane should be 22½°. Height of the riser should be less than 250 mm.

C-3.3.2 *Water Closet/Bathroom*

1) The size of independent water-closet shall be 0.90 m^2 with minimum width of 0.9 m;
2) The size of independent bathroom shall be 1.20 m^2 with a minimum width of 1.0 m; and
3) The size of combined bathroom and water-closet shall be 1.80 m^2 with minimum width of 1.0 m.

C-3.3.3 *Kitchen*

The size of a cooking alcove serving as cooking space shall not be less than 2.4 m^2 with a minimum width of 1.2 m. The size of individual kitchen provided in a two-roomed house shall not be less than 3.3 m^2 with a minimum width of 1.5 m.

C-3.3.4 *Balcony*

The minimum width of individual balcony, where provided, shall be 0.9 m and shall not be more than 1.2 m and it shall not project beyond the plot line and on roads or pathway.

C-3.4 Basement

No basement floor shall be allowed.

C-3.5 Minimum Height

The minimum height of rooms/spaces shall be as follows:

a)	Habitable room	2.6 m
b)	Kitchen	2.6 m
c)	Bath/water-closet	2.1 m
d)	Corridor	2.1 m

C-3.5.1 In the case of sloping roofs, the average height of roof for habitable rooms shall be 2.6 m and the minimum height at eaves shall be 2.0 m.

C-3.6 Lighting and Ventilation

The openings through windows, ventilators and other openings for lighting and ventilation shall be in accordance with **15.1.2**.

NOTE — The windows and other openings shall abut onto open spaces either through areas left open within the plot or the front, side and rear spaces provided in the layouts which shall be deemed to be sufficient for light and ventilation purposes. Wherever ventilation/lighting is provided by means of *JALI* or grill of any material, total area of openings shall calculated excluding solid portion of the *JALI* or grill.

C-3.7 Stairs

The following criteria shall be adopted for internal individual staircase:

a)	*Minimum Width*	
	1) 2 storeyed — straight	0.60 m
	2) 2 storeyed — winding	0.75 m
	3) 3 or more storeyed — straight	0.75 m
	4) 3 or more storeyed — winding	0.90 m
b)	*Riser*	200 mm, *Max*
c)	*Tread*	
	1) 2 storeyed	225 mm, *Min* *(see* Note*)*
	2) 3 storeyed or more	250 mm, *Min*
d)	*Head Room* — The minimum clear head room shall be 2.1 m.	

NOTE — This could be reduced to 200 mm as the clear tread between perpends, with possibility of open riser as well as nosing and inclined riser to have an effective tread of 225 mm.

C-3.8 Circulation Area

The circulation area on any floor including staircase, shall not exceed 8 m^2/dwelling unit.

C-3.9 Water Seal Latrine

No building plan shall be approved and no building shall be deemed to have been completed and fit for human occupation unless provision is made for water seal latrine. No dry latrine shall be allowed. Water seal latrines can also be provide on the basis of community toilets or shared toilets as per the recommendation given in good practice [3(3)].

Where leaching pits are used, it should be constructed within the premises of the households as it would be economical as well as facilitate their cleaning. However, where, due to space constraint, construction of pits within the premises may not be possible, pits may be constructed in places like lanes, streets and roads.

In case the pit is located under the road, street or foot path, the inverted level of the pipe connecting the latrine pan with the pit shall be at least 1.1 m below ground level or below the bottom of the water main existing within a distance of 3 m from the pits whichever is more. Construction of such pits may be in accordance with good practice [3(4)].

The water seal latrine should be properly maintained and kept in sanitary condition by the owner or the occupier. The contents of the septic tanks, soak pits, leach pits, etc should be periodically emptied.

The leach pits should be cleaned only after 2 years of their being put out of service after they were full.

C-4 ROADS AND PATHWAYS

The area under roads and pathways in such housing projects should normally not exceed 20 percent of the total land area of the project.

Access to the dwelling units, particularly where motorized vehicles are not normally expected should be by means of paved footpaths with a right of way of 6 m and a pathway of 2 m only. The right of way should be adequate to allow for the plying of emergency vehicles and also for road side drains and plantation.

Where pedestrian pathways are not meant for motorable access to the minimum, right of way of such pedestrian pathway shall be 3 m. Where houses are accessible from one side only pathway can be 2 m wide. The maximum length of such pathways should not be more than 60 m.

C-5 OTHER REQUIREMENTS

C-5.1 Requirements of fire safety, structural design, building services and plumbing services shall be as specified in the Code.

C-5.2 One water tap per dwelling unit may be provided, where adequate drinking water supply is available. If supply is inadequate, public hydrants shall be provided. In the absence of piped water supply, *hand pumps may be used for provision of water supply.*

C-5.3 Recognising the need for informal use of space for shopping and informal occupation like road side repairs, pan shops, etc, it is suggested that about ¼ of the total shopping area in a layout should be reserved for such informal uses to cater to the needs of low income families.

C-5.4 The infrastructural services shall be provided before the plots are handed over to individual owners.

C-6 SITE AND SERVICES SCHEMES

C-6.1 The developed plot sizes shall be as per **C-2.3.1**. Services would have to be laid by the Agency concerned as per the provisions of the Code. In so far as roads and pathways are concerned, they could also be in line with **C-4**.

C-6.2 Site and services schemes shall provide for the following.

a) Complete infrastructural needs for a permanent housing, on the periphery of individual plot or a group/cluster plots;
b) A service sanitary core in the plot;
c) A skeletal structure of columns and roof or a developed plinth; and
d) Permission to allow temporary construction on the plot.

While provisions in **C-6.2**(a) and **C-6.2**(d) are essential in site and services projects provisions, recommendations in **C-6.2**(b) and **C-6.2**(c) are additional provisions depending upon affordability.

ANNEX D

(*Clause* 12.21)

SPECIAL REQUIREMENTS FOR PLANNING OF PUBLIC BUILDINGS MEANT FOR USE OF PHYSICALLY CHALLENGED

D-1 GENERAL

D-1.1 These requirements apply to all buildings and facilities used by the public. These apply to temporary or emergency conditions as well as permanent conditions. It does not apply to private residences.

These requirements are concerned with non-ambulatory disabilities, semi-ambulatory disabilities, sight disabilities, hearing disabilities, disabilities of inco-ordination, aging, allergies, heart and lung diseases, epilepsy, haemophilia, incontinence and enterostomy.

It is intended to make all buildings and facilities used by the public accessible to, and functional for the physically challenged through and within their doors, without loss of function, space or facility where the general public is concerned. It supplements the general requirements of the Code, and reflects greater concern for safety of life and limb. In cases of practical difficulty, unnecessary hardship, or extreme differences, the Authority may grant exceptions from the literal requirements of this Annex or permit the use of other methods or materials, but only when it is clearly evident that equivalent facilities and protection are thereby secured.

D-1.2 For the purpose of this Annex, the following definitions shall apply.

D-1.2.1 *Aging*

Those manifestations of the aging processes that significantly reduce mobility, flexibility, co-ordination, and perceptiveness but are not accounted for in the categories mentioned in **D-1.2.3.1** to **D-1.2.3.9**.

D-1.2.2 *Appropriate Number*

The number of a specific item that would be necessary, in accordance with the purpose and function of building or facility, to accommodate individuals with specific disabilities in proportion to the anticipated number or individuals with disabilities who would use a particular building or facility.

D-1.2.3 *Disabilities*

D-1.2.3.1 *Non-ambulatory disabilities*

Impairments that, regardless of cause or manifestation, for all practical purposes, confine individuals to wheelchairs.

D-1.2.3.2 *Semi-ambulatory disabilities*

Impairments that cause individuals to walk with difficulty or insecurity. Individuals using braces or crutches, amputees, arthritis, spastics and those with pulmonary and cardiac ills may be semi-ambulatory.

D-1.2.3.3 *Sight disabilities*

Total blindness or impairments affecting sight to the extent that the individual functioning in public areas is insecure or exposed to danger.

D-1.2.3.4 *Hearing disabilities*

Deafness or hearing handicaps that might make an individual insecure in public areas because he is unable to communicate or hear warning signals.

D-1.2.3.5 *Disabilities of inco-ordination*

Faulty co-ordination or palsy from brain spinal, or peripheral nerve injury.

D-1.2.3.6 *People with allergies*

People with allergies may be sensitive to dust, mildew, pollen, animal hair, formalin, turpentine, etc. Some are sensitive to contact with substances and materials, such as, nickel, chromium and rubber.

D-1.2.3.7 *People with heart and lung diseases*

People with heart and lung diseases may only be able to walk short distances and may be unable to climb stairs. The requirements of these people are similar to those with impaired mobility.

D-1.2.3.8 *People with epilepsy, haemophilia, etc*

The requirements of those with epilepsy, heamophilia, etc, are related primarily to the design of buildings and the need to minimize the risk of injury caused by falling or encountering obstacles.

D-1.2.3.9 *People with incontinence, enterostomy operations, etc*

The requirements of people with incontinence, enterostomy operations, etc (colostomies, ileostomies and urostomies) are mainly related to bathroom provision. In certain circumstances, for example, in public water-closet compartments, it may be desirable to provide a special sink for emptying urine bags.

D-1.2.4 *Fixed Turning Radius, Front Structure to Rear Structure*

The turning radius of a wheelchair, left front-foot platform to right rear wheel, or right front-foot platform to left rear wheel, when pivoting on a spot.

D-1.2.5 *Fixed Turning Radius Wheel*

The tracking of the caster wheels and large wheels of a wheelchair when pivoting on a spot.

D-1.2.6 *Involved (Involvement)*

A portion or portions of the human anatomy or physiology, or both, that have a loss or impairment of normal function as a result of genesis, trauma, disease, inflammation or degeneration.

D-1.2.7 *Ramps, Ramps with Gradients*

Because the term 'ramp' has a multitude of meanings and uses, its use in this text is clearly defined as ramps with gradients (gradual slope joining two level surfaces) that deviate from what would otherwise be considered the normal level. An exterior ramp, as distinguished from a 'walk', would be considered an appendage to a building leading to a level above or below the existing ground level.

D-1.2.8 *Walk, Walks*

Because the terms 'walk' and 'walks' have a multitude of meanings and uses, their use in this standard is clearly defined as a predetermined prepared surface, exterior pathway leading to or from a building or facility, or from one exterior area to another, placed on the existing ground level and not deviating from the level of the existing ground immediately adjacent.

D-2 SITE DEVELOPMENT

D-2.1 Almost any building can be made accessible to physically challenged persons by so planning the site that the terraces, retaining walls and winding walks are used effectively.

D-2.1.1 Site development is the most effective means to resolve the problems created by topography, definitive architectural designs or concepts, water table, existing streets, and typical problems, singularly or collectively, so that aggress, ingress and egress to buildings by physically challenged may be facilitated while preserving the desired design and effect of the architecture.

D-2.2 Walks

D-2.2.1 Public walks should be at least 1 200 mm wide and should have a gradient not greater than 1 in 20.

D-2.2.1.1 It is essential that the gradient of walks and driveways be less than that prescribed for ramps, since walks would be devoid of handrails and kerbs and would be considerably longer and more vulnerable to the elements. Walks of near maximum grade and considerable length should have level areas at intervals for purposes of rest and safety. Walks or driveways should have a non-slip surface.

D-2.2.2 Such walks shall be of a continuing common surface not interrupted by steps or abrupt changes in level.

D-2.2.3 Wherever walks cross other walks, driveways, or parking lots they should blend to a common level.

D-2.2.3.1 This requirement, does not require the elimination of kerbs, which, particularly if they occur at regular intersections, are a distinct safety feature for all of the challenged, particularly the blind. The preferred method of meeting the requirement is to have the walk incline to the level of the street. However, at principal intersections, it is vitally important that the kerbs run parallel to the street, up to the point where the walk is inclined, at which point the kerb would turn in and gradually meet the level of the walk at its highest point. A less preferred method would be to gradually bring the surface of the driveway or street to the level of the walk. The disadvantage of this method is that a blind person would not know when he has left the protection of a walk and has entered the hazards of a street or driveway (*see* Fig. 9).

D-2.2.4 A walk shall have a level platform at the top which is at least 1 500 mm long, if a door swings out onto the platform or towards the walk. This platform shall extend at least 300 mm beyond each side of the doorway.

D-2.2.5 A walk shall have a level platform at least 900 mm deep, if the door does not swing onto the platform or towards the walk. This platform shall extend at least 300 mm beyond each side of the doorway.

D-2.3 Parking Space

D-2.3.1 Spaces that are accessible and approximate to the facility should be set aside and identified for use by individuals with physical disabilities.

D-2.3.2 A parking space open on one side, allowing room for individuals in wheelchairs or individuals on braces and crutches to get in and out of an automobile onto a level surface, is adequate. It should have a minimum width of 2 700 mm preferably 2 800 mm for ambulant disabled and minimum 3 000 mm preferably 3 300 mm for wheel chair users.

D-2.3.3 Parking spaces for individuals with physical disabilities when placed between two conventional diagonal or head-on parking spaces should be 3.6 m to 3.8 m wide and the length of the aisle should 7.3 m, 6.1 m and 6.5 m for head-on, 90° and 60° parking respectively.

D-2.3.4 Care in planning should be exercised, so that individuals in wheelchairs and individuals using braces and crutches are not compelled to wheel or walk behind parked cars.

D-2.3.5 Consideration should be given to the distribution of spaces for use by the disabled in accordance with the frequency and persistency of parking needs.

D-2.3.6 Walks shall be in conformity with **D-2.2.**

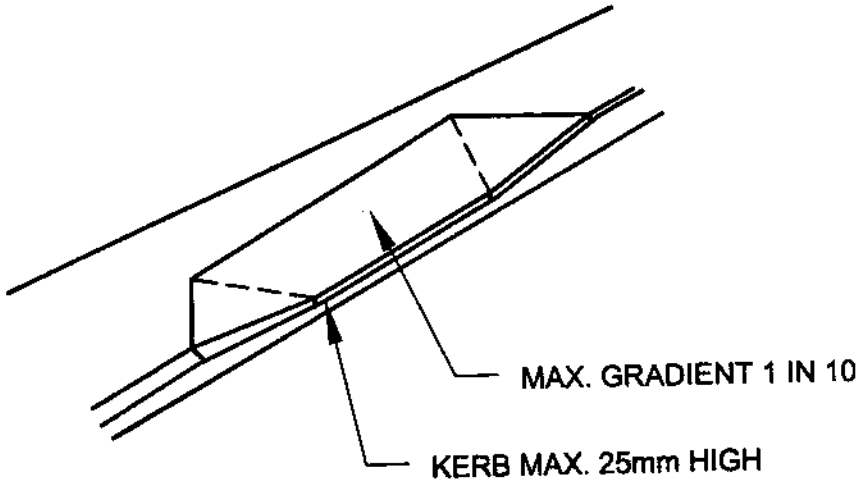


FIG. 9 SUITABLE METHOD OF BLENDING PAVEMENT AND ROADWAY SURFACES

D-3 BUILDINGS

D-3.1 Ramps with Gradients

Where ramps with gradients are necessary or desired, they shall conform to the following requirements (*see* Fig. 10).

D-3.1.1 A ramp when provided should not have a slope greater than 1 in 20 or maximum of 1 in 12 for short distance up to 9 000 mm.

D-3.1.2 A ramp shall have handrails on at least one side, and preferably two sides, that are 900 mm high, measured from the surface of the ramp, that are smooth, and that extend 300 mm beyond the top and bottom of the ramp. Where major traffic is predominantly children, the handrails should be placed 760 mm high.

NOTES

1 Where handrails are specified to be of heights other than 80 cm, it is recommended that two sets of handrails be installed to serve all people. Where major traffic is predominantly children, particularly physically disabled children, extra care should be exercised in the placement of handrails, in accordance with the nature of the facility and the age group or groups being serviced (*see also* **D-3**).

2 Care should be taken that the extension of the handrails is not in itself a hazard. Extension up to 300 mm may be made on the side of a continuing wall.

D-3.1.3 A ramp shall have a surface that is non-slip surface and if length is 3 500 mm, the minimum width shall be 1 500 mm.

D-3.1.3.1 The provision of non-slip surfaces on ramps greatly assists the challenged persons with semi-ambulatory and ambulatory disabilities. Non-slip surfaces are provided by many finishes and materials. The surfaces of the concrete ramps can be made non-skid by brooming the surface or by finishing with an indenting roller.

D-3.1.4 A ramp shall have a level platform at the top which is at least 1 800 mm long, if a door swings out onto the platform or toward the ramp. This platform shall extend at least 300 mm beyond each side of the doorway (*see* Fig. 11).

D-3.1.5 Each ramp shall have at least 1 800 mm of straight clearance at the bottom.

D-3.1.6 Ramps shall have level platforms at 10 m to 12 m intervals for purposes of rest and safety, and shall have platforms minimum 1.5 m length wherever they turn.

D-3.1.7 For visually impaired people, ramps may be colour contrasted with landing.

D-3.1.8 To minimize rise to wheelchair users, ramps should be equipped with herbs approximately 50 mm high at exposed sides.

D-3.2 Entrances

D-3.2.1 At least one primary entrance to each building shall be usable by individuals in wheelchairs (*see* Fig. 12A) and shall be indicated by a sign (*see* Fig. 12B).

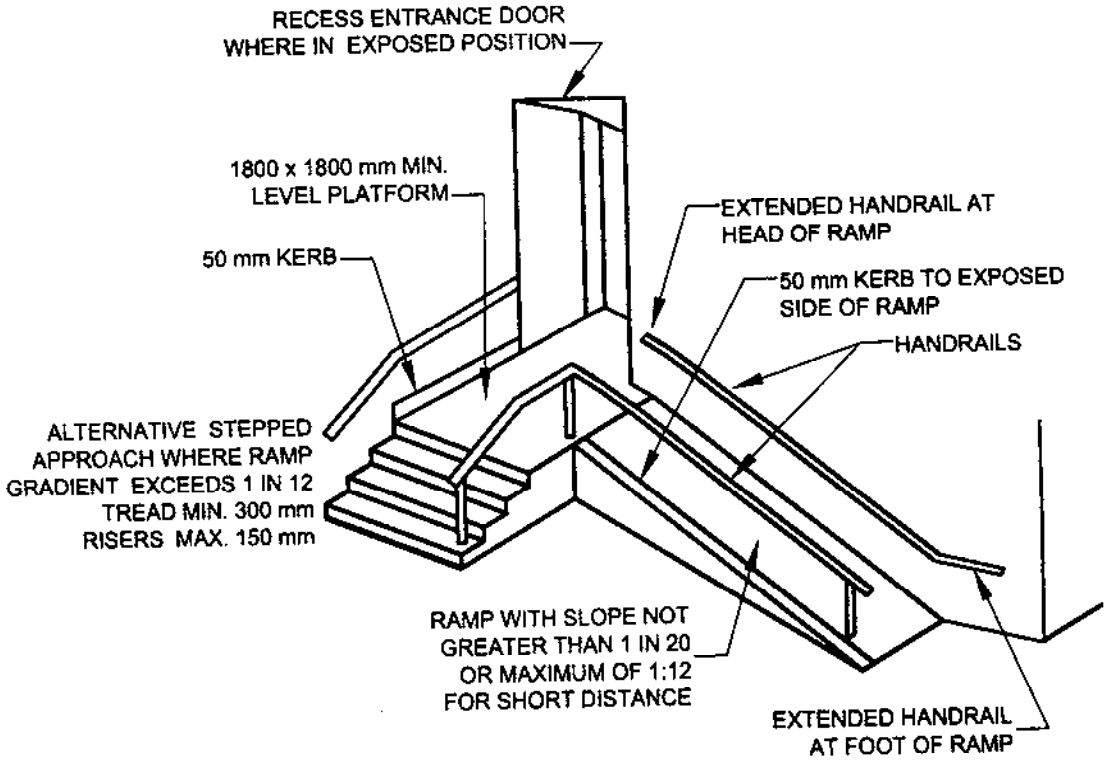
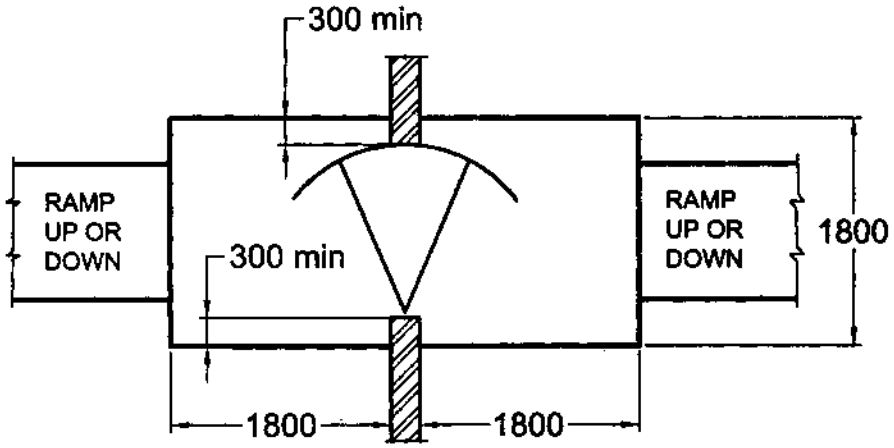
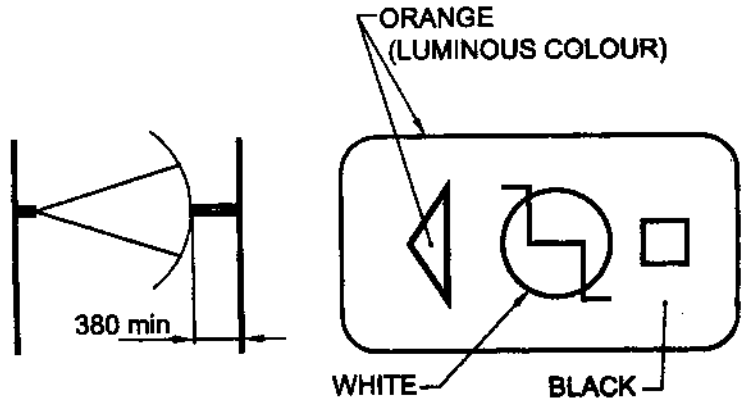


FIG. 10 EXAMPLE OF RAMPED APPROACH



All dimensions in millimetres.

FIG. 11 LEVEL AREAS REQUIRED AT END OF RAMPS LEADING TO DOORWAYS



12A PLAN OF DOORS SUITABLE FOR THE WHEELCHAIR BOUND

12B SIGN FOR USE AT THE ENTRANCE

FIG. 12 ENTRANCES

D-3.2.2 At least one entrance usable by individuals in wheelchairs shall be on a level that would make the elevators accessible.

D-3.3 Doors and Doorways

D-3.3.1 *Doorwidth*

To enable wheelchair users to pass through doors, the minimum clear width should be 900 mm and shall be operable by a single effort. In certain cases the clear width should be 900 mm to 1 000 mm; for example, if the wheelchair has to be turned in the doorway, where there is a door-closer or at entrance doors to public buildings and in other situations where there is considerable traffic.

D-3.3.1.1 Two-leaf doors are not usable by those with disabilities defined in **D-1.2.1, D-1.2.2** and **D-1.2.5** unless they operate by a single effort, or unless one of the two leaves meets the requirements of **D-3.3.1**.

D-3.3.1.2 *Side-hung doors*

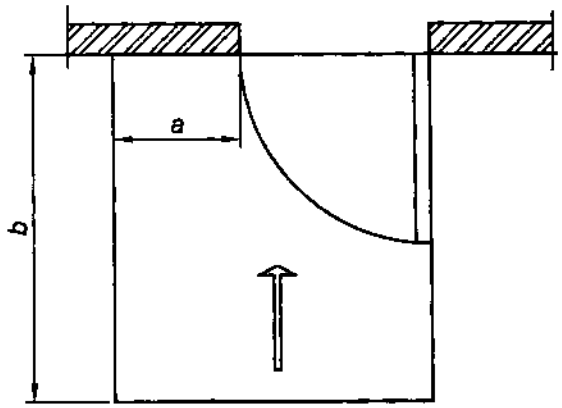
To facilitate wheelchair manoeuvre, doors should be hung with the hinges in room corners. Doors opening out into corridors or circulation spaces should be avoided as far as possible.

D-3.3.1.3 It is recommended that all doors have kick plates extending from the bottom of the door to at least 400 mm from the floor, or be made of a material and finish that would safely withstand the abuse they might

receive from canes, crutches, wheelchair foot-platforms, or wheelchair wheels.

D-3.3.2 *Wheelchair Manoeuvring Space*

To enable wheelchair users to approach doors manoeuvring space is needed as shown in the Fig. 13. A corridor should have a width of at least 1 200 mm to allow a 90° turn to be made through a door. In narrow spaces sliding doors may be preferable.



a	b
450	1500
550	1400

All dimensions in millimetres.

NOTE — Depending on the free space beside the opening side (450 or 550 mm), the depth of free space should be 1 500 or 1 400 mm.

FIG. 13 MANOEUVRING SPACE NEEDED FOR WHEELCHAIR USERS TO APPROACH DOORS

D-3.3.3 *Thresholds*

Raised thresholds should be avoided, but where this is not possible, their height should not exceed 25 mm. Rubber thresholds are advantageous for wheelchair users.

D-3.3.3.1 Care should be taken in the selection, placement and setting of door closers so that they do not prevent the use of doors by the physically disabled. Time-delay door closers are recommended.

D-3.3.3.2 *Self-closing doors*

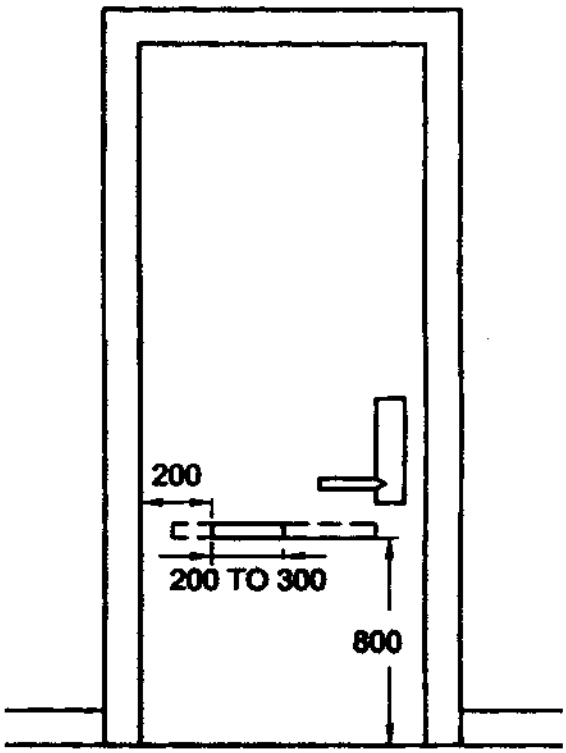
Wheelchair users and other with impaired mobility have difficulty in using self-closing doors. The force required to open them should be reduced as far as possible. Public buildings should preferably have sliding automatic doors.

D-3.3.4 *Door Indentification*

To help people with impaired vision to see doors, the door and frame should be in a colour which contrasts with the adjoining wall. Glass or glazed doors should be marked with a coloured band or frame, a little below eye-level.

D-3.3.5 *Handles*

Door handles and locks should be easy to manipulate. To facilitate the closing of a door by wheelchair users (for example, a water-closet compartment), the door should have a horizontal handle approximately 800 mm from the floor. Self-closing doors should be equipped with an easy gripped vertical pull-handle with a length of at least 300 mm, and with the lower end approximately 800 mm above floor. For many people and specially those with impaired vision, it is helpful to make clear whether doors are to be pulled or pushed (*see* Fig. 14).

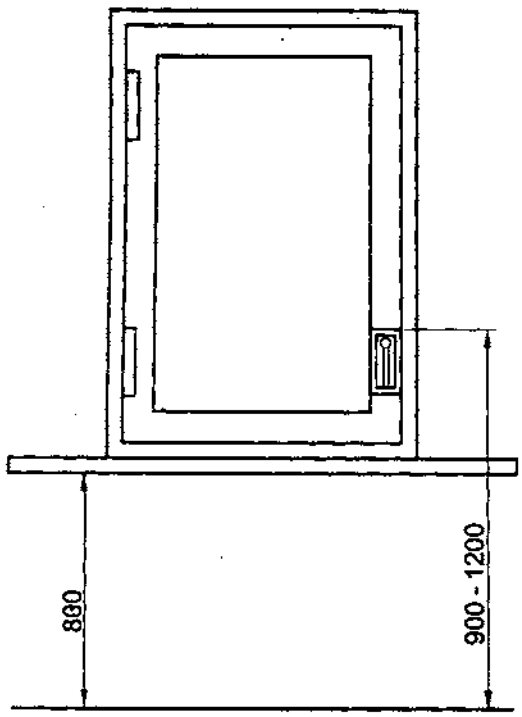


All dimensions in millimetres.

FIG. 14 POSITION OF HANDLE

D-3.4 Windows

Windows should be designed to avoid the glare which is a particular problem for people with impaired vision. Large glass areas close to circulation spaces should be marked a little below eye-level with a coloured band or frame. To enable wheelchair users to see through a window comfortably, the sill should be not higher than 800 mm from the floor. Windows should be easy to open and close. Their controls should be placed in the zone 900 to 1 200 mm from the floor (*see* Fig. 15).



All dimensions in millimetres.

FIG. 15 POSITION OF SILL AND WINDOW CONTROL

D-3.5 Stairs

Stairs should not be the only means of moving between floors. They should be supplemented by lifts or ramps.

D-3.5.1 Straight flights of steps are preferred by ambulant disabled people. Treads should be approximately 300 mm deep and risers not higher than 150 mm. Steps should be of a consistent height and depth throughout the stair. Projecting nosings and open stairs should be avoided to minimize the risk of stumbling.

D-3.5.2 Handrails should be provided to both sides of any stairway. They should be continuous and extend not less than 300 mm beyond the top and bottom step (otherwise it is difficult for the disabled to use the rail at the first and last step; *see* Fig. 16).

D-3.5.3 For people with impaired vision, there should be a colour contrast between landings, and top and bottom steps of a flight of steps, or the front edge of each step should have a contrasting colour.

D-3.6 Floors

D-3.6.1 Floors shall have a non-slip surface.

D-3.6.2 Floors on a given storey shall be of a common level through out or be connected by a ramp in accordance with **D-3.1.1** to **D-3.1.8**.

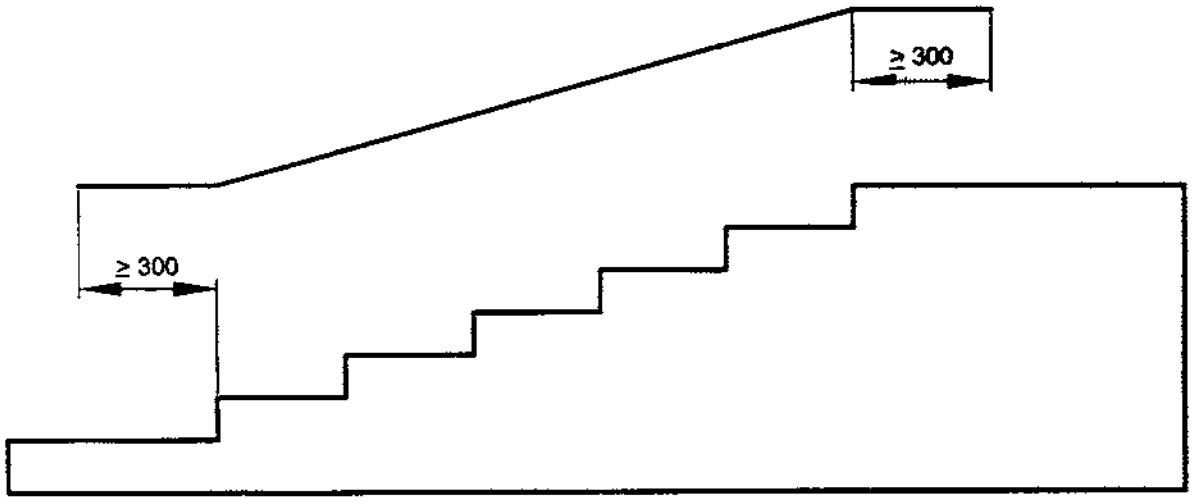
D-3.6.2.1 A gentle slope up to 10 mm may be given between the level of the floor of the corridor and the level of the floor of the toilet rooms.

D-3.6.2.2 There should not be a difference between the level of the floor of a corridor and the level of a meeting room, dining room, or any other room, unless proper ramps are provided.

D-3.7 Sanitary Facilities

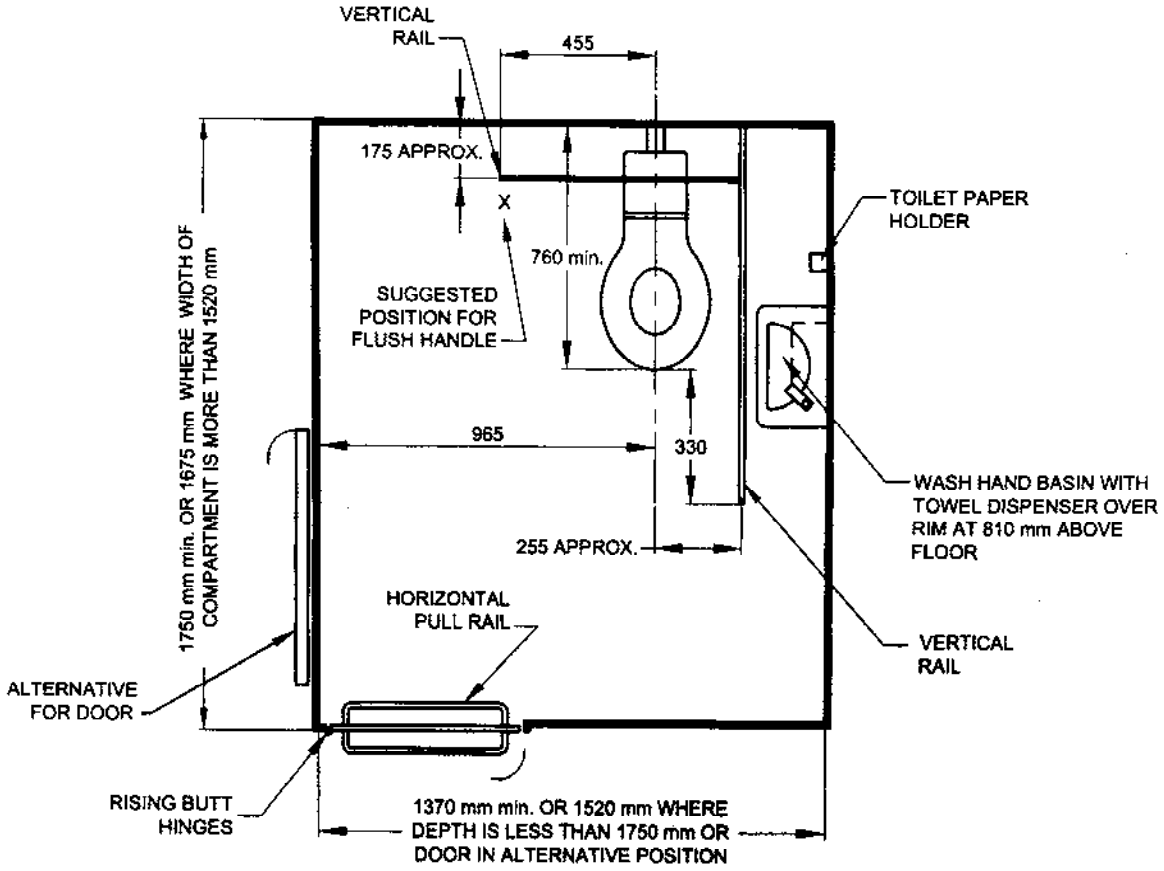
It is essential that sanitary facilities, in accordance with the nature and use of a specific building or facility, be made accessible to, and usable by, the physically challenged.

D-3.7.1 Sanitary facilities shall have space to allow traffic of individuals in wheelchairs (*see* Fig. 17 and 18).



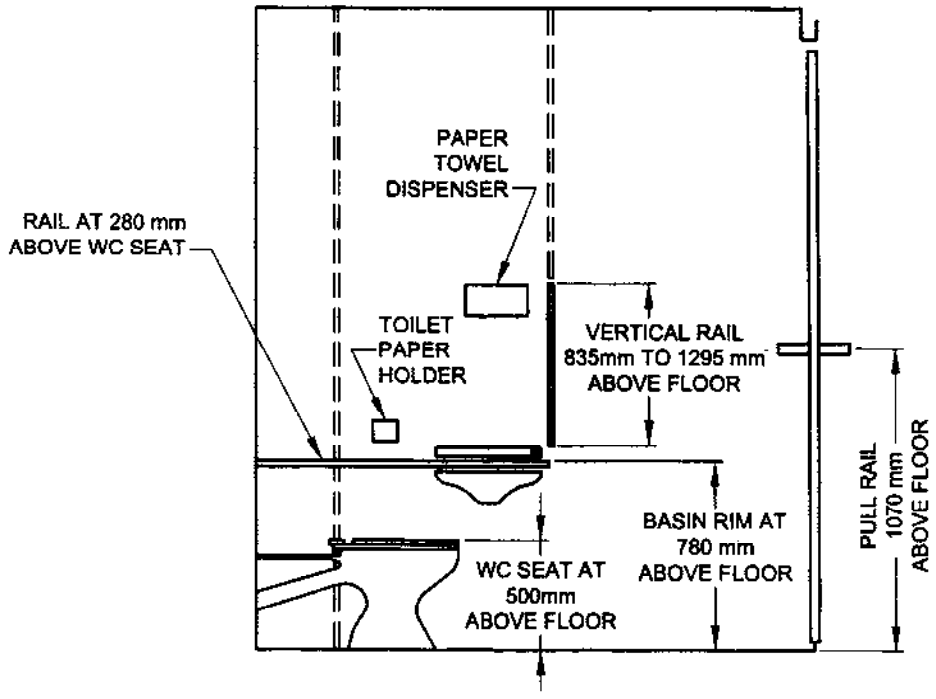
All dimensions in millimetres.

FIG. 16 EXTENSION OF HANDRAIL IN STAIRS



All dimensions in millimetres.

FIG. 17 SUGGESTED PLAN OF WC COMPARTMENT FOR THE WHEELCHAIR BOUND



All dimensions in millimetres.

FIG. 18 SECTION THROUGH WC COMPARTMENT FOR THE WHEELCHAIR BOUND

D-3.7.2 Sanitary facilities shall have at least one water-closet cubical for the ambulant disabled (*see* Fig. 19 and 20), that:

a) is 900 mm wide;
b) is at least 1 500 mm, preferably 1 600 mm deep;
c) has a door (where doors are used), that is, 800 mm wide and swings out;
d) has handrails on each side, 780 mm high and parallel to the floor, 40 mm clearance between rail and wall, and fastened securely at ends and centre; and
e) has a water-closet with the seat 500 mm from the floor.

NOTE — The design and mounting of the water-closet is of considerable importance. A wall-mounted water-closet with a narrow understructure that recedes sharply is most desirable. If a floor mounted water-closet must be used, it should not have a front that is wide and perpendicular to the floor at the front of the seat. The bowl should be shallow at the front of the seat and turn backwards more than downwards to allow the individual in a wheelchair to get close to the water-closet with the seat of the wheelchair.

D-3.7.3 Sanitary facilities shall have wash basins with narrow aprons, which when mounted at standard height are usable by individuals in wheelchairs; or they shall have wash basins mounted higher, when particular designs demand, so that they are usable by individuals in wheelchairs.

D-3.7.3.1 The drain pipes and hot-water pipes under a sanitary appliance shall be covered or insulated so that a wheelchair individual do not find it inconvenient.

D-3.7.4 Some mirrors and shelves shall be provided above the wash basins at a height as low as possible and not higher than 1 m above the floor, measured from the top of the shelf and the bottom of the mirror.

D-3.7.5 Sanitary facilities for men shall have wall-mounted urinals with the opening of the basin 460 mm from the floor, or shall have floor-mounted urinals that are on level with the main floor of the toilet room.

D-3.7.6 Toilet rooms shall have an appropriate number of towel racks, towel dispensers, and other dispensers and disposal units mounted not higher than 910 mm from the floor.

D-3.8 Drinking Fountains

An appropriate number of drinking fountains or other water-dispensing means shall be accessible to and usable by the physically disabled.

D-3.8.1 Drinking water fountains or water coolers shall have up front spouts and control.

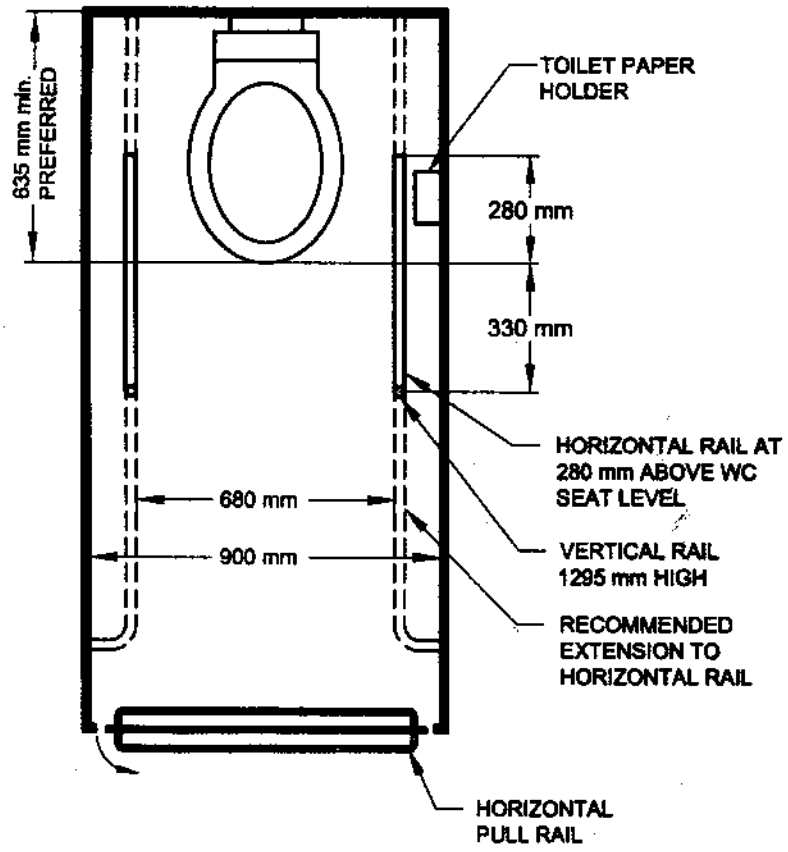


FIG. 19 SUGGESTED PLAN WC COMPARTMENT FOR THE AMBULANT

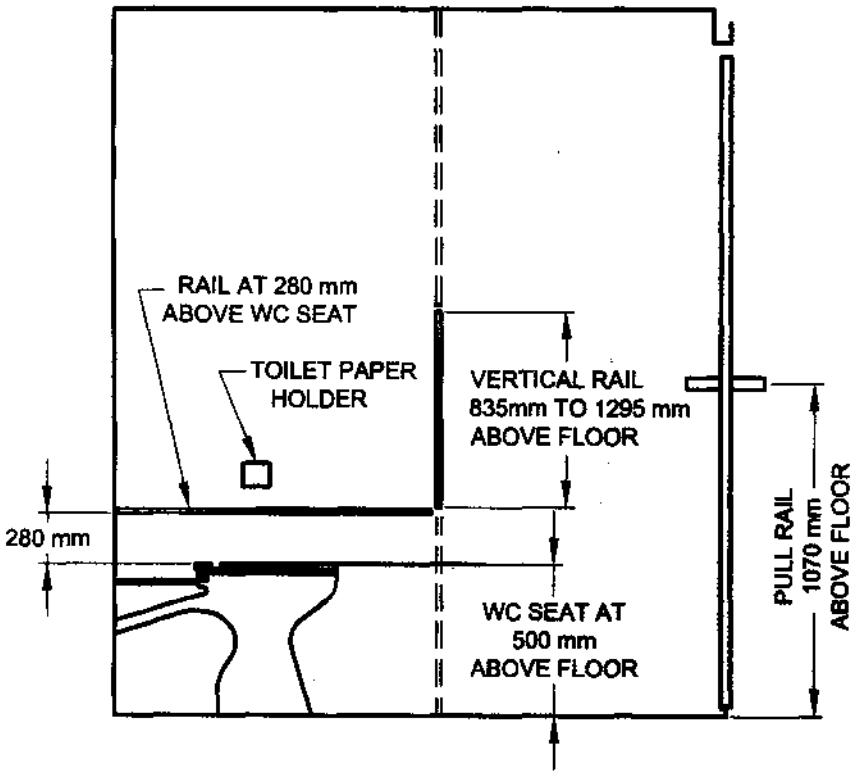


FIG. 20 SECTION THROUGH WC COMPARTMENT FOR THE AMBULANT DISABLED

D-3.8.2 Drinking water fountains or water coolers shall be hand-operated or hand and foot-operated.

D-3.8.2.1 Conventional floormounted water coolers may be convenient to individuals in wheelchairs if a small fountain is mounted on the side of the cooler 800 mm above the floor.

D-3.8.2.2 Fully recessed drinking water fountains are not recommended.

D-3.8.2.3 Drinking water fountains should not be set into an alcove unless the alcove is wider than a wheelchair.

D-3.9 Public Telephones

An appropriate number of public telephones should be made accessible to and usable by the physically disabled.

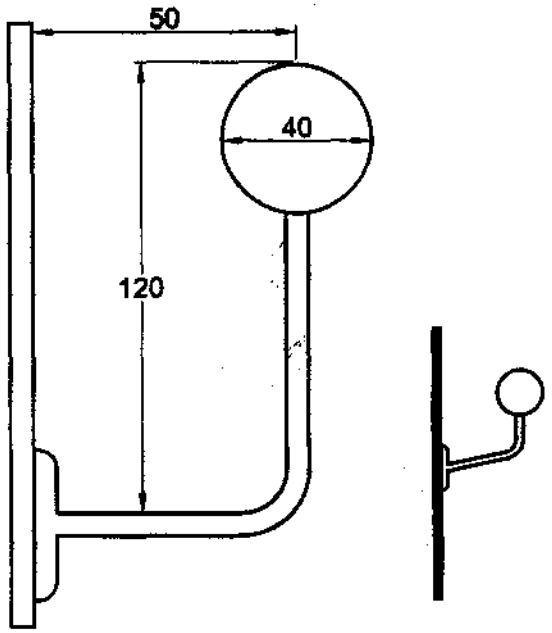
NOTE — The conventional public telephone booth is not usable by most physically disabled individuals. There are many ways in which public telephones may be made accessible and usable. It is recommended that architects and builders confer with the telephone companies in the planning of the building or facility.

D-3.9.1 Such telephones should be kept so that the dial is placed at minimum 1 200 mm from floor and the handset may be reached by individuals in wheelchairs.

D-3.10 Handrails

Handrails are used as a locational and mobility aid by blind and visually impaired people, and as a support for people with mobility impairments. The handrail should be securely fitted to the wall to withstand heavy pressure. Handrails should turn in towards the wall at either end.

D-3.10.1 Handrails should be approximately 900 mm from the floor. The rail should be easy to grip, having a circular section with a diameter of approximately 40 mm and fixed as shown in Fig. 21.



All dimensions in millimetres.

FIG. 21 FIXING OF HAND RAIL

D-3.10.2 To aid indentification, the colour of the rail should contrast with the wall behind.

D-3.11 Elevators

In a multi-storey building, elevators are essential to the successful functioning of physically disabled individuals. They shall conform to the requirements given in **D-3.11.1** and **D-3.11.2**.

D-3.11.1 Elevators shall be accessible to, and usable by the physically disabled on the level that they use to enter the building, and at all levels normally used by the general public.

D-3.11.2 Elevators shall allow for traffic by wheelchairs (*see also* **D-3.3**).

D-3.12 Controls

It is advantageous for wheelchair users if controls are placed at low level. For visually impaired people, they should be at eye-level.

D-3.12.1 To enable wheelchair users to reach controls while not placing them too low for visually impaired people, controls should be in the zone 900 mm to 1 200 mm from the floor. It is advantageous if controls in, for example, lifts are placed at an angle of approximately 45° to the wall so that they are easier to read and operate. To cater for wheelchair users, controls should be placed not less than 400 mm from room corners. All the power and electric points should be placed at one metre above the floor level and should not project outside walls.

D-3.12.2 Again, to cater for visually impaired people, controls should be colour-contrasted with backgrounds. Information should preferably be in relief for tactile reading.

D-3.12.3 To aid operation for people with impaired co-ordination or impaired vision, switches, etc, should have large push plates.

D-3.12.4 Controls for powered door openers to hinged doors should be located so that the doors do not conflict with wheelchairs, sticks, walking aids, etc.

D-3.12.5 To facilitate operation for people with limited strength in arms and hands, handles should be easy to grip and turn.

D-3.13 Identification

Appropriate identification of specific facilities within a building used by the public is particularly essential to the blind.

D-3.13.1 Raised letters or numbers shall be used to identify rooms or offices.

D-3.13.2 Such identification should be placed on the wall, to left of the door, preferably at a height of 1 500 mm from the floor.

D-3.13.3 Doors that are not intended for normal use, and that might prove dangerous if a blind person were to exit or enter by them, should be made quickly identifiable to the touch by knurling the door handle or knob (*see* Fig. 22).

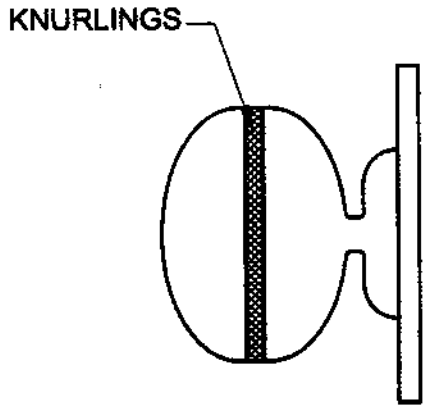


FIG. 22 DOOR HANDLE

D-3.14 Warning Signals

D-3.14.1 Audible warning signals shall be accompanied by simultaneous visual signals for the benefit of those with hearing disabilities.

D-3.14.2 Visual signals shall be accompanied by simultaneous audible signals for the benefit of the blind. To assist blind people, lettering and symbols on signs should be in relief for tactile reading.

D-3.14.3 Signs should be designed and located so that they are easy to read. For visually impaired people, signs should preferably be at eye-level and it should be possible to approach them closely. Text and symbols should be colour-contrasted with the background. The letters should not be less than 12 mm high.

D-3.14.4 Signs should be well illuminated and surfaces should not cause mirroring or reflections. Signs should not be behind glass or similar materials.

D-3.14.5 Information based on colour codes only should be avoided; colourblind people may find them difficult to understand.

D-3.15 Work Bench

This should be at least 800 mm wide, 600 mm deep and 650 mm to 700 mm high. For wheelchair users, the convenient height of work tops is between 750 mm and 850 mm; flexible provision is preferred. Further, for wheelchair access to a work bench, wash basin or table, a clear space for knees and footrests is needed.

D-3.16 Hazards

Every effort shall be exercised to obviate hazards to individuals with physical disabilities.

D-3.16.1 Access panels or manholes in floors, walks, and walls may be extremely hazardous, particularly when in use, and should be avoided.

D-3.16.2 When manholes or access panels are open and in use, or when an open excavation exists on a site, particularly when it is in proximity of normal pedestrian traffic, barricades shall be placed on all open sides, at least 8.5 m from the hazard, and warning devices shall be installed in accordance with **D-3.14.2.**

D-3.16.3 Low-hanging door closers that remain within the opening of a doorway, when the door is open or that protrude hazardously into regular corridors or traffic ways when the door is closed, shall be avoided.

D-3.16.4 Low-hanging signs, ceiling lights, and similar objects or signs and fixtures that protrude into regular corridors or traffic way shall be avoided. A minimum height of 2.1 m measured from the floor is recommended.

D-3.16.5 Ramps shall be adequately lighted.

D-3.16.6 Exit signs shall be in accordance with good practices [3(5)].

D-3.16.7 Equipment and materials causing allergic reactions should as far as possible be avoided in dwellings and buildings.

D-4 DESIGNING FOR CHILDREN

The dimensions given in this Annex are for adults of average stature. In designing buildings for use by children, it may be necessary to alter some dimensions, such as, height of handrails, in accordance with accepted standards [3(6)].

D-5 For additional information regarding other facilities and conveniences required in buildings meant for use of physically challenged, reference may be made to accepted standards [3(7)].

ANNEX E

(*Clauses* 12.22, C-2.3.1 *and* C-2.6)

SPECIAL REQUIREMENTS OF CLUSTER PLANNING FOR HOUSING

E-1 GENERAL

E-1.1 These guidelines cover planning and building requirements of housing developed as clusters. These requirements are applicable to all housing projects taken up by public, private or co-operative agencies.

E-2 PLANNING

E-2.1 Plot Size

The minimum plot size permissible shall be 15 m^2 with 100 percent ground coverage and an FSI of two. Hundred percent ground coverage and FSI of 2 will be applicable up to plot size of 25 m^2. For plot sizes beyond 25 m^2, provision in accordance with good practice [3(1)] shall be applicable.

E-2.2 Plot/Plinth Area for Slum Resettlement on Same Site

In case of slum resettlement on the same site, minimum area may be reduced to 12.5 m^2 with potential for adding another 12.5 m^2 on first floor with an internal staircase.

E-2.3 Group Housing

Group housing may be permitted within cluster housing concept. However, dwelling units with plinth areas up to 20 m^2 should have scope for adding a habitable room. Group housing in a cluster should not be more than 15 m in height.

E-2.4 Size of Cluster

In ground and one storeyed structures not more than 20 houses should be grouped in a cluster. Clusters with more dwelling units may create problems relating to identity, encroachment and maintenance.

E-2.5 Size of Cluster Open Space

Minimum dimensions of open spaces shall be not less than 6 m or 3/4th of the height of buildings along the cluster open space, whichever is higher. The area of such cluster court shall not be less than 36 m^2. Group housing around a cluster open space should not be normally more than 15 m in height. Maximum cluster courtyard width and breadth shall be 13 m.

E-2.6 Setbacks

No setbacks are needed from the edges of cluster as pedestrian/vehicular access roads surrounding the cluster.

Pedestrian paths and vehicular access roads to clusters separating two adjacent clusters may be bridged to provide additional dwelling units. While bridging the pedestrian path way minimum clearance should be one storey height; length of such bridging should be not more than two dwelling units. While bridging the vehicular access roads minimum clearance should be 6 m.

E-2.8 Vehicular Access

A right of way of at least 6 m width should be provided up to the entrance to the cluster to facilitate emergency vehicle movement up to cluster.

E-2.9 Pedestrian Paths

Minimum width of pedestrian paths shall be 3 m.

E-2.10 Width of Access Between Two Clusters

Built area of dwelling unit within cluster shall have no setbacks from the path or road, space. Hence, the height of the building along the pathway or roads shall be not less than 60 percent of the height of the adjacent building subject to minimum of 3 m in case of pathway and 6 m in case of vehicular access.

Cluster planning methodologies result in higher densities with low rise structures. With per dwelling unit covered area of 15 m^2 densities of 500 dwelling units per hectare (net) shall be permissible. Densities higher than this should not allowed.

E-2.12 Group Toilet

Cluster housing for economically weaker section families can have group toilets at the rate of one water-closet, one bath and a washing place for three families. These shall not be community toilets, as keys to these toilets shall be only with these three families, making them solely responsible for the maintenance and upkeep of these toilets.

E-3 OTHER REQUIREMENTS

E-3.1 Requirements of Building Design

With the exception of clauses mentioned above, requirements of building will be governed by the provision of this Code and good practice [3(1)].

E-3.2 Requirements of fire safety, structural design, building services and plumbing services shall be as specified in this Code.

ANNEX F

(*Clause* 12.23)

SPECIAL REQUIREMENTS FOR LOW INCOME HABITAT PLANNING IN RURAL AREAS

F-1 GENERAL

F-1.1 These guidelines cover planning and general building requirements for low-income houses having a maximum built-up area of 40 m^2 including future expansion, built on notified (as notified by the State Governments) rural areas. The provisions on layout planning of low-income housing colonies in rural areas are applicable to public and private agencies/ government bodies. The provisions of this Code on design and construction of buildings for low income housing in approved layouts are applicable to all private and public agencies.

F-2 SETTLEMENT AND ENVIRONMENT PLANNING

F-2.1 While planning for rural settlements the following factors shall be taken into consideration:

a) Ecosystem and Biodiversity.

b) Topography with its direct effect on climate, likelihood of natural disasters, natural drainage, etc.

c) Identity of the place rooted in its culture and heritage.

d) Nearness and connectivity with nearby urban centres.

e) Occupation related requirements.

f) Water management.

g) Waste management.

h) Land tenure.

j) Site selected shall be conveniently approachable and suitably developed and shall not be subjected to water logging/ flooding.

k) Plot size : 80 m^2, *Min*

m) Density (Gross) : 60 plots per hectare, *Max*

n) Minimum frontage : 6 m

p) Ground Coverage : 33 percent (subject to a maximum of 50 percent)

q) Floor area ratio (FAR): 2, *Max*

r) Open spaces : 1.21 hectare open space for a village with 200 houses.

s) Facilities like branch of co-operative bank, a fertilizer depot, a veterinary hospital, market place and a branch of the co-operative consumer store besides facilities for educational and health care should be available within a maximum distance of 5 km from any settlement.

t) Proposed Road Hierarchy

Road Type (1)	*Road Description* (2)	*Road Width* (3)	*Function/Remarks* (4)
R1	Road which connects village to nearby areas	9 m	Widest road
R2	Road which take major traffic to the village	6 m	Main village roads with drain on both sides to facilitate drainage system of the village
R3	Internal village road	4.5 m	Other village roads
R4	Internal village road	3 m	Village lanes

F-3 GENERAL BUILDING REQUIREMENTS (HOMESTEAD)

F-3.1 General

The requirements of parts of buildings shall be as given in **F-3.2** to **F-3.7**.

F-3.2 Plinth

The minimum height of plinth shall be regulated on the basis of environmental and topographical condition and higher plinth height may be required in areas prone to flooding.

F-3.3 Size of Room

F-3.3.1 *Habitable Room*

Every dwelling unit to be provided should have at least two habitable rooms. Even if one room house is provided initially it should be capable of adding a new second room in future. In a house of two rooms, first room shall not be less than 9.0 m^2 with minimum width of 2.5 m and second room shall not be less than 6.5 m^2 with a minimum width of 2.1 m provided the total area of both the rooms is not less than 15.5 m^2. In incremental housing the bigger room shall always be the first room.

F-3.3.1.1 To facilitate incremental housing in case of flatted development or otherwise, habitable space at mezzanine level may be permitted. The minimum size of such a mezzanine floor should not be lesser than 6.5 m^2 and such a floor should occupy not more than 50 percent of the room area of which it is a part. Such a mezzanine floor should have appropriate openings to facilitate light and ventilation as per **F-3.5**. Minimum clear height below and above the mezzanine floor should be 2.4 m and 2.1 m respectively.

As far as possible mezzanine floor should have direct ventilation from the external face of the building. Where this is not possible ventilation through main room may be allowed provided total area of openings in the main room is provided taking into consideration area of mezzanine floor.

Such mezzanine floor may be accessible through the main room by a ladder, whose minimum angle with vertical plane should be 22½°. Height of the riser should be less than 250 mm.

F-3.3.2 *Water-Closet/Bathroom*

a) The size of independent water-closet shall be 0.9 m^2; with minimum width of 90 cm.

b) The size of independent bathroom shall be 1.2 m^2 with minimum width of 1m, and

c) The size of combined bath and water closet shall be 1.8 m^2 with minimum width of 1 m.

F-3.3.3 *Kitchen*

The size of a cooking alcove serving as cooking space shall not be less than 2.4 m^2 with a minimum width of 1.2 m. The size of individual kitchen shall not be less than 3.3 m^2 with a minimum width of 1.5 m. Semi-open spaces with low walls and roof may also be provided for cooking in areas where such provision is suitable with respect to climatic comfort. Provision for smokeless *CHULLHA* shall be made in all kitchens considering fuel efficiency and health hazard due to smoke inhalation.

F-3.3.4 *Balcony*

The minimum width of individual balcony, where provided, shall be 0.9 m and shall not be more than 1.2 m and it shall not project beyond the plot line and on roads or pathway.

F-3.4 Minimum Height

The minimum height of rooms/spaces shall be as follows:

a)	Habitable room	2.75 m
b)	Kitchen	2.6 m
c)	Bath/water-closet	2.2 m
d)	Corridor	2.1 m

F-3.4.1 In the case of sloping roofs, the average height of roof for habitable rooms shall be 2.75 m and the minimum height at eaves shall be 2.10 m.

F-3.5 Lighting and Ventilation

The openings through windows, ventilators and other openings for lighting and ventilation shall be as per in accordance with **15.1.2**.

NOTE — The windows and other openings shall abut onto open spaces either through areas left open within the plot or the front, side and rear spaces provided in the layouts which shall be deemed to be sufficient for light and ventilation purposes. Wherever ventilation/lighting is provided by means of *JALI* or grill of any material, total area of openings shall calculated excluding solid portion of the *JALI* or grill.

F-3.6 Stairs

The following criteria shall be adopted for internal individual staircase:

a)	*Minimum width*	
	1) 2 storeyed-straight	0.60 m
	2) 2 storeyed-winding	0.75 m
	3) 3 or more storeyed-straight	0.75 m
	4) 3 or more storeyed-winding	0.90 m
b)	*Riser*	200 mm, *Max*
c)	*Tread*	
	1) 2 storeyed	225 mm, *Min*
	2) 3 storeyed or more	250 mm, *Min*

NOTE — This could be reduced to 20 cm as the clear tread between perpends, with possibility of open riser as well as nosing and inclined riser to have an effective going of 22.5 cm.

F-3.7 Water Seal Latrine

No building plan shall be approved and no building shall be deemed to have been completed and fit for human occupation unless provision is made for water seal latrine. No dry latrine shall be allowed. Water seal latrines can also be provide on the basis of community toilets or shared toilets as per the recommendation given in [3(3)].

Where leaching pits are used, it should be constructed within the premises of the households as it would be economical as well as facilitate their cleaning. However, where, due to space constraint, construction of pits within the premises may not be possible, pits may be constructed in places like lanes, streets and roads.

In case the pit is located under the road, street or foot path, the inverted level of the pipe connecting the latrine pan with the pit shall be at least 1.1 m below ground level or below the bottom of the water main existing within a distance of 3 m from the pits whichever is more. Construction of such pits may be in accordance with [3(4)].

The water seal latrine should be properly maintained and kept in sanitary condition by the owner or the occupier. The contents of the septic tanks, soak pits, leach pits, etc, should be periodically emptied.

The leach pits should be cleaned only after 2 years of their being put out of service after they were full.

Location of sanitary facility either as part of the house or separately shall be decided on the basis of felt perceptions.

F-3.8 The house site shall provide space for storage of food grains and keeping cattle. A manure pit having a minimum area of 1.0 m^2 shall also be catered for. This will take care of composting of biodegradable waste.

F-4 OTHER REQUIREMENTS

F-4.1 Requirements of fire safety, structural design, building services and plumbing services shall be as specified in relevant parts of the Code.

F-4.2 One water tap per dwelling unit may be provided, where adequate drinking water supply is available. If supply is inadequate, public hydrants shall be provided. In the absence of piped water supply, hand pumps may be used for provision of water supply.

F-4.3 Drainage System

F-4.3.1 Water from drains shall be connected to village ponds and appropriate eco-friendly methods like growing of duck weed plants shall be adopted to treat waste water.

F-4.3.2 This treated water may be used for irrigation and agriculture.

F-4.4 Appropriate methods (namely conservation, ground water recharging, rain water harvesting, etc.) should be employed to ensure effective water management.

F -4.5 Community Facilities

F-4.5.1 A community hall/*BARAAT GHAR* shall be established.

F-4.5.2 Rural Development Centre shall include *PANCHAYAT GHAR*, a *MAHILA KENDRA* that may also serve as a vocational training centre.

F-4.5.3 School, health centre, post office, police post, shopping, work sheds for the artisans, telephone facilities, etc should also be established.

F-4.6 The use (to the extent possible) of locally

available building materials and cost effective substitutes for scarce building materials. Appropriate technology inputs shall be introduced for improving the local materials or conventional or traditional practices for improved efficiency.

F-4.7 The concept of 'aided self-help' shall be ensured for active participation of the prospective users and association in the construction and development of dwelling units and other community building.

F-4.8 The special needs of women headed households/ single and working women/woman in difficult circumstances should be addressed. The specific requirement of women in terms of providing necessary facilities in homes to lessen their drudgery would be given sufficient attention.

F-4.9 Protecting and promoting our cultural heritage, architecture and traditional skills should be given due importance.

ANNEX G

(*Clause* 12.24)

SPECIAL REQUIREMENTS FOR DEVELOPMENT PLANNING IN HILLY AREAS

G-1 GENERAL

G-1.1 These guidelines provides requirements relating to development planning and design of buildings in hilly areas. Any area above 600 m in height form mean sea level may be classified as hilly, or any area with average slope of 30° may also be classified as hilly, considering the sensitive and fragile eco-system of hills and mountains. However, the State Governments may identify and notify areas to be covered under 'Hilly Area', which need to be dealt with special consideration, when developmental activities are taken up.

G-1.2 Hilly areas have one of the most fragile eco-systems, which need to be conserved. Therefore planning and development strategies for hilly areas shall have to be designed with added sensitivity and stress on integrated development. The development approach shall comprise sound land use planning and settlement planning.

G-1.3 Settlement planning in the hill areas has extremely large implications on the environment. For planning of the new settlements or working out the strategies for the growth of the existing settlements, it is necessary to conduct detailed environmental inventory/impact assessment. The inventory would involve geological investigations, slope analysis, soil, flora and fauna analysis, climatic inventories, vulnerability to natural disasters, etc. In addition to this the aesthetic factors, cultural, architectural and historical heritage, scenic/landscape value should also be taken into consideration. Keeping in view the scarcity of good buildable land and also the high cost of the construction, it is necessary to optimize the use of land and at the same time, use cost effective, appropriate building materials and technologies.

G-2 LAND USE PLANNING

G-2.1 The following land use structure shall be adopted in Development Planning in Hilly areas:

Land Use	*Percentage of Developed Area*		
	Small Towns	Medium Towns	Large Cities
(1)	(2)	(3)	(4)
Residential	50-55	48-52	45-50
Commercial	2-3	2-3	4-5
Industrial	3-4	4-5	5-7
Public and semi-public	8-10	8-10	12-15
Recreational	15-18	15-18	18-20
Transport and commerce	5-6	5-6	6-8
Ecological	8-10	8-10	8-10

G-3 OPEN SPACES

G-3.1 The following standards shall be adopted in Development Planning in Hilly areas.

Type	*Area Range* (in ha)	*Area per 1 000 Population* (in ha)	*Remarks*
(1)	(2)	(3)	(4)
Tot lot	0.03-0.05	—	Minimum width 15 m
Playground	0.50-1.00	0.12 to 0.20	One for every 5 000 may be combined with schools.
Parks	1.20-2.00	0.12 to 0.20	One for every 10 000 population.
City parks/playgrounds/*maidan*/ exhibition grounds/cultural gathering grounds	—	0.12 to 0.20	For the entire town at one of more sites, depending upon design and space availability.
Botanical garden	10-20	—	One for every town
Recreational complex including zoo	10-12	—	One for every settlement with tourist potential

G-4 ROADS AND PATHS

G-4.1 Street orientation shall preferably be East-West to allow for maximum South sun to enter the buildings. The street shall be wide enough to ensure that the buildings on one side do not shade those on the other side.

G-4.2 The following road widths shall be adopted for urban roads in Hilly areas.

Road Type	*Width* (in m)		
	Open Areas	Built-up Areas	Plains
(1)	(2)	(3)	(4)
Arterial road	18-24	15-18	50-60
Sub-arterial road	15-18	12-15	30-40
Collector road	9-12	7.5-9	20-30
Local street	4.5-6	3-6	10-20
Loop street (maximum length = 500 m)	4.5	4.5	9
Cul-de-sac (maximum length = 500 m)	4.5	4.5	7.5
Pedestrian path	1.5-2.5	1-1.5	1.5-4.5

G-4.3 Hill Road Manual (IRC:SP:48-1998), a publication of the Indian Roads Congress shall be referred to for detailed guidelines for planning roads in Hilly areas.

G-5 COMMUNITY FACILITIES AND SERVICES

G-5.1 The following standards shall be adopted for community facilities and Services in Hilly areas.

Type	*Population*	*Distance*	*Area Range* (in ha)
(1)	(2)	(3)	(4)
A. *Educational*			
Primary school	4 000	1-2	0.20 to 0.30
Secondary school (10+2)	15 000	5-7	0.30 to 0.50
Industrial training centre	—	8-12	0.30 to 0.60
College	30 000	8-12	2.00 to 3.00

Type	Population	Distance	Area Range (in ha)
(1)	(2)	(3)	(4)
B. Health			
Health sub-centre	3 000	2-4	0.025 to 0.067
Primary health centre	20 000	16-20	0.105 to 0.210
(25-50 beds)	80 000	16-20	0.840 to 2.100
Hospital (200-250 beds)	1 000	16-20	0.050 to 0.100
Veterinary centre			
C. Other facilities			
Community welfare centre	16 000	5-7	0.10 to 0.15
D. Services			
Fire station	50 000	—	0.30 to 0.80
General post office	50 000	10-15	0.20 to 0.40
Post office	10 000	5-7	0.10 to 0.15
Rural post office	2 000	2-4	0.025 to 0.050
Rural post office	1 000	1-2	—
Bank (tribal areas)	10 000	16-20	0.100 to 0.150
Telephone exchange	50 000	10-15	0.20 to 0.40
Electric sub-station (66 kV)	—	—	1.00
Electric sub-station (11 kV)	—	—	0.05
LPG godown	—	—	0.15

G-6 GENERAL BUILDING REQUIREMENTS

G-6.1 General

The provisions contained in this Part shall apply excepting for the specific provisions given hereunder.

G-6.2 Siting

G-6.2.1 No house shall preferably be located closer than 1 m to another house.

G-6.2.2 No house shall be located closer than 10 m to a steep slope.

G-6.2.3 No house shall be built on a landfill or on the edge of a slope known to have been levelled.

G-6.2.4 Buildings in hills shall be clustered together to minimise the exposure to cold winds. Open spaces provided shall allow for maximum South sun.

G-6.2.5 Buildings shall be located on the south slope of a hill or mountain for better exposure to solar radiation. At the same time, exposure to cold winds may be minimized by locating the building on the leeward side.

G-6.3 Passive Systems for Climatic Control

G-6.3.1 Appropriate solar passive methods, such as orientation, double-glazing, trombe walls and solar collectors, shall be adopted to achieve climatic comfort with little use of conventional energy.

G-6.3.2 Care shall be taken in siting and design of buildings to provide passive controls to modify the effect of cold/strong winds.

G-6.4 Flat land is normally not available in hilly regions. The houses are required to be constructed on partially sloping land made available by cutting and filling. It shall be necessary to protect the house by building retaining walls/breast walls [*see* 3(8)] to avoid landslides occurring at time of earthquakes or heavy rains.

G-6.5 Disaster Resistance

All necessary steps shall be taken in designing and building in hilly regions to achieve disaster resistance as per the relevant codes and Part 6 'Structural Design'. All natural disasters likely to affect the locality shall be taken into consideration, namely earthquakes, cyclones, avalanches, flash floods, landslides etc.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 8888 (Part 1) : 1993	Guide for requirements of low income housing: Part 1 Urban area (*first revision*)
(2) 3792 : 1978	Guide for heat insulation of non-industrial buildings (*first revision*)
11907 : 1986	Recommendations for calculation of solar radiation on buildings
(3) 13727 : 1993	Guide for requirements of cluster planning for housing
(4) 12314 : 1987	Code of practice for sanitation for leaching pits for rural community
(5) 4878 : 1986	Byelaws for construction of cinema buildings (*first revision*)
(6) 4838 : 1990	Anthropometric dimensions for school children age group 5-17 years (*second revision*)
(7) 4963 : 1987	Recommendations for buildings and facilities for the physically challenged (*first revision*)
(8) 14458	Guidelines for retaining walls for hill area:
(Part 1) : 1998	Selection of type of wall
(Part 2) : 1997	Design of retaining/breast walls

NATIONAL BUILDING CODE OF INDIA

PART 4 FIRE AND LIFE SAFETY

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Part of the Code deals with safety from fire. It specifies the demarcation of fire zones, restrictions on construction of buildings in each fire zone, classification of buildings based on occupancy, types of building construction according to fire resistance of the structural and non-structural components and other restrictions and requirements necessary to minimize danger to life from fire, smoke, fumes or panic before the buildings can be evacuated. The Code recognizes that safety of life is more than a matter of means of exits and accordingly deals with various matters which are considered essential to the safety of life.

Fire protection techniques have to be based on the fire behaviour characteristics of different materials and structural elements of buildings. The activities pursued by the occupants of buildings must also be taken into consideration for assessing the extent of hazards, and method should then be devised by which the hazards could be minimized. An indefinite combination of variables is involved in the phenomenon of fire, all of which cannot be quantified. The requirements of this Code should, therefore, be taken as a guide and an engineering design approach should be adopted for ensuring a fire safe design for buildings. It would also be necessary for this purpose to associate qualified and trained fire protection engineers with the planning of buildings, so that adequate fire protection measures could be incorporated in the building design right from the beginning.

Absolute safety from fire is not attainable in practice. The objective of this Part is to specify measures that will provide that degree of safety from fire which can be reasonably achieved. The Code endeavours to avoid requirements that might involve unreasonable hardships or unnecessary inconvenience or interference with normal use and occupancy of buildings, but insists upon compliance with minimum standards for fire safety necessary in public interest. For ensuring compliance of fire protection equipments/installations to the laid down quality requirements, it is desirable to use such equipments/installation duly certified under the BIS Certification Marks Scheme.

While providing guidelines for minimizing chances of occurrence of fire through passive fire protection measures, this Part does not intend to cover all aspects of general fire prevention including sources of ignition. Nor does it cover the prevention of accidental personal injuries during the course of normal occupancy of buildings.

This Part while recognizing that panic in a building on fire may be uncontrollable, deals with the potential panic hazard through measures designed to prevent the development of panic. Experience indicates that panic seldom develops even in the presence of potential danger, so long as occupants of buildings are moving towards exits which they can see within a reasonable distance and with no obstruction or undue congestion in the path of travel. However, any uncertainty as to the location or adequacy of means of egress, the presence of smoke or fumes and the stoppage of travel towards the exit, such as may occur when one person stumbles and falls on stairs, may be conducive to panic. Danger from panic is greater when a large number of people are trapped in a confined area.

Experience has shown that concealed spaces within a building, such as, space between ceiling and false ceiling, horizontal and vertical ducts, etc, tend to act as flues/tunnels during a fire. Provision should, therefore, be made to provide fire stopping within such spaces.

Nothing in this Part of the Code shall be construed to prohibit better types of building construction, more exits or otherwise safer conditions than the minimum requirements specified in this Part.

Compliance with this Part shall not be construed as eliminating or reducing the necessity for other provisions for safety of persons using a building or structure under normal occupancy conditions. Nor shall any provision of this Code be construed as requiring or permitting any addition that may be hazardous under normal occupancy conditions.

One of the major points brought out in this Part is the limitation of heights and areas of buildings based on fire safety of the occupants. Individual municipal corporations are free to alter Table 19 based on local conditions,

but the ratios of areas as maintained in the table for different occupancies and types of construction shall be adhered to.

Advantage has been taken of the developments, particularly in fire resistance rating of materials, designating types of construction in a rational manner and relating the area limitations of different occupancies to different types of construction.

Halons (halogenated hydrocarbons) which exhibit exceptional fire fighting and explosion prevention/suppression characteristics have been found to possess high ozone depleting potential. They come under Group II of Annex A of the Montreal Protocol on Substances that Deplete the Ozone Layer, the international environmental agreement for phasing out ozone depleting substances. Due to increasing evidence that the ozone layer is getting depleted at a faster rate than thought earlier, the developed countries accelerated their phase-out schedule with a view to achieving 100 percent phase-out of halons by 1 January 1994, instead of the earlier target date of 1 January 2000 after which only essential use of halon was allowed. For developing countries like India, the total phase-out of halons is to be achieved by 1 January 2010, as per Montreal Protocol, unless a decision is taken in between to hasten up the phase-out of ozone depleting substances. India, having become a signatory to the Protocol in June 1992, is committed to abide by the Montreal Protocol decisions. In accordance with Ministry of Environment and Forests, Government of India, Ozone Depleting Substances (Regulations), Rules, 2000, the manufacture of halon based fire extinguishers and extinguishing systems has been phased out by 1 January 2001. Meanwhile, the practical implications of the phasing out of the halons cover, by and large, the following aspects:

a) Availability of halons will be restricted;

b) Non-standard halon extinguishers, like aerosol type, shall not be permitted;

c) Discharge of halons for training/testing, etc shall not be permitted;

d) All efforts shall be made for avoiding/minimizing halon emissions at various levels such as production, fire equipment manufacture, use, service and maintenance;

e) Since 'drop-in' substitutes for halons are not likely to be available on a commercial scale in the near future, wherever possible, instead of halon, use of suitable alternative extinguishing media/methods will be resorted to, even accepting some trade-offs, if necessary; and

f) Halons shall be restricted for 'essential uses' only, for protection of critical fire explosion risk areas which would otherwise result in serious impairment of an essential service to society, or pose an unacceptable threat to life, the environment, or national security.

NOTE — Detailed instructions which will be issued by the Government of India from time-to-time for implementation of the Country Programme for the phasing out of ozone depleting substance (ODS) and regarding permitting use of halons for applications till the availability of proper substitutes, shall have to be complied with.

The first version of this Part was formulated in 1970 and first revision was brought out in 1983. Subsequently the first revision of this Part was modified in 1997 through Amendment No. 3 to 1983 version of the Code. This modified version of this part included few tables for the fire resistance ratings of various building components, such as walls, columns, beams and floors. The requirements for wet riser, down-comer, automatic sprinkler installation, high velocity (10-15 m/s) water spray or foam generating system, etc, for buildings were modified. Annex giving guidelines for selection of fire detectors had been deleted and relevant Indian Standards on fire alarm system and smoke detectors had been referred. Also, Annex for determination of fire loads and fire load density for arriving at the classification of occupancy hazard and calorific values of some common materials were included. Annex for broad classification of industrial and non-industrial occupancies into low, moderate and high hazard had also been included.

As a result of implementation of this Part, some useful suggestions have emerged. This revision has, therefore, been prepared to take care of the same. The significant modifications incorporated include:

a) The text has now been divided into the following broad clauses:

   1) *Fire Prevention* — Covering aspects of fire prevention pertaining to design and construction of buildings on passive fire protection measures, also describing the various types of building materials and their fire rating.

   2) *Life Safety* — Covering life safety provisions in the event of fire and similar emergencies, also addressing construction and occupancy features that are necessary to minimize danger to life from fire, smoke, fumes or panic.

for selecting the correct type of equipment and installation meant for fire protection of the building, depending upon the classification and type of the building.

b) The classification of building based on occupancy has been elaborated, with:
   1) Starred hotels now covered as a new sub-division A-6 under occupancy Group A Residential.
   2) Heritage structures and archeological monuments now covered under sub-division D-3 occupancy Group D Assembly buildings.
   3) Mixed assembly occupancies now covered as a new sub-division D-6 and under ground elevated railways have been covered as a new sub-division D-7 under occupancy Group D Assembly buildings.
   4) TV stations now covered under sub-division E-5 of occupancy Group E Business buildings.

c) The minimum capacity of smoke exhaust equipment has been increased to 12 air changes per hour.

d) For the external stairs for exit requirements, the width and treads have been increased to 1 250 mm and 250 mm respectively.

e) Under the requirements for institutional buildings the clear width of all required exits which serve as egress from hospital or infirmary section has been increased from 1.5 m to 2 m. Also, provision of patient-lift has been included.

f) Due cognizance of halon phase out programme has been taken, while specifying provisions in this Part with respect to fire protection using fire extinguishers/systems.

All standards cross-referred to in the main text of this section, are subject to the revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 4 FIRE AND LIFE SAFETY

1 SCOPE

This Part covers the requirements for fire prevention, life safety in relation to fire and fire protection of buildings. The Code specifies construction, occupancy and protection features that are necessary to minimize danger to life and property from fire.

2 TERMINOLOGY

2.0 For the purpose of this Part, the following definitions shall apply.

2.1 Automatic Fire Detection and Alarm System — Fire alarm system comprising components for automatically detecting a fire, initiating an alarm of fire and initiating other actions as appropriate.

NOTE — The system may also include manual fire alarm call points.

2.2 Automatic Sprinkler System — A system of water pipes fitted with sprinkler heads at suitable intervals and heights and designed to actuate automatically, control and extinguish a fire by the discharge of water.

2.3 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, *VERANDAH*, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents, *SHAMIANAHS*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

2.4 Building, Height of — The vertical distance measured in the case of flat roofs, from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of the last livable floor of the building adjacent to the external wall; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof; and in the case of gables facing the road, the mid-point between the eaves level and the ridge. Architectural features serving no other function except that of decoration, shall be excluded for the purpose of measuring heights.

2.5 Combustible Material — The material which either burns itself or adds heat to a fire, when tested for non-combustibility in accordance with accepted standard [4(1)].

2.6 Covered Area — Ground area covered by the building immediately above the plinth level. The area covered by the following in the open spaces is excluded from covered area (*see* Table 19):

a) garden, rockery, well and well structures, plant nursery, waterpool, swimming pool (if uncovered), platform round a tree, tank, fountain, bench, *CHABUTARA* with open top and unenclosed on sides by walls and the like;

b) drainage culvert, conduit, catch-pit, gully pit, chamber, gutter and the like;

c) compound wall, gate, unstoreyed porch and portico, slide, swing, uncovered staircases, ramp areas covered by *CHHAJJA* and the like; and

d) watchman's booth, pumphouse, garbage shaft, electric cabin or sub-stations, and such other utility structures meant for the services of the building under consideration.

NOTE — For the purpose of this Part, covered area equals the plot area minus the area due for open spaces in the plot.

2.7 Down-comer — An arrangement of fire fighting within the building by means of down-comer pipe connected to terrace tank through terrace pump, gate valve and non-return valve and having mains not less than 100 mm internal diameter with landing valves on each floor/landing. It is also fitted with inlet connections at ground level for charging with water by pumping from fire service appliances and air release valve at roof level to release trapped air inside.

2.8 Dry Riser — An arrangement of fire fighting within the building by means of vertical rising mains not less than 100 mm internal diameter with landing valves on each floor/landing which is normally dry but is capable of being charged with water usually by pumping from fire service appliances.

2.9 Emergency Lighting — Lighting provided for use when the supply to the normal lighting fails.

2.10 Emergency Lighting System — A complete but discrete emergency lighting installation from the standby power source to the emergency lighting lamp(s), for example, self-contained emergency luminaire or a circuit from central battery generator connected through wiring to several escape luminaries.

2.11 Escape Lighting — That part of emergency lighting which is provided to ensure that the escape route is illuminated at all material times, for example, at all times when persons are on the premises, or at times the main lighting is not available, either for the whole building or for the escape routes.

2.12 Fire Door — A fire-resistive door approved for openings in fire separation.

2.13 Fire Exit — A way out leading to an escape route having panic bar hardware provided on the door.

2.14 Fire Lift — The lift installed to enable fire services personnel to reach different floors with minimum delay, having such features as required in accordance with this Part.

2.15 Fire Load — Calorific energy, of the whole contents contained in a space, including the facings of the walls, partitions, floors and ceilings.

2.16 Fire Load Density — Fire load divided by floor area.

2.17 Fire Resistance Rating — The time that a material or construction will withstand the standard fire exposure as determined by fire test done in accordance with the standard methods of fire tests of materials/structures.

2.18 Fire Resistance — Fire resistance is a property of an element of building construction and is the measure of its ability to satisfy for a stated period some or all of the following criteria:

a) resistance to collapse,

b) resistance to penetration of flame and hot gases, and

c) resistance to temperature rise on the unexposed face up to a maximum of 180°C and/or average temperature of 150°C.

2.19 Fire Separation — The distance in metres measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of street or other public space for the purpose of preventing the spread of fire.

2.20 Fire Separating Wall — The wall provides complete separation of one building from another or part of a building from another or part of a building from another part of the same building to prevent any communication of fire or heat transmission to wall itself which may cause or assist in the combustion of materials on the side opposite to that portion which may be on fire.

2.21 Fire Stop — A fire resistant material, or construction, having a fire resistance rating of not lesss than the fire separating elements, installed in concealed spaces or between structural elements of a building to prevent the spread/propagation of fire and smoke through walls, ceilings and like as per the laid down criteria.

2.22 Fire Tower — An enclosed staircase which can only be approached from the various floors through landings or lobbies separated from both the floor areas and the staircase by fire-resisting doors, and open to the outer air.

2.23 Fire Resisting Wall — A fire resistance rated wall, having protected openings, which restricts the spread of fire and extends continuously from the foundation to at least 1 m above the roof.

2.24 Floor Area Ratio (FAR) — The quotient obtained by dividing the total covered area (plinth area) on all floors by the area of the plot:

$$\text{FAR} = \frac{\text{Total covered area of all floors}}{\text{Plot area}}$$

2.25 High Rise Building — For the purpose of this Part, all buildings 15 m or above in height shall be considered as high rise buildings.

2.26 Horizontal Exit — An arrangement which allows alternative egress from a floor area to another floor at or near the same level in an adjoining building or an adjoining part of the same building with adequate fire separation.

2.27 Means of Egress — A continuous and unobstructed way of travel from any point in a building or structure to a place of comparative safety.

2.28 Occupancy or Use Group — The principal occupancy for which a building or a part of a building is used or intended to be used; for the purpose of classification of a building according to the occupancy, an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it.

2.29 Plinth Area — The built-up covered area measured at the floor level of the basement or of any storey.

2.30 Pressurization — The establishment of a pressure difference across a barrier to protect a stairway, lobby, escape route or room of a building from smoke penetration.

2.31 Pressurization Level — The pressure difference between the pressurized space and the area served by the pressurized escape route, expressed in pascals (Pa).

2.32 Roof Exits — A means of escape on to the roof of a building, where the roof has access to it from the ground. The exit shall have adequate cut-off within the building from staircase below.

2.33 Site Plot — A parcel (piece) of land enclosed by definite boundaries.

2.34 Stack Pressure — Pressure difference caused by a temperature difference creating an air movement within a duct, chimney or enclosure.

2.35 Travel Distance — The distance to be travelled from any point in a building to a protected escape route, external escape route or final exit.

2.36 Ventilation — Supply of outside air into, or the removal of inside air from an enclosed space.

2.37 Venting Fire — The process of inducing heat and smoke to leave a building as quickly as possible by such paths that lateral spread of fire and heat is checked, fire fighting operations are facilitated and minimum fire damage is caused.

2.38 Volume to Plot Area Ratio (VPR) — The ratio of volume of building measured in cubic metres to the area of the plot measured in square metres and expressed in metres.

2.39 Wet Riser — An arrangement for fire fighting within the building by means of vertical rising mains not less than 100 mm nominal diameter with landing valves on each floor/landing for fire fighting purposes and permanently charged with water from a pressurized supply.

NOTE — For definitions of other terms, reference shall be made to good practice [4(2)].

3 FIRE PREVENTION

3.1 Classification of Building Based on Occupancy

3.1.1 *General Classification*

All buildings, whether existing or hereafter erected shall be classified according to the use or the character of occupancy in one of the following groups:

Group A	Residential
Group B	Educational
Group C	Institutional
Group D	Assembly
Group E	Business
Group F	Mercantile
Group G	Industrial
Group H	Storage
Group J	Hazardous

3.1.1.1 Minor occupancy incidental to operations in another type of occupancy shall be considered as part of the main occupancy and shall be classified under the relevant group for the main occupancy.

Examples of buildings in each group are given in **3.1.2** to **3.1.10**.

3.1.2 *Group A Residential Buildings*

These shall include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities, except any building classified under Group C.

Buildings and structures under Group A shall be further sub-divided as follows:

Sub-division A-1 Lodging or rooming houses

Sub-division A-2 One or two-family private dwellings

Sub-division A-3 Dormitories

Sub-division A-4 Apartment houses (flats)

Sub-division A-5 Hotels

Sub-division A-6 Hotels (Starred)

a) *Sub-division A-1 Lodging or rooming houses* — These shall include any building or group of buildings under the same management, in which separate sleeping accommodation for a total of not more than 40 persons (beds), on transient or permanent basis, with or without dining facilities but without cooking facilities for individuals is provided. This includes inns, clubs, motels and guest houses.

   A lodging or rooming house shall be classified as a dwelling in sub-division A 2 if no room in any of its private dwelling units is rented to more than three persons.

b) *Sub-division A-2 One or two-family private dwellings* — These shall include any private dwelling which is occupied by members of one or two families and has a total sleeping accommodation for not more than 20 persons.

   If rooms in a private dwelling are rented to outsiders, these shall be for accommodating not more than three persons per room.

   If sleeping accommodation for more than 20 persons is provided in any one residential building, it shall be classified as a building in sub-division A-1, A-3 or A-4 as the case may be.

c) *Sub-division A-3 Dormitories* — These shall include any building in which group sleeping accommodation is provided, with or without dining facilities for persons who are not members of the same family, in one room or a series of closely associated rooms under joint occupancy and single management, for example, school and college dormitories, students, and other hostels and military barracks.

d) *Sub-division A-4 Apartment houses (flats)* — These shall include any building or structure in which living quarters are provided for three or more families, living independently of each other and with independent cooking facilities, for example, apartment houses, mansions and chawls.

e) *Sub-division A-5 Hotels* — These shall include any building or group of buildings under single management, in which sleeping accommodation is provided, with or without dining facilities for hotels classified up to 4 Star Category.

f) *Sub-division A-6 Hotels (starred)* — These shall include the hotels duly approved by the concerned authorities as Five Star and above Hotels.

3.1.3 *Group B Educational Buildings*

These shall include any building used for school, college, other training institutions for day-care purposes involving assembly for instruction, education or recreation for not less than 20 students.

Buildings and structures under Group B shall be further sub-divided as follows:

Sub-division B-1 Schools up to senior secondary level

Sub-division B-2 All others/training institutions

a) *Sub-division B-1 Schools up to senior secondary level* — This sub-division shall include any building or a group of buildings under single management which is used for students not less than 20 in number.

b) *Sub-division B-2 All others/training institutions* — This sub-division shall include any building or a group of buildings under single management which is used for students not less than 100 in number.

In the case of temporary buildings/structures which are utilized for educational purposes, the provisions of **3.2.5.3** shall apply.

If residential accommodation is provided in the schools/institutions, that portion of occupancy shall be classified as a building in sub-division A-3.

3.1.4 *Group C Institutional Buildings*

These shall include any building or part thereof, which is used for purposes, such as medical or other treatment or care of persons suffering from physical or mental illness, disease or infirmity; care of infants, convalescents or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants.

Buildings and structures under Group C shall be further sub-divided as follows:

Sub-division C-1 Hospitals and sanatoria

Sub-division C-2 Custodial institutions

Sub-division C-3 Penal and mental institutions

a) *Sub-division C-1 Hospitals and sanatoria* — This sub-division shall include any building or a group of buildings under single management, which is used for housing persons suffering from physical limitations because of health or age, for example, hospitals, infirmaries, sanatoria and nursing homes.

b) *Sub-division C-2 Custodial institutions* — This sub-division shall include any building or a group of buildings under single management, which is used for the custody and care of persons, such as children, convalescents and the aged, for example, homes for the aged and infirm, convalescent homes and orphanages.

c) *Sub-division C-3 Penal and mental institutions* — This sub-division shall include any building or a group of buildings under single management, which is used for housing persons under restraint, or who are detained for penal or corrective purposes, in which the liberty of the inmates is restricted, for example, jails, prisons, mental hospitals, mental sanatoria and reformatories.

3.1.5 *Group D Assembly Buildings*

These shall include any building or part of a building, where number of persons not less than 50 congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes, for example, theatres, motion picture houses, assembly halls, auditoria, exhibition halls, museums, skating rinks, gymnasiums, restaurants, places of worship, dance halls, club rooms, passenger stations and terminals of air, surface and marine public transportation services, recreation piers and stadia, etc.

Buildings under Group D shall be further sub-divided as follows:

Sub-division D-1 Buildings having a theatrical or motion picture or any other stage and fixed seats for over 1 000 persons

Sub-division D-2 Buildings having a theatrical or motion picture or any other stage and fixed seats upto 1 000 persons

Sub-division D-3 Buildings without a permanent stage having accommodation for 300 or more persons but no permanent seating arrangement.

Sub-division D-4 Buildings without a permanent stage having accommodation for less than 300 persons with no permanent seating arrangement.

Sub-division D-5 All other structures including temporary structures designed for assembly of people not covered by sub-divisions D-1 to D-4, at ground level.

Sub-division D-6 Buildings having mixed occupancies providing facilities such as shopping, cinema theatres, and restaurants.

Sub-division D-7 All other structures, elevated or underground, for assembly of people not covered by sub-divisions D-1 to D-6.

a) *Sub-division D-1* — This sub-division shall

exhibitions and which has a raised stage, proscenium curtain, fixed or portable scenery or scenery loft, lights, motion picture houses, mechanical appliances or other theatrical accessories and equipment and which is provided with fixed seats for over 1 000 persons.

b) *Sub-division D-2* — This sub-division shall include any building primarily meant for use as described for sub-division D-1, but with fixed seats up to 1 000 persons.

c) *Sub-division D-3* — This sub-division shall include any building, its lobbies, rooms and other spaces connected thereto, primarily intended for assembly of people, but which has no theatrical stage or permanent theatrical and/or cinematographic accessories and has accommodation for 300 persons or more, for example, dance halls, night clubs, halls for incidental picture shows, dramatic, theatrical or educational presentation, lectures or other similar purposes having no theatrical stage except a raised platform and used without permanent seating arrangement; art galleries exhibition halls, community halls, marriage halls, places of worship, museums, lecture halls, passenger terminals and Heritage and Archeological Monuments.

d) *Sub-division D-4* — This sub-division shall include any building primarily intended for use as described in sub-division D-3, but with accommodation for less than 300 persons with no permanent seating arrangements.

e) *Sub-division D-5* — This sub-division shall include any building or structure permanent or temporary meant for assembly of people not covered by sub-divisions D-1 to D-4, for example, grandstands, stadia, amusement park structures, reviewing stands and circus tents.

f) *Sub-division D-6* — This sub-division shall include any building for assembly of people provided with multiple services/facilities like shopping, cinema theatres and restaurants, for example, multiplexes.

g) *Sub-division D-7* — This sub-division shall include any building or structure permanent or temporary meant for assembly of people not covered by D-1 to D-6, for example, underground or elevated railways.

3.1.6 *Group E Business Buildings*

These shall include any building or part of a building which is used for transaction of business (other than that covered by Group F and part of buildings covered facilities, etc. City halls, town halls, court houses and libraries shall be classified in this group so far as the principal function of these is transaction of public business and keeping of books and records.

Business buildings shall be further sub-divided as follows:

Sub-division E-1 Offices, banks, professional establishments, like offices of architects, engineers, doctors, lawyers and police stations.

Sub-division E-2 Laboratories, research establishments, libraries and test houses.

Sub-division E-3 Computer installations.

Sub-division E-4 Telephone exchanges.

Sub-division E-5 Broadcasting stations and T.V. stations.

3.1.7 *Group F Mercantile Buildings*

These shall include any building or part of a building, which is used as shops, stores, market, for display and sale of merchandise, either wholesale or retail.

Mercantile buildings shall be further sub-divided as follows:

Sub-division F-1 Shops, stores, departmental stores markets with area up to 500 m^2.

Sub-division F-2 Shops, stores, departmental stores markets with area more than 500 m^2.

Sub-division F-3 Underground shopping centres.

Storage and service facilities incidental to the sale of merchandise and located in the same building shall be included under this group.

3.1.8 *Group G Industrial Buildings*

These shall include any building or part of a building or structure, in which products or materials of all kinds and properties are fabricated, assembled, manufactured or processed, for example, assembly plants, industrial laboratories, dry cleaning plants, power plants, generating units, pumping stations, fumigation chambers, laundries, buildings or structures in gas plants, refineries, dairies and saw-mills, etc.

Buildings under Group G shall be further sub-divided as follows:

Sub-division G-1 Buildings used for low hazard industries.

Sub-division G-2 Buildings used for moderate hazard industries.

Sub-division G-3 Buildings used for high hazard industries.

The hazard of occupancy, for the purpose of the Code, shall be the relative danger of the start and spread of

fire, the danger of smoke or gases generated, the danger of explosion or other occurrences potentially endangering the lives and safety of the occupants of the buildings.

Hazard of occupancy shall be determined by the Authority on the basis of the fire loads of the contents, and the processes or operations conducted in the building, provided, however, that where the combustibility of the material, the flame spread rating of the interior finish or other features of the building or structure are such as to involve a hazard greater than the occupancy hazard, the greater degree of hazard shall govern the classification.

For determination of fire loads and fire load density for arriving at the classification of occupancy hazard, guidance including the calorific values of some common materials, is given at Annex A.

A broad classification of industrial and non-industrial occupancies into low, moderate and high hazard classes is given at Annex B, for guidance. Any occupancy not covered in Annex B, shall be classified in the most appropriate class depending on the degree of hazard.

Where different degrees of hazard of occupancy exist in different parts of a building, the most hazardous of those shall govern the classification for the purpose of this Code, except in cases where hazardous areas are segregated or protected as specified in the Code.

a) *Sub-division G-1* — This sub-division shall include any building in which the contents are of such comparative low combustibility and the industrial processes or operations conducted therein are of such a nature that there are hardly any possibilities for any self propagating fire to occur and the only consequent danger to life and property may arise from panic, fumes or smoke, or fire from some external source.

b) *Sub-division G-2* — This sub-division shall include any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with moderate rapidity or result in other hazardous situation and may give off a considerable volume of smoke, but from which neither toxic fumes nor explosions are to be feared in the event of fire.

c) *Sub-division G-3* — This sub-division shall include any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with extreme rapidity or result in other hazardous situation or from which poisonous fumes or explosions are to be feared in the event of a fire. For fire safety in petroleum and fertilizer plant, good practice [4(3)] may be referred.

3.1.9 *Group H Storage Buildings*

These shall include any building or part of a building used primarily for the storage or sheltering (including servicing, processing or repairs incidental to storage) of goods, ware or merchandise (except those that involve highly combustible or explosive products or materials) vehicles or animals, for example, warehouses, cold storage, freight depots, transit sheds, storehouses, truck and marine terminals, garages, hangers, grain elevators, barns and stables. Storage properties are characterized by the presence of relatively small number of persons in proportion to the area. Any new use which increase the number of occupants to a figure comparable with other classes of occupancy shall change the classification of the building to that of the new use, for example, hangars used for assembly purposes, warehouses used for office purposes, garage buildings used for manufacturing.

3.1.10 *Group J Hazardous Buildings*

These shall include any building or part of a building which is used for the storage, handling, manufacture or processing of highly combustible or explosive materials or products which are liable to burn with extreme rapidity and or which may produce poisonous fumes or explosions for storage, handling, manufacturing or processing which involve highly corrosive, toxic or noxious alkalis, acids or other liquids or chemicals producing flame, fumes and explosive, poisonous, irritant or corrosive gases; and for the storage, handling or processing of any material producing explosive mixtures of dust which result in the division of matter into fine particles subject to spontaneous ignition. Examples of buildings in this class are those buildings which are used for:

a) Storage, under pressure of more than 0.1 N/mm^2 and in quantities exceeding 70 m^3, of acetylene, hydrogen, illuminating and natural gases, ammonia, chlorine, phosgene, sulphur dioxide, carbon dioxide, methyloxide and all gases subject to explosion, fume or toxic hazard, cryogenic gases, etc;

b) Storage and handling of hazardous and highly flammable liquids, liquefiable gases like LPG, rocket propellants, etc;

c) Storage and handling of hazardous and highly flammable or explosive materials (other than liquids); and

d) Manufacture of artificial flowers, synthetic leather, ammunition, explosives and fireworks.

NOTE — A list of hazardous substances giving quantities, for which or exceeding which owners handling such substances are required to be covered under the Public Liability Insurance Act, has been notified under Government of India, Ministry of Environment and Forests Notification No. G.S.R. 347(E) dated 1 August 1996.

resembles its existing or proposed use.

3.1.12 Where change in the occupancy of any building places it in a different group or in a different sub-division of the same group, such building shall be made to comply with the requirements of the Code for the new group or its sub-division.

3.1.13 Where the new occupancy of a building is less hazardous, based on life and fire risk, than its existing occupancy, it shall not be necessary to conform to the requirements of the Code for the new group or its sub-division.

3.1.14 A certificate of occupancy shall be necessary, as required under Part 2 'Administration', before any change is effected in the character of occupancy of any building.

3.2 Fire Zones

3.2.1 *Demarcation*

The city or area under the jurisdiction of the Authority shall for the purpose of the Code, be demarcated into distinct zones, based on fire hazard inherent in the buildings and structures according to occupancy (*see* **3.1**), which shall be called as 'Fire Zones'.

3.2.2 *Number and Designation of Fire Zones*

3.2.2.1 The number of fire zones in a city or area under the jurisdiction of the Authority depends upon the existing layout, types of building construction (*see* **3.3**), classification of existing buildings based on occupancy (*see* **3.1**) and expected future development of the city or area. In large cities or areas, three fire zones may be necessary, while in smaller ones, one or two may be adequate.

3.2.2.2 The fire zones shall be made use of in land use development plan and shall be designated as follows:

a) *Fire Zone No. 1* — This shall comprise areas having residential (Group A), educational (Group B), institutional (Group C), and assembly (Group D), small business (Sub-divisions E-1) and retail mercantile (Group F) buildings, or areas which are under development for such occupancies.

b) *Fire Zone No. 2* — This shall comprise business (Sub-divisions E-2 to E-5) and industrial buildings (Sub-division G-1 and G-2), except high hazard industrial buildings (Sub-division G-3) or areas which are under development for such occupancies.

c) *Fire Zone No. 3* — This shall comprise areas having high hazard industrial buildings (Sub-division G-3), storage buildings (Group H) and buildings for hazardous used (Group J)

3.2.3 *Change in the Fire Zone Boundaries*

When the boundaries of any fire zone are changed, or when it is intended to include other areas or types of occupancies in any fire zone, it shall be done by following the same procedure as for promulgating new rules or ordinances or both.

3.2.4 *Overlapping Fire Zones*

3.2.4.1 When any building is so situated that it extends to more than one fire zone, it shall be deemed to be in the fire zone in which the major portion of the building or structure is situated.

3.2.4.2 When any building is so situated that it extends equally to more than one fire zone, it shall be deemed to be in the fire zone having more hazardous occupancy buildings.

3.2.5 *Temporary Buildings or Structures*

3.2.5.1 Temporary buildings and structures shall be permitted only in Fire Zones No. 1 and 2 as the case may be, according to the purpose for which these are to be used, by special permit from the Authority for a limited period and subject to such conditions as may be imposed in the permit.

3.2.5.2 Such buildings and temporary structures shall be completely removed on the expiry of the period specified in the permit.

3.2.5.3 Adequate fire precautionary measures in the construction of temporary structures and *PANDALS* shall be taken in accordance with good practice [4(4)].

3.2.6 *Restrictions on the Type of Construction for New Buildings*

3.2.6.1 Buildings erected in Fire Zone No. 1 shall conform to construction of Type 1, 2, 3 or 4.

3.2.6.2 Buildings erected in Fire Zone No. 2 shall conform to construction of Type 1, 2 or 3.

3.2.6.3 Buildings erected in Fire Zone No. 3 shall conform to construction of Type 1 or 2.

3.2.7 *Restrictions on Existing Buildings*

The existing buildings in any fire zone shall not be required to comply with the requirement of the Code unless these are altered, or in the opinion of the Authority, such building constitutes a hazard to the safety of the adjacent property or the occupants of the building itself or is an unsafe building. In the event of alteration, it shall be necessary to obtain permission of the Authority for such alteration consistent with fire hazard (*see* Part 2 'Administration').

Alterations/modifications/renovations shall be accomplished so as to ensure conformity with all the

safety requirements of the new buildings. Such alterations shall not in anyway bring down level of fire and life safety below that which existed earlier. Any addition or alterations or construction of cubicles or partitioning for floor area exceeding 500 m^2 for all high rise buildings shall be with approval of local fire authority.

3.3 Types of Construction

3.3.1 *General*

The design of any building and the type of materials used in its construction are important factors in making the building resistant to a complete burn-out and in preventing the rapid spread of fire, smoke or fumes, which may otherwise contribute to the loss of lives and property.

The fire resistance of a building or its structural and non-structural elements is expressed in hours against a specified fire load which is expressed in kcal/m^2, and against a certain intensity of fire. The fire-resistance test for structural element shall be done in accordance with good practice [4(5)]. For the purpose of the Code, the types of construction according to fire resistance shall be classified into four categories, namely, Type 1 Construction, Type 2 Construction, Type 3 Construction and Type 4 'Construction'. The fire resistance ratings for various types of construction for structural and non-structural members shall be as given in Table 1.

For buildings 15 m in height or above non-combustible materials should be used for construction and the internal walls of staircase enclosures should be of brick work or reinforced concrete or any other material of construction with minimum of 2 h rating. The walls for the chimney shall be of Type 1 and Type 2 Construction depending on whether the gas temperature is above 200°C or less.

3.3.2 It is required that an element/component shall have the requisite fire resistance rating when tested in acco"rdance with the accepted standard [4(1)]. Tables 2 to 18 provide available data regarding fire resistance ratings of various building components such as walls, columns, beams and floors. Fire damage assessment, post fire structural safety assessment of various structural elements of the building and adequacy of the structural repairs can be done by the fire resistance ratings mentioned in Tables 2 to 18.

Table 1 Fire Resistance Ratings of Structural and Non-Structural Elements (Hours)

(*Clause* 3.3.1)

Sl No.	Structural Element		Type of Construction			
			Type 1	Type 2	Type 3	Type 4
(1)	(2)		(3)	(4)	(5)	(6)
i)	Exterior walls:					
	a) Fire separation less than 3.7 m	a) Bearing	4	2	2	1
		b) Non-bearing	2	1½	1	1
	b) Fire separation of 3.7 m or more but less than 9 m	a) Bearing	4	2	2	1
		b) Non-bearing	1½	1	1	1
	c) Fire separation of 9 m or more	a) Bearing	4	2	2	1
		b) Non-bearing	1	1	1	1
ii)	Fire resisting walls		4	2	2	2
iii)	Fire separation assemblies (like fire check doors)		4	2	2	2
iv)	Fire enclosures of exitways, hallways and stairways		2	2	2	2
v)	Shaft other than exitways, elevator and hoistways		2	2	2	2
vi)	Exitway access corridors		1	1	1	1
vii)	Vertical separation of tenant spaces		1	1	1	1
viii)	Dwelling unit separation		1	1	1	1
	Non-load bearing partitions			— At least half an hour —		
ix)	Interior bearing walls, bearing partitions, columns, girders, trusses (other than roof trusses) and framing	a) Supporting more than one floor	4	2	2	2
		b) Supporting one floor only	3	1½	1	1
		c) Supporting a roof only	3	1½	1	1
x)	Structural members support walls		3	1½	1	1
xi)	Floor construction including walls		3	1½	1	1
xii)	Roof construction	a) 5 m or less in height to lowest member	2	1½	1	1
		b) More than 5 m but less than 6.7 m in height to lowest member	1	1	1	1
		c) 6.7 m or more in height to lowest member	0	0	0	0

Table 2 Masonry Walls: Solid (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish for a Fire Resistance (Hours) of									
		Load Bearing					Non-load Bearing				
		1	1½	2	3	4	1	1½	2	3	4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	Reinforced[1] cement concrete	120 (25)[2]	140 (25)[2]	160 (25)[2]	200 (25)[2]	240 (25)[2]					
ii)	Unreinforced cement concrete	150	175	—	—	—					
iii)	No-fines concrete with :										
	a) 13 mm cement/sand or gypsum/sand	—	—	—	—	—	150	150	150	150	150
	b) 13 mm light weight aggregate gypsum plaster	—	—	—	—	—	150	150	150	150	150
iv)	Bricks of clay:										
	a) Without finish	90	100	100	170	170	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
v)	Bricks of sand lime:										
	a) Without finish	90	100	100	190	190	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
vi)	Blocks of concrete:										
	a) Without finish	90	100	100	—	—	75	90	100	140	150
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	75	75	90	100
	c) With 13 mm cement/sand or gypsum/ sand						75	90	90	100	140
vii)	Blocks of lightweight concrete:										
	a) Without finish	90	100	100	140	150	75	75	75	125	140
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	50	63	75	75	75
	c) With 13 mm cement/sand or gypsum/ sand	—	—	—	—	—	75	75	75	90	100
viii)	Blocks of aerated concrete:										
	a) Without finish	90	100	100	140	180	50	63	63	75	100
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	100	100	150					

[1] Walls containing at least 1 percent of vertical reinforcement.

[2] Minimum thickness of actual cover to reinforcement.

Table 3 Masonry Walls: Hollow (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish for a Fire Resistance (Hours) of										
		Load Bearing					Non-load Bearing					
		1	1½	2	3	4	½	1	1½	2	3	4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	Bricks of clay:											
	a) Without finish	170	170	170	200	200	75	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	100	100	170	170	170	75	75	90	90	90	100
ii)	Blocks of concrete:											
	a) Without finish						90	125	125	140	140	150
	b) With 13 mm cement/sand or gypsum/sand	190	200	200	—	—	90	125	125	140	140	140
	c) With 13 mm lightweight aggregate gypsum plaster						75	90	90	100	125	125
iii)	Blocks of lightweight concrete:											
	a) Without finish	100	100	100	—	—	75	90	90	100	140	150
	b) With 13 mm cement/sand or gypsum/sand	—	—	—	—	—	75	75	75	100	140	140
	c) With 13 mm lightweight aggregate gypsum plaster	—	—	—	—	—	63	63	63	75	90	100

Table 4 Framed Construction, Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials/Timber Studs at Centres not Exceeding 600 mm, Faced on Each Side with	Minimum Thickness (mm) of Protection for a Fire Resistance of 1h
(1)	(2)	(3)
i)	Plasterboard layers with joints staggered, joints in outer layer taped and filled — Total thickness for each face	25
ii)	One layer of 12.7 mm plasterboard with a finish of lightweight aggregate gypsum plaster	13
iii)	Metal lath and plaster, thickness of plaster:	
	a) Sanded gypsum plaster (metal lathing grade)	22
	b) Lightweight aggregate gypsum plaster	13

Table 5 Framed Construction, Non-Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Nature of Construction and Materials/Steel or Timber Frame at Centres not Exceeding 600 mm, Facings on Both Sides of	Stud Construction	Minimum Thickness (mm) of Protection for a Fire Resistance			
		½ h	1 h	1½ h	2 h
(1)	(2)	(3)	(4)	(5)	(6)
A) Dry lining with materials fixed direct to studs (without plaster finish)					
1. One layer of plasterboard with taped and filled joints	Timber or steel	12.7			
2. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled — Total thickness for each face	Timber or steel	19	25		
3. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	Timber or steel	9	12		
4. One layer of wood wool slabs	Timber	25			
5. One layer of chipboard or of plywood	Timber or steel	18			
B) Lining with materials fixed direct to suds, with plaster finish:					
Plasterboard of thickness:	Timber or steel				
a) With not less than 5 mm gypsum plaster finish		9.5			
b) With not less than 13 mm gypsum plaster finish			12.7		
C) Wet finish:					
Metal lath and plaster, thickness of plaster:					
a) Sanded gypsum plaster	Timber or steel	13			
b) Lightweight aggregate gypsum plaster	Timber		13	19	25
	Steel		13		

Table 6 Framed External Walls Load Bearing (Required to Resist Fire from One Side at a Time)

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 1 h
(1)	(2)	(3)
	Timber studs at centers not exceeding 600 mm with internal linings of :	
i)	Plasterboard layers with joints in outer layer taped and filled, total thickness of plasterboard	25

Table 7 Framed External Walls Non-Load Bearing Required to Resist Fire only from Inside the Building (A)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance					
	½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Steel frame with an external cladding of non-combustible sheets (excluding sheet steel), with a steel supporting framework and internal lining of:						
1. Metal lath and plaster, thickness of plaster:						
a) Sanded gypsum plaster (metal lathing grade)	13	13				
b) Lightweight aggregate gypsum plaster	10	13	15	15	15	19
2. Two layer of plasterboard with joints staggered joints in outer layer taped and filled — Total thickness	21	32				
3. Plasterboard of thickness:						
a) With not less than 5 mm gypsum plaster finish	12.7					
b) With not less than 13 mm gypsum plaster finish	9.5					
c) With not less than 10 mm lightweight aggregate gypsum plaster	9.5					
4. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9	9	12	12	12	12
5. One layer of wood/wool slabs without finish		50				
6. One layer of compressed straw building slabs:						
a) Without finish	50					
b) With not less than 5 mm gypsum plaster finish		50				
7. Aerated concrete blocks	50	50	63	63	75	100
8. Bricks of clay:						
a) Without finish	75	75	90	90	100	100
b) With not less than 13 mm lightweight aggregate gypsum plaster			75	75	90	90

Table 8 Framed External Walls Non-Load Bearing Required to Resist Fire only from Inside the Building (B)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection to Provide Sufficient Insulation to Achieve a Modified Fire Resistance of Up to 4 h
(1)	(2)
Steel frame with an external cladding of sheet steel fully lapped, steel bolted and fixed to steel sheeting rails, with timber or steel supporting framework and internal lining of:	
1. Metal lath and plaster, thickness of plaster:	
a) Sanded gypsum plaster (metal lathing grade)	13
b) Lightweight aggregate gypsum plaster	10
2. One layer of plasterboard with joints taped and filled	12.7
3. Plasterboard of thickness with not less than 5 mm gypsum plaster finish	9.5
4. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9
5. One layer of wood/wool slabs	25
6. One layer of compressed straw building slabs	50
7. One layer of chipboard or of plywood	18
8. Aerated concrete blocks	50
9. Bricks of clay	75
10. Any internal decorative lining with a cavity fill independently supported and retained in position of mineral fibre insulating material (excluding glass) at a density of 48 kg/m^3	50

Table 9 Framed Walls Non-Load Bearing Required to Resist Fire only from Inside the Building (C)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 1½ h
(1)	(2)
Timber frame with external cladding of weather boarding or external plywood, 9.5 mm with an internal lining of:	
1. Plasterboard not less than 9.5 mm thick, finished with:	
a) Gypsum plaster	13
b) Lightweight aggregate gypsum plaster	10
2. Plasterboard not less than 12.7 mm thick, finished with:	
a) Gypsum plaster	10
b) Lightweight aggregate gypsum plaster	10
3. One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9 12

Table 10 Reinforced Concrete Columns

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Fully exposed	Width	150	200	250	300	400	450
		Cover	40	40	40	40	40	40
ii)	50 percent exposed	Width	125	160	200	200	300	350
		Cover	40	40	40	40	40	40
iii)	One face exposed	Thickness	100	120	140	160	200	240
		Cover	40	40	40	40	40	40

Table 11 Concrete Beams

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	Width	200	200	200	200	240	280
		Cover	20	20	20	40	60[1)]	70[1)]
ii)	Reinforced concrete (continuous)	Width	200	200	200	200	240	280
		Cover	20	20	20	30	40	50[1)]
iii)	Prestressed concrete (simply supported)	Width	100	120	150	200	240	280
		Cover	25	40	55	70	80	90
iv)	Prestressed concrete (continuous)	Width	80	100	120	150	200	240
		Cover	20	30	40	55	70	80

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 12 Concrete Floors

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	Thickness	75	95	110	125	150	170
		Cover	20	20	25	35	45[1)]	55[1)]
ii)	Reinforced concrete (continuous)	Thickness	75	95	110	125	150	170
		Cover	20	20	20	25	35	45[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 13 Concrete Floors: Ribbed Open Soffit

(*Clause* 3.3.2)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	Thickness of floor	75	95	110	125	150	170
		Rib width	125	125	125	125	150	175
		Cover	20	20	35	45	55	65
ii)	Reinforced concrete (continuous)	Thickness	75	95	110	125	150	170
		Width	125	125	125	125	150	175
		Cover	20	20	20	35	45	55

Table 14 Encased Steel Columns, 203 mm × 203 mm (Protection Applied on Four Sides)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of				
	1 h	1½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)
A) Hollow protection (without an air cavity over the flanges):					
1. [1] Metal lathing with trowelled lightweight aggregate gypsum plaster	13	15	20	32	
2. Plasterboard with 1.6 mm wire binding at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:					
a) 9.5 mm plaster board	10	15			
b) 19 mm plaster board			10	13	20
3. Asbestos insulating boards, thickness of board:					
a) Single thickness of board, with 6 mm cover fillets at transverse joints		19	25		
b) Two layers, of total thickness				38	50
4. Solid bricks of clay, composition or sand lime, reinforced in every horizontal joint, unplastered	50	50	50	75	100
5. Aerated concrete blocks	60	60	60		
6. Solid blocks of lightweight concrete hollow protection (with an air cavity over the flanges)	50	50	50	60	75
B) Asbestos insulating board screwed to 25 mm asbestos battens	12	19			
C) Solid protections					
1. Concrete, not leaner than 1:2:4 mix (unplastered):					
a) Concrete not assumed to be load bearing, reinforced [2]	25	25	25	50	75
b) Concrete assumed to be load bearing	50	50	50	75	75
2. Lightweight concrete, not leaner than 1:2:4 mix (unplastered): concrete not assumed to be load bearing, reinforced [2]	25	25	25	40	60

[1] So fixed or designed, as to allow full penetration for mechanical bond.

[2] Reinforcement shall consist of steel binding wire not less than 2.3 mm in thickness, or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.

Table 15 Encased Steel Beams, 406 mm × 176 mm (Protection Applied on Three Sides)

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of					
	½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
A) Hollow protection (without an air cavity beneath the lower flange):						
1. [1] Metal lathing with trowelled lightweight aggregate gypsum plaster	13	13	15	20	25	
2. Plasterboard with 1.6 mm wire binding[2] at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:						
a) 9.5 mm plaster board	10	10	15			
b) 19 mm plaster board	10	10		13	20	
3. Asbestos insulating boards, thickness of board:						
a) Single thickness of board, with 6 mm cover fillets at transverse joints			19	25		
b) Two layers, of total thickness					38	50
B) Hollow protection (with an air cavity below the lower flange):						
1. Asbestos insulating board screwed to 25 mm asbestos battens	9	12				
C) Solid protection:						
1. Concrete, not leaner than 1:2:4 mix (unplastered):						
a) Concrete not assumed to be load bearing, reinforced [3]	25	25	25	25	50	75
b) Concrete assumed to be load bearing	50	50	50	50	75	75
2. Lightweight concrete[4], not leaner than 1:2:4 (mix) unplastered	25	25	25	25	40	60

[1] So fixed or designed, as to allow full penetration for mechanical bond.

[2] Where wire binding cannot be used, expert advice should be sought regarding alternative methods of support to enable the lower edges of the plasterboard to be fixed together and to the lower flange, and for the top edge of the plasterboard to be held in position.

[3] Reinforcement shall consist of steel binding wire not less than 2.3 mm in thickness or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.

[4] Concrete not assumed to be load bearing, reinforced.

Table 16 Timber Floors — Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 21 mm Finished Thickness

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of		
	½ h	1 h	2 h
(1)	(2)	(3)	(4)
37 mm (minimum) timber joists with a ceiling of:			
1. Timber lathing and plaster, plaster of thickness	15		
2. Metal lathing and plaster, thickness of plaster:			
a) Sanded gypsum plaster (metal lathing grade)	15		
b) Lightweight aggregate gypsum plaster	13	13	25
3. One layer of plasterboard with taped and filled joints	12.7		
4. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	19	31	
5. One layer of plasterboard not less than 9.5 mm thick, finished with:			
a) Gypsum plaster	5		
b) Sanded gypsum plaster	13		
c) Lightweight aggregate gypsum plaster	13		
6. One layer of plasterboard not less than 12.7 mm thick, finished with:			
a) Gypsum plaster	5		
b) Lightweight aggregate gypsum plaster	10		
7. One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12	

Table 17 Timber Floors — Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 15 mm Finished Thickness

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of		
	1½ h	1 h	2 h
(1)	(2)	(3)	(4)
37 mm (minimum) timber joists with a ceiling of:			
1. Timber lathing and plaster, plaster of thickness	15		
2. Metal lathing and plaster, thickness of plaster for:			
a) Sanded gypsum plaster (metal lathing grade)	15		
b) Lightweight aggregate gypsum plaster	13	13	25
3. One layer of plasterboard with taped and filled joints	12.7		
4. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	22	31	
5. One layer of plasterboard not less than 9.5 mm thick, finish with:			
a) Gypsum plaster	5		
b) Sanded gypsum plaster	15		
c) Lightweight aggregate gypsum plaster	13		
6. One layer of plasterboard not less than 12.7 mm thick, finished with:			
a) Gypsum plaster	5		
b) Lightweight aggregate gypsum plaster	10		
7. One layer of asbestos insulating board, with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12[1)]	

[1)] Finished on top with 25 mm minimum thick glass fibre or mineral wool laid between joints.

Table 18 Timber Floors — Any Structurally Suitable Flooring of Timber or Lignocelluloses Boards

(*Clause* 3.3.2)

Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of	
	½ h	1 h
(1)	(2)	(3)
37 mm (minimum) timber joists with a ceiling of:		
1. Timber lathing and plaster, plaster of thickness	15	
2. Metal lathing and plaster, thickness of plaster for:		
a) Sanded gypsum plaster (metal lathing grade)	15	
b) Lightweight aggregate gypsum plaster	13	19
3. One layer of plasterboard with joints taped and filled and backed by timber	12.7	
4. Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	25	
5. Two layers of plasterboard, each not less than 9.5 mm thick, joints between boards staggered and outer layer finished with gypsum plaster	5	
6. One layer of plasterboard not less than 9.5 mm thick, finish with:		
a) Sanded gypsum plaster	13	
b) Lightweight aggregate gypsum plaster	15	
7. One layer of plasterboard not less than 12.7 mm thick, finished with:		
a) Sanded gypsum plaster	15	
b) Lightweight aggregate gypsum plaster	13	
8. One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	12	

3.3.3 *Steel Construction*

Load bearing steel beams and columns of buildings having total covered area of 500 m^2 and above shall be protected against failure/collapse of structure in case of fire. This could be achieved by use of appropriate methodology using suitable fire resistance rated materials alongwith suppression system {*see* Table 14, Table 15 and *also* accepted standard [4(5)]}.

3.4 General Requirements of All Individual Occupancies

3.4.1 *General*

All buildings shall satisfy certain requirements which contribute, individually and collectively, to the safety of life from fire, smoke, fumes and panic arising from these or similar causes. There are, however, certain general principles and common requirements which are applicable to all or most of the occupancies.

3.4.2 *Exceptions and Deviations*

Exceptions and deviations to the general provisions of requirements of individual occupancies are given as applicable to each type of occupancy in **6.1** to **6.9**. In case of practical difficulty or to avoid unnecessary hardship, without sacrificing reasonable safety, the Authority may grant exemptions from the Code.

3.4.3 *Occupation of Buildings under Construction*

3.4.3.1 A building or portion of the building may be occupied during construction, repairs, alterations or additions only if all means of exit and fire protection measures are in place and continuously maintained for the occupied part of the building.

3.4.3.2 A high rise building during construction shall be provided with the following fire protection measures, which shall be maintained in good working condition at all the times:

a) Dry riser of minimum 100 mm diameter pipe with hydrant outlets on the floors constructed with a fire service inlet to boost the water in the dry riser and maintenance should be as per the requirements laid down in good practice [4(6)].

b) Drums filled with water of 2 000 litres capacity with two fire buckets on each floor; and

c) A water storage tank of minimum 20 000 litres capacity, which may be used for other construction purposes also.

3.4.4 *Maximum Height*

Every building shall be restricted in its height above the ground level and the number of storeys, depending upon its occupancy and the type of construction. The height shall be measured as specified in Part 3 'Development Control Rules and General Building Requirements'. The maximum permissible height for any combination of occupancy and types of construction should necessarily be related to the width of street fronting the building, or floor area ratios and the local fire fighting facilities available.

3.4.5 *Floor Area Ratio*

The comparative floor area ratios for different occupancies and types of construction are given in Table 19 (*see also* Part 3 'Development Control Rules and General Building Requirements').

Table 19 Comparative Floor Area Ratios for Occupancies Facing One Public Street Atleast 9 m Wide

(*Clauses* 2.6 *and* 3.4.5)

Occupancy Classification	Type of Construction			
	Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)
Residential	UL	2.0	1.4	1.0
Educational	UL	2.0	1.4	1.0
Institutional	UL	1.5	1.0	0.8
Assembly	UL	1.0	0.7	0.5
Business	UL	2.9	2.3	1.6
Mercantile	8.0	1.8	1.4	1.0
Industrial	7.5	1.9	1.6	1.3
Storage (*see* Note 5)	6.0	1.5	1.3	1.0
Hazardous (*see* Note 5)	2.8	1.1	0.9	NP

UL — Unlimited.

NP — Not permitted.

NOTES

1 The FAR values given in this table are subject to overall restrictions on the heights of buildings in the case of educational, institutional, assembly, storage and hazardous occupancies as specified in col 2 of Table 23.

2 This table has been prepared, taking into account the combustible content in the different occupancies as well as the fire resistance offered by the type of construction.

3 This table should be modified by the Authority, taking into account the other aspects as given below:

a) Density in terms of dwelling units per hectare;

b) Traffic considerations;

c) Parking spaces;

d) Local fire fighting facilities; and

e) Water supply, drainage and sanitation requirements.

4 The FAR values specified in this table may be increased by 20 percent for the following services:

a) A basement or cellar space under a building constructed on stilts and used as a parking space and air-conditioning plant room used as accessory to the principal use;

b) Watchman's booth, pumphouse, garbage shaft, electric cabin or sub-station and other utility structures meant for the services of the building under considerations;

c) Projections and accessory buildings as specifically exempted under the Code; and

d) Staircase room and lift rooms above the topmost storey; architectural feature; and chimneys and elevated tanks of dimensions as permissible under the Code; the area of the lift shaft shall be taken only on one floor.

5 In so far as single storey storage and hazardous occupancies are concerned, they would be further governed by volume to plot area ratio (VPR) to be decided by the Authority.

3.4.5.1 Each portion of a building, which is separated by one or more continuous fire resisting walls, having a fire resistance of not less than 2 h, extending from the foundation to 1 m above the roof at all points, may

area, provided openings, if any, in the separating wall are also protected by fire assemblies of not less than 2 h.

3.4.6 *Open Spaces*

The open spaces around or inside a building shall conform to the requirements of Part 3 'Development Control Rules and General Building Requirements'.

3.4.6.1 For high rise buildings, the following additional provisions of means of access to the building shall be ensured (*see* Part 3 'Development Control Rules and General Building Requirements'):

a) The width of the main street on which the building abuts shall not be less than 12 m and one end of this street shall join another street not less than 12 m in width;

b) The road shall not terminate in a dead end; except in the case of residential building, up to a height of 30 m.

c) The compulsory open spaces around the building shall not be used for parking; and

d) Adequate passageway and clearances required for fire fighting vehicles to enter the premises shall be provided at the main entrance; the width of such entrance shall be not less than 4.5 m. If an arch or covered gate is constructed, it shall have a clear head-room of not less than 5 m.

3.4.7 *Mixed Occupancy*

When any building is used for more than one type of occupancy, then in so far as fire safety is concerned, it shall conform to the requirements for the occupancies of higher hazard. Unless the high hazard area is separated by separating walls of 4 h rating, the occupancies shall not be treated individually.

3.4.8 *Openings in Separating Walls and Floors*

At the time of designing openings in separating walls and floors, particular attention shall be paid to all such factors as will limit fire spread through these openings and maintain fire rating of the structural member.

3.4.8.1 For Types 1 to 3 construction, a doorway or opening in a separating wall on any floor shall be limited to 5.6 m^2 in area with a maximum height/width of 2.75 m. Every wall opening shall be protected with fire-resisting doors having the fire rating of not less than 2 h in accordance with accepted standard [4(7)]. All openings in the floors shall be protected by vertical enclosures extending above and below such openings, the walls of such enclosures having a fire resistance of not less than 2 h and all openings therein being

3.4.8.2 For Type 4 construction, openings in the separating walls or floors shall be fitted with 2 h fire-resisting assemblies.

3.4.8.3 Openings in walls or floors which are necessary to be provided to allow passages of all building services like cables, electrical wirings, telephone cables, plumbing pipes, etc, shall be protected by enclosure in the form of ducts/shafts having a fire resistance not less than 2 h. The inspection door for electrical shafts/ducts shall be not less than 2 h and for other services shafts/ducts, the same shall have fire resistance not less than 1 h. Medium and low voltage wiring running in shafts/ducts, shall either be armoured type or run through metal conduits. Further, the space between the conduits pipes and the walls/ slabs shall be filled in by a filler material having fire resistance rating of not less than 1 h.

NOTE — In the case of buildings where it is necessary to lower or lift heavy machinery or goods from one floor to the other, it may be necessary to provide larger openings in the floor. Such openings shall be provided with removable covers which shall have the same strength and fire resistance as the floor.

3.4.8.4 *Vertical opening*

Every vertical opening between the floors of a building shall be suitably enclosed or protected, as necessary, to provide the following:

a) Reasonable safety to the occupants while using the means of egress by preventing spread of fire, smoke, or fumes through vertical openings from floor to floor to allow occupants to complete their use of the means of egress. Further it shall be ensured to provide a clear height of 2 100 mm in the passage/escape path of the occupants.

b) Limitation of damage to the building and its contents.

3.4.9 *Fire Stop or Enclosure of Openings*

Where openings are permitted, they shall not exceed three-fourths the area of the wall in the case of an external wall and they shall be protected with fire resisting assemblies or enclosures having a fire resistance equal to that of the wall or floor in which these are situated. Such assemblies and enclosures shall also be capable of preventing the spread of smoke or fumes through the openings so as to facilitate the safe evacuation of building in case of a fire {*see also* accepted standard [4(8)]}.

3.4.10 *Electrical Installations*

For requirements regarding electrical installations from the point of view of fire safety, reference may be made

to good practice [4(9)] (*see also* Part 8 'Building Services, Section 2 Electrical and Allied Installations').

3.4.11 *Air-conditioning and Ventilation*

Air-conditioning and ventilation requirements of different rooms or areas in any occupancy shall be as given in Part 8 'Building Services, Section 1 Lighting and Ventilation and Section 3 Air-conditioning, Heating and Mechanical Ventilation'.

3.4.11.1 Air-conditioning and ventilating systems shall be so installed and maintained as to minimize the danger of spread of fire, smoke or fumes from one floor to other or from outside to any occupied building or structure (*see* **C-1.17**).

3.4.11.2 Air-conditioning and ventilating systems circulating air to more than one floor or fire area shall be provided with dampers designed to close automatically in case of fire and thereby preventing spread of fire or smoke and shall be in accordance with the accepted standard [4(10)]. Such a system shall also be provided with automatic controls to stop fans in case of fire, unless arranged to remove smoke from a fire, in which case these shall be designed to remain in operation.

3.4.11.3 Air-conditioning system serving large places of assembly (over 1 000 persons), large departmental stores or hotels with over 100 rooms in a single block shall be provided with effective means for preventing circulation of smoke through the system in the case of a fire in air filters or from other sources drawn into the system, and shall have smoke sensitive devices for actuation in accordance with the accepted standards [4(11)].

3.4.11.4 From fire safety point of view, separate air handling units for the various floors shall be provided so as to avoid the hazards arising from spread of fire and smoke through the air-conditioning ducts. The requirements of air-conditioning ducts shall be in accordance with good practice [4(12)].

3.4.11.5 For normal operation, air changes schedule shall be as given in Part 8 'Building Services, Section 3 Air-conditioning, Heating and Mechanical Ventilation'.

3.4.12 *Smoke Venting*

3.4.12.1 Smoke venting facilities for safe use of exits in windowless buildings, underground structures, large area factories, hotels and assembly buildings (including cinema halls) shall be automatic in action with manual controls in addition.

3.4.12.2 Natural draft smoke venting shall utilize roof vents or vents in walls at or near the ceiling level; such vents shall be normally open, or, if closed, shall be designed for automatic opening in case of fire, by release of smoke sensitive devices.

3.4.12.3 Where smoke venting facilities are installed for purposes of exit safety, these shall be adequate to prevent dangerous accumulation of smoke during the period of time necessary to evacuate the area served, using available exit facilities with a margin of safety to allow for unforeseen contingencies. It is recommended that smoke exhaust equipment should have a minimum capacity of 12 air changes per hour. Where mechanical venting is employed, it shall be firesafe.

3.4.12.4 The discharge apertures of all natural draft smoke vents shall be so arranged as to be readily accessible for opening by fire service personnel.

3.4.12.5 Power operated smoke exhausting systems shall be substituted for natural draft vents only by specific permission of the Authority.

3.4.13 *Heating*

Installation of chimney and heating apparatus shall be in accordance with good practice [4(13)].

3.4.14 *Additional Precautions*

In addition to the factors covered by **3.4.2** to **3.4.12** there are certain aspects, applicable to particular occupancies only, which may effect the spread of fumes and thus the safe evacuation of the building in case of fire. Some such aspects are:

a) interior finish and decoration;
b) seating, aisles, railings, turnstiles and revolving doors in places of assembly;
c) service equipment and storage facilities in buildings other than storage buildings; and
d) hazards on stage, in waiting spaces, projection booths, etc, in theatres and cinemas.

3.4.15 *Surface Interior Finishes*

3.4.15.1 The use of combustible surface finishes on walls (including facade of the building) and ceilings affects the safety of the occupants of a building. Such finishes tend to spread the fire and even though the structural elements may be adequately fire resistant, serious danger to life may result. It is, therefore, essential to have adequate precautions to minimize spread of flame on wall, facade of building and ceiling surfaces.

The finishing materials used for various surfaces and décor shall be such that it shall not generate toxic smoke/fumes.

3.4.15.2 The susceptibility to fire of various types of wall surfaces is determined in terms of the rate of spread of flame. Based on the rate of spread of flame, surfacing material shall be considered as divided into four classes as follows {*see also* good practice [4(14)]}.

Class 1 Surfaces of very low flame spread.

Class 2 Surfaces of low flame spread.

Class 3 Surfaces of medium flame spread.

Class 4 Surfaces of rapid flame spread.

3.4.15.3 The uses for which surface materials falling into various classes shall be adopted in building construction are given below:

Class 1	*Class 2*	*Class 3*
May be used in any situation	May be used in any situation, except on walls, facade of the building, staircase and corridors	May be used only in living rooms and bed rooms (but not in rooms on the roof) and only as a lining to solid walls and partitions; not on staircases or corridors or facade of the building.

NOTE — Panelling (lining) shall be permitted in a limited area. It shall not be permitted in a vestibule.

3.4.15.4 Materials of Class 4 which include untreated wood fibreboards may be used with due fire retardant treatment as ceiling lining, provided the ceiling is at least, 2.4 m from the top surface of the floor below, and the wall surfaces conform to requirements of class [*see* Note *under* **3.4.15.3**] Class 4 materials shall not be used in kitchens, corridors and staircases. Some materials contain bitumen and, in addition to risk from spread of fire, emit dense smoke on burning; such materials shall be excluded from use under these conditions and shall also not be used for construction of ceiling where the plenum is used for return air in air-conditioned buildings [*see also* **5.1.7**(m)].

3.4.15.5 When frames, walls, partitions or floors are lined with combustible materials, the surfaces on both sides of the materials shall conform to the appropriate class, because there is considerable danger from fire starting and rapidly spreading within the concealed cavity unknown to the occupants whose escape may be hampered there by. For detailed information on materials and details of construction with their fire-resistance rating, reference may be made to good practice [4(15)].

3.4.16 *Glazing*

3.4.16.1 Building of Types 1 to 4 construction shall employ one of the two types of glazing described in **3.4.16.2** and **3.4.16.3** except that Type 4 construction may have the alternative of hardwood sashes or frames or both.

3.4.16.2 Wired glass shall comply with the following requirements:

a) *Wired glass* — The wired glass shall be of minimum half hour fire resistance rating.

b) *Sashes and frames* — The sashes or frames or both shall be entirely of iron or other suitable metal such as stainless steel, securely bolted or keyed into the wall, except in the case of panels in internal doors.

c) *Setting of glass* — The panels of glass shall be set in rebates or grooves not less than 6.0 mm in width or depth, with due allowance for expansion, and shall be secured by hard metal fastenings to the sashes or frames independently of any cement or putty used for weather-proofing purposes.

3.4.16.3 Electro-copper glazing shall comply with the following requirements:

a) *Electro-copper glazing* — The electro-copper glazing shall be of minimum half hour fire resistance rating.

b) *Sashes and frames* — The sashes or frames or both shall be entirely of iron or other hard metal, securely bolted or keyed into the wall, except when in panels in internal doors.

c) *Fixing of sectional lights* — The sectional lights shall be set in rebate or grooves not less than 6.5 mm in width or depth, with due allowance for expansion and shall be secured by hard metal fastenings to the sashes or frames independently of any lead, cement or putty used for weather-proofing purposes.

3.4.16.4 Maximum permissible area shall be 5 m^2 for protection by wired glass or electro-copper glazing.

3.4.16.5 *Casement*

Hard metal casements, not exceeding 0.8 m^2 fitted with wired glass or electro-copper glazing in accordance with **3.4.16.2** and **3.4.16.3**, secured to the frames by hard metal hinges not more than 600 mm apart and by fastening at top, centre and bottom shall be permissible.

3.4.17 *Skylights*

3.4.17.1 Wired glass for skylights or monitor lights shall comply with the following requirements:

a) *Wired glass for skylights or monitor lights* — The wired glass for skylights or monitor lights shall be of minimum half hour fire resistance rating.

b) *Frames and glazing* — The frame shall be continuous and divided by bars spaced at not more than 700 mm centres. The frame and bars shall be of iron or other hard metal, and supported on a curb either of metal or of wood covered with sheet metal. The toughened glass

shall be secured by hard metal fastenings to the frame and bars independently of any lead, cement or putty used for weather-proofing purposes.

3.4.18 *Louvers*

Louvers wherever provided shall be of minimum half hour fire resistance rating.

3.4.19 Glass of facade for high rise buildings, etc shall be of minimum 1 h fire resistance rating.

4 LIFE SAFETY

4.1 General

Every building shall be so constructed, equipped, maintained and operated as to avoid undue danger to the life and safety of the occupants from fire, smoke, fumes or panic during the time period necessary for escape.

4.2 General Exit Requirements

4.2.1 An exit may be a doorway; corridor; passageway(s) to an internal staircase, or external staircase, or to a *VERANDAH* or terrace(s), which have access to the street, or to the roof of a building or a refuge area. An exit may also include a horizontal exit leading to an adjoining building at the same level.

4.2.2 Lifts and escalators shall not be considered as exits.

4.2.3 Every exit, exit access or exit discharge shall be continuously maintained free of all obstructions or impediments to full use in the case of fire or other emergency.

4.2.4 Every building meant for human occupancy shall be provided with exits sufficient to permit safe escape of occupants, in case of fire or other emergency.

4.2.5 In every building or structure, exits shall comply with the minimum requirements of this part, except those not accessible for general public use.

4.2.6 No building shall be so altered as to reduce the number, width or protection of exits to less than that required.

4.2.7 Exits shall be clearly visible and the route to reach the exits shall be clearly marked and signs posted to guide the occupants of the floor concerned. Signs shall be illuminated and wired to an independent electrical circuit on an alternative source of supply. The sizes and colours of the exit signs shall be in accordance with good practice [4(16)]. The colour of the exit signs shall be green.

NOTE — This provision shall not apply to A-2 and A-4 occupancies less than 15 m in height.

4.2.8 The floors of areas covered for the means of exit shall be illuminated to values not less than 1 ft candle (10 lux) at floor level. In auditoriums, theatres, concert halls and such other places of assembly, the illumination of floor exit/access may be reduced during period of performances to values not less than 1/5 ft candle (2 lux).

4.2.9 Fire doors with 2 h fire resistance shall be provided at appropriate places along the escape route and particularly at the entrance to lift lobby and stair well where a 'funnel or flue effect' may be created, inducing an upward spread of fire to prevent spread of fire and smoke.

4.2.10 All exits shall provide continuous means of egress to the exterior of a building or to an exterior open space leading to a street.

4.2.11 Exits shall be so arranged that they may be reached without passing through another occupied unit.

4.3 Occupant Load

For determining the exits required, the number of persons within any floor area or the occupant load shall be based on the actual number of occupants, but in no case less than that specified in Table 20.

4.3.1 *Mezzanine*

The occupant load of a mezzanine floor discharging to a floor below shall be added to that floor occupancy and the capacity of the exits shall be designed for the total occupancy load thus established.

4.4 Capacities of Exits

4.4.1 The unit of exit width, used to measure the capacity of any exit, shall be 500 mm. A clear width of 250 mm shall be counted as an additional half unit. Clear widths less than 250 mm shall not be counted for exit width.

NOTE — The total occupants from a particular floor must evacuate within 2½ minutes for Type 1 construction, 1½ minutes for Type 2 construction and 1 minute for Type 3 construction. Size of the exit door/exitway shall be calculated accordingly keeping in view the travel distance as per Table 22.

4.4.2 Occupants per unit exit width shall be in accordance with Table 21.

4.4.3 *Horizontal Exit Allowance*

When horizontal exit is provided in buildings of mercantile, storage, industrial, business and assembly occupancies, the capacity per storey per unit width of exit of stairways in Table 21 may be increased by 50 percent and in buildings of institutional occupancy it may be increased by 100 percent.

Table 20 Occupant Load

(*Clause* 4.3)

Sl No.	Group of Occupancy	Occupant Load, Floor Area in m^2/Person
(1)	(2)	(3)
i)	Residential (A)	12.5
ii)	Educational (B)	4
iii)	Institutional (C)	15 (*see* Note 1)
iv)	Assembly (D)	
	a) With fixed or loose seats and dance floors	0.6 (*see* Note 2)
	b) Without seating facilities including dining rooms	1.5 (*see* Note 2)
v)	Mercantile (F)	
	a) Street floor and sales basement	3
	b) Upper sale floors	6
vi)	Business and industrial (E&G)	10
vii)	Storage (H)	30
viii)	Hazardous (J)	10

NOTES

1 Occupant load in dormitory portions of homes for the aged, orphanages, insane asylums, etc, where sleeping accommodation is provided, shall be calculated at not less than 7.5 m^2 gross floor area/person.

2 The gross floor area shall include, in addition to the main assembly room or space, any occupied connecting room or space in the same storey or in the storeys above or below, where entrance is common to such rooms and spaces and they are available for use by the occupants of the assembly place. No deductions shall be made in the gross area for corridors, closets or other sub-divisions; the area shall include all space serving the particular assembly occupancy.

Table 21 Occupants per Unit Exit Width

(*Clauses* 4.4.2, 4.4.3 *and* C-1.6.2)

Sl No.	Group of Occupancy	Number of Occupants		
		Stairways	Ramps	Doors
(1)	(2)	(3)	(4)	(5)
i)	Residential (A)	25	50	75
ii)	Educational (B)	25	50	75
iii)	Institutional (C)	25	50	75
iv)	Assembly (D)	40	50	60
v)	Business (E)	50	60	75
vi)	Mercantile (F)	50	60	75
vii)	Industrial (G)	50	60	75
viii)	Storage (H)	50	60	75
ix)	Hazardous (J)	25	30	40

4.5 Arrangement of Exits

4.5.1 Exits shall be so located that the travel distance on the floor shall not exceed the distance given in Table 22.

4.5.2 The travel distance to an exit from the dead end of a corridor shall not exceed half the distance specified in Table 22, except in assembly and institutional occupancies in which case it shall not exceed 6 m.

4.5.3 Whenever more than one exit is required for any room space or floor of a building, exits shall be placed as remote from each other as possible and shall be arranged to provide direct access in separate directions from any point in the area served.

Table 22 Travel Distance for Occupancy and Type of Construction

(*Clauses* 4.4.1, 4.5.1 *and* 4.5.2)

Sl No.	Group of Occupancy	Maximum Travel Distance Construction	
		Types 1 & 2 m	Types 3 & 4 m
(1)	(2)	(3)	(4)
i)	Residential (A)	30.0	22.5
ii)	Educational (B)	30.0	22.5
iii)	Institutional (C)	30.0	22.5
iv)	Assembly (D)	30.0	30.0
v)	Business (E)	30.0	30.0
vi)	Mercantile (F)	30.0	30.0
vii)	Industrial (G)	45.0	[1]
viii)	Storage (H)	30.0	[1]
ix)	Hazardous (J)	22.5	[1]

NOTES

1 For fully sprinklered building, the travel distance may be increased by 50 percent of the values specified.

2 Ramps shall be protected with automatic sprinkler system and shall be counted as one of the means of escape.

[1] Construction of type 3 or 4 is not permitted.

4.6 Number of Exits

4.6.1 *General*

The general requirements of number of exits shall supplement the requirement of different occupancies in **6.1** to **6.9**.

4.6.2 All buildings, which are 15 m in height or above, and all buildings used as educational, assembly, institutional, industrial, storage, and hazardous occupancies and mixed occupancies with any of the aforesaid occupancies, having area more than 500 m^2 on each floor shall have a minimum of two staircases. They shall be of enclosed type; at least one of them shall be on external walls of buildings and shall open directly to the exterior, interior open space or to an open place of safety. Further, the provision or otherwise of alternative staircases shall be subject to the requirements of travel distance being complied with.

4.7 Doorways

4.7.1 Every exit doorway shall open into an enclosed stairway or a horizontal exit of a corridor or passageway providing continuous and protected means of egress.

4.7.2 No exit doorway shall be less than 1 000 mm in width except assembly buildings where door width shall be not less than 2 000 mm. Doorways shall be not less than 2 000 mm in height.

4.7.3 Exit doorways shall open outwards, that is, away from the room, but shall not obstruct the travel along any exit. No door, when opened, shall reduce the required width of stairway or landing to less than 900 mm; overhead or sliding doors shall not be installed.

NOTE — In the case of buildings where there is a central corridor, the doors of rooms shall open inwards to permit smooth flow of traffic in the corridor.

4.7.4 Exit door shall not open immediately upon a flight of stairs; a landing equal to at least the width of the door shall be provided in the stairway at each doorway; the level of landing shall be the same as that of the floor which it serves.

4.7.5 Exit doorways shall be openable from the side which they serve without the use of a key.

4.7.6 Mirrors shall not be placed in exit ways or exit doors to avoid confusion regarding the direction of exit.

4.8 Corridors and Passageways

4.8.1 Exit corridors and passageways shall be of width not less than the aggregate required width of exit doorways leading from them in the direction of travel to the exterior.

4.8.2 Where stairways discharge through corridors and passageways, the height of corridors and passageways shall be not less than 2.4 m.

4.8.3 All means of exit including staircases lifts lobbies and corridors shall be adequately ventilated.

4.9 Internal Staircases

4.9.1 Internal stairs shall be constructed of non-combustible materials throughout.

4.9.2 Internal stairs shall be constructed as a self-contained unit with an external wall of the building constituting at least one of its sides and shall be completely enclosed.

4.9.3 A staircase shall not be arranged round a lift shaft.

4.9.4 Hollow combustible construction shall not be permitted.

4.9.5 No gas piping or electrical panels shall be allowed in the stairway. Ducting in stairway may be permitted if it is of 1 h fire resistance rating.

4.9.6 Notwithstanding the detailed provision for exits in accordance with **4.3**, **4.4** and **4.5**, the following minimum width shall be provided for staircases:

a)	Residential buildings (dwellings)	1.0 m
b)	Residential hotel buildings	1.5 m
c)	Assembly buildings like auditorium, theatres and cinemas	2.0 m
d)	Educational buildings up to 30 m in height	1.5 m
e)	Institutional buildings like hospitals	2.0 m
f)	All other buildings	1.5 m

4.9.7 The minimum width of tread without nosing shall be 250 mm for internal staircase of residential buildings. This shall be 300 mm for assembly, hotels, educational, institutional, business and other buildings. The treads shall be constructed and maintained in a manner to prevent slipping.

4.9.8 The maximum height of riser shall be 190 mm for residential buildings and 150 mm for other buildings and the number shall be limited to 15 per flight.

4.9.9 Handrails shall be provided at a height of 1 000 mm to be measured from the base of the middle of the treads to the top of the handrails. Balusters/railing shall be provided such that the width of staircase does not reduce (*see* Fig. 1).

4.9.10 The number of people in between floor landings in staircase shall not be less than the population on each floor for the purpose of design of staircase. The design of staircase shall also take into account the following:

a) The minimum headroom in a passage under the landing of a staircase and under the staircase shall be 2.2 m.

b) For building 15 m in height or more, access to main staircase shall be through a fire/smoke check door of a minimum 2 h fire resistance rating. Fire resistance rating may be reduced to 1 h for residential buildings (except hotels and starred hotels).

c) No living space, store or other fire risk shall open directly into the staircase or staircases.

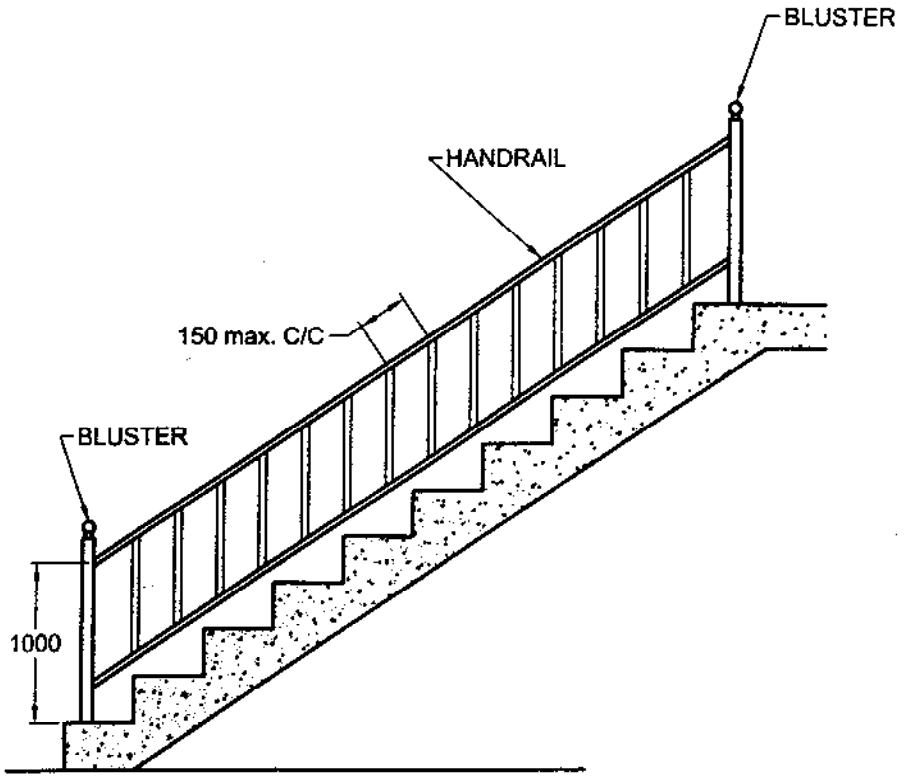
d) External exit door of staircase enclosure at ground level shall open directly to the open spaces or through a large lobby, if necessary.

e) The main and external staircases shall be continuous from ground floor to the terrace level.

f) No electrical shafts/AC ducts or gas pipes, etc, shall pass through or open in the staircases. Lifts shall not open in staircase.

g) No combustible material shall be used for decoration/wall paneling in the staircase.

h) Beams/columns and other building features shall not reduce the head room/width of the staircase.



All dimensions in millimetres.

FIG. 1 TYPICAL DETAIL FOR HANDRAIL/BLUSTERS OF A STAIRCASE

j) The exit sign with arrow indicating the way to the escape route shall be provided at a suitable height from the floor level on the wall and shall be illuminated by electric light connected to corridor circuits. All exit way marking signs should be flush with the wall and so designed that no mechanical damage shall occur to them due to moving of furniture or other heavy equipments. Further, all landings of floor shall have floor indicating boards prominently indicating the number of floor as per bye-laws.

The floor indication board shall be placed on the wall immediately facing the flight of stairs and nearest to the landing. It shall be of size not less than 0.5 m × 0.5 m.

k) Individual floors shall be prominently indicated on the wall facing the staircases.

m) In case of single staircase it shall terminate at the ground floor level and the access to the basement shall be by a separate staircase. The second staircase may lead to basement levels provided the same is separate at ground level by ventilated lobby with discharge points to two different ends through enclosures.

4.10 Pressurization of Staircases (Protected Escape Routes)

4.10.1 Though in normal building design, compartmentation plays a vital part in limiting the spread of fire, smoke will readily spread to adjacent spaces through the various leakage openings in the compartment enclosure, such as cracks, openings around pipes ducts, airflow grills and doors, as perfect sealing of all these openings is not possible. It is smoke and toxic gases, rather than flame, that will initially obstruct the free movement of occupants of the building through the means of escape (escape routes). Hence the exclusion of smoke and toxic gases from the protected routes is of great importance.

4.10.2 Pressurization is a method adopted for protected escape routes against ingress of smoke, especially in high-rise buildings. In pressurization, air is injected into the staircases, lobbies or corridors, to raise their pressure slightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the escape routes will be prevented. The pressurization of staircases shall be adopted for high rise buildings and building having mixed occupancy/ multiplexes having covered area more than 500 m^2.

4.10.3 The pressure difference for staircases shall be as under:

Building Height	*Pressure Difference*	
	Reduced Operation (Stage 1 of a 2-Stage System)	Emergency Operation (Stage 2 of a 2-Stage System or Single Stage System)
	(Pa)	(Pa)
Less than 15 m	8	50
15 m or above	15	50

If possible, the same levels shall be used for lobbies and corridors, but levels slightly lower may be used for these spaces if desired. The difference in pressurization levels between staircase and lobbies (or corridors) shall not be greater than 5 Pa.

4.10.4 Pressurization system may be of two types:

a) Single-stage, designed for operation only in the event of an emergency, and

b) Two-stage, where normally a level of pressurization is maintained in the protected escape routes and an increased level of pressurization can be brought into operation in an emergency.

4.10.5 The normal air-conditioning system and the pressurization system shall be treated as an integral one, especially for a two-stage system. When the emergency pressurization is brought into action, the following changes in the normal air-conditioning system shall be effected:

a) Any re-circulation of air shall be stopped and all exhaust air vented to atmosphere;

b) Any air supply to the spaces/areas other than escape routes shall be stopped;

c) The exhaust system may be continued provided:

1) the positions of the extraction grills permit a general air flow away from the protected escape route entry;

2) the construction of the ductwork and fans is such that, it will not be rendered inoperable by hot gases and smoke; and

3) there is no danger of spread of smoke to other floors by the path of the extraction system which can be ensured by keeping the extraction fans running.

4.10.6 The pressurization system can be interconnected with the automatic/manual fire alarm system for actuation.

4.10.7 It will be desirable to have all the staircases in a building pressurized, if pressurization system is to be resorted to. The use of pressurized and naturally ventilated staircases in the same building may introduce difficulties and hence shall be avoided. Under no circumstances shall a pressurized staircase be connected by a corridor or lobby to an un-pressurized staircase. Wherever pressurized staircase is to be connected to un-pressurized area, the two areas shall be segregated.

4.11 External Stairs

An external staircase is desirable to be provided for high rise buildings.

External stairs, when provided shall comply the following:

4.11.1 External stairs shall always be kept in sound operable conditions.

4.11.2 All external stairs shall be directly connected to the ground.

4.11.3 Entrance to the external stairs shall be separate and remote from the internal staircase.

4.11.4 Care shall be taken to ensure that no wall opening or window opens on to or close to an external stairs.

4.11.5 The route to the external stairs shall be free of obstructions at all times.

4.11.6 The external stairs shall be constructed of non-combustible materials, and any doorway leading to it shall have the required fire resistance.

4.11.7 No external staircase, used as a fire escape, shall be inclined at an angle greater than 45° from the horizontal.

4.11.8 External stairs shall have straight flight not less than 1 250 mm wide with 250 mm treads and risers not more than 190 mm. The number of risers shall be limited to 15 per flight.

4.11.9 Handrails shall be of a height not less than 1 000 mm and not exceeding 1 200 mm. There shall be provisions of balusters with maximum gap of 150 mm.

4.11.10 The use of spiral staircase shall be limited to low occupant load and to a building not exceeding 9 m in height.

A spiral stair case shall be not less than 1 500 mm in diameter and shall be designed to give adequate headroom.

4.11.11 Unprotected steel frame staircase will not be accepted as means of escape. However, steel staircase in an enclosed fire rated compartment of 2 h will be accepted as means of escape.

4.12 Horizontal Exits

4.12.1 The width of horizontal exit shall be same as for the exit doorways.

4.12.2 A horizontal exit shall be equipped with at least one fire/smoke door of minimum 1 h fire resistance, of self-closing type. Further, it is required to have direct connectivity to the fire escape staircase for evacuation.

4.12.3 For buildings more than 24 m in height, refuge area of 15 m^2 or an area equivalent to 0.3 m^2 per person to accommodate the occupants of two consecutive floors, whichever is higher, shall be provided as under:

The refuge area shall be provided on the periphery of the floor or preferably on a cantilever projection and open to air at least on one side protected with suitable railings.

a) *For floors above* 24 *m and Up to* 39 *m* — One refuge area on the floor immediately above 24 m.

b) *For floors above* 39 *m* — One refuge area on the floor immediately above 39 m and so on after every 15 m. Refuge area provided in excess of the requirements shall be counted towards FAR.

NOTE — Residential flats in multi-storied building with balcony, need not be provided with refuge area, however flats without balcony shall provide refuge area as given above.

4.12.4 Where there is a difference in level between connected areas for horizontal exits, ramps, not more than 1 in 10 m slope shall be provided; steps shall not be used.

4.12.5 Doors in horizontal exits shall be openable at all times from both sides.

4.13 Fire Tower

Fire towers are the preferred type of escape route for storeyed buildings and these shall be considered as the safest route for escape. Their number, location and size shall depend on the building concerned, and its associated escape routes.

4.13.1 In high rise buildings with over 8 storeys or 24 m in height, at least one required means of egress shall preferably be a fire tower.

4.13.2 The fire towers shall be constructed of walls with a 2 h fire resistance rating without openings other than the exit doorways, with platforms, landings and balconies having the same fire-resistance rating.

4.14 Ramps

4.14.1 Ramps shall comply with all the applicable requirements for stairways regarding enclosure, capacity and limiting dimensions except where specified in **6.1** to **6.9** for special uses and occupancies.

4.14.2 The slope of a ramp shall not exceed 1 in 10. In certain cases steeper slopes may be permitted but in no case greater than 1 in 8.

4.14.3 For all slopes exceeding 1 in 10 and wherever the use is such as to involve danger of slipping, the ramp shall be surfaced with approved non-slipping material.

4.15 Fire Lifts

4.15.1 Where applicable, fire lifts shall be provided with a minimum capacity for 8 passengers and fully automated with emergency switch on ground level. In general, buildings 15 m in height or above shall be provided with fire lifts.

4.15.2 In case of fire, only fireman shall operate the fire lift. In normal course, it may be used by other persons.

4.15.3 Each fire lift shall be equipped with suitable inter-communication equipment for communicating with the control room on the ground floor of the building.

4.15.4 The number and location of fire lifts in a building shall be decided after taking into consideration various factors like building population, floor area, compartmentation, etc.

4.16 Emergency and Escape Lighting

4.16.1 Emergency lighting shall be powered from a source independent of that supplying the normal lighting [*see* good practice [4(17)].

Escape lighting shall be capable of:

a) Indicating clearly and unambiguously the escape routes,

b) Providing adequate illumination along such routes to allow safe movement of persons towards and through the exits,

c) Ensuring that fire alarm call points and fire-fighting equipments provided along the escape routes can be readily located.

4.16.2 The horizontal luminance at floor level on the centreline of an escape route shall be not less than 10 lux. In addition, for escape routes up to 2 m wide, 50 percent of the route width shall be lit to a minimum of 5 lux.

4.16.3 The emergency lighting shall be provided to be put on within 1 s of the failure of the normal lighting supply.

4.16.4 Escape lighting luminaries should be sited to cover the following locations:

a) Near each intersection of corridors,
b) at each exit door,
c) Near each change of direction in the escape route,
d) Near each staircase so that each flight of stairs receives direct light,
e) Near any other change of floor level,
f) Outside each final exit and close to it,
g) Near each fire alarm call point,
h) Near fire-fighting equipment, and
j) To illuminate exit and safety signs as required by the enforcing authority.

NOTE — For the purposes of this clause 'near' is normally considered to be within 2 m measured horizontally.

4.16.5 Emergency lighting systems shall be designed to ensure that a fault or failure in any one luminaire does not further reduce the effectiveness of the system.

4.16.6 The luminairies shall be mounted as low as possible, but at least 2 m above the floor level.

4.16.7 Signs are required at all exits, emergency exits and escape routes, which should comply with the graphic requirements of the relevant Indian Standards.

4.16.8 Emergency lighting luminaires and their fittings shall be of non-flammable type.

4.16.9 It is essential that the wiring and installation of the emergency lighting systems are of high quality so as to ensure their perfect serviceability at all times.

4.16.10 The emergency lighting system shall be capable of continuous operation for a minimum duration of 1 h and 30 m even for the smallest premises.

4.16.11 The emergency lighting system shall be well maintained by periodical inspections and tests so as to ensure their perfect serviceability at all times.

4.17 Illumination of Means of Exit

Staircase and corridor lights shall conform to the following:

a) The staircase and corridor lighting shall be on separate circuits and shall be independently connected so that it could be operated by one switch installation on the ground floor easily accessible to fire fighting staff at any time irrespective of the position of the individual control of the light points, if any. It should be of miniature circuit breaker type of switch so as to avoid replacement of fuse in case of crisis;
b) Staircase and corridor lighting shall also be connected to alternative supply. The alternative source of supply may be provided by battery continuously trickle charged from the electric mains; and
c) Suitable arrangements shall be made by installing double throw switches to ensure that the lighting installed in the staircase and the corridor does not get connected to two sources of supply simultaneously. Double throw switch shall be installed in the service room for terminating the stand-by supply.

4.18 Fire Detection and Warning

In buildings of such size, arrangement or occupancy where a fire may not itself provide adequate warning to occupants, automatic fire detection and alarm facilities shall be provided, where necessary, to warn occupants early of the existence of fire, so that they may escape, and to facilitate the orderly conduct of fire exit drills.

4.18.1 The fire detection system shall be in accordance with accepted standards [4(18)]. Guidelines for selection of various types of fire detectors for different occupancies and their installation and maintenance shall be in accordance with [4(19)].

4.18.2 The requirements of fire detection and alarm systems are covered for each occupancy in Table 23 and under **6.1** to **6.9**; attention is also drawn to such requirements in case of high rise buildings (15 m or more in height) as given in Annex C.

5 FIRE PROTECTION

5.1 Fire Extinguishers/Fixed Fire Fighting Installations

5.1.1 All buildings depending upon the occupancy use and height shall be protected by fire extinguishers, wet riser, down-comer, automatic sprinkler installation, high/medium velocity water spray, foam, gaseous or dry powder system in accordance with the provisions of **5.1.2** to **5.1.9.**

5.1.2 These fire extinguishers/fixed installations shall be in accordance with accepted standards [4(20)]. The typical requirements of fire extinguishers/wet riser/ down-comer installation and capacity of water storage tanks and fire pumps, etc shall be as specified in Table 23. The requirements regarding size of mains/ risers shall be as given in Table 24. The typical arrangements of down-comer and wet riser installations are shown in Fig. 2 and Fig. 3. The wet riser shall be designed for zonal distribution ensuring that unduly high pressures are not developed in risers and hose-pipes.

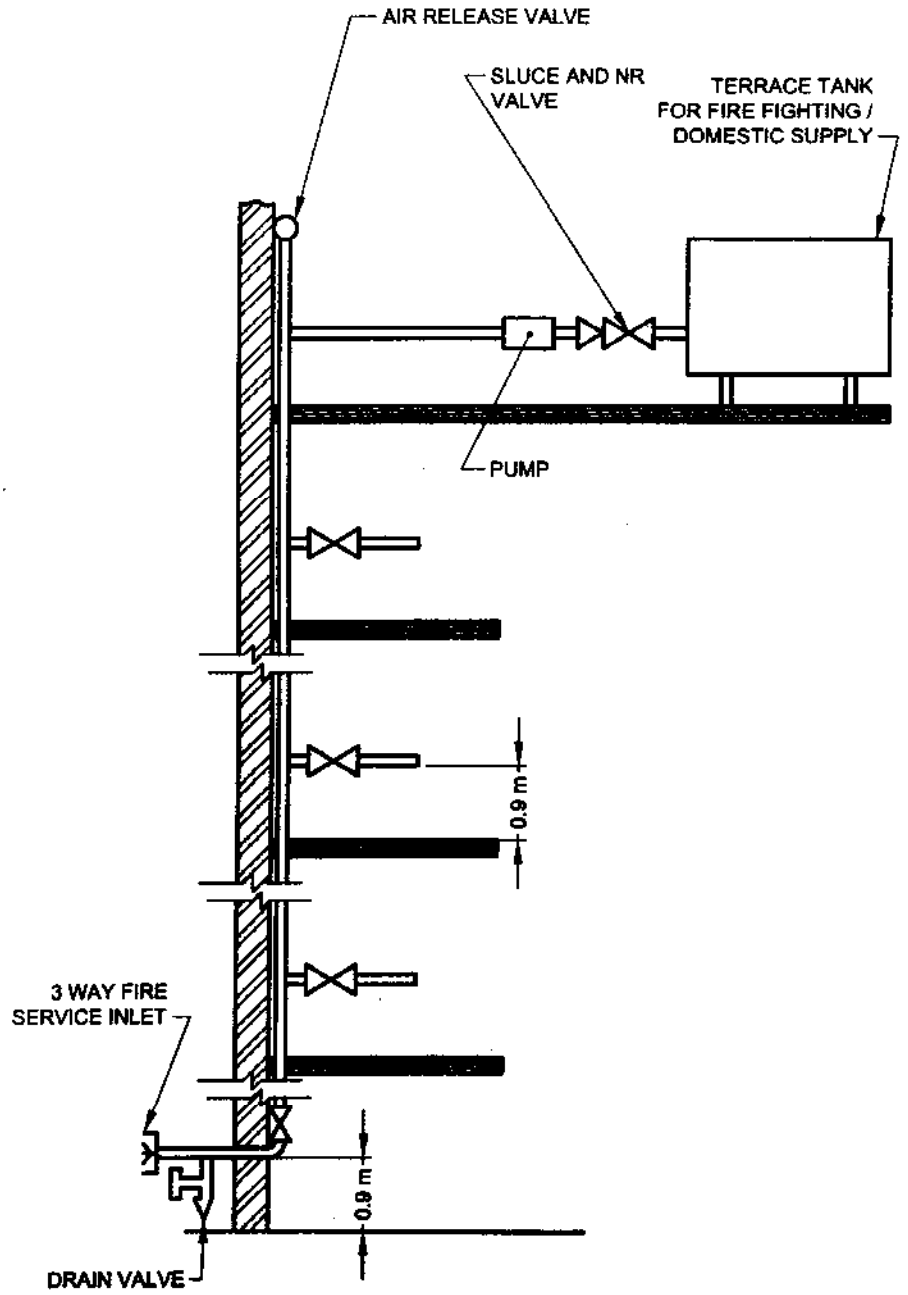


FIG. 2 TYPICAL ARRANGEMENT OF DOWN-COMER FOR BUILDING ABOVE 15 m BUT NOT EXCEEDING 30 m IN HEIGHT

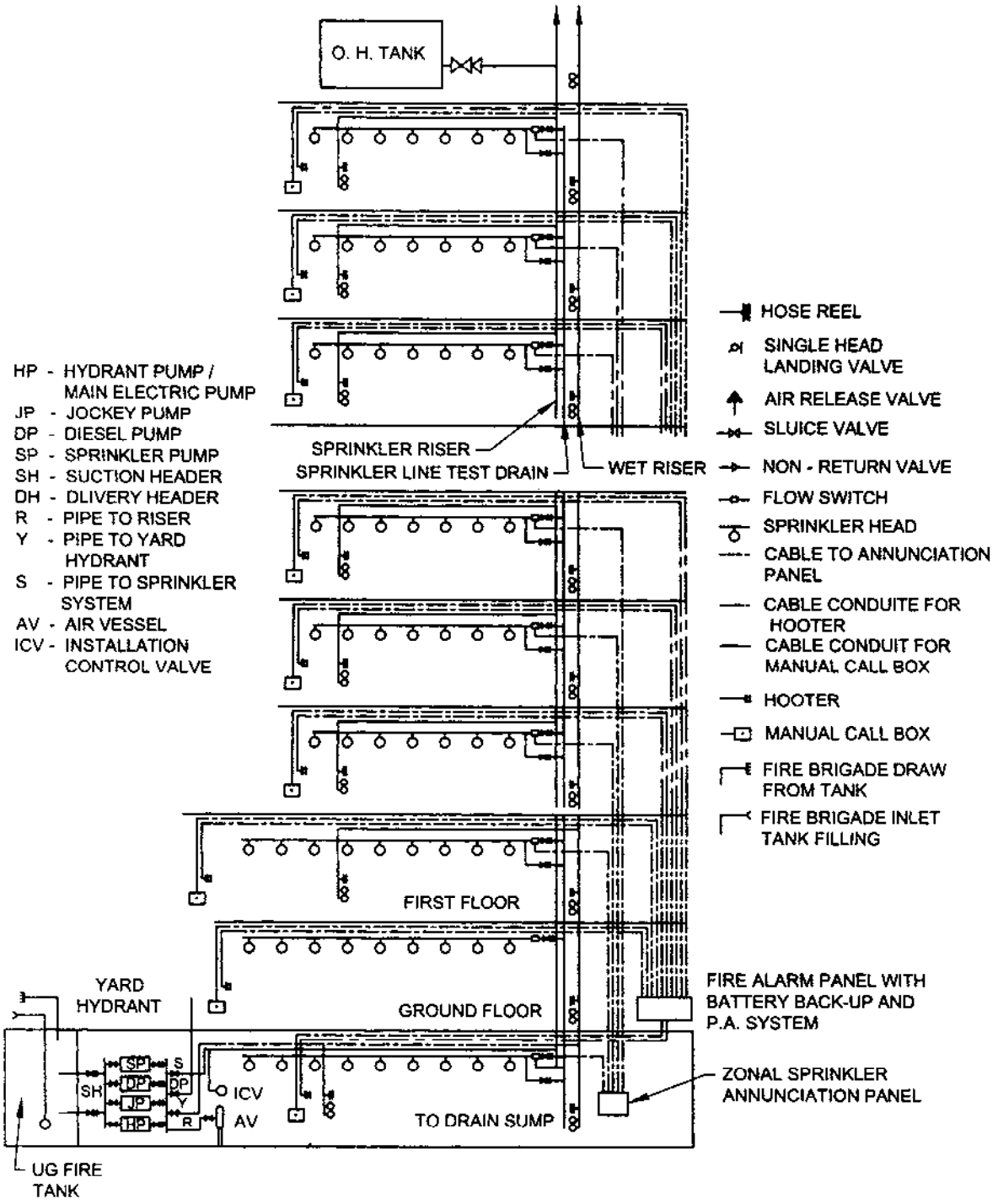


FIG. 3 TYPICAL ARRANGEMENT OF WET RISER AND TOTAL SPRINKLER SYSTEM OF BUILDING OTHER THAN APPARTMENT EXCEEDING 30 m IN HEIGHT

Table 23 Minimum Requirements for Fire Fighting Installations

(*Clauses* 4.18.2, 6.1.2, 6.2.3, 6.3.2, 6.4.3, 6.5.2, 6.5.2.1, 6.5.2.2, 6.5.2.3, 6.5.2.4, 6.5.2.5, 6.6.2, 6.7.2, 6.8.2 *and* 6.9.2)

Sl No.	Type of Building Occupancy	Type of Installation									Water Supply (in l)		Pump Capacity (in l/min)	
		Fire Extin-gusher	Hose Reel	Dry Riser (*see* Note 6)	Wet Riser	Down-Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electric Fire Alarm Systems	Automatic Detection and Alarm System	Underground Static Water Storage Tank	Terrace Tank	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Terrace Level	At the Terrace Tank Level with Minimum Pressure of 2.0 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
RESIDENTIAL BUILDINGS (A)														
a)	**Lodging or Rooming Houses (A-1)** (*see* Note 1)													
1)	Less than 15 m in height													
	i) Up to 15 rooms	R	NR	NR	NR	NR	NR	R (*see* Note 2)	NR	NR	NR	5 000 (*see* Note 3)	NR	NR
	ii) More than 15 and up to 30 rooms	R	R	NR	NR	NR	NR	R (*see* Note 2)	NR	NR	NR	5 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)
	iii) More than 30 rooms	R	R	NR	NR	NR	NR	R (*see* Note 2)	R (*see* Note 5)	NR	NR	10 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)
b)	**One or two Family Private Dwellings (A-2)** (*see* Note 1)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR

Table 23 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
c)	**Dormitories (A-3) Apartment Houses (A-4)**													
1)	Less than 15 m in height	R	R	NR	NR	NR	NR	R (*see* Note 2)	NR	NR	NR	5 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)
2)	15 m and above but not exceeding 35 m in height	R	R	NR	NR	R	NR	R (*see* Note 2)	R (*see* Note 7)	NR	NR	25 000	NR	900
3)	Above 35 m but not exceeding 45 m in height	R	R	NR	R	NR	NR	R (*see* Notes 2 and 8)	R	NR	75 000	5 000 (5 000) (*see* Note 4)	(*see* Note 19)	NR
4)	Above 45 m in height but not exceeding 60 m in height	R	R	NR	R	NR	R	R	R	NR	75 000	10 000	(*see* Note 20)	NR
5)	Above 60 m in height	R	R	NR	R	NR	R	R	R	R	100 000	25 000	(*see* Note 21)	NR
d)	**Hotels (A-5)**													
1)	Less than 15 m in height													
	i) Covered area not exceeding 300 m^2 on each floor	R	R	NR	NR	NR	NR	R (*see* Note 2)	R	NR	NR	5 000 (*see* Note 2)	NR	450 (*see* Note 3)
	ii) Covered area exceeding 300 m^2 but not more 1 000 m^2 on each floor	R	R	NR	R (*see* Note 5)	NR	NR	R (*see* Note 2)	R	R	10 000 for every 500 m^2 covered area subject to minimum of 50 000 (*see* Note 5)	10 000 (*see* Note 2)	(*see* Notes 5 and 19)	NR
	iii) Covered area exceeding 1 000 m^2 on each floor	R	R	NR	R (*see* Note 9)	NR	R	R (*see* Note 10)	R	R	100 000 (*see* Note 9)	10 000 (*see* Note 2)	(*see* Notes 9 and 19)	NR

Table 23 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
2)	15 m and above but not exceeding 30 m	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	150 000	20 000	(*see* Note 20)	NR
3)	Above 30 m in height	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	200 000	20 000	(*see* Note 21)	NR
e)	**Hotels (A-6)**	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	200 000	20 000	(*see* Note 22)	NR
EDUCATIONAL BUILDINGS (B) (*see* Note 12)														
1)	Less than 15 m in height													
	i) Ground plus one storey	R	NR	NR	NR	NR	NR	R (*see* Note 2)	NR	NR	NR	5 000 (*see* Note 3)	NR	450 (*see* Note 3)
	ii) Ground plus two or more storeys	R	R	NR	NR	NR	NR	R (*see* Note 2)	NR	NR	NR	10 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)
2)	15 m and above but not exceeding 30 m in height	R	R	NR	NR	R	NR	R (*see* Note 2)	R	NR	NR	25 000	NR	900
INSTITUTIONAL BUILDINGS (C) (*see* Note 12)														
a)	**Hospitals, Sanatoria and Nursing Homes (C-1)**													
1)	Less than 15 m in height with plot area up to 1 000 m^2													
	i) Up to ground plus one storey, with no beds	R	R	NR	NR	NR	NR	R (*see* Note 2)	R	NR	NR	2 500 (2 500) (*see* Note 4)	NR	NR
	ii) Up to ground plus one storey with beds	R	R	NR	NR	R	NR	R (*see* Note 2)	R	NR	NR	5 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)
	iii) Ground plus two or more storeys, with no beds	R	R	NR	NR	R	NR	R (*see* Note 2)	R	R	NR	5 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)
	iv) Ground plus two or more storeys, with beds	R	R	NR	R	NR	NR	R (*see* Note 2)	R	R	50 000	5 000 (5 000) (*see* Note 4)	(*see* Note 19)	NR

Table 23 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
2)	Less than 15 m in height with plot area more than 1 000 m^2	R	R	NR	R	NR	R	R (see Note 2)	R	R	1 00 000	10 000	(*see* Note 19)	NR
3)	15 m and above but not exceeding 24 m in height	R	R	NR	R	NR	R	R (*see* Note 11)	R	R	100 000	20 000	(*see* Note 20)	NR
4)	Above 24 m and not exceeding 30 m in height	R	R	NR	R	NR	R	R (*see* Note 11)	R	R	150 000	20 000	(*see* Note 21)	NR
b)	**Custodial (C-2), and Penal and Plental (C-3)**													
1)	Less than 10 m in height													
	i) Up to 300 persons	R	R	NR	NR	NR	NR	R (*see* Note 2)	R	NR	NR	10 000 (5 000) (*see* Note 4)	NR	450 (900) (*see* Note 4)
	ii) More than 300 persons	R	R	NR	NR	R	NR	R (*see* Note 2)	R	NR	NR	15 000 (5 000) (*see* Note 4)	NR	450 (900) (*see* Note 4)
2)	10 m and above but not exceeding 15 m in height	R	R	NR	R	NR	R	R (*see* Note 2)	R	R	50 000	5 000 (5 000) (*see* Note 4)	(*see* Note 20)	NR
3)	15 m and above but not exceeding 24 m in height	R	R	NR	R	NR	R	R (*see* Note 11)	R	R	75 000	10 000	(*see* Note 20)	NR
4)	24 m and above but not exceeding 30 m in height	R	R	NR	R	NR	R	R (*see* Note 11)	R	R	100 000	20 000	(*see* Note 21)	NR
ASSEMBLY BUILDINGS (D) (*see* Note 12)														
a)	**Buildings (D-1 to D-5)**													
1)	Less than 10 m in height													
	i) Up to 300 persons	R	R	NR	NR	R	NR	R (*see* Note 2)	R	NR	NR	10 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)

Table 23 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	ii) More than 300 persons	R	R	NR	NR	R	NR	R (*see* Note 2)	R	NR	NR	15 000 (5 000) (*see* Note 4)	NR	900
2)	Above 10 m but not exceeding 15 m in height	R	R	NR	R	NR	NR	R (*see* Note 2)	R	R	50 000	5 000 (5 000) (*see* Note 4)	(*see* Note 20)	450 (450) (*see* Note 4)
3)	Above 15 m but not exceeding 24 m in height	R	R	NR	R	NR	R	R (*see* Note 11)	R	R	75 000	10 000	(*see* Note 20)	NR
4)	Above 24 m but not exceeding 30 m in height	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	100 000	20 000	(*see* Note 21)	NR
b)	**Multiplex D-6**	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	200 000	20 000	(*see* Note 22)	NR
c)	**D-7**	For details *see* **6.4.8**												
BUSINESS BUILDINGS (E)														
1)	Less than 10 m in height	R	R	NR	NR	R	NR	R (*see* Note 2)	R	NR	NR	10 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)
2)	Above 10 m but not exceeding 15 m in height	R	R	NR	R	NR	NR	R (*see* Note 2)	R	R	50 000	5 000 (5 000) (*see* Note 4)	(*see* Note 20)	450 (450) (*see* Note 4)
3)	Above 15 m and up to 24 m in height	R	R	NR	R	NR	R	R (*see* Note 11)	R	R	75 000	10 000	(*see* Note 20)	NR
4)	Above 24 m and up to 30 m in height	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	100 000	20 000	(*see* Note 21)	NR
5)	Above 30 m in height	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	200 000	20 000	(*see* Note 22)	NR
MERCANTILE BUILDINGS (F)														
a)	**F-1 & F-2** (*see* Note 12)													
1)	Less than 15 m in height													
	i) Ground plus one storey, with total covered area not exceeding 500 m^2	R	R	NR	NR	R	NR	R (*see* Note 2)	NR	NR	NR	5 000 (5 000) (*see* Note 4)	NR	450 (450) (*see* Note 4)

Table 23 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	ii) Ground plus one storey and covered area exceeding 500 m^2	R	R	NR	NR	R	NR	R (*see* Note 2)	R	NR	NR	25 000	NR	900
	iii) More than ground plus one storey	R	R	R	NR	R	NR	R (*see* Note 2)	R	NR	NR	5 000 (5 000) (*see* Note 4)	NR	900
2)	Above 15 m but not exceeding 24 m in height	R	R	NR	R	NR	NR	R (*see* Note 11)	R	R	100 000	10 000	(*see* Note 20)	NR
3)	Above 24 m but not exceeding 30 m in height	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	150 000	10 000	(*see* Note 21)	NR
b)	**Underground shopping complex (F-3)** (*see* Note 13)	R	R	NR	R	NR	R	R (*see* Note 10)	R	R	150 000	10 000	(*see* Note 21)	NR
INDUSTRIAL BUILDINGS (G) (*see* Note 14)														
a)	**Low Hazard (G-1)** (*see* Note 15)													
	i) Built up area up to 100 m^2	R	NR	NR	NR	NR	NR	R (*see* Note 2)	NR	NR	NR	5 000 (*see* Note 3)	NR	450 (*see* Note 3)
	ii) Built up area more than 100 m^2 and up to 500 m^2	R	R	NR	NR	R	NR	R (*see* Note 2)	NR	NR	NR	5 000 (5 000) (*see* Note 4)	NR	450
	iii) Built up area more than 500 m^2	R	R	NR	R	R (*see* Note 7)	R	R	NR	R	100 000	10 000	(*see* Note 20)	450
b)	**Moderate Hazard (G-2)** (*see* Note 14)													
	i) Built up area up to 100 m^2	R	R	NR	NR	NR	NR	R	NR	NR	NR	10 000	NR	450
	ii) Built up area more than 100 m^2 and up to 500 m^2	R	R	NR	NR	NR	NR	R	NR	NR	NR	10 000	NR	900

Table 23 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	iii) Built up area more than 500 m^2 and up to 1 000 m^2	R	R	NR	R	R (*see* Note 7)	R	R	R	R	75 000	20 000	(*see* Note 20)	900
	iv) Built up area more than 1 000 m^2	R	R	NR	R	R (*see* Note 7)	R	R	R	R	100 000	20 000	(*see* Note 20)	900
c)	**High Hazard** (G-3) (*see* Note 16)													
	i) Built up area up to 50 m^2	R	R	NR	NR	NR	NR	R	NR	NR	NR	5 000	NR	450
	ii) Built up area more than 50 m^2 and up to 150 m^2	R	R	NR	NR	NR	NR	R	NR	R	NR	5 000	NR	450
	iii) Built up area more than 150 m^2 and up to 300 m^2	R	R	NR	R	NR	NR	R	NR	R	25 000	10 000	(*see* Note 19)	450
	iv) Built up area more than 300 m^2 and up to 500 m^2	R	R	NR	R	NR	R	R	R	R	50 000	20 000	(*see* Note 19)	900
	v) Built up area more than 500 m^2	R	R	NR	R	R (*see* Note 7)	R	R	R	R	100 000	20 000	(*see* Note 20)	900
STORAGE BUILDINGS (H) (*see* Note 17)														
1)	Below 15 m in height and covered area less than 250 m^2	R	R	NR	NR	NR	NR	R	NR	NR	25 000	5 000	(*see* Note 19)	450
2)	Below 15 m in height and covered area more than 250 m^2													
	i) Ground floor only	R	R	NR	R	NR	R	R	NR	R	50 000	10 000	(*see* Note 20)	450
	ii) Ground plus one floor	R	R	NR	R	NR	R	R	NR	R	75 000	10 000	(*see* Note 20)	450

Table 23 — *Concluded*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	iii) More than ground plus one floor	R	R	NR	R	NR	R	R	NR	R	100 000	10 000	(*see* Note 20)	450
HAZARDOUS BUILDINGS (J) (*see* Note 17)														
1)	Up to 15 m in height													
	i) Single Storey Building	R	R	NR	NR	NR	R	R	R	R	Minimum 4 h fire fighting requirements	NR	(*see* Note 18)	NR
	ii) More than one floor building but not exceeding 15 m	R	R	NR	R	R	R	R	R	R	Minimum 4 h fire fighting requirements	50 000	(*see* Note 18)	900

R — Required

NR — Not Required

NOTES

1 Buildings above15 m in height not to be permitted for occupancies A-1 and A-2.

2 Required to be installed in basement if area of basement exceeds 200 m^2.

3 Required to be provided if basement area exceeds 200 m^2.

4 Additional value given in parenthesis shall be added if basement area exceeds 200 m^2.

5 Required to be provided for buildings with more than two storeys (Ground + One).

6 As per the requirement of local authority Dry Riser may be used in hilly areas, industrial areas or as required.

7 Required to be provided for buildings with height above 15 m.

8 To be installed in basement. If basement provided is used for car parking and area thereof exceeds 750 m^2 then the sprinklers shall be fed water from both underground static water storage tank and terrace tank.

9 Required to be provided for buildings with more than one storey.

10 To be installed in entire building.

11 To be installed in all floors at appropriate places and in consultation with local fire authorities.

12 Buildings above 30 m in height not to be permitted for Group B, Group C, Group D and Group F occupancies.

13 All underground shopping areas should be fully air-conditioned.

14 The requirements given in this table for Group G Industrial Buildings are for small scale industry units. For other industries the requirements will have to be worked out on the basis of relevant Indian Standards and also in consultation with the local fire authorities.

15 Buildings above 18 m in height not to be permitted for G-1 and G-2 occupancies.

16 Buildings above 15 m in height not to be permitted for G-3 occupancies.

17 Buildings above 15 m in height not to be permitted for Group H and Group J occupancies.

18 Pump capacity shall be based on the covered area of the building.

19 One electric and one diesel pump of capacity 1 620 l/min and one electric pump of capacity 180 l/min (*see* Fig. 4).

20 One electric and one diesel pump of capacity 2 280 l/min and one electric pump of capacity 180 l/min (*see* Fig. 4).

21 Two electric and one diesel pump of capacity 2 280 l/min and one electric pump of capacity 180 l/min (*see* Fig. 5).

22 Two electric and one diesel pump of capacity 2 850 l/min and one electric pump of capacity 180 l/min (*see* Fig. 5).

23 For buildings 45 m and above, the entire quantity of water for fire fighting purpose (as required in respective occupancy), if provided at the terrace level, the main pump sprinkler pump, jockey pump and common pump need not be provided, however one electric fire pump of 900 LPM capacity with automatic operation is required to be provided.

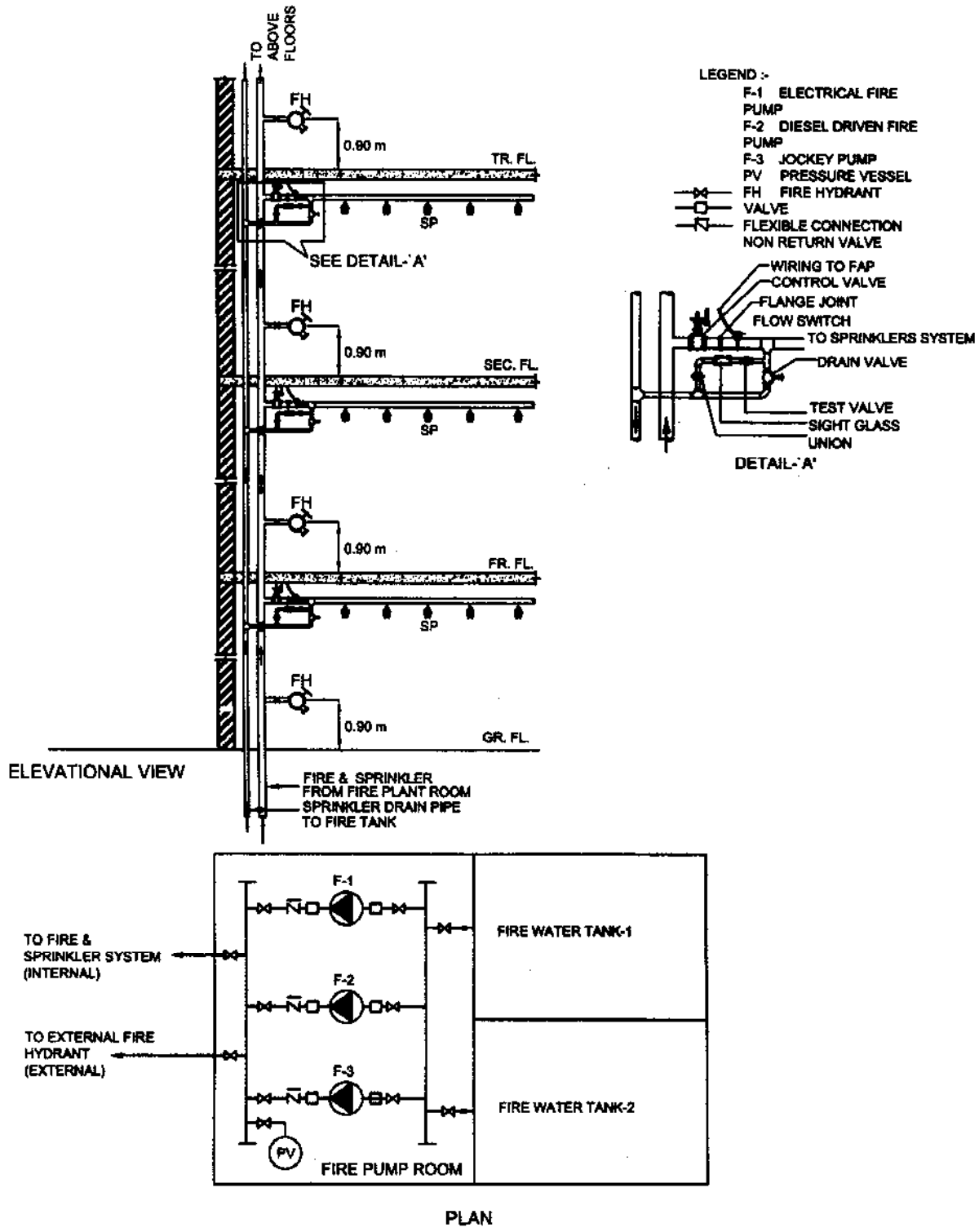


FIG. 4 TYPICAL SYSTEM OF PUMPING WITH ONE ELECTRIC AND ONE DIESEL FIRE PUMP

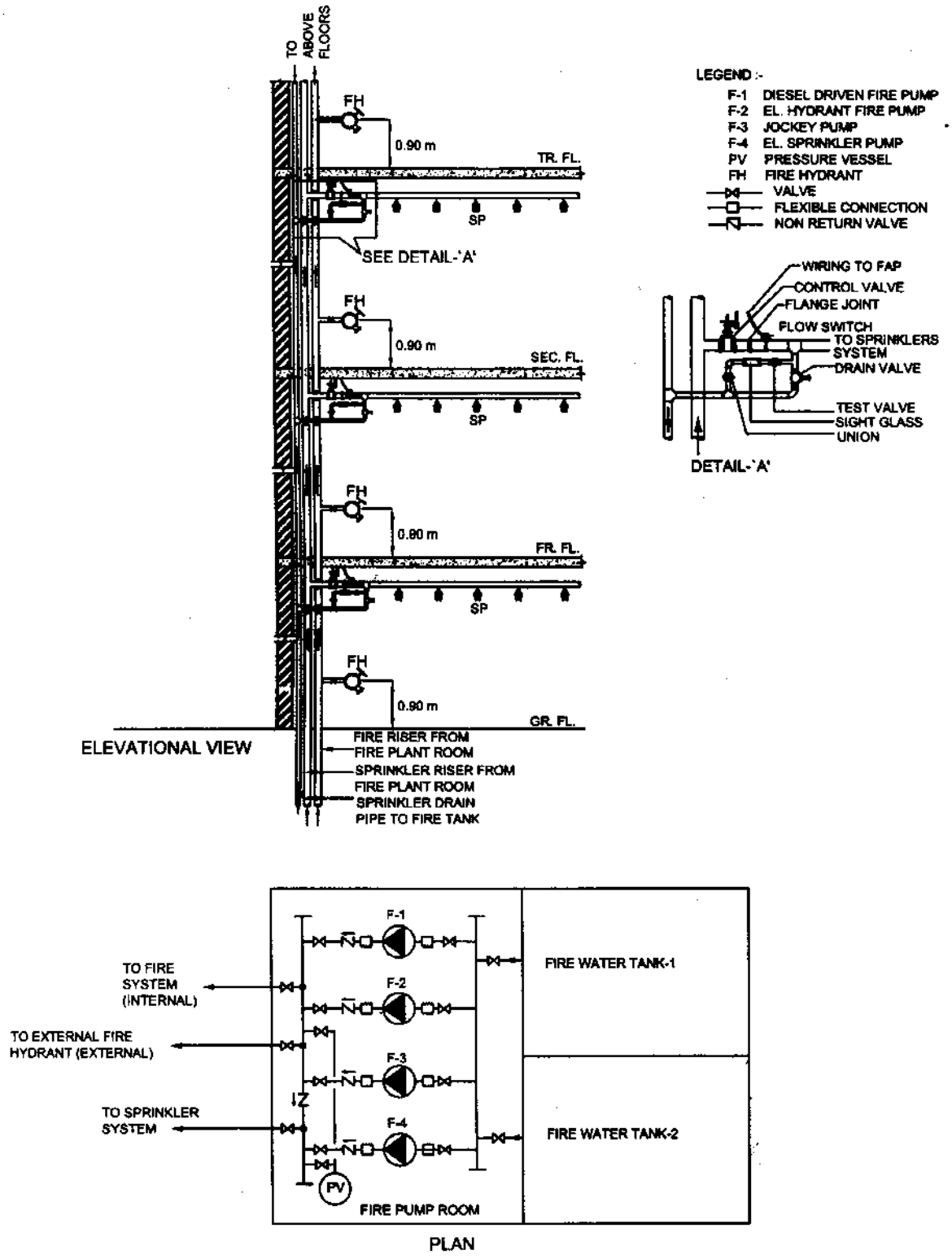


FIG. 5 TYPICAL SYSTEM OF PUMPING WITH TWO ELECTRIC, ONE DIESEL FIRE PUMP

5.1.3 In situations where one occupancy is provided with all the required fire protection arrangements but due to proximity of unprotected buildings around, causing exposure hazard to the protected building, the protected building walls facing the unprotected building shall be made of the requisite fire resistance rated materials or alternatively provided with water curtain/drencher system which can be actuated, when necessary.

5.1.4 First-aid fire fighting appliances shall be provided and installed in accordance with good practice [4(21)]. The fire fighting equipment and accessories to be installed in buildings for use in fire fighting shall be in accordance with the accepted standards contained in [4(20)] and shall be maintained periodically so as to ensure their perfect serviceability at all times.

5.1.5 In addition to wet riser or down-comer, first-aid hose reels shall be installed on all the floors of buildings of 15 m in height or more and shall be in accordance with accepted standards [4(22)]. The first-aid hose reel shall be connected directly to the riser/down-comer main and diameter of the hose reel shall not be less than 19 mm.

5.1.6 *Static Water Storage Tanks*

A satisfactory supply of water for the purpose of fire fighting shall always be available in the form of underground/terrace level static storage tank with capacity specified for each building with arrangements or replenishment by mains of alternative source of supply at the rate of 1 000 l/min for underground static tank. When this is not practicable, the capacity of static storage tank(s) shall be increased proportionately in consultation with the local fire brigade.

The static storage water supply required for the above mentioned purpose shall entirely be accessible to the fire engines of the local fire service. Provision of suitable number of manholes shall be made available for inspection, repairs, insertion of suction hose, etc. The covering slab shall be able to withstand the total vehicular load of 45 T equally divided as a four point load when the slab forms a part of pathway/ driveway.

The domestic suction tank connected to the static water storage tank shall have an overflow capable of discharging 2 250 l/min to a visible drain point from which by a separate conduit, the overflow shall be conveyed to a storm water drain.

a) To prevent stagnation of water in the static water storage tank, the suction tank of the domestic water supply shall be fed only through an overflow arrangement to maintain the level therein at the minimum specified capacity (*see* Fig. 6).

b) The static water storage tank shall be provided with a fire brigade collecting head with 4 number 63 mm diameter (2 number 63 mm diameter for pump with capacity 1 400 l/min) instantaneous male inlets arranged in a valve box at a suitable point at street level and connected to the static tank by a suitable fixed pipe not less than 150 mm in diameter to discharge water into the tank when required at the rate of 2 250 l/min, if tank is in the basement or not approachable for the fire engines.

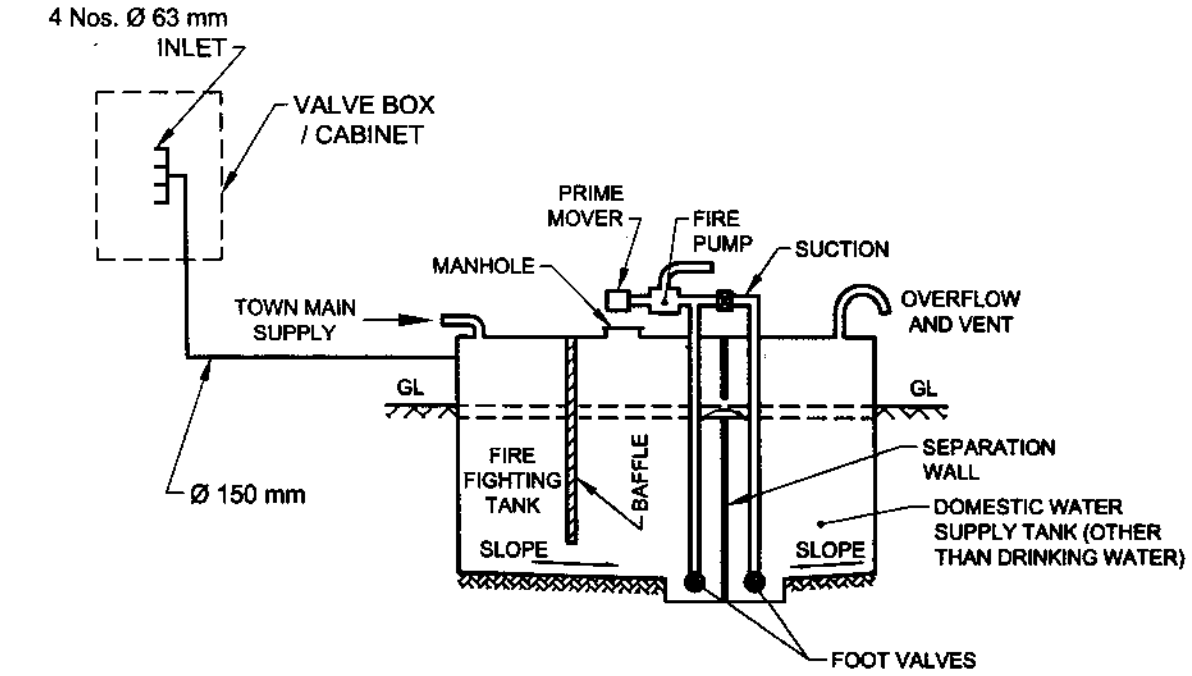
5.1.7 *Automatic Sprinklers*

Automatic sprinklers shall be installed in:

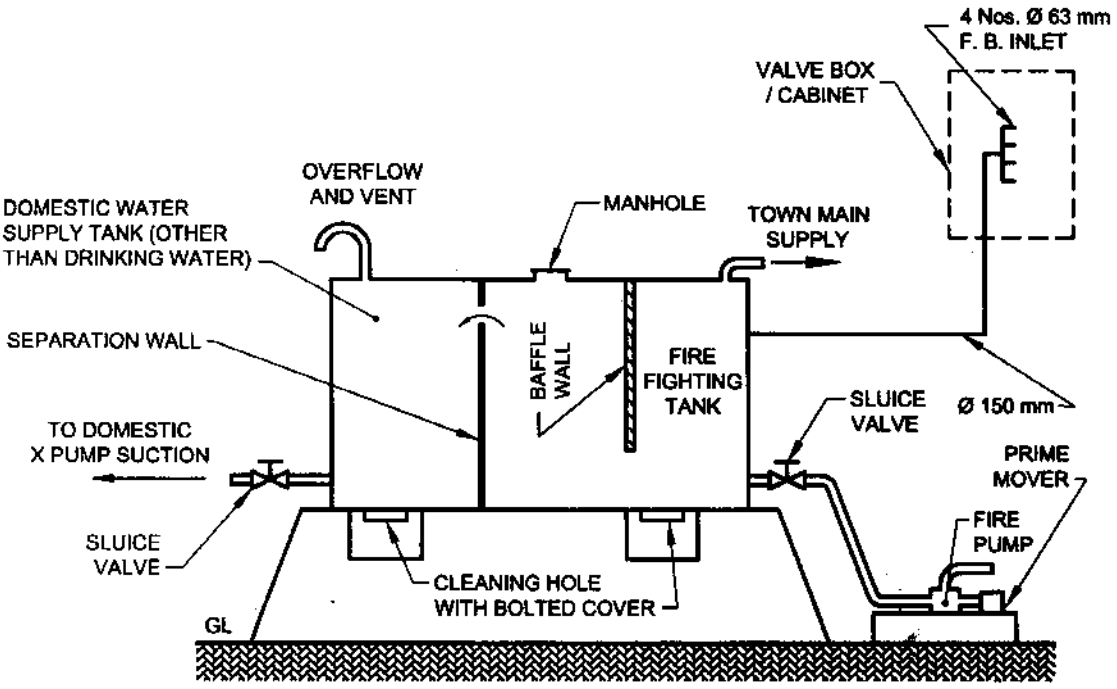
a) basements used as car parks or storage occupancy, if the area exceeds 200 m^2;
b) multi-level basements, covered upper floors used as car parks, and for housing essential services ancillary to a particular occupancy or for storage occupancy, excluding any area to be used for sub-station, A.C. plant and DG set;
c) any room or other compartment of a building exceeding 1 125 m^2 in area except as in (g) (*see* Note 1), if so advised by local authority;
d) departmental stores or shops, if the aggregate covered area exceeds 500 m^2;
e) all non-domestic floors of mixed occupancy which constitute a hazard and are not provided with staircases independent of the remainder of the buildings;
f) godowns and warehouses, as considered necessary;
g) on all floors of the buildings other than residential and educational buildings, if the height of the building exceeds 15 m (45 m in case of group housing and apartments) (*see* Note 1);
h) dressing room, scenery docks, stages and stage basements of theatres;
j) in hotels, hospitals, industries low and moderate hazard mercantile buildings of height 15 m or above;
k) in hotels below 15 m, if covered area at each floor is more than 1 000 m^2;
m) false ceiling voids exceeding 800 mm in height (*see* Note 2); and
n) canteen provided in upper floors of D-1 and D-2 occupancies shall be sprinklered.

NOTES

1 It is desirable that all high rise buildings should be fully sprinklered irrespective of their height and occupancy. If



6A WITH NEGATIVE SUCTION



3B WITH POSITIVE SUCTION

FIG. 6 TYPICAL ARRANGEMENT FOR PROVIDING COMBIND FIRE FIGHTING AND DOMESTIC WATER STORAGE TANK

Table 24 Size of Rising Mains/Risers

(*Clause* 5.1.2)

Size of the Mains (1)	Type of Building (2)	Height of Building (3)
100 mm as single outlet landing valves	1. Residential buildings (A)	
	i) [1] Lodging or rooming houses	
	ii) Dormitories	
	iii) One or two family private dwellings	15 m or above and not exceeding 45 m
	iv) Apartment houses (flats)	
	v) With shopping area not exceeding 500 m^2	Less than 15 m
	vi) Hotels	15 m or above in height but not exceeding 30 m and area not exceeding 600 m^2 per floor
-do-	2. Educational buildings (B)	15 m or above but not exceeding 30 m
-do-	3. Institutional buildings (C)	
	i) For hospitals and sanitorium	15 m or above but not exceeding 30 m
	ii) For custodial institutions and mental institutions	15 m or above but not exceeding 30 m
-do-	4. Assembly buildings (D)	15 m or above but not exceeding 30 m and total floor area not exceeding 500 m^2/floor (above 30 m, not to be permitted)
-do-	5. Business buildings (E)	15 m or above but not exceeding 30 m
-do-	6. Mercantile buildings (F)	15 m or above but not exceeding 30 m (above 30 m, not to be permitted)
-do-	7. Industrial buildings (G)	15 m or above but not exceeding 18 m
-do-	8. All buildings classified under 1 (i) to (iv)	Above 45 m
-do-	9. All buildings classified under 5 above with shopping area exceeding 500 m^2	Above 15 m
-do-	10. All buildings classified under 1 (v) above	Above 30 m and area exceeding 500 m^2
150 mm with twin outlet landing valves	11. Hotels	Above 30 m
-do-	12. All buildings classified under 2 and 3 above	Above 30 m
-do-	13. All buildings classified under 5 above	Above 30 m
-do-	14. All storage buildings (H)	Above 10 m but not exceeding 15 m
-do-	15. All Hazardous buildings (J)	Above 10 m but not exceeding 15 m

[1] Buildings above 15 m in height not permitted in case of high hazard industrial buildings.

selective sprinklering is adopted, there is a real danger of a fire starting on one of the lower unsprinklered floors gathering momentum, spreading upwards from floor to floor through the unsprinklered floor and reaching the first sprinklered floor as a fully developed fire. In such an event, the sprinklers can be rendered useless or ineffective.

2 Use of false ceiling voids for storage or as return air plenums should be discouraged.

3 For areas having very high ceiling height and other special function areas, where automatic sprinklers cannot be provided, appropriate sprinklers/provisions shall be provided in consultation with local fire authorities.

5.1.8 *Automatic High Velocity Water Spray or Emulsifying System*

Automatic high velocity water spray or emulsifying system shall be provided for protection of indoor oil-cooled transformers as applicable in accordance with **C-1.16** and good practice [4(23)].

5.1.9 *Fixed Foam Installation*

Fixed foam generating system shall be provided for protection of oil storage area for boilers with its ancillary storage of furnace oils in basement. Fixed foam installations can be low, medium or high expansion types, which can cover fire risks in oil storage areas generally. High expansion foams are used for cable tunnels and other confined areas.

5.1.10 *Carbon Dioxide Fire Extinguishing System*

Fixed carbon dioxide fire extinguishing installation shall be provided in accordance with good practice

[4(24)] on premises where water or foam cannot be used for fire extinguishing because of the special nature of the contents of the buildings/areas to be protected. For some special fire risk/essential applications, carbon dioxide may not be suitable and it may be necessary to provide BCF (Bromochlorodifluoromethane) — Halon 1211 or BTM (Bromochlorotrifluoromethane) — Halon 1301 or some other identified substitutes.

However, the use of halons shall be discouraged, as halons are ozone depleting substances (ODS) and their use is being phased out throughout the world.

5.1.11 Fire fighting equipment shall be suitably located and clearly marked by luminous signs.

NOTE — This provision shall not apply to occupancies A-2 and A-4 less than 15 m in height.

5.2 Fire Detection/Extinguishing System

In buildings of such size, arrangement or occupancy that a fire may not itself provide adequate warning to occupants, automatic fire detection and alarm facilities shall be provided, where necessary, to warn occupants early of the existence of fire, so that they may escape, or to facilitate the orderly conduct of fire exit drills.

5.2.1 The fire detection and extinguishing system shall be in accordance with accepted standards [4(18)]. Guidelines for selection of various types of fire detectors for different occupancies shall be in accordance with good practice [4(19)]. Addressable analog fire detection system shall be preferred.

5.2.2 The requirements of fire detection and alarm systems are also covered for each occupancy in **6.1** to **6.9**; and for high rise buildings (15 m or more in height) in Annex C.

5.3 Fire Extinguisher/Extinguishing System Using Halon Alternatives

Provisions for certain fire extinguishers and extinguishing systems for fire protection which may be used as halon alternatives, shall be in accordance in [4(25)].

6 ADDITIONAL OCCUPANCY-WISE REQUIREMENTS

6.1 Requirements of Residential Buildings (Group A)

6.1.1 In addition to the general requirements for the type of construction and occupancy group specified in **3.4** and the exit requirements given in **4**, the requirements **6.1.2** to **6.1.4.10** shall be complied with. The capacity of any open mezzanine or balcony shall be added to the capacity of the floor below for the purpose of determining exit capacity.

6.1.2 *Fire Detection/Extinguishing System*

The requirements for occupancy sub-divisions A-1 to A-5 as specified in Table 23 and Annex C (for High Rise Buildings) shall apply.

6.1.3 *Exit Facilities*

The capacity of any open mezzanine or balcony shall be added to the capacity of the floor for the purpose of determining the exit capacity.

6.1.3.1 In addition to requirements specified for occupancy sub-division A-2, the following shall be provided for occupancy sub-division A-1:

> Every sleeping room above the street floor shall have access to two separate means of exits, at least one of which shall consist of an enclosed interior stairway, or a fire escape or horizontal exit all so arranged as to provide a safe path of travel to the outside of the building without traversing any corridor or space exposed to an unprotected vertical opening.

6.1.3.2 For occupancy sub-division A-2 of more than two rooms, every occupied room, excluding areas used solely for storage shall have at least two means of exits, at least one of which shall be a door or a stairway providing a means of un-obstructed travel to the outside of the building or street or grade level. No room or space shall be occupied which is accessible only by a ladder, folding stairs or through a trap door.

Further the following provisions shall be made:

> All locking devices, which would impede or prohibit exit, such as chain type bolts, limited opening sliding type locks and burglar locks, which are not dis-engaged easily by quick-releasing catches, shall be prohibited. All closet door latches shall be such that even children can open the doors from inside. All bathroom door locks or fasteners shall be designed to permit the opening of the locked or closed door from the outside in an emergency without the use of a special key.

6.1.3.3 For occupancy sub-division A-3, the following provisions shall apply:

> All dormitories shall have exits so arranged that from any sleeping room or open dormitory sleeping area, there shall be access to two separate and distinct exits in different directions with no common path of travel unless the room or space is subject to occupancy by not more than 10 persons and has a door opening directly to the outside of the building at street or grade level, or to an outside stairway in which case one means of exit may be accepted.

6.1.3.4 For occupancy sub-division A-4, the following provisions shall apply:

a) Every individual living unit covered by occupancy sub-division A-4 shall comply with the requirement for occupancy sub-division A-2 in respect of exits.

b) Every living unit shall have access to at least two separate exits, which are remote from each other and are reached by travel in different directions, except that a common path of travel may be permitted for the first 6 m (that is a dead end corridor up to 6 m long may be permitted) provided that single exit may be permitted under any of the conditions given under (c).

c) Any part of building lower than the grade level shall have direct accessibility from outside.

d) At least half of required exits shall discharge direct to the outside of the buildings; any other exit shall be the same as required for hotels.

6.1.3.5 For occupancy sub-divisions A-5 and A-6, the following provisions shall apply:

a) Not less than two exits, as remote from each other as practicable, shall be accessible from every floor, including basements occupied for hotel purpose, except as a single exit as permitted in (b) below. Exits and ways of access thereto shall be so arranged that they are accessible in at least two different directions from every point in any open area, or from any room door.

b) Any room or section with an outside door at street or grade level may have such outside door as a single exit, provided no part of the room or area is more than 15 m from the door measured along the natural path of travel.

c) Provision of panic bars shall be provided in the exits.

6.1.3.5.1 Where stairways or other exits serve two or more upper floors, the same stairway or other exit required to serve any one upper floor may also serve other upper floors, except that no inside open stairway or ramp may serve as a required egress facility from more than one floor [*see* good practice 4(26)].

6.1.3.6 *Basement Exits*

a) Basements occupied for hotel purposes shall have exits arranged in accordance with **6.1.3.5**.

b) Basement exits shall be sufficient to provide for the capacity of the basement as determined in accordance with **6.1.1**. In no case shall there be less than two independent basement exits.

c) Basement or sub-basements not open to the public and used only for heating equipment, storage and service operations (other than kitchens, which are considered part of the hotel occupancy) shall have exits appropriate to the actual occupancy, in accordance with other applicable provisions of the Code, or in case of mixed occupancy where there may be doubt as to which other section is applicable, such basements shall have exits determined on the basis of lesser exit capacity.

6.1.4 Additional Precautions

6.1.4.1 Flammable liquids for household purposes shall be kept in tightly stoppered or sealed containers. For the limits of quantities of flammable liquids to be allowed in various occupancies, reference may be made to appropriate regulations.

6.1.4.2 No stove or combustion heater shall be located directly under or immediately at the foot of stairs or otherwise so located as to block escape in case of malfunctioning of the stove or heater.

6.1.4.3 All kitchen exhaust fans, where provided, shall be fixed to an outside wall or to a duct of non-combustible material, which leads directly to the outside. The ducts must not pass through areas having combustible materials.

6.1.4.4 All wiring shall be done in accordance with Part 8 'Building Services, Section 2 Electrical Installations', good practice [4(10)] and National Electric Code.

6.1.4.5 Where television is installed, all outdoor antennae shall be properly grounded and protected from lightning (*see* Part 8 'Building Services, Section 2 Electrical Installations').

6.1.4.6 Doors leading to rooms in which flammable liquids are stored or used shall be as in **4.7**. Such assembly shall be self-closing and shall be posted with a sign on each side of the door in 25 mm high block letters stating — 'FIREDOOR — KEEP CLOSED'.

6.1.4.7 Where a boiler room is provided or a central heating plant is installed, which uses solid or liquid fuel, it shall be separated from rest of the building by a separation wall with all openings protected as in **3.4.7** and **3.4.8**.

6.1.4.8 Rooms containing high pressure boilers, refrigerating machinery, transformers or other service equipment subject to possible explosion shall not be located directly under or adjacent to exits. All such rooms shall be effectively cut off from other parts of the building and shall be provided with adequate vents to the outside air.

6.1.4.9 All rooms or areas of high hazard in additions to those herein before mentioned, shall be segregated

or shall be protected as may be directed by the enforcing Authority where, in the opinion of the enforcing Authority, fire, explosion or smoke there from is likely to interfere with safe egress from the building.

6.1.4.10 For detailed information regarding fire safety requirements for hazardous petroleum products, reference may be made to the *Petroleum Act*, 1934 and the Rules thereof.

6.2 Requirements of Educational Buildings (Group B)

6.2.1 In addition to the general requirements specified in **3.4** for the type of construction and occupancy group and the exit requirements given in **4**, the requirements given in **6.2.2** to **6.2.6.3** shall be complied with.

6.2.2 Buildings intended for educational occupancy shall not be used for any hazardous occupancy.

6.2.3 *Fire Detection/Extinguishing System*

The requirements for occupancy sub-divisions B-1 and B-2 as specified in Table 23 and Annex C (for High Rise Buildings) shall apply.

6.2.4 *Exit Facilities*

The capacity of any open mezzanine or balcony shall be added to the capacity of the floor for the purpose of determining the exit capacity.

In addition to the provisions in **4**, the following shall be provided:

6.2.4.1 Exits, in accordance with **4** shall be so arranged that at least two separate exits are available in every floor area. Exits shall be as remote from each other as practicable and so arranged that there are no pockets or dead ends of appreciable size in which occupants may be trapped.

6.2.4.2 Every room with a capacity of over 45 persons in area shall have at least two doorways.

6.2.4.3 Exterior doors shall be operated by panic bars or some other panic hardware device, except that doors leading from classrooms directly to the outside may be equipped with the same type of lock as is used on classroom doors leading to corridor, with no provision whatsoever for locking against egress from the classroom.

6.2.5 *Additional Precautions*

6.2.5.1 Storage of volatile flammable liquids shall be prohibited and the handling of such liquids shall be restricted to science laboratories only.

6.2.5.2 Each building shall be provided with an approved outside gas shut-off valve conspicuously marked. The detailed requirements regarding safe use of gas shall be as specified in Part 9 'Plumbing Services, Section 3 Gas Supply'.

6.2.5.3 All exterior openings in a boiler room or rooms containing central heating equipment, if located below opening in another storey or if less than 3 m from other doors or windows of the same building, shall be protected by a fire assembly as in **3.4.8**. Such assemblies shall be fixed, automatic or self-closing. Provisions of **6.1.4.7** shall also apply to this group of occupancy.

6.2.6 *Exception and Deviation*

6.2.6.1 Gymnasiums, indoor stadiums and similar occupancies may have floors/running tracks of wood, cinder, synthetic or unprotected steel or iron.

6.2.6.2 In gymnasiums and in multi-purpose school rooms having an area not greater than 300 m^2, 25 mm nominal tight tongue-and-grooved or 20 mm plywood wall covering may be used in the inner side in lieu of fire-resistant plaster.

6.2.6.3 A building, which will have only the first floor and is accessible to not more than 20 pupils at any time, may be used for school purposes with the following exceptions:

a) Exterior walls or parts of walls which are less than 900 mm from adjacent property lines shall have no openings therein.

b) Classrooms may have only one exit not less than 900 mm wide.

6.3 Requirements of Institutional Buildings (Group C)

6.3.1 In addition to the general requirements specified in **3.4** for the type of construction and occupancy group and the exit requirements given in **4**, the requirements given in **6.3.2** to **6.3.5** shall be complied with.

6.3.2 *Fire Detection/Extinguishing System*

The requirements for occupancy sub-divisions as specified in Table 23 and Annex C (for High Rise Buildings) shall apply.

6.3.3 *Exit Facilities*

In addition to the provisions of **4**, the following requirements shall be complied with.

6.3.3.1 In buildings or sections occupied by bed-ridden patients where the floor area is over 280 m^2, facilities shall be provided to move patients in hospital beds to the other side of a smoke barrier from any part of such building or section not directly served by approved horizontal exits or exits from the first floor (floor 2) of a building to the outside.

6.3.3.2 Not less than two exits of one or more of the following types shall be provided for every floor, including basement, of every building or section:

a) Doors leading directly outside the building;
b) Stairways;
c) Ramps;
d) Horizontal exits; and
e) Fire tower.

6.3.3.3 All required exits that serve as egress from hospital or infirmary sections shall be not less than 2 m in clear width including patient bedroom doors to permit transportation of patients on beds, litters, or mattresses. The minimum width of corridors serving patients bedrooms in buildings shall be 2 400 mm. For detailed information on recommendations for buildings and facilities for the physically handicapped, reference may be made to good practice [4(27)].

6.3.3.4 Elevators constitute a desirable supplementary facility, but are not counted as required exits. Patient lifts shall also be provided with enough room for transporting a stretcher trolley.

6.3.3.5 Any area exceeding 500 m^2 shall be divided into compartments by fire resistant walls.

6.3.3.6 Doors in fire resistant walls shall be so installed that these may normally be kept in open position, but will close automatically. Corridor door openings in smoke barriers shall be not less than 2 000 mm in width. Provision shall also be made for double swing single/ double leaf type door.

6.3.3.7 Exits and other features for penal and mental institutions, and custodial institutions shall be the same as specified for hospitals, in so far as applicable. Reliable means shall be provided to permit the prompt release of inmates from any locked section in case of fire or other emergency.

6.3.3.8 Wherever any inmates are confined in any locked rooms or spaces, adequate guards or other personnel shall be continuously on duty or immediately available to provide for release of inmates or for such other action as may be indicated in case of fire or other emergency.

6.3.3.9 No building constructed in whole or in part of combustible materials shall be used to confine inmates in cells or sleeping quarters, unless automatic sprinkler protection is provided.

6.3.3.10 All buildings or sections of buildings in penal and mental institutions used for manufacturing, storage or office purposes shall have exits in accordance with the provisions of the Code for those occupancies.

6.3.4 *Additional Precautions*

6.3.4.1 No combustible material of any kind shall be stored or used in any building or section thereof used for institutional occupancy, except as necessary to normal occupancy and use of the building.

6.3.4.2 Bare minimum quantities of flammable material such as chloroform, ethyl alcohol, spirit, etc shall be allowed to be stored and handled. The handling of such liquids shall not be permitted by un-authorized persons. Bulk storage of these items, will be governed by relevant rules and safe practices.

6.3.5 *Exceptions and Deviations*

It is recognized that in institutions or part of buildings housing various types of psychiatric patients, or used as penal and mental institutions, it is necessary to maintain locked doors and barred windows; and to such extent the necessary provision in other sections of the Code requiring the keeping of exits unlocked may be waived. It is also recognized that certain type of psychiatric patients are not capable of seeking safety without adequate guidance. In buildings where this situation prevails, reliable means for the rapid release of occupants shall be provided, such as remote control of locks, or by keying all locks to keys commonly used by attendants.

6.4 Requirements of Assembly Buildings (Group D)

6.4.1 In addition to the general requirements specified in **3.4** for type of construction and occupancy group and the exit requirements given in **4**, the requirements given in **6.4.2** to **6.4.8.9** shall be complied with.

6.4.2 *Mixed Occupancy*

Places of assembly in buildings of other occupancy, such as ballrooms in hotels, restaurants in stores and assembly rooms in schools, shall be so located, separated or protected as to avoid any undue danger to the occupants of the place of assembly from a fire originating in the other occupancy or smoke therefrom.

6.4.3 *Fire Detection/Extinguishing System*

The requirements for occupancy sub-divisions D-1 to D-5 as specified in Table 23 and Annex C (for High Rise Buildings) shall apply.

NOTE — Canteens shall not be provided in basements. If provided in the upper floors, it shall be sprinklered.

6.4.4 *Exit Facilities*

6.4.4.1 Every place of assembly, every tier or balcony, and every individual room used as a place of assembly shall have exits sufficient to provide for the total capacity thereof as determined in accordance with **4**. Door width for assembly buildings shall not be less than 2 000 mm.

a) Every place of assembly of sub-division D-1

shall have at least four separate exits as remote from each other as practicable.

b) Every place of assembly of sub-division D-2, shall have at least two separate exits as remote from each other as practicable and if of capacity over 600 at least three exits shall be provided with each exit not less than of 2 000 mm width.

6.4.4.2 Clear aisles not less than 1.2 m in width shall be formed at right angles to the line of seating in such number and manner that no seat shall be more than seven seats away from an aisle. Rows of seats opening on to an aisle at one end only shall have not more than seven seats. Under the conditions, where all these aisles do not directly meet the exit doors, cross-aisles shall be provided parallel to the line of seating so as to provide direct access to the exit, provided that not less than one cross aisle for every 10 rows shall be required. The width of cross-aisles shall be minimum of 1 m. Steps shall not be placed in aisles to overcome differences in levels, unless the gradient exceeds 1 in 10.

6.4.4.3 The fascia of boxes, balconies and galleries shall have substantial railings not less than 1 000 mm high above the floor. The railings at the end of aisles extending to the fascia shall be not less than 1 100 mm high for the width of the aisle or 1 200 mm high at the foot of steps.

6.4.4.4 Cross-aisles except where the backs of seats on the front of the aisle project 600 mm or more above the floor of the aisle shall be provided with railings not less than 900 mm high.

6.4.4.5 No turnstiles or other devices to restrict the movement of persons shall be installed in any place of assembly in such a manner as to interfere in any way with the required exit facilities.

6.4.4.6 In theatres and similar places of public assembly where persons are admitted to the building at a time when seats are not available for them and are allowed to wait in a lobby or similar space until seats are available, such use of lobby or similar space shall not encroach upon the required clear width of exits. Such waiting shall be restricted to areas separated from the required exit ways by substantial permanent partitions or fixed rigid railing not less than 105 cm high. Exits shall be provided for such waiting spaces on the basis of one person for each 0.3 m^2 of waiting space area. Such exits shall be in addition to the exits specified for the main auditorium area and shall conform in construction and arrangement to the general rules of exits given above.

6.4.4.7 No display or exhibit shall be so installed or operated as to interfere in any way with access to any required exit, or with any required exit sign.

All displays or exhibits of combustible material or construction and all booths and temporary construction in connection therewith shall be so limited in combustibility or protected as to avoid any undue hazard of fire which might endanger occupants before they have opportunity to use the available exits, as determined by the authority.

6.4.4.8 Places of assembly in buildings of other occupancy may use exits common to the place of assembly and the other occupancy, provided the assembly area and the other occupancy are considered separately, and each has exits sufficient to meet the requirements of the Code.

6.4.4.9 Exits shall be sufficient for simultaneous occupancy of both the places of assembly and other parts of the building, unless the Authority determines that the conditions are such that simultaneous occupancy will not occur.

6.4.4.10 For any place of assembly under sub-division D-1, at least half the required means of exits shall lead directly outdoors or through exit ways completely separated from exits serving other parts of the building.

6.4.4.11 For detailed information regarding cinema buildings, reference may be made to good practice [4(28)].

6.4.5 *Lighting*

No open flame lighting devices shall be used in any place of assembly, except in the following cases:

a) Where necessary for ceremonial purposes, the enforcing Authority may permit open flame lighting under such restrictions as are necessary to avoid danger of ignition of combustible materials or injury to occupants.

b) Candles may be used on restaurant tables if securely supported on non-combustible bases and so located as to avoid danger of ignition of combustible materials.

c) Open flame devices may be used on stages where they are a necessary part of theatrical performance, provided adequate precautions, satisfactory to the Authority are taken to prevent ignition of combustible materials.

6.4.6 *Additional Precautions*

6.4.6.1 The decorations of places of assembly shall be of non-flammable materials. Fabrics and papers used for such purpose shall be treated with an effective flame-retardant material. Stage settings made of combustible materials shall likewise be treated with fire retardant materials of Class 1 flame spread.

6.4.6.2 Seats in places of public assembly, accommodating more than 300 persons, shall be

securely fastened to the floor, except as permitted in **6.4.6.3**. All seats in balconies and galleries shall be securely fastened to the floor, except that in nailed-in enclosures, boxes with level floors and having not more than 14 seats, the seats need not be fastened.

6.4.6.3 Chairs not secured to the floor may be permitted in restaurants, night clubs and other occupancies where the fastening of seats to the floor may not be practicable, provided that in the area used for seating, excluding dance floor, stage, etc, there shall be not more than one seat for each 1.4 m^2 of floor area and adequate aisles to reach exits shall be maintained at all times.

6.4.6.3.1 Rows of seats between aisles shall have not more than 14 seats.

6.4.6.3.2 Rows of seats opening on to an aisle at one end only shall have not more than 7 seats.

6.4.6.3.3 Seats without dividing arms shall have their capacity determined by allowing 450 mm per person.

6.4.6.4 The spacing of rows of seats from back-to-back shall be neither less than 850 mm nor less than 700 mm plus the sum of the thickness of the back and inclination of the back. There shall be a space of not less than 350 mm between the back of one seat and the front of the seat immediately behind it as measured between plumb lines.

6.4.6.5 Rooms containing high pressure boilers, refrigerating machinery other than domestic refrigerator type, large transformers or other service equipments subject to possible explosion shall not be located directly under or adjacent to the required exits. All such rooms shall be effectively cut off from other parts of the building and provided with adequate vents to the outer air.

6.4.6.6 All rooms or areas used for storage of any combustible materials or equipment, or for painting, refinishing, repair or similar purposes shall be effectively cut off from assembly areas or protected with a standard system of automatic sprinklers. They shall be located away from staircases.

6.4.6.7 Every stage equipped with fly galleries, grid irons and rigging for movable theatre type scenery, shall have a system of automatic sprinklers over and under such stage areas or spaces and auxiliary spaces, such as dressing rooms, store rooms and workshops, and the proscenium opening shall be provided with a fire- resisting curtain, capable of withstanding a lateral pressure of 4 kN/m^2 over the entire area. The curtain shall have an emergency closing device capable of causing the curtain to close without the use of power and when so closed, it shall be reasonably tight against the passage of smoke.

6.4.6.8 The stage roof of every theatre using movable scenery or having a motion picture screen of highly combustible construction shall have a ventilator or ventilators in or above it, openable from the stage floor by hand and also opening by fusible links or some other approved automatic heat/smoke actuated device, to give a free opening equal to at least one-eighth the area of the floor of the stage.

6.4.6.9 The proscenium wall of every theatre using movable scenery of decorations shall have, exclusive of the proscenium opening, not more than two openings entering the stage, each not to exceed 2 m^2 and fitted with self-closing fire resistant doors.

6.4.6.10 Every place of assembly in which projection of motion pictures by light is made shall have the projection apparatus enclosed in a fire-resisting fixed booth in accordance with good practice [4(27)], except that such booth shall not be required where no nitrocellulose motion picture film is used.

6.4.6.11 Automatic smoke vents actuated by smoke detectors shall be installed above the auditorium or theatres, including motion picture houses, with vent area equal to not less than 3 percent of the floor area of the auditorium, including the sum of the floor areas of all balconies, galleries, boxes and tiers. It may be desirable to provide a large number of small vents rather than a small number of large vents.

6.4.7 *Exception and Deviation*

6.4.7.1 Where boilers or central heating plants using liquid or solid fuel are located at grade level, these shall be separated from the remainder of the building by a separating wall with openings protected as in **3.4.7** and **3.4.8**.

6.4.7.2 Gymnasiums, indoor stadiums and similar occupancies may have floors/running tracks of wood, cinder, synthetic or un-protected steel or iron.

6.4.7.3 The underside of continuous steel deck grand stands when erected outdoors need not be fire-protected when occupied for public toilets.

6.4.8 *Fire Protection and Fire Fighting System for Metro Stations*

6.4.8.1 *Wet riser system*

Main and diesel fire pump of 1 800 l/min capacity to be provided to support 3 to 4 hydrants at a time. Jockey pump capacity shall be 180 l/min. Where it is possible to extend reliable DG supply to the fire pump room without routing through the station building, the provision of diesel pump can be dispensed with and instead, two electric pumps may be provided out of which at least one should have DG back-up. The jockey pump should also have DG back-up.

2 number RRL hose pipes of 38 mm dia with 63 mm standard instantaneous coupling along with associated branch pipes and cabinet and a first aid hose reel of 25 mm dia, length 45 m and fitted with 6.5 mm nozzle.

Two internal hydrants are proposed to be provided on each platform in such a way so that most of the platform is covered by hose. However, in case of necessity, the hose pipes from other hose cabinets can be utilized for extending the length of fire hose pipe for fire fighting, if need be. At the concourse level minimum two hydrants will be provided. In station where the concourse is split into two halves at least one hydrant is to be provided in each half of the concourse. Further, in case the area is more than 2 000 m^2, an additional first aid hose-reel point shall be provided for every additional 1 000 m^2.

In addition, hydrants shall be provided in commercial areas also.

One hydrant shall be provided at entry of each station at ground floor for providing the coverage to the parking area.

6.4.8.3 *Sprinklers*

Sprinklers are required to be provided only in the commercial areas, if any, in the station. The commercial areas will be segregated from the station area through 2 h fire rated walls and doors. Additional sprinkler pumps are not required, as two pumps already provided for hydrant system will take care of the sprinkler flow requirements.

However, if such commercial areas in the premises of stations are in isolated building separate from the station building then the provision of sprinkler pump and water tank capacities shall be as per this Code. The water storage and pumps may however be common.

6.4.8.4 *Detectors*

Detectors are required to be provided only in areas where there are false ceiling and false floor and areas of equipment rooms. Wherever there are false ceiling, the detectors should be provided both above and below cross ventilation and therefore may not be provided. In other areas, because of high heights and cross-ventilations, detectors will not be effective and hence therefore can be dispensed. A conventional detection system will suffice at a normal station.

6.4.8.5 *Manual call box*

Manual call box should be provided at a central place on each platform (near emergency plunger) and at least two on the concourse, on each sidewall. When the concourse in two halves there should be one manual call box on each side.

6.4.8.6 *Manual panel gas flooding*

Electric panels should have provision of manual gas flooding. Alternatively panels can be provided with linear heat sensing tubes with CO_2 cylinder. This required to be provided only in main power panels, that is HT panel, main LT panel, main LT distribution board and essential power panels and other such major panels.

6.4.8.7 *External area of the station*

A 'two way/four way' fire brigade inlet to be provided at ground level on each rising main for hydrants/ sprinkles.

The 'Draw Off Connection' shall be provided on the underground tank for fire brigade.

6.4.8.8 *Water tank capacity*

Capacity of fire tanks at stations without any commercial development (Beverage stall/ATM/Florist/ Book stalls up to total 250 m^2 excluded) shall be 50 000 litres.

However, at stations having commercial development, the fire tank capacity shall be 100 000 litres.

6.4.8.9 *Portable fire extinguishers*

For the purpose of standardization, the following portable extinguishers are recommended:

a)	Water CO_2 type	9 litres
b)	CO_2 fire extinguishers	4.5 kg

They shall be provided in various areas as detailed hereunder:

Sl No.	*Item*	*Numbers and Location*
(1)	(2)	(3)
PLATFORM		
1.	Internal Hydrants	Two at each platform. The hydrants at two platforms may be staggered for maximum coverage.
2.	Manual call box	One on each platform preferably near emergency plunger.
3.	Portable Extinguishers	One set of Water CO_2 and CO_2 type on each platform at a central area.
CONCOURSE		
1.	Internal Hydrants	Two at each concourse. When concourse is in two parts then each part should have at least one hydrant.
2.	Additional first-aid reel point	Additional first-aid reel point for every additional 1 000 m^2, if the area is more than 2 000 m^2. Similarly, if the concourse is in two parts then additional first aid reel point for every additional 1 000 m^2, if the area of the part is more than 1 000 m^2.
3.	Manual call box	Two at each concourse. When concourse is in two parts then each part should have at least one.
4.	Portable Extinguishers	Two sets at each concourse. When concourse is in two parts then each part should have at least one set.
5.	Detectors	Above false ceiling where depth of false ceiling is greater than 800 mm. Required in commercial areas also.
EQUIPMENT ROOM AREAS		
1.	Internal Hydrants/first-aid reel point	The requirement shall get covered with platform/concourse. Additional first-aid reel point may be provided, if required.
2.	Manual call box	One at a central place. When the equipment rooms are in two/more parts then each part should have one.
3.	Portable Extinguishers	One set for each room.
4.	Detectors	Above and below false ceiling and below floor giving due consideration to depth of false ceiling/floor.
5.	Response Indicator	To be provided.
6.	Panel gas flooding	To be provided for HT panel, main LT panel, main LT distribution board and essential power panels and other such major panels.
EXTERNAL AREAS		
1.	Hydrants	One at ground floor at each entry to station near staircase/DG room.
2.	Two/four way fire brigade inlet	To be provided for each riser/sprinkler riser.
3.	Fire brigade Draw-off connection	To be provided on water tank.

6.5 Business Buildings (Group E)

6.5.1 In addition to the general requirements specified in **3.4** for type of construction and occupancy group and the exit requirements given in **4**, the requirements given in **6.5.2** to **6.5.5** shall be complied with.

6.5.2 *Fire Detection/Extinguishing System*

The requirements for occupancy sub-divisions as specified in Table 23 and Annex C (for High Rise Buildings) shall apply.

6.5.2.1 *Occupancy sub-division E-1 (except office buildings)*

Details of Occupancy	*Fire Detection/Extinguishing System*
E-1	Automatic fire alarm system {good practice [4(17)] and [4(18)], and Table 23}.

6.5.2.2 *Occupancy sub-division E-2*

Details of Occupancy	*Fire Detection/Extinguishing System*
a) Laboratory with delicate instruments	Fixed automatic CO_2 fire extinguishing system or automatic fire alarm system {good practice [4(18)] and [4(19)], and Table 23}
b) Solvent storage and/or flammable liquid	Automatic foam installation or automatic CO_2 fire extinguishing system

6.5.2.3 *Occupancy sub-division E-3*

Details of Occupancy	*Fire Detection/Extinguishing System*
a) Area of computer installations	Automatic fire alarm system {good practice [4(18)] and [4(19)], and Table 23} any suitable halon alternative fire extinguishing system (*see* **5.3**) or any other suitable fire extinguishing installation {*see also* [4(29)]}.
b) Space under false ceiling (floor)	Automatic fire alarm system {good practice [4(18)] and [4(19)], and Table 23}
c) Space above false ceiling and below false floor	Automatic fire alarm system {good practice [4(18)] and [4(19)], and Table 23}
d) Electrical switch board	Automatic fire alarm system {good practice [4(18)] and [4(19)], and Table 23} and CO_2 fire extinguishing installation

6.5.2.4 *Occupancy sub-division E-4*

Details of Occupancy	*Fire Detection/Extinguishing System*
Telephone exchanges	Any suitable halon alternative fire extinguishing system (*see* **5.3**) and/or automatic sprinkler system as per requirement (*see also* Table 23)

6.5.2.5 *Occupancy sub-division E-5*

Details of Occupancy	*Fire Detection/ Extinguishing System*
Broadcasting stations	Automatic fire alarm system based on smoke detectors and sprinkler system (*see also* Table 23)

6.5.3 *Exit Facilities*

6.5.3.1 In the case of mezzanines or balconies open to the floor below, or other unprotected vertical openings between floors, the population of the mezzanine or other subsidiary floor for level shall be added to that of the main floor for the purpose of determining the required exits, provided, however, that in no case shall the total number of exit units be less than that required if all vertical openings were enclosed.

6.5.3.2 Not less than two exits shall be provided for every floor, including basements occupied for office purposes or uses incidental thereto.

6.5.4 *Additional Requirements*

6.5.4.1 The handling and use of gasoline, fuel oil and other flammable liquids shall not be permitted, unless such use and handling complies with the appropriate regulations.

6.5.4.2 Every boiler room or room containing a central heating plant using solid or liquid fuel shall be separated from the rest of the building by a separating wall. Every boiler room or room containing a central heating plant, which burns gas as a fuel shall be adequately separated from the rest of the building.

6.5.5 *Exception and Deviation*

6.5.5.1 Basements used only for storage, heating, any other service equipment shall conform to exit requirements for Group H occupancies in all respects.

6.6 Requirements of Mercantile Buildings (Group F)

6.6.1 In addition to the general requirements specified in **3.4** for type of construction and occupancy and the exit requirements given in **4**, the requirements given in **6.6.1.1** to **6.6.5** shall be complied with.

6.6.1.1 *Mixed occupancy*

No dwelling unit shall have its sole means of exit through any mercantile occupancy in the same building except in the case of a single family unit where the family operates the store.

6.6.2 *Fire Detection/Extinguishing System*

The requirements for occupancy sub-divisions F-1 to F-3 as specified in Table 23 and Annex C (for High Rise Buildings) shall apply.

6.6.3 *Exit Facilities*

In addition to the provisions of **4**, the following requirements shall be complied with.

6.6.3.1 In the case of mezzanines or balconies open to the floor below, or other un-protected vertical openings between floors, the population or area of the

mezzanine or other subsidiary floor level shall be added to that of the main floor for the purpose of determining the required exits, provided, however, that in no case shall the total number of exit units be less than that required if all vertical openings were enclosed.

6.6.3.2 At least two separate exits shall be accessible from every part of every floor, including basements; such exits shall be as remote from each other as practicable and so arranged as to be reached by different paths of travel in different directions, except that a common path of travel may be permitted for the first 15 m from any point.

6.6.4 *Additional Precautions*

6.6.4.1 Requirements specified in **6.5.4.1** shall be applicable to all Group F occupancies also.

6.6.4.2 Hazardous areas of mercantile occupancies shall be segregated or protected suitably.

6.6.4.3 In self-service stores, no check-out stand or associated railings or barriers shall obstruct exits or required aisles or approaches thereto.

6.6.4.4 Open-air mercantile operations, such as open-air markets, gasoline filling stations, roadside stands for the sale of a farm produce and other outdoor mercantile operations shall be so arranged and conducted as to maintain free and unobstructed ways of travel at all times to permit prompt escape from any point of danger in case of fire or other emergency, but no dead-ends in which persons might be trapped due to display stands, adjoining buildings, fences, vehicles or other obstructions.

6.6.4.5 If mercantile operations are conducted in roofed-over areas, these shall be treated as mercantile buildings, provided canopies over individual small stands to protect merchandise from the weather shall not be constructed to constitute buildings for the purpose of the Code.

6.6.5 *Exception and Deviation*

Any mercantile occupancy, where goods of a highly hazardous nature are pre-dominant, shall be considered under Group J occupancy for the purpose of the Code.

6.7 Requirements of Industrial Buildings (Group G)

6.7.1 In addition to the general requirements specified in **3.4** for the type of construction and occupancy group and the exit requirements given in **4**, the requirements given in **6.7.2** to **6.7.5** shall be complied with.

6.7.2 *Fire Detection/Extinguishing System*

The requirements for occupancy sub-divisions G-1 to G-3 as specified in Table 23 and Annex C (for High Rise Buildings) shall apply.

6.7.3 *Exit Facilities*

In addition to the provisions of **4**, the following requirements shall be complied with.

6.7.3.1 Not less than two exits shall be provided for every floor or section, including basements used for industrial purposes or uses incidental thereto.

6.7.3.2 In buildings used for aircraft assembly or other occupancy requiring undivided floor areas so large that the distances from points within the area to the nearest outside walls where exit doors could be provided are in excess of 45 m, requirements for distance to exits may be satisfied by providing stairs leading to exit tunnels or to overhead passageways. In cases where such arrangements are not practicable, the Authority may, by special ruling, permit other exit arrangements for one storey buildings with distances in excess of the maximum distances specified in **4**, if completely automatic sprinkler protection is provided and if the heights of ceiling curtain boards and roof ventilation are such as to minimize the possibility that employees will be overtaken by the spread of fire or smoke within 1 800 mm of the floor level before they have time to reach exits, provided, however, that in no case may the distance of travel to reach the nearest exit exceed 45 m where smoke venting is required as a condition for permitting distances of travel to exits in excess of the maximum otherwise allowed.

6.7.3.3 *Additional precautions*

a) In any room in which volatile flammable substances are used or stored, no device generating a glow or flame capable of igniting flammable vapour shall be installed or used. Such a room shall be provided with a suitably designed exhaust ventilation system (*see* Annex D). To ensure safety from fire due to short circuit, faulty electrical connection or some similar cause, proper care shall be taken in designing electrical installations in such room (*see* Part 8 'Building Services, Section 2 Electrical Installations').

b) The storage, use and handling of gasoline, fuel oil and other flammable liquids shall not be permitted in any Group G occupancy unless it complies with regulations pertaining to *Petroleum Act*, 1934 and Rules thereunder.

c) Every boiler room or room below the first floor containing a heating plant shall be adequately separated from the rest of the buildings.

d) For requirements regarding electrical generating and distribution stations, reference may be made to good practice [4(23)].

6.7.3.4 *Exception and deviation*

a) Basements used only for storage, heating or other service equipment, and not subject to industrial occupancy, shall have exits in accordance with the requirements of Group H occupancies.

b) The following exceptions shall apply to special purpose industrial occupancies:

1) Exits need be provided only for the persons actually employed; spaces not subject to human occupancy because of the presence of machinery or equipment may be excluded from consideration.

2) Where unprotected vertical openings are necessary to manufacturing operations, these may be permitted beyond the limits specified for industrial occupancy, provided every floor level has direct access to one or more enclosed stairways or other exits protected against obstruction by any fire in the open areas connected by the unprotected vertical openings or smoke therefrom.

3) Industrial buildings of low and moderate hazard are permitted only up to 18 m height.

c) The following exceptions shall apply to high hazard industrial occupancies:

1) Exits shall be so located that it will not be necessary to travel more than 22.5 m from any point to reach the nearest exit.

2) From every point in every floor area, there shall be at least two exits accessible in different directions; where floor areas are divided into rooms, there shall be at least two ways of escape from every room, however small, except toilet rooms, so located that the points of access thereto are out of or suitably shielded from areas of high hazard.

3) In addition to types of exits for upper floors specified for Group G occupancies, slide escapes may be used as required exits for both new and existing buildings.

4) All high hazard industrial occupancies shall have automatic sprinkler protection or such other protection as may be appropriate to the particular hazard, including explosion venting for any area subject to explosion hazard, designed to minimize danger to occupants in case of fire or other emergency before they have time to utilize exits to escape.

5) Industrial buildings of high hazard are permitted only up to 15 m height.

6.7.4 For detailed information on fire safety of certain individual (specific) industrial occupancies reference may be made to good practice [4(39)].

6.7.5 Fire protection considerations for venting industrial occupancies shall be as given in Annex D.

6.8 Requirements of Storage Buildings (Group H)

6.8.1 In addition to the general requirements specified in **3.4** for type of construction and occupancy group and the exit requirements given in **4**, the requirements given in **6.8.2** to **6.8.5** shall be complied with.

6.8.2 *Fire Detection/Extinguishing System*

The requirements for occupancy group H, as specified in Table 23 and Annex C (for High Rise Building) shall apply.

NOTE — Automatic sprinklers are prohibited where water reactive materials are kept. Instead automatic fire alarm system coupled with suitable fire extinguishing systems shall be installed.

6.8.3 *Exit Facilities*

In addition to the provisions of **4**, the following requirements shall also be complied with.

6.8.3.1 Every building or structure used for storage and every section thereof considered separately, shall have access to at least one exit so arranged and located as to provide a suitable means of escape for any person employed therein and in any room or space exceeding 1 400 m^2 gross area, or where more than 10 persons may be normally present, at least two separate means of exit shall be available, as remote from each other as practicable.

6.8.3.2 Every storage area shall have access to at least two means of exit, which can be readily opened. This shall not be subject to locking so long as any persons are inside and shall not depend on power operation.

6.8.3.3 The following special provisions shall apply to parking garages of closed or open type, above or below ground, but not to mechanical parking facilities where automobiles are moved into and out of storage mechanically which are not normally occupied by persons and thus require no exit facilities. Where repair operations are conducted, the exits shall comply with the requirements of Group G occupancies in addition to compliance with the following:

a) Where both parking and repair operations are conducted in the same building, the entire building shall comply with the requirements for Group G occupancies, unless the parking

and repair sections are effectively separated by separation walls.

b) Every floor of every closed parking garage shall have access to at least two separate means of exit, so arranged that from any point in the garage the paths of travel to the two means of exit shall be in different directions, except that a common path of travel may be permitted for the first 15 m, from any point.

c) On the street floor, at least two separate exit doors shall be provided, except that any opening for the passage of automobiles may serve as a means of exit, provided no door or shutter is installed thereon. Street floor exits in closed garages shall be so arranged that no point in the area is more than 30 m from the nearest exit, or 45 m in the case of garages protected by automatic sprinklers, distance being measured along the natural path of travel.

d) On floors above the street, at least two means of exit shall be provided, one of which shall be an enclosed stairway. The other means of egress may be a second exit of any of the types, or in a ramp type garage with open ramps not subject to closure, the ramp may serve as the second means of exit.

e) Upper floor exits in closed garages shall be so arranged that no point in the area shall be more than 30 m from the nearest exit other than a ramp on the same floor level or 45 m in the case of garages protected by automatic sprinklers.

f) On floors below the street (either basement or outside underground garages) at least two exits shall be provided, not counting any automobile ramps, except that for garages extending only one floor level below the street, a ramp leading direct to the outside may constitute one required means of exit. In garages below street level, exits shall be so arranged that no part of the area shall be more than 30 m from the nearest stair exit.

g) If any gasoline pumps are located within any closed parking garage, exits shall be so located that travel away from the gasoline pump in any direction shall lead to an exit; with no dead-end in which occupants might be trapped by fire or explosion at any gasoline pump. Such exit shall lead to the outside on the building on the same level, or downstairs; no upward travel shall be permitted unless direct outside exits are available from that floor and any floor below (as in the case of a basement garage where the grade is one storey or more lower at the rear than at the street).

6.8.3.4 Exits from aircraft hangers (storage or servicing areas) shall be provided at intervals of not more than 45 m on all exterior walls of aircraft hangers. There shall be a minimum of two exits serving each aircraft storage or servicing areas. Horizontal exits through interior fire walls shall be provided at intervals of not more than 30 m. 'Dwarf or 'smash' doors accommodating aircraft may be used to comply with these requirements. All doors designated as exits shall be kept unlocked in the direction of exit travel while the area is occupied.

6.8.3.5 Exits from mezzanine floors in aircraft storage or servicing areas shall be so arranged that the maximum travel to reach the nearest exits from any point on the mezzanine shall not exceed 22.5 m. Such exits shall lead directly to a properly enclosed stairwell discharging directly to the exterior or to a suitably cut-off area or to outside fire escape stairs.

6.8.3.6 The following special provisions shall apply to grain elevators:

a) There shall be at least one stair tower from basement to first floor and from the first floor to the top floor of workhouse which is enclosed in a dust-tight non-combustible shaft.

b) Non-combustible doors of self-closing type shall be provided at each floor landing.

c) An exterior fire escape of the stair or basket ladder type shall be provided from the roof of the workshop to ground level or the roof of an adjoining annexe with access from all floors above the first.

d) An exterior fire escape of either the stair or basket ladder type shall be provided from the roof of each storage annexe to ground level.

6.8.4 *Additional Precautions*

Requirements specified in **6.7.3.3** shall apply to Group H occupancies also.

6.8.5 *Exceptions and Deviations*

Every area used for the storage of hazardous commodities shall have an exit within 22.5 m of any point in the area where persons may be present or 35 m where automatic sprinkler protection is provided.

6.9 Requirements of Buildings for Hazardous Uses (Group J)

6.9.1 In addition to the general requirements specified in **3.4** for type of construction and occupancy group and the exit requirements given in **4**, the requirements given in **6.9.2** to **6.9.4** shall be complied with.

6.9.2 *Fire Detection/Extinguishing System*

The requirements for occupancy Group J, as specified in Table 23 and Annex C (for High Rise Building) shall apply.

NOTE — Hazardous buildings shall have vapour detectors/ explosion suppression systems/automatic sprinklers, besides hydrant system, wet risers and automatic fire alarm system depending on the type of fire hazard involved.

6.9.3 *Exit Facilities*

Requirements specified in **4** and **6.7.3.4** (c) shall apply to Group J occupancies also.

6.9.4 *Additional Precautions*

The following requirements shall apply to all Group J occupancies, as applicable:

a) Each building where gas is employed for any purpose shall be provided with an approved outside gas shut-off valve conspicuously marked. The detailed requirements regarding safe use of gas shall be as specified in Part 9 'Plumbing Services, Section 2 Gas Supply'.

b) Each boiler room or room containing a heating plant shall be separated from the rest of the building by a separating wall.

c) In any room in which volatile flammable substances are used or stored, no device generating a spark, or glow flame capable of igniting flammable vapour shall be installed or permitted unless it is enclosed in a flameproof enclosure.

d) The use, handling, storage and sale of gasoline, fuel oil and other flammable liquids snail not be permitted in Group J occupancies unless such use, handling, storage and sale is in accordance with appropriate legislation in force.

e) All openings in exterior walls except wall vents shall be protected by a fire stop assembly as in **4** and they shall be fixed, automatic or self-closing. Wall vents having an area of not less than 100 cm^2 each shall be placed in the exterior walls near the floor line, not more than 1 800 mm apart horizontally. Each building shall be provided with a power driven fan exhaust system of ventilation which shall be arranged and operated so as to produce a complete change of air in each room every 3 min.

f) Each machine in dry-cleaning establishments which uses flammable liquid shall have an adequate steam line or any other suitable extinguishing agent directly connected to it, so arranged as to have the agent automatically released to the inside of each machine should an explosion occur in the machine.

g) Equipment or machinery which generates or emits combustible or explosive dust or fibres shall be provided with an adequate dust collecting and exhaust system.

ANNEX A

(*Clause* 3.1.8)

CALORIFIC VALUES OF COMMON MATERIALS AND TYPICAL VALUES OF FIRE LOAD DENSITY

A-1 The calorific values of some common materials are given in Table 25 for guidance.

Table 25 Calorific Values of Common Materials

Material	Calorific Value (10^3 kJ/kg^{-1})[1]	Wood Equivalent (kg/kg)
(1)	(2)	(3)
Solid Fuels		
Anthracite	28.6	1.66
Bituminous Coal	30.8	1.75
Charcoal	28.4	1.61
Coke (average)	27.5	1.56
Peats	20.9	1.19
Sub-bituminous Coal	22.0	1.25
Woods (hard or softwood)	17.6	1.00
Hydrocarbons		
Benzene	39.6	2.25
Butane	47.1	2.68
Ethane	49.1	2.79
Ethylene	47.7	2.71
Fuel Oil	41.6	2.36
Gas Oil	42.9	2.44
Hexane	44.9	2.55
Methane (natural gas)	52.8	3.00
Octane	45.3	2.58
Paraffin	39.6-44.0	2.3-2.5
Pentane	46.0	2.61
Propane	47.3	2.69
Propylene	46.2	2.63
Alcohols		
Ethyl Alcohol	28.4	1.61
Methyl Alcohol	21.1	1.20
Propyl Alcohol	31.9	1.81
Polymers		
Casein	23.1	1.31
Cellulose	16.5	0.94
Cellulose Acetate	17.8	1.01
Polyethylene	48.4	2.75
Polypropylene	48.4	2.75
Polystyrene	41.8	2.38
Polyvinylchloride	20.9	1.19
Polymethylmethacrylate	24.6	1.40
Polyurethane	35.2	2.00
Polyamide (nylon)	22.0	1.25
Polyester	22.0	1.25
Common Solids		
Asphalt	38.3	2.13
Bitumen	33.4	1.90
Carbon	32.1	1.83
Cotton (Dry)	15.8	0.90
Flax	14.3	0.81
Furs and Skins	18.7	1.06
Hair (animal)	20.9	1.19
Leather	17.6	1.00
Ozokerite (wax)	43.3	2.46
Paper (average)	15.4	0.88
Paraffin wax	40.9	2.33
Pitch	33.0	1.88
Rubber	37.4	2.13
Straw	13.2	0.75
Tallows	37.6	2.14
Tan bark	20.9	1.19
Tar (bituminous)	35.2	2.00
Wool (raw)	21.6	1.23
Wool (scoured)	19.6	1.11
Foodstuffs		
Barely	14.1	0.80
Bran	11.0	0.63
Bread	9.9	0.56
Butter	29.5	1.68
Cheese (Cheddar)	18.1	1.03
Cornmeal	14.1	0.80
Flour	14.1	0.80
Margarine	29.5	1.68
Oatmeal	15.8	0.90
Rice	13.9	0.79
Soyabean Flour	16.1	0.91
Sugar	15.4	0.88
Whole Wheat	14.3	0.81
Miscellaneous		
Acetone	29.7	1.69
Acetaldehyde	25.1	1.43
Formaldehyde	17.6	1.00
Hydrogen	134.2	7.63
Magnesium	24.0	1.36

[1] 1 kJ is approximately equal to 1 Btu so the figures in the tables are also equivalent to Btu/kg.

A-2 The typical values fire load density for arriving at the classification of occupancy hazard is given in Table 26 for guidance.

Table 26 Typical Values of Fire Load Density

Sl No.	Building Type	Fire Load Density (Expressed as Wood Equivalent kg/m^2)
(1)	(2)	(3)
i)	Residential (A-1 and A-2)	25
ii)	Residential (A-3 to A-5)	25
iii)	Institutional and Educational (B and C)	25
iv)	Assembly (D)	25-50
v)	Business (E)	25-50
vi)	Mercantile (F)	Up to 250
vii)	Industrial (G)	Up to 150
viii)	Storage and Hazardous (H and J)	Up to 500

ANNEX B

(*Clauses* 3.1.8 *and* 3.1.11)

BROAD CLASSIFICATION OF INDUSTRIAL AND NON-INDUSTRIAL OCCUPANCIES INTO DIFFERENT DEGREE OF HAZARD

B-1 LOW HAZARD OCCUPANCIES

Abrasive manufacturing premises

Aerated water factories

Agarbatti manufacturing premises

Analytical and/or Q.C. Laboratories

Arecanut slicing and/or Betelnut factories

Asbestos steam packing and lagging manufacturers

Assembly buildings small (D-4 and D-5)

Battery charging and service stations

Battery manufacturing

Breweries

Brickworks

Canning factories

Cardamom factories

Cement factories and/or asbestos or concrete products manufacturing premises

Ceramic factories, crockery, stoneware pipe manufacturing

Clay works

Clock and watch manufacturing

Clubs

Coffee curing, roasting and grinding factories

Condensed milk factories, milk pasturising plants and dairies

Confectionary manufacturing

Dwellings, lodges, dormitories, etc

Educational and research institutions

Electric lamps (incandescent and fluorescent) and T.V. tube manufacturing

Electroplating works

Engineering workshops

Fruits and vegetables dehydrating and drying factories

Fruits products and condiment factories

Glass and glass fibre manufacturing

Godowns and warehouses (non-combustible goods)

Gold thread/gilding factories

Gum and/or glue and gelatine manufacturing

Ice candy and ice-cream and ice factories

Ink (excluding printing ink) factories

Mica products manufacturing

Office premises

Places of worship

Pottery works

Poultry farms

Residential buildings (A-1 to A-4) (except hotels A-5)

Salt crushing factories/refineries stables

Sugar candy manufacturing

Sugar factories and refineries

Tanneries

Umbrella assembling factories

Vermicelli factories

Water treatment/filtration plants and water pump houses

Zinc/copper factories

B-2 MODERATE HAZARD OCCUPANCIES

Airport and other transportation terminal buildings

Aluminium factories

Assembly buildings (D-1 to D-3)

Atta and cereal grinding

Bakeries and biscuit factories

Beedi factories

Bobbin factories

Book-binders, envelopes and paper bag manufacturing

Cable manufacturing

Camphor boiling

Candle works

Carbon paper/typewriter ribbon makers

Card board box manufacturing

Carpenters, wood wool and furniture makers

Carpet and durries factories

Cashewnut factories

Chemical manufacturers (using raw materials having F.P > 23°C)

Cigar and cigarette factories

Coir factories

Cold storage premises

Computer installations

Cork products manufacturing (coir, carpets, rugs and tobacco) (hides and skin presses)

Dry cleaning, dyeing and laundries

Electric sub-stations/distribution stations

Enamelware factories

Filler and wax paper manufacturing

Flour mills

Garment makers

Ghee factories (other than vegetable)

Godowns and warehouses (other than non-combustible goods)

Grains and seed disintegrating or crushing

Grease manufacturing

Hosiery, lace, embroidery and thread

Hospitals including 'X'-ray and other diagonastic clinics (institutional buildings)

Incandescent gas mantle manufacturers

Industrial gas manufacturing (only halogenated hydrocarbons/inert gases)

Man-made yarn/fibre (except acrylic fibre/yarn)

Manure and fertilizer works (blending, mixing and granulating only)

Mercantile occupancies (departmental stores, shopping complex, etc)

Mineral oil blending and processing

Museums, archieves, record rooms

Oil and leather cloth factories

Open storage of flammable liquids (in drums, cans, etc)

Oxygen plants

Paper and cardboard mills (except raw material yard)

Piers, wharves, dockyards

Plastic goods manufacturing

Plywood/wood veneering factories

Printing press premises

Pulverizing and crushing mills

Residential apartments, hotels, cafes, restaurants

Rice mills

Rope works

Rubber goods manufacturing

Rubber tyres and tubes manufacturing

Shellac factories

Silk filiatures

Soaps and glycerine factories

Spray painting

Starch factories

Tea factories (including blending packing of tea)

Telephone exchanges, garages

Textile mills

Woolen mills

B-3 HIGH HAZARD OCCUPANCIES

A)

Aircraft hangers

Aluminium/magnesium powder plants

Bitumanized paper/hessian cloth/tar felt manufacturing

Bulk storage of flammable liquids (tank farm, etc)

Celluloid goods making

Chemical manufacturers (where raw materials have a F.P. < 23°C)

Cigarette filter manufacturing

Cinema films and T.V. production studios

Coal, coke and charcoal ball and briquettes making

Collieries, steel plants

Cotton seeds cleaning and delinting factories

Cotton waste factories

Distilleries

Duplicating/stencil paper making

Fire works manufacture

Foamed plastic and/or converting plants

Godowns of warehouses (combustible/hazardous goods) (H)

Grass, hay, fodder and *BHOOSA* (chaff)

Hazardous occupancy buildings (J)

Industrial gas manufacturing (except halogenated hydrocarbon gases/inert gases)

Industrial units (G-3 occupancies)

Jute mills and jute presses

Linoleum factories

Man-made fibres (only acrylic fibre/yarn making)

Match factories

Mattress and pillow makings (foam plastics)

Metal or tin printers (if more than 50 percent is engineering, shift to ordinary hazard)

Oil mills

Oil extraction plants

Oil terminals/depots

Paints/Varnish factories

Paper and cardboard mills (only raw material yard)

Pressing factories

Printing ink making

Resin, lamp black and turpentine manufacture

Saw mills

Surgical cotton manufacturing

Tarpaulin and canvas proofing factories

Turpentine and resin distilleries

Tyre retreading and resolving factories

Underground shopping complexes (F-3)

B)

Ammonia and urea synthesis plants

Explosive factories

LPG bottling plants

Petrochemical plants

Petroleum refineries

NOTE — In case of complexes having segregated plants with varying degrees of hazards, the competent authority having jurisdictions shall be consulted to decide the level of protections to be provided.

ANNEX C

(*Clauses* 3.4.11.1, 4.18.2, 5.1.8, 5.2.2, 6.1.2, 6.2.3, 6.3.2, 6.4.3, 6.5.2, 6.6.2, 6.7.2, 6.8.2 *and* 6.9.2)

FIRE PROTECTION REQUIREMENTS FOR HIGH RISE BUILDINGS — 15 m IN HEIGHT OR ABOVE

C-0 GENERAL

In addition to the general provisions given in this Part, the Authority may insist on suitable protection measures (*see* **C-1** to **C-11**) in a building 15 m in height or above.

C-1 CONSTRUCTION

C-1.1 All materials of constructions in load bearing elements, stairways and corridors and facades shall be non-combustible.

C-1.2 The interior finish materials shall not have a flame spreadability rating exceeding Class 1 (*see* **3.4.15.2**).

C-1.3 The internal walls or staircase shall be of brick or reinforced concrete with a minimum of 2 h fire rating.

C-1.4 The staircase shall be ventilated to the atmosphere at each landing and a vent at the top; the vent openings shall be of 0.5 m^2 in the external wall and the top. If the staircase cannot be ventilated, because of location or other reasons, a positive pressure 50 Pa shall be maintained inside. The mechanism for pressurizing the staircase shall operate automatically with the fire alarm. The roof of the shaft shall be 1 m above the surrounding roof. Glazing or glass bricks if used in staircase, shall have fire resistance rating of minimum 2 h.

C-1.5 Lifts

General requirements of lifts shall be as follows:

a) Walls of lift enclosures shall have a fire rating of 2 h; lifts shafts shall have a vent at the top of area not less than 0.2 m^2.

b) Lift motor room shall be located preferably on top of the shaft and separated from the shaft by the floor of the room.

c) Landing doors in lift enclosures shall have a fire resistance of not less than 1 h.

d) The number of lifts in one row for a lift bank shall not exceed 4 and the total number of lifts in the bank (of two rows) shall not exceed 8. A wall of 2 h fire rating shall separate individual shafts in a bank.

e) Lift car door shall have a fire resistance rating of half an hour.

f) Collapsible gates shall not be permitted for lifts and shall have solid doors with fire resistance of at least 1 h.

g) If the lift shaft and lobby is in the core of the building, a positive pressure between 25 and 30 Pa shall be maintained in the lobby and a positive pressure of 50 Pa shall be maintained in the lift shaft. The mechanism for pressurization shall act automatically with the fire alarm; it shall be possible to operate this mechanically also.

h) Exit from the lift lobby, if located in the core of the building, shall be through a self-closing smoke stop door of half an hour fire resistance.

j) Lifts shall not normally communicate with the basement; if, however, lifts are in communication, the lift lobby of the basements shall be pressurized as in (g), with self-closing door as in (h).

k) Grounding switch(es), at ground floor level, shall be provided on all the lifts to enable the fire service to ground the lifts.

m) Telephone or other communication facilities

shall be provided in lift cars for building of 30 m in height and above. Communication system for lifts shall be connected to fire control room for the building.

n) Suitable arrangements such as providing slope in the floor of lift lobby, shall be made to prevent water used during fire fighting, etc. at any landing from entering the lift shafts.

p) A sign shall be posted and maintained on every floor at or near the lift indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall also contain a plan for each floor showing the locations of the stairways.

Alternate source of power supply shall be provided for all the lifts through a manually operated changeover switch.

q) *Fire Lifts* — Following details shall apply for a fire lift:

1) To enable fire services personnel to reach the upper floors with the minimum delay, one fire lift per 1 200 m^2 of floor area shall be provided and shall be available for the exclusive use of the firemen in an emergency.

2) The lift shall have a floor area of not less than 1.4 m^2. It shall have loading capacity of not less than 545 kg (8 persons lift) with automatic closing doors of minimum 0.8 m width.

3) The electric supply shall be on a separate service from electric supply mains in a building and the cables run in a route safe from fire, that is, within the lift shaft. Lights and fans in the elevators having wooden paneling or sheet steel construction shall be operated on 24 V supply.

4) Fire fighting lift should be provided with a ceiling hatch for use in case of emergency, so that when the car gets stuck up, it shall be easily openable.

5) In case of failure of normal electric supply, it shall automatically trip over to alternate supply. For apartment houses, this changeover of supply could be done through manually operated changeover switch. Alternatively, the lift shall be so wired that in case of power failure, it comes down at the ground level and comes to stand-still with door open.

6) The operation of a fire lift is by a simple toggle or two-button switch situated in a glass-fronted box adjacent to the lift at the entrance level. When the switch is on, landing call-points will become inoperative and the lift will be on car control only or on a priority control device. When the switch is off, the lift will return to normal working. This lift can be used by the occupants in normal times.

7) The words 'Fire Lift' shall be conspicuously displayed in fluorescent paint on the lift landing doors at each floor level.

8) The speed of the fire lift shall be such that it can reach the top floor from ground level within 1 min.

C-1.6 Basements

C-1.6.1 Each basement shall be separately ventilated. Vents with cross-sectional area (aggregate) not less than 2.5 percent of the floor area spread evenly round the perimeter of the basement shall be provided in the form of grills, or breakable stallboard lights or pavement lights or by way of shafts. Alternatively, a system of air inlets shall be provided at basement floor level and smoke outlets at basement ceiling level. Inlets and extracts may be terminated at ground level with stallboard or pavement lights as before, but ducts to convey fresh air to the basement floor level have to be laid. Stallboard and pavement lights should be in positions easily accessible to the fire brigade and clearly marked 'SMOKE OUTLET' or 'AIR INLET' with an indication of area served at or near the opening.

C-1.6.2 The staircase of basements shall be of enclosed type having fire resistance of not less than 2 h and shall be situated at the periphery of the basement to be entered at ground level only from the open air and in such positions that smoke from any fire in the basement shall not obstruct any exit serving the ground and upper stores of the building and shall communicate with basement through a lobby provided with fire resisting self closing doors of 1 h resistance. For travel distance *see* **4.5**. If the travel distance exceeds as given in Table 21, additional staircases shall be provided at proper places.

C-1.6.3 In multi-storey basements, intake ducts may serve all basement levels, but each basement levels and basement compartment shall have separate smoke outlet duct or ducts. Ducts so provided shall have the same fire resistance rating as the compartment itself. Fire rating may be taken as the required smoke extraction time for smoke extraction ducts.

C-1.6.4 Mechanical extractors for smoke venting system from lower basement levels shall also be provided. The system shall be of such design as to

operate on actuation of heat/smoke sensitive detectors or sprinklers, if installed, and shall have a considerably superior performance compared to the standard units. It shall also have an arrangement to start it manually.

C-1.6.4.1 Mechanical extractors shall have an internal locking arrangement, so that extractors shall continue to operate and supply fans shall stop automatically with the actuation of fire detectors.

C-1.6.4.2 Mechanical extractors shall be designed to permit 30 air changes per hour in case of fire or distress call. However, for normal operation, air changes schedule shall be as given in **3.4.11.5**.

C-1.6.4.3 Mechanical extractors shall have an alternative source of supply.

C-1.6.4.4 Ventilating ducts shall be integrated with the structure and made out of brick masonry or reinforced cement concrete as far as possible and when this duct crosses the transformer area or electrical switchboard, fire dampers shall be provided.

C-1.6.5 Use of basements for kitchens working on gas fuel shall not be permitted, unless air conditioned.

The basement shall not be permitted below the ward block of a hospital/nursing home unless it is fully sprinkled.

Building services such as electrical sub-stations, boiler rooms in basements shall comply with the provisions of the *Indian Electricity Act/Rules*.

C-1.6.6 If cut outs are provided from basements to the upper floors or to the atmospheres, all sides cut out openings in the basements shall be protected by sprinkler head at close spacing so as to form a water curtain in the event of a fire.

C-1.7 Openable windows on external walls shall be fitted with such locks that can be opened by a fireman's axe.

C-1.8 All floors shall be compartmented with area not exceeding 750 m^2 by a separation wall with 2 h fire rating, for floors with sprinklers the area may be increased by 50 percent. In long building, the fire separation walls shall be at distances not exceeding 40 m. For departmental stores, shopping centres and basements, the area may be reduced to 500 m^2 for compartmentation. Where this is not possible, the spacings of the sprinklers shall be suitably reduced. When reducing the spacing of sprinklers, care should be taken to prevent spray from one sprinkler impeding the performance of an adjascent sprinkler head.

C-1.8.1 It is essential to make provisions for drainage of any such water on all floors to prevent or minimize water damage of the contents. The drain pipes should be provided on the external wall for drainage of water from all floors. On large area floors several such pipes may be necessary which should be spaced 30 m apart. Care shall be taken to ensure that the construction of the drain pipe does not allow spread of fire/smoke from floor to floor.

C-1.9 Service Ducts/Shafts

a) Service ducts and shafts shall be enclosed by walls of 2 h and doors of 1 h, fire rating. All such ducts/shafts shall be properly sealed and fire stopped at all floor levels.

b) A vent opening at the top of the service shaft shall be provided having between one-fourth and one-half of the area of the shaft.

C-1.10 Refuse chutes shall have opening at least 1 m above roof level or venting purpose and they shall have an enclosure wall of non-combustible material with fire resistance of not less than 2 h. They shall not be located within the staircase enclosure or service shafts, or air-conditioning shafts inspection panel and doors shall be tight fitting with 1 h fire resistance; the chutes should be as far away as possible from exits.

C-1.11 Refuge Area

Provisions contained in **4.12.3** shall apply for all buildings except multi-family dwellings, refuge area of not less than 15 m^2 shall be provided on the external walls.

C-1.12 Electrical services shall conform to the following:

a) The electric distribution cables/wiring shall be laid in a separate duct. The duct shall be sealed at every floor with non-combustible materials having the same fire resistance as that of the duct. Low and medium voltage wiring running in shaft and in false ceiling shall run in separate conduits;

b) Water mains, telephone lines, intercom lines, gaspipes or any other service line shall not be laid in the duct for electrical cables; use of bus ducts/solid rising mains instead of cables is preferred;

c) Separate circuits for fire fighting pumps, lifts, staircases and corridor lighting and blowers for pressurizing system shall be provided directly from the main switch gear panel and these circuits shall be laid in separate conduit pipes, so that fire in one circuit will not affect the others. Such circuits shall be protected at origin by an automatic circuit breaker with its no-volt coil removed. Master switches controlling essential service circuits shall be clearly labelled;

air-tight fire doors having fire resistance of not less than 2 h;

e) Medium and low voltage wiring running in shafts, and within false ceiling shall run in metal conduit. Any 230 V wiring for lighting or other services, above false ceiling, shall have 660 V grade insulation. The false ceiling, including all fixtures used for its suspension, shall be of non-combustible material and shall provide adequate fire resistance to the ceiling in order to prevent spread of fire across ceiling reference may be made to good practice [4(29)];

f) An independent and well ventilated service room shall be provided on the ground level or first basement with direct access from outside or from the corridor for the purpose of termination of electric supply from the licensees' service and alternative supply cables. The doors provided for the service room shall have fire resistance of not less than 2 h;

NOTE — If service room is located at the first basement, it should have automatic fire extinguishing system.

g) If the licensees agree to provide meters on upper floors, the licensees' cables shall be segregated from consumers' cables by providing a partition in the duct. Meter rooms on upper floors shall not open into stair case enclosures and shall be ventilated directly to open air outside; and

h) Suitable circuit breakers shall be provided at the appropriate points.

C-1.13 Gas supply shall conform to the following:

a) *Town Gas/L.P. Gas Supply Pipes* — Where gas pipes are run in buildings, the same shall be run in separate shafts exclusively for this purpose and these shall be on external walls, away from the staircases. There shall no interconnection of this shaft with the rest of the floors. LPG distribution pipes shall always be below the false ceiling. The length of these pipes shall be as short as possible. In the case of kitchen cooking range area, apart from providing hood, covering the entire cooking range, the exhaust system should be designed to take care of 30 m^3 per minute per m^2 of hood protected area. It should have grease filters using metallic grill to trap oil vapours escaping into the fume hood.

NOTE — For detailed information on gas pipe installations, reference may be made to Part 9 'Plumbing Services, Section 3 Gas Supply'.

installed into fume hoods of large kitchens for hotels, hospitals, and similar areas located in high rise buildings. Arrangements shall be made for automatic tripping of the exhaust fan in case of fire. If LPG is used, the same shall be shut off. The voltage shall be 24 V or 100 V dc operated with external rectifier. The valve shall be of the hand re-set type and shall be located in an area segregated from cooking ranges. Valves shall be easily accessible. The hood shall have manual facility for steam or carbon dioxide gas injection, depending on duty condition; and

c) Gas meters shall be housed in a suitably constructed metal cupboard located in a well ventilated space, keeping in view the fact that LPG is heavier than air and town gas is lighter than air.

C-1.14 Illumination of Means of Exit

Staircase and corridor lights shall conform to the following (*see* **4.16** and **4.17** for additional details):

a) The staircase and corridor lighting shall be on separate circuits and shall be independently connected so as it could be operated by one switch installation on the ground floor easily accessible to fire fighting staff at any time irrespective of the position of the individual control of the light points, if any. It should be of miniature circuit breaker type of switch so as to avoid replacement of fuse in case of crisis;

b) Staircase and corridor lighting shall also be connected to alternative supply. The alternative source of supply may be provided by battery continuously trickle charged from the electric mains;

c) Suitable arrangements shall be made by installing double throw switches to ensure that the lighting installed in the staircase and the corridor does not get connected to two sources of supply simultaneously. Double throw switch shall be installed in the service room for terminating the stand-by supply;

d) Emergency lights shall be provided in the staircase and corridor; and

e) All wires and other accessories used for emergency light shall have fire retardant property.

C-1.15 A stand-by electric generator shall be installed to supply power to staircase and corridor lighting circuits, fire lifts, the stand-by fire pump, pressurization

fans and blowers, smoke extraction and damper systems in case of failure of normal electric supply. The generator shall be capable of taking starting current of all the machines and circuits stated above simultaneously. If the stand-by pump is driven by diesel engine, the generator supply need not be connected to the stand-by pump. Where parallel HV/LV supply from a separate sub-station is provided with appropriate transformer for emergency, the provision of generator may be waived in consultation with the Authority.

C-1.16 Transformers shall conform to the following:

a) A sub-station or a switch-station with oil filled equipment shall not be located in the building. The sub-station structure shall have separate fire resisting walls/surroundings and shall necessarily be located at the periphery of the floor having separate access from fire escape stair case. The outside walls, ceiling, floor, openings including doors and windows to the sub-station area shall be provided with a fire resisting door of 2 h fire rating. Direct access to the transformer room shall be provided, preferably from outside fire escape staircase.

b) The sub-station area needs to be maintained at negative air pressures and area in sub-station shall not be used as storage/dump areas.

c) When housed inside the building, the transformer shall be of dry type and shall be cut off from the other portion of premises by walls/doors/cutout having fire resistance rating of 4 h.

C-1.17 Air-conditioning shall conform to the following:

a) Escape routes like staircases, common corridors, lift lobbies, etc, shall not be used as return air passage.

b) The ducting shall be constructed of substantial gauge metal in accordance with good practice [4(31].

c) Wherever the ducts pass through fire walls or floors, the opening around the ducts shall be sealed with materials having fire resistance rating of the compartment.

d) Where duct crosses a compartment which is fire rated, the ducts shall be fire rated for same fire rating. Further depending on services passing around the duct work, which may get affected in case of fire temperature rising, the ducts shall be insulated.

e) As far as possible, metallic ducts shall be used even for the return air instead of space above the false ceiling.

f) Where plenum is used for return air passage, ceiling and its fixtures shall be of non-combustible material.

g) The materials used for insulating the duct system (inside or outside) shall be of non-combustible materials. Glass wool shall not be wrapped or secured by any material of combustible nature.

h) Area more than 750 m^2 on individual floor shall be segregated by a fire wall and automatic fire dampers for isolation shall be provided [*see* (j)].

j) Air ducts serving main floor areas, corridors, etc, shall not pass through the staircase enclosure.

k) The air-handling units shall be separate for each floor and air ducts for every floor shall be separated and in no way inter-connected with the ducting of any other floor.

m) If the air-handling unit serves more than one floor, the recommendations given above shall be complied with in addition to the conditions given below:

1) proper arrangements by way of automatic fire dampers working on smoke detector/ or fusible link for isolating all ducting at every floor from the main riser shall be made.

2) When the automatic fire alarm operates, the respective air-handling units of the air-conditioning system shall automatically be switched off.

n) The vertical shaft for treated fresh air shall be of masonry construction.

p) The air filters of the air-handling units shall be of non-combustible materials.

q) The air-handling unit room shall not be used for storage of any combustible materials.

r) Inspection panels shall be provided in the main trunking to facilitate the cleaning of ducts of accumulated dust and to obtain access for maintenance of fire dampers.

s) No combustible material shall be fixed nearer than 150 mm to any duct unless such duct is properly enclosed and protected with non-combustible material (glass wool or spunglass with neoprene facing enclosed and wrapped with aluminimum sheeting) at least 3.2 mm thick and which would not readily conduct heat.

t) *Fire Dampers*

1) These shall be located in conditioned air ducts and return air ducts/passages at the following points:

i) At the fire separation wall.

ii) Where ducts/passages enter the central vertical shaft.

iii) Where the ducts pass through floors.

iv) At the inlet of supply air duct and the return air duct of each compartment on every floor.

2) The dampers shall operate automatically and shall simultaneously switch off the air-handling fans. Manual operation facilities shall also be provided.

NOTE — For blowers, where extraction system and duct accumulators are used, dampers shall be provided.

3) Fire/smoke dampers (for smoke extraction shafts) for buildings more than 24 m in height.

For apartment houses	In non-ventilated lobbies/ corridors operated by fusible link/smoke detectors and with manual control.
For other buildings	On operation of smoke detection system and with manual control.

4) Automatic fire dampers shall be so arranged as to close by gravity in the direction of air movement and to remain tightly closed on operation of a fusible link/smoke detector.

C-1.18 Provisions of boiler and boiler rooms shall conform to Indian Boiler Act. Further, the following additional aspects may be taken into account in the location of boiler room:

a) The boilers shall not be allowed in sub-basement, but may be allowed in the basements away from the escape routes.

b) The boilers shall be installed in a fire resisting room of 4 h fire resistance rating, and this room shall be situated on the periphery of the basement. Catch-pits shall be provided at the low level.

c) Entry to this room shall be provided with a composite door of 2 h fire resistance.

d) The boiler room shall be provided with fresh air inlets and smoke exhausts directly to the atmosphere.

e) The furnace oil tank for the boiler, if located in the adjoining room shall be separated by fire resisting wall of 4 h rating. The entrance to this room shall be provided with double composite doors. A curb of suitable height shall be provided at the entrance in order to prevent the flow of oil into the boiler room in case of tank rupture.

f) Foam inlets shall be provided on the external walls of the building near the ground level to enable the fire services to use foam in case of fire.

C-2 PROVISION OF FIRST-AID FIRE FIGHTING APPLIANCES

The first-aid fire fighting equipment shall be provided on all floors, including basements, lift rooms, etc, in accordance with good practice [4(21)] in consultation with the Authority.

C-3 FIRE ALARM SYSTEM

C-3.1 All buildings with heights of 15 m or above shall be equipped with manually operated electrical fire alarm (MOEFA) system and automatic fire alarm system in accordance with good practice [4(18)] and [4(19)]. However, apartment buildings between 15 m and 30 m in height may be exempted from the installation of automatic fire alarm system provided the local fire brigade is suitably equipped for dealing with fire in a building of 15 m in height or above and in the opinion of the Authority, such building does not constitute a hazard to the safety of the adjacent property or occupants of the building itself.

C-3.1.1 Manually operated electrical fire alarm system shall be installed in a building with one or more call boxes located at each floor. The call boxes shall conform to good practice [4(18)] and [4(19)].

C-3.1.2 The installation of call boxes in hostels and such other places where these are likely to be misused shall as far as possible be avoided. Location of call boxes in dwelling units shall preferably be inside the building.

C-4 LIGHTNING PROTECTION OF BUILDINGS

The lightning protection for buildings shall be provided as given in Part 8 'Building Services, Section 2 Electrical Installations'.

C-5 FIRE CONTROL ROOM

For all buildings 15 m in height or above and apartment buildings with a height of 30 m and above, there shall be a control room on the entrance floor of the building with communication system (suitable public address system) to all floors and facilities for receiving the message from different floors. Details of all floor plans along with the details of fire fighting equipment and installations shall be maintained in the fire control room. The fire control room shall also have facilities to detect the fire on any floor through indicator boards connection; fire detection and alarm systems on all floors. The fire staff incharge of the fire control room

shall be responsible for the maintenance of the various services and fire fighting equipment and installations in co-ordination with security, electrical and civil staff of the building.

C-6 FIRE OFFICER FOR HOTELS, BUSINESS AND MERCANTILE BUILDINGS WITH HEIGHT MORE THAN 30 m

C-6.1 A qualified Fire Officer with experience of not less than 3 years shall be appointed who will be available on the premises.

C-6.2 The Fire Officer shall:

a) maintain the fire fighting equipment in good working condition at all times,

b) prepare fire orders and fire operational plans and get them promulgated,

c) impart regular training to the occupants of the buildings in the use of fire fighting equipments provided on the premises and keep them informed about the fire emergency evacuation plan,

d) keep proper liaison with city Fire Brigade, and

e) ensure that all fire precautionary measures are observed at the times.

NOTE — Competent authority having jurisdiction may insist on compliance of the above rules in case of buildings having very large areas even if the height is less than 30 m.

C-7 HOUSE KEEPING

To eliminate fire hazards, good house keeping, both inside and outside the building, shall be strictly maintained by the occupants and/or the owner of the building.

C-8 FIRE DRILLS AND FIRE ORDERS

Fire notices/orders shall be prepared to fulfil the requirements of fire fighting and evacuation from the buildings in the event of fire and other emergency. The occupants shall be made thoroughly conversant with their actions in the event of emergency, by displaying fire notices at vantage points and also through regular training. Such notices should be displayed prominently in broad lettering.

For guidelines for fire drills and evacuation procedures for high rise buildings, *see* Annex E.

C-9 COMPARTMENTATION

The building shall be suitably compartmentalized so that fire/smoke remain confined to the area where fire incident has occurred and does not spread to the remaining part of the building.

C-10 HELIPAD

For high rise buildings above 60 m in height, provision for helipad should be made.

C-11 MATERIALS FOR INTERIOR DECORATION/FURNISHING

The use of materials which are combustible in nature and may spread toxic fume/gases should not be used for interior decoration/furnishing, etc.

ANNEX D

(*Clauses* 6.7.3.3 (a) *and* 6.7.5)

FIRE PROTECTION CONSIDERATIONS FOR VENTING IN INDUSTRIAL BUILDINGS

D-1 APPLICATION AND SCOPE

D-1.1 The provisions given below are applicable only to single storey industrial buildings (factories and storage buildings) covering large floor areas without sub-dividing/separating walls which are usually designed to meet modern production methods.

D-1.2 The requirements of fire and explosion venting of industrial buildings, as dealt with in this section, fall under two categories:

a) Smoke and fire venting, and

b) Explosion relief vents.

D-2 SMOKE AND FIRE VENTING

D-2.1 The basic considerations for formulating the design and other requirements for smoke and fire vents are as given in **D-2.1.1** to **D-2.1.20**.

D-2.1.1 The smoke and hot combustion products from a fire, being lighter than the surrounding air, tend to rise and on reaching the roof or ceiling spread out (mushroom) on all sides and form a layer which floats on top of the cold air beneath. In the absence of vents, this layer becomes progressively deeper until the whole building is filled with hot smoky gases. The time consumed for this to happen may be only a few

minutes, depending on variables like, type of materials on fire, process/storage conditions involved, etc.

D-2.1.2 The hot gases at the roof level moved by convection currents contribute to rapid lateral spread of fire.

D-2.1.3 The provision of properly designed and suitably located vents in adequate number helps the speedy removal of smoke and hot gases, thereby preventing spread of fire, besides reducing risks of explosion of unburnt gases and reducing damage to the contents and structure of the building by heat and smoke. In addition, they facilitate fire fighting operations, and minimize personal hazards to the firemen.

D-2.1.4 The time taken for accumulation of smoke and hot gases within a building on fire being very short, the venting devices installed shall be designed to operate in the early stage of the fire and must be automatic so as to ensure speed and efficiency in their operation.

D-2.1.5 The smoke and fire venting system shall be designed in such a manner as to keep the temperature of the combustion products from the fire as low as possible, preferably below approximately 150°C.

D-2.1.6 Automatic venting systems are complementary to the fire extinguishing systems, and automatic sprinklers, where provided, should operate before the operation of the vents; otherwise, venting may delay sprinkler operation.

D-2.1.7 It is easier to vent a building of smoke than clear it of smoke once it has been filled.

D-2.1.8 Venting is particularly desirable in large area industrial buildings or warehouses, windowless buildings, underground structures or in areas housing hazardous operations. Automatic fire vents shall be provided for all industrial occupancies (including storage buildings) classified as medium hazard or above having floor areas exceeding 750 m^2, irrespective of whether they are compartmentalized or not.

D-2.1.9 These provisions do not cover other aspects, of ventilation (or lighting) designed for regulation of temperature within a building for personal comfort or meeting process needs.

D-2.1.10 Similarly, fire and smoke venting requirements as given here under are also not applicable to multi-storey buildings, as their requirements are different and more complex.

D-2.1.11 It is difficult to determine precise venting requirements on account of the many variables involved. For instance, the rate of combustion varies appreciably according to the nature, shape, size and packaging of the combustible materials as well as the size, height and disposition of the stacks of materials.

D-2.1.12 In industrial buildings of floor area less than 750 m^2 and used as low fire hazard occupancies, conventional ventilators fitted high up near the eaves of the external walls may serve as vents for smoke and hot gases, provided care is taken to ensure that they are kept open at all times or are designed to open automatically in case of fire.

D-2.1.13 Extinction of fires by closing the doors and windows is not likely in the case of industrial buildings because of their large size, where sufficient air to sustain the fire at least in the initial stages can be expected to be present.

D-2.1.14 Of the two types of building ventilation, namely, vertical and horizontal, vertical ventilation is the one commonly adopted in the case of single storey industrial buildings.

D-2.1.15 Since 70 to 80 percent of heat produced in a fire is convective heat, the ventilation system has to be suitably designed to ensure early outflow of the heat and thereby minimize fire spread.

D-2.1.16 Combustible roof linings shall be avoided, as they themselves will contribute to the spread of fire, thereby multiplying the venting problems.

D-2.1.17 A wind blowing across a flat roof or a roof with a pitch under 40° produces a negative pressure, that is, it tends to draw gases out of the building and so aids venting of hot gases. Wind blowing across a roof of pitch greater than 40° will draw gases out on the leeward side, but oppose outward flow on the windward side of the roof.

D-2.1.18 For vents to work at full efficiency, the area of the inlets for cold air entering the compartment must equal at least the total area of the vents. Ideally, the inlets shall be as close to the ground as possible.

D-2.1.19 Where roof vents are installed in a single-storey building any neighbouring buildings, particularly those of more than one storey, will be subject to some degree of exposure hazard either from flying birds or radiation, or both, as a result.

D-2.1.20 If vents are to be installed, the size, design, number and disposition of the vents and the associated roof screens/curtain boards have to be assessed after careful analysis of the various factors stated under **D-2.1.11** above, as well as other related factors like type of building construction, nature and height of roof, process hazards, exposure hazard, etc.

D-2.2 Venting Area

D-2.2.1 The estimated requirements for ventilation are

largely based on the assumed build-up of the fire from the time of initial outbreak to the time of effective fire fighting action by fire brigade.

D-2.2.2 The vent area required to be provided shall be approximately proportional to the perimeter of the fire area, because the entrained air forms the bulk of the vented gases.

D-2.2.3 The effective area shall be the minimum cross-sectional area through which the hot gases must flow out to the atmosphere.

D-2.2.4 No consideration shall be given to the increased air movement obtained by power operated fans, since it must be assumed that in the event of fire, power will be interrupted, or fans damaged by heat.

D-2.2.5 The total vent areas to be provided shall be as per the following ratios of effective area of vent openings to floor area for various occupancy classifications indicated:

a) Low heat release content (Sub-division G-1)	1:150
b) Moderate heat release content (Sub-division G-2)	1:100
c) High heat release content (Sub-division G-3)	1:30 to 1:50

D-2.3 Types of Vents

D-2.3.1 Venting shall be accomplished by any of the types such as monitors continuous gravity vents, until type vents or sawtooth roof skylights.

D-2.3.2 Where monitor type vents are installed, wired glass or metal panels shall be used only if the sash is arranged to open automatically.

D-2.3.3 The use of plain thin glass for venting shall be avoided on account of its unpredictable behaviour during fire. However, if glass or other suitable plastic sheet materials with early disintegration characteristics are used, they should be designed for automatic operation.

D-2.3.4 Where monitors or unit type vents are used, the panels shall be hinged at the bottom and designed to open automatically. Both sides of the vents shall be designed to vent simultaneously to ensure that their effectiveness at the time of fire is not in any way impeded by wind direction.

D-2.3.5 Where movable shutters are provided for continuous gravity vents, these shall open automatically in the event of fire.

D-2.3.6 Unit type vents shall be of relatively small area, ranging between 1 m^2 and 9 m^2, having light weight metal frames and housing with hinged dampers which shall be designed for both manual and automatic operation.

D-2.3.7 Sawtooth roof skylight shall be considered as satisfactory for venting purposes only when designed for automatic operation.

D-2.3.8 Likewise, exterior wall windows shall not be reckoned as satisfactory means for venting of fire gases and smoke in industrial buildings. However, they may be reckoned as additional means of venting when, they are located close to the eaves and are provided with ordinary glass or movable sash arranged for both manual and automatic operation.

D-2.3.9 Baffles shall not be installed inside vents, as they greatly reduce the effective area for venting.

D-2.4 Vent Operation

D-2.4.1 The vents shall be automatic in operation, unless where specified in these provisions that they shall be designed for both manual and automatic operation.

D-2.4.2 The release mechanism shall be simple for operation and independent of electrical power, since electrical services may be interrupted by fire.

D-2.4.3 The automatic operation of vents shall be achieved by actuation of fusible links or other types of heat and smoke detectors, or by interlocking with operation of sprinkler system or any other automatic fire extinguishing system covering the area. Following their release, the vents shall be designed to open by a system of counterweights and associated equipment utilizing the force of gravity or spring loaded levers.

D-2.4.4 Automatic fire alarm system, where installed, shall be coupled to the automatic vents to ensure simultaneous operation.

D-2.4.5 Automatic sprinklers, where installed, shall operate before the vents open in order to avoid any likely delay in sprinkler operation. However, heat actuated devices used for vent release shall be suitably shielded from sprinkler discharge so that water does not delay their action.

D-2.4.6 Premises where height of roof apex is 10 m or more or where the materials handled or stored have high smoke producing characteristics, in addition to fusible links, the vent release mechanism shall be interlinked to smoke actuated automatic fire detectors to ensure early operation of vents.

D-2.4.7 Non-corrosive materials shall be used for hinges, hatches and other related parts to ensure long fail-safe operation of the vents.

D-2.4.8 In case of any doubts regarding the types of vents required to be installed for any particular

occupancy, authorities having jurisdiction shall be consulted.

D-2.5 Size, Spacing and Disposition of Vents

D-2.5.1 Vents shall be correctly sited to ensure their functional efficiency. Ideally, they shall be sited at the highest point in each area to be covered.

D-2.5.2 They shall, as far as possible, be located immediately above the risk to be protected so as to allow free and speedy removal of smoke and other combustion products in the event of fire.

D-2.5.3 The minimum dimension for an effective vent opening shall be not less than 1.25 m in any direction.

D-2.5.4 The spacing of the individual vents shall be based on the principle that more number of well distributed smaller vents are more effective than less number of badly located larger vents.

D-2.5.5 The maximum spacing between vents for the three occupancy classifications shall be as follows:

a) *Low heat release content* — 45 m between centres
b) *Moderate heat release content* — 36 to 37 m between centres
c) *High heat release content* — 22.5 to 30 m between centres, depending on the severity of fire potential.

D-2.5.6 Vents shall be placed in a sheltered situation where advantage can be taken of the prevailing wind. The design of the vent shall be such as to produce a suction effect. A wind blowing across a flat roof or one with a pitch be 40° produces a negative pressure, that is, it tends to draw gases out of the building and so aids venting of hot gases. Wind blowing across a roof of pitch greater than 40° will draw gases out on the leeward side, but oppose outward flow on the windward side of the roof.

D-2.5.7 Low level inlets, with total area not less than the total area of vents, shall be provided to permit outside air to be drawn in to aid automatic venting. These inlets, which may be in the form of doors, windows or such other openings, shall be designed for manual operation when desired.

D-2.6 Roof Screens or Curtain Boards

D-2.6.1 Industrial buildings with large areas and having no sub-division/separating walls limiting the area of individual compartments to 750 m^2 or less, shall be provided with roof screens or curtain boards.

These screens which extend from the roof downwards at specific intervals not only prevent lateral spread of heat and smoke in the event of fire below, but substantially assist in early operation of automatic sprinklers and vents.

D-2.6.2 They shall be of sheet metal or any other substantial non-combustible material strong enough to withstand damage by heat or impact.

D-2.6.3 They shall be reasonably gas-tight, although small openings for passage of pipes, conduits, etc, shall be permitted.

D-2.6.4 They shall extend down from the roof/ceiling for a minimum depth of 2.2 m. Around specific hazards, the depth shall be 4 m. Where roof/ceiling height exceeds 15 m they shall extend down to within 3 m of the floor. For pitched sawtoothed roofs, they shall extend down to truss level dividing the roof into compartments.

D-2.6.5 In moderate hazard occupancies, the distance between the screens/curtain boards shall not exceed 75 m and the curtained areas shall be limited to a maximum of 4 500 m^2.

D-2.6.6 In high hazard occupancies, the distance between screens shall not exceed 30 m and the curtained area shall be limited to 750 m^2.

D-2.6.7 The curtained roof area shall be so arranged that they effectively aid in the venting of smoke and hot gases through the automatic vents provided in each area.

D-2.6.8 In sprinklered buildings, the screens shall preferably be so located as to coincide with the individual sprinkler system areas.

D-3 EXPLOSION RELIEF VENTS

D-3.1 Industrial premises where combustible dusts can accumulate or where flammable gases, vapours or mists in explosive concentrations may be present are constantly exposed to explosion hazards. Pressures developed by such explosions may be of the order of 7×10^5 Pa and ordinary buildings will not be able to withstand the shock of such pressures. Hence, such buildings require explosion relief vents for preventing structural damage.

D-3.2 Basic Principle/Considerations

D-3.2.1 Most ordinary building walls will not withstand a sustained internal pressure as great as 6.9×10^3 Pa. Hence, explosion relief vents for buildings must be designed to operate at pressures well below those at which the building walls will fail.

D-3.2.2 There is a rise in pressure during an explosion within an enclosure even with open, unobstructed vents, and any delay in opening the venting devices increases that pressure.

D-3.2.3 Structural damage can be minimized by locating hazardous operations or equipment outside buildings and cut off from other operations by a pressure resisting wall. Such isolated processes or equipment shall be housed in single-storey buildings properly vented and a device provided at the inlet of the collector which will prevent an explosion from blowing back through the duct work and into the building.

D-3.2.4 Where highly hazardous operations cannot be located outside of main buildings they shall be segregated by pressure resisting walls and each such unit shall be ventilated outdoors. External walls may be of heavy construction if equipped with suitable vents or high weight panels which blow out easily.

D-3.2.5 Operations or equipment involving explosion hazards shall not be permitted in basements or areas partially below grade.

D-3.2.6 Fire can be expected to follow an explosion in most occupancies, so that any fixed fire extinguishing equipment, like sprinklers, if installed, shall be such that only the minimum damage is caused to it.

D-3.2.7 For a given material, the finer the particle size of the dust, the more violent is the explosion. Some materials, such as aluminium powder, hydrogen, and acetylene, are difficult to vent effectively due to the rapid rate of pressure rise. Some slow burning materials, such as coal dust in a confined space, may do much damage because of the longer duration of their presence. Some dusts, such as magnesiusm, titanium and zirconium and several metal hydrides may react with water and ignite in some common inert gases, such as nitrogen and carbon dioxide.

D-3.2.8 The maximum explosion pressure in a vented structure decreases as the size of the vent increases, but is independent of the rupturing pressure of a diaphragm.

D-3.2.9 The most effective vent for the release of explosion pressures is an unobstructed vent opening.

D-3.2.10 Pressure required to rupture diaphragms of the same area and material directly varies with the thickness of the material.

D-3.2.11 The slower the rate of pressure rise, the more easily can the explosion be vented.

D-3.2.12 The degree of venting required is directly proportional to the degree of explosion hazard.

D-3.2.13 Experience has shown that most explosions of dusts, vapours and gases do not involve a large part of the total volume of the enclosure, and frequently occur near the upper or lower limits of the explosive range. Consequently, such explosions are relatively weak compared with the optimum.

D-3.2.14 Rectangular unrestricted vents are as effective as square vents of equal area.

D-3.3 Types of Explosion Relief Vents

D-3.3.1 The explosion relief vents shall be any one or more of the following types, depending on individual requirements as assessed by the Authority. Open or unobstructed vents, louvers, open roof vents, hanger type doors, building doors, windows, roof or wall panels or movable fixed sash.

D-3.3.2 The effect of external wind pressure or suction on these devices shall be taken into consideration while designing and selecting the type of vents, since wind pressures may reach over 2×10^5 Pa in severe wind storms.

D-3.3.3 The type of vent for explosion relief for any occupancy shall be selected with life safety as the primary aim followed by minimum damage to property.

D-3.3.4 Where large hanger type doors or metal curtain doors in side walls are used as vents care shall be taken to ensure that they are kept wide open during operations.

D-3.3.5 Where weather hoods are used to cover roof vents, they shall be as light as possible and lightly attached so as to enable them to be blown off quickly when an explosion occurs.

D-3.3.6 Doors and windows when used as explosion vents shall be installed to swing outwards. Doors shall have friction, spring or magnetic latches that will function automatically to permit the door to open under slight internal pressure.

D-3.3.7 Movable sash shall be of the top or bottom hinged or protected type. These shall be equipped with a latch or friction device to prevent accidental opening due to wind action or intrusion. Such latches or locks shall be well maintained.

D-3.3.8 Fixed sash shall be set in place with very light wall anchorages, or, if right, shall be securely fitted and glazed with plastic panes in plastic putty.

D-3.3.9 Where the process is such that the whole of a building or a room may be desirable to arrange for a lightly constructed wall or roof to collapse and thus avert the worst effects of an explosion.

D-3.4 Design, Size and Disposition of Vents

D-3.4.1 The required area of explosion vents shall ordinarily depend on the expected maximum intensity of an explosion in the occupancy, the strength of the structure, the type of vent closure and other factors.

D-3.4.2 Venting shall be planned in such a manner as

to prevent injury to personnel and damage to explosures. In congested locations, substantial ducts or diverters shall be provided to direct the blast.

D-3.4.3 When ductwork is used, the ducts shall be of sufficient strength to withstand the maximum expected explosion pressure.

D-3.4.4 Where explosions are likely within duct and piping systems, they shall be vented by the use of suitable diaphragms designed to blow out at a predetermined pressure. There shall be no physical connection between ductwork system for more than one collector.

D-3.4.5 In large structures, the position of vents shall be relative to the point of origin of explosion, when it can be determined.

D-3.4.6 Where relatively slow explosions involving coal dust, chlorinated solvents, etc, are involved, light, hinged swinging panels may be preferred to diaphragm type of vents.

D-3.4.7 Obstructions of any kind blocking the vents from the risk covered shall be avoided, particularly where risks of rapid violent explosions are present.

D-3.4.8 Counter weights add to the inertia of the vents and so shall be avoided.

D-3.4.9 Various relieving devices, including devices actuated by detonators, shall start to open at as low a pressure as possible. They shall be of light construction, so that full opening can be quickly attained.

D-3.4.10 Vents shall be of such size and design as to prevent rupture of the protected device or apparatus.

D-3.4.11 Skylights or monitors with movable sash that will open outwards, or fixed sash containing panes of glass or plastic that will blow out readily under pressure from within, can be used to supplement wall vents or windows, provided resistance to their displacement or opening is kept as low as consistent with the requirements for structural strength.

D-3.4.12 Flexible plastic sheets when used for vent closures shall be installed in slotted frames in such a way that pressure from within bulges the sheets and releases them from the holding frame.

D-3.4.13 Fragile sheets made of plastic, when used for vent closures, shall be thin sheets that will crack or rupture under less pressure than single strength glass. For this reason use of transparent or translucent plastic sheets is more advantageous instead of glass in window sash.

D-3.4.14 If closed vents are used they shall be larger in area than unenclosed vents to provide equivalent explosion pressure relief.

D-3.4.15 Small enclosures, such as machines, shall be vented more generously than buildings, because if an explosion occurs in a machine, its entire volume may be involved.

D-3.4.16 Vents for the protection of buildings and equipment shall be installed on the following basis:

D-3.4.16.1 Small enclosures of less than 30 m^3, machines and ovens of light construction: 1 000 cm^2 for each 0.3 m^3 to 0.9 m^3.

D-3.4.16.2 For small enclosures of more substantial construction having reasonably high bursting strength: 1 000 cm^2 for each 0.9 m^3.

D-3.4.16.3 Fairly large enclosures of 30 to 700 m^3, such as bins, silos, rooms, storage tanks, etc: 1 000 cm^2 for each 0.9 m^3 to 1.5 m^3. In these cases, attempt shall be made to the extent possible to predict the likely point of origin of the explosion in relation to the vent.

D-3.4.16.4 Large rooms and buildings over 700 m^3 containing hazardous equipment comprising a small fraction of the entire volume:

a) *For heavy reinforced concrete, walls* — 100 cm^2 for each 2.25 m^3.

b) *For light reinforced concrete, brick or wood construction* — 1 000 cm^2 for each 1.65 m^3 to 2.25 m^3.

c) *For lightweight construction such as prefabricated panels* — 1 000 cm^2 for each 1.5 m^3 to 1.65 m^3.

D-3.4.16.5 Large rooms or building over 700 m^3 containing hazardous equipment comprising a large part of the entire volume of a room or building shall be vented as generously as possible 1 000 cm^2 for each 0.3 m^3 to 1.05 m^3.

D-3.4.16.6 In order to obtain these ratios, the size of the building or room must be limited. For some hazardous materials, such as hydrogen, acetylene, carbon disulphide, etc, these limits are extremely low.

D-3.4.17 Emphasis shall always be placed on segregating hazardous areas by means of firewalls or separating walls to prevent spread of fire.

D-3.4.18 Interior walls of light construction, such as tile, shall be avoided in hazardous locations, since they can cause injuries to personnel in the event of an explosion.

ANNEX E

(Clause C-8)

GUIDELINES FOR FIRE DRILL AND EVACUATION PROCEDURES FOR HIGH RISE BUILDINGS (ABOVE 15 m IN HEIGHT)

E-1 INTRODUCTION

In case of fire in a high rise building, safe evacuation of its occupants may present serious problems unless a plan for orderly and systematic evacuation is prepared in advance and all occupants are well drilled in the operation of such plan. These guidelines are intended to assist them in this task.

E-2 ALARMS

Any person discovering fire, heat or smoke shall immediately report such condition to the fire brigade, unless he has personal knowledge that such a report has been made. No person shall make, issue, post or maintain any regulation or order, written or verbal, that would require any person to take any unnecessary delaying action prior to reporting such condition to the fire brigade.

E-3 DRILLS

E-3.1 Fire drills shall be conducted, in accordance with the Fire Safety Plan, at least once every three months for existing buildings during the first two years. Thereafter, fire drills shall be conducted at least once every six months.

E-3.2 All occupants of the building shall participate in the fire drill. However, occupants of the building, other than building service employees, are not required to leave the floor or use the exits during the drill.

E-3.3 A written record of such drills shall be kept on the premises for a three years period and shall be readily available for fire brigade inspection.

E-4 SIGNS AND PLANS

E-4.1 Signs at Lift Landings

A sign shall be posted and maintained in a conspicuous place on every floor at or near the lift landing in accordance with the requirements, indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall contain a diagram showing the location of the stairways except that such diagram may be omitted, provided signs containing such diagram are posted in conspicuous places on the respective floor.

A sign shall read "IN CASE OF FIRE, USE STAIRS UNLESS INSTRUCTED OTHERWISE". The lettering shall be at least 12.5 mm block letters in red and white background. Such lettering shall be properly spaced to provide good legibility. The sign shall be at least 250 mm × 300 mm, where the diagram is also incorporated in it and 62.5 mm × 250 mm where the diagram is omitted. In the latter case, the diagram sign shall be at least 200 mm × 300 mm. The sign shall be located directly above a call-button and squarely attached to the wall or partition. The top of the sign shall not be above 2 m from the floor level.

E-4.2 Floor Numbering Signs

A sign shall be posted and maintained within each stair enclosure on every floor, indicating the number of the floor, in accordance with the requirements given below.

The numerals shall be of bold type and at least 75 mm high. The numerals and background shall be in contrasting colours. The sign shall be securely attached to the stair side of the door.

E-4.3 Stair and Elevator Identification Signs

Each stairway and each elevator back shall be identified by an alphabetical letter. A sign indicating the letter of identification shall be posted and maintained at each elevator landing and on the side of the stairway door from which egress is to be made, in accordance with the requirements given below:

The lettering on the sign shall be at least 75 mm high, of bold type and of contrasting colour from the background. Such signs shall be securely attached.

E-4.4 Stair Re-entry Signs

A sign shall be posted and maintained on each floor within each stairway and on the occupancy side of the stairway where required, indicating whether re-entry is provided into the building and the floor where such re-entry is provided, in accordance with the requirements given below:

The lettering and numerals of the signs shall be at least 12.5 mm high of bold type. The lettering and background shall be of contrasting colours and the signs shall be securely attached approximately 1.5 m above the floor level.

E-4.5 Fire command station shall be provided with floor plan of the building and other pertinent information relative to the service equipment of the building.

E-5 FIRE SAFETY PLAN

E-5.1 A format for the Fire Safety Plan shall be as given in **E-8**.

E-5.2 The applicable parts of the approved Fire Safety Plan shall be distributed to all tenants of the building by the building management when the Fire Safety Plan has been approved by the Fire Authority.

E-5.3 The applicable parts of the approved Fire Safety Plan shall then be distributed by the tenants to all their employees and by the building management to all their building employees.

E-5.4 Where the owner of the building is also an occupant of the building, he shall be responsible for the observance of these rules and the Fire Safety Plan in the same manner as a tenant.

E-5.5 In the event there are changes from conditions existing at the time the Fire Safety Plan for the building was approved, and the changes are such so as to require amending the Fire Safety Plan, within 30 days after such changes, an amended Fire Safety Plan shall be submitted to the fire brigade for approval.

E-6 FIRE COMMAND STATION

A Fire Command Station shall be established in the lobby of the building on the entrance floor. Such command station shall be adequately illuminated.

E-7 COMMUNICATIONS AND FIRE ALARM

A means of communication and fire alarm for use during fire emergencies shall be provided and maintained by the owner or person in charge of the building.

E-8 FIRE SAFETY PLAN FORMAT

E-8.1 Building Address

Street and Pin Code Number .....

Telephone Number .....

E-8.2 Purpose and Objective

E-8.2.1 *Purpose*

To establish method of systematic, safe and orderly evacuation of an area or building by its occupants in case of fire or other emergency, in the least possible time, to a safe area by the nearest safe means of egress; also the use of such available fire appliances (including sounding of alarms) as may have been provided for controlling or extinguishing fire and safeguarding of human life.

E-8.2.2 *Objective*

To provide proper education as a part of continuing employee indoctrination and through a continuing written programme for all occupants, to ensure prompt reporting of fire, the response of fire alarms as designated, and the immediate initiation of fire safety procedures to safeguard life and contain fire until the arrival of the fire brigade.

E-8.3 Fire Safety Director

a) Name
b) Regularly assigned employment — Title
c) Regularly assigned location
d) How is he notified when at regular location?
e) How is he notified when not at regular location?
f) Normal working hours
g) Duties of Fire Safety Director (*see* **E-9.1**)

E-8.4 Deputy Fire Safety Director

a) Name
b) Regularly assigned employment — Title
c) Regularly assigned location
d) How is he notified when at regular location?
e) How is he notified when not at regular location?
f) Normal working hours
g) Duties of Deputy Fire Safety Director (*see* **E-9.2**)

E-8.5 Fire Wardens and Deputy Fire Wardens

a) Are their names on Organization Charts for each floor and/or tenancy?
b) Submit typical completed Organization Chart for Fire Drill and Evacuation Assignment.
c) Duties of Fire Wardens and Deputy Fire Wardens (*see* **E-9.3**).

E-8.6 Building Evacuation Supervisor

a) Name
b) Regularly assigned employment — Title
c) Regularly assigned location
d) How is he notified when at regular location?
e) How is he notified when not at regular location?
f) Normal working hours
g) Duties of Building Evacuation Supervisor (*see* **E-9.4**).

E-8.7 Fire Party

a) Submit a completed Organization Chart for Fire Parties naming person in charge, and his title in the building.
b) Indicate standards of selection from building employees based on background and availability.

c) How are they notified?

d) How are they notified when they are not at their regular locations?

e) Means of responding

f) Duties of each member of Fire Party (*see* **E-9.5**).

E-8.8 Occupants Instructions

Distribution of instructions to all tenants, tenents' employees and building employees (*see* **E-9.6**).

E-8.9 Evacuation Drills

a) Frequency of drills

b) How conducted?

c) Participation: Who participated? How?

d) Controls and supervision

e) Recording of details of drills

E-8.10 Fire Command Station

a) Location

b) Requirements

1) Adequate illumination

2) Adequate communication to mechanical equipment room and elevator control room on each floor

3) Copy of Fire Safety Plan

4) Copy of Building Information Form

5) Representative floor plans showing location of signs, floor remote station, communications, etc.

E-8.11 Signs

a) Signs at elevator landings, Floor diagrams

b) Floor numbering

c) Stairway identification

d) Elevator identification

e) Stair re-entry

E-8.12 Fire Prevention and Fire Protection Programme (*see* **E- 9.7**).

E-8.13 Building Information Form (*see* **E-9.8**).

E-8.14 Representative Floor Plan (*see* **E-9.9**).

E-8.15 Fire Safety Plan Prepared by (*see* **E-9.10**).

a) Date when prepared.

b) Date when revised.

E-9 DUTIES

E-9.1 Fire Safety Director's Duties

E-9.1.1 Be familiar with the written Fire Safety Plan providing for fire drill and evacuation procedure in accordance with orders on the subject.

E-9.1.2 Select qualified building service employees for a Fire Party and organize, train and supervise such Fire Brigade.

E-9.1.3 Be responsible for the availability and state of readiness of the Fire Party.

E-9.1.4 Conduct fire and evacuation drills.

E-9.1.5 Be responsible for the designation and training of a Fire Warden for each floor, and sufficient Deputy Fire Wardens for each tenancy in accordance with orders on the subject.

E-9.1.6 Be responsible for a daily check for the availability of the Fire Wardens, and see that up-to-date organization charts are posted.

NOTE — If the number of Fire Wardens and Deputy Fire Wardens in the building is such that it is impractical to individually contact each one daily, a suggested method to satisfy the requirements is to make provisions for the Fire Warden, or a Deputy Fire Warden in the absence of the Fire Warden, to notify the Fire Safety Director when the Fire Warden or required number of Deputy Fire Wardens are not available. In order to determine the compliance by the Fire Warden and Deputy Fire Wardens, when this method is used, the Fire Safety Director shall make a spot check of several different floors each day.

E-9.1.7 Notify the owner or some other person having charge of the building when any designated individual is neglecting his responsibilities contained in Fire Safety Plan. The owner or the other person in-charge of the building shall bring the matter to the attention of the firm employing the individual. If the firm fails to correct the condition, the Fire Department shall be notified by the owner/person in-charge of the building.

E-9.1.8 In the event of fire, shall report to the Fire Command Station to supervise, provide for and coordinate:

a) Ensure that the Fire Department has been notified of any fire or fire alarm.

b) Manning of the Fire Command Station.

c) Direction of evacuating procedures as provided in the Fire Safety Plan.

d) Reports on conditions on fire floor for information of Fire Department on their arrival.

e) Advise the Fire Department Officer in-charge in the operation of the Fire Command Station.

E-9.1.9 Be responsible for the training and activities of the Building Evacuation Supervisor.

E-9.2 Deputy Fire Safety Director's Duties

E-9.2.1 Subordinate to the Fire Safety Director.

E-9.2.2 Perform duties of Fire Safety Director in his absence.

E-9.3 Fire Wardens and Deputy Fire Wardens Duties

The tenant or tenants of each floor shall, upon request of the owner or person in charge of buildings, make responsible and dependable employees available for designation by the Fire Safety Director as Fire Warden and Deputy Fire Wardens.

E-9.3.1 Each floor of a building shall be under the direction of a designated Fire Warden for the evacuation of occupants in the event of fire. He shall be assisted in his duties by the Deputy Fire Wardens. A Deputy Fire warden shall be provided for each tenancy. When the floor area of a tenancy exceeds 700 m^2 of occupiable space, a Deputy Fire Warden shall be assigned for each 700 m^2 or part thereof.

E-9.3.2 Each Fire Warden and Deputy Fire Warden shall be familiar with the Fire Safety Plan, the location of exits and the location and operation of any available fire alarm system.

E-9.3.3 In the event of fire, or fire alarm the Fire Warden shall ascertain the location of the fire, and direct evacuation of the floor in accordance with directions received and the following guidelines:

a) The most critical areas for immediate evacuation are the fire floor and floors immediately above.

   Evacuation from the other floors shall be instituted when instructions from the Fire Command Station or conditions indicate such action. Evacuation shall be via uncontaminated stairs. The Fire Warden shall try to avoid stairs being used by the Fire Department. If this is not possible, he shall try to attract the attention of the Fire Department Personnel before such personnel open the door to the fire floor.

b) Evacuation to two or more levels below the fire floor is generally adequate. He shall keep the Fire Command Station informed regarding his location.

c) Fire Wardens and their Deputies shall see that all occupants are notified of the fire, and that they proceed immediately to execute the Fire Safety Plan.

d) The Fire Warden on the fire floor shall, as soon as practicable, notify the Fire Command Station of the particulars.

e) Fire Wardens on floors above the fire shall, after executing the Fire Safety Plan, notify the Fire Command Station of the means being used for evacuation and any other particulars.

f) In the event that stairways serving fire floor and/or floors above are unusable due to contamination or cut off by fire and/or smoke or that several floors above fire involve large numbers of occupants who must be evacuated, consideration may be given to using elevators in accordance with the following:

   1) If the elevators servicing his floor also service the fire floor, they shall not be used. However, elevators may be used if there is more than one bank of elevators, and he is informed from the Fire Command Station that one bank is unaffected by the fire.
   2) If elevators do not service the fire floor and their shafts have no openings on the fire floor, they may be used, unless directed otherwise.
   3) Elevators manned by trained building personnel or firemen may also be used.
   4) In the absence of a serviceable elevator, the Fire Warden shall select the safest stairway to use for evacuation on the basis of the location of the fire and any information received from the Fire Command Station. The Fire Warden shall check the environment in the stairs prior to entry for evacuation. If it is affected by smoke, alternative stair shall be selected, and the Fire Command Station notified.
   5) The Fire Warden shall keep the Fire Command Station informed of the means being employed for evacuation by the occupants of his floor.

g) Ensure that an alarm has been transmitted.

E-9.3.4 *Organization Chart for Fire Drill and Evacuation Assignment*

A chart designating employees and their assignments shall be prepared and posted in a conspicuous place in each tenancy and on each floor of a tenancy that occupies more than one floor and a copy shall be in the possession of the Fire Safety Director.

E-9.3.5 Keep available an updated listing of all personnel with physical disabilities who cannot use stairs unaided. Make arrangements to have these occupants assisted in moving down the stairs to two or more levels below fire floor. If it is necessary to move such occupants to a still lower level during the fire, move them down the stairs to the uppermost floor served by an uninvolved elevator bank and then remove them the street floor by elevator. Where assistance is required for such evacuation, notify Fire Safety Director.

E-9.3.6 Provide for Fire Warden identification during fire drills and fires, such as using armband, etc.

E-9.3.7 Ensure that all persons on the floor are notified of fire and all are evacuated to safe areas. A search must be conducted in the lavatories to ensure all are out. Personnel assigned as searchers can promptly and efficiently perform this duty.

E-9.3.8 Check availability of applicable personnel on Organization Chart and provide for a substitute when the position on a chart is not covered.

E-9.3.9 After evacuation, perform a head count to ensure that all regular occupants known to have occupied the floor have been evacuated.

E-9.3.10 When alarm is received, the Fire Warden shall remain at a selected position in the vicinity of the communication station on the floor, in order to maintain communication with the Fire Command Station and to receive and give instructions.

E-9.4 Building Evacuation Supervisor's Duties

A building Evacuation Supervisor is required at all times other than normal working or business hours when there are occupants in the building and there is no Fire Safety Director on duty in the building.

E-9.4.1 He should be capable of directing the evacuation of the occupants as provided by the Fire Safety Plan.

E-9.4.2 During fire emergencies, the primary responsibility of the Building Evacuation Supervisor shall be to man the Fire Command Station, and the direction and execution of the evacuation as provided in the Fire Safety Plan. The Building Evacuation Supervisor's training and related activities shall be under the direction of the Fire Safety Director in accordance with these rules, and the Fire Safety Plan. Such activities shall be subject to Fire Department control.

E-9.5 Fire Party Duties

On receipt of an alarm for fire the Fire Party shall:

a) report to the floor below the fire to assit in evacuation and provide information to the Fire Command Station.

b) after evacuations of fire floor, endeavour to control spread of fire by closing doors, etc.

c) attempt to control the fire until arrival of the Fire Department, if the fire is small and conditions do not pose a personal threat.

d) leave one member on the floor below the fire to direct the Fire Department to the fire location and to inform them of conditions.

e) on arrival of the Fire Department, the Fire Party shall report to the Fire Command Station for additional instructions.

f) have a member designated as runner, who shall know the location of the nearest telephone, and be instructed in its use. Such member shall immediately upon receipt of information that there is a fire or evidence of fire, go to the telephone, transmit an alarm and await the arrival of the Fire Department and direct such department to the fire.

NOTE — A chart designating employees and their assignments shall be prepared.

E-9.6 Occupant's Instructions

a) The applicable parts of the approved Fire Safety Plan shall be distributed to all tenants of the building by the building management when the Fire Safety Plan has been approved by the Fire Commissioner.

b) The applicable parts of the approved Fire Safety Plan shall then be distributed by the tenants to all their employees and by the building management to all their building employees.

c) All occupants of the building shall participate and cooperate in carrying out the provisions of the Fire Safety Plan.

E-9.7 Fire Prevention and Fire Protection Programme

a) A plan for periodic formal inspections of each floor area, including exit facilities, fire extinguishers and house keeping shall be developed. A copy of such plan be submitted.

b) Provision shall be made for the monthly testing of communication and alarm systems.

E-9.8 Building Information Form

It shall include the following information:

a) Building address.....Pin Code.....

b) Owner or person in-charge of building — Name, Address and Telephone Number.

c) Fire Safety Director and Deputy Fire Safety Director's Name and Telephone Number.

d) Certificate of occupancy. Location where posted, or duplicate attached.

e) Height, area, class of construction.

f) Number, type and location of fire stairs and/ or fire towers.

g) Number, type and location of horizontal exits or other areas of refuge.

h) Number, type, location and operation of elevators and escalators.

j) Interior fire alarms, or alarms to central stations.

k) Communications systems and/or walkie talkie, telephones, etc.

m) Standpipe system; size and location of risers, gravity or pressure tank, fire pump, location of siamese connections, name of employee with certificate of qualification and number of certificate.

n) Sprinkler system; name of employee with Certificate of Fitness and certificate number. Primary and secondary water supply, fire pump and areas protected.

p) Special extinguishing system, if any, components and operation.

q) Average number of persons normally employed in building. Daytime and night time.

r) Average number of handicapped people in building. Location. Daytime and night time.

s) Number of persons normally visiting the building. Daytime and night time.

t) Service equipment such as:

1) Electric power, primary, auxiliary;

2) Lighting, normal, emergency, type and location;

3) Heating, type, fuel, location of heating unit;

4) Ventilation — with fixed windows, emergency means of exhausting heat and smoke;

5) Air-Conditioning Systems — Brief description of the system, including ducts and floors serviced;

6) Refuse storage and disposal;

7) Fire fighting equipment and appliances, other than standpipe and sprinkler system; and

8) Other pertinent building equipment.

u) Alterations and repair operations, if any, and the protective and preventive measures necessary to safeguard such operations with attention to torch operations.

v) Storage and use of flammable solids, liquids and/or gases.

w) Special occupancies in the building and the proper protection and maintenance thereof. Places of public assembly, studios, and theatrical occupancies.

E-9.9 Representative Floor Plan

A floor plan, representative of the majority or the floor designs of the entire building, shall be at the Command Post, in the main lobby, under the authority of the Fire Safety Director. One copy of a representative floor plan shall be submitted to the Fire Department with the Fire Safety plan.

E-9.10 Fire Safety Plan

In planning, evaluate the individual floor layouts, the population of floors, the number and kinds of exits, the zoning of the floor by area and occupants. Determine the movement of traffic by the most expeditious route to an appropriate exit and alternative route for each zone, since under fire conditions one or more exits may not be usable. This format is to be used in the preparation of the Fire Safety Plan. Nothing contained in this Fire Safety Plan format is to be construed as all inclusive. All rules and other requirements are to be fully complied with.

E-9.11 Personal Fire Instruction Card

All the occupants of the building shall be given a Personal Fire Instruction Card giving the details of the floor plan and exit routes along with the instruction to be followed in the event of fire. A typical Personal Fire Instruction Card shall be as follows:

PERSONAL FIRE

INSTRUCTION CARD

SEAL

NAME OF THE ORGANIZATION

ADDRESS OF THE ORGANIZATION

NAME: .....

DESIGNATION: .....

FLOOR NO.: .....

DATE: .....

FIRE WARDEN

INSTRUCTIONS

FOR YOUR OWN SAFETY YOU SHOULD KNOW

1. Two push button fire alarm boxes are provided per floor. You should read the operating instructions.
2. You should read the operating instructions on the body of the fire extinguishers provided on your floor.
3. The nearest exit from your table.
4. Your assembly point on ground floor (check with your Fire/Deputy Fire Warden).
5. FOR YOUR OWN PROTECTION YOU SHOULD REPORT TO YOUR FIRE/ DEPUTY FIRE WARDEN

b) If any staircase door, lift lobby door does not close automatically, or does not close completely.

c) If any push button fire alarm point, or fire extinguisher is obstructed, damaged or apparently out of order.

IF YOU DISCOVER A FIRE

1. Break the glass of the nearest push button fire alarm and push the button.
2. Attack the fire with extinguishers provided on your floor. Take guidance from your Wardens.

IF YOU HEAR EVACUATION INSTRUCTIONS

1. Leave the floor immediately by the south/ north staircase.
2. Report to your Warden, at your predetermined assembly point outside the building.
3. Do not try to use lifts.
4. Do not go to cloakroom.
5. Do not run or shout.
6. Do not stop to collect personal belongings.
7. Keep the lift lobby and staircase doors shut.

YOUR ASSEMBLY POINT IS .....

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 3808 : 1979	Method of test for non-combustibility of building materials (*first revision*)
(2) 8757 : 1999	Glossary of terms associated with fire safety (*first revision*)
7673 : 1975	Glossary of terms for fire fighting equipment
(3) 15394 : 2003	Fire safety in petroleum refinery and fertilizer plants — Code of practice
(4) 8758 : 1993	Recommendations for fire precautionary measures in the construction of temporary structures and *PANDALS* (*first revision*)
(5) 3809 : 1979	Fire resistance test of structure (*first revision*)
1641 : 1988	Code of practice for fire safety of buildings (general): General principles of fire grading and classification (*first revision*)
15103 : 2002	Specification for fire resistant steel
(6) 9668 : 1990	Code of practice for provision and maintenance of water supplies and fire fighting
3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision*)
(7) 3614 (Part 1) : 1966	Specification for fire check doors: Part 1 Plate, metal covered and rolling type
(8) 12458 : 1988	Method of test for fire resistance test for fire stops
(9) 1646 : 1997	Code of practice for fire safety of buildings (general) : Electrical installations (*second revision*)
2309 : 1989	Code of practice for protection of building and allied structures against lighting (*second revision*)
(10)	Specification for fire dampers for air conditioning ducts (*under preparation*)
(11) 11360 : 1985	Specification for smoke detectors for use in automatic electrical fire alarm system
(12) 659 : 1964	Safety code for air-conditioning
(13) 1649 : 1962	Code of practice for design and construction of flues and chimneys for domestic heating appliances (*first revision*)
1642 : 1989	Code of practice for safety of buildings (general): Details of construction (*first revision*)
(14) 12777 : 1989	Fire safety-flame-spread of products — Method for classification

IS No.	*Title*
(15) 1642 : 1989	Code of practice for fire safety of buildings (general): Details of construction (*first revision*)
1643 : 1988	Code of practice for fire safety of buildings (general): Exposure hazard (*first revision*)
1644 : 1988	Code of practice for fire safety of buildings (general): Exit requirements and personal hazard (*first revision*)
(16) 9457 : 1980	Safety colours and safety signs
12349 : 1988	Fire protection — Safety sign
12407 : 1988	Graphic symbols for fire protection plan
(17) 2175 : 1988	Specification for heat sensitive fire detectors for use in automatic fire alarm system (*second revision*)
11360 : 1985	Specification for smoke detectors for use in automatic electrical fire alarm system
(18) 2189 : 1999	Code of practice for selection, installation and maintenance of automatic fire detection and alarm system (*second revision*)
(19) 636 : 1988	Non-percolating flexible fire fighting delivery hose (*third revision*)
884 : 1985	Specification for first-aid hose reel for fire fighting (*first revision*)
901 : 1988	Specification for couplings, double male and double female instantaneous pattern for fire fighting (*third revision*)
902 : 1992	Specification for suction hose couplings for fire fighting purposes (*third revision*)
903 : 1993	Specification for fire hose delivery couplings, branch pipe, nozzles and nozzle spanner (*fourth revision*)
904 : 1983	Specification for two-way and three-way suction collecting heads for fire fighting purposes (*second revision*)
905 : 1980	Specification for delivery breechings, dividing and collecting, instantaneous pattern for fire fighting purposes (*second revision*)
906 : 1988	Specification for revolving branch pipe for fire fighting (*third revision*)
907 : 1984	Specification for suction strainers, cylindrical type for fire fighting purpose (*second revision*)
908 : 1975	Specification for fire hydrant, stand post type (*second revision*)
909 : 1992	Specification for underground fire hydrant: Sluice valve type (*third revision*)
910 : 1980	Specification for combined key for hydrant, hydrant cover and lower valve (*second revision*)
926 : 1985	Specification for fireman's axe (*second revision*)
927 : 1981	Specification for fire hooks (*second revision*)
928 : 1984	Specification for fire bells (*second revision*)
937 : 1981	Specification for washers for water fittings for fire fighting purposes (*second revision*)
939 : 1977	Specification for snatch block for use with fibre rope for fire brigade use (*first revision*)
940 : 1989	Specification for portable fire extinguisher, water type (gas cartridge) (*third revision*)
941 : 1985	Specification for blowers and exhauster for fire fighting (*second revision*)
942 : 1982	Functional requirements for 275-l/min portable pump set for fire fighting (*second revision*)
943 : 1979	Functional requirement for 680-l/min trailer pump for fire brigade use (*second revision*)
944 : 1979	Functional requirement for 1800-l/min trailer pump for fire brigade use (*second revision*)
947 : 1985	Functional requirement for towing tender for trailer fire pump for fire brigade use (*first revision*)
948 : 1983	Functional requirement for water tender, Type A, for fire brigade use (*second revision*)
949 : 1985	Functional requirement for emergency (rescue) tender for fire brigade use (*second revision*)

IS No.	*Title*
950 : 1980	Functional requirements for water tender, Type B for fire brigade use (*second revision*)
952 : 1986	Specification for foghnozzle for fire brigade use (*first revision*)
955 : 1980	Functional requirements for dry power tender for fire-brigade use (150 kg capacity) (*first revision*)
957 : 1967	Specification for control van for fire brigade
1941 (Part 1) : 1976	Functional requirements for electric motor sirens: Part 1 ac 3 phase 50Hz, 415 V type (*second revision*)
2097 : 1983	Specification for foam making branch pipe (*first revision*)
2171 : 1999	Specification for portable fire extinguishers, dry powder (cartridge type) (*third revision*)
2175 : 1988	Specification for heat sensitive fire detectors for use in automatic detectors for use in automatic fire alarm system (*second revision*)
2298 : 1977	Specification for single-barrel stirrup pump for fire fighting purposes (*second revision*)
2546 : 1974	Specification for galvanized mild steel fire bucket (*first revision*)
2696 : 1974	Functional requirements for 1 125 l/min light fire engine (*first revision*)
2745 : 1983	Specification for non-metal helmet for firemen and civil defence personnel (*second revision*)
2871 : 1983	Specification for branch pipe, universal for fire fighting purposes (*first revision*)
2878 : 2004	Specification for fire extinguisher, carbon-dioxide type (portable and trolley mounted) (*third revision*)
2930 : 1980	Functional requirements for hose laying tender for fire brigade use (*first revision*)
3582 : 1984	Specification for basket strainers for fire fighting purposes (cylindrical type) (*first revision*)
4308 : 1982	Specification for dry powder for fire fighting (*first revision*)
4571 : 1977	Specification for aluminium extension ladders for fire brigade use (*first revision*)
4643 : 1984	Specification for suction wrenches for fire brigade use (*first revision*)
4861 : 1984	Specification for dry powder for fighting fires in burning metals (*first revision*)
4927 : 1992	Specification for unlined flax canvas hose for fire fighting (*first revision*)
4928 : 1986	Specification for delivery valve for centrifugal pump outlets (*first revision*)
4947 : 1985	Specification for gas cartridges for use in fire extinguishers (*second revision*)
4989 (Part 1) : 2004	Specifications for multipurpose aqueous film forming foam liquid concentrate for extinguishing hydrocarbon and polar solvent fires (*third revision*)
4989 (Part 2) : 1984	Specification for foam concentrate (compound) for producing mechanical foam for fire fighting: Part 2 Aqueous film forming foam (AFFF)
(Part 3) : 1987	Fluoro protein foam
5131 : 1986	Specification for dividing breeching with control, for fire brigade use (*first revision*)
5290 : 1993	Specification for landing valve (*third revision*)
5486 : 1985	Specification for quick release knife (*first revision*)
5505 : 1985	Specification for multi-edged rescue axe (non-wedging) (*first revision*)
5612	Specification for hose-clamps and hose-bandages for fire brigade use:
(Part 1) : 1977	Hose clamps (*first revision*)
(Part 2) : 1977	Hose bandages (*first revision*)
5714 : 1981	Specification for hydrant, stand-pipe for fire fighting (*first revision*)

IS No.	*Title*
6026 : 1985	Specification for hand-operated sirens (*first revision*)
6067 : 1983	Functional requirements for water tender, Type 'X' for fire brigade use (*first revision*)
6234 : 1986	Specification for portable fire extinguishers, water type (stored pressure) (*first revision*)
8090 : 1992	Specification for couplings, branch pipe, nozzle, used in hose reel tubing for fire fighting (*first revision*)
8096 : 1992	Specification for fire beaters (*first revision*)
8149 : 1994	Functional requirements for twin CO_2 fire extinguishers (trolley mounted) (*first revision*)
8423 : 1994	Specification for controlled percolating hose for fire fighting (*first revision*)
8442 : 1977	Specification for stand post type water monitor for fire fighting
9972 : 1981	Specification for automatic sprinkler heads
10204 : 1982	Specification for portable fire extinguisher mechanical foam type
10460 : 1983	Functional requirements for small foam tender for fire brigade use
10658 : 1999	Specification for higher capacity dry powder fire extinguisher (trolley mounted)
10993 : 1984	Functional requirements for 2000 kg dry powder tender for fire brigade us
11070 : 1984	Specification for bromo chlorodifluoromethane (Halon-1211) for fire fighting
11101 : 1984	Specification for extended branch pipe for fire brigade use
11108 : 1984	Specification for portable fire extinguisher halon-1211 type
11360 : 1985	Specification for smoke detectors for use in automatic electrical fire alarm systems
11833 : 1986	Specification for dry powder fire extinguisher for metal fires
12717 : 1989	Functional requirements of fire fighting equipment — High capacity portable pumpset (1 100-1 600 l/min)
12796 : 1989	Specification for fire rake
13039 : 1991	Code of practice for provision and maintenance of external hydrant system
13385 : 1992	Specification for fire extinguisher 50 capacity wheel mounted water type (gas cartridge)
13386 : 1992	Specification for 50 litre capacity fire extinguisher, mechanical foam type
13849 : 1993	Specification for portable fire extinguisher dry powder type (constant pressure)
14609 : 1999	Specification for ABC dry powder for fire fighting
14933 : 2001	Specification for high pressure fire fighting hose
14951 : 2001	Specification for fire extinguisher, 135 litre capacity mechanical foam type
15051 : 2002	Specification for high pressure fire hose delivery couplings
15105 : 2002	Design and installation of fixed automatic sprinkler fire extinguishing system
15220 : 2002	Specification for halon 1211 and halon 1301 — Fire extinguishing media for fire protection
15493 : 2004	Gaseous fire extinguishing systems — General requirements
15497 : 2004	Specification for gaseous fire extinguishing system — IG 01 extinguishing system
15501 : 2004	Specification for gaseous fire extinguishing system — IG 541 extinguishing system
15505 : 2004	Gaseous fire extinguishing systems — HCFC blend A extinguishing systems
15506 : 2004	Specification for inert gaseous total fire protection total flooding system — Argonite, IG 55 extinguishing system
15517 : 2004	Gaseous fire extinguishing systems — HFC 227 (heptafluoro propane) extinguishing system

IS No.	*Title*
15519 : 2004	Code of practice for water mist fire protection systems — System design, installation and commissioning
15525 : 2004	Specification for gaseous fire extinguishing system — IG 100 extinguishing system
15528 : 2004	Gaseous fire extinguishing systems — Carbon dioxide, total flooding and local application (sub-flour and in-cabinet), high and low pressure (refrigerated) systems
(20) 2190 : 1992	Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (*third revision*)
(21) 884 : 1985	Specification for first-aid hose reel for fire fighting (*first revision*)
15517 : 2004	Code of practice for inspection and maintenance of gaseous fire extinguishing systems
(22) 3034 : 1993	Code of practice for fire safety of industrial buildings: Electrical generating and distributing stations (*second revision*)
(23) 6382 : 1984	Code of practice for design and installation of fixed carbon dioxide fire extinguishing system (*first revision*)
(24) 14609 : 2001	Specification for dry powder for fire fighting — Class ABC fires
15493 : 2004	General requirement for commissioning of gaseous fire extinguishing systems
(25) 13716 : 1993	Code of practice for fire safety in hotels
(26) 4963 : 1987	Recommendations for buildings and facilities for the physically handicapped (*first revision*)
(27) 4878 : 1986	Bye-laws for construction of cinema buildings (*first revision*)
(28) 12456 : 1988	Code of practice for fire protection of electronic data processing installations
(29) 1646 : 1997	Code of practice for fire safety of buildings (general) : Electrical installations (*second revision*)
2726 : 1988	Code of practice for fire safety of industrial buildings: Cotton ginning and pressing (including cotton seed delintering) factories (*first revision*)
3034 : 1993	Code of practice for fire safety of industrial buildings: Electrical generating and distributing stations (*second revision*)
3058 : 1990	Code of practice for fire safety of industrial buildings: Viscose rayon yarn and/or staple fibre plants (*first revision*)
3079 : 1990	Code of practice for fire safety of industrial buildings: Cotton textile mills (*first revision*)
3594 : 1991	Code of practice for fire safety of industrial buildings: General storage and warehousing including cold storage (*first revision*)
3595 : 1984	Code of practice for fire safety of industrial buildings: Coal pulverizers and associated equipment (*first revision*)
3836 : 2000	Code of practice for fire safety of industrial buildings: Jute mills (*second revision*)
4209 : 1987	Code of safety in chemical laboratories (*first revision*)
4226 : 1988	Code of practice for fire safety of industrial buildings: Aluminium/ Magnesium powder factories (*first revision*)
4886 : 1991	Code of practice for fire safety of industrial buildings: Tea factories (*first revision*)
6329 : 2000	Code of practice for fire safety of industrial buildings: Saw mills and wood works (*first revision*)
9109 : 2000	Code of practice for fire safety of industrial buildings: Paint and varnish factories
11457 (Part 1) : 1985	Code of practice for fire safety of chemical industries: Part 1 Rubber and plastic
11460 : 1985	Code of practice for fire safety of libraries and archives buildings
12349 : 1988	Fire protection — Safety signs
12407 : 1988	Graphic symbols for fire protection plans

IS No.	*Title*
12456 : 1988	Code of practice for fire protection of electronic data processing installation
12458 : 1988	Method of test for fire resistance test of fire stops
12459 : 1988	Code of practice for fire-protection of cable runs
12777 : 1989	Fire safety — Flame spread of products — Method for classification
13045 : 1991	Code of practice for fire safety in industrial buildings: Floor mills
13694 : 1993	Code of practice for fire safety in iron and steel industries
13716 : 1993	Code of practice for fire safety of hotels
14435 : 1997	Code of practice for fire safety in educational institutions
14689 : 1999	Code of practice for fire safety in printing and publishing industry
14850 : 2000	Code of practice for fire safety of museums
(30) 655 : 1963	Specification for metal air ducts (*revised*)
(31) 9583 : 1981	Emergency lighting units

NATIONAL BUILDING CODE OF INDIA

PART 5 BUILDING MATERIALS

BUREAU OF INDIAN STANDARDS

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FOREWORD

Ensuring the quality and effectiveness of building materials used in the construction and their storage are as important as the other phases of building activity like planning, designing and constructing the building itself. This Part, therefore, lists Indian Standards for materials used in building construction. The methods of tests, to ensure the requirements demanded of the materials in the various situations, are also included.

Historically choice of building materials was determined by what was locally available, appropriateness to geo-climatic conditions and affordability of users. In recent past, different initiatives have been taken in the areas of research and development, standardization, and development and promotion of innovative materials. A review of the recent trends indicates that the growth in the area of building materials covers emerging trends and latest developments in the use of wastes, mineral admixtures in cement and concrete, substitutes to conventional timber, composite materials and recycling of wastes, at the same time ensuring desired response of materials to fire, long term performance and durability. In addition to these developments, the future decade may witness development of specific materials which may be structured and designed to meet needs to specially developed construction technologies, such as, for disaster prone areas or aggressive climatic and industrial situations.

In this context, the following factors have become important for facilitating application and adoption in practice, of the materials:

a) Utilization of industrial, mining, mineral and agricultural wastes; plantation timbers; and renewable natural fibres and residues for production of building materials.
b) Impact of production of building materials on the consumption levels of natural resources.
c) Change in energy demand in production of building materials due to development of efficient manufacturing processes.
d) Impact of production and usage of materials and disposal thereof on the environment.

To encourage use of appropriate materials, it may be desirable to have, to the extent possible, performance oriented approach for specifications rather than prescriptive approach. The approach has been already adopted in some cases in development of standards, wherever found possible.

Indian Standards cover most of the requirements for materials in use. However, there may be a gap between development of new materials and techniques of application and formulation of standards. It, therefore, becomes necessary for a Building Code to be flexible to recognize building materials other than those for which Indian Standards are available. This Part, therefore, since its first version, duly takes care of this aspect and explicitly provides for use of new or alternate building materials, provided it is proved by authentic tests that the new or alternative material is effective and suitable for the purpose intended. However, it is worthwhile that more and more emphasis is given to the satisfaction of performance requirements expected of a building material, so that a wide range of such new or alternate materials can be evaluated and used, if found appropriate.

As already emphasized, quality of material is quite important for their appropriate usage, whether it is a material for which an Indian Standard is available or a new or alternative material as defined in 3 of this Part. Third party certification schemes available in the country for quality assurance of above materials can be used with advantage to ensure the appropriateness of these materials.

This Part of the Code was first published in 1970 and subsequently revised in 1983. The first revision of this Part incorporated an updated version of the list of Indian Standards given at the end of this Part of the Code. The present draft revision of this Part, while basically retaining the structure of 1983 version of the Code, explicitly takes care of the following:

a) While continuing to emphasize on conformity of building materials to available Indian Standards, the building regulating authority also recognizes use of building materials conforming to other specifications and test methods (*see* 3), in case Indian Standards are not available for particular materials.

b) The list at the end of this part has been completely reclassified to make it more user friendly and updated to reflect the latest available Indian Standard and methods of test.

A reference to SP 21 'Summaries of Indian Standards for building materials' may be useful. This publication gives the summaries of Indian Standards covering various building materials, fittings and components except standards relating to paints.

All standards cross-referred to in the main text of this Part, are subject to revision. The parties to agreement based on this section are encouraged to investigate the possibility of applying the most recent editions of the standards.

NATIONAL BUILDING CODE OF INDIA

PART 5 BUILDING MATERIALS

1 SCOPE

This Part of the Code covers the requirements of building materials and components, and criteria for accepting new or alternative building materials and components.

2 MATERIALS

Every material used in fulfilment of the requirements of this Part, unless otherwise specified in the Code or approved, shall conform to the relevant Indian Standards. A list of Indian Standards as the 'accepted standards' is given at the end of this Part of the Code. At the time of publication of the Code, the editions indicated were valid. All standards are subject to amendments and revisions. The Authority shall take cognizance of such amendments and revisions. The latest version of a standard shall, as far as possible, be adopted at the time of enforcement of this Part of the Code.

3 NEW OR ALTERNATIVE MATERIALS

3.1 The provisions of this Part are not intended to prevent the use of any material not specifically prescribed under **2**. Any such material may be approved by the Authority or an agency appointed by them for the purpose, provided it is established that the material is satisfactory for the purpose intended and the equivalent of that required in this Part or any other specification issued or approved by the Authority. The Authority or an agency appointed by them shall take into account the following parameters, as applicable to the concerned new or alternative building material:

a) Requirements of the material specified/ expected in terms of the provisions given in the standards on its usage, including its applicability in geo-climatic condition;
b) General appearance;
c) Dimension and dimensional stability;
d) Structural stability including strength properties;
e) Fire safety;
f) Durability;
g) Thermal properties;
h) Mechanical properties;
j) Acoustical properties;
k) Optical properties;
m) Biological effect;
n) Environmental aspects;
p) Working characteristics;
q) Ease of handling; and
r) Consistency and workability.

For establishing the performance of the material/ component, laboratory/field tests, and field trials, as required, and study of historical data are recommended.

3.2 Approval in writing of the Authority or an agent appointed by them for the purpose of approval of material, shall be obtained by the owner or his agent before any new, alternative or equivalent material is used. The Authority or their agent shall base such approval on the principle set forth in **3.1** and shall require that tests be made (*see* **7.1**) or sufficient evidence or proof be submitted, at the expense of the owner or his agent, to substantiate any claim for the proposed material.

NOTE — For interpretation of the term 'Authority' (*see also* **7.1**), the definition of 'Authority having jurisdiction' given in Part 2 'Administration' shall apply.

4 THIRD PARTY CERTIFICATION

For ensuring the conformity of materials for which Indian Standards exist and for new or alternative building materials, to requisite quality parameters the services under the third party certification schemes of the Government, may be utilized with advantage.

5 USED MATERIALS

The use of used materials may not be precluded provided these meet the requirements of this Part for new materials (*see* Part 2 'Administration').

6 STORAGE OF MATERIALS

All building materials shall be stored on the building site in such a way as to prevent deterioration or the loss or impairment of their structural and other essential properties (*see* Part 7 'Constructional Practices and Safety').

7 METHODS OF TEST

7.1 Every test of material required in this Part or by the Authority shall be carried out in accordance with the Indian Standard methods of test. In the case of methods of tests where Indian Standards are not available, the same shall conform to the methods of tests issued by the Authority or their agent. A list of Indian Standard methods of test is given at the end of this Part of the Code as the 'good practices'. Laboratory tests shall be conducted by recognized laboratories acceptable to the Authority.

7.1.1 The manufacturer/supplier shall satisfy himself that materials conform to the requirements of the specifications and if requested shall supply a certificate to this effect to the purchaser or his representative. When such test certificates are not available, the specimen of the material shall be tested.

LIST OF STANDARDS

Following are the Indian Standards for various building materials and components, to be complied with in fulfillment of the requirements of the Code.

In the following list, while enlisting the Indian Standards, the materials have been categorized in such a way as to make the list user friendly. In the process, if so required, some of the standards have been included even in more than one category of products, such as in the category based on composition as well as on end application of the materials. The list has been arranged in alphabetical order of their principal category as given below:

1. ALUMINIUM AND OTHER LIGHT METALS AND THEIR ALLOYS
2. BITUMEN AND TAR PRODUCTS
3. BUILDER'S HARDWARES
4. BUILDING CHEMICALS
5. BUILDING LIME AND PRODUCTS
6. BURNT CLAY PRODUCTS
7. CEMENT AND CONCRETE (including concrete reinforcement)
8. COMPOSITE MATRIX PRODUCTS (including cement matrix products)
9. CONDUCTORS AND CABLES
10. DOORS, WINDOWS AND VENTILATORS
11. ELECTRICAL WIRING, FITTINGS AND ACCESSORIES
12. FILLERS, STOPPERS AND PUTTIES
13. FLOOR COVERING, ROOFING AND OTHER FINISHES
14. GLASS
15. GYPSUM BASED MATERIALS
16. LIGNOCELLULOSIC BUILDING MATERIALS (including timber, bamboo and products thereof)
17. PAINTS AND ALLIED PRODUCTS
18. POLYMERS, PLASTICS AND GEOSYNTHETICS/GEOTEXTILES
19. SANITARY APPLIANCES AND WATER FITTINGS
20. SOIL-BASED PRODUCTS
21. STEEL AND ITS ALLOYS
22. STONES
23. STRUCTURAL SECTIONS
24. THERMAL INSULATION MATERIALS
25. THREADED FASTENERS AND RIVETS
26. UNIT WEIGHTS OF BUILDING MATERIALS
27. WATERPROOFING AND DAMP-PROOFING MATERIALS
28. WELDING ELECTRODES AND WIRES
29. WIRE ROPES AND WIRE PRODUCTS

1. ALUMINIUM AND OTHER LIGHT METALS AND THEIR ALLOYS

IS No.	*Title*
733 : 1983	Specification for wrought aluminium and aluminium alloys, bars, rods and sections for general engineering purposes (*third revision*)
737 : 1986	Specification for wrought aluminium and aluminium alloys, sheet rods and strip for general engineering purposes (*third revision*)
738 : 1994	Specification for wrought aluminium and aluminium alloy drawn tube for general engineering purposes (*third revision*)
740 : 1977	Specification for wrought aluminium and aluminium alloy rivet stock for general engineering purposes (*second revision*)
1254 : 1991	Specification for corrugated aluminium sheet (*third revision*)
1284 : 1975	Wrought aluminium alloy bolt and screw stock for general engineering purposes (*second revision*)
1285 : 2002	Specification for wrought aluminium and aluminium alloys, extruded round tube and hollow sections for general engineering purposes (*third revision*)
2479 : 1981	Colour code for the identification of aluminium and aluminium alloys for general engineering purposes (*second revision*)
2676 : 1981	Dimensions for wrought aluminium and aluminium alloy sheet and strip
2677 : 1979	Dimensions for wrought aluminium and aluminium alloys, plates and hot rolled sheets
14712 : 1999	Wrought aluminium and its alloys — Chequered/tread sheets for general engineering purposes — Specification

2. BITUMEN AND TAR PRODUCTS

73 : 1992	Specification for paving bitumen (*second revision*)

IS No.	Title
212 : 1983	Specification for crude coal tar for general use (*second revision*)
215 : 1995	Specification for road tar (*third revision*)
216 : 1961	Specification for coal tar pitch (*first revision*)
217 : 1988	Specification for cutback bitumen (*second revision*)
218 : 1983	Specification for creosote oil for use as wood preservatives (*second revision*)
454 : 1994	Specification for cutback bitumen from waxy crude (*second revision*)
702 : 1988	Specification for industrial bitumen (*second revision*)
1201 to 1220	Methods for testing tar and bituminous materials
1201 : 1978	Sampling (*first revision*)
1202 : 1978	Determination of specific gravity (*first revision*)
1203 : 1978	Determination of penetration (*first revision*)
1204 : 1978	Determination of residue of specified penetration (*first revision*)
1205 : 1978	Determination of softening point (*first revision*)
1206	Determination of viscosity:
(Part 1) : 1978	Industrial viscosity (*first revision*)
(Part 2) : 1978	Absolute viscosity (*first revision*)
(Part 3) : 1978	Kinematic viscosity (*first revision*)
1207 : 1978	Determination of equiviscous temperature (EVT) (*first revision*)
1208 : 1978	Determination of ductility (*first revision*)
1209 : 1978	Determination of flash point and fire point (*first revision*)
1210 : 1978	Float test (*first revision*)
1211 : 1978	Determination of water content (Dean and Stark method) (*first revision*)
1212 : 1978	Determination of loss of heating (*first revision*)
1213 : 1978	Distillation test (*first revision*)
1215 : 1978	Determination of matter insoluble in toluene (*first revision*)
1216 : 1978	Determination of solubility in carbon disulphide or trichloroethylene (*first revision*)
1217 : 1978	Determination of mineral matter (ASH) (*first revision*)
1218 : 1978	Determination of phenols (*first revision*)
1219 : 1978	Determination of naphthalene (*first revision*)
1220 : 1978	Determination of volatile matter content (*first revision*)
3117 : 2004	Specification for bitumen emulsion for roads (anionic type) (*first revision*)
8887 : 2004	Specification for bitumen emulsion for roads (cationic type) (*second revision*)
9381 : 1979	Methods for testing tar and bituminous materials: Determination of FRAASS breaking point of bitumen
9382 : 1979	Methods for testing tar and bituminous materials: Determination of effect of heat and air by thin film oven test
10511 : 1983	Method for determination of asphaltenes in bitumen by precipitation with normal haptane
10512 : 2003	Method for determination of wax content in bitumen (*first revision*)
13758	Coal tar pitch:
(Part 1) : 1993	Determination of matter insoluble in quinoline
(Part 2) : 1993	Determination of coking value
15172 : 2002	Methods for testing tar and bituminous materials — Determination of curing index for cutback bitumens
15173 : 2002	Methods for testing tars and bituminous materials — Determination of breaking point for cationic bitumen emulsion
15174 : 2002	Methods for testing tar and bituminous material — Determination of breaking point for anionic bitumen emulsion
15462 : 2004	Specification for polymer and rubber modified bitumen

3. BUILDER'S HARDWARE

204	Specification for tower bolts:
(Part 1) : 1991	Ferrous metals (*fifth revision*)
(Part 2) : 1992	Non-ferrous metals (*fifth revision*)
205 : 1992	Specification for non-ferrous metal butt hinges (*fourth revision*)

	hinges (*fourth revision*)
208 : 1996	Specification for door handles (*fifth revision*)
281 : 1991	Specification for mild steel sliding door bolts for use with padlock (*third revision*)
362 : 1991	Specification for parliament hinges (*fifth revision*)
363 : 1993	Specification for hasps and staples (*fourth revision*)
364 : 1993	Specification for fanlight catch (*third revision*)
452 : 1973	Specification for door springs, rat-tail type (*second revision*)
453 : 1993	Specification for double-acting spring hinges (*third revision*)
729 : 1979	Specification for drawer locks, cupboard locks and box locks (*third revision*)
1019 : 1974	Specification for rim latches (*second revision*)
1341 : 1992	Specification for steel butt hinges (*sixth revision*)
1823 : 1980	Specification for floor door stoppers (*third revision*)
1837 : 1966	Specification for fanlight pivots (*first revision*)
2209 : 1976	Specification for mortice locks (vertical type) (*third revision*)
2681 : 1993	Specification for non-ferrous metal sliding door bolts for use with padlocks (*third revision*)
3564 : 1995	Specification for door closers (hydraulically regulated) (*second revision*)
3818 : 1992	Specification for continuous (piano) hinges (*third revision*)
3828 : 1966	Specification for ventilator chains
3843 : 1995	Specification for steel backflap hinges (*first revision*)
3847 : 1992	Specification for mortice night latches (*first revision*)
4621 : 1975	Specification for indicating bolts for use in public baths and lavatories (*first revision*)
4948 : 2002	Specification for welded steel wire fabric for general use (*second revision*)
	mortice locks (vertical type) (*first revision*)
5187 : 1972	Specification for flush bolts (*first revision*)
5899 : 1970	Specification for bathroom latches
5930 : 1970	Specification for mortice latch (vertical type)
6315 : 1992	Specification for floor springs (hydraulically regulated) for heavy doors (*second revision*)
6318 : 1971	Specification for plastic window stays and fasteners
6343 : 1982	Specification for door closers (pneumatically regulated) for light door weighing up to 40 kg (*first revision*)
6607 : 1972	Specification for rebated mortice locks (vertical type)
7196 : 1974	Specification for hold fast
7197 : 1974	Specification for double action floor springs (without oil check) for heavy doors
7534 : 1985	Specification for sliding locking bolts for use with padlocks (*first revision*)
7540 : 1974	Specification for mortice dead locks
8756 : 1978	Specification for ball catches for use in wooden almirah
8760 : 1978	Specification for mortice sliding door locks, with lever mechanism
9106 : 1979	Specification for rising butt hinges
9131 : 1979	Specification for rim locks
9460 : 1980	Specification for flush drop handle for drawer
9899 : 1981	Specification for hat coat and wardrobe hooks
10019 : 1981	Specification for mild steel stays and fasteners
10090 : 1982	Specification for numericals
10342 : 1982	Specification for curtain rail system
12817 : 1997	Specification for stainless steel butt hinges (*first revision*)
12867 : 1989	Specification for PVC hand rails covers
14912 : 2001	Specification for door closers concealed type (hydraulically regulated)

IS No.	*Title*

4. BUILDING CHEMICALS

a) Anti-termite Chemicals

632 : 1978	Specification for gamma-BHC (lindane) emulsifiable concentrates (*fourth revision*)
8944 : 1978	Specification for chlorpyrifos emulsifiable concentrates

b) Chemical Admixture/Water Proofing Compounds

2645 : 2003	Specification for integral waterproofing compounds for cement mortar and concrete (*second revision*)
6925 : 1973	Methods of test for determination of water soluble chlorides in concrete admixtures
9103 : 1999	Specification for concrete admixtures (*first revision*)

c) Sealants/Fillers

1834 : 1984	Specification for hot applied sealing compound for joint in concrete (*first revision*)
1838	Specification for preformed fillers for expansion joint in concrete pavements and structures (non-extruding and resilient type):
(Part 1) : 1983	Bitumen impregnated fibre (*first revision*)
(Part 2) : 1984	CNSL aldehyde resin and coconut pith
11433	Specification for one grade
(Part 1) : 1985	polysulphide based joint sealant: Part 1 General requirements
12118	Specification for two parts polysulphide based sealants:
(Part 1) : 1987	General requirements
(Part 2) : 1987	Methods of test

d) Adhesives

848 : 1974	Specification for synthetic resin adhesives for plywood (phenolic and aminoplastic) (*first revision*)
849 : 1994	Specification for cold setting case in glue for wood (*first revision*)
851 : 1978	Specification for synthetic resin adhesives for construction work (non-structural) in wood (*first revision*)
852 : 1994	Specification for animal glue for general wood-working purposes (*second revision*)
1508 : 1972	Specification for extenders for use in synthetic resin adhesives (urea-formaldehyde) for plywood (*first revision*)
4835 : 1979	Specification for polyvinyl acetate dispersion-based adhesives for wood (*first revision*)
9188 : 1979	Performance requirements for adhesive for structural laminated wood products for use under exterior exposure condition
12830 : 1989	Rubber based adhesives for fixing PVC tiles to cement
12994 : 1990	Epoxy adhesives, room temperature curing general purpose

5. BUILDING LIME AND PRODUCTS

712 : 1984	Specification for building limes (*third revision*)
1624 : 1986	Method of field testing of building lime (*first revision*)
2686 : 1977	Specification for cinder as fine aggregates for use in lime concrete (*first revision*)
3068 : 1986	Specification for broken brick (burnt-clay) coarse aggregates for use in lime concrete (*second revision*)
3115 : 1992	Specification for lime based blocks (*second revision*)
3182 : 1986	Specification for broken bricks (burnt clay) fine aggregates for use in lime mortar (*second revision*)
4098 : 1983	Specification for lime-pozzolana mixture (*first revision*)
4139 : 1989	Specification for calcium silicate bricks (*second revision*)
6932	Method of tests for building limes:
(Part 1) : 1973	Determination of insoluble residue, loss on ignition, insoluble matter, silicon dioxide, ferric and aluminium oxide, calcium oxide and magnesium oxide
(Part 2) : 1973	Determination of carbon dioxide content
(Part 3) : 1973	Determination of residue on slaking of quicklime
(Part 4) : 1973	Determination of fineness of hydrated lime
(Part 5) : 1973	Determination of unhydrated oxide

IS No.	*Title*
(Part 6) : 1973	Determination of volume yield of quicklime
(Part 7) : 1973	Determination of compressive and transverse strength
(Part 8) : 1973	Determination of workability
(Part 9) : 1973	Determination of soundness
(Part 10) : 1973	Determination of popping and pitting of hydrated lime
(Part 11) : 1984	Determination of setting time of hydrated lime
10360 : 1982	Specification for lime pozzolana concrete blocks for paving
10772 : 1983	Specification for quick setting lime pozzolana mixture
12894 : 2002	Specification for pulverized fuel ash lime bricks (*first revision*)

6. BURNT CLAY PRODUCTS

a) Blocks

3952 : 1988	Specification for burnt hollow bricks for walls and partitions (*second revision*)

b) Soil-Based Products

1725 : 1982	Specification for soil-based blocks used in general building construction

c) Bricks

1077 : 1992	Specification for common burnt clay building bricks (*fifth revision*)
2117 : 1991	Guide for manufacture of hand-made-common burnt clay building bricks (*third revision*)
2180 : 1988	Specification for heavy duty burnt clay building bricks (*third revision*)
2222 : 1991	Specification for burnt clay perforated building bricks (*fourth revision*)
2691 : 1988	Specification for burnt clay facing bricks (*second revision*)
3495 (Parts 1 to 4) : 1992	Methods of test of burnt clay building bricks (*third revision*)
3583 : 1988	Specification for burnt clay paving bricks (*second revision*)
4885 : 1988	Specification for sewer bricks (*first revision*)
5454 : 1978	Methods for sampling of clay building bricks
5779 : 1986	Specification for burnt clay soling bricks (*first revision*)
6165 : 1992	Dimensions for special shapes of clay bricks (*first revision*)
11650 : 1991	Guide for manufacture of common burnt clay building bricks by semi-mechanized process (*first revision*)
13757 : 1993	Specification for burnt clay fly ash building bricks

d) Jallies

7556 : 1988	Specification for burnt clay jallies (*first revision*)

e) Tiles

654 : 1992	Specification for clay roofing tiles, Mangalore pattern (*third revision*)
1464 : 1992	Specification for clay ridge and ceiling tiles (*second revision*)
1478 : 1992	Specification for clay flooring tiles (*second revision*)
2690	Specification for burnt clay flat terracing tiles:
(Part 1) : 1993	Machine made (*second revision*)
(Part 2) : 1992	Handmade (*second revision*)
3367 : 1993	Specification for burnt clay tiles for use in lining irrigation and drainage works (*second revision*)
3951	Specification for hollow clay tiles for floor and roofs:
(Part 1) : 1975	Filler type (*first revision*)
(Part 2) : 1975	Structural type (*first revision*)
13317 : 1992	Specification for clay roofing camty tiles, half round and flat tiles

7. CEMENT AND CONCRETE (including concrete reinforcement)

a) Aggregates

383 : 1970	Specification for coarse and fine aggregates from natural sources for concrete (*second revision*)
1542 : 1992	Specification for sand for plaster (*second revision*)
2116 : 1980	Specification for sand for masonry mortars (*first revision*)
2386	Methods of test for aggregates for concrete:
(Part 1) : 1963	Particle size and shape
(Part 2) : 1963	Estimation of deleterious materials and organic impurities
(Part 3) : 1963	Specific gravity, density, voids, absorption and bulking

(Part 4) : 1963	Mechanical properties
(Part 5) : 1963	Soundness
(Part 6) : 1963	Measuring mortar making properties of fine aggregates
(Part 7) : 1963	Alkali aggregate reactivity
(Part 8) : 1963	Petrographic examination
2430 : 1986	Methods of sampling of aggregates of concrete (*first revision*)
6579 : 1981	Specification for coarse aggregate for water bound macadam (*first revision*)
9142 : 1979	Specification for artificial light-weight aggregates for concrete masonry units

b) Cement

269 : 1989	Specification for ordinary portland cement, 33 Grade (*fourth revision*)
455 : 1989	Specification for Portland slag cement (*fourth revision*)
1489	Specification for Portland pozzolana cement:
(Part 1) : 1991	Flyash based (*third revision*)
(Part 2) : 1991	Calcined clay based (*third revision*)
3466 : 1988	Specification for masonry cement (*second revision*)
6452 : 1989	Specification for high alumina cement for structural use (*first revision*)
6909 : 1990	Specification for supersulphated cement
8041 : 1990	Specification for rapid hardening Portland cement (*second revision*)
8042 : 1989	Specification for white Portland cement (*second revision*)
8043 : 1991	Specification for hydrophobic Portland cement (*second revision*)
8112 : 1989	Specification for 43 grade ordinary Portland cement (*first revision*)
12269 : 1987	Specification for 53 grade ordinary Portland cement
12330 : 1988	Specification for sulphate resisting Portland cement
12600 : 1989	Specification for low heat Portland cement

c) Mineral/Chemical Admixtures and Pozzolanas

1344 : 1981	Specification for calcined clay pozzolana (*second revision*)
1727 : 1967	Methods of test for pozzolanic materials (*first revision*)
3812	Specification for pulverized fuel ash:
(Part 1) : 2003	For use as pozzolana in cement, cement mortar and concrete (*second revision*)
(Part 2) : 2003	For use as admixture in cement mortar and concrete (*second revision*)
6491 : 1972	Method of sampling of flyash
6925 : 1973	Methods of test for determination of water soluble chlorides in concrete admixtures
9103 : 1999	Specification for admixtures for concrete (*first revision*)
12089 : 1987	Specification for granulated slag for manufacture of Portland slag cement
12870 : 1989	Methods of sampling calcined clay pozzolana
15388 : 2003	Specification for silica fume

d) Concrete

456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
1343 : 1980	Code of practice for prestressed concrete (*first revision*)
4926 : 2003	Code of practice for ready-mixed concrete (*third revision*)

e) Cement and Concrete Sampling and Methods of Test

516 : 1959	Methods of test for strength of concrete
1199 : 1959	Methods of sampling and analysis of concrete
2770 (Part 1) : 1967	Methods of testing bond in reinforced concrete: Part 1 Pullout test
3085 : 1965	Methods of test for permeability of cement mortar and concrete
3535 : 1986	Methods of sampling hydraulic cement (*first revision*)
4031	Methods of physical tests for hydraulic cement:
(Part 1) : 1996	Determination of fineness by dry sieving (*second revision*)
(Part 2) : 1999	Determination of fineness by specific surface by Blaine air permeability method (*second revision*)

IS No.	*Title*
(Part 3) : 1988	Determination of soundness (*first revision*)
(Part 4) : 1988	Determination of consistency of standard cement paste (*first revision*)
(Part 5) : 1988	Determination of initial and final setting times (*first revision*)
(Part 6) : 1988	Determination of compressive strength of hydraulic cement (other than masonry cement) (*first revision*)
(Part 7) : 1988	Determination of compressive strength of masonry cement (*first revision*)
(Part 8) : 1988	Determination of transverse and compressive strength of plastic mortar using prism (*first revision*)
(Part 9) : 1988	Determination of heat of hydration (*first revision*)
(Part 10) : 1988	Determination of drying shrinkage (*first revision*)
(Part 11) : 1988	Determination of density (*first revision*)
(Part 12) : 1988	Determination of air content of hydraulic cement mortar (*first revision*)
(Part 13) : 1988	Measurement of water retentivity of masonry cement (*first revision*)
(Part 14) : 1989	Determination of false set
(Part 15) : 1991	Determination of fineness by wet sieving
4032 : 1985	Methods of chemical analysis for hydraulic cement (*first revision*)
5816 : 1999	Method of test for splitting tensile strength of concrete (*first revision*)
8142 : 1976	Methods of test for determining setting time of concrete by penetration resistance
9013 : 1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
9284 : 1979	Method of test for abrasion resistance of concrete
12423 : 1988	Methods for colorometric analysis of hydraulic cement
12803 : 1989	Methods of analysis of hydraulic cement by X-ray fluorescence spectrometer
12813 : 1989	Method of analysis of hydraulic cement by atomic absorption spectrophotometer
13311	Methods of non-destructive testing of concrete:
(Part 1) : 1992	Ultrasonic pulse velocity
(Part 2) : 1992	Rebound hammer

f) Treatment of Concrete Joints

1834 : 1984	Specification for hot applied sealing compound for joint in concrete (*first revision*)
1838	Specification for preformed fillers for expansion joint in concrete pavements and structures (non-extruding and resilient type):
(Part 1) : 1983	Bitumen impregnated fibre (*first revision*)
(Part 2) : 1984	CNSL aldehyde resin and coconut pith
10566 : 1983	Methods of test for preformed fillers for expansion joints in concrete paving and structural construction
11433	Specification for one grade polysulphide based joint sealant:
(Part 1) : 1985	General requirements
(Part 2) : 1986	Methods of test
12118	Specification for two parts polysulphide based sealants:
(Part 1) : 1987	General requirements
(Part 2) : 1987	Methods of test

g) Concrete Reinforcement

432	Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement:
(Part 1) : 1982	Mild steel and medium tensile steel bars (*third revision*)
(Part 2) : 1982	Hard drawn steel wire (*third revision*)
1566 : 1982	Specification for hard drawn steel wire fabric for concrete reinforcement (*second revision*)
1608 : 1995	Mechanical testing of materials — Tensile testing
1785	Specification for plain hard drawn steel wire for prestressed concrete:

IS No.	*Title*
(Part 1) : 1983	Cold drawn stress-relieved wire (*second revision*)
(Part 2) : 1983	As drawn wire (*first revision*)
1786 : 1985	Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*)
2090 : 1983	Specification for high tensile steel bars used in prestressed concrete (*first revision*)
6003 : 1983	Specification for indented wire for prestressed concrete (*first revision*)
6006 : 1983	Specification for uncoated stress-relieved strand for prestressed concrete (*first revision*)
10790	Methods of sampling of steel for prestressed and reinforced concrete:
(Part 1) : 1984	Prestressing steel
(Part 2) : 1984	Reinforcing steel
13620 : 1993	Specification for fusion bonded epoxy coated reinforcing bars
14268 : 1995	Specification for uncoated stress relieved low relaxation seven ply strand for prestressed concrete

8. COMPOSITE MATRIX PRODUCTS

a) Cement Matrix Products

i) *Precast Concrete Products*

2185	Specification for concrete masonry units:
(Part 1) : 1979	Hollow and solid concrete blocks (*second revision*)
(Part 2) : 1983	Hollow and solid lightweight concrete blocks (*first revision*)
(Part 3) : 1984	Autoclaved cellular (aerated) concrete blocks (*first revision*)
4996 : 1984	Specification for reinforced concrete fence posts (*first revision*)
5751 : 1984	Specification for precast concrete coping blocks (*first revision*)
5758 : 1984	Specification for precast concrete kerbs (*first revision*)
5820 : 1970	Specification for precast concrete cable covers
6072 : 1971	Specification for autoclaved reinforced cellular concrete wall slabs
6073 : 1971	Specification for autoclaved reinforced cellular concrete floor and roof slabs
6441	Methods of test for autoclaved cellular concrete products:
(Part 1) : 1972	Determination of unit weight or bulk density and moisture content
(Part 2) : 1972	Determination of drying shrinkage
(Part 4) : 1972	Corrosion protection of steel reinforcement in autoclaved cellular concrete
(Part 5) : 1972	Determination of compressive strength
(Part 6) : 1973	Strength, deformation and cracking of flexural members subject to bending-short duration loading test
(Part 7) : 1973	Strength, deformation and cracking of flexural members subject to bending-sustained loading test
(Part 8) : 1973	Loading tests for flexural members in diagonal tension
(Part 9) : 1973	Jointing of autoclaved cellular concrete elements
6523 : 1983	Specification for precast reinforced concrete door and window frames (*first revision*)
9872 : 1981	Specification for precast concrete septic tanks
9893 : 1981	Specification for precast concrete blocks for lintels and sills
12440 : 1988	Specification for precast concrete stone masonry blocks
12592 : 2002	Specification for precast concrete manhole covers and frames (*first revision*)
13356 : 1992	Specification for precast ferrocement water tanks (250 to 10 000 litres capacity)
13990 : 1994	Specification for precast reinforced concrete planks and joists for flooring and roofing
14143 : 1994	Specification for prefabricated brick panel and partially precast concrete joist for flooring and roofing
14201 : 1994	Specification for precast reinforced concrete channel unit for construction of floors and roofs
14241 : 1994	Specification for precast L-Panel units for roofing

IS No.	*Title*
ii) *Asbestos Fibre Cement Products*	
459 : 1992	Specification for corrugated and semi-corrugated asbestos cement sheets (*third revision*)
1592 : 2003	Specification for asbestos cement pressure pipes and joints (*fourth revision*)
1626	Specification for asbestos cement building pipes and pipe fittings, gutters and gutter fittings and roofing fittings:
(Part 1) : 1994	Pipes and pipe fittings (*second revision*)
(Part 2) : 1994	Gutters and gutter fittings (*second revision*)
(Part 3) : 1994	Roofing fittings (*second revision*)
2096 : 1992	Specification for asbestos cement flat sheets (*first revision*)
2098 : 1997	Specification for asbestos cement building boards (*first revision*)
5913 : 2003	Methods of test for asbestos cement products (*second revision*)
6908 : 1991	Specification for asbestos cement pipes and fittings for sewerage and drainage (*first revision*)
7639 : 1975	Method of sampling asbestos cement products
9627 : 1980	Specification for asbestos cement pressure pipes (light duty)
13000 : 1990	Silica-asbestos-cement flat sheets — Specification
13008 : 1990	Specification for shallow corrugated asbestos cement sheets
iii) *Other Fibre Cement Products*	
14862 : 2000	Specification for fibre cement flat sheets
14871 : 2000	Specification for products in fibre reinforced cement long corrugated or asymmetrical section sheets and fittings for roofing and cladding
iv) *Concrete Pipes and Pipes Lined/Coated with Concrete or Mortar*	
458 : 2003	Specification for precast concrete pipes (with and without reinforcement) (*fourth revision*)
784 : 2001	Specification for prestressed concrete pipes (including specials) (*second revision*)
1916 : 1989	Specification for steel cylinder pipe with concrete lining and coating (*first revision*)
3597 : 1998	Methods of test for concrete pipes (*second revision*)
4350 : 1967	Specification for concrete porous pipes for under drainage
7319 : 1974	Specification for perforated concrete pipes
7322 : 1985	Specification for specials for steel cylinder reinforced concrete pipes (*first revision*)
15155 : 2002	Specification for bar/wire wrapped steel cylinder pipe with mortar lining and coating
b) Resin Matrix Products	
1998 : 1962	Methods of test for thermosetting synthetic resin bonded laminated sheets
2036 : 1995	Specification for phenolic laminated sheets (*second revision*)
2046 : 1995	Specification for decorative thermosetting synthetic resin bonded laminated sheets (*second revision*)
9. CONDUCTORS AND CABLES	
694 : 1990	Specification for PVC insulated cables for working voltages up to and including 1 100 V (*third revision*)
1554	Specification for PVC insulated (heavy duty) electric cables:
(Part 1) : 1988	For working voltages up to and including 1 100 V (*third revision*)
(Part 2) : 1988	For working voltages from 3.3 kV up to and including 11 kV (*second revision*)
4289	Specification for flexible cables for lifts and other flexible:
(Part 1) : 1984	Elastomer insulated cables (*first revision*)
(Part 2) : 2000	PVC insulated circular cables
7098	Specification for cross-linked polyethylene insulated PVC sheathed cables:
(Part 1) : 1988	For working voltage up to and including 1 100 V (*second revision*)

IS No.	*Title*
(Part 2) : 1985	For working voltages from 3.3 kV up to and including 33 kV (*first revision*)
(Part 3) : 1993	For working voltages from 66 kV up to and including 220 kV (*first revision*)
9968	Specification for elastomer-insulated cables:
(Part 1) : 1988	For working voltages up to and including 1 100 V (*first revision*)
(Part 2) : 2002	For working voltages from 3.3 kV up to and including 33 kV (*first revision*)
10810	Methods of test for cables
(Part 0) : 1984	General
(Part 1) : 1984	Annealing test for wires used in conductors
(Part 2) : 1984	Tensile test for aluminium wires
(Part 3) : 1984	Wrapping test for aluminium wires
(Part 4) : 1984	Persulphate test of conductor
(Part 5) : 1984	Conductor resistance test
(Part 6) : 1984	Thickness of thermoplastic and elastomeric insulation and sheath
(Part 7) : 1984	Tensile strength and elongation at break of thermoplastic and elastomeric insulation and sheath
(Part 8) : 1984	Breaking strength and elongation at break for impregnated paper insulation
(Part 9) : 1984	Tear resistance for paper insulation
(Part 10) : 1984	Loss of mass test
(Part 11) : 1984	Thermal ageing in air
(Part 12) : 1984	Shrinkage test
(Part 13) : 1984	Ozone resistance test
(Part 14) : 1984	Heat shock test
(Part 15) : 1984	Hot deformation test
(Part 16) : 1986	Accelerated ageing test by oxygen pressure method
(Part 17) : 1986	Tear resistance test for heavy duty sheath
(Part 18) : 1984	Colour fastness to day light
(Part 19) : 1984	Bleeding and blooming test
(Part 20) : 1984	Cold bend test
(Part 21) : 1984	Cold impact test
(Part 22) : 1984	Vicat softening point
(Part 23) : 1984	Melt-flow index
(Part 24) : 1984	Water soluble impurities test of insulating paper
(Part 25) : 1984	Conductivity of water extract test of insulating paper
(Part 26) : 1984	*p*H value of water extract test of insulating paper
(Part 27) : 1984	Ash content test of insulating paper
(Part 28) : 1984	Water absorption test (Electrical)
(Part 29) : 1984	Environmental stress cracking test
(Part 30) : 1984	Hot set test
(Part 31) : 1984	Oil resistance test
(Part 32) : 1984	Carbon content test for polyethylene
(Part 33) : 1984	Water absorption test (Gravimetric)
(Part 34) : 1984	Measurement of thickness of metallic sheath
(Part 35) : 1984	Determination of tin in lead alloy for sheathing
(Part 36) : 1984	Dimensions of armouring material
(Part 37) : 1984	Tensile strength and elongation at break of armouring materials
(Part 38) : 1984	Torsion test on galvanized steel wires for armouring
(Part 39) : 1984	Winding test on galvanized steel strips for armouring
(Part 40) : 1984	Uniformity of zinc coating on steel armour
(Part 41) : 1984	Mass of zinc coating on steel armour
(Part 42) : 1984	Resistivity test of armour wires and strips and conductance test of armour (wires/strips)
(Part 43) : 1984	Insulation resistance
(Part 44) : 1984	Spark test
(Part 45) : 1984	High voltage test
(Part 46) : 1984	Partial discharge test
(Part 47) : 1984	Impulse test
(Part 48) : 1984	Dielectric power factor test
(Part 49) : 1984	Heating cycle test
(Part 50) : 1984	Bending test
(Part 51) : 1984	Dripping test
(Part 52) : 1984	Drainage test
(Part 53) : 1984	Flammability test
(Part 54) : 1984	Static flexibility test
(Part 55) : 1986	Abrasion test
(Part 56) : 1987	Accelerated ageing by the air-pressure method

(Part 57) : 1987	Flexing test
(Part 58) : 1998	Oxygen index test
(Part 59) : 1988	Determination of the amount of halogen acid gas evolved during combustion of polymeric materials taken from cables
(Part 60) : 1988	Thermal stability of PVC insulation and sheath
(Part 61) : 1988	Flame retardant test
(Part 62) : 1993	Fire resistance test for bunched cables
(Part 63) : 1993	Smoke density of electric cables under fire conditions
(Part 64) : 2003	Measurement of temperature index
12943 : 1990	Brass glands for PVC cables

10. DOORS, WINDOWS AND VENTILATORS

a) Wooden Doors, Windows and Ventilators

1003	Specification for timber panelled and glazed shutters:
(Part 1) : 2003	Door shutters (*fourth revision*)
(Part 2) : 1994	Window and ventilator shutters (*third revision*)
1826 : 1961	Specification for venetian blinds for windows
2191	Specification for wooden flush door shutters (cellular and hollow core type):
(Part 1) : 1983	Plywood face panels (*fourth revision*)
(Part 2) : 1983	Particle board face panels and hardboard face panels (*third revision*)
2202	Specification for wooden flush door shutters (solid core type):
(Part 1) : 1991	Plywood face panels (*fifth revision*)
(Part 2) : 1983	Particle board face panels and hardboard face panels (*third revision*)
4020	Method of tests for door shutters:
(Part 1) : 1998	General (*third revision*)
(Part 2) : 1998	Measurement of dimensions and squareness (*third revision*)
(Part 3) : 1998	Measurement of general flatness (*third revision*)
(Part 4) : 1998	Local planeness test (*third revision*)
(Part 5) : 1998	Impact indentation test (*third revision*)
(Part 6) : 1998	Flexure test (*third revision*)
(Part 7) : 1998	Edge loading test (*third revision*)
(Part 8) : 1998	Shock resistance test (*third revision*)
(Part 9) : 1998	Buckling resistance test (*third revision*)
(Part 10) : 1998	Slamming test (*third revision*)
(Part 11) : 1998	Misuse test (*third revision*)
(Part 12) : 1998	Varying humidity test (*third revision*)
(Part 13) : 1998	End immersion test (*third revision*)
(Part 14) : 1998	Knife test (*third revision*)
(Part 15) : 1998	Glue adhesion test (*third revision*)
(Part 16) : 1998	Screw withdrawal resistance test (*third revision*)
4021 : 1995	Specification for timber door, window and ventilator frames
4962 : 1968	Specification for wooden side sliding doors
6198 : 1992	Specification for ledged, braced and battened timber shutters (*second revision*)

b) Metal Doors, Windows Frames and Ventilators

1038 : 1983	Specification for steel doors, windows and ventilators (*third revision*)
1361 : 1978	Specification for steel windows for industrial buildings (*first revision*)
1948 : 1961	Specification for aluminium doors, windows and ventilators
1949 : 1961	Specification for aluminium windows for industrial buildings
4351 : 2003	Specification for steel door frames (*second revision*)
6248 : 1979	Specification for metal rolling shutters and rolling grills (*first revision*)
7452 : 1990	Specification for hot rolled steel sections for doors, windows and ventilators (*second revision*)
10451 : 1983	Specification for steel sliding shutters (top hung type)
10521 : 1983	Specification for collapsible gates

c) Plastic Doors and Windows

14856 : 2000	Specification for glass fibre reinforced (GRP) panel type door shutters for internal use

IS No.	*Title*
15380 : 2003	Specification for moulded raised high density fibre (HDF) panel doors

11. ELECTRICAL WIRING FITTINGS AND ACCESSORIES

371 : 1999	Specification for ceiling roses (*third revision*)
374 : 1979	Specification for electric ceiling type fans and regulators (*third revision*)
418 : 1978	Specification for tungsten filament general service electric lamps (*third revision*)
1258 : 1987	Specification for bayonet lamp holders (*third revision*)
1293 : 1988	Specification for plugs and socket-outlets rated voltage up to and including 250 V and rated current up to and including 16 amperes (*second revision*)
1534	Specification for ballasts for
(Part 1) : 1977	fluorescent lamps: Part 1 For switch start circuits (*second revision*)
1554	PVC insulated (heavy duty) electric cables:
(Part 1) : 1988	For working voltages upto and including 1 100 V (*third revision*)
(Part 2) : 1988	For working voltages from 3.3 kV upto and including 11 kV (*second revision*)
1777 : 1978	Specification for industrial luminaire with metal reflectors (*first revision*)
2086 : 1993	Specification for carriers and bases used in re-wirable type electric fuses up to 650 V (*third revision*)
2148 : 2004	Specification for flameproof enclosures "d" for electrical apparatus for explosive gas atmospheres (*third revision*)
2206	Specification for flameproof electric lighting fittings:
(Part 1) : 1984	Well glass and bulkhead types (*first revision*)
(Part 2) : 1976	Fittings using glass tubes
(Part 3) : 1989	Fittings using fluorescent lamps and plastic covers
(Part 4) : 1987	Portable flame-proof handlamps and approved flexible cables
2215 : 1983	Specification for starters for fluorescent lamps (*third revision*)
2412 : 1975	Specification for link clips for electrical wiring (*first revision*)
2418	Specification for tubular fluorescent lamps for general lighting services:
(Part 1) : 1977	Requirements and tests (*first revision*)
(Part 2) : 1977	Standard lamp data sheets (*first revision*)
(Part 3) : 1977	Dimensions of G-5 and G-13 bi-pin caps (*first revision*)
(Part 4) : 1977	Go and no-go gauges for G-5 and G-13 bi-pin caps (*first revision*)
2667 : 1988	Specification for fittings for rigid steel conduits for electrical wiring (*second revision*)
2675 : 1983	Specification for enclosed distribution fuseboards and cutouts for voltages not exceeding 1 000 V (*second revision*)
3287 : 1965	Specification for industrial lighting fittings with plastic reflectors
3323 : 1980	Specification for bi-pin lamp holders for tubular fluorescent lamps (*first revision*)
3324 : 1982	Specification for holders for starters for tubular fluorescent lamps (*first revision*)
3419 : 1989	Specification for fittings for rigid non-metallic conduits (*second revision*)
3480 : 1966	Specification for flexible steel conduits for electrical wiring
3528 : 1966	Specification for waterproof electric lighting fittings
3553 : 1966	Specification for watertight electric lighting fittings
3837 : 1976	Specification for accessories for rigid steel conduits for electrical wiring (*first revision*)
3854 : 1997	Specification for switches for domestic and similar purposes (*second revision*)
4012 : 1967	Specification for dust-proof electric lighting fittings
4013 : 1967	Specification for dust-tight electric lighting fittings

IS No.	*Title*
4160 : 1967	Specification for interlocking switch socket outlet
4615 : 1968	Specification for switch socket outlets (non-interlocking type)
4649 : 1968	Specification for adaptors for flexible steel conduits
5077 : 1969	Specification for decorative lighting outfits
6538 : 1971	Specification for three-pin plugs made of resilient material
8030 : 1976	Specification for luminaires for hospitals
8828 : 1996	Specification for circuit-breakers for over current protection for household and similar installation (*second revision*)
9537	Specification for conduits for electrical installations:
(Part 1) : 1980	General requirements
(Part 2) : 1981	Rigid steel conduits
(Part 3) : 1983	Rigid plain conduits for insulating materials
(Part 4) : 1983	Pliable self-recovering conduits for insulating materials
(Part 5) : 2000	Pliable conduits of insulating materials
(Part 6) : 2000	Pliable conduits of metal or composite materials
(Part 8) : 2003	Rigid non-threadable conduits of aluminium alloy
9926 : 1981	Specification for fuse wires used in rewirable type electric fuses up to 650 V
10322	Specification for luminaires:
(Part 1) : 1982	General requirements
(Part 2) : 1982	Constructional requirements
(Part 3) : 1984	Screw and screwless terminations
(Part 4) : 1984	Methods of tests
(Part 5/Sec 1) : 1985	Particular requirements, Section 1 General purpose luminaires
(Part 5/Sec 2) : 1985	Particular requirements, Section 2 Recessed luminaires
(Part 5/Sec 3) : 1987	Particular requirements, Section 3 Luminaires for road and street lighting
(Part 5/Sec 4) : 1987	Particular requirements, Section 4 Portable general purpose luminaires
(Part 5/Sec 5) : 1987	Particular requirements, Section 5 Flood light
11037 : 1984	Electronic type fan regulators
13010 : 2002	AC watt-hour meters, Class 0.5, 1 and 2 (*first revision*)
13779 : 1999	AC static watthour meters (Class 1 and 2) (*first revision*)
13947 (Part 3) : 1993	Specification for low-voltage switchgear and controlgear: Part 3 Switches, disconnectors, switch disconnectors and fuse combination units
14763 : 2000	Conduit for electrical purposes, outside diameters of conduits for electrical installations and threads for conduits and fittings
14768	Conduit fittings for electrical installations:
(Part 1) : 2000	General requirements
(Part 2) : 2003	Metal conduit fittings
14772 : 2000	Enclosures for accessories for household and similar fixed electrical installations
14927	Cable trunking and ducting systems for electrical installations
(Part 1) : 2001	General requirements
(Part 2) : 2001	Cable trunking and ducting systems intended for mounting on walls or ceilings
14930	Conduit systems for electrical installations:
(Part 1) : 2001	General requirements
(Part 2) : 2001	Particular requirements for conduit system buried underground
15368 : 2003	Cable reels for household and similar purposes

12. FILLERS, STOPPERS AND PUTTIES

110 : 1983	Specification for ready mixed paint, brushing, grey filler, for enamels, for use over primers (*first revision*)
419 : 1967	Specification for putty for use on window frames (*first revision*)
423 : 1961	Specification for plastic wood, for joiner's filler (*revised*)
3709 : 1966	Specification for mastic cement for bedding of metal windows
7164 : 1973	Specification for stopper

IS No.	Title
13184 : 1991	Specification for mastic filler, epoxy based

13. FLOOR COVERING, ROOFING AND OTHER FINISHES

a) Concrete Flooring

1237 : 1980	Specification for cement concrete flooring tiles (*first revision*)
13801 : 1993	Specification for chequered cement concrete tiles

b) Flooring Compositions

657 : 1982	Specification for materials for use in the manufacture of magnesium oxychloride flooring compositions (*second revision*)
9162 : 1979	Methods of tests for epoxy resin, hardeners and epoxy resin composition for floor topping
9197 : 1979	Specification for epoxy resin, hardness and epoxy resin compositions for floor topping
10132 : 1982	Method of test for materials for use in the preparation of magnesium oxychloride flooring composition

c) Linoleum Flooring

653 : 1992	Specification for linoleum sheets and tiles (*third revision*)
9704 : 1980	Methods of tests for linoleum sheets and tiles

d) Rubber Flooring

809 : 1992	Specification for rubber flooring materials for general purposes (*second revision*)

e) Bituminous Flooring

1195 : 2002	Specification for bitumen mastic for flooring (*third revision*)
8374 : 1977	Specification for bitumen mastic, anti-static and electrically conducting grade
9510 : 1980	Specification for bitumen mastic acid resisting grade
13026 : 1991	Specification for bitumen mastic for flooring for industries handling LPG and other light hydrocarbon products
15194 : 2002	Specification for pitch-mastic flooring for industries handling heavy hydrocarbon products like kerosene, diesel and furnace oil

f) Plastic Flooring

3461 : 1980	Specification for PVC asbestos floor tiles (*first revision*)
3462 : 1986	Specification for unbacked flexible PVC flooring (*second revision*)
3464 : 1986	Methods of test for plastic flooring and wall tiles (*second revision*)

g) Ceramic/Vitreous

2333 : 1992	Specification for plaster of Paris for ceramic industry (*second revision*)
4457 : 1982	Specification for ceramic unglazed vitreous acid resisting tile (*first revision*)
13630	Method of test for ceramic tiles:
(Part 1) : 1993	Determination of dimensions and surface quality
(Part 2) : 1992	Determination of water absorption
(Part 3) : 1992	Determination of moisture expansion using boiling water — Unglazed tiles
(Part 4) : 1992	Determination of linear thermal expansion
(Part 5) : 1992	Determination of resistance to thermal shock
(Part 6) : 1993	Determination of modulus of rupture
(Part 7) : 1993	Determination of chemical resistance — Unglazed tiles
(Part 8) : 1993	Determination of chemical resistance — Glazed tiles
(Part 9) : 1993	Determination of crazing resistance — Glazed tiles
(Part 10) : 1993	Determination of frost resistance
(Part 11) : 1993	Determination of resistance to surface abrasion — Glazed tiles
(Part 12) : 1993	Determination of resistance to deep abrasion — Unglazed tiles
(Part 13) : 1993	Determination of scratch hardness of surface according to Mohs'
13711 : 1993	Sampling and basis for acceptance of ceramic tiles
13753 : 1993	Specification for dust pressed ceramic tiles with water absorption of E > 10% Group (B III)
13754 : 1993	Specification for dust pressed ceramic tiles with water absorption of 6% < E < 10% Group (B II b)

IS No.	*Title*
13755 : 1993	Specification for dust pressed ceramic tiles with water absorption of 3% < E < 6% Group (B II a)
13756 : 1993	Specification for dust pressed ceramic tiles with water absorption of E < 3% Group B I

h) Other Floorings

4456	Methods of test for chemical resistant mortars:
(Part 1) : 1967	Silicate type and resin type
(Part 2) : 1967	Sulphur type
4457 : 1982	Specification for ceramic unglazed vitreous acid resisting tile (*first revision*)
4832	Specification for chemical resistant mortars:
(Part 1) : 1969	Silicate type
(Part 2) : 1969	Resin type
(Part 3) : 1968	Sulphur type
4860 : 1968	Specification for acid resistant bricks

j) Roofing

277 : 1992	Specification for galvanized steel sheets (plain and corrugated (*fifth revision*)
459 : 1992	Specification for corrugated and semi-corrugated asbestos cement sheets (*third revision*)
654 : 1992	Specification for clay roofing tiles, Mangalore pattern (*third revision*)
1464 : 1992	Specification for clay ridge and ceiling tiles (*second revision*)
2690	Specification for burnt clay flat terracing tiles:
(Part 1) : 1993	Machine made (*second revision*)
(Part 2) : 1992	Hand-made (*second revision*)
3951	Specification for hollow clay tiles for floor and roofs:
(Part 1) : 1975	Filler type (*first revision*)
(Part 2) : 1975	Structural type (*first revision*)
10388 : 1982	Specification for corrugated coir wood wool cement roofing sheets
12583 : 1988	Specification for corrugated bitumen roofing sheets
12866 : 1989	Specification for plastic translucent sheets made from thermosetting polyester resin (glass fibre reinforced)
13317 : 1992	Specification for clay roofing camty tiles, half round and flat tiles

k) Wall Coverings/Finishing

1542 : 1992	Specification for sand for plaster (*second revision*)
4456	Methods of test for chemical resistant mortars:
(Part 1) : 1967	Silicate type and resin type
(Part 2) : 1967	Sulphur type
4832	Specification for chemical resistant mortars:
(Part 1) : 1969	Silicate type
(Part 2) : 1969	Resin type
(Part 3) : 1968	Sulphur type
15418 : 2003	Specification for finished wall papers, wall vinyls and plastic wall coverings in roll form

14. GLASS

2553 (Part 1) : 1990	Specification for safety glass: Part 1 General purpose (*third revision*)
2835 : 1987	Specification for flat transparent sheet glass (*third revision*)
3438 : 1994	Specification for silvered glass mirrors for general purposes (*second revision*)
5437 : 1994	Specification for figured rolled and wired glass (*first revision*)
14900 : 2000	Specification for transparent float glass

15. GYPSUM BASED MATERIALS

2095	Specification for gypsum plaster boards:
(Part 1) : 1996	Plain gypsum plaster boards
(Part 2) : 2001	Coated/laminated gypsum plaster boards
(Part 3) : 1996	Reinforced gypsum plaster boards (*second revision*)
2542	Methods of test for gypsum plaster, concrete and products:
(Part 1/Sec 1) : 1978	Plaster and concrete, Section 1 Normal consistency of gypsum plaster (*first revision*)
(Part 1/Sec 2) : 1978	Plaster and concrete, Section 2 Normal consistency of gypsum concrete (*first revision*)

IS No.	Title
(Part 1/Sec 3) : 1978	Plaster and concrete, Section 3 Setting time of plaster and concrete (*first revision*)
(Part 1/Sec 4) : 1978	Plaster and concrete, Section 4 Transverse strength of gypsum plaster (*first revision*)
(Part 1/Sec 5) : 1978	Plaster and concrete, Section 5 Compressive strength and dry set density of gypsum plaster (*first revision*)
(Part 1/Sec 6) : 1978	Plaster and concrete, Section 6 Soundness of gypsum plaster (*first revision*)
(Part 1/Sec 7) : 1978	Plaster and concrete, Section 7 Mechanical resistance of gypsum plaster by dropping ball test (*first revision*)
(Part 1/Sec 8) : 1978	Plaster and concrete, Section 8 Freedom from coarse particles (*first revision*)
(Part 1/Sec 9) : 1978	Plaster and concrete, Section 9 Expansion of plaster (*first revision*)
(Part 1/Sec 10) : 1978	Plaster and concrete, Section 10 Sand in set plaster (*first revision*)
(Part 1/Sec 11) : 1978	Plaster and concrete, Section 11 Wood fibre content in gypsum plaster (*first revision*)
(Part 1/Sec 12) : 1978	Plaster and concrete, Section 12 Dry bulk density (*first revision*)
(Part 2/Sec 1) : 1981	Gypsum products, Section 1 Measurement of dimensions (*first revision*)
(Part 2/Sec 2) : 1981	Gypsum products, Section 2 Determination of mass (*first revision*)
(Part 2/Sec 3) : 1981	Gypsum products, Section 3 Determination of mass and thickness of paper surfacing (*first revision*)
(Part 2/Sec 4) : 1981	Gypsum products, Section 4 Transverse strength (*first revision*)
(Part 2/Sec 5) : 1981	Gypsum products, Section 5 Compressive strength (*first revision*)
(Part 2/Sec 6) : 1981	Gypsum products, Section 6 Water absorption (*first revision*)
(Part 2/Sec 7) : 1981	Gypsum products: Section 7 Moisture content (*first revision*)
(Part 2/Sec 8) : 1981	Gypsum products, Section 8 Nail retention of precast reinforced gypsum slabs (*first revision*)
2547	Specification for gypsum building plaster:
(Part 1) : 1976	Excluding premixed lightweight plaster (*first revision*)
(Part 2) : 1976	Premixed lightweight plaster (*first revision*)
2849 : 1983	Specification for non-load bearing gypsum partition blocks (solid and hollow types)
8272 : 1984	Specification for gypsum plaster or use in the manufacture of fibrous plasterboards (*first revision*)
9498 : 1980	Specification for inorganic aggregates for use in gypsum plaster

16. LIGNOCELLULOSIC BUILDING MATERIALS

a) Timber and Bamboo

i) *Timber Classification*

399 : 1963	Classification of commercial timbers and their zonal distribution (*revised*)
1150 : 2000	Trade names and abbreviated symbols for timber species (*third revision*)
4970 : 1973	Key for identification of commercial timber (*first revision*)

ii) *Timber Conversion and Grading*

190 : 1991	Specification for coniferous sawn timber (baulks and scantlings) (*fourth revision*)
1326 : 1992	Specification for non-coniferous sawn timber (baulks and scantlings) (*second revision*)
1331 : 1971	Specification for cut sizes of timber (*second revision*)
3337 : 1978	Specification for ballies for general purposes (*first revision*)
5966 : 1993	Specification for non-coniferous timber in converted form for general purpose (*first revision*)
14960 : 2001	Specification for preservative treated and seasoned sawn timber from rubberwood (*Hevea brasiliensis*)

iii) *Timber Testing*

1708	Methods of testing small clear specimens of timber:
(Part 1) : 1986	Determination of moisture content (*second revision*)

IS No.	*Title*
(Part 2) : 1986	Determination of specific gravity (*second revision*)
(Part 3) : 1986	Determination of volumetric shrinkage (*second revision*)
(Part 4) : 1986	Determination of radial and tangential shrinkage and fibre saturation point (*second revision*)
(Part 5) : 1986	Determination of static bending strength (*second revision*)
(Part 6) : 1986	Determination of static bending strength under two point loading (*second revision*)
(Part 7) : 1986	Determination of impact bending strength (*second revision*)
(Part 8) : 1986	Determination of compressive strength parallel to grain (*second revision*)
(Part 9) : 1986	Determination of compressive strength perpendicular to grain (*second revision*)
(Part 10) : 1986	Determination of hardness under static indentation (*second revision*)
(Part 11) : 1986	Determination of shear strength parallel to grain (*second revision*)
(Part 12) : 1986	Determination of tensile strength parallel to grain (*second revision*)
(Part 13) : 1986	Determination of tensile strength perpendicular to grain (*second revision*)
(Part 14) : 1986	Determination of cleavage strength parallel to grain (*second revision*)
(Part 15) : 1986	Determination of nail and screw holding power (*second revision*)
(Part 16) : 1986	Determination of brittleness by izod impact (*second revision*)
(Part 17) : 1986	Determination of brittleness by Charpy impact (*second revision*)
(Part 18) : 1986	Determination of torsional strength (*second revision*)
1900 : 1974	Method of testing wood poles (*first revision*)
2408 : 1963	Methods of static tests of timbers in structural sizes
2455 : 1990	Method of sampling of model trees and logs for timber testing and their conversion (*second revision*)
2753	Methods for estimation of preservatives in treated timber and treating solutions:
(Part 1) : 1991	Determination of copper, arsenic, chromium, zinc, boron, creosote and fuel oil (*first revision*)
(Part 2) : 1991	Determination of copper (in copper organic preservative salt) and pentachlorophenol (*first revision*)
4907 : 1968	Method of testing timber connectors
8292 : 1992	Methods for evaluation of working quality of timber under different wood operations — Method of test (*first revision*)
8720 : 1978	Methods of sampling of timber scantlings from depots and their conversion for testing
8745 : 1994	Methods of presentation of data of physical and mechanical properties of timber (*first revision*)
10420 : 1982	Method of determination of sound absorption coefficient of timber by standing wave method
10754 : 1983	Method of determination of thermal conductivity of timber
11215 : 1991	Methods for determination of moisture content of timber and timber products (*first revision*)
13621 : 1993	Method of test for determination of dielectric constant of wood under microwave frequencies
iv) *Structural Timber and Test*	
3629 : 1986	Specification for structural timber in building (*first revision*)
4891 : 1988	Specification for preferred cut sizes of structural timber (*first revision*)
4924	Method of test for nail jointed timber trusses:
(Part 1) : 1968	Destructive test
(Part 2) : 1968	Proof test
v) *Logs*	
3364	Method of measurement and evaluation of defects in timber:
(Part 1) : 1976	Logs (*first revision*)
(Part 2) : 1976	Converted timber (*first revision*)
4895 : 1985	Specification for teak logs (*first revision*)
5246 : 2000	Specification for coniferous logs (*first revision*)
7308 : 1999	Specification for non-coniferous logs (*first revision*)

vi) *Bamboo*

6874 : 1973	Method of tests for round bamboos
8242 : 1976	Methods of tests for split bamboos

b) Reconstituted Products

i) *Plywood*

303 : 1989	Specification for plywood for general purposes (*third revision*)
1328 : 1996	Specification for veneered decorative plywood (*third revision*)
1734	Method of test for plywood:
(Part 1) : 1983	Determination of density and moisture content (*second revision*)
(Part 2) : 1983	Determination of resistance of dry heat (*second revision*)
(Part 3) : 1983	Determination of fire resistance (*second revision*)
(Part 4) : 1983	Determination of glue shear strength (*second revision*)
(Part 5) : 1983	Test for adhesion of plies (*second revision*)
(Part 6) : 1983	Determination of water resistance (*second revision*)
(Part 7) : 1983	Mycological test (*second revision*)
(Part 8) : 1983	Determination of *p*H value (*second revision*)
(Part 9) : 1983	Determination of tensile strength (*second revision*)
(Part 10 : 1983	Determination of compressive strength (*second revision*)
(Part 11) : 1983	Determination of static bending strength (*second revision*)
(Part 12) : 1983	Determination of scarf joint strength (*second revision*)
(Part 13) : 1983	Determination of panel shear strength (*second revision*)
(Part 14) : 1983	Determination of plate shear strength (*second revision*)
(Part 15) : 1983	Central loading of plate test (*second revision*)
(Part 16) : 1983	Vibration of plywood plate test (*second revision*)
(Part 17) : 1983	Long time loading test of plywood strips (*second revision*)
(Part 18) : 1983	Impact resistance test on the surface of plywood (*second revision*)
(Part 19) : 1983	Determination of nails and screws holding power (*second revision*)
(Part 20) : 1983	Acidity and alkalinity resistance test (*second revision*)
4990 : 1993	Specification for plywood for concrete shuttering work (*second revision*)
5509 : 2000	Specification for fire retardant plywood (*second revision*)
5539 : 1969	Specification for preservative treated plywood
7316 : 1974	Specification for decorative plywood using plurality of veneers for decorative faces
10701 : 1983	Specification for structural plywood
13957 : 1994	Specification for metal faced plywood

ii) *Blockboards, Particle Boards and Fibre Boards*

1658 : 1977	Specification for fibre hardboards (*second revision*)
1659 : 1990	Specification for block boards (*third revision*)
2380	Methods of test for wood particle boards and boards from other lignocellulosic materials:
(Part 1) : 1977	Preparation and conditioning of test specimens (*first revision*)
(Part 2) : 1977	Accuracy of dimensions of boards (*first revision*)
(Part 3) : 1977	Determination of moisture content and density (*first revision*)
(Part 4) : 1977	Determination of static bending strength (*first revision*)
(Part 5) : 1977	Determination of tensile strength perpendicular to surface (*first revision*)
(Part 6) : 1977	Determination of tensile strength parallel to surface (*first revision*)
(Part 7) : 1977	Determination of compression — Perpendicular to plane of the board (*first revision*)
(Part 8) : 1977	Compression parallel to surface test (*first revision*)
(Part 9) : 1977	Determination of resistance to shear in plane of the board (*first revision*)
(Part 10) : 1977	Falling hammer impact test (*first revision*)
(Part 11) : 1977	Surface hardness (*first revision*)
(Part 12) : 1977	Central loading of plate test (*first revision*)

IS No.	Title
(Part 13) : 1977	Long time loading bending test (*first revision*)
(Part 14) : 1977	Screw and nail withdrawal test (*first revision*)
(Part 15) : 1977	Lateral nail resistance (*first revision*)
(Part 16) : 1977	Determination of water absorption (*first revision*)
(Part 17) : 1977	Determination of swelling in water (*first revision*)
(Part 18) : 1977	Determination of mass and dimensional changes caused by moisture changes (*first revision*)
(Part 19) : 1977	Durability cyclic test for interior use (*first revision*)
(Part 20) : 1977	Accelerated weathering cyclic test for exterior use (*first revision*)
(Part 21) : 1977	Planeness test under uniform moisture content (*first revision*)
(Part 22) : 1981	Determination of surface glueability test
(Part 23) : 1981	Vibration test for particle boards
3087 : 1985	Specification for wood particle boards (medium density) for general purposes (*first revision*)
3097 : 1980	Specification for veneered particle boards (*first revision*)
3129 : 1985	Specification for low density particle board (*first revision*)
3308 : 1981	Specification for wood wool building slabs (*first revision*)
3348 : 1965	Specification for fibre insulation boards
3478 : 1966	Specification for high density wood particle boards
12406 : 2003	Specification for medium density fibreboards for general purposes (*first revision*)
12823 : 1990	Specification for prelaminated particle boards
13745 : 1993	Method for determination of formaldehyde content in particle board by extraction method called perforator method
14276 : 1995	Specification for cement bonded particle boards
14587 : 1998	Specification for prelaminated medium density fibre board

IS No.	Title
iii) *Wood-Based Laminates*	
3513 (Part 3) : 1989	Specification for resin treated compressed wood laminates (compregs): Part 3 For general purposes (*first revision*)
3513 (Part 4) : 1966	Specification for high and medium density wood laminates (compreg): Part 4 Sampling and tests
7638 : 1998	Methods of sampling for wood/ lignocellulosic based panel products
9307	Methods of tests for wood-based structural sandwich construction:
(Part 1) : 1979	Flexure test
(Part 2) : 1979	Edgewise compression test
(Part 3) : 1979	Flatwise compression test
(Part 4) : 1979	Shear test
(Part 5) : 1979	Flatwise tension test
(Part 6) : 1979	Flexure creep test
(Part 7) : 1979	Cantilever vibration test
(Part 8) : 1979	Weathering test
14315 : 1995	Specification for commercial veneers
14616 : 1999	Specification for laminated veneer lumber
iv) *Bamboo and Coir Board Products*	
13958 : 1994	Specification for bamboo mat board for general purposes
14588 : 1999	Specification for bamboo mat veneer composite for general purposes
14842 : 2000	Specification for coir veneer board for general purposes
15476 : 2004	Specification for bamboo and corrugated sheets
v) *Adhesives*	
848 : 1974	Specification for synthetic resin adhesives for plywood (phenolic and aminoplastic) (*first revision*)
849 : 1994	Specification for cold setting case in glue for wood (*first revision*)
851 : 1978	Specification for synthetic resin adhesives for construction work (non-structural) in wood (*first revision*)
852 : 1994	Specification for animal glue for general wood-working purposes (*second revision*)

IS No.	Title
1508 : 1972	Specification for extenders for use in synthetic resin adhesives (urea-formaldehyde) for plywood (*first revision*)
4835 : 1979	Specification for polyvinyl acetate dispersion-based adhesives for wood (*first revision*)
9188 : 1979	Performance requirements for adhesive for structural laminated wood products for use under exterior exposure condition

17. PAINTS AND ALLIED PRODUCTS

a) Water Based Paints and Pigments

427 : 1965	Specification for distemper, dry, colour as required (*revised*)
428 : 2000	Specification for distemper, washable (*second revision*)
5410 : 1992	Specification for cement paint, colour as required (*first revision*)
5411	Specification for plastic emulsion paint:
(Part 1) : 1974	For interior use (*first revision*)
(Part 2) : 1972	For exterior use

b) Ready Mixed Paints, Enamels and Powder Coatings

101	Methods of sampling and test for paints, varnishes and related products:
(Part 1/Sec 1) : 1986	Test on liquid paints (general and physical), Section 1 Sampling (*third revision*)
(Part 1/Sec 2) : 1987	Test on liquid paints (general and physical), Section 2 Preliminary examination and preparation of samples for testing (*third revision*)
(Part 1/Sec 3) : 1986	Test on liquid paints (general and physical), Section 3 Preparation of panels (*third revision*)
(Part 1/Sec 4) : 1987	Test on liquid paints (general and physical), Section 4 Brushing test (*third revision*)
(Part 1/Sec 5) : 1989	Test on liquid paints (general and physical), Section 5 Consistency (*third revision*)
(Part 1/Sec 6) : 1987	Test on liquid paints (general and physical), Section 6 Flash point (*third revision*)
(Part 1/Sec 7) : 1987	Test on liquid paints (general and physical), Section 7 Mass per 10 litres (*third revision*)
(Part 2/Sec 1) : 1988	Test on liquid paints (chemical examination), Section 1 Water content (*third revision*)
(Part 2/Sec 2) : 1986	Test on liquid paints (chemical examination), Section 2 Volatile matter (*third revision*)
(Part 3/Sec 1) : 1986	Tests on paint film formation, Section 1 Drying time (*third revision*)
(Part 3/Sec 2) : 1989	Tests on paint film formation, Section 2 Film thickness (*third revision*)
(Part 3/Sec 4) : 1987	Tests on paint film formation, Section 4 Finish (*third revision*)
(Part 3/Sec 5) : 1987	Tests on paint film formation, Section 5 Fineness of grind (*third revision*)
(Part 4/Sec 1) : 1988	Optical test, Section 1 Opacity (*third revision*)
(Part 4/Sec 2) : 1989	Optical test, Section 2 Colour (*third revision*)
(Part 4/Sec 3) : 1988	Optical test, Section 3 Light fastness test (*third revision*)
(Part 4/Sec 4) : 1986	Optical test, Section 4 Gloss (*third revision*)
(Part 5/Sec 1) : 1988	Mechanical test on paint films, Section 1 Hardness tests (*third revision*)
(Part 5/Sec 2) : 1988	Mechanical test on paint films, Section 2 Flexibility and adhesion (*third revision*)
(Part 5/Sec 3) : 1986	Mechanical test on paint films, Section 3 Impact resistance (*fourth revision*)
(Part 5/Sec 4) : 1986	Mechanical test on paint films, Section 4 Print free test (*third revision*)
(Part 6/Sec 1) : 1988	Durability tests, Section 1 Resistance to humidity under conditions of condensation (*third revision*)
(Part 6/Sec 2) : 1989	Durability tests, Section 2 Keeping properties (*third revision*)
(Part 6/Sec 3) : 1990	Durability tests, Section 3 Moisture vapour permeability (*third revision*)

IS No.	*Title*
(Part 6/Sec 4) : 1991	Durability tests, Section 4 Degradation of coatings (pictorial aids for evaluation)
(Part 6/Sec 5) : 1997	Durability tests, Section 5 Accelerated weathering test (*third revision*)
(Part 7/Sec 1) : 1989	Environmental tests on paint films, Section 1 Resistance to water (*third revision*)
(Part 7/Sec 2) : 1990	Environmental tests on paint films, Section 2 Resistance to liquids (*third revision*)
(Part 7/Sec 3) : 1990	Environmental tests on paint films, Section 3 Resistance to heat (*third revision*)
(Part 7/Sec 4) : 1990	Environmental tests on paint films, Section 4 Resistance to bleeding of pigments (*third revision*)
(Part 8/Sec 1) : 1989	Tests for pigments and other solids, Section 1 Residue on sieve (*third revision*)
(Part 8/Sec 2) : 1990	Tests for pigments and other solids, Section 2 Pigments and non-volatile matter (*third revision*)
(Part 8/Sec 3) : 1993	Tests for pigments and other solids, Section 3 Ash content
(Part 8/Sec 4) : 1993	Tests for pigments and other solids, Section 4 Phthalic anhydride
(Part 8/Sec 5) : 1993	Tests for pigments and other solids, Section 5 Lead restriction test (*third revision*)
(Part 8/Sec 6) : 1993	Tests for pigments and other solids, Section 6 Volume solids
(Part 9/Sec 1) : 1993	Tests for lacquers and varnish, Section 1 Acid value
(Part 9/Sec 2) : 1993	Tests for lacquers and varnish, Section 2 Rosin test
104 : 1979	Specification for ready mixed paint, brushing, zinc chrome, priming (*second revision*)
109 : 1968	Specification for ready mixed paint, brushing, priming, plaster to Indian Standard colours No. 361 and 631 (*first revision*)
123 : 1962	Specification for ready mixed paint, brushing, finishing, semi-gloss, for general purposes, to Indian Standard colours No. 445, 446, 448, 449, 451 and 473; and red oxide (colour unspecified) (*revised*)
133 : 1993	Specification for enamel, interior (a) undercoating, (b) finishing (*third revision*)
137 : 1965	Specification for ready mixed paint, brushing, matt or egg-shell flat, finishing, interior, to Indian Standard colour, as required (*revised*)
158 : 1981	Specification for ready mixed paint, brushing, bituminous, black, lead-free, acid, alkali, and heat resisting (*third revision*)
168 : 1993	Specification for ready mixed paint, air-drying semi-glossy/matt, for general purposes (*third revision*)
341 : 1973	Specification for black Japan, Types A, B and C (*first revision*)
2074 : 1992	Specification for ready mixed paint, air drying red oxide-zinc chrome, priming (*second revision*)
2075 : 2000	Specification for ready mixed paint, stoving, red oxide-zinc chrome, priming (*second revision*)
2339 : 1963	Specification for aluminium paint for general purposes, in dual container
2932 : 2003	Specification for enamel, synthetic, exterior, (a) undercoating, (b) finishing (*third revision*)
2933 : 1975	Specification for enamel, exterior, (a) undercoating, (b) finishing (*first revision*)
3536 : 1999	Specification for ready mixed paint, brushing, wood primer (*first revision*)
3537 : 1966	Specification for ready mixed paint, finishing, interior for general purposes, to Indian Standard colours No. 101, 216, 217, 219, 275, 281, 352, 353, 358 to 361, 363, 364, 388, 410, 442, 444, 628, 631, 632, 634, 693, 697, white and black
3539 : 1966	Specification for ready mixed paint, undercoating, for use under oil finishes, to Indian Standard colours, as required
3585 : 1966	Specification for ready mixed paint, aluminium, brushing, priming, water resistant, for wood work

IS No.	Title
3678 : 1966	Specification for ready mixed paint, thick white, for lettering
8662 : 1993	Specification for enamel, synthetic, exterior, (a) undercoating, (b) finishing, for railway coaches (*first revision*)
9862 : 1981	Specification for ready mixed paint, brushing, bituminous black lead free, acid, alkali, water and chlorine resisting
11883 : 1986	Specification for ready mixed paint, brushing, red oxide, priming for metals
13183 : 1991	Specification for aluminium paints, heat resistant
13213 : 1991	Specification for polyurethane full gloss enamel (two pack)
13607 : 1992	Specification for ready mixed paint, finishing, general purposes, synthetic
13871 : 1993	Specification for powder coatings

c) Thinners and Solvents

82 : 1992	Methods of sampling and test for thinners and solvents for paints (*first revision*)
324 : 1959	Specification for ordinary denatured spirit (*revised*)
533 : 1998	Specification for gum spirit of turpentine (oil of turpentine) (*second revision*)
14314 : 1995	Specification for thinner general purposes for synthetic paints and varnishes

d) Varnishes and Lacquers

337 : 1975	Specification for varnish, finishing, interior (*first revision*)
347 : 1975	Specification for varnish, shellac, for general purposes (*first revision*)
348 : 1968	Specification for French polish (*first revision*)
524 : 1983	Specification for varnish, finishing, exterior, synthetic (*second revision*)
525 : 1968	Specification for varnish, finishing, exterior and general purposes (*first revision*)
642 : 1963	Specification for varnish medium for aluminium paint (*revised*)

IS No.	Title

18. POLYMERS, PLASTICS AND GEOSYNTHETICS/GEOTEXTILES

1998 : 1962	Methods of test for thermosetting synthetic resin bonded laminated sheets
2036 : 1995	Specification for phenolic laminated sheets (*second revision*)
2046 : 1995	Specification for decorative thermosetting synthetics resin bonded laminated sheets (*second revision*)
2076 : 1981	Specification for unsupported flexible vinyl film and sheeting (*first revision*)
2508 : 1984	Specification for low density polyethylene films (*second revision*)
6307 : 1971	Specification for rigid PVC sheets
9766 : 1992	Specification for flexible PVC compound (*first revision*)
10889 : 1984	Specification for high density polyethylene films
12830 : 1989	Specification for rubber based adhesives for fixing PVC tiles to cement
13162	Methods of test for geotextiles:
(Part 2) : 1991	Determination of resistance to exposure of ultra-violet light and water (Xenon arc type apparatus)
(Part 3) : 1992	Determination of thickness at specified pressure
(Part 4) : 1992	Determination of puncture resistance by falling cone method
(Part 5) : 1992	Determination of tensile properties using a wide width strip
13262 : 1992	Specification for pressure sensitive adhesive tapes with plastic base
13325 : 1992	Method of test for the determination to tensile properties of extruded polymer geogrids using the wide strip
13326 (Part 1) : 1992	Method of test for the evaluation of interface friction between geosynthetics and soil: Part 1 Modified direct shear technique
14182 : 1994	Specification for solvent cement for use with unplasticized polyvinylchloride plastic pipe and fittings

IS No.	*Title*
14293 : 1995	Method of test for trapezoid tearing — Geotextiles
14294 : 1995	Method of determination of apparent opening size by dry sieving technique — Geotextiles
14324 : 1995	Method of test for determination of water permeability-permittivity — Geotextiles
14443 : 1997	Specification for polycarbonate sheets
14643 : 1999	Specification for unsintered polytetrafluoroethylene (PTFE) tape for thread sealing applications
14706 : 1999	Sampling and preparation of test specimen of geotextiles
14714 : 1999	Determination of abrasion resistance of geotextiles
14715 : 2000	Specification for woven jute geotextiles
14716 : 1999	Determination of mass per unit area of geotextiles
14739 : 1999	Methods for determination of creep of geotextiles
14753 : 1999	Specification for poly (methyl) methacrylate (PMMA) (Acrylic) sheets
14986 : 2001	Jute geo-grid for rain water erosion control in road and railway embankments and hill slopes
15060 : 2001	Tensile test for joints/seams by wide width method of geotextiles

19. SANITARY APPLIANCES AND WATER FITTINGS

a) General

775 : 1970	Specification for cast iron brackets and supports for wash basins and sinks (*second revision*)
782 : 1978	Specification for caulking lead (*third revision*)
804 : 1967	Specification for rectangular pressed steel tanks (*first revision*)
1700 : 1973	Specification for drinking fountains (*first revision*)
2963 : 1979	Specification for copper alloy waste fittings for wash-basins and sinks (*first revision*)
3489 : 1985	Specification for enamelled steel bath tubs (*first revision*)
5219 (Part 1) : 1969	Specification for cast copper alloy traps: Part 1 'P' and 'S' traps
5455 : 1969	Specification for cast-iron steps for manholes
6411 : 1985	Specification for gel-coated glass fibre reinforced polyester resin bath tubs (*first revision*)
8718 : 1978	Specification for vitreous enamelled steel kitchen sinks
8727 : 1978	Specification for vitreous enamelled steel wash basins
9140 : 1996	Method of sampling of vitreous and fire clay sanitary appliances (*second revision*)
12701 : 1996	Specification for rotational moulded polyethylene water storage tanks (*first revision*)
13983 : 1994	Specification for stainless steel sinks for domestic purposes
14399	Hot press moulded thermosetting glass fibre reinforced (GRP) sectional water storage tanks:
(Part 1) : 1996	Specification for panels
(Part 2) : 1996	Guidelines for assembly, installation and testing

b) Pipes and Fittings Excluding Valves

i) *Brass and Copper Pipes and Fittings*

407 : 1981	Specification for brass tubes for general purposes (*third revision*)
2501 : 1995	Specification for solid drawn copper tubes for general engineering purposes (*third revision*)

ii) *Cast Iron Pipes and Fittings*

1536 : 2001	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*fourth revision*)
1537 : 1976	Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*)
1538 : 1993	Specification for cast iron fittings for pressure pipes for water, gas and sewage (*third revision*)
1729 : 2002	Specification for sand cast iron spigot and socket soil, waste and ventilating pipes, fittings and accessories (*second revision*)

IS No.	*Title*
1879 : 1987	Specification for malleable cast iron pipe fittings (*second revision*)
3486 : 1966	Specification for cast iron spigot and socket drain pipes
3989 : 1984	Specification for centrifugally cast (spun) iron spigot and socket soil, waste and ventilating pipes, fittings and accessories (*second revision*)
5531 : 1988	Specification for cast iron specials for asbestos cement pressure pipes for water, gas and sewage (*second revision*)
6163 : 1978	Specification for centrifugally cast (spun) iron low pressure pipes for water, gas and sewage (*first revision*)
6418 : 1971	Specification for cast iron and malleable cast iron flanges for general engineering purposes
7181 : 1986	Specification for horizontally cast iron double flanged pipes for water, gas and sewage (*first revision*)
8329 : 2000	Specification for centrifugally cast (spun) ductile iron pressure pipes for water, gas and sewage (*third revision*)
8794 : 1988	Specification for cast iron detachable joints for use with asbestos cement pressure pipes (*first revision*)
9523 : 1980	Specification for ductile iron fittings for pressure pipes for water, gas and sewage
10292 : 1988	Dimensional requirements for rubber sealing rings for CID joints in asbestos cement piping (*first revision*)
10299 : 1982	Cast iron saddle pieces for service connection from asbestos cement pressure pipes
11606 : 1986	Methods of sampling cast iron pipes and fittings
12820 : 1989	Dimensional requirements of rubber gaskets for mechanical joints and push on joints for use with cast iron pipes and fittings for carrying water, gas and sewage
12987 : 1991	Cast iron detachable joints for use with asbestos cement pressure pipes (light duty)
12988 : 1991	Rubber sealing rings for CID joints for light duty AC pipes — Dimensional requirements
13382 : 1992	Cast iron specials for mechanical and push on flexible joints for pressure pipelines for water, gas and sewage
iii) *Lead Pipes and Fittings*	
404 (Part 1) : 1993	Specification for lead pipes: Part 1 For other than chemical purpose (*third revision*)
iv) *Fibre Pipes and Fittings*	
11925 : 1986	Specification for pitch-impregnated fibre pipes and fittings for drainage purposes
v) *Plastic Pipes and Fittings*	
3076 : 1985	Specification for low density polyethylene pipes for potable water supplies (*second revision*)
4984 : 1995	Specification for high density polyethylene pipes for water supply (*fourth revision*)
4985 : 2000	Specification for unplasticized PVC pipes for potable water supplies (*third revision*)
7834	Specification for injection moulded PVC socket fittings with solvent cement joints for water supplies:
(Part 1) : 1987	General requirements (*first revision*)
(Part 2) : 1987	Specific requirements for 45° elbows (*first revision*)
(Part 3) : 1987	Specific requirements for 90° elbows (*first revision*)
(Part 4) : 1987	Specific requirements for 90° tees (*first revision*)
(Part 5) : 1987	Specific requirements for 45° tees (*first revision*)
(Part 6) : 1987	Specific requirements for sockets (*first revision*)
(Part 7) : 1987	Specific requirements for unions (*first revision*)
(Part 8) : 1987	Specific requirements for caps (*first revision*)
8008	Specification for injection moulded high density polyethylene (HDPE) fittings for potable water supplies:
(Part 1) : 2003	General requirements

IS No.	Title
(Part 2) : 2003	Specific requirements for 90° bends (*first revision*)
(Part 3) : 2003	Specific requirements for 90° tees
(Part 4) : 2003	Specific requirements for reducers
(Part 5) : 2003	Specific requirements for ferrule reducers (*first revision*)
(Part 6) : 2003	Specific requirements for pipe ends
(Part 7) : 2003	Specific requirements for sandwich flanges
(Part 8) : 2003	Specific requirements for reducing tests
(Part 9) : 2003	Specific requirements for end caps (*first revision*)
8360	Specification for fabricated high density polyethelene (HDPE) fittings for potable water supplies:
(Part 1) : 1977	General requirements
(Part 2) : 1977	Specific requirements for 90° tees
(Part 3) : 1977	Specific requirements for 90° bends
10124	Specification for fabricated PVC fittings for potable water supplies:
(Part 1) : 1988	General requirements (*first revision*)
(Part 2) : 1988	Specific requirements for sockets (*first revision*)
(Part 3) : 1988	Specific requirements of straight reducers (*first revision*)
(Part 4) : 1988	Specific requirements for caps (*first revision*)
(Part 5) : 1988	Specific requirements for equal tees (*first revision*)
(Part 6) : 1988	Specific requirements for flanged tail piece with metallic flanges (*first revision*)
(Part 7) : 1988	Specific requirements for threaded adaptors (*first revision*)
(Part 8) : 1988	Specific requirements for 90° bends (*first revision*)
(Part 9) : 1988	Specific requirements for 60° bends (*first revision*)
(Part 10) : 1988	Specific requirements for 45° bends (*first revision*)
(Part 11) : 1988	Specific requirements for 30° bends (*first revision*)
(Part 12) : 1988	Specific requirements for 22½° bends (*first revision*)
(Part 13) : 1988	Specific requirements for 11¼° bends (*first revision*)
12235	Methods of test for unplasticized PVC pipes for potable water supplies:
(Part 1) : 1986	Method of measurement of outside diameter
(Part 2) : 1986	Measurement of wall thickness
(Part 3) : 1986	Test for opacity
(Part 4) : 1986	Determining the detrimental effect on the composition of water
(Part 5) : 1986	Reversion test
(Part 6) : 1986	Stress relief test
(Part 7) : 1986	Test for resistance to sulphuric acid
(Part 8) : 1986	Internal hydrostatic pressure test
(Part 9) : 1986	Impact strength test
(Part 10) : 1986	Method for determination of organotin as tin aqueous solution
(Part 11) : 1986	Extractability of cadmium and mercury occurring as impurities
12709 : 1994	Specification for glass-fibre reinforced plastic (GRP) pipes joints and fittings for use for potable water supply (*first revision*)
12818 : 1992	Specification for unplasticized PVC screen and casing pipes for bore/tubewell (*first revision*)
13592 : 1992	Specification for UPVC pipes for soil and waste discharge systems inside buildings including ventilation and rainwater system
14333 : 1996	Specification for high density polyethylene pipes for sewerage
14402 : 1996	Specification for GRP pipes, joints and fittings for use for sewerage, industrial waste and water (other than potable)
14735 : 1999	Specification for unplasticized polyvinyl chloride (UPVC) injection moulded fittings for soil and waste discharge system for inside buildings including ventilation and rain water system
14885 : 2001	Specification for polyethylene pipe for supply of gaseous fuel
15225 : 2002	Specification for chlorinated polyvinyl chloride compounds used for pipes and fittings
15328 : 2003	Specification for unplasticized non-pressure polyvinyl chloride (PVC-U) pipes for use in underground drainage and sewerage system

IS No.	Title
vi) *Steel Tubes, Pipes and Fittings*	
1239	Mild steel tubes, tubular and other wrought steel fittings:
(Part 1) : 1990	Mild steel tubes (*fifth revision*)
(Part 2) : 1992	Mild steel tubular and other wrought steel pipe fittings (*third revision*)
3589 : 1991	Specification for seamless or electrically welded steel pipes for water, gas and sewage (168.3 to 2 032 mm outside size) (*second revision*)
4270 : 1992	Steel tubes used for water wells (*second revision*)
5504 : 1997	Specification for spiral welded pipes (*first revision*)
6286 : 1979	Seamless and welded steel pipe for sub-zero temperature service
6392 : 1971	Steel pipe flanges
vii) *Stoneware Pipes and Fittings*	
651 : 1992	Specification for salt-glazed stoneware pipes and fittings (*fifth revision*)
3006 : 1979	Specification for chemically resistant glazed stoneware pipes and fittings (*first revision*)
viii) *Asbestos Cement Pipes*	
[*See* 8 (a) (ii) under the category 'Composite Matrix Products']	
ix) *Concrete Pipes and Pipes Lined/Coated with Concrete or Mortar*	
[*See* 8 (a) (iv) under the category 'Composite Matrix Products']	
c) Kitchen and Sanitary Appliances	
771	Specification for glazed fire clay sanitary appliances:
(Part 1) : 1979	General requirements (*second revision*)
(Part 2) : 1985	Specific requirements of kitchen and laboratory sinks (*third revision*)
(Part 3/Sec 1) : 1979	Specific requirements of urinals, Section 1 Slab urinals (*second revision*)
(Part 3/Sec 2) : 1985	Part 3 Specific requirements of urinals, Section 2 Stall urinals (*third revision*)
(Part 4) : 1979	Specific requirements of post mortom slabs (*second revision*)
(Part 5) : 1979	Specific requirements of shower trays (*second revision*)
(Part 6) : 1979	Specific requirements of bed-pan sinks (*second revision*)
(Part 7) : 1981	Specific requirements of slop sinks (*second revision*)
772 : 1973	Specification for general requirements of enamelled cast iron sanitary appliances (*second revision*)
773 : 1988	Specification for enamelled cast iron water-closets railway stock type (*fourth revision*)
774 : 1984	Specification for flushing cisterns for water-closets and urinals (other than plastic cisterns) (*fourth revision*)
1726 : 1991	Specification for cast iron manhole covers and frames (*third revision*)
2326 : 1987	Specification for automatic flushing cisterns for urinals (*second revision*)
2548	Specification for plastic seats and covers for water-closets:
(Part 1) : 1996	Thermoset seats and covers (*fifth revision*)
(Part 2) : 1996	Thermoplastic seats and covers (*fifth revision*)
2556	Specification for vitreous sanitary appliances (vitreous china):
(Part 1) : 1994	General requirements (*third revision*)
(Part 2) : 1994	Specific requirements of wash-down water-closets (*fourth revision*)
(Part 3) : 1994	Specific requirements of squatting pans (*fourth revision*)
(Part 4) : 1994	Specific requirements of wash basins (*third revision*)
(Part 5) : 1994	Specific requirements of laboratory sinks (*third revision*)
(Part 6) : 1995	Specific requirements of urinals and partition plates (*fourth revision*)
(Part 7) : 1995	Specific requirements of accessories for sanitary appliances (*third revision*)
(Part 8) : 1995	Specific requirements of siphonic wash-down water closets (*fourth revision*)

(Part 9) : 1995	Specific requirements of bidets (*fourth revision*)
(Part 14) : 1995	Specific requirements of integrated squatting pans (*first revision*)
(Part 15) : 1995	Specific requirements of universal water closets (*first revision*)
(Part 16) : 2002	Specific requirements for wash down wall mounted water-closets
(Part 17) : 1995	Specific requirements for wall mounted bidets
5961 : 1970	Specification for cast iron gratings for drainage purposes
7231 : 1984	Specification for plastic flushing cisterns for water-closets and urinals (*second revision*)
11246 : 1992	Specification for glass fibre reinforced polyester resins (GRP) squatting pans (*first revision*)

d) Valves and Fittings (Including Ferrules)

778 : 1984	Specification for copper alloy gate, globe, and check valves for water works purposes (*fourth revision*)
781 : 1984	Specification for cast copper alloy screw-down bib taps and stop valves for water services (*third revision*)
1701 : 1960	Specification for mixing valves for ablutionary and domestic purposes
1703 : 2000	Specification for copper alloy float valves (horizontal plunger type) for water supply fittings (*third revision*)
1711 : 1984	Specification for self-closing taps for water supply purposes (*second revision*)
1795 : 1982	Specification for pillar taps for water supply purposes (*second revision*)
2692 : 1989	Specification for ferrules for water services (*second revision*)
3004 : 1979	Specification for plug cocks for water supply purposes (*first revision*)
3042 : 1965	Specification for single faced sluice gates (200 to 1 200 mm size)
3311 : 1979	Specification for waste plug and its accessories for sinks and washbasins (*first revision*)
3950 : 1979	Specification for surface boxes for sluice valves (*first revision*)
4038 : 1986	Specification for foot valves for water works purposes (*second revision*)
4346 : 1982	Specification for washers for use with fittings for water services (*first revision*)
5312	Specification for swing check type reflux (non-return) valves:
(Part 1) : 1984	Single door pattern (*first revision*)
(Part 2) : 1986	Multi-door pattern
8931 : 1993	Specification for cast copper alloy fancy single tap combination tap and stop valves for water services (*first revision*)
9338 : 1984	Specification for cast iron screw-down stop valves and stop and check valves for water works purposes (*first revision*)
9739 : 1981	Specification for pressure reducing valves for domestic water supply systems
9758 : 1981	Specification for flush valves and fittings for water-closets and urinals
9762 : 1994	Specification for polyethylene floats (spherical) for float valves (*first revision*)
9763 : 2000	Specification for plastic bib taps, pillar taps, angle valves, hot and cold water services (*second revision*)
12234 : 1988	Specification for plastic equilibrium float valve for cold water services
13049 : 1991	Specification for diaphragm type (plastic body) float operated valves for cold water services
13114 : 1991	Specification for forged brass gate, globe and check valves for water works purposes
14845 : 2000	Specification for resilient seated cast iron air relief valves for water works purposes
14846 : 2000	Specification for sluice valves for water works purposes (50 to 1 200 mm)

e) Water Meters

779 : 1994	Specification for water meters (domestic type) (*sixth revision*)

IS No.	Title
2104 : 1981	Specification for water meter boxes (domestic type) (*first revision*)
2373 : 1981	Specification for water meters (bulk type) (*third revision*)
6784 : 1996	Method for performance testing of water meters (domestic type) (*second revision*)

20. SOIL-BASED PRODUCTS

1725 : 1982	Specification for soil-based blocks used in general building construction

21. STEEL AND ITS ALLOYS

a) General

1030 : 1998	Carbon steel castings for general engineering purposes (*fifth revision*)
1136 : 1990	Preferred sizes for wrought metal products (*first revision*)
1137 : 1990	Thickness of sheet and diameters of wire (*first revision*)
1762 (Part 1) : 1974	Code for designation of steels: Part 1 Based on letter symbols (*first revision*)
2049 : 1978	Colour code for the identification of wrought steel for general engineering purposes (*first revision*)
2644 : 1994	High tensile steel castings (*fourth revision*)
7598 : 1990	Classification of steels (*first revision*)

b) Structural Steel

1977 : 1996	Specification for low tensile structural steels (*third revision*)
2062 : 1999	Specification for steel for general structural purposes (*fifth revision*)
2830 : 1992	Specification for carbon steel billets ingots, blooms and slabs for re-rolling into steel for general structural purposes (*second revision*)
2831 : 2000	Specification for carbon steel billets ingots, blooms and slabs for re-rolling into low tensile structural steel (*third revision*)
8053 : 1976	Specification for steel ingots and billets for the production of steel wire for the manufacture of wood screws
8500 : 1991	Specification for structural steels microalloyed (medium and high strength qualities)
8952 : 1995	Steel ingots, blooms and billets for production of mild steel wire rods for general engineering purposes (*first revision*)
9467 : 1980	Steel ingots and billets for production of rivet bars for structural purposes

c) Sheet and Strip

277 : 2003	Specification for galvanized steel sheets (plain and corrugated) (*sixth revision*)
412 : 1975	Specification for expanded metal steel sheets for general purposes (*second revision*)
513 : 1994	Specification for cold rolled low carbon steel sheets and strips (*fourth revision*)
1079 : 1994	Specification for hot rolled carbon steel sheet and strip (*fifth revision*)
6911 : 1992	Stainless steel plate, sheet and strip (*first revision*)
7226 : 1974	Specification for cold rolled medium, high carbon and low alloy steel strip for general engineering purposes
11587 : 1986	Specification for structural weather resistant steels
14246 : 1995	Specification for continuously pre-painted galvanized steel sheets and coils
15103 : 2002	Specification for fire resistant steel

d) Bars, Rods, Wire and Wire Rods

280 : 1978	Specification for mild steel wire for general engineering purposes (*third revision*)
1148 : 1982	Specification for hot rolled steel rivet bars (up to 40 mm diameter) for structural purposes (*third revision*)
1149 : 1982	Specification for high tensile steel rivet bars for structural purposes (*third revision*)
1673 : 1984	Specification for mild steel wire cold heading quality (*second revision*)

IS No.	*Title*
1812 : 1982	Specification for carbon steel wire for the manufacture of wood screw (*second revision*)
1835 : 1976	Specification for round steel wire for ropes (*third revision*)
2591 : 1982	Dimensions for hot rolled bars for threaded components (*second revision*)
3150 : 1982	Specification for hexagonal wire netting for general purposes
4826 : 1979	Specification for hot-dipped galvanized coatings on round steel wires (*first revision*)
6527 : 1995	Stainless steel wire rod (*first revision*)
6528 : 1995	Specification for stainless steel wire (*first revision*)
6603 : 2001	Specification for stainless steel bars and flats (*first revision*)
7887 : 1992	Specification for mild steel wire rods for general engineering purposes (*first revision*)
10631 : 1983	Stainless steel for welding electrode core wire
e) Plates	
3502 : 1994	Specification for steel chequered plates (*second revision*)
f) Tubes and Tubulars	
1161 : 1998	Specification for steel tubes for structural purposes (*fourth revision*)
4516 : 1968	Specification for elliptical mild steel tubes
4923 : 1997	Specification for hollow mild steel sections for structural use (*first revision*)
g) Slotted Sections	
8081 : 1976	Specification for slotted sections
22. STONES	
1121	Methods of test for determination of strength properties of natural building stones:
(Part 1) : 1974	Compressive strength (*first revision*)
(Part 2) : 1974	Transverse strength (*first revision*)
(Part 3) : 1974	Tensile strength (*first revision*)
(Part 4) : 1974	Shear strength (*first revision*)
1122 : 1974	Method of test for determination of true specific gravity of natural building stones (*first revision*)
1123 : 1975	Method of identification of natural building stones (*first revision*)
1124 : 1974	Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones (*first revision*)
1125 : 1974	Method of test for determination of weathering of natural building stones (*first revision*)
1126 : 1974	Method of test for determination of durability of natural building stones (*first revision*)
1127 : 1970	Recommendations for dimensions and workmanship of natural building stones for masonry work (*first revision*)
1128 : 1974	Specification for limestone (slab and tiles) (*first revision*)
1129 : 1972	Recommendation for dressing of natural building stones (*first revision*)
1130 : 1969	Specification for marble (blocks, slabs and tiles)
1706 : 1972	Method of determination of resistance to wear by abrasion of natural building stones (*first revision*)
3316 : 1974	Specification for structural granite (*first revision*)
3620 : 1979	Specification for laterite stone block for masonry (*first revision*)
3622 : 1977	Specification for sand stone (slabs and tiles) (*first revision*)
4121 : 1967	Method of test for determination of water transmission rate by capillary action through natural building stones
4122 : 1967	Method of test for surface softening of natural building stones by exposure to acidic atmospheres
4348 : 1973	Methods of test for determination of permeability of natural building stones (*first revision*)
5218 : 1969	Method of test for toughness of natural building stones
5640 : 1970	Method of test for determining the aggregate impact value of soft coarse aggregates

IS No.	Title
6250 : 1981	Specification for roofing slate tiles (*first revision*)
7779	Schedule for properties and availability of stones for construction purposes:
(Part 1/Sec 1) : 1975	Gujarat state, Section 1 Availability of stones
(Part 1/Sec 2) : 1975	Gujarat state, Section 2 Engineering properties of building stones
(Part 1/Sec 3) : 1975	Gujarat state, Section 3 Engineering properties of stone aggregates
(Part 2/Sec 1) : 1979	Maharashtra state, Section 1 Availability of stones
(Part 2/Sec 2) : 1979	Maharashtra state, Section 2 Engineering properties of building stones
(Part 2/Sec 3) : 1979	Maharashtra state, Section 3 Engineering properties of stone aggregates
(Part 3/Sec 2) : 1990	Tamil Nadu state, Section 2 Engineering properties of building stones
(Part 3/Sec 3) : 1980	Tamil Nadu state, Section 3 Engineering properties of stone aggregates
(Part 4/Sec 1 to 3) : 1996	Karnataka state, Sections (1 to 3)
(Part 5/Sec 1) : 1997	Andhra Pradesh, Section 1 Availability of stones
(Part 5/Sec 2) : 1997	Andhra Pradesh, Section 2 Engineering properties of building stones
(Part 5/Sec 3) : 1997	Andhra Pradesh, Section 3 Engineering properties of stone aggregates
9394 : 1979	Specification for stone lintels
14223 (Part 1) : 1994	Specification for polished building stones: Part 1 Granite

23. STRUCTURAL SECTIONS

a) Structural Shapes

811 : 1987	Specification for cold formed light gauge structural steel sections (*revised*)
1173 : 1978	Specification for hot rolled and slit steel tee bars (*second revision*)
1852 : 1985	Specification for rolling and cutting tolerances for hot rolled steel products (*fourth revision*)
1863 : 1979	Specification for hot rolled steel bulb flats (*first revision*)
2314 : 1986	Specification for steel sheet piling sections (*first revision*)
3443 : 1980	Specification for crane rail sections (*first revision*)
3908 : 1986	Specification for aluminium equal leg angles (*first revision*)
3909 : 1986	Specification for aluminium unequal leg angles (*first revision*)
3921 : 1985	Specification for aluminium channels (*first revision*)
3954 : 1991	Specification for hot rolled steel channels sections for general engineering purposes (*first revision*)
3964 : 1980	Specification for light rails (*first revision*)
5384 : 1985	Specification for aluminium I-beams (*first revision*)
6445 : 1985	Specification for aluminium tee sections (*first revision*)
12779 : 1989	Rolling and cutting tolerances for hot rolled parallel flange beam and column sections

b) Dimensional Standards

808 : 1989	Dimensions for hot rolled steel beam, column channel and angle sections (*third revision*)
1730 : 1989	Dimensions for steel plates, sheets strips and flats for general engineering purposes (*second revision*)
1732 : 1989	Dimensions for round and square steel bars for structural and general engineering purposes (*second revision*)
2525 : 1982	Dimensions for wrought aluminium and aluminium alloy wire (*first revision*)
2591 : 1982	Dimensions for hot rolled steel bars for threaded components (*second revision*)
2673 : 2002	Dimensions for wrought aluminium and aluminium alloys, extruded round tube (*second revision*)
2676 : 1981	Dimensions for wrought aluminium and aluminium alloys, sheet and strip (*first revision*)

IS No.	*Title*
2677 : 1979	Dimensions for wrought aluminium and aluminium alloys, plates and hot rolled sheets (*first revision*)
2678 : 1987	Dimensions and tolerances for wrought aluminium and aluminium alloys, drawn round tubes (*second revision*)
3577 : 1992	Dimensions and tolerances for wrought aluminium and aluminium alloys rivet, bolt and screw stock (*first revision*)
3965 : 1981	Dimensions for wrought aluminium and aluminium alloys, bar, rod and section (*first revision*)
6477 : 1983	Dimensions for wrought aluminium and aluminium alloys, extruded hollow sections
12778 : 1989	Dimensions for hot rolled steel parallel flange beam and column sections

24. THERMAL INSULATION MATERIALS

3144 : 1992	Methods of test for mineral wool thermal insulation material (*second revision*)
3346 : 1980	Methods for the determination of thermal conductivity of thermal insulation materials (two slab, guarded hot-plate method) (*first revision*)
3677 : 1985	Specification for unbonded rock and slag wool for thermal insulation (*second revision*)
4671 : 1984	Specification for expanded polystyrene for thermal insulation purposes (*first revision*)
5688 : 1982	Methods of test for preformed block-type and pipe-covering type thermal insulation (*first revision*)
5724 : 1970	Methods of test for thermal insulating cement
6598 : 1972	Specification for cellular concrete for thermal insulation
7509 : 1993	Specification for thermal insulating cement (*first revision*)
8154 : 1993	Specification for preformed calcium silicate insulation for temperature up to 650°C) (*first revision*)
8183 : 1993	Specification for bonded mineral wool (*first revision*)
9403 : 1980	Method of test for thermal conductance and transmittance of built up sections by means of guarded hot box
9489 : 1980	Method of test for thermal conductivity of materials by means of heat flow meter
9490 : 1980	Method of determination for thermal conductivity of insulation materials (water calorimeter method)
9742 : 1993	Specification for sprayed mineral wool thermal insulation (*first revision*)
9743 : 1990	Specification for thermal insulation finishing cements (*first revision*)
9842 : 1994	Specification for preformed fibrous pipe insulation (*first revision*)
11128 : 1994	Specification for spray applied hydrated calcium silicate thermal insulation
11129 : 1984	Method of test for tumbling friability of preformed block-type thermal insulation
11239	Method of test for rigid cellular thermal insulation materials:
(Part 1) : 1985	Dimensions
(Part 2) : 1985	Apparent density
(Part 3) : 1985	Dimensional stability
(Part 4) : 1985	Water vapour transmission rate
(Part 5) : 1985	Volume percent of open and closed cells
(Part 6) : 1985	Heat distortion temperature
(Part 7) : 1985	Coefficient of linear thermal expansion at low temperatures
(Part 8) : 1985	Flame height, time of burning and loss of mass
(Part 9) : 1985	Water absorption
(Part 10) : 1985	Flexural strength
(Part 11) : 1985	Compressive strength
(Part 12) : 1989	Horizontal burning characteristics
(Part 13) : 1992	Determination of flammability by oxygen index
11307 : 1985	Specification for cellular glass block and pipe thermal insulating
11308 : 1985	Specification for thermal insulating castables (hydraulic setting) for temperatures up to 1 250°C

IS No.	Title
12436 : 1988	Specification for preformed rigid polyurethane (PUR) and polyisocyanurate (Pir) foams for thermal insulation
13204 : 1991	Specification for rigid phenolic foams for thermal insulation
13286 : 1992	Methods of test for surface spread of flame for thermal insulation materials

25. THREADED FASTENERS AND RIVETS

207 : 1964	Specification for gate and shutter hooks and eyes (*revised*)
451 : 1999	Specification for technical supply conditions for wood screws (*third revision*)
554 : 1999	Specification for pipe threads where pressure-tide joints are made on the threads — Dimensions, tolerances and designation (*fourth revision*)
723 : 1972	Specification for steel countersunk head wire nails (*second revision*)
724 : 1964	Specification for mild steel and brass cup, ruler and square hooks and screw eyes (*revised*)
725 : 1961	Specification for copper wire nails (*revised*)
730 : 1978	Specification for hook bolts for corrugated sheet roofing (*second revision*)
1120 : 1975	Specification for coach screws (*first revision*)
1363	Specification for hexagon head bolts, screws and nuts of product grade C:
(Part 1) : 2002	Hexagon head bolts (size range M5 to M64) (*fourth revision*)
(Part 2) : 2002	Hexagon head screws (size range M5 to M64) (*fourth revision*)
(Part 3) : 2002	Part 3 Hexagon nuts (Size range M5 to M64) (*fourth revision*)
1364	Specification for hexagon head bolts, screws and nuts of product Grades A and B:
(Part 1) : 2002	Hexagon head bolts (size range M1.6 to M64) (*fourth revision*)
(Part 2) : 2002	Hexagon head screws (size range M1.6 to M64) (*fourth revision*)
(Part 3) : 2002	Hexagon nuts (size range M1.6 to M64) (*fourth revision*)
(Part 4) : 2003	Hexagon thin nuts (chamfered) (size range M1.6 to M64) (*fourth revision*)
(Part 5) : 2002	Hexagon thin nuts (unchamfered) (size range M1.6 to M10) (*fourth revision*)
(Part 6) : 2002	Hexagon nuts, style 2
1365 : 1978	Specification for slotted countersunk head screws (*third revision*)
1366 : 2002	Specification for slotted cheese head screws (*third revision*)
1367	Specification for technical supply conditions for threaded steel fasteners:
(Part 1) : 2002	Introduction and general information (*third revision*)
(Part 2) : 2002	Product grades and tolerances (*third revision*)
(Part 3) : 2002	Mechanical properties and test methods for bolts, screws and studs with full loadability (*fourth revision*)
(Part 5) : 2002	Mechanical properties and test methods for set screws and similar threaded fasteners not under tensile stresses (*third revision*)
(Part 6) : 1994	Mechanical properties and test methods for nuts with specified proof loads (*third revision*)
(Part 7) : 1980	Mechanical properties and test methods for nuts without specified proof loads (*second revision*)
(Part 8) : 2002	Mechanical and performance properties for prevailing torque type steel hexagon nuts (*third revision*)
(Part 9/Sec 1) : 1993	Surface discontinuities, Section 1 Bolts, screws and studs for general applications (*third revision*)
(Part 9/Sec 2) : 1993	Surface discontinuities, Section 2 Bolts, screws and studs for special applications (*third revision*)
(Part 10) : 2002	Surface discontinuities on nuts (*third revision*)
(Part 11) : 2002	Electroplated coatings (*third revision*)
(Part 12) : 1981	Phosphate coatings on threaded fasteners (*second revision*)

IS No.	*Title*
(Part 13) : 1983	Hot dip galvanized coatings on threaded fasteners (*second revision*)
(Part 14/Sec 1) : 2002	Mechanical properties of corrosion resistance stainless steel fasteners, Section 1 Bolts, screws and studs (*third revision*)
(Part 14/Sec 2) : 2002	Mechanical properties of corrosion resistance stainless steel fasteners, Section 2 Nuts (*third revision*)
(Part 14/Sec 3) : 2002	Mechanical properties of corrosion resistance stainless steel fasteners, Section 3 Set screws and similar fasteners not under tensile stress (*third revision*)
(Part 16) : 2002	Designation system and symbols (*third revision*)
1929 : 1982	Specification for hot forged steel rivets for hot closing (12 to 36 mm diameter) (*first revision*)
2016 : 1967	Specification for plain washers (*first revision*)
2155 : 1982	Specification for cold forged solid steel rivets for hot closing (6 to 16 mm diameter) (*first revision*)
2585 : 1968	Specification for black square bolts and nuts (dia range 6 to 39 mm) and black square screws (dia range 6 to 24 mm) (*first revision*)
2643 : 1999	Dimensions, tolerances and designation for pipe threads where pressure-tight joints are not made on the threads (*second revision*)
2687 : 1991	Specification for cap nuts (*second revision*)
2907 : 1998	Specification for non-ferrous rivets (*first revision*)
2998 : 1982	Specification for cold forged steel rivets for cold closing (1 to 16 mm diameter) (*first revision*)
3063 : 1994	Specification for fasteners single coil rectangular section spring lock washers (*second revision*)
3121 : 1981	Specification for rigging screws and stretching screws (*first revision*)
3468 : 1991	Specification for pipe nuts (*second revision*)
3757 : 1985	Specification for high strength structural bolts (*second revision*)
4206 : 1987	Dimensions for nominal lengths, and thread lengths for bolts, screws and studs (*first revision*)
4762 : 2002	Specification for worm drive hose clips for general purposes (*second revision*)
5369 : 1975	General requirements for plain washers and lock washers (*first revision*)
5372 : 1975	Specification for taper washer for channels (ISMC) (*first revision*)
5373 : 1969	Specification for square washers for wood fastenings
5374 : 1975	Specification for taper washers for L-beam (ISMB) (*first revision*)
5624 : 1993	Specification for foundation bolts (*first revision*)
6113 : 1970	Specification for aluminium fasteners for building purposes
6610 : 1972	Specification for heavy washers for steel structures
6623 : 1985	Specification for high strength structural nuts (*first revision*)
6639 : 1972	Specification for hexagon bolts for steel structures
6649 : 1985	Specification for hardened and tempered washers for high strength structural bolts and nuts (*first revision*)
6733 : 1972	Specification for wall and roofing nails
6736 : 1972	Specification for slotted raised countersunk head wood screws
6739 : 1972	Specification for slotted round head wood screws
6760 : 1972	Specification for slotted countersunk head wood screws
8033 : 1976	Specification for washers with square hole for wood fastenings
8412 : 1977	Specification for slotted countersunk head bolts for steel structures
8822 : 1978	Specification for slotted mushroom head roofing bolts
8869 : 1978	Specification for washers for corrugated sheet roofing
8911 : 1978	Specification for slotted raised countersunk head screws
10102 : 1982	Specification for technical supply conditions for rivets

IS No.	Title
10238 : 2001	Specification for step bolts for steel structures
12427 : 2001	Specification for transmission tower bolts

26. UNIT WEIGHTS OF BUILDING MATERIALS

875 (Part 1) : 1987	Code of practice for design loads (other than earthquake) for buildings and structures: Part 1 Dead loads — Unit weights of building material and stored materials (*second revision*)

27. WATERPROOFING AND DAMP-PROOFING MATERIALS

1322 : 1993	Specification for bitumen felts for waterproofing and damp-proofing (*fourth revision*)
1580 : 1991	Specification for bituminous compound for waterproofing and caulking purposes (*first revision*)
3037 : 1986	Specification for bitumen mastic for use in waterproofing of roofs (*first revision*)
3384 : 1986	Specification for bitumen primer for use in waterproofing and damp-proofing (*first revision*)
5871 : 1987	Specification for bitumen mastic for tanking and damp-proofing (*first revision*)
7193 : 1994	Specification for glass fibre base coal tar pitch and bitumen felts (*first revision*)
12027 : 1987	Specification for silicone-based water repellents
13435	Method of tests for acrylic based waterproofing material:
(Part 1) : 1992	Determination of solid content
(Part 2) : 1992	Determination of coarse particle
(Part 3) : 1992	Determination of capillary water take-up
(Part 4) : 1992	Determination of *p*H value
(Part 5) : 1992	Determination of minimum film forming temperature and white point
13826	Bitumen based felts — Method of test:
(Part 1) : 1993	Breaking strength test
(Part 2) : 1993	Pliability test
(Part 3) : 1993	Storage sticking test
(Part 4) : 1993	Pressure head test
(Part 5) : 1993	Heat resistance test
(Part 6) : 1993	Water absorption test
(Part 7) : 1993	Determination of binder content
14695 : 1999	Specification for glass fibre base coal tar pitch outer wrap

28. WELDING ELECTRODES AND WIRES

814 : 1991	Specification for covered electrodes for manual metal arc welding of carbon and carbon manganese steel (*fifth revision*)
1278 : 1972	Specification for filler rods and wires for gas welding (*second revision*)
1395 : 1982	Specification for low and medium alloy steel covered electrodes for manual metal arc welding (*third revision*)
2879 : 1998	Mild steel for metal arc welding electrodes (*third revision*)
3613 : 1974	Acceptance tests for wire flux combinations for submerged-arc welding of structural steel (*first revision*)
4972 : 1968	Specification for resistance spot-welding electrodes
5206 : 1983	Covered electrodes for manual arc welding of stainless steel and other similar high alloy steels (*first revision*)
5511 : 1991	Specification for covered electrodes for manual metal arc welding of cast iron (*first revision*)
5897 : 1985	Specification for aluminium and aluminium alloy welding rods and wires and magnesium alloy welding rods (*first revision*)
5898 : 1970	Specification for copper and copper alloy bare solid welding rods and electrodes
6419 : 1996	Specification for welding rods and bare electrodes for gas shielded arc welding of structural steel (*first revision*)
6560 : 1996	Specification for molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding (*first revision*)

IS No.	*Title*
7280 : 1974	Specification for bare wire electrodes for submerged-arc welding of structural steels
8363 : 1976	Specification for bare wire electrodes for electroslag welding of steels
10631 : 1983	Stainless steel for welding electrode core wire

29. WIRE ROPES AND WIRE PRODUCTS

278 : 1978	Specification for galvanized steel barbed wire for fencing (*third revision*)
2140 : 1978	Specification for stranded galvanized steel wire for fencing (*first revision*)
2266 : 2002	Specification for steel wire ropes for general engineering purposes (*fourth revision*)
2365 : 1977	Specification for steel wire suspension ropes for lifts, elevators and hoists (*first revision*)
2721 : 2003	Specification for galvanized steel wire chain link fences fabric (*second revision*)
6594 : 1977	Specification for technical supply conditions for wire ropes and strands (*first revision*)
12776 : 2002	Specification for galvanized strand for earthing (*first revision*)

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 1 Loads, Forces and Effects

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section covers the various loads, forces and effects which are to be taken into account for structural design of buildings. The various loads that are covered under this Section are dead load, imposed load, wind load, seismic load, snow load, special loads and load combinations.

This Code was first published in 1970 and revised in 1983. Subsequently the first revision of this Section was modified in 1987 through Amendment No. 2 to the 1983 version of the Code to bring this Section in line with the latest revised loading code. Now, in view of the revision of the important Indian Standard on earthquake resistant design of structure, that is IS 1893, a need to revise this Part was felt. This revision has therefore been prepared to take into account this revised standard, IS 1893 (Part 1) : 2002 'Criteria for earthquake resistant design of structures: Part 1 General provision and buildings (*fifth revision*)' and also incorporate latest information on additional loads, forces and effects as also the details regarding multi-hazard risk in various districts of India.

The significant changes incorporated in this revision include:

a) The seismic zone map is revised with only four zones, instead of five. Erstwhile Zone I has been merged in to Zone II. Hence, Zone I does not appear in the new zoning; only Zones II, III, IV and V do.

b) The values of seismic zone factors have been changed; these now reflect more realistic values of effective peak ground acceleration considering Maximum Considered Earthquake (MCE) and service life of structure in each seismic zone.

c) Response spectra are now specified for three types of founding strata, namely rock and hard soil, medium soil and soft soil.

d) Empirical expression for estimating the fundamental natural period T_a of multi-storeyed buildings with regular moment resisting frames has been revised.

e) This revision adopts the procedure of first calculating the actual force that may be experienced by the structure during the probable maximum earthquake, if it were to remain elastic. Then, the concept of response reduction due to ductile deformation or frictional energy dissipation in the cracks is brought in this Section explicitly, by introducing the 'response reduction factor' in place of the earlier performance factor.

f) A lower bound is specified for the design base shear of buildings, based on empirical estimate of the fundamental natural period T_a.

g) The soil-foundation system factor is dropped. Instead, a clause has been introduced to restrict the use of foundations vulnerable to differential settlements in severe seismic zones.

h) Torsional eccentricity values have been revised upwards in view of serious damages observed in buildings with irregular plans.

j) Modal combination rule in dynamic analysis of buildings has been revised.

k) Other clauses have been redrafted where necessary for more effective implementation.

m) A new clause on multi-hazard risk in various districts of India and a list of districts identified as multi-hazard prone districts have been included.

n) Latest amendments issued to IS 875 have been incorporated.

p) A clause on vibration in buildings has been introduced for general guidance.

q) Reference has been included to the Indian Standards on landslide control and design of retaining walls, formulated after the last revision of the Section.

The information contained in this Section is largely based on the following Indian Standards:

IS 1893 (Part 1) : 2002 Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*fifth revision*)

IS 875 (Part 2) : 1987	Code of practice for design loads (other than earthquake) for buildings and structures: Part 2 Imposed loads (*second revision*)
IS 875 (Part 3) : 1988	Code of practice for design loads (other than earthquake) for buildings and structures: Part 3 Wind loads (*second revision*)
IS 875 (Part 4) : 1987	Code of practice for design loads (other than earthquake) for buildings and structures: Part 4 Snow loads (*second revision*)
IS 875 (Part 5) : 1987	Code of practice for design loads (other than earthquake) for buildings and structures: Part 5 Special loads and load combinations (*second revision*)

This Section has to be read together with Sections 2 to 7 of Part 6 'Structural Design'.

A reference to SP 64 (S&T) : 2001 'Explanatory Handbook on Indian Standard Code of practice for design loads (other than earthquake) for buildings and structures: Part 3 Wind loads IS 875 (Part 3) : 1987' may be useful. This publication gives detailed background information on the provisions for wind loads and also the use of these provisions for arriving at the wind loads on buildings and structures while evaluating their structural safety.

Reference may also be made to the Vulnerability Atlas of India, 1997 and Landslide Hazard Zonation Atlas of India, 2003 Building Materials and Technology Promotion Council, Ministry of Urban Development and Poverty Alleviation, Government of India. The vulnerability Atlas contains information pertaining to each State and Union Territory of India, on (a) seismic hazard map, (b) cyclone, and wind map, (c) flood prone area map, and (d) housing stock vulnerability table for each district indicating for each house type the level of risk to which it could be subjected. The Atlas can be used to identify areas in each district of the country which are prone to high risk from more than one hazard. The information will be useful in establishing the need of developing housing designs to resist the combination of such hazards.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 1 Loads, Forces and Effects

1 SCOPE

1.1 This Section covers basic design loads to be assumed in the design of buildings. The imposed loads, wind loads, seismic loads, snow loads and other loads, which are specified herein, are minimum working loads which should be taken into consideration for purposes of design.

1.2 This Section does not take into consideration loads incidental to construction.

2 DEAD LOAD

2.1 Assessment of Dead Load

The dead load in a building shall comprise the weight of all walls, partitions, floors and roofs, and shall include the weights of all other permanent constructions in the building and shall conform to good practice [6-1(1)].

3 IMPOSED LOAD

3.1 This clause covers imposed loads (live loads) to be assumed in the design of buildings. The imposed loads specified herein are minimum loads which should be taken into consideration for the purpose of structural safety of buildings.

NOTE — This Section does not cover detailed provisions for loads incidental to construction and special cases of vibration, such as moving machinery, heavy acceleration from cranes, hoists and the like. Such loads shall be dealt with individually in each case.

3.2 Terminology

3.2.1 For the purpose of imposed loads specified herein, the following definitions shall apply:

3.2.1.1 *Assembly Buildings* — These shall include any building or part of a building where groups of people congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes; for example, theatres, motion picture houses, assembly halls, city halls, marriage halls, town halls, auditoria, exhibition halls, museums, skating rinks, gymnasiums, restaurants (also used as assembly halls), place of worship, dance halls, club rooms, passenger stations and terminals of air, surface and other public transportation services, recreation piers and stadia, etc.

3.2.1.2 *Business Buildings* — These shall include any building or part of a building, which is used for transaction of business (other than that covered by mercantile buildings); for keeping of accounts and records for similar purposes; offices, banks, professional establishments, court houses, and libraries shall be classified in this group so far as principal function of these is transaction of public business and the keeping of books and records.

3.2.1.3 *Dwellings* — These shall include any building or part occupied by members of single/multi-family units with independent cooking facilities. These shall also include apartment houses (flats).

3.2.1.4 *Educational Buildings* — These shall include any building used for school, college or day-care purposes involving assembly for instruction, education or recreation and which is not covered by assembly buildings.

3.2.1.5 *Imposed Load* — The load assumed to be produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, loads due to impact and vibration, and dust loads but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement, etc.

3.2.1.6 *Industrial Buildings* — These shall include any building or a part of a building or structure, in which products or materials of various kinds and properties are fabricated, assembled or processed like assembly plants, power plants, refineries, gas plants, mills, dairies, factories, workshops, etc.

3.2.1.7 *Institutional Buildings* — These shall include any building or a part thereof, which is used for purposes, such as, medical or other treatment in case of persons suffering from physical and mental illness, disease or infirmity; care of infants, convalescents or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants. It includes hospitals, sanitoria, custodial institutions or penal institutions like jails, prisons and reformatories.

3.2.1.8 *Occupancy or Use Group* — The principal occupancy for which a building or part of a building is used or intended to be used; for the purpose of classification of a building according to occupancy, an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it. The occupancy classification is given in the following groups.

3.2.1.9 *Office Buildings* — The buildings primarily to be used as an office or for office purposes; 'office purposes' include the purpose of administration, clerical work, handling money, telephone and telegraph operating, and operating computers, calculating machines, 'clerical work' includes writing, book-keeping, sorting papers,

typing, filing, duplicating, punching cards or tapes, drawing of matter for publication and the editorial preparation of matter for publication.

3.2.1.10 *Mercantile Buildings* — These shall include any building or a part of a building which is used as shops, stores, market for display and sale of merchandize either wholesale or retail. Office, storage and service and facilities incidental to the sale of merchandize and located in the same building shall be included under this group.

3.2.1.11 *Residential Buildings* — These shall include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities (except buildings under institutional buildings). It includes one or multi-family dwellings, apartment houses (flats), lodging or rooming houses, restaurants, hostels, dormitories and residential hotels.

3.2.1.12 *Storage Buildings* — These shall include any building or part of a building used primarily for the storage or sheltering of goods, wares or merchandize, like warehouses, cold storages, freight depots, transity sheds, store houses, garages, hangers, truck terminals, grain elevators, barns and stables.

3.3 Imposed Loads on Floors Due to Use and Occupancy

3.3.1 *Imposed Loads*

The imposed loads to be assumed in the design of buildings shall be the greatest loads that probably will be produced by the intended use or occupancy, but shall not be less than the equivalent minimum loads specified in Table 1 subject to any reductions permitted in **3.3.2**.

Floors shall be investigated for both the uniformly distributed load (UDL) and the corresponding concentrated load specified in Table 1, and designed for the most adverse effects but they shall not be considered to act simultaneously. The concentrated loads specified in Table 1 may be assumed to act over an area of 0.3 m × 0.3 m. However, the concentrated loads need not be considered where the floors are capable of effective lateral distribution of this load.

All other structural elements shall be investigated for the effects of uniformly distributed loads on the floors specified in Table 1.

NOTES

1 Where, in Table 1, no values are given for concentrated load, it may be assumed that the tabulated distributed load is adequate for design purposes.

2 The loads specified in Table 1 are equivalent uniformly distributed loads on the plan area and provide for normal effects of impact and acceleration. They do not take into consideration special concentrated loads and other loads.

3 Where the use of an area or floor is not provided in Table 1, the imposed load due to the use and occupancy of such an area shall be determined from the analysis of loads resulting from:

a) weight of the probable assembly of persons;
b) weight of the probable accumulation of equipment and furnishing;
c) weight of the probable storage materials; and
d) impact factor, if any.

4 While selecting a particular loading, the possible change in use or occupancy of the building should be kept in view. Designers should not necessarily select in every case the lower loading appropriate to the first occupancy. In doing this they might introduce considerable restrictions in the use of the building at a later date, and thereby reduce its utility.

5 The loads specified herein, which are based on estimations, may be considered as the characteristic loads for the purpose of limit state method of design till such time statistical data are established based on load surveys to be conducted in the country.

6 When an existing building is altered by an extension in height or area, all existing structural parts affected by the addition shall be strengthened where necessary and all new structural parts shall be designed to meet the requirements for building hereafter erected.

7 The loads specified in the section does not include loads incidental to construction. Therefore, close supervision during construction is essential to ensure that overloading of the building due to loads by way of stacking of building materials or use of equipment (for example, cranes and trucks) during construction or loads which may be induced by floor to floor propping in multi-storeyed construction, does not occur. However, if construction loads were of short duration, permissible increase in stresses in the case of working stress method or permissible decrease in load factors in limit state method, as applicable to relevant design codes, may be allowed for.

8 The loads in Table 1 are grouped together as applicable to buildings having separate principal occupancy or use. For a building with multiple occupancies, the loads appropriate to the occupancy with comparable use shall be chosen from other occupancies.

9 Regarding loading on lift machine rooms including storage space used for repairing lift machines, designers should go by the recommendations of lift manufacturers for the present. Regarding loading due to false ceiling, the same should be considered as imposed loads on the roof/floor to which it is fixed.

Table 1 Imposed Floor Loads for Different Occupancies

(*Clause* 3.3.1)

Sl No.	Occupancy Classification	Uniformly Distributed Load (UDL)	Concentrated Load
(1)	(2)	(3)	(4)
i)	*Residential Buildings*	KN/m^2	KN
	a) Dwelling houses:		
	1) All rooms and kitchens	2.0	1.8
	2) Toilets and bathrooms	2.0	

Table 1 — *Continued*

(1)	(2)	(3)	(4)
	3) Corridors, passages, staircases including fire escapes and store rooms	3.0	4.5
	4) Balconies	3.0	1.5 per metre run concentrated at the outer edge
	b) Dwelling units planned and executed in accordance with [6-1(2)] only:		
	1) Habitable rooms, kitchens, and toilets and bathrooms	1.5	1.4
	2) Corridors, passages and staircases including fire escapes	1.5	1.4
	3) Balconies	3.0	1.5 per metre run concentrated at the outer edge
	c) Hotels, hostels, boarding houses, lodging houses, dormitories and residential clubs:		
	1) Living rooms, bed rooms and dormitories	2.0	1.8
	2) Kitchen and laundries	3.0	4.5
	3) Billiards room and public lounges	3.0	2.7
	4) Store rooms	5.0	4.5
	5) Dining rooms, cafeterias and restaurants	4.0	2.7
	6) Office rooms	2.5	2.7
	7) Rooms for indoor games	3.0	1.8
	8) Baths and toilets	2.0	—
	9) Corridors, passages staircases including fire escapes and lobbies as per the floor services (excluding stores and the like) but not less than	3.0	4.5
	10) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 per metre run concentrated at the outer edge
	d) Boiler rooms and plant roomsto be calculated but not less than	5.0	6.7
	e) Garages:		
	1) Garage floors (including parking area and repair workshops for passenger cars and vehicles not exceeding 2.5 tonnes gross weight, including access ways and ramps — to be calculated but not less than	2.5	9.0
	2) Garage floors for vehicles not exceeding 4.0 tonnes gross weight (including access ways and ramps) — to be calculated but not less than	5.0	9.0
ii)	*Educational Buildings*		
	a) Class rooms and lecture rooms (not used for assembly purposes)	3.0	2.7
	b) Dining rooms, cafeterias and restaurants	3.0[1)]	2.7
	c) Offices, lounges and staff rooms	2.5	2.7
	d) Dormitories	2.0	2.7
	e) Projection rooms	5.0	—
	f) Kitchens	3.0	4.5
	g) Toilets and bathrooms	2.0	—
	h) Store rooms	5.0	4.5
	j) Libraries and archives:		
	1) Stack room/stack area	6.0 kN/m^2 for a minimum height of 2.2 m + 2.0 kN/m^2 per metre height beyond 2.2 m	4.5
	2) Reading rooms (without separate storage)	4.0	4.5
	3) Reading rooms (with separate storage)	3.0	4.5
	k) Boiler rooms and plant rooms — to be calculated but not less than	4.0	4.5
	m) Corridors, passages, lobbies, staircases including fire escapes — as per the floor serviced (without accounting for storage and projection rooms) but not less than	4.0	4.5
	n) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 metre run concentrated at the outer edge

Table 1 — *Continued*

(1)	(2)	(3)	(4)
iii)	*Institutional Buildings*		
	a) Bed rooms, wards, dressing rooms, dormitories and lounges	2.0	1.8
	b) Kitchens, laundries and laboratories	3.0	4.5
	c) Dining rooms, cafeterias and restaurants	3.0[1)]	2.7
	d) Toilets and bathrooms	2.0	—
	e) X-ray rooms, operating rooms and general storage areas — to be calculated but not less than	3.0	4.5
	f) Office rooms and O.P.D. rooms	2.5	2.7
	g) Corridors, passages, lobbies, staircases including fire escapes — as per the floor serviced (without accounting for storage and projection rooms) but not less than	4.0	4.5
	h) Boiler rooms and plant rooms — to be calculated but not less than	5.0	4.5
	j) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 metre run concentrated at the outer edge
iv)	*Assembly Building*		
	a) Assembly areas:		
	1) With fixed seats [2)]	4.0	—
	2) Without fixed seats	5.0	3.6
	b) Restaurants (subject to assembly), museums and art galleries and gymnasia	4.0	4.5
	c) Projection rooms	5.0	—
	d) Stages	5.0	4.5
	e) Office rooms, kitchens and laundries	3.0	4.5
	f) Dressing rooms	2.0	1.8
	g) Lounges and billiards rooms	2.0	2.7
	h) Toilets and bathrooms	2.0	—
	j) Corridors, passages and staircases including fire escapes	4.0	4.5
	k) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 metre run concentrated at the outer edge
	m) Boiler rooms and plant rooms including weight of machinery	7.5	4.5
	n) Corridors, passages, subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like corridors, staircases and passages in grandstands	5.0	4.5
v)	*Business and Office Buildings* (*see also* **3.2.1**)		
	a) Rooms for general use with separate storage	2.5	2.7
	b) Rooms without separate storage	4.0	4.5
	c) Banking halls	3.0	2.7
	d) Business computing machine rooms (with fixed computers or similar equipment)	3.5	4.5
	e) Records/files store rooms and storage space	5.0	4.5
	f) Vaults and strong rooms — to be calculated but not less than	5.0	4.5
	g) Cafeterias and dinning rooms	3.0[1)]	2.7
	h) Kitchens	3.0	2.7
	j) Corridors, passages, lobbies, staircases including fire escapes — as per the floor serviced (excluding stores) but not less than	4.0	4.5
	k) Bath and toilets rooms	2.0	—
	m) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 metre run concentrated at the outer edge
	n) Stationary stores	4.0 for each metre of storage height	9.0
	p) Boiler rooms and plant rooms — to be calculated but not less than	5.0	6.7
	q) Libraries	*See* Sl No. (ii)	

Table 1 — *Concluded*

(1)	(2)	(3)	(4)
vi)	*Merchantile Buildings*		
	a) Retail shops	4.0	3.6
	b) Wholesale shops — to be calculated but not less than	6.0	4.5
	c) Office rooms	2.5	2.7
	d) Dining rooms, restaurants and cafeterias	3.0[1]	2.7
	e) Toilets	2.0	—
	f) Kitchens and laundries	3.0	4.5
	g) Boiler rooms and plant rooms — to be calculated but not less than	5.0	6.7
	h) Corridors, passages, staircases including fire escapes and lobbies	4.0	4.5
	j) Corridors, passages, staircases subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like	5.0	4.5
	k) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 metre run concentrated at the outer edge
vii)	*Industrial Buildings*[4]		
	a) Work areas without machinery/equipment	2.5	4.5
	b) Work areas with machinery/equipment[3]		
	1) Light duty } To be calculated but not less than	5.0	4.5
	2) Medium duty } To be calculated but not less than	7.0	4.5
	3) Heavy duty } To be calculated but not less than	10.0	4.5
	c) Boiler rooms and plant rooms — to be calculated but not less than	5.0	6.7
	d) Cafeterias and dinning rooms	3.0[1]	2.7
	e) Corridors, passages, staircases including fire escapes	4.0	4.5
	f) Corridors, passages, lobbies, staircases subject to machine loads and wheeled vehicles — to be calculated but not less than	5.0	4.5
	g) Kitchens	3.0	4.5
	h) Toilets and bathrooms	2.0	—
viii)	*Storage Buildings*[4]		
	a) Storage rooms (other than cold storage) and warehouses — to be calculated based on the bulk density of materials stored but not less than	2.4 kN/m^2 per metre of storage height with a minimum of 7.5 kN/m^2	7.0
	b) Cold storage — to be calculated but not less than	5.0 kN/m^2 per metre of storage height with a minimum of 15 kN/m^2	9.0
	c) Corridors, passages, staircases including fire escapes — as per the floor serviced but not less than	4.0	4.5
	d) Corridors, passages subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like	5.0	4.5
	e) Boiler rooms and plant rooms	7.5	4.5

[1] Where unrestricted assembly of persons is anticipated, the value of UDL should be increased to 4.0 kN/m^2

[2] With fixed seats' implies that the removal of the seating and the use of the space for other purposes is improbable. The maximum likely load in this case is, therefore, closely controlled.

[3] The loading in industrial buildings (workshops and factories) varies considerably and so three loadings under the terms 'light', 'medium' and 'heavy' are introduced in order to allow for more economical designs but the terms have no special meaning in themselves other than the imposed load for which the relevant floor is designed. It is, however, important particularly in the case of heavy weight loads, to assess the actual loads to ensure that they are not in excess of 10 kN/m^2; in case where they are in excess, the design shall be based on the actual loadings.

[4] For various mechanical handling equipment which are used to transport goods, as in warehouses, workshops, store rooms, etc, the actual load coming from the use of such equipment shall be ascertained and design should cater to such loads.

3.3.1.1 *Load application*

The uniformly distributed loads specified in Table 1 shall be applied as static loads over the entire floor area under consideration or a portion of the floor area whichever arrangement produces critical effects on the structural elements as provided in respective design codes.

In the design of floors, the concentrated loads are

considered to be applied in the positions which produce the maximum stresses and where deflection is the main criterion in the positions which produce the maximum deflections. Concentrated load, when used for the calculation of bending and shear, are assumed to act at a point. When used for the calculation of local effects, such as, crushing or punching, they are assumed to act over an actual area of application of 0.3 m × 0.3 m.

3.3.1.2 *Loads due to light partitions*

In office and other buildings, where actual loads due to light partitions cannot be assessed at the time of planning the floors and the supporting structural members shall be designed to carry, in addition to other loads, uniformly distributed loads per square metre of not less than 33.33 percent of weight per metre run of finished partitions, subject to a minimum of 1 kN/m^2, provided total weight of partition walls per m^2 of the wall area does not exceed 1.5 kN/m^2 and the total weight per metre length is not greater than 4.0 kN.

3.3.2 *Reduction in Imposed Loads on Floors*

3.3.2.1 *For members supporting floors*

Except as provided for in **3.3.2.1** (a), the following reductions in assumed total imposed loads on the floors may be made in designing columns, load bearing walls, piers, their supports and foundations.

Number of Floors (Including the Roof) to be Carried by Member Under Consideration	*Reduction in Total Distributed Imposed Load on All Floors to be Carried by the Member Under Consideration Percent*
(1)	(2)
1	0
2	10
3	20
4	30
5 to 10	40
Over 10	50

a) No reduction shall be made for any plant or machinery which is specifically allowed for, or for buildings for storage purposes, warehouses and garages. However, for other buildings, where the floor is designed for an imposed floor load of 5.0 kN/m^2 or more, the reductions shown in **3.3.2.1** may be taken provided that the loading assumed is not less than it would have been if all the floors had been designed for 5.0 kN/m^2 with no reductions.

NOTE — In case if the reduced load in the lower floor is lesser than the reduced load in the upper floor, then the reduced load of the upper floor will be adopted.

b) An example is given in Annex A illustrating the reduction of imposed loads in a multi-storeyed building in the design of column members.

3.3.2.2 *For beams in each floor level*

Where a single span of beam, girder or truss supports not less than 50 m^2 of floor at one general level, the imposed floor load may be reduced in the design of the beams, girders or trusses by 5 percent for each 50 m^2 area supported subject to a maximum reduction of 25 percent. However, no reduction shall be made in any of the following types of loads:

a) any superimposed moving load,
b) any actual load due to machinery or similar concentrated loads,
c) the additional load in respect of partition walls; and
d) any impact or vibration.

NOTE — The above reduction does not apply to beams, girdes or trusses supporting roof loads.

3.3.3 *Posting of Floor Capacities*

Where a floor or part of a floor of a building has been designed to sustain a uniformly distributed load exceeding 3.0 kN/m^2 and in assembly, business mercantile, industrial or storage buildings, a permanent notice in the form shown below indicating the actual uniformly distributed and/or concentrated loadings for which the floor has been structurally designed shall be posted in a conspicuous place in a position adjacent to such floor or on such part of a floor.

DESIGNED IMPOSED FLOOR LOADING

Distributed.....kN/m^2

Concentrated.....kN

Label Indicating Designed Imposed Floor Loading

NOTES

1 The lettering of such notice shall be embossed or cast suitably on a tablet whose least dimension shall not be less than 0.25 m and located not less than 1.5-m above floor level with lettering of a minimum size of 25 mm.

2 If a concentrated load or a bulk load has to occupy a definite position on the floor, the same could also be indicated in the lable.

3.4 Imposed Loads on Roofs

3.4.1 *Imposed Loads on Various Types of Roofs*

On flat roofs, sloping roofs and curved roofs, the imposed loads due to use and occupancy of the buildings and the geometry of the types of roofs shall be as given in Table 2.

Table 2 Imposed Loads on Various Types of Roofs

(*Clause* 3.4.1)

Sl No.	Type of Roof	Imposed Load Measured on Plan Area	Minimum Imposed Load Measured on Plan
(1)	(2)	(3)	(4)
i)	Flat, sloping or curved roof with slopes up to and including 10 degrees		
	a) Access provided	1.5 kN/m^2	3.75 kN uniformly distributed over any span of one metre width of the roof slab and 9 kN uniformly distributed over the span of any beam or truss or wall
	b) Access not provided except for maintenance	0.75 kN/m^2	1.9 kN uniformly distributed over any span of one metre width of the roof slab and 4.5 kN uniformly distributed over the span of any beam or truss or wall
ii)	Sloping roof with slope greater than 10°	For roof membrane sheets or purlins – 0.75 kN/m^2 less 0.02 kN/m^2 for every degree increase in slope over 10°	Subject to a minimum of 0.4 kN/m^2
iii)	Curved roof with slope of line obtained by joining springing point to the crown with the horizontal, greater than 10°	$(0.75 - 0.52\,\alpha^2)$ kN/m^2 where $\alpha = h/l$ h = height of the highest point of the structure measured from its springing; and l = chord width of the roof if singly curved and shorter of the two sides if doubly curved. Alternatively, where structural analysis can be carried out for curved roofs of all slopes in a simple manner applying the laws of statistics, the curved roofs shall be divided into minimum 6 equal segments and for each segment imposed load shall be calculated appropriate to the slope of the chord of each segment as given in (i) and (ii).	Subject to a minimum of 0.4 kN/m^2

NOTES

1 The loads given above do not include loads due to snow, rain, dust collection, etc. The roof shall be designed for imposed loads given above or for snow/rain load, whichever is greater.

2 For special types of roofs with highly permeable and absorbent material, the contingency of roof material increasing in weight due to absorption of moisture shall be provided for.

3.4.1.1 Roofs of buildings used for promenade or incidental to assembly purposes shall be designed for the appropriate imposed floor loads given in Table 1 for the occupancy.

3.4.2 *Concentrated Load on Roof Coverings*

To provide for loads incidental to maintenance, unless otherwise specified by the Engineer-in-Charge, all roof coverings (other than glass or transparent sheets made of fibre glass) shall be capable of carrying an incidental load of 0.90 kN concentrated on an area of 12.5 cm^2 so placed as to produce maximum stresses in the covering. The intensity of the concentrated load may be reduced with the approval of the Engineer-in-Charge, where it is ensured that the roof coverings would not be traversed without suitable aids. In any case, the roof coverings shall be capable of carrying the loads in accordance with **3.4.1**, **3.4.3**, **3.4.4** and wind load.

3.4.3 *Loads Due to Rain*

On surfaces whose positioning, shape and drainage system are, such as, to make accumulation of rain water possible, loads due to such accumulation of water and the imposed loads for the roof as given in Table 2 shall be considered separately and the more critical of the two shall be adopted in the design.

3.4.4 *Dust Loads*

In areas prone to settlement of dust on roofs (example, steel plants, cement plants), provision for dust load equivalent to probable thickness of accumulation of dust may be made.

3.4.5 *Loads on Members Supporting Roof Coverings*

Every member of the supporting structure which is directly supporting the roof covering(s) shall be

designed to carry the more severe of the following loads except as provided in **3.4.5.1**:

a) The load transmitted to the members from the roof covering(s) in accordance with **3.4.1**, **3.4.3** and **3.4.4**; and

b) An incidental concentrated load of 0.90 kN concentrated over a length of 12.5 cm placed at the most favourable positions on the member.

NOTE — Where it is ensured that the roofs would be traversed only with the aid of planks and ladders capable of distributing the loads on them to two or more supporting members, the intensity of concentrated load indicated in **3.4.5** (b) may be reduced to 0.5 kN with the approval of the Engineer-in-Charge.

3.4.5.1 In case of sloping roofs with slope greater than 10°, members supporting the roof purlins, such as trusses, beams, girders, etc, may be designed for two-thirds of the imposed load on purlin or roofing sheets.

3.5 Imposed Horizontal Loads on Parapets and Balustrades

3.5.1 *Parapets, Parapet Walls and Balustrades*

Parapets, parapet walls and balustrades, together with the members which give them structural support, shall be designed for the minimum loads given in Table 3. These are expressed as horizontal forces acting at handrail or coping level. These loads shall be considered to act vertically also but not simultaneously with the horizontal forces. The values given in Table 3 are minimum values and where values for actual loadings are available, they shall be used instead.

3.5.2 *Grandstands and the Like*

Grandstands, stadia, assembly platforms, reviewing stands and the like shall be designed to resist a horizontal force applied to seats of 0.35 kN per linear metre along the line of seats and 0.15 kN per linear metre perpendicular to the line of the seats. These loadings need not be applied simultaneously. Platforms without seats shall be designed to resist a minimum horizontal force of 0.25 kN/m^2 of plan area.

3.6 Loading Effects Due to Impact and Vibration

The crane loads to be considered under imposed loads shall include the vertical loads, eccentricity effects induced by vertical loads, impact factors, lateral and longitudinal braking forces acting across and along the crane rails respectively.

3.6.1 *Impact Allowance for Lifts, Hoists and Machinery*

The imposed loads specified in **3.3.1** shall be assumed to include adequate allowance for ordinary impact conditions. However, for structures carrying loads which induce impact or vibration, as far as possible, calculations shall be made for increase in the imposed load due to impact or vibration. In the absence of sufficient data for such calculation, the increase in the imposed loads shall be as follows:

Table 3 Horizontal Loads on Parapets, Parapet Walls and Balustrades

(*Clause* 3.5.1)

Sl No.	Usage Area	Intensity of Horizontal Load kN/m Run
(1)	(2)	(3)
i)	Light access stairs, gangways and like not more than 600 mm wide	0.25
ii)	Light access stairs, gangways and like, more than 600 mm wide; stairways, landings, balconies and parapet walls (private and part of dwellings)	0.35
iii)	All other stairways, landings and balconies and all parapets and handrails to roofs [except those subject to overcrowding covered under (iv)]	0.75
iv)	Parapets and balustrades in place of assembly, such as theatres, cinemas, churches, schools, places of entertainment, sports and buildings and buildings likely to be overcrowded	2.25

NOTE — In the case of guard parapets on a floor of multi-storeyed car park or crash barriers provided in certain buildings for fire escape, the value of imposed horizontal load (together with impact load) may be determined.

	Structures	*Impact Allowance, Percent, Min*
a)	For frames supporting lifts and hoists	100
b)	For foundations, footings and piers supporting lifts and hoisting apparatus	40
c)	For supporting structures and foundations for light machinery, shaft or motor units	20
d)	For supporting structures and foundations for reciprocating machinery or power units	50

3.6.2 *Concentrated Imposed Loads with Impact and Vibration*

Concentrated imposed loads with impact and vibration which may be due to installed machinery shall be considered and provided for in the design. The impact factor shall not be less than 20 percent which is the amount allowable for light machinery.

3.6.2.1 Provision shall also be made for carrying any

concentrated equipment loads while the equipment is being installed or moved for servicing and repairing.

3.6.3 *Impact Allowance for Crane Girders*

For crane gantry girders and supporting columns, the impact allowances (given in informal table below) shall be deemed to cover all forces set up by vibration, shock from slipping of slings, kinetic action of acceleration, and retardation and impact of wheel loads.

Forces specified in (c) and (d) shall be considered as acting at the rail level and being appropriately transmitted to the supporting system. Gantry girders and their vertical supports shall be designed on the assumption that either of the horizontal forces in (c) and (d) may act at the same time as the vertical load.

NOTE — *See* [6-1(3)] for classification (Class I to IV) of cranes.

Impact Allowance for Crane Girders

(*Clause* 3.6.3)

Type of Load	*Additional Load*
a) Vertical loads for electric overhead cranes	25 percent of maximum static loads for crane girders for all class of cranes 25 percent for columns supporting Class III and Class IV cranes. 10 percent for columns supporting Class I and Class II cranes. No additional load for design of foundations.
b) Vertical loads for hand operated cranes	10 percent of maximum wheel loads for crane girders only
c) Horizontal forces transverse to rails:	
1) For electric overhead cranes with trolley having rigid mast for suspension of lifted weight (such as, soaker crane, stripper crane, etc)	10 percent of weight of crab and the weight lifted by the cranes, acting on any one crane track rail, acting in either direction and equally distributed amongst all the wheels on one side of rail track For frame analysis, this force, calculated as above, shall be applied on one side of the frame at a time in either direction.
2) For all other electric overhead cranes and hand operated cranes	5 percent of weight of crab and the weight lifted by the cranes, acting on any one crane track rail, acting in either direction and equally distributed amongst the wheels on one side of rail track For the frame analysis, the force, calculated as above, shall be applied on one side of the frame at a time in either direction.
d) Horizontal traction forces along the rails for overhead cranes, either electrically operated or hand operated	5 percent of all static wheel loads

3.6.3.1 *Overloading factors in crane supporting structures*

For all ladle cranes and charging cranes where there is possibility of overloading from production considerations, an overloading factor of 10 percent of the maximum wheel loading shall be taken.

3.6.4 *Crane Load Combinations*

In the absence of any specific indications, the load combinations shall be as indicated below.

3.6.4.1 *Vertical loads*

In an aisle, where more than one crane is in operation or has provision for more than one crane in future, the following load combinations shall be taken for vertical loading:

a) Two adjacent cranes working in tandem with full load and with overloading according to **3.6.3.1**; and

b) For long span gantries, where more than one crane can come in the span, the girder shall be designed for one crane fully loaded with overloading according to **3.6.3.1** plus as many loaded cranes as can be accommodated on the span but without taking into account overloading according to **3.6.3** (a) to give the maximum effect.

3.6.4.2 *Lateral surge*

For design of columns and foundations, supporting crane girders, the following crane combinations shall be considered:

a) *For Single Bay Frames* — Effect of one crane in the bay giving the worst effect shall be considered for calculation of surge force; and

b) *For Multi-Bay Frames* — Effect of two cranes working, one each in any of two bays in the cross-section to give the worst effect shall be considered for calculation of surge force.

3.6.4.3 *Tractive force*

a) Where one crane is in operation with no provision for future crane, tractive force from only one crane shall be taken.

b) Where more than one crane is in operation or there is provision for future crane, tractive force from two cranes giving maximum effect shall be considered.

NOTE – Lateral surge force and longitudinal tractive force acting across and along the crane rail respectively shall not be assumed to act simultaneously. However, if there is only one crane in the bay, the lateral and longitudinal forces may act together simultaneously with vertical loads.

4 WIND LOAD

4.1 General

This clause gives wind forces and their effects (static and dynamic) that should be taken into account when designing buildings, structures and components thereof.

NOTES

1 It is believed that ultimately wind load estimation will be made by taking into account the random variation of wind speed with time, but available theoretical methods have not matured sufficiently at present for use in the Section. For this reason, equivalent static load estimation which implies a steady wind speed, which has proved to be satisfactory for normal, short and heavy structures, is given in **4.5** and **4.6**. However, a beginning has been made to take account of the random nature of the wind speed by requiring that the along-wind or drag load on structures which are prone to wind induced oscillations, be also determined by the gust factor method (*see* **4.8**) and the more severe of the two estimates be taken for design.

A large majority of structures met within practice do not, however, suffer wind induced oscillations and generally do not require to be examined for the dynamic effects of wind including use of gust factor method. Nevertheless, there are various types of structures or their components, such as some tall buildings, etc, which require investigation of wind induced oscillations. In identifying and analyzing such structures **4.6** shall be followed.

2 In the case of tall structures with unsymmetrical geometry, the designs may have to be checked for torsional effects due to wind pressure.

4.1.1 Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind, vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 m above ground.

4.1.2 Very strong wind speeds (greater than 80 km/h) are generally associated with cyclonic storms, thunderstorms, dust storms or vigorous monsoons. A feature of the cyclonic storms over the Indian area is that they rapidly weaken after crossing the coasts and move as depressions/lows inland. The influence of a severe storm after striking the coast does not, in general, exceed about 60 km, though sometimes, it may extend even up to 120 km. Very short duration hurricanes of very high wind speeds called *Kal Baisaki* or Norwesters occur fairly frequently during summer months over North-Eastern India.

4.1.3 The wind speeds recorded at any locality are extremely variable and, in addition to steady wind at any time, there are effects of gusts which may last for a few seconds. These gusts cause increase in air pressure but their effect on the stability of the building may not be so important; often, gusts affect only part of the building and the increased local pressures may be more than balanced by a momentary reduction in the pressure elsewhere. Because of the inertia of the building, short period gusts may not cause any appreciable increase in stress in the main components of the building, although the walls, roof sheeting and individual cladding units (glass panels) and their supporting members, such as purlins, sheeting rails and glazing bars may be more seriously affected. Gusts can also be extremely important for the design of structures with high slenderness ratios.

4.1.4 The liability of a building to high wind pressures depends not only upon the geographical location and proximity of other obstructions to air flow but also upon the characteristics of the structure itself.

4.1.5 The effect of wind on the structure as a whole is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply.

4.1.6 Buildings shall also be designed with due attention to the effects of wind on the comfort of people inside and outside the buildings.

4.1.7 The stability calculations of the building as a whole shall be done considering the combined effect, as well as separate effects of imposed loads and wind

loads on vertical surfaces, roofs and other parts of the building above the general roof level.

4.2 Notations

The notations to be followed, unless otherwise specified in relevant clauses under wind loads, are given in Annex B.

4.3 Terminology

4.3.1 For the purpose of wind loads, the following definitions shall apply.

4.3.1.1 *Angle of attack* — Angle between the direction of wind and a reference axis of the structure.

4.3.1.2 *Breadth* — Breadth means horizontal dimension of the building measured normal to the direction of wind.

4.3.1.3 *Depth* — Depth means the horizontal dimension of the building measured in the direction of the wind.

NOTE — Breadth and depth are dimensions measured in relation to the direction of the wind, whereas length and width are dimensions related to the plan.

4.3.1.4 *Developed height*

Developed height is the height of upward penetration of the velocity profile in a new terrain. At large, fetch lengths, such penetration reaches the gradient height above which the wind speed may be taken to be constant. At lesser-fetch lengths, a velocity profile of a smaller height but similar to that of the fully developed profile of that terrain category has to be taken, with the additional provision that the velocity at the top of this shorter profile equals that of the unpenetrated earlier velocity profile at that height.

4.3.1.5 *Effective frontal area*

The projected area of the structure normal to the direction of the wind.

4.3.1.6 *Element surface area*

The area of surface over which the pressure coefficient is taken to be constant.

4.3.1.7 *Force coefficient*

A non-dimensional coefficient such that the total wind force on a body is the product of the force coefficient, the dynamic pressure of the incident design wind speed and the reference area over which the force is required.

NOTE — When the force is in the direction of the incident wind, the non-dimensional coefficient will be called as drag coefficient. When the force is perpendicular to the direction of incident wind the non-dimensional coefficient will be called as 'lift coefficient'.

4.3.1.8 *Ground roughness*

The nature of the earth's surface as influenced by small scale obstructions such as trees and buildings (as distinct from topography) is called ground roughness.

4.3.1.9 *Gust*

A positive or negative departure of wind speed from its mean value, lasting for not more than say 2 min over a specified interval of time.

4.3.1.10 *Peak gust*

Peak gust or peak gust speed is the wind speed associated with the maximum amplitude.

4.3.1.11 *Fetch length*

Fetch length is the distance measured along the wind from a boundary at which a change in the type of terrain occurs. When the changes in terrain types are encountered (such as the boundary of a town or city, forest, etc), the wind profile changes in character but such changes are gradual and start at ground level, spreading or penetrating upwards with increasing fetch length.

4.3.1.12 *Gradient height*

Gradient height is the height above the mean ground level at which the gradient wind blows as a result of balance among pressure gradient force, coriolis force and centrifugal force. For the purpose of this Section, the gradient height is taken as the height above the mean ground level above which the variation of wind speed with height need not be considered.

4.3.1.13 *Mean ground level*

The mean ground level is the average horizontal plane of the area enclosed by the boundaries of the structure.

4.3.1.14 *Pressure coefficient*

Pressure coefficient is the ratio of the difference between the pressure acting at a point on a surface and the static pressure of the incident wind to the design wind pressure, where the static and design wind pressure are determined at the height of the point considered after taking into account the geographical location, terrain conditions and shielding effect. The pressure coefficient is also equal to $[1-(V_p/V_z)^2]$, where V_p is the actual wind speed at any point on the structure at a height corresponding to that of V_z.

NOTE — Positive sign of the pressure coefficient indicates pressure acting towards the surface and negative sign indicates pressure acting away from the surface.

4.3.1.15 *Return period*

Return period is the number of years, the reciprocal of which gives the probability of extreme wind exceeding a given wind speed in any one year.

4.3.1.16 *Shielding effect*

Shielding effect or shielding refers to the condition where wind has to pass along some structure(s) or structural element(s) located on the upstream wind side, before meeting the structure or structural element under consideration. A factor called 'shielding factor' is used to account for such effects in estimating the force on the shielded structures.

4.3.1.17 *Suction*

Suctions means pressure less than the atmospheric (static) pressure and is taken to act away from the surface.

4.3.1.18 *Solidity ratio*

Solidity ratio is equal to the effective area (projected area of all the individual elements) of a frame normal to the wind direction divided by the area enclosed by the boundary of the frame normal to the wind direction.

NOTE — Solidity ratio is to be calculated for individual frames.

4.3.1.19 *Terrain category*

Terrain category means the characteristics of the surface irregularities of an area which arise from natural or constructed features. The categories are numbered in increasing order of roughness.

4.3.1.20 *Velocity profile*

The variation of the horizontal component of the atmospheric wind speed at different heights above the mean ground level is termed as velocity profile.

4.3.1.21 *Topography*

The nature of the earth's surface as influenced by the hill and valley configurations.

4.4 Wind Speed and Pressure

4.4.1 *Nature of Wind in Atmosphere*

In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to a maximum at a height called the gradient height. There is usually a slight change in direction (Ekman effect) but this is ignored in the Section. The variation with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this average value. The average value depends on the averaging time employed in analyzing the meteorological data and this averaging time varies from a few seconds to several minutes. The magnitude of the fluctuating component of the wind speed, which is called as gust, depends on the averaging time. In general, smaller the averaging interval, greater is the magnitude of the gust speed.

4.4.2 *Basic Wind Speed*

Figure 1 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 s and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 1 have been worked out for a 50 year return period. Basic wind speed for some important cities/towns is also given in Annex C.

4.4.3 *Design Wind Speed* (V_z)

The basic wind speed (V_b) for any site shall be obtained from Fig. 1 and shall be modified to include the following effects to get V_z, design wind speed at any height for the chosen structure.

a) risk level;
b) terrain roughness, height and size of structure; and
c) local topography.

It can be mathematically expressed as follows:

$$V_z = V_b k_1 k_2 k_3$$

where

V_z = design of wind speed at any height z in m/s;
V_b = basic wind speed in m/s (Fig. 1);
k_1 = probability factor (risk coefficient) (**4.4.3.1**);
k_2 = terrain, height and structure size factor (**4.4.3.2**); and
k_3 = topography factor (**4.4.3.3**)

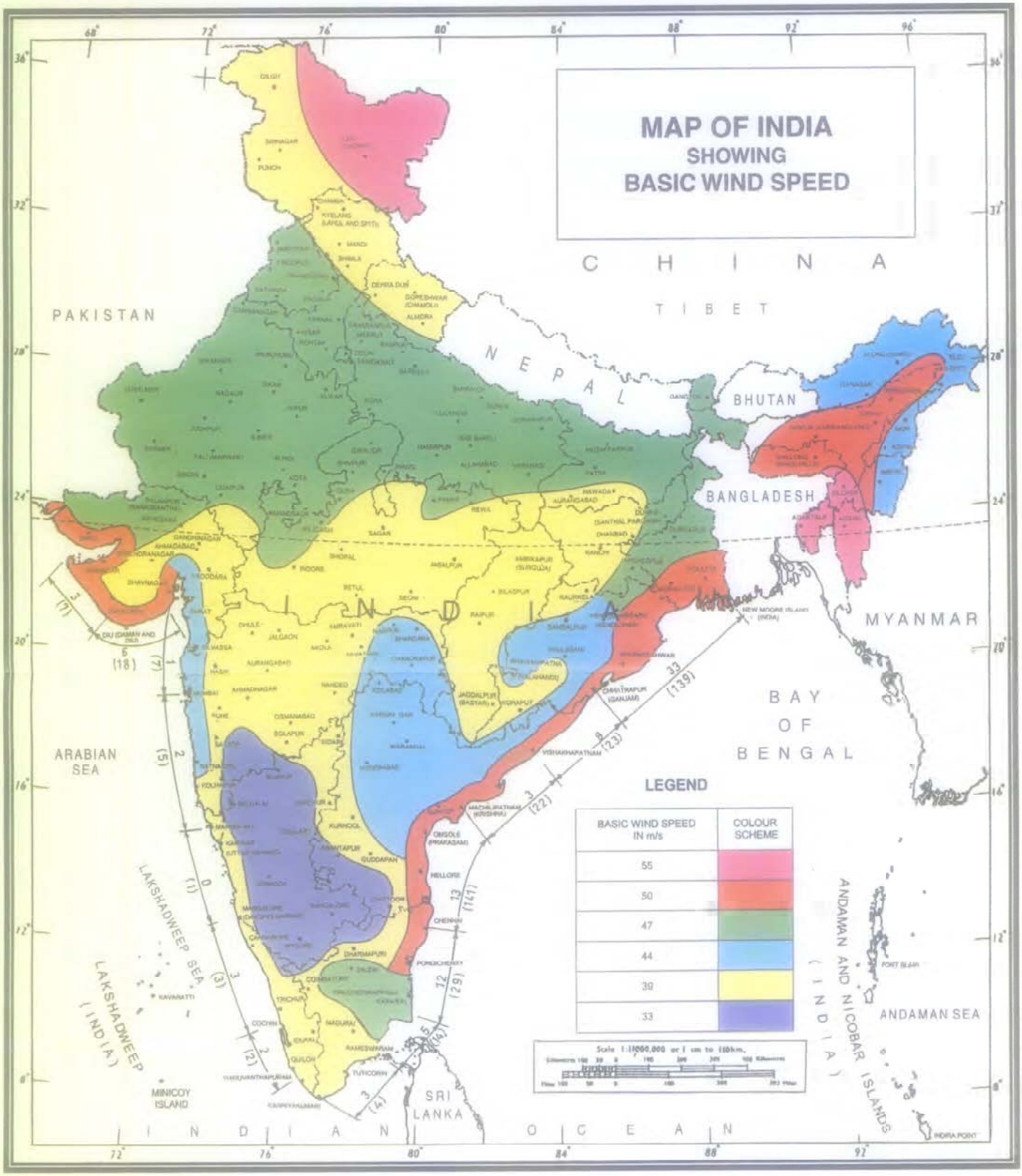
NOTE — Design wind speed up to 10 m height from mean ground level shall be considered constant.

4.4.3.1 *Risk coefficient* (k_1)

Figure 1 gives basic wind speeds for terrain Category 2 as applicable at 10 m above ground level based on 50 year mean return period. The suggested life period to be assumed in design and the corresponding k_1 factors for different classes of structure for the purpose of design is given in Table 4. In the design of all buildings and structures, a regional basic wind speed having a mean return period of 50 years shall be used except as specified in the note of Table 4.

4.4.3.2 *Terrain, height and structure size factor* (k_2)

a) *Terrain* — Selection of terrain categories shall be made with due regard to the effect of the obstruction which constitute the ground surface roughness. The terrain category used in the



Based upon Survey of India Outline Map printed in 1993.

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

FIG. 1 BASIC WIND SPEED IN m/s (BASED ON 50-YEARS RETURN PERIOD)

Table 4 Risk Coefficients for Different Classes of Structures in Different Wind Speed Zones

(*Clause* 4.4.3.1)

Class of Structure	Mean Probable Design Life of Structure in Years	k_1 Factor for Basic Wind Speed (m/s) of					
		33	39	44	47	50	55
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
All general buildings and structures	50	1.0	1.0	1.0	1.0	1.0	1.0
Temporary sheds, structures such as those used during construction operations (for example, formwork and falsework), structures during construction stages and boundary walls	5	0.82	0.76	0.73	0.71	0.70	0.67
Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings, other than residential buildings	25	0.94	0.92	0.91	0.90	0.90	0.89
Important buildings and structures, such as hospitals, communications buildings/towers and power plant structures	100	1.05	1.06	1.07	1.07	1.08	1.08

$$k_1 = \frac{X_N P_N}{X_{50,0.63}} = \frac{A - B\left[ln\{-\frac{1}{N} ln(1-P_N)\}\right]}{A+4B}$$

where

N = mean probable design life of structure in years;

P_N = risk level in N consecutive years (probability that the design wind speed is exceeded at least once in N successive years), nominal value = 0.63;

X_N, P_N = extreme wind speed for given values of N and P_N; and

$X_{50,0.63}$ = extreme wind speed for N = 50 years and P_N = 0.63

A and B are coefficients having the following values for different basic wind speed zones:

Zone	A	B
33 m/s	83.2	9.2
39 m/s	84.2	14.0
44 m/s	88.0	18.0
47 m/s	88.0	20.5
50 m/s	88.8	22.8
55 m/s	90.8	27.3

NOTE — The factor k_1 is based on statistical concepts which take account of the degree of reliability required and period of time in years during which there will be exposure to wind, that is, life of the structure. Whatever wind speed is adopted for design purposes, there is always a probability (however small) that it may be exceeded in a storm of exceptional violence; the greater the period of years over which there will be exposure to wind, the greater is the probability. Higher return periods ranging from 100 to 1 000 years (implying lower risk level) in association with greater periods of exposure may have to be selected for exceptionally important structures, such as nuclear power reactors and satellite communication towers. Equation given above may be used in such cases to estimate k_1 factors for different periods of exposure and chosen probability of exceedence (risk level). The probability level of 0.63 is normally considered sufficient for design of buildings and structures against wind effects and the values of k_1 corresponding to this risk level are given in Table 4.

design of a structure may vary depending on the direction of wind under consideration. Wherever sufficient meteorological information is available about the nature of wind direction, the orientation of any building or structure may be suitably planned.

Terrian, in which a specific structure stands, shall be assessed as being one of the following terrain categories:

Category 1 — Exposed open terrain with few or no obstructions and in which the average height of any objects surrounding the structure is less than 1.5 m.

NOTE — This category includes open sea-coasts and flat treeless plains.

Category 2 — Open terrain with well scattered obstructions having heights generally between 1.5 and 10 m.

NOTE — This is the criterion for measurement of regional basic wind speeds and includes airfields, open parklands and undeveloped sparsely built-up outskirts of towns and suburbs. Open land adjacent to sea coast may also be classified as category 2 due to roughness of large sea waves at high winds.

Category 3 — Terrain with numerous closely spaced obstruction having the size of building-structures up to 10 m in height with or without a few isolated tall structures.

NOTES

1 This category includes well wooded areas and shrubs, towns and industrial areas fully or partially developed.

2 It is likely that the next higher category than this will not exist in most design situations and that selection of a more severe category will be deliberate.

3 Particular attention must be given to the performance of the obstructions in areas affected by fully developed tropical cyclones. Vegetation, which is likely to be blown down or defoliated, cannot be relied upon to maintain Category 3 conditions. Where such situation may exist, either an intermediate category with velocity multipliers midway between the values for Categories 2 and 3 given in Table 5 or Category 2 should be selected having due regard to local conditions.

Category 4 — Terrain with numerous large high closely spaced obstructions.

NOTE — This category includes large city centres, generally with obstructions above 25 m and well developed industrial complexes.

b) *Variation of Wind Speed with Height for Different Sizes of Structure in Different Terrains (k_2 Factor)* — Table 5 gives multiplying factors (k_2) by which the basic wind speed given in Fig. 1 shall be multiplied to obtain the wind speed at different heights, in each terrain category for different sizes of buildings/structures.

The buildings/structures are classified into the following three different classes depending upon their size:

Class A — Buildings and/or their components, such as cladding, glazing, roofing etc, having maximum dimension (greatest horizontal or vertical dimension) less than 20 m.

Class B — Buildings and/or their components, such as cladding, glazing, roofing etc, having maximum dimension (greatest horizontal or vertical dimension) between 20 m and 50 m.

Class C — Buildings and/or their components, such as cladding, glazing, roofing etc, having maximum dimension (greatest horizontal or vertical dimension) greater than 50 m.

c) *Terrain Categories in Relation to the Direction of Wind* — The terrain category used in the design of a building may vary depending on the direction of wind under consideration. Where sufficient meteorological information is available, the basic wind speed may be varied for specific wind direction.

Table 5 k_2 Factors to Obtain Design Wind Speed Variation with Height in Different Terrains for Different Classes of Building Structures

[*Clause* 4.4.3.2 (b)]

Height (m)	Terrain Category 1 Class			Terrain Category 2 Class			Terrain Category 3 Class			Terrain Category 4 Class		
	A	B	C	A	B	C	A	B	C	A	B	C
10	1.05	1.03	0.99	1.00	0.98	0.93	0.91	0.88	0.82	0.80	0.76	0.67
15	1.09	1.07	1.03	1.05	1.02	0.97	0.97	0.94	0.87	0.80	0.76	0.67
20	1.12	1.10	1.06	1.07	1.05	1.00	1.01	0.98	0.91	0.80	0.76	0.67
30	1.15	1.13	1.09	1.12	1.10	1.04	1.06	1.03	0.96	0.97	0.93	0.83
50	1.20	1.18	1.14	1.17	1.15	1.10	1.12	1.09	1.02	1.10	1.05	0.95
100	1.26	1.24	1.20	1.24	1.22	1.17	1.20	1.17	1.10	1.20	1.15	1.05
150	1.30	1.28	1.24	1.28	1.25	1.21	1.24	1.21	1.15	1.24	1.20	1.10
200	1.32	1.30	1.26	1.30	1.28	1.24	1.27	1.24	1.18	1.27	1.22	1.13
250	1.34	1.32	1.28	1.32	1.31	1.26	1.29	1.26	1.20	1.28	1.24	1.16
300	1.35	1.34	1.30	1.34	1.32	1.28	1.31	1.28	1.22	1.30	1.26	1.17
350	1.37	1.35	1.31	1.36	1.34	1.29	1.32	1.30	1.24	1.31	1.27	1.19
400	1.38	1.36	1.32	1.37	1.35	1.30	1.34	1.31	1.25	1.32	1.28	1.20
450	1.39	1.37	1.33	1.38	1.36	1.31	1.35	1.32	1.26	1.33	1.29	1.21
500	1.40	1.38	1.34	1.39	1.37	1.32	1.36	1.33	1.28	1.34	1.30	1.22

NOTES

1 *See* **4.4.3.2** (b) for definitions of Class A, Class B and Class C structures.

2 Intermediate values may be obtained by linear interpolation, if desired. It is permissible to assume constant wind speed between two heights for simplicity.

d) *Changes in Terrain Categories* — The velocity profile for a given terrain category does not develop to full height immediately with the commencement of that terrain category, but develops gradually to height (h_x), which increases with the fetch or upwind distance (x)

1) *Fetch and Developed Height Relationship* — The relation beween the developed height (h_x) and the fetch (x) for wind-flow over each of the four terrain categories may be taken as given in Table 6.

2) For buildings of heights greater than the developed height (h_x) in Table 6, the velocity profile may be determined in accordance with the following:

i) The less or least terrain; or

ii) The method described in Annex D.

Table 6 Fetch and Developed Height Relationship

[*Clause* 4.4.3.2 (b)]

Developed Height, h_x in m

Fetch (x) km	Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
(1)	(2)	(3)	(4)	(5)
0.2	12	20	35	60
0.5	20	30	35	95
1	25	45	80	130
2	35	65	110	190
5	60	100	170	300
10	80	140	250	450
20	120	200	350	500
50	180	300	400	500

4.4.3.3 *Topography (k_3, factor)*

The basic wind speed V_b given in Fig. 1 takes account of the general level of the site above sea level. This does not allow for local topographic features, such as hills, valleys, cliffs, escarpments or ridges, which can significantly affect wind speed in their vicinity. The effect of topography is to accelerate wind near the summits of hills or crests of cliffs, escarpments or ridges and decelerate the wind in valleys or near the foot of cliffs, steep escarpments or ridges.

The effect of topography will be significant at a site when the upwind slope is greater than about 3°, and below that the value of k_3 may be taken to be equal to 1.0. The value of k_3 is confined in the range of 1.0 to 1.36 for slopes greater than 3°. A method of evaluating the value of k_3 for slope greater than 3° is given in Annex E. It may be noted that the value of k_3 varies with height above ground level with a maximum near the ground, and reducing to 1.0 at higher levels.

4.4.4 *Design Wind Pressure*

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity:

$$p_z = 0.6\ V_z^2$$

where

p_z = design wind pressure in N/m^2 at height Z, and

V_z = design wind velocity in m/s at height Z.

NOTE — The coefficient 0.6 (in SI units) in the above formula depends on a number of factors, and mainly on the atmospheric pressure and air temperature. The value chosen corresponds to the average appropriate Indian atmospheric conditions.

4.4.5 *Offshore Wind Velocity*

Cyclonic storms form far way from the sea coast and gradually reduce in speed as they approach the sea coast. Cyclonic storms generally extend up to about 60 km inland after striking the coast. Their effect on land is already reflected in basic wind speeds specified in Fig. 1. The influence of wind speed off the coast up to a distance of about 200 km may be taken as 1.15 times the value on the nearest coast in the absence of any definite wind data.

4.5 Wind Pressure and Forces on Buildings/ Structure

4.5.1 *General*

The wind load on a building shall be calculated for:

a) the building as a whole;

b) individual structural elements as roofs and walls; and

c) individual cladding units including glazing and their fixings.

4.5.2 *Pressure Coefficients*

The pressure coefficients are always given for a particular surface or part of the surface of a building. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (C_p); and the design wind pressure at the height of the surface from the ground. The average values of these pressure coefficients for some building shapes are given in **4.5.2.2** and **4.5.2.3**.

Average values of pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building, the total load should be calculated for each of the critical directions shown from all quadrants.

coefficients given for each of its several parts.

In addition, areas of high local suction (negative pressure concentration) frequently occurring near the edges of walls and roofs are separately shown. Coefficients for the local effects should only be used for calculation of forces on these local areas affecting roof sheeting, glass panels and individual cladding units including their fixtures. They should not be used for calculating force on entire structural elements such as roof, walls or structure as a whole.

NOTES

1 The pressure coefficients given in the different tables have been obtained mainly from measurements on models in wind tunnels, and the great majority of data available have been obtained in conditions of relatively smooth flow. Where sufficient field data exist as in the case of rectangular buildings, values have been obtained to allow for turbulent flow.

2 In recent years, wall glazing and cladding design has been a source of major concern. Although of less consequence than collapse of the main structures, damage to glass can be hazardous and cause considerable financial losses.

3 For pressure coefficients for structures not covered herein, reference may be made to specialist literature on the subject or advise may be sought from specialists in the subject.

4.5.2.1 *Wind load on individual members*

When calculating the wind load on individual structural elements such as roofs and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite faces of such elements or units. For clad structures, it is, therefore, necessary to know the internal pressure as well as external pressure. Then the wind load, F (in N) acting in a direction normal to the individual structural element or cladding unit is:

$$F = (C_{pe} - C_{pi}) A p_d$$

where

C_{pe} = external pressure coefficient;

C_{pi} = internal pressure coefficient;

A = surface area of structural element or cladding unit in m^2; and

p_d = design wind pressure in N/m^2

NOTES

1 If the surface design pressure varies with height, the surface areas of the structural element may be sub-divided so that the specified pressures are taken over appropriate areas.

2 Positive wind load indicates the force acting towards the structural element and negative away from it.

4.5.2.2 *External pressure coefficients*

a) *Walls* — The average external pressure coefficient for the walls of clad buildings of coefficients are also given.

b) *Pitched Roofs of Rectangular Clad Buildings* — The average external pressure coefficients and pressure concentration coefficients for pitched roofs of rectangular clad building shall be as given in Table 8. Where no pressure concentration coefficients are given, the average coefficients apply. The pressure coefficients on the underside of any overhanging roof shall be taken in accordance with **4.5.2.2** (g).

NOTES

1 The pressure concentration shall be assumed to act outward (suction pressure) at the ridges, eaves, cornices and 90° corners of roofs.

2 The pressure concentration shall not be included with the net external pressure when computing overall loads.

c) *Monoslope Roofs of Rectangular Load Buildings* — The average pressure coefficient and pressure concentration coefficient for monoslope (lean-to) roofs of rectangular clad buildings shall be as given in Table 9.

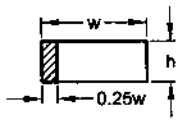
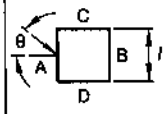
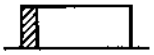
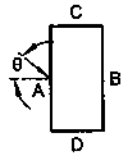
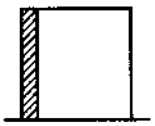
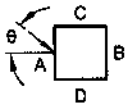
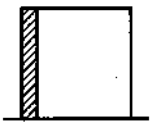
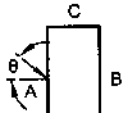
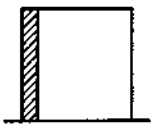
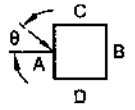
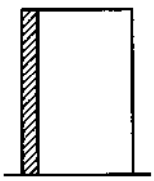
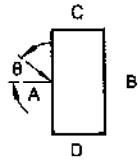
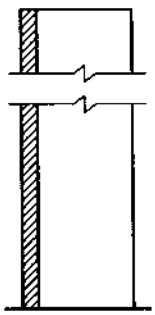
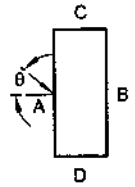
d) *Canopy Roofs with* $\frac{1}{4} < h/w < 1$ and $1 < L/w < 3$ — The pressure coefficients are given in Tables 10 and 11 separately for monopitch and double pitch canopy roofs, such as open-air parking garages, shelter areas, outdoor areas, railway platforms, stadiums and theatres. The coefficients take account of the combined effect of the wind exerted on and under the roof for all wind directions; the resultant is to be taken normal to the canopy. Where the local coefficients overlap the greater of the two given values should be taken. However, the effect of partial closures of one side and or both sides, such as those due to trains, buses and stored materials shall be foreseen and taken into account.

The solidity ratio ϕ is equal to the area of obstruction under the canopy divided by the gross area under the canopy, both areas normal to the wind direction. $\phi = 0$ represents a canopy with no obstructions underneath. $\phi = 1$ represents the canopy fully blocked with contents to the downwind eaves. Values of C_p for intermediate solidities may be linearly interpolated between these two extremes, and apply upwind of the position of maximum blockage only. Downwind of the position of maximum blockage the coefficients for $\phi = 0$ may be used.

In addition to the pressure forces normal to

Table 7 External Pressure Coefficients (C_{pe}) for Walls of Rectangular Clad Buildings

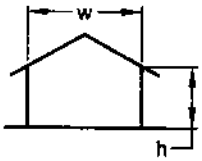
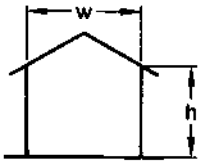
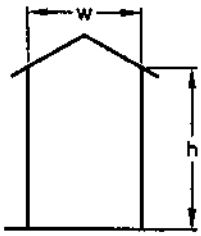
[*Clause* 4.5.2.2 (a)]

Building Height Ratio	Building Plan Ratio	Elevation	Plan	Wind Angle θ Degree	C_{pe} for Surface				Local C_{pe}
					A	B	C	D	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\frac{h}{w} \le \frac{1}{2}$	$1 < \frac{l}{w} \le \frac{3}{2}$			0	+0.7	–0.2	–0.5	–0.5	–0.8
				90	–0.5	–0.5	+0.7	–0.2	
	$\frac{3}{2} < \frac{l}{w} < 4$			0	+0.7	–0.25	–0.6	–0.6	–1.0
				90	–0.5	–0.5	+0.7	–0.1	
$\frac{1}{2} < \frac{h}{w} \le \frac{3}{2}$	$1 < \frac{l}{w} \le \frac{3}{2}$			0	+0.7	–0.25	–0.6	–0.6	–1.1
				90	–0.6	–0.6	+0.7	–0.25	
	$\frac{3}{2} < \frac{l}{w} < 4$			0	+0.7	–0.3	–0.7	–0.7	–1.1
				90	–0.5	–0.5	+0.7	–0.1	
$\frac{3}{2} < 1\frac{h}{w} < 6$	$1 < \frac{l}{w} \le \frac{3}{2}$			0	+0.8	–0.25	–0.8	–0.8	–1.2
				90	–0.8	–0.8	+0.8	–0.25	
	$\frac{3}{2} < \frac{l}{w} < 4$			0	+0.7	–0.4	–0.7	–0.7	–1.2
				90	–0.5	–0.5	+0.8	–0.1	
$\frac{h}{w} \ge 6$	$\frac{l}{w} = \frac{3}{2}$			0	+0.95	–1.85	–0.9	–0.9	–1.25
				90	–0.8	–0.8	+0.9	–0.85	
	$\frac{l}{w} = 1.0$			0	+0.95	–0.25	–0.7	–0.7	–1.25
				90	–0.7	–0.7	+0.95	–1.25	
	$\frac{l}{w} = 2$			0	+0.85	–0.75	–0.75	–0.75	–1.25
				90	–0.75	–0.75	+0.85	–0.75	

NOTE — h is the height of eaves or parapet, l is the greater horizontal dimension of a building and w is the lesser horizontal dimension of a building.

Table 8 External Pressure Coefficients (C_{pe}) for Pitched Roofs of Rectangular Clad Buildings

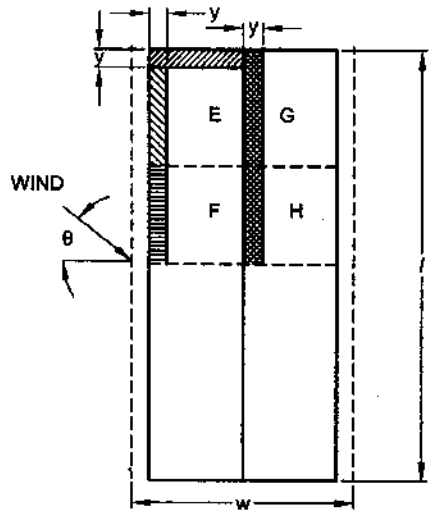
[*Clause* 4.5.2.2 (b)]

Building Height Ratio		Roof Angle	Wind Angle θ 0°		Wind Angle θ 90°		Local Coefficients			
		degrees	EF	GH	EG	FH				
(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
$\frac{h}{w} \leq \frac{1}{2}$		0	–0.8	–0.4	–0.8	–0.4	–2.0	–2.0	–2.0	—
		5	–0.9	–0.4	–0.8	–0.4	–1.4	–1.2	–1.2	–1.0
		10	–1.2	–0.4	–0.8	–0.6	–1.4	–1.4		–1.2
		20	–0.4	–0.4	–0.7	–0.6	–1.0			–1.2
		30	0	–0.4	–0.7	–0.6	–0.8			–1.1
		45	+0.3	–0.5	–0.7	–0.6				–1.1
		60	+0.7	–0.6	–0.7	–0.6				–1.1
$\frac{1}{2} < \frac{h}{w} \leq \frac{3}{2}$		0	–0.8	–0.6	–1.0	–0.6	–2.0	–2.0	–2.0	—
		5	–0.9	–0.6	–0.9	–0.6	–2.0	–2.0	–1.5	–1.0
		10	–1.1	–0.6	–0.8	–0.6	–2.0	–2.0	–1.5	–1.2
		20	–0.7	–0.5	–0.8	–0.6	–1.5	–1.5	–1.5	–1.0
		30	–0.2	–0.5	–0.8	–0.8	–1.0			–1.0
		45	+0.2	–0.5	–0.8	–0.8				
		60	+0.6	–0.5	–0.8	–0.8				
$\frac{3}{2} < \frac{h}{w} < 6$		0	–0.7	–0.6	–0.9	–0.7	–2.0	–2.0	–2.0	—
		5	–0.7	–0.6	–0.8	–0.8	–2.0	–2.0	–1.5	–1.0
		10	–0.7	–0.6	–0.8	–0.8	–2.0	–2.0	–1.5	–1.2
		20	–0.8	–0.6	–0.8	–0.8	–1.5	–1.5	–1.5	–1.2
		30	–1.0	–0.5	–0.8	–0.7	–1.5			
		40	–0.2	–0.5	–0.8	–0.7	–1.0			
		50	+0.2	–0.5	–0.8	–0.7				
		60	+0.5	–0.5	–0.8	–0.7				

NOTES

1 h is the height to caves or parapet, w is the lesser horizontal dimension of a building.

2 Where no local coefficients are given the overall coefficients apply.

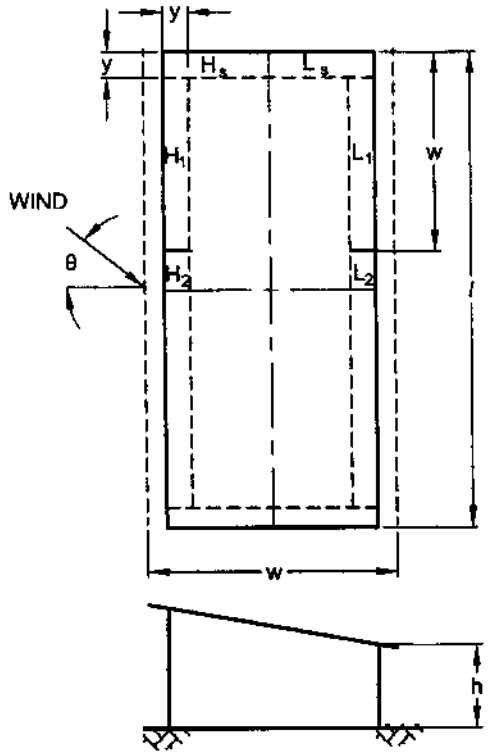


KEY PLAN

$y = h$ or 0.15 w,
whichever is the lesser

Table 9 External Pressure Coefficients (C_{pe}) for Monoslope Roofs for Rectangular

[*Clause* 4.5.2.2 (c)]



$y = h$ or 0.15 w, whichever is the lesser

NOTE — Area H and area L refer to the whole quadrant.

OVERALL COEFFICIENTS

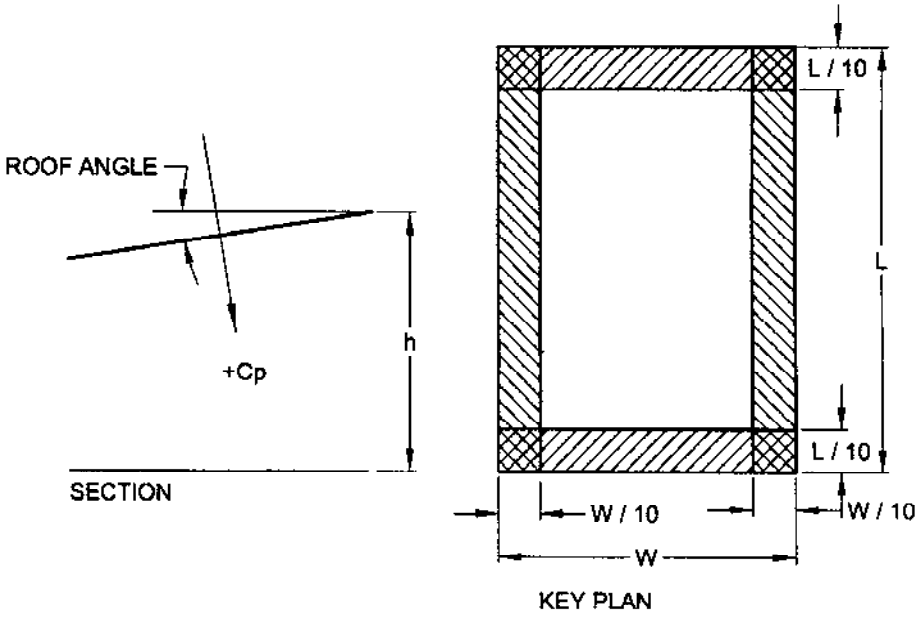
Roof Angle	Wind Angle θ									
	0°		45°		90°		135°		180°	
Degree	*H*	*L*	*H*	*L*	*H* & *L*	*H* & *L*	*H*	*L*	*H*	*L*
					Applies to length *w*/2 from wind ward end	Applies to remainder				
5	–1.0	–0.5	–1.0	–0.9	–1.0	–0.5	–0.9	–1.0	–0.5	–1.0
10	–1.0	–0.5	–1.0	–0.8	–1.0	–0.5	–0.8	–1.0	–0.4	–1.0
15	–0.9	–0.5	–1.0	–0.7	–1.0	–0.5	–0.6	–1.0	–0.3	–1.0
20	–0.8	–0.5	–1.0	–0.6	–0.9	–0.5	–0.5	–1.0	–0.2	–1.0
25	–0.7	–0.5	–1.0	–0.6	–0.8	–0.5	–0.3	–0.9	–0.1	–0.9
30	–0.5	–0.5	–1.0	–0.6	–0.8	–0.5	–0.1	–0.6	0	–0.6

Roof Angle	LOCAL COEFFICIENTS C_{pe}					
Degree	H_1	H_2	L_1	L_2	*H*	*L*
5	–2.0	–1.5	–2.0	–1.5	–2.0	–2.0
10	–2.0	–1.5	–2.0	–1.5	–2.0	–2.0
15	–1.8	–0.9	–1.8	–1.4	–2.0	–2.0
20	–1.8	–0.8	–1.8	–1.4	–2.0	–2.0
25	–1.8	–0.7	–0.9	–0.9	–2.0	–2.0
30	–1.8	–0.5	–0.5	–0.5	–2.0	–2.0

NOTE — h is the height to eaves at lower side, l is greater horizontal dimension of a building and w is the lesser horizontal dimension of a building.

Table 10 Pressure Coefficients for Free Standing Monosloped Roofs

[*Clause* 4.5.2.2 (d)]

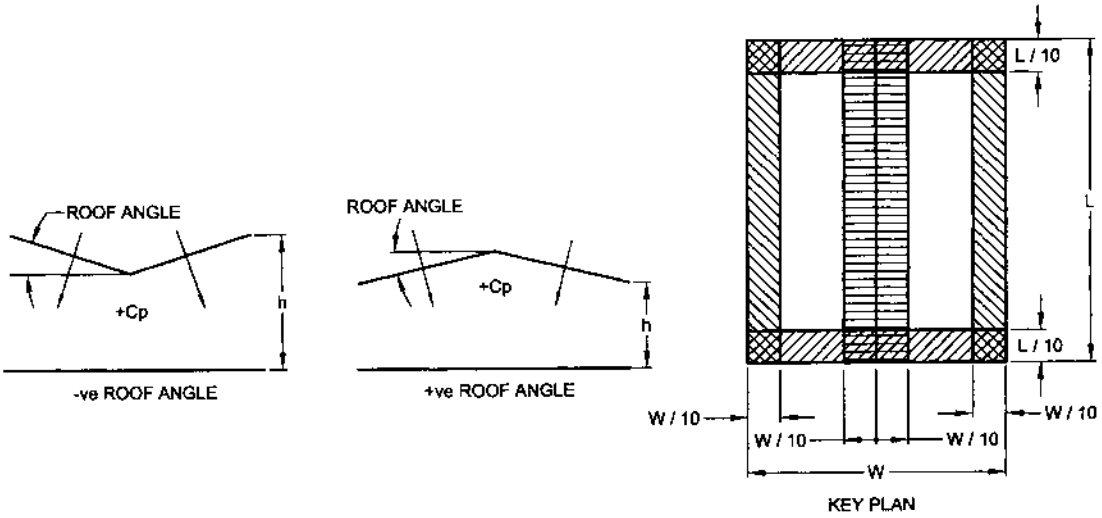


Roof Angle	Solidity Ratio	Maximum (Largest +ve) and Minimum (Largest –ve) Pressure Coefficients			
		Overall coefficients	Local coefficients		
Degree			▭	▨	▨
0	All values of Ø	+0.2	+0.5	+1.8	+1.1
5		+0.4	+0.8	+2.1	+1.3
10		+0.5	+1.2	+2.4	+1.6
15		+0.7	+1.4	+2.7	+1.8
20		+0.8	+1.7	+2.9	+2.1
25		+1.0	+2.0	+3.1	+2.3
30		+1.2	+2.2	+3.2	+2.4
0	Ø = 0	–0.5	–0.6	–1.3	–1.4
	Ø = 1	–1.0	–1.2	–1.8	–1.9
5	Ø = 0	–0.7	–1.1	–1.7	–1.8
	Ø = 1	–1.1	–1.6	–2.2	–2.3
10	Ø = 0	–0.9	–1.5	–2.0	–2.1
	Ø = 1	–1.3	–2.1	–2.6	–2.7
15	Ø = 0	–1.1	–1.8	–2.4	–2.5
	Ø = 1	–1.4	–2.3	–2.9	–3.0
20	Ø = 0	–1.3	–2.2	–2.8	–2.9
	Ø = 1	–1.5	–2.6	–3.1	–3.2
25	Ø = 0	–1.6	–2.6	–3.2	–3.2
	Ø = 1	–1.7	–2.8	–3.5	–3.5
30	Ø = 0	–1.8	–3.0	–3.8	–3.6
	Ø = 1	–1.8	–3.0	–3.8	–3.6

NOTE — For monopitch canopies the centre of pressure should be taken to act at 0.3 *w* from the windward edge.

Table 11 Pressure Coefficients for Free Standing Double Sloped Roofs

[*Clause* 4.5.2.2 (d)]



Roof Angle	Solidity Ratio	Maximum (Largest +ve) and Minimum (Largest –ve) Pressure Coefficients				
		Overall coefficients	Local coefficients			
Degree						
–20	All values of Ø	+0.7	+0.8	+1.6	+0.6	+1.7
–15		+0.5	+0.6	+1.5	+0.7	+1.4
–10		+0.4	+0.6	+1.4	+0.8	+1.1
–5		+0.3	+0.5	+1.5	+0.8	+0.8
+5		+0.3	+0.6	+1.8	+1.3	+0.4
+10		+0.4	+0.7	+1.8	+1.4	+0.4
+15		+0.4	+0.9	+1.9	+1.4	+0.4
+20		+0.6	+1.1	+1.9	+1.5	+0.4
+25		+0.7	+1.2	+1.9	+1.6	+0.5
+30		+0.9	+1.3	+1.9	+1.6	+0.7
–20	Ø = 0	–0.7	–0.9	–1.3	–1.6	–0.6
	Ø = 1	–0.9	–1.2	–1.7	–1.9	–1.2
–15	Ø = 0	–0.6	–0.8	–1.3	–1.6	–0.6
	Ø = 1	–0.8	–1.1	–1.7	–1.9	–1.2
–10	Ø = 0	–0.6	–0.8	–1.3	–1.5	–0.6
	Ø = 1	–0.8	–1.1	–1.7	–1.9	–1.3
–5	Ø = 0	–0.5	–0.7	–1.3	–1.6	–0.6
	Ø = 1	–0.8	–1.5	–1.7	–1.9	–1.4
+5	Ø = 0	–0.6	–0.6	–1.4	–1.4	–1.1
	Ø = 1	–0.9	–1.3	–1.8	–1.8	–2.1
+10	Ø = 0	–0.7	–0.7	–1.5	–1.4	–1.4
	Ø = 1	–1.1	–1.4	–2.0	–1.8	–2.4
+15	Ø = 0	–0.8	–0.9	–1.7	–1.4	–1.8
	Ø = 1	–1.2	–1.5	–2.2	–1.9	–2.8
+20	Ø = 0	–0.9	–1.2	–1.8	–1.4	–2.0
	Ø = 1	–1.3	–1.7	–2.3	–1.9	–3.0
+25	Ø = 0	–1.0	–1.4	–1.9	–1.4	–2.0
	Ø = 1	–1.4	–1.9	–2.4	–2.1	–3.0
+30	Ø = 0	–1.0	–1.4	–1.9	–1.4	–2.0
	Ø = 1	–1.4	–2.1	–2.6	–2.2	–3.0

NOTE — Each slope of a duopitch canopy should be able to withstand forces using both the maximum and the minimum coefficients, and the whole canopy should be able to support forces using one slope at the maximum coefficient with the other slope at the minimum coefficient. For duopitch canopies the centre of pressure should be taken to act at the centre of each slope.

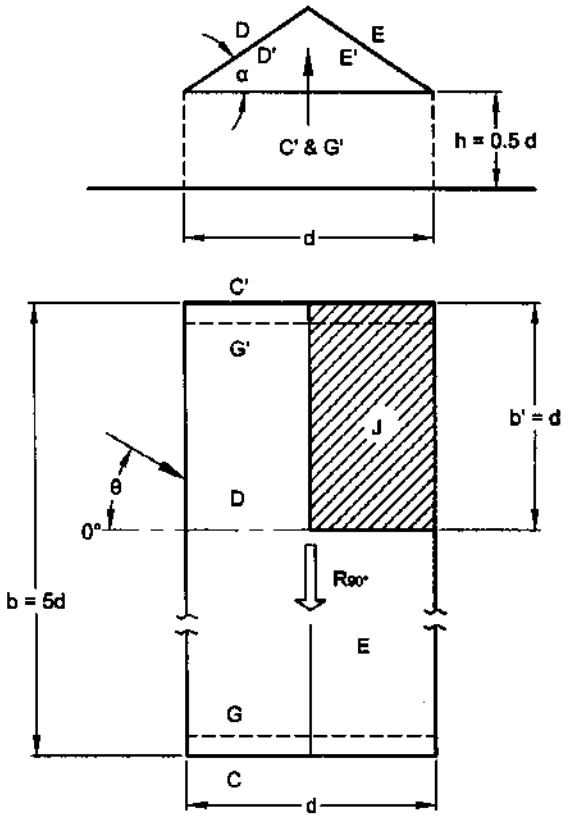
the canopy, there will be horizontal loads on the canopy due to the wind pressure on any fascia and to friction over the surface of the canopy. For any wind direction, only the greater of these two forces need be taken into account. Fascia loads should be calculated on the area of the surface facing the wind, using a force coefficient of 1.3. Frictional drag should be calculated using the coefficients given in **4.5.3.1**.

NOTE — Tables 12 to 17 may be used to get internal and external pressure coefficients for pitches and troughed free roofs for some specific cases for which aspect ratios and roof slopes have been specified. However, while using Tables 12 to 17 any significant departure from it should be investigated carefully. No increase shall be made for local effects except as indicated.

e) *Curved Roofs* — For curved roofs, the external pressure coefficients shall be as given in Table 18. Allowance for local effects shall be made in accordance with Table 8.

Table 12 Pressure Coefficients (Top and Bottom) for Pitched Roofs, α = 30°

[*Clause* 4.5.2.2 (d)]



α = 30°
θ = 0° – 45°, *D, D', E, E'* full length
θ = 90°, *D, D', E, E'* part length *b'*

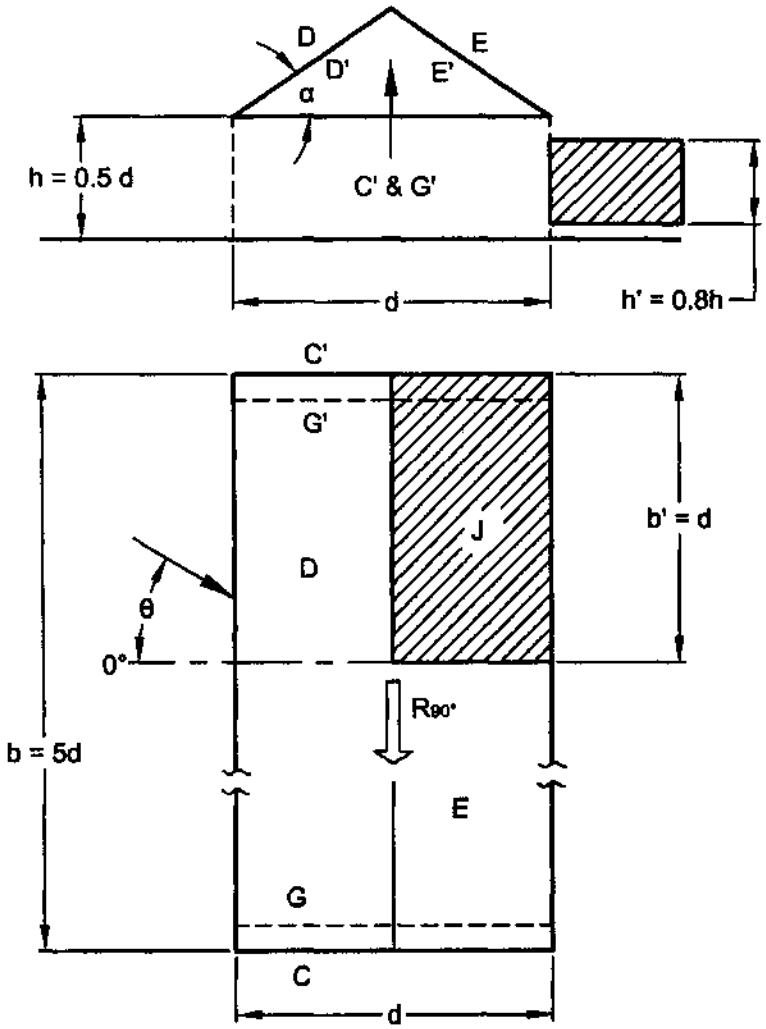
PRESSURE COEFFICIENTS, C_p

θ	D	D'	E	E'	End Surfaces			
					C	C'	G	G'
0°	0.6	–1.0	–0.5	–0.9	—	—	—	—
45°	0.1	–0.3	–0.6	–0.3	—	—	—	—
90°	–0.3	–0.4	–0.3	–0.4	–0.3	0.8	0.3	–0.4

45° For *j*: C_p top = –1.0; C_p bottom = –0.2.

90° Tangentially acting friction: $R_{90°} = 0.05\ p_d.db$.

[*Clause* 4.5.2.2 (d)]



α = 30°

Effects of trains or stored materials:

θ = 0° – 45°, or 135° – 180°, *D, D', E, E'* full length

θ = 90°, *D, D', E, E'* part length *b'*

PRESSURE COEFFICIENTS, C_p

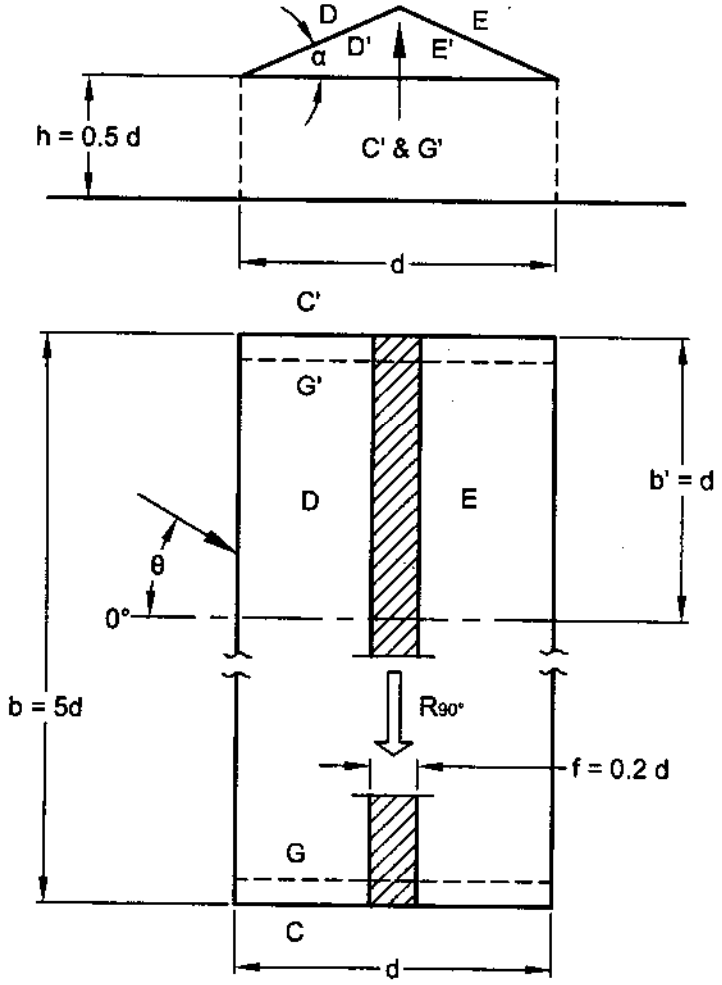
θ	*D*	*D'*	*E*	*E'*	End Surfaces			
					C	*C'*	*G*	*G'*
0°	0.1	0.8	–0.7	0.9	—	—	—	—
45°	–0.1	0.5	–0.8	0.5	—	—	—	—
90°	–0.4	–0.5	–0.4	–0.5	–0.3	0.8	0.3	–0.4
180°	–0.3	0.6	0.4	–0.6	—	—	—	—

45° For *j*: C_p top = –1.5; C_p bottom = 0.5.

90° Tangentially acting friction: $R_{90°} = 0.05\ p_a.db$.

Table 14 Pressure Coefficients (Top and Bottom) for Pitched Free Roofs, α = 10°

[*Clause* 4.5.2.2 (d)]



α = 10°
θ = 0° – 45°, *D*, *D'*, *E*, *E'* full length
θ = 90°, *D*, *D'*, *E*, *E'* part length *b'*

PRESSURE COEFFICIENTS, C_p

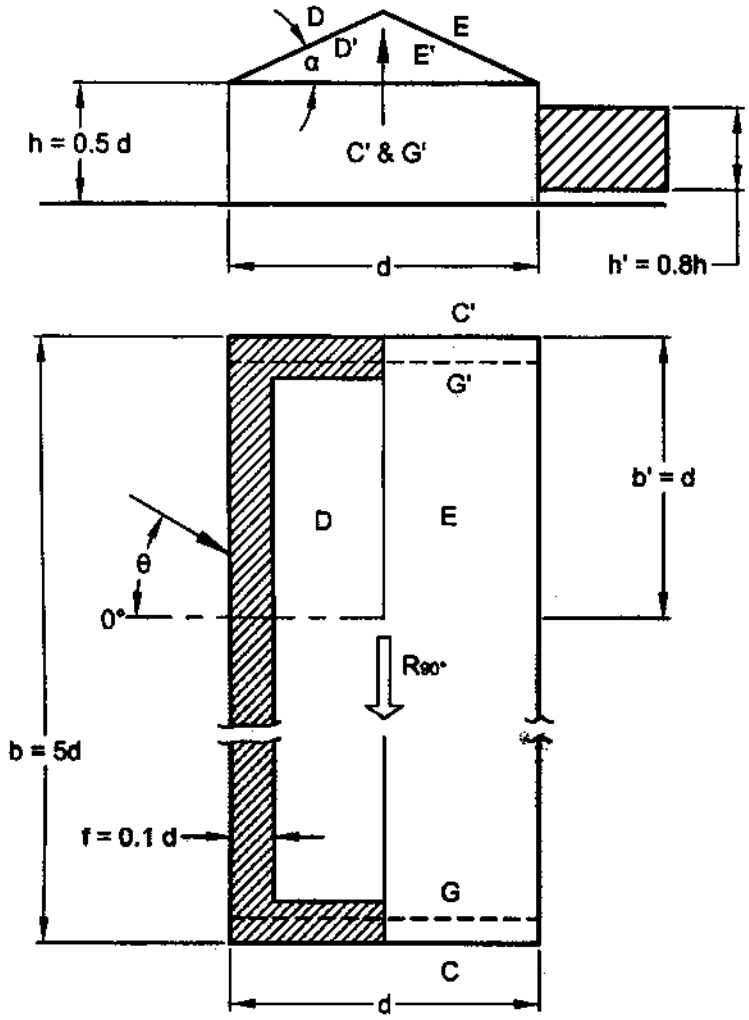
θ	*D*	*D'*	*E*	*E'*	End Surfaces			
					C	*C'*	*G*	*G'*
0°	–1.0	0.3	–0.5	0.2	—	—	—	—
45°	–0.3	0.1	–0.3	0.1	—	—	—	—
90°	–0.3	0.0	–0.3	0.0	–0.4	0.8	0.3	–0.6

0° For *f*: C_p top = –1.0; C_p bottom = 0.40.

0-90° Tangentially acting friction: $R_{90°} = 0.1\ p_d.db$.

Table 15 Pressure Coefficients (Top and Bottom) for Pitched Free Roofs, α = 10° with Effects of Train or Stored Materials

[*Clause* 4.5.2.2 (d)]



α = 10°

Effects of trains or stored materials:

θ = 0° – 45°, 135° – 180°, *D*, *D'*, *E*, *E'* full length

θ = 90°, *D*, *D'*, *E*, *E'* part length *b'*

PRESSURE COEFFICIENTS, C_p

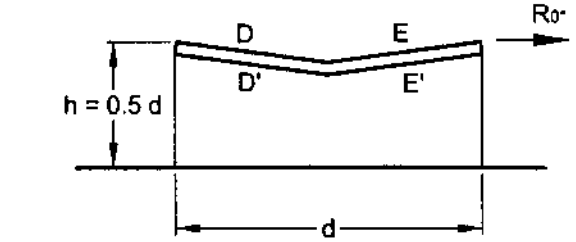
θ	*D*	*D'*	*E*	*E'*	End Surfaces			
					C	*C'*	*G*	*G'*
0°	–1.3	0.8	–0.6	0.7	—	—	—	—
45°	0.5	0.4	–0.3	0.3	—	—	—	—
90°	–0.3	0.0	–0.3	0.0	—	—	—	—
180°	–0.4	–0.3	–0.6	–0.3	–0.4	0.8	0.3	–0.6

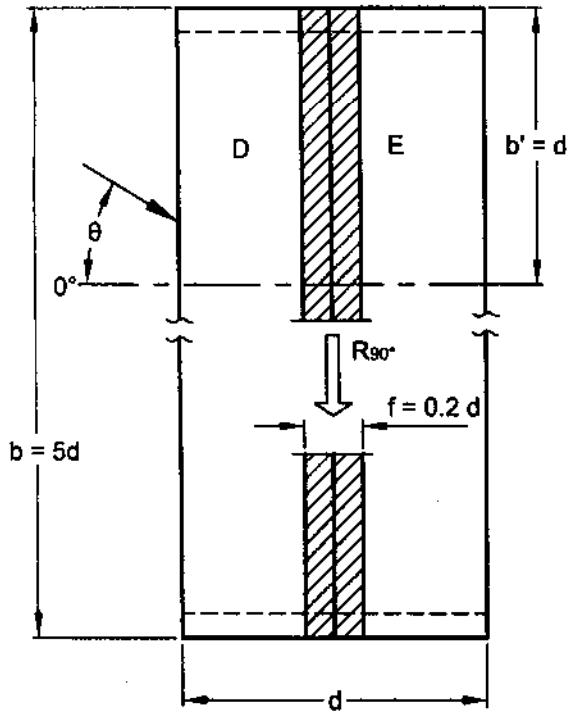
0° For *f*: C_p top = –1.6; C_p bottom = 0.9.

0° – 180° Tangentially acting friction: $R_{90°} = 0.1\ p_d.db$.

Table 16 Pressure Coefficients for Troughed Free Roofs, α = 10°

[*Clause* 4.5.2.2 (d)]





Roof slope α = 10°

θ = 0° – 45°, *D, D′, E, E′* full length

θ = 90°, *D, D′, E, E′* part length *b′*

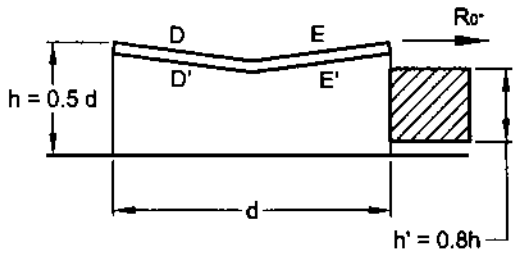
	PRESSURE COEFFICIENTS, C_p			
θ	*D*	*D′*	*E*	*E′*
0°	0.3	–0.7	0.2	–0.9
45°	0.0	–0.2	0.1	–0.3
90°	–0.1	0.1	–0.1	0.1

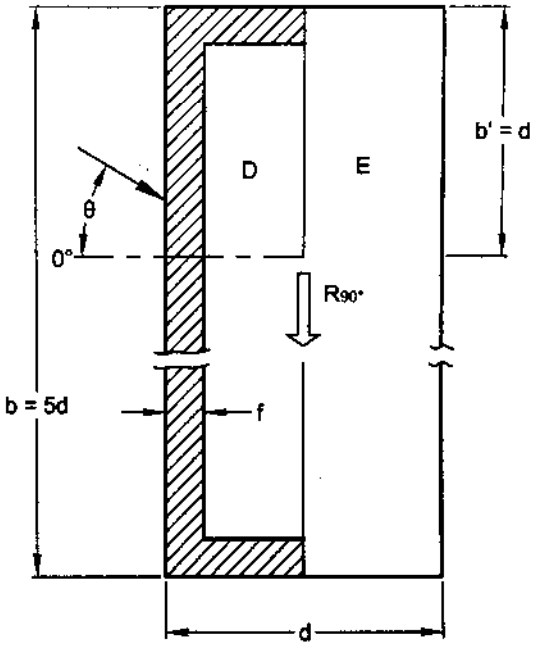
0° For *f*: C_p top = 0.4; C_p bottom = 1.5.

0° – 90° Tangentially acting friction: $R_{90°} = 0.1\ p_d.bd$.

Table 17 Pressure Coefficients for Troughed Free Roofs, α = 10° with Effects of Trains or Stored Materials

[*Clause* 4.5.2.2 (d)]





Roof slope α = 10°

Effects of trains or stored materials:

θ = 0° – 45°, or 135° – 180°, *D, D′, E, E′* full length

θ = 90°, D, D′, E, E′ part length *b′*

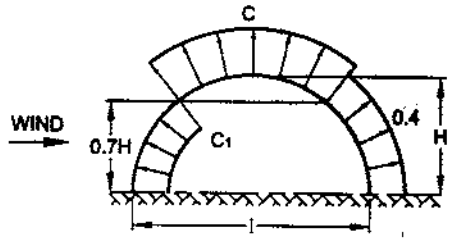
	PRESSURE COEFFICIENTS, C_p			
θ	*D*	*D′*	*E*	*E′*
0°	–0.7	0.8	–0.6	0.6
45°	–0.4	0.3	–0.2	0.2
90°	–0.1	0.1	–0.1	0.1
180°	–0.4	–1.2	–0.6	–0.3

0° For *f*: C_p top = 1.1; C_p bottom = 0.9.

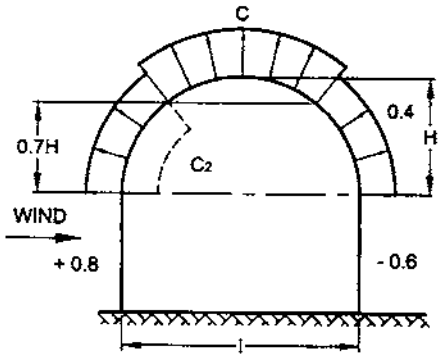
0° – 180° Tangentially acting friction: $R_{90°} = 0.1\ p_d.bd$.

Table 18 External Pressure Coefficients for Curved Roofs

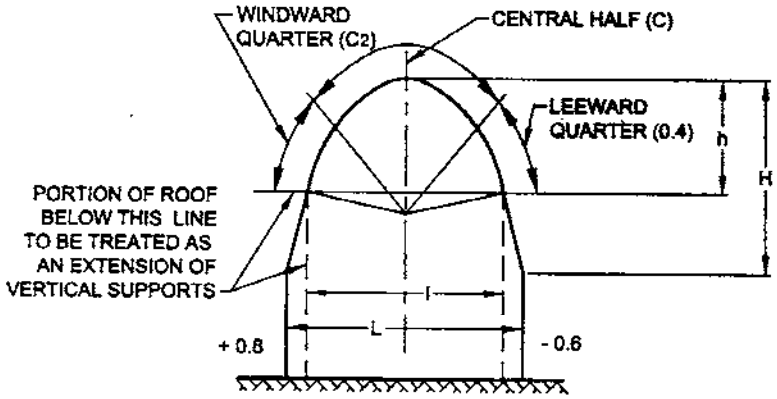
[*Clause* 4.5.2.2 (e)]



a) ROOF SPRINGING FROM GROUND LEVEL



b) ROOF ON ELEVATED STRUCTURE



c) DOUBLY CURVED ROOFS

$$\frac{\overline{H}}{l} \neq 0.6 \text{ and } \frac{h}{l} > 0.6$$

Values of C, C_1 and C_2

H/l	C	C_1	C_2
0.1	–0.8	+0.1	–0.8
0.2	–0.9	+0.3	–0.7
0.3	–1.0	+0.4	–0.3
0.4	–1.1	+0.6	+0.4
0.5	–1.2	+0.7	+0.7

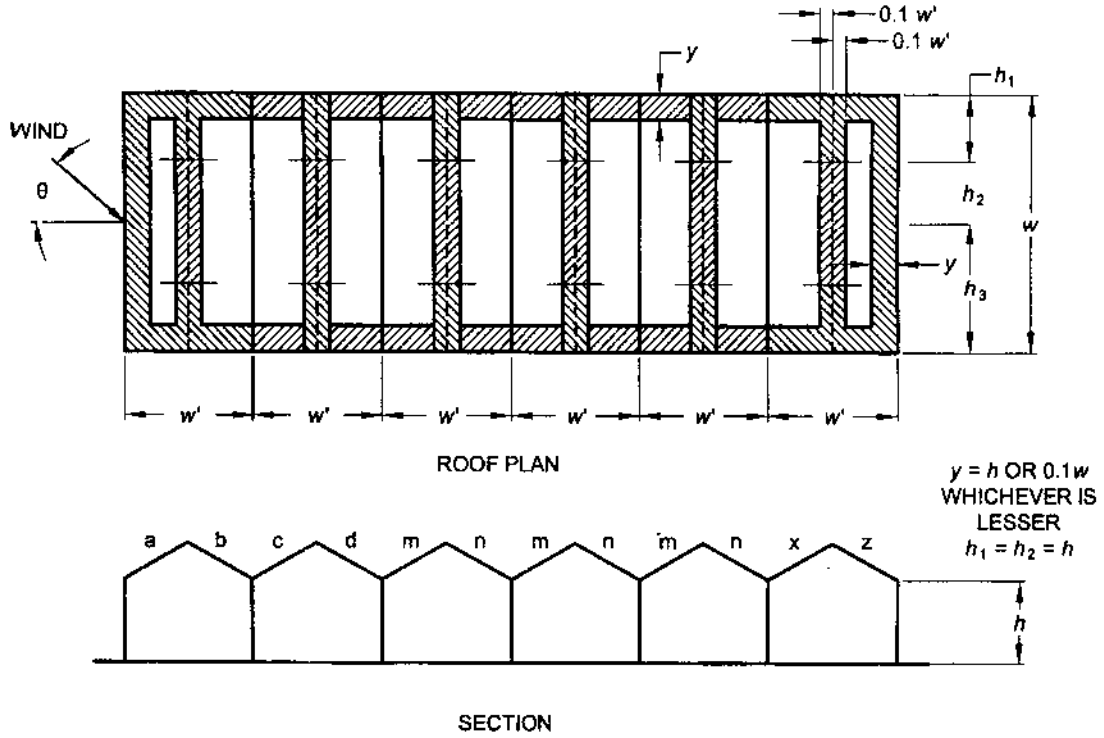
NOTE — When the wind is blowing normal to the gable ends, C_{pe} may be taken as equal to –0.7 for the full width of the roof over a length of $l/2$ from the gable ends and –0.5 for the remaining portion.

f) *Pitched and Saw-Tooth Roofs of Multi-span Buildings* — For pitched and saw-tooth roofs of multi-span buildings, the external average pressure coefficients and pressure concentration coefficients shall be as given in Tables 19 and 20 respectively, provided that all spans shall be equal and the height to the eaves shall not exceed the span.

NOTE — Evidence on multi-span buildings is fragmentary. Any departure given in Tables 19 and 20 should be investigated separately.

Table 19 External Pressure Coefficients (C_{pe}) for Pitched Roofs of Multi-span Buildings (All Spans Equal) with $h > w'$

[*Clause* 4.5.2.2 (f)]



Roof Angle degrees	Wind Angle degrees	First Span	First Intermediate Span			Other Intermediate Span		End Span		Local Coefficient	
α	θ	*a*	*b*	*c*	*d*	*m*	*n*	*x*	*z*	▨	▨
5	0	–0.9	–0.6	–0.4	–0.3	–0.3	–0.3	–0.3	–0.3		
10		–1.1	–0.6	–0.4	–0.3	–0.3	–0.3	–0.3	–0.4		
20		–0.7	–0.6	–0.4	–0.3	–0.3	–0.3	–0.3	–0.5	–2.0	–1.5
30		–0.2	–0.6	–0.4	–0.3	–0.2	–0.3	–0.2	–0.5		
45		+0.3	–0.6	–0.6	–0.4	–0.2	–0.4	–0.2	–0.5		

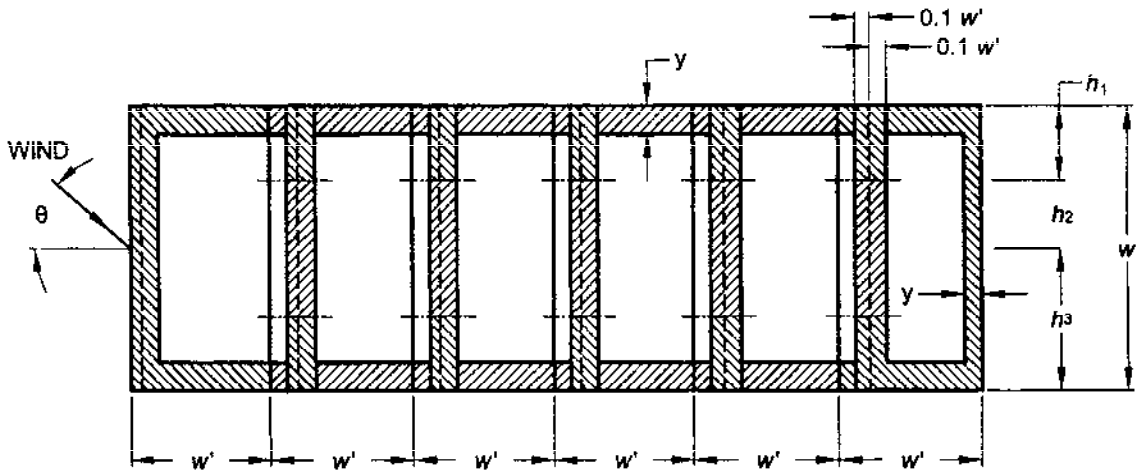
Roof Angle degrees	Wind Angle degrees	Distance		
α	θ	h_1	h_2	h_3
Up to 45	90	–0.8	–0.6	–0.2

Frictional drag: when wind angle $\theta = 0°$ horizontal forces due to frictional drag are allowed for in the above values; when wind angle $\theta = 90°$ allow for frictional drag in accordance with **4.5.3.1**.

NOTE — Evidence on these buildings is fragmentary and any departures from the cases given should be investigated separately.

Table 20 External Pressure Coefficients (C_{pe}) for Saw-Tooth Roofs of Multispan Buildings (All Spans Equal) with $h > w'$

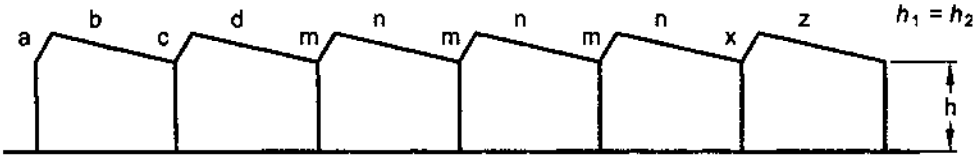
[Clause 4.5.2.2 (f)]



ROOF PLAN

$y = h$ OR $0.1w$ WHICHEVER IS LESSER

$h_1 = h_2 = h$



SECTION

Wind Angle degrees	First Span		First Intermediate Span		Other Intermediate Span		End Span		Local Coefficient	
θ	a	b	c	d	m	n	x	z	▨	▨
0	+0.6	–0.7	–0.7	–0.4	–0.3	–0.2	–0.1	–0.3	–2.0	–1.5
180	–0.5	–0.3	–0.3	–0.3	–0.4	–0.6	–0.6	–0.1		

Wind Angle degrees	Distance		
θ	h_1	h_2	h_3
90	–0.8	–0.6	–0.2
270	Similarly, but handed		

Frictional drag: when wind angle $\theta = 0°$ horizontal forces due to frictional drag are allowed for in the above values; when wind angle $\theta = 90°$ allow for frictional drag in accordance with **4.5.3.1**.

NOTE — Evidence on these buildings is fragmentary and any departures from the cases given should be investigated separately.

g) *Pressure Coefficients on Overhangs from Roofs* — The pressure coefficients on the top overhanging portion of the roofs shall be taken to be the same as that of the nearest top portion of the non-pressure coefficients for the underside surface of the overhanging portions shall be taken as follows and shall be taken as positive if the overhanging portion is on the windward side:

1) 1.25, if the overhanging slopes; downwards;
2) 1.0, if the overhanging is horizontal; and
3) 0.75, if the overhanging slopes upwards.

For overhanging portions on sides other than windward side, the average pressure coefficients on the adjoining walls may be used.

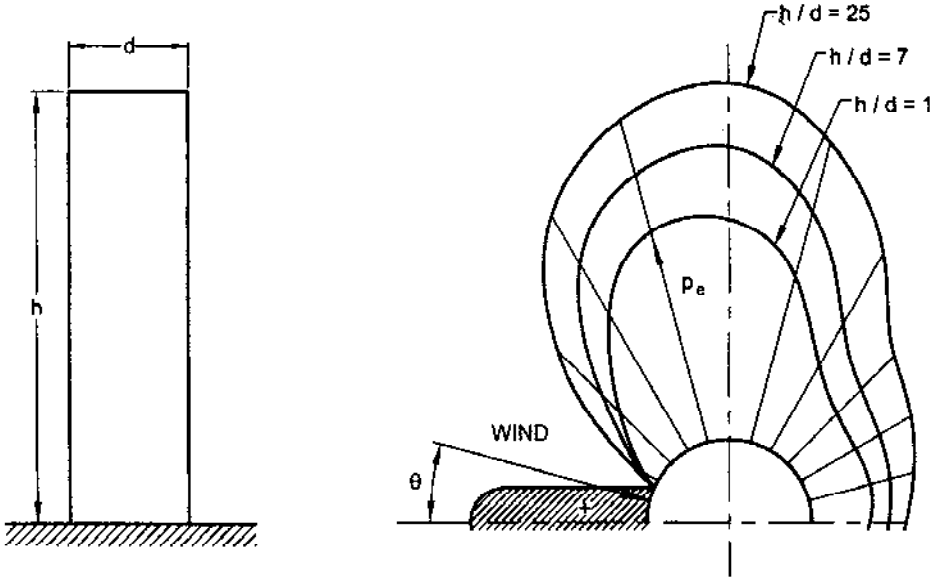
h) *Cylindrical Structures* — For the purpose of calculating the wind pressure distribution around a cylindrical structure of circular cross-section, the value of external pressure coefficients given in Table 21 may be used provided that the Raynolds number is greater than 10 000. They may be used for wind blowing normal to the axes of cylinders having axis normal to the ground plane (that is, chimneys and silos) and cylinders having their axis parallel to the ground plane (that is, horizontal tanks) provided that the clearance between the tank and the ground is not less than the diameter of the cylinder.

h is the height of a vertical cylinder or length of a horizontal cylinder. Where there is a free flow of air around both ends, h is to be taken as half the length when calculating h/D ratio.

1) –0.8, where h/D is not less than 0.3; and
2) –0.5, where h/D is less than 0.3.

Table 21 External Pressure Distribution Coefficients Around Cylindrical Structures

[*Clause* 4.5.2.2 (h)]



Position of Periphery, θ	Pressure Coefficient, C_{pe}		
in degrees	H/D = 25	H/D = 7	H/D = 1
0	1.0	1.0	1.0
15	0.8	0.8	0.8
30	0.1	0.1	0.1
45	–0.9	–0.8	–0.7
60	–1.9	–1.7	–1.2
75	–2.5	–2.2	–1.6
90	–2.6	–2.2	–1.7
105	–1.9	–1.7	–1.2
120	–0.9	–0.8	–0.7
135	–0.7	–0.6	–0.5
150	–0.6	–0.5	–0.4
165	–0.6	–0.5	–0.5
180	–0.6	–0.5	–0.4

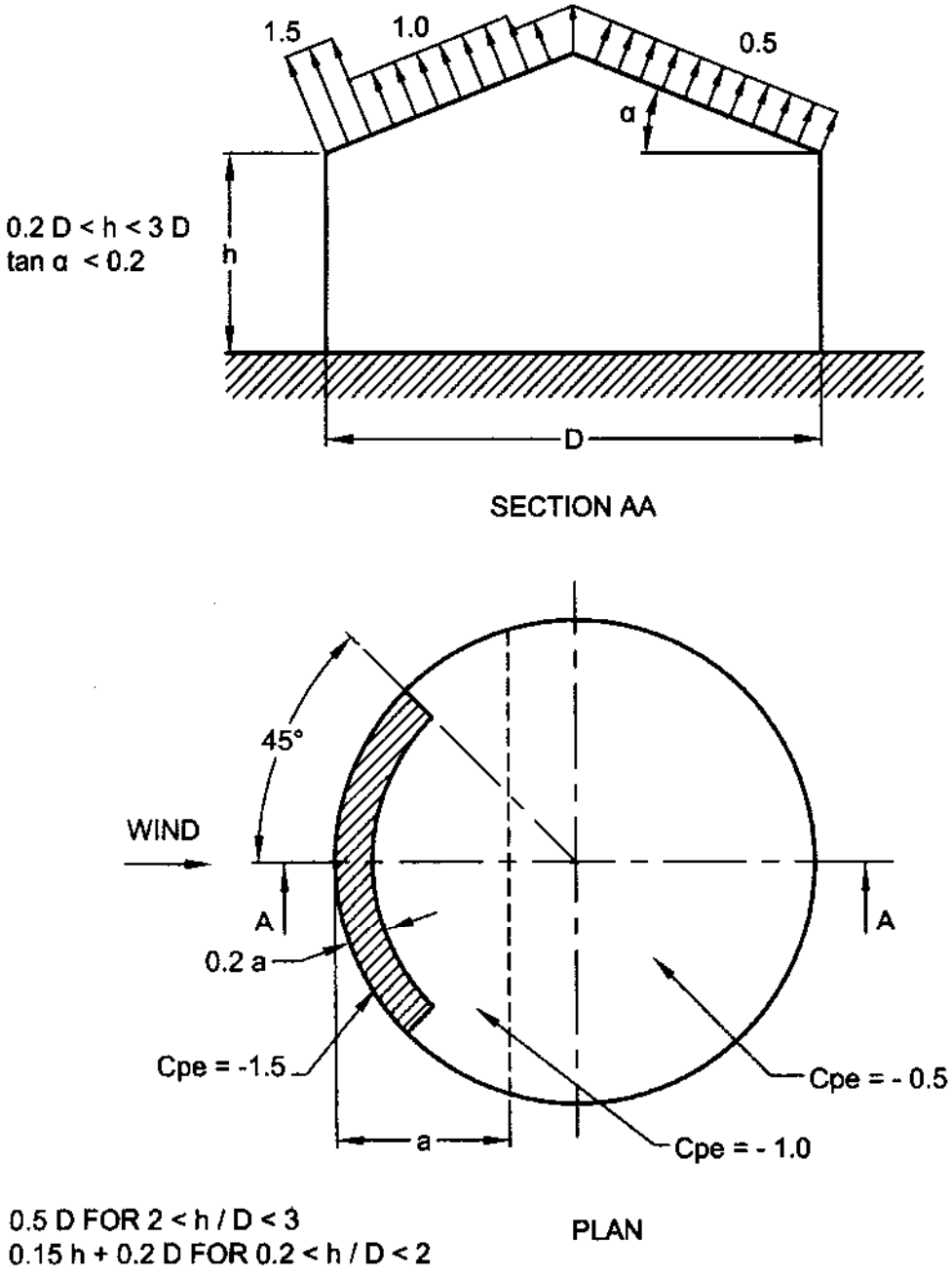
j) *Roofs and Bottom of Cylindrical Related Structure* — The external pressure coefficients for roofs and bottoms of cylindrical elevated structures shall be as given in Table 22 (*see also* Fig. 2).

The total resultant load (P) acting on the roof of the structure is given by the following formula:

$$P = 0.785\ D^2\ (C_{pi} - C_{pe})\ p_d$$

The resultant of P for roofs lies at 0.1 D from the centre of the roof on the windward side.

k) *Combined Roofs and Roofs with a Sky Light* — The average external pressure coefficients for combined roofs and roofs with a sky light are shown in Table 23.

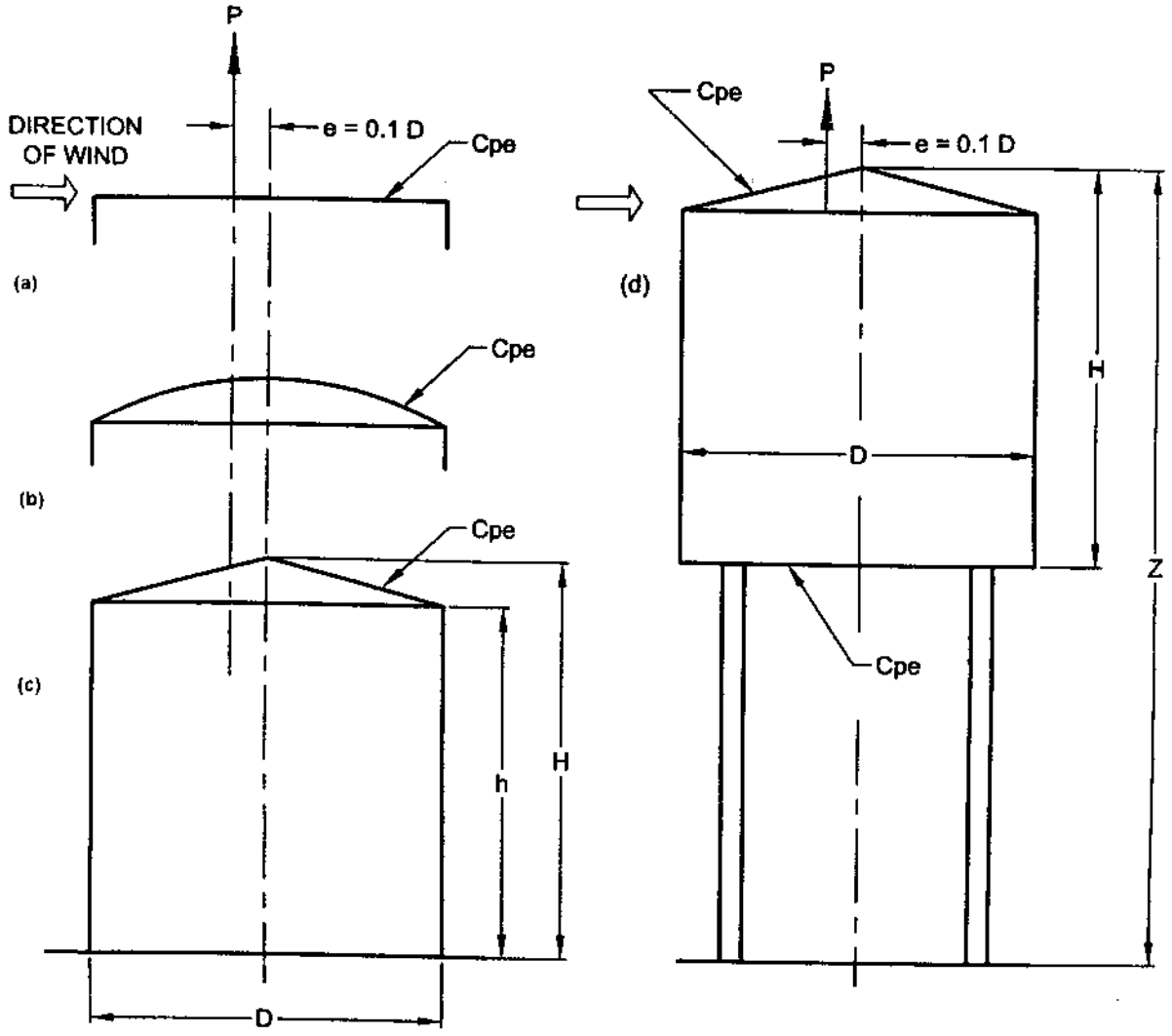


(For force coefficient corresponding to shell portion *see* Table 23)

FIG. 2 EXTERNAL PRESSURE COEFFICIENTS ON THE UPPER ROOF SURFACE OF SINGULAR CIRCULAR STANDING ON THE GROUND

Table 22 External Pressure Coefficients for Roofs and Bottoms of Cylindrical Structures

[*Clause* 4.5.5.2 (j)]



Coefficient of External Pressure, C_{pe}

Structure According to Shape				
a, b and c		d		
H/D	Roof	(*Z/H*) –1	Roof	Bottom
0.5	–0.65	1.00	–0.75	–0.8
1.0	–1.00	1.25	–0.75	–0.7
2.0	–1.00	1.50	–0.75	–0.6

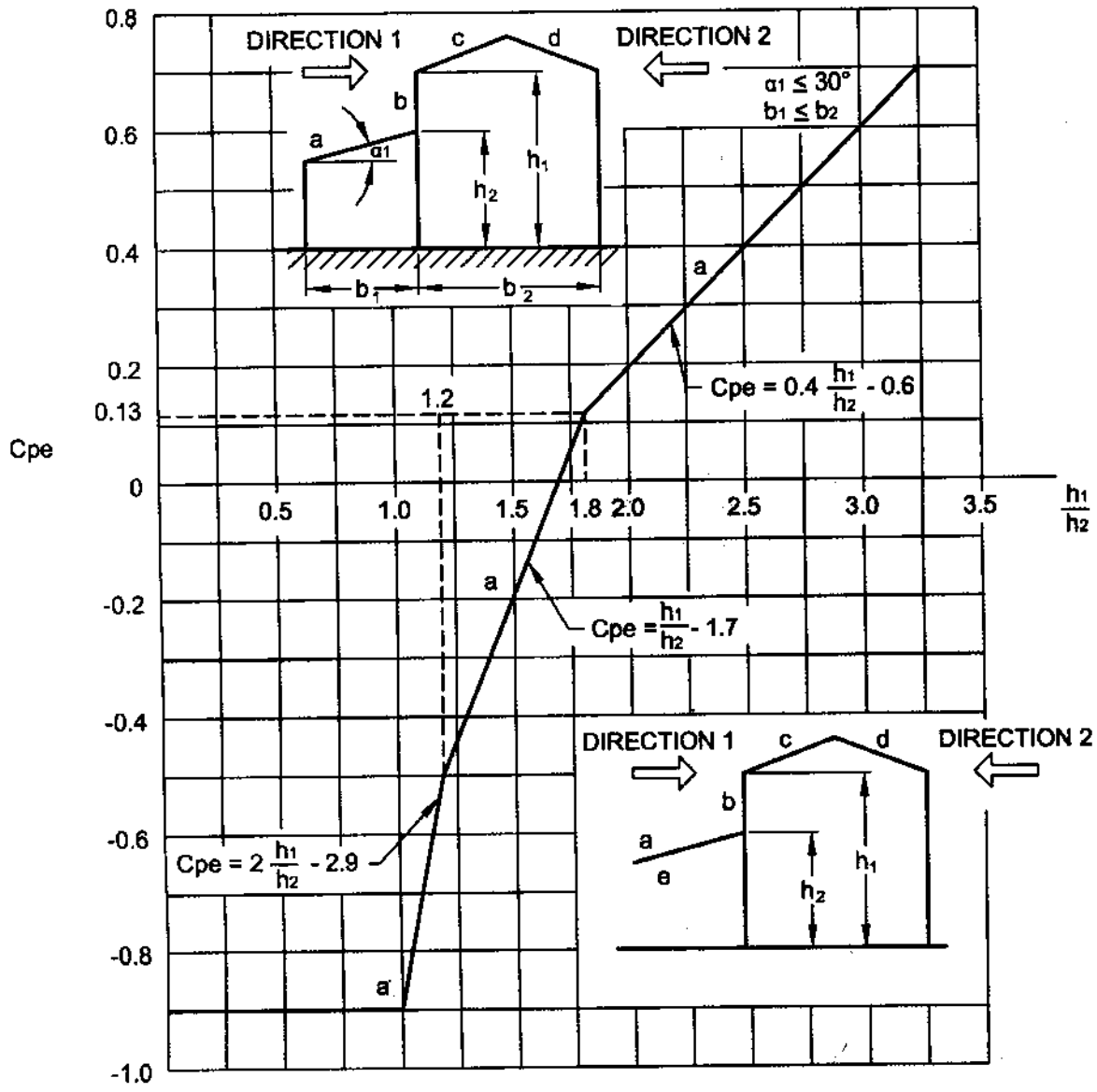
Total force acting on the roof of the structure, $P = 0.785\ D^2\ (C_{pi} - C_{pe})p_d$.

The resultant of P lies eccentrically, $e = 0.1\ D$.

Table 23 External Pressure Coefficients, C_{pe} for Combined Roofs and Roofs with a Sky Light

[*Clause* 4.5.2.2 (k)]

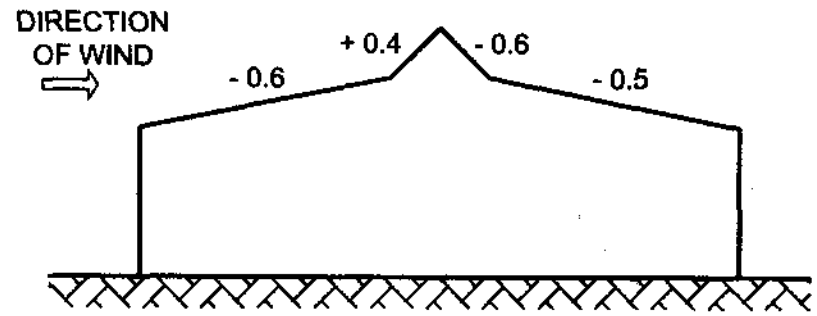
a) Combined Roofs

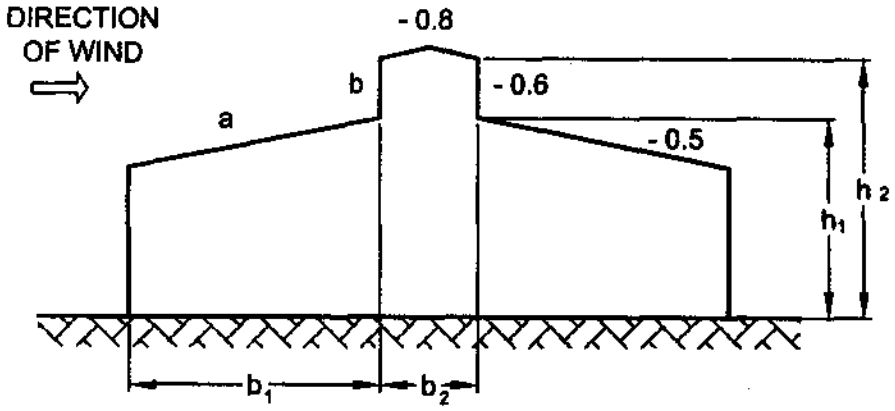


Values of C_{pe}

Portion	Direction 1	Direction 2
a	From the Diagram	–0.4
b	$C_{pe} = -0.5$, $h_1/h_2 < 1.5$ $C_{pe} = -0.7$, $h_1/h_2 > 1.5$	
c and *d*	*See* Table 5	
e	*See* **4.5.2.2** (g)	

b) **Roofs with a Sky Light**





	$b_1 > b_2$		$b_1 \leq b_2$
Portion	*a*	*b*	*a* & *b*
C_{pe}	-0.6	+0.7	*See* Table for Combined Roofs

m) *Grandstands* — The pressure coefficients on the roof (top and bottom) and rear wall of a typical grandstand roof, which is open on three sides, is given in Table 24. The pressure coefficients are valid for a particular ratio of dimensions as specified in Table 24, but may be used for deviations up to 20 percent. In general, the maximum wind load occurs, when the wind is blowing into the open front of the stand causing positive pressure under the roof and negative pressure on the roof.

n) *Upper Surface of Round Silos and Tanks* — The pressure coefficients on the upper surface of round silos and tanks standing on ground shall be as given in Fig. 2.

p) *Spheres* — The external pressure coefficients for spheres shall be as given in Table 25.

4.5.2.3 *Internal pressure coefficients*

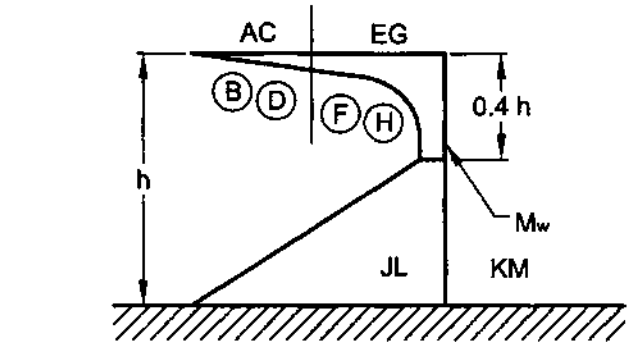
Internal air pressure in a building depends upon the degree of permeability of the cladding to the flow of air. The internal air pressure may be positive or negative depending on the direction of flow of air in relation to the openings in the buildings.

a) In the case of buildings where the claddings permit the flow of air with openings not more than about 5 percent of the wall areas but where there are no large openings, it is necessary to consider the possibility of the internal pressure being positive or negative.

Open Three Sides (Roof = 5°)

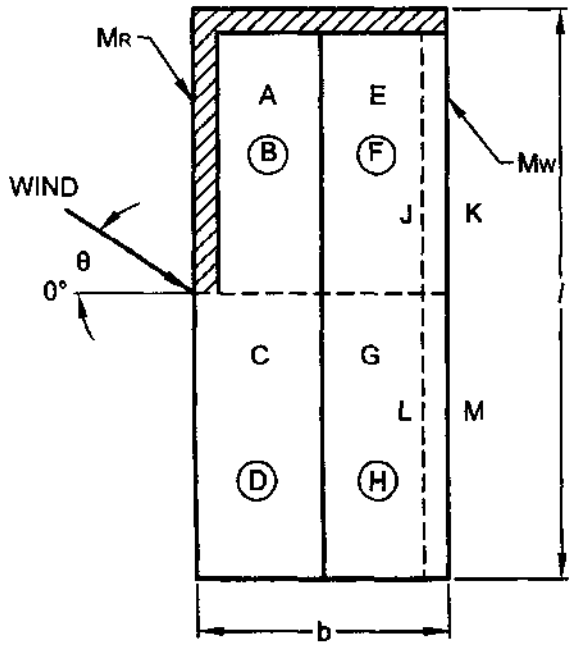
[*Clause* 4.5.2.2 (m)]

($h:b:l$ = 0.8: 1: 2.2)



Front and Back of Wall

θ	*J*	*K*	*L*	*M*
0°	+0.9	–0.5	+0.9	–0.5
45°	+0.8	–0.6	+0.4	–0.4
135°	–1.1	+0.6	–1.0	+0.4
180°	–0.3	+0.9	–0.3	+0.9
60°	$M_w - C_p$ of $K = -1.0$			
60°	$M_w - C_p$ of $J = +1.0$			



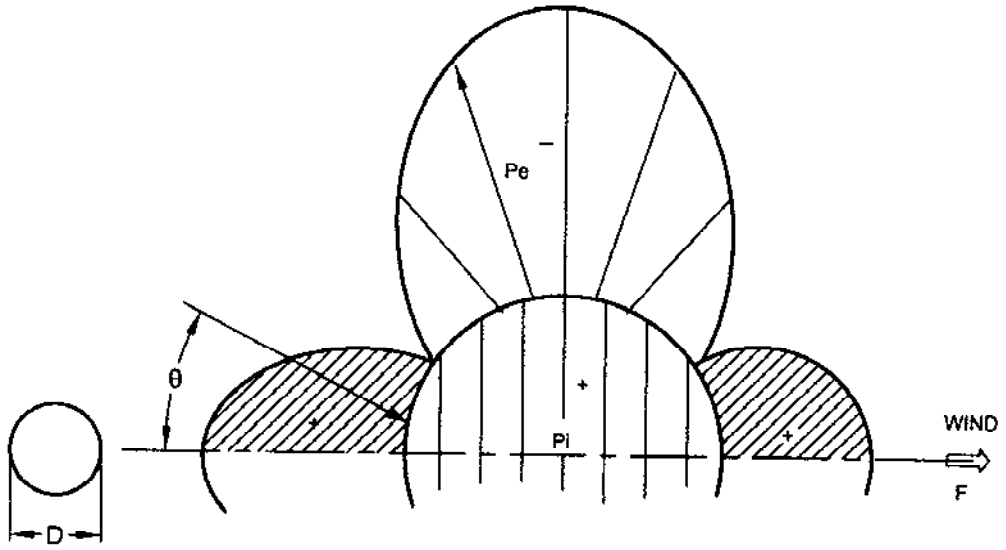
(Shaded area to scale)

Top and Bottom of Roof

θ	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
0°	–1.0	+0.9	–1.0	+0.9	–0.7	+0.9	+0.7	+0.9
45°	–1.0	+0.7	–0.7	+0.4	–0.5	+0.8	–0.5	+0.3
135°	–0.4	–1.1	–0.7	–1.0	–0.9	–1.1	–0.9	–1.0
180°	–0.6	–0.3	–0.6	–0.3	–0.6	–0.3	–0.6	–0.3
45°	$M_R - C_p$ (top) = –2.0							
45°	$M_R - C_p$ (bottom) = +1.0							

Table 25 External Pressure Distribution Coefficients Around Spherical Structures

[*Clause* 4.5.2.2 (p)]



Position of Periphery, θ in degrees	C_{pe}	Remarks
0	+1.0	
15	+0.9	C_f = 0.5 for $DV_z < 7$
30	+0.5	= 0.2 for $DV_z \geq 7$
45	–0.1	
60	–0.7	
75	–1.1	
90	–1.2	
105	–1.0	
120	–0.6	
135	–0.2	
150	+0.1	
165	+0.3	
180	+0.4	

Two design conditions shall be examined, one with an internal pressure coefficient of +0.2 and another with an internal pressure coefficient of –0.2.

The internal pressure coefficient is algebraically added to the external pressure coefficient and the analysis, which indicates greater distress of the member, shall be adopted. In most situations, a simple inspection of the sign of the external pressure will at once indicate the proper sign of the internal pressure coefficient to be taken for design.

NOTE — The terms normal permeability relates to the flow of air commonly afforded by the claddings not only through the open windows and doors, but also through the slits round the closed windows and doors and through chimneys, ventilators and through the joints between roof coverings, the total open area being less than 5 percent of the area of the walls having the openings.

b) *Building with medium and large openings* — Buildings with medium and large openings may also exhibit either positive or negative internal pressure depending upon the direction of wind. Buildings with medium openings between about 5 to 20 percent of wall area shall be examined for an internal pressure coefficient of +0.5 and later with an internal pressure coefficient of –0.5, and the members shall be adopted. Buildings with large openings, that is, openings larger than

20 percent of the wall area shall be examined once with an internal pressure coefficient of +0.7 and again with an internal pressure coefficient of –0.7, and the analysis which produces greater distress on the members shall be adopted.

Buildings with one open side or openings exceeding 20 percent of wall area may be assumed to be subjected to internal positive pressure or suction similar to those for buildings with large openings. A few examples of buildings with one sided openings are shown in Fig. 3 indicating values of internal pressure coefficients with respect to direction of wind.

c) In buildings with roofs but no walls, the roofs will be subjected to pressure from both inside and outside, and the recommendations shall be as given in **4.5.2.2.**

4.5.3 *Force Coefficients*

The value of force coefficients apply to a building or structure as a whole, and when multiplied by the effective frontal area, A_e of the building or structure and by design wind pressure, p_d give the total wind load on that particular building or structure.

$$F = C_f A_e p_d$$

where F is the force acting in a direction specified in the respective tables and C_f is the force coefficient for the building.

NOTES

1 The value of the force coefficient differs for the wind acting on different faces of a building or structure. In order to

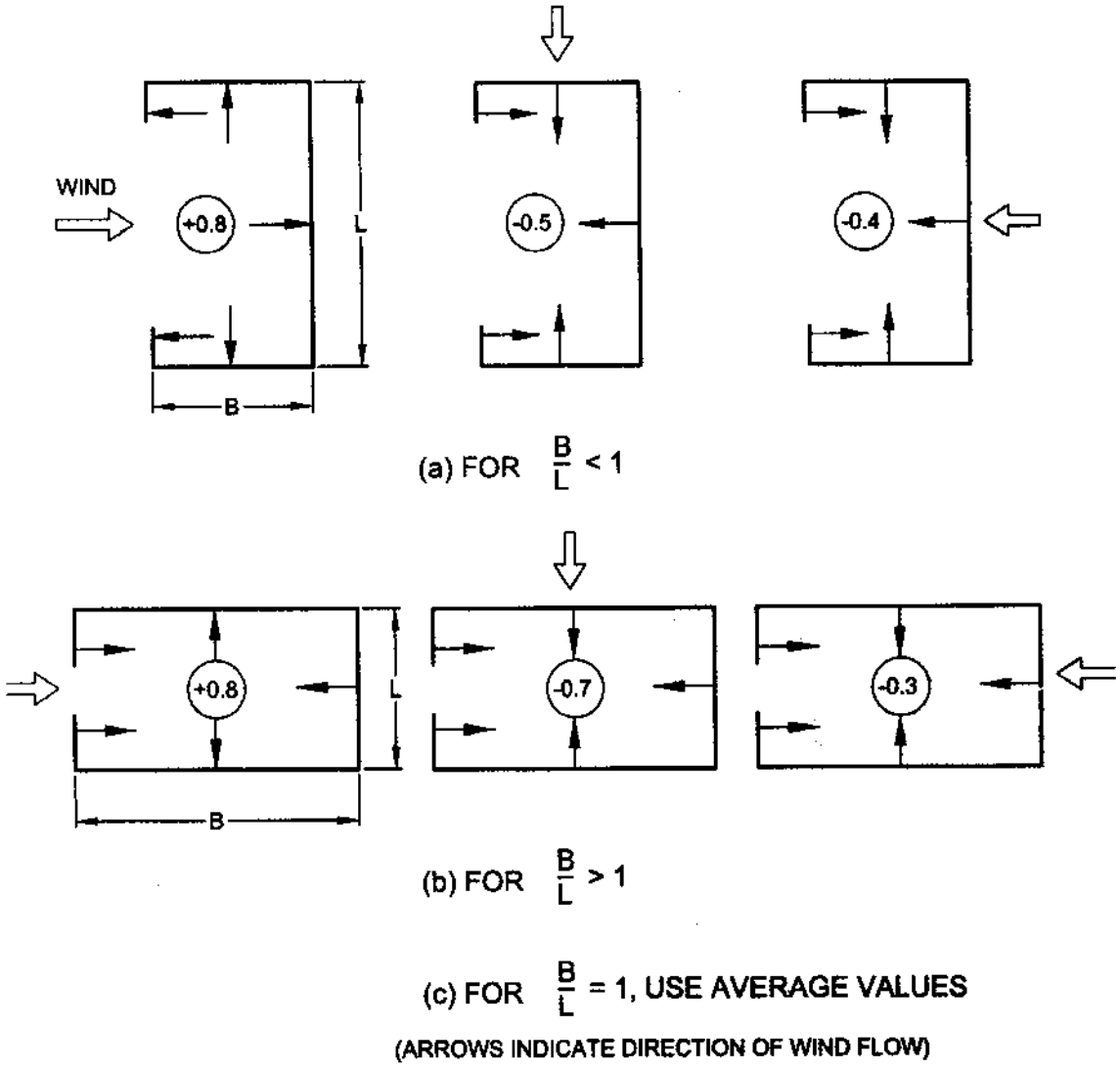


FIG. 3 LARGE OPENING IN BUILDINGS (VALUES OF COEFFICIENT OF INTERNAL PRESSURE) (WITH TOP CLOSED)

determine the critical load, the total wind load should be calculated for each wind direction.

2 If surface design pressure varies with height, the surface area of the building/structure may be sub-divided so that specified pressure are taken over appropriate areas.

3 In tapered buildings/structures, the force coefficients shall be applied after sub-dividing the building/structure into suitable number of strips and the load on each strip calculated individually, taking the area of each strip as A_e.

4 Force coefficients for structures not covered herein, reference may be made to specialist literature on the subject or advise may be sought from specialists in the subject.

4.5.3.1 *Frictional drag*

In certain buildings of special shape, a force due to frictional drag shall be taken into account, in addition to those loads specified in **4.5.2**. For rectangular clad buildings, this addition is necessary only where the ratio *d*/*h* or *d*/*b* is greater than 4. The frictional drag force, F' in the direction or the wind given by the following formulae:

$$\text{If } h \leq b,\ F' = C'_f (d - 4h)\, bp_d + C'_f (d - 4h)\, 2hp_d$$

$$\text{or If } h > b,\ F' = C'_f (d - 4b)\, bp_d + C'_f (d - 4b)\, 2hp_d$$

The first term in each case gives the drag on the roof and the second on the walls. The value of C'_f has the following values:

C'_f = 0.01 for smooth surfaces without corrugations or ribs across the wind direction;

C'_f = 0.02 for surfaces with corrugations or ribs across the wind direction;

C'_f = 0.04 for surfaces with ribs across the wind direction.

For other buildings, the frictional drag has been indicated, where necessary, in the tables of pressure coefficients and force coefficients.

4.5.3.2 *Force coefficients for clad buildings*

a) *Clad buildings of uniform section* — The overall force coefficients for rectangular clad buildings of uniform section with flat roofs in uniform flow shall be as given in Fig. 4 and for other clad buildings of uniform section (without projections, except where otherwise shown) shall be as given in Table 26.

b) *Buildings of circular shapes* — Force coefficients for buildings of circular cross-section shall be as given in Table 27 (*see* Fig. 5 and Annex F).

c) *Low walls and hoardings* — Force coefficients for low walls and hoardings less than 15 m high shall be as given in Table 27 provided the height shall be measured from the ground to the top of the walls or hoarding, and provided that for walls or hoardings above the ground the clearance between the wall or hoarding and the ground shall be not less than 0.25 times the vertical dimension of the wall or hoarding.

To allow for oblique winds the design shall also be checked for the net pressure normal to the surface varying linearly from a maximum of 1.7 C_f at the up wind edge to 0.44 C_f at the down wind edge.

The wind load on appurtenances and supports for hoardings shall be accounted for separately by using the appropriate net pressure coefficients. Allowance shall be made for the shielding effects of one element or another.

d) *Solid circular shapes mounted on a surface* — The force coefficients for solid circular shapes mounted on a surface shall be as given in Fig. 6.

4.6 Dynamic Effects

4.6.1 *General*

Flexible slender structures and structural elements shall be investigated to ascertain the importance of wind induced oscillations for excitations along and across the direction of wind.

In general the following guidelines may be used for examining the problems of wind induced oscillations:

a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0; or

b) Buildings and structures whose natural frequency in the first mode is less than 1.0 Hz.

Any building or structure which satisfies either of the above two criteria shall be examined for dynamic effects of wind.

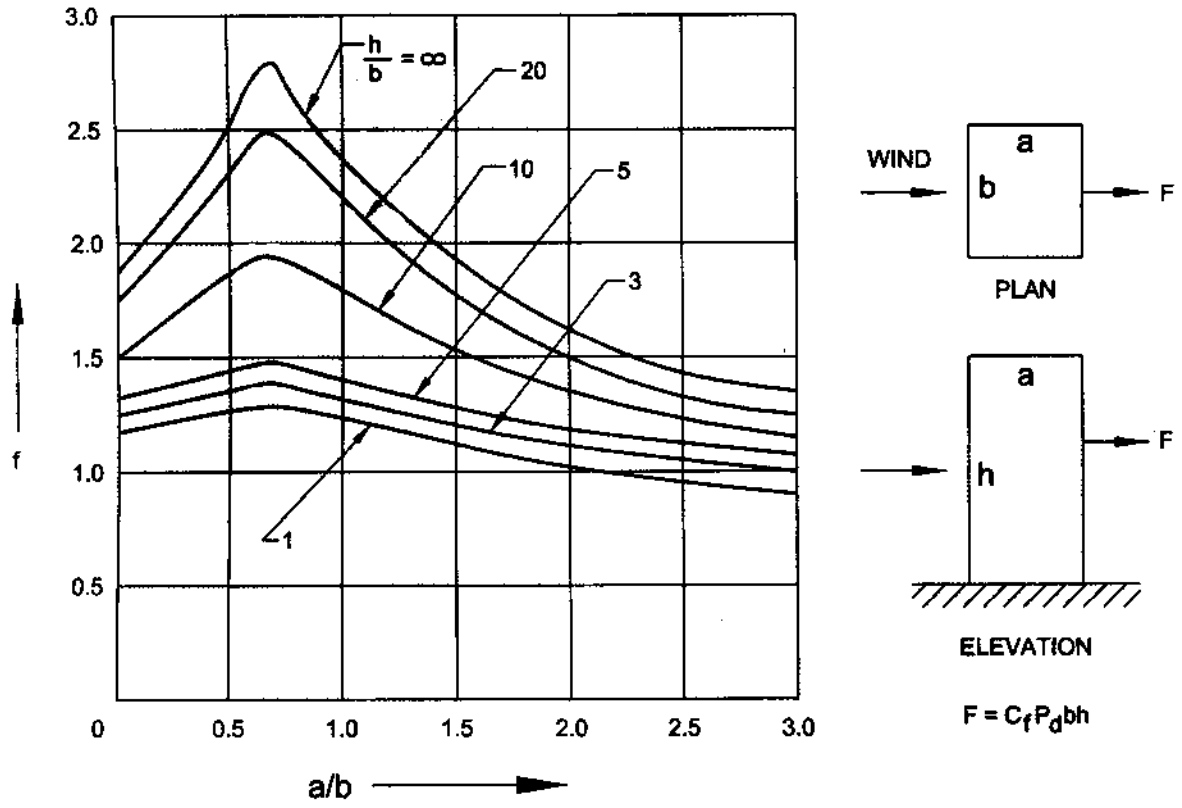
NOTES

1 The fundamental natural period (T_a), in seconds, of a moment-resisting frame building without brick infil panels and of all other buildings including with brick infil panels may be estimated in accordance with **5.4.6**.

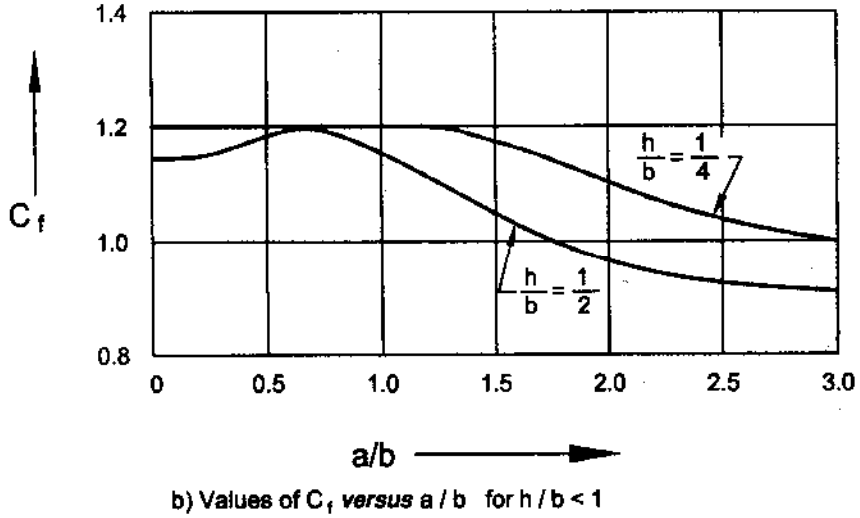
2 If preliminary studies indicate that wind-induced oscillations are likely to be significant, investigations should be persued with the aid of analytical methods or, if necessary, by means of wind tunnel tests on models.

3 Cross wind motions may be due to the lateral gustiness of the wind, unsteady wake flow (for example, vortex shedding), negative aerodynamic damping or to a combination of these effects. These cross-wind motions can become critical in the design of tall building structures.

4 Motions in the direction of the wind (also known as buffeting) are caused by fluctuating wind force associated with gusts. The excitations depend on the gust energy available at the resonant frequency.



a) Values of C_f *versus* a / b for h / b ≥ 1



b) Values of C_f *versus* a / b for h / b < 1

FIG. 4 FORCE COEFFICIENT FOR RECTANGULAR CLAD BUILDING IN UNIFORM FLOW

Table 26 Force Coefficients C_f for Clad Buildings of Uniform Section (Acting in the Direction of Wind)

[*Clause* 4.5.3.2 (a)]

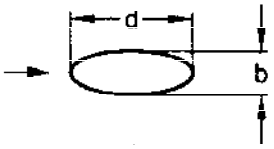
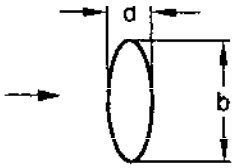
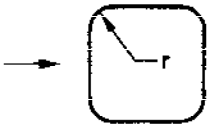
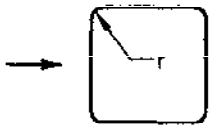
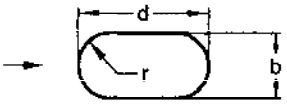
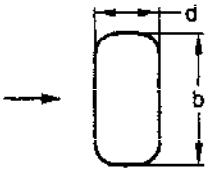
Plan Shape		$V_z b$	C_f for Height/Breadth Ratio						
		m^2/s	Up to 1/2	1	2	5	10	20	∝
(*see also* Annex E)	All surfaces	< 6	0.7	0.7	0.7	0.8	0.9	1.0	1.2
	Rough or with projections	> 6							
	Smooth	>6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
	Ellipse b/d = 1/2	< 10	0.5	0.5	0.5	0.5	0.6	0.6	0.7
		≥ 10	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Ellipse b/d = 2	< 8	0.8	0.8	0.9	1.0	1.1	1.3	1.7
		≥ 8	0.8	0.8	0.9	1.0	1.1	1.3	1.5
	b/d = 1 r/b = 1/3	< 4	0.6	0.6	0.6	0.7	0.8	0.8	1.0
		≥ 4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
	b/d = 1 r/b = 1/6	< 10	0.7	0.8	0.8	0.9	1.0	1.0	1.3
		≥ 10	0.5	0.5	0.5	0.5	0.6	0.6	0.6
	b/d = 1/2 r/b = 1/2	< 3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
		≥ 3	0.2	0.2	0.2	0.2	0.3	0.3	0.3
	b/d = 1/2 r/b = 1/6	All values	0.5	0.5	0.5	0.5	0.6	0.6	0.7
	b/d = 2 r/b = 1/12	All values	0.9	0.9	1.0	1.1	1.2	1.5	1.9

Table 26 — *Continued*

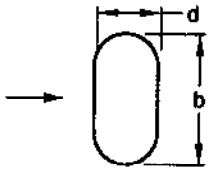
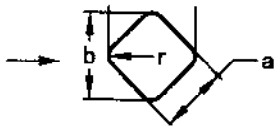
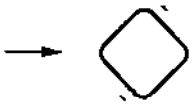
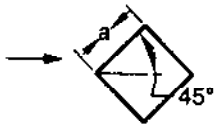
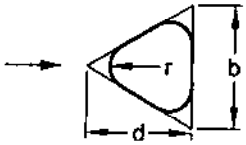
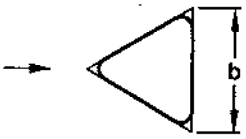
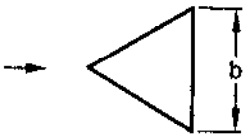
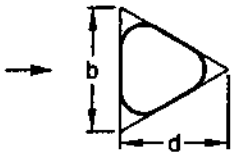
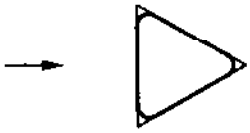
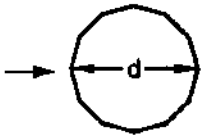
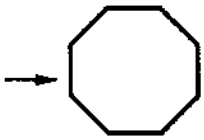
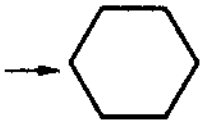
Plan Shape	$V_z b$	C_f for Height/Breadth Ratio						
	m^2/s	Up to 1/2	1	2	5	10	20	∞
 All surfaces $b/d = 2$ $r/b = 1/4$	< 6	0.7	0.8	0.8	0.9	1.0	1.2	1.6
	≥ 6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 $r/a = 1/3$	< 10	0.8	0.8	0.9	1.0	1.1	1.3	1.5
	≥ 10	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 $r/a = 1/12$	All values	0.9	0.9	0.9	1.1	1.2	1.3	1.6
 $r/a = 1/48$	All values	0.9	0.9	0.9	1.1	1.2	1.3	1.6
 $r/b = 1/4$	< 11	0.7	0.7	0.7	0.8	0.9	1.0	1.2
	≥ 11	0.4	0.4	0.4	0.4	0.5	0.5	0.5
 $r/b = 1/12$	All values	0.8	0.8	0.8	1.0	1.1	1.2	1.4
 $r/b = 1/48$	All values	0.7	0.7	0.8	0.9	1.0	1.1	1.3

Table 26 — *Concluded*

Plan Shape		$V_z b$	C_f for Height/Breadth Ratio						
		m^2/s	Up to 1/2	1	2	5	10	20	∞
	r/b = 1/4	< 8	0.7	0.7	0.8	0.9	1.0	1.1	1.3
		≥ 8	0.4	0.4	0.4	0.4	0.5	0.5	0.5
	1/48 < r/b < 1/12	All values	1.2	1.2	1.2	1.4	1.6	1.7	2.1
	12 sided polygon	< 12	0.7	0.7	0.8	0.9	1.0	1.1	1.3
		≥ 12	0.7	0.7	0.7	0.7	0.8	0.9	1.1
	Octagon	All values	1.0	1.0	1.1	1.2	1.2	1.3	1.4
	Hexagon	All values	1.0	1.1	1.2	1.3	1.4	1.4	1.5

NOTE — Structures that, because of their size and the design wind velocity, are in the supercritical flow regime may need further calculation to ensure that the greatest loads do not occur at some wind speed below the maximum when the flow will be subcritical.

The coefficients are for buildings without projections, except where otherwise shown. In this table V b is used as an indication of the airflow regime.

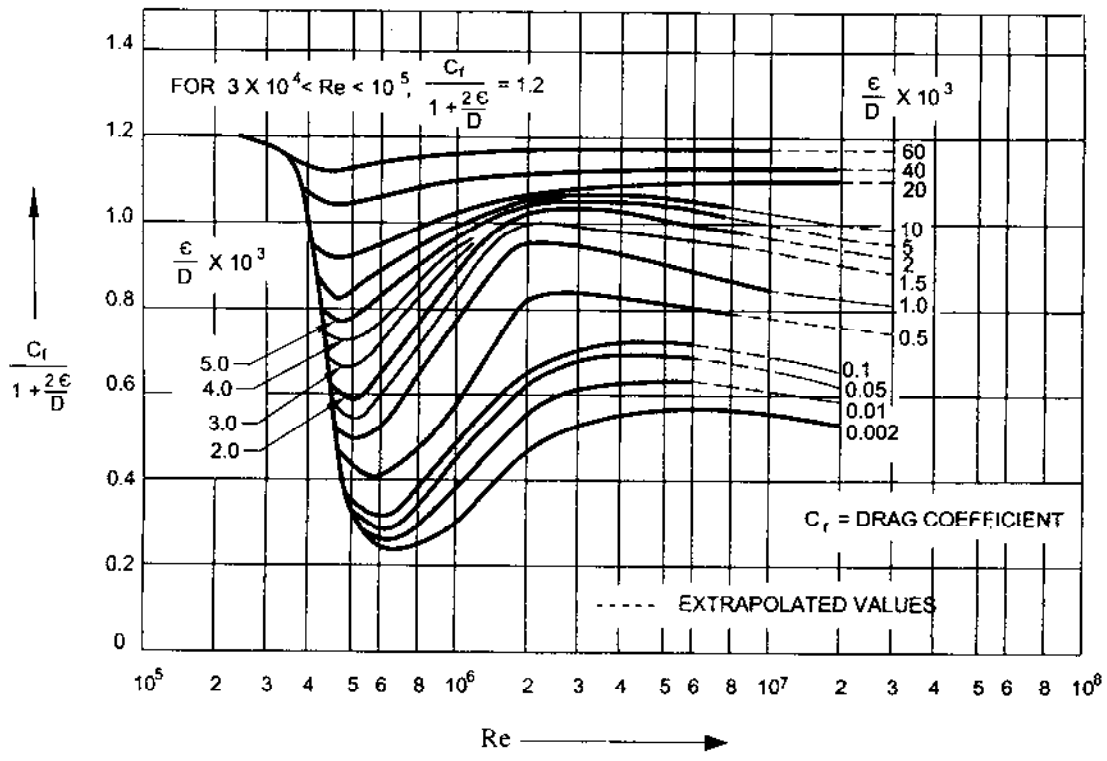
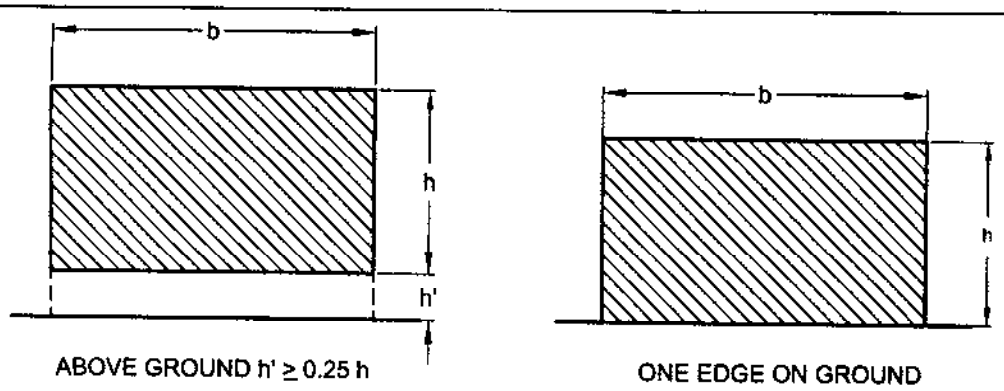


FIG. 5 VARIATION OF $\frac{C_f}{1+\frac{2\varepsilon}{D}}$ WITH $Re < 3 \times 10^4$ FOR CIRCULAR SECTIONS

Table 27 Force Coefficients for Low Walls or Hoardings (<15 m High)

[*Clause* 4.5.3.2 (b)]



(Wind normal to face)

Width to Height Ratio, *b/h*		Drag Coefficient, C_f
Wall above ground	Wall on ground	
From 0.5 to 6	From 1 to 12	1.2
10	20	1.3
16	32	1.4
20	40	1.5
40	80	1.7
60	120	1.8
80 or more	160 more 20	2.0

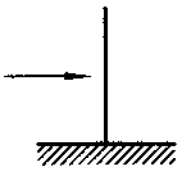
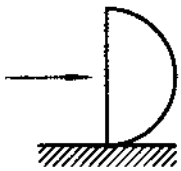
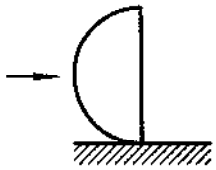
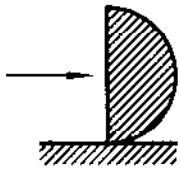
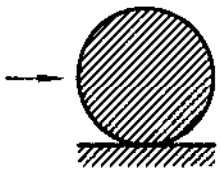
SIDE ELEVATION	DESCRIPTION OF SHAPE	C_f
	CIRCULAR DISC	1.2
	HEMISPHERICAL BOWL	1.4
	HEMISPHERICAL BOWL	0.4
	HEMISPHERICAL SOLID	-1.2
	SPHERICAL SOLID	0.5 FOR V D < 7 0.2 FOR V D ≥ 7

FIG. 6 FORCE COEFFICIENTS FOR SOLID SHAPES MOUNTED ON A SURFACE

5 The wake shed from an upstream body may intensify motions in the direction of the wind, and may also effect crosswind motions.

6 The designer must be aware of the following three forms of wind induced motion which are characterized by increasing amplitude of oscillation with increase of wind speed.

a) *Galloping* — Galloping is transverse oscillations of some structures due to the development of aerodynamic forces which are in phase with the motion. It is characterized by the progressively increasing amplitude of transverse vibration with increase of wind speed. The cross-sections which are particularly prone to this type of excitation include the following:

   i) All structures with non-circular cross-sections, such as triangular, square, polygons, as well as angles, crosses and T-sections.

   ii) Twisted cables and cables with ice encrustations.

b) *Flutter* — Flutter is unstable oscillatory motion of a structure due to coupling between aerodynamic force and the elastic deformation of the structure. Perhaps the most common form is the oscillatory motion due to combined bending and torsion. Although oscillatory motions in each degree of freedom may be dampled, instability can set in due to energy transfer from one mode of oscillation to another, and the structure is seen to execute sustained or divergent oscillations with a type of motion which is a combination of the individual modes of motion. Such energy transfer takes place when the natural frequencies of the modes, taken individually, are close to each other (ratio being typically less than 2.0). Flutter can set in at wind speeds much less than those required for exciting the individual modes of motion. Long span suspension bridge decks or any member of a structure with large values of d/t (where d is the depth of a structure or structural member parallel to wind stream and t is the least lateral dimension

of a member) are prone to low speed flutter. Wind tunnel testing is required to determine critical flutter speeds and the likely structural response. Other types of flutter are single degree of freedom stall flutter, torsional flutter etc.

c) *Ovalling* — Thin walled structures with open ends at one or both ends, such as oil storage tanks, and natural draught cooling towers, in which the ratio of the diameter of minimum lateral dimension to the wall thickness is of the order of 100 or more, are prone to ovalling oscillations. These oscillations are characterized by periodic radial deformation of the hollow structure.

7 Buildings and structures that may be subjected to serious wind excited oscillations require careful investigation. It is to be noted that wind induced oscillations may occur at wind speeds lower than the static design wind speed for the location.

8 Analytical methods for determining dynamic response of structures to wind loading can be found in the following publications:

a) Engineering Science Data, Wind Engineering sub-series (4 volumes), London, ESDU International.

b) 'Wind Engineering in the Eighties'. Construction Industry Research and Information Association. 1981, London.

c) 'Wind Effects on Structures' by E Simiu and R.H. Scanlan. Johan Wiley and Sons, New York, 1978.

d) Supplement to the National Building Code of Canada, 1980. NRCC, No. 17724. National Research Council of Canada, Ottawa, 1980.

e) Wind Forces on Structures by Peter Sachs. Pergamon Press.

f) Flow Induced Vibration by Robert D. Clevins. Von Nostrand Reinfold Co.

9 In assessing wind loads due to such dynamic phenomenon as galloping, flutter and ovalling, if the required information is not available either in the references of Note 8 or other literature, specialist advice shall be sought, including experiments on models in wind tunnels.

4.6.2 *Motions Due to Vortex Shedding*

4.6.2.1 *Slender structures* — For a structure, the shedding frequency, η shall be determined by the following formula:

$$\eta = \frac{SV_d}{b}$$

where

S = Strouhal number,

V_d = design wind velocity, and

b = The breadth of a structure or structural members in the horizontal plane normal to the wind direction.

a) *Circular Structures* — For structures circular in cross-section:

$S = 0.20$ for bV_z not greater than 7, and

$S = 0.25$ for bV_z greater than 7.

b) *Rectangular Structures* — For structures of rectangular cross-section:

$S = 0.15$ for all values of bV_z.

NOTES

1 Significant cross wind motions may be produced by vortex shedding if the natural frequency of the structure or structural element is equal to the frequency of the vortex shedding within the range of expected wind velocities. In such cases, further analysis should be carried out on the basis of references given in Note 8 of **4.6.1**.

2 Unlined welded steel chimney stacks and similar structures are prone to excitation by vortex shedding.

3 Intensification of the effects of periodic vortex shedding has been reported in cases where two or more similar structures are located in close proximity, for example, at less than 20 b apart, where b is the dimension of the structure normal to the wind.

4 The formulae given in **4.6.2.1** (a) and **4.6.2.1** (b) are valid for infinitely long cylindrical structures. The value of S decreases slowly as the ratio of length to maximum transverse width decreases; the reduction being up to about half the value, if the structure is only three times higher than its width. Vortex shedding need not be considered if the ratio of length to maximum transverse width is less than 2.0.

4.7 Gust Factor (GF) or Gust Effectiveness Factor (GEF) Method

4.7.1 *Application*

Only the method of calculating load along wind or drag load by using gust factor method is given in the section since methods for calculating load across-wind or other components are not fully matured for all types of structures. However, it is permissible for a designer to use gust factor method to calculate all components of load on a structure using any available theory. However, such a theory must take into account the random nature of atmospheric wind speed.

NOTE — It may be noted that investigations for various types of wind induced oscillations out lined in **4.6** are in no way related to the use of gust factor method given in **4.7**. Although study of **4.6** is needed for using gust factor method.

4.7.2 *Hourly Mean Wind*

Use of the existing theories of gust factor method require a knowledge of the maximum of the wind speeds averaged over one hour at a particular site. Hourly mean wind speeds at different heights over different terrains is given in Table 28.

NOTE — It must also be recognized that the ratio of hourly mean wind (HMW) to peak gust (PG) given in Table 28 may not be obtainable in India since extreme wind occurs mainly due to cyclones and thunderstorms, unlike in UK and Canada where the mechanism is fully developed pressure system. However Table 28 may be followed at present for the estimation of the hourly mean wind speed till more reliable values become available.

Table 28 Hourly Mean Wind Speed Factor k_2 in Different Terrains for Different Heights

(*Clause* 4.7.2)

Height	Terrain			
m	Category 1	Category 2	Category 3	Category 4
(1)	(2)	(3)	(4)	(5)
10	0.78	0.67	0.50	0.24
15	0.82	0.72	0.55	0.24
20	0.85	0.75	0.59	0.24
30	0.88	0.79	0.64	0.34
50	0.93	0.85	0.70	0.45
100	0.99	0.92	0.79	0.57
150	1.03	0.96	0.84	0.64
200	1.06	1.00	0.88	0.68
250	1.08	1.02	0.91	0.72
300	1.09	1.04	0.93	0.74
350	1.11	1.06	0.95	0.77
400	1.12	1.07	0.97	0.79
450	1.13	1.08	0.98	0.81
500	1.14	1.09	0.99	0.82

4.7.2.1 *Variation of hourly mean wind speed with height*

The variation of hourly mean wind speed with height shall be calculated as follows:

$$\bar{V}_z = V_b k_1 \bar{k}_2 k_3$$

where

$\bar{V}_z$ = hourly mean wind speed in m/s at height z,

V_b = regional basic wind speed in m/s (*see* Fig. 1),

k_1 = probability factor (Table 4),

$\bar{k}_2$ = terrain and height factor (Table 28), and

k_3 = topography factor (**4.4.3.3**).

4.7.3 *Along Wind Load*

Along wind load on a structure on a strip area (A_e) at any height (Z) is given by:

$$F_z = C_f A_e \bar{p}_z G$$

where

F_z = along wind load on the structure at any height Z corresponding to strip area A_e,

C_f = force coefficient for the building,

A_e = effective frontal area considered for the structure at height Z,

p_z = design pressure at height Z due to mean hourly wind obtained as 0.6 V_z^2 (N/m^2), and

G = gust factor $\dfrac{\text{peak load}}{\text{mean load}}$ and is given by:

$$G = 1 + g_f r \sqrt{\left[B(1+\phi)^2 + \frac{SE}{\beta}\right]}$$

where

g_f = peak factor defined as the ratio of the expected peak value to the root mean value of a fluctuating load, and

r = a roughness factor which is dependent on the size of the structure in relation to the ground roughness.

The value of '$g_f r$' is given in Fig. 7.

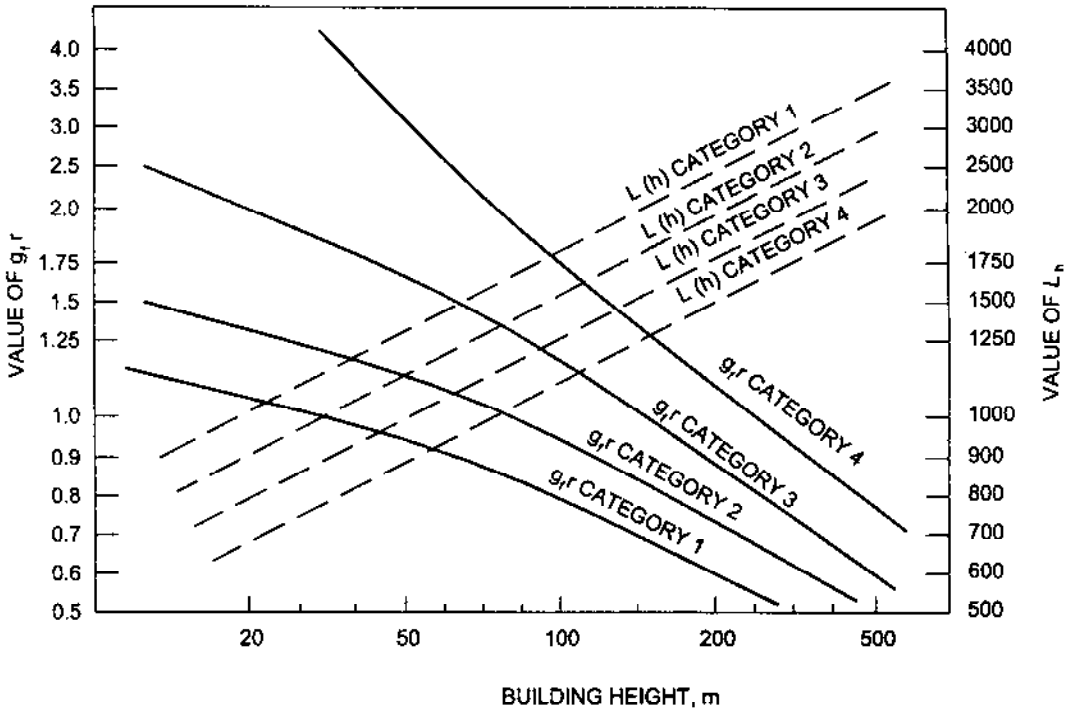


FIG. 7 VALUES OF $g_f r$ AND L_h

Table 28 Hourly Mean Wind Speed Factor k_2 in Different Terrains for Different Heights

(*Clause* 4.7.2)

Height m	Terrain			
	Category 1	Category 2	Category 3	Category 4
(1)	(2)	(3)	(4)	(5)
10	0.78	0.67	0.50	0.24
15	0.82	0.72	0.55	0.24
20	0.85	0.75	0.59	0.24
30	0.88	0.79	0.64	0.34
50	0.93	0.85	0.70	0.45
100	0.99	0.92	0.79	0.57
150	1.03	0.96	0.84	0.64
200	1.06	1.00	0.88	0.68
250	1.08	1.02	0.91	0.72
300	1.09	1.04	0.93	0.74
350	1.11	1.06	0.95	0.77
400	1.12	1.07	0.97	0.79
450	1.13	1.08	0.98	0.81
500	1.14	1.09	0.99	0.82

4.7.2.1 *Variation of hourly mean wind speed with height*

The variation of hourly mean wind speed with height shall be calculated as follows:

$$\bar{V}_z = V_b k_1 \bar{k}_2 k_3$$

where

V_z = hourly mean wind speed in m/s at height z,

V_b = regional basic wind speed in m/s (*see* Fig. 1),

k_1 = probability factor (Table 4),

$\bar{k}_2$ = terrain and height factor (Table 28), and

k_3 = topography factor (**4.4.3.3**).

4.7.3 *Along Wind Load*

Along wind load on a structure on a strip area (A_e) at any height (Z) is given by:

$$F_z = C_f A_e \bar{p}_z G$$

where

F_z = along wind load on the structure at any height Z corresponding to strip area A_e,

C_f = force coefficient for the building,

A_e = effective frontal area considered for the structure at height Z.

$\bar{p}_z$ = design pressure at height Z due to mean hourly wind obtained as 0.6 V_z^2 (N/m^2), and

G = gust factor $\dfrac{\text{peak load}}{\text{mean load}}$ and is given by:

$$G = 1 + g_f r \sqrt{\left[B(1+\phi)^2 + \frac{SE}{\beta}\right]}$$

where

g_f = peak factor defined as the ratio of the expected peak value to the root mean value of a fluctuating load, and

r = a roughness factor which is dependent on the size of the structure in relation to the ground roughness.

The value of '$g_f r$' is given in Fig. 7.

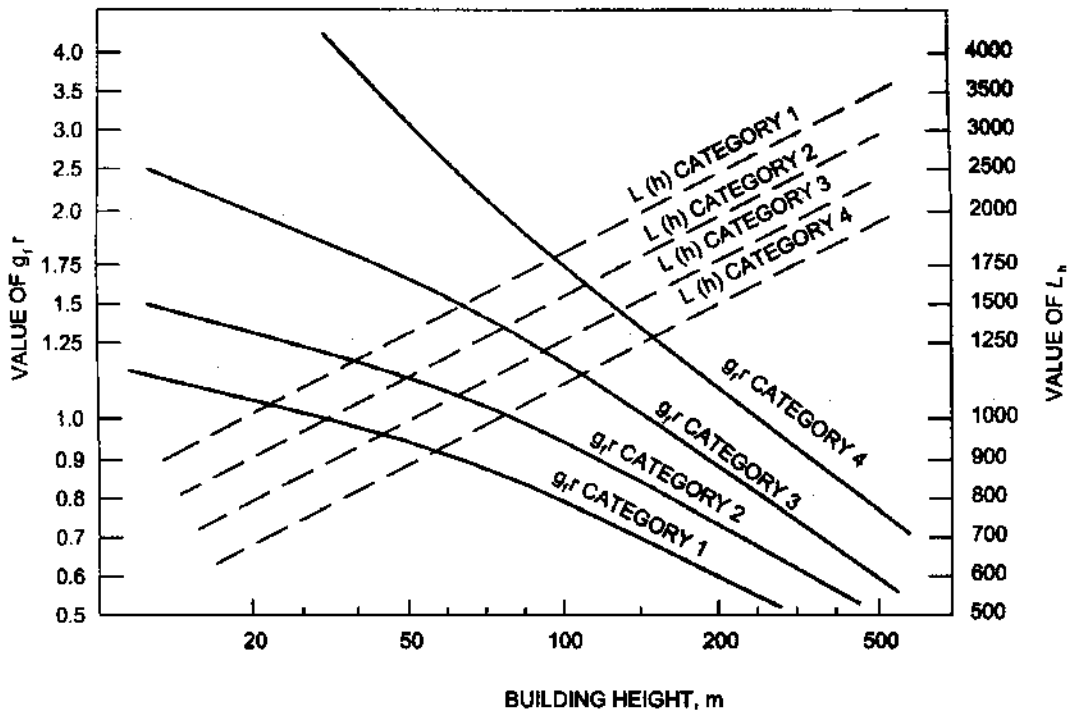


FIG. 7 VALUES OF $g_f r$ AND L_h

B is a background factor indicating a measure of the slowly varying component of the fluctuating wind load and is obtained from Fig. 8.

$\frac{SE}{\beta}$ is a measure of the resonant component of the fluctuating wind load.

E is a measure of the available energy in the wind stream at the natural frequency of the structure (*see* Fig. 9).

S is size reduction factor (*see* Fig. 10).

β is the damping coefficient (as a fraction of critical damping) of the structure (*see* Table 29).

$\varphi = \frac{g_f \sqrt{B}}{4}$ and is to be accounted only for buildings less than 75 m high in terrain category 4 and for buildings less than 25 high in terrain category 3, and is to be taken as zero in all other cases.

In Fig. 8 and 10,

$$\lambda = \frac{C_y b}{C_z h} \text{ and } f_o = \frac{C_z f_o h}{V_h}$$

where

C_y = lateral correlation constant which may be taken as 10 in the absence of more precise load data;

C_z = longitudinal correlation constant which may be taken as 12 in the absence of more precise load data;

b = breadth of a structure normal to the wind stream;

h = height of a structure;

V_z = hourly mean wind speed at height Z;

f_o = natural frequency of the structure in the fundamental mode; and

L_h = a measure of turbulence length scale (*see* Fig. 7)

Table 29 Suggested Values of Damping Coefficient

(*Clause* 4.7.3)

Nature of Structure	Damping Coefficient, β
(1)	(2)
Welded steel structures	0.010
Bolted steel structures	0.020
Reinforced concrete structures	0.016

The peak acceleration along the wind direction at the top of the structure is given by the following formula:

$$a = (2\pi f_o)^2 \bar{x}\, g_f r \frac{SE}{\beta}$$

where

$\bar{x}$ = mean deflection at the position where the acceleration is required.

5 SEISMIC LOAD

5.0 This clause deals with assessment of seismic loads on various structures and earthquake resistant design of buildings. (For the purpose of this clause the symbols given at Annex G are applicable).

5.1 Terminology for Earthquake Engineering

5.1.1 For the purpose of this standard, the following definitions shall apply which are applicable generally to all structures:

NOTE — For the definitions of terms pertaining to soil mechanics and soil dynamics references may be made to Part 6 'Structural Design, Section 2 Soils and Foundations'.

5.1.2 *Closely-Spaced Modes*

Closely-spaced modes of a structure are those of its natural modes of vibration whose natural frequencies differ from each other by 10 percent or less of the lower frequency.

5.1.3 *Critical Damping*

The damping beyond which the free vibration motion will not be oscillatory.

5.1.4 *Damping*

The effect of internal friction, imperfect elasticity of material, slipping, sliding etc, in reducing the amplitude of vibration and is expressed as a percentage of critical damping.

5.1.5 *Design Acceleration Spectrum*

Design acceleration spectrum refers to an average smoothened plot of maximum acceleration as a function of frequency or time period of vibration for a specified damping ratio for earthquake excitations at the base of a single degree of freedom system.

5.1.6 *Design Basis Earthquake (DBE)*

It is the earthquake which can reasonably be expected to occur at least once during the design life of the structure.

5.1.7 *Design Horizontal Acceleration Coefficient (A_h)*

It is a horizontal acceleration coefficient that shall be used for design of structures.

5.1.8 *Design Lateral Force*

It is the horizontal seismic force prescribed by this standard, that shall be used to design a structure.

5.1.9 *Ductility*

Ductility of a structure, or its members, is the capacity to undergo large inelastic deformations without significant loss of strength or stiffness.

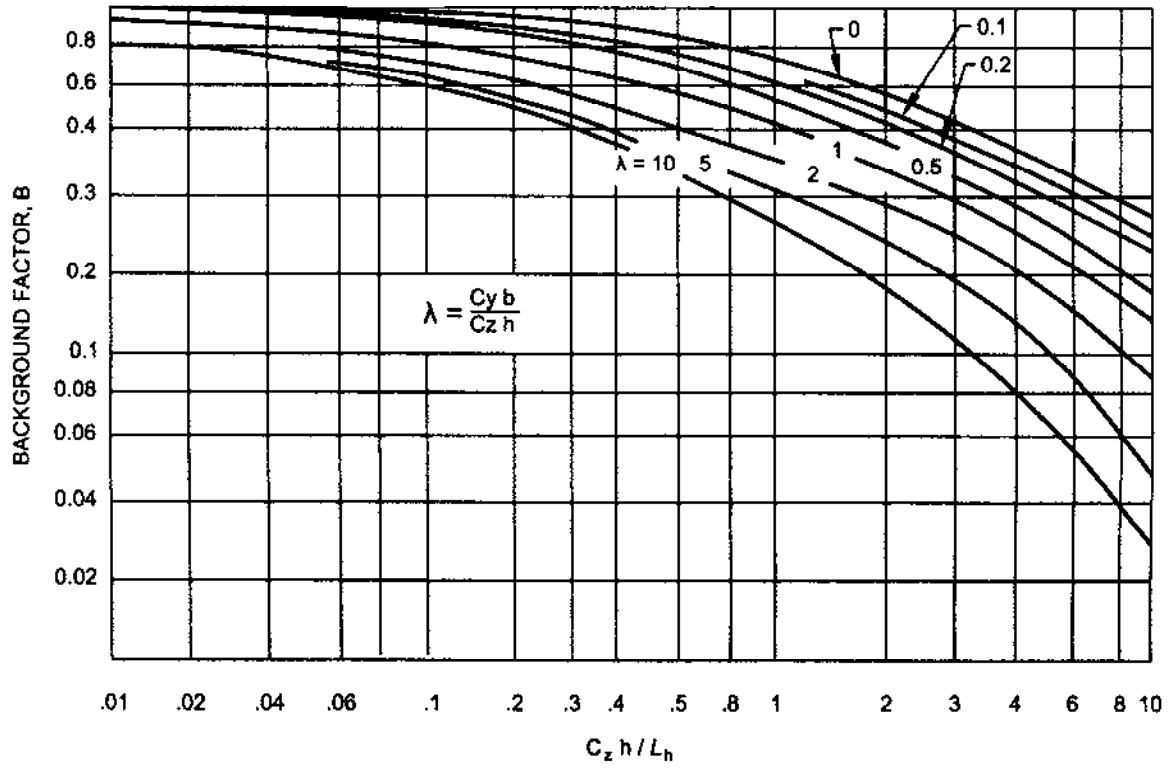


FIG. 8 BACKGROUND FACTOR, *B*

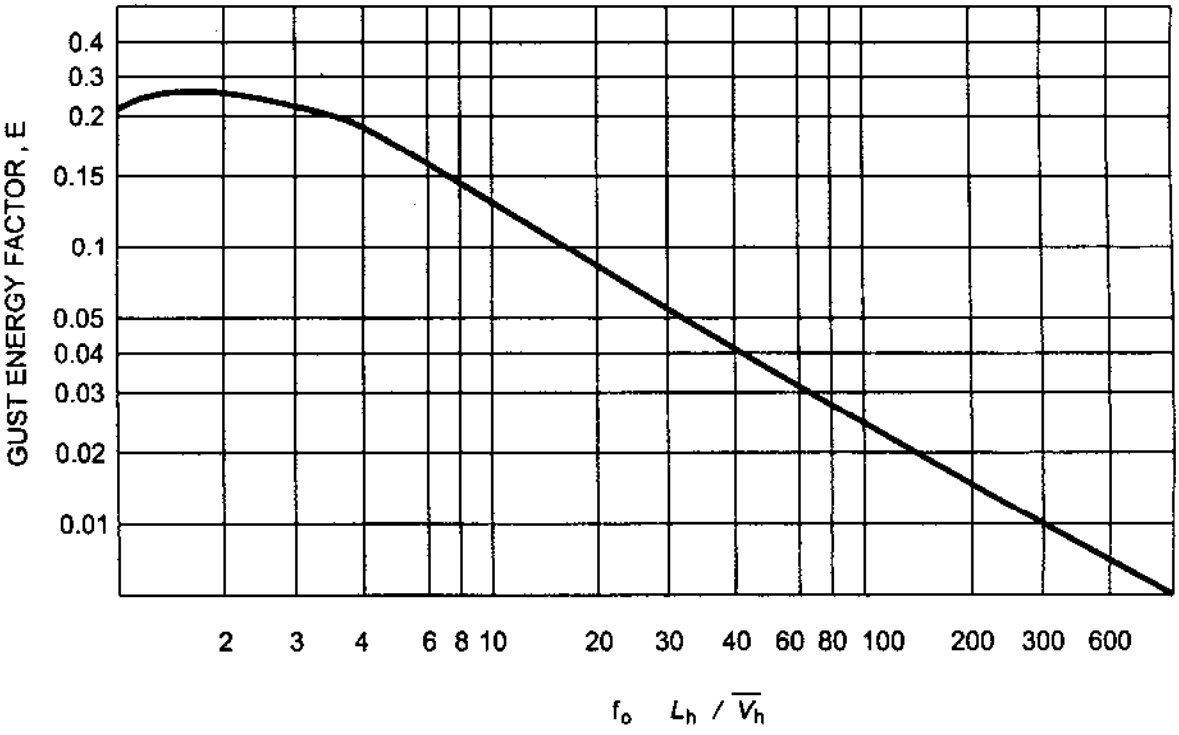


FIG. 9 GUST ENERGY FACTOR, *E*

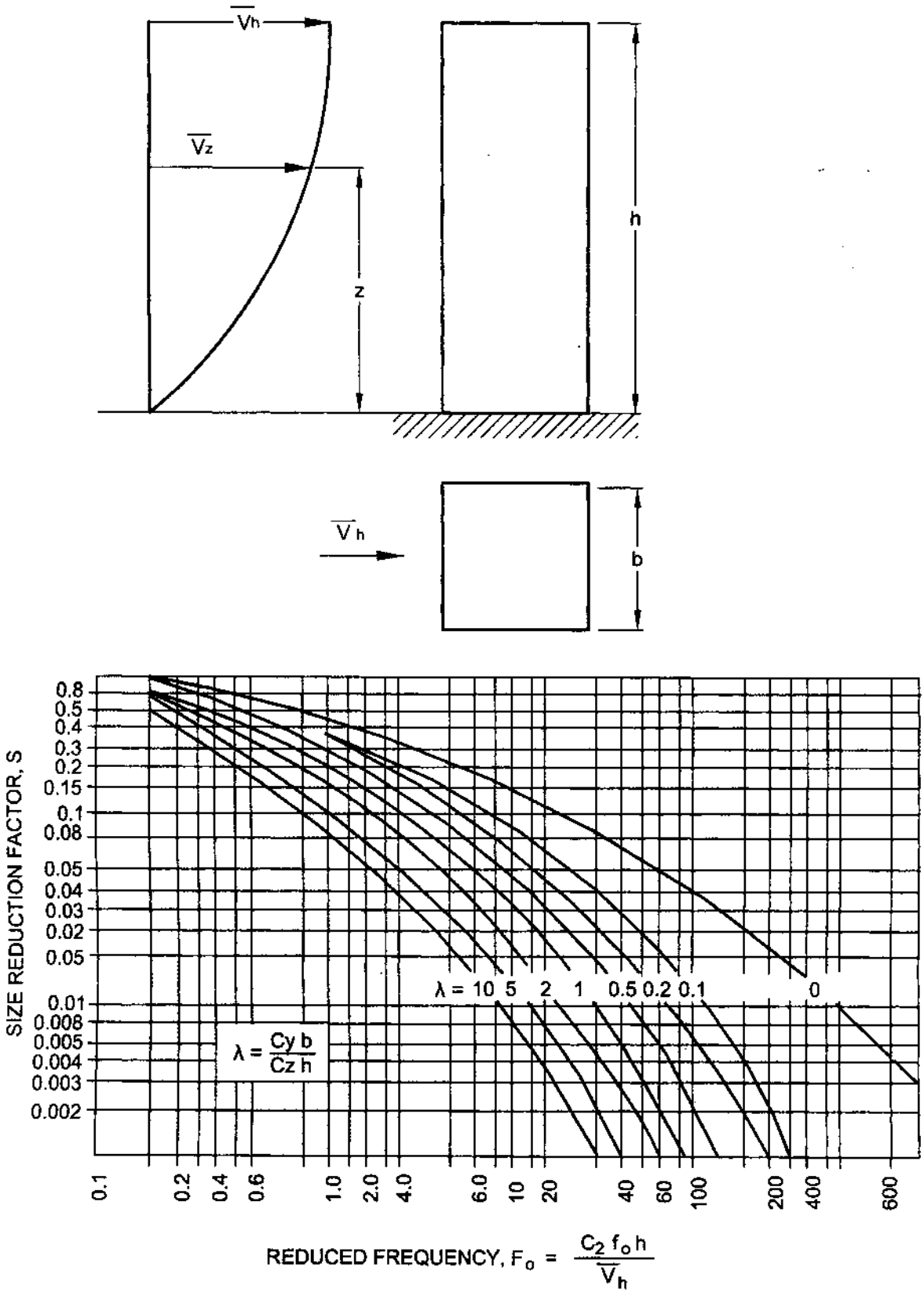


FIG. 10 SIZE REDUCTION FACTOR, *S*

5.1.10 *Epicentre*

The geographical point on the surface of earth vertically above the focus of the earthquake.

5.1.11 *Effective Peak Ground Acceleration (EPGA)*

It is 0.4 times the 5 percent damped average spectral acceleration between period 0.1 to 0.3 s. This shall be taken as zero period acceleration (ZPA).

5.1.12 *Floor Response Spectra*

Floor response spectra is the response spectra for a time history motion of a floor. This floor motion time history is obtained by an analysis of multi-storey building for appropriate material damping values subjected to a specified earthquake motion at the base of structure.

5.1.13 *Focus*

The originating earthquake source of the elastic waves inside the earth which cause shaking of ground due to earthquake.

5.1.14 *Importance Factor (I)*

It is a factor used to obtain the design seismic force depending on the functional use of the structure, characterised by hazardous consequences of its failure, its post-earthquake functional need, historic value, or economic importance.

5.1.15 *Intensity of Earthquake*

The intensity of an earthquake at a place is a measure of the strength of shaking during the earthquake, and is indicated by a number according to the modified Mercalli Scale or M.S.K. scale of Seismic Intensities (*see* Annex H).

5.1.16 *Liquefaction*

Liquefaction is a state in saturated cohesionless soil wherein the effective shear strength is reduced to negligible value for all engineering purpose due to pore pressure caused by vibrations during an earthquake when they approach the total confining pressure. In this condition the soil tends to behave like a fluid mass.

5.1.17 *Lithological Features*

The nature of the geological formation of the earth's crust above bed rock on the basis of such characteristics as colour, structure, mineralogical composition and grain size.

5.1.18 *Magnitude of Earthquake (Richter's Magnitude)*

The magnitude of earthquake is a number, which is a measure of energy released in an earthquake. It is defined as logarithm to the base 10 of the maximum trace amplitude, expressed in microns, which the standard short-period torsion seismometer (with a period of 0.8 s, magnification 2 800 and damping nearly critical) would register due to the earthquake at an epicentral distance of 100 km.

5.1.19 *Maximum Considered Earthquake (MCE)*

The most severe earthquake effects considered by this Code.

5.1.20 *Modal Mass (M_k)*

Modal mass of a structure subjected to horizontal or vertical, as the case may be, ground motion is a part of the total seismic mass of the structure that is effective in *mode k* of vibration. The modal mass for a given mode has a unique value irrespective of scaling of the mode shape.

5.1.21 *Modal Participation Factor (P_k)*

Modal participation factor of mode k of vibration is the amount by which mode k contributes to the overall vibration of the structure under horizontal and vertical earthquake ground motions. Since the amplitudes of 95 per cent mode shapes can be scaled arbitrarily, the value of this factor depends on the scaling used for mode shapes.

5.1.22 *Modes of Vibration* (*see* **5.1.25**)

5.1.23 *Mode Shape Coefficient (ϕ_{ik})*

When a system is vibrating in normal *mode k*, at any particular instant of time, the amplitude of mass i expressed as a ratio of the amplitude of one of the masses of the system, is known as mode shape coefficient (ϕ_{ik}).

5.1.24 *Natural Period (T)*

Natural period of a structure is its time period of undamped free vibration.

5.1.24.1 *Fundamental natural period (T_1)*

It is the first (longest) modal time period of vibration.

5.1.24.2 *Modal natural period (T_k)*

The modal natural period of mode k is the time period of vibration in *mode k*.

5.1.25 *Normal Mode*

A system is said to be vibrating in a normal mode when all its masses attain maximum values of displacements and rotations simultaneously, and pass through equilibrium positions simultaneously.

5.1.26 *Response Reduction Factor (R)*

It is the factor by which the actual base shear force, that would be generated if the structure were to remain elastic during its response to the design basis

5.1.27 *Response Spectrum*

The representation of the maximum response of idealized single degree freedom systems having certain period and damping, during earthquake ground motion. The maximum response is plotted against the undamped natural period and for various damping values, and can be expressed in terms of maximum absolute acceleration, maximum relative velocity, or maximum relative displacement.

5.1.28 *Seismic Mass*

It is the seismic weight divided by acceleration due to gravity.

5.1.29 *Seismic Weight (W)*

It is the total dead load plus appropriate amounts of specified imposed load.

5.1.30 *Structural Response Factors (S_a/g)*

It is a factor denoting the acceleration response spectrum of the structure subjected to earthquake ground vibrations, and depends on natural period of vibration and damping of the structure.

5.1.31 *Tectonic Features*

The nature of geological formation of the bed rock in the earth's crust revealing regions characterized by structural features, such as dislocation, distortion, faults, folding, thrusts, volcanoes with their age of formation, which are directly involved in the earth movement or quake resulting in the above consequences.

5.1.32 *Time History Analysis*

It is an analysis of the dynamic response of the structure attach increment of time, when its base is subjected to a specific ground motion time history.

5.1.33 *Zone Factor (Z)*

It is a factor to obtain the design spectrum depending on the perceived maximum seismic risk characterized by maximum considered earthquake (MCE) in the zone in which the structure is located. The basic zone factors included in this standard are reasonable estimate of effective peak ground acceleration.

5.1.34 *Zero Period Acceleration (ZPA)*

It is the value of acceleration response spectrum for period below 0.03 s (frequencies above 33 Hz).

5.2 Terminology for Earthquake Engineering of Buildings

5.2.1 For the purpose of earthquake resistant design

5.2.2 *Base*

It is the level at which inertia forces generated in the structure are transferred to the foundation, which then transfers these forces to the ground.

5.2.3 *Base Dimensions (d)*

Base dimension of the building along a direction is the dimension at its base, in metres, along that direction.

5.2.4 *Centre of Mass*

The point through which the resultant of the masses of a system acts. This point corresponds to the centre of gravity of masses of system.

5.2.5 *Centre of Stiffness*

The point through which the resultant of the restoring forces of a system acts.

5.2.6 *Design Eccentricity (e_{di})*

It is the value of eccentricity to be used at floor i in torsion calculations for design.

5.2.7 *Design Seismic Base Shear (V_B)*

It is the total design lateral force at the base of a structure.

5.2.8 *Diaphragm*

It is a horizontal, or nearly horizontal system, which transmits lateral forces to the vertical resisting elements, for example, reinforced concrete floors and horizontal bracing systems.

5.2.9 *Dual System*

Buildings with dual system consist of shear walls (or braced frames) and moment resisting frames such that:

a) the two systems are designed to resist the total design lateral force in proportion to their lateral stiffness considering the interaction of the dual system at all floor levels; and

b) the moment resisting frames are designed to independently resist at least 25 percent of the design base shear.

5.2.10 *Height of Floor (h_i)*

It is the difference in levels between the base of the building and that of floor i.

5.2.11 *Height of Structure (h)*

It is the difference in levels, in metres, between its base and its highest level.

5.2.12 *Horizontal Bracing System*

It is a horizontal truss system that serves the same function as a diaphragm.

5.2.13 *Joint*

It is the portion of the column that is common to other members, for example, beams, framing into it.

5.2.14 *Lateral Force Resisting Element*

It is part of the structural system assigned to resist lateral forces.

5.2.15 *Moment-Resisting Frame*

It is a frame in which members and joints are capable of resisting forces primarily by flexure.

5.2.15.1 *Ordinary moment-resisting frame*

It is a moment-resisting frame not meeting special detailing requirements for ductile behaviour.

5.2.15.2 *Special moment-resisting frame*

It is a moment-resisting frame specially detailed to provide ductile behaviour and comply with the requirements given in IS 4326 or IS 13920 or SP 6(6).

5.2.16 *Number of Storeys (n)*

Number of storeys of a building is the number of levels above the base. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But, it includes the basement storeys, when they are not so connected.

5.2.17 *Principal Axes*

Principal axes of a building are generally two mutually perpendicular horizontal directions in plan of a building along which the geometry of the building is oriented.

5.2.18 *$P-\Delta$ Effect*

It is the secondary effect on shears and moments of frame members due to action of the vertical loads, interacting with the lateral displacement of building resulting from seismic forces.

5.2.19 *Shear Wall*

It is a wall designed to resist lateral forces acting in its own plane.

5.2.20 *Soft Storey*

It is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above.

5.2.21 *Static Eccentricity (e_{si})*

It is the distance between centre of mass and centre of rigidity of floor *i*.

5.2.22 *Storey*

It is the space between two adjacent floors.

5.2.23 *Storey Drift*

It is the displacement of one level relative to the other level above or below.

5.2.24 *Storey Shear (V_i)*

It is the sum of design lateral forces at all levels above the storey under consideration.

5.2.25 *Weak Storey*

It is one in which the storey lateral strength is less than 80 percent of that in the storey above. The storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction.

5.3 General Principles and Design Criteria

5.3.1 *General Principles*

5.3.1.1 *Ground motion*

The characteristics (intensity, duration, etc) of seismic ground vibrations expected at any location depends upon the magnitude of earthquake, its depth of focus, distance from the epicentre, characteristics of the path through which the seismic waves travel, and the soil strata on which the structure stands. The random earthquake ground motions, which cause the structure to vibrate, can be resolved in any three mutually perpendicular directions. The predominant direction of ground vibration is usually horizontal.

Earthquake-generated vertical inertia forces are to be considered in design unless checked and proven by specimen calculations to be not significant. Vertical acceleration should be considered in structures with large spans, those in which stability is a criterion for design, or for overall stability analysis of structures. Reduction in gravity force due to vertical component of ground motions can be particularly detrimental in cases of prestressed horizontal members and of cantilevered members. Hence, special attention should be paid to the effect of vertical component of the ground motion on prestressed or cantilevered beams, girders and slabs.

5.3.1.2 The response of a structure to ground vibrations is a function of the nature of foundation soil, materials, form, size and mode of construction of structures; and the duration and characteristics of ground motion. This standard specifies design forces for structures standing on rocks or soils which do not

settle, liquefy or slide due to loss of strength during ground vibrations.

5.3.1.3 The design approach adopted in this standard is to ensure that structures possess at least a minimum strength to withstand minor earthquakes (<DBE), which occur frequently, without damage; resist moderate earthquakes (DBE) without significant structural damage though some non-structural damage may occur; and aims that structures withstand a major earthquake (MCE) without collapse. Actual forces that appear on structures during earthquakes are much greater than the design forces specified in this Code. However, ductility, arising from inelastic material behaviour and detailing, and overstrength, arising from the additional reserve strength in structures over and above the design strength, are relied upon to account for this difference in actual and design lateral loads.

Reinforced and prestressed concrete members shall be suitably designed to ensure that premature failure due to shear or bond does not occur, subject to the provisions of Part 6 'Structural Design, Section 5 Concrete'. Provisions for appropriate ductile detailing of reinforced concrete members shall be in accordance with good practice [6-1(4)].

In steel structures, members and their connections should be so proportioned that high ductility is obtained, vide SP 6(6), avoiding premature failure due to elastic or inelastic buckling of any type.

The specified earthquake loads are based upon post-elastic energy dissipation in the structure and because of this fact, the provision of this Code for design, detailing and construction shall be satisfied even for structures and members for which load combinations that do not contain the earthquake effect indicate larger demands than combinations including earthquake.

5.3.1.4 *Soil-structure interaction*

The soil-structure interaction refers to the effects of the supporting foundation medium on the motion of structure. The soil-structure interaction may not be considered in the seismic analysis for structures supported on rock or rock-like material.

5.3.1.5 The design lateral force specified in this Code shall be considered in each of the two orthogonal horizontal directions of the structure. For structures which have lateral force resisting elements in the two orthogonal directions only, the design lateral force shall be considered along one direction at a time, and not in both directions simultaneously. Structures, having lateral force resisting elements (for example, frames, shear walls) in directions other than the two orthogonal directions, shall be analysed considering the load combinations specified in **5.3.3.2**.

Where both horizontal and vertical seismic forces are taken into account, load combinations specified in **5.3.3.3** shall be considered.

5.3.1.6 Equipment and other systems, which are supported at various floor levels of the structure, will be subjected to motions corresponding to vibration at their support points. In important cases, it may be necessary to obtain floor response spectra for design of equipment supports. For detail reference be made to good practice [6-1(5)]

5.3.1.7 *Additions to existing structures*

Additions shall be made to existing structures only as follows:

a) An addition that is structurally independent from an existing structures shall be designed and constructed in accordance with the seismic requirements for new structures.

b) An addition that is not structurally independent from an existing structure shall be designed and constructed such that the entire structure conforms to the seismic force resistance requirements for new structures unless the following three conditions are complied with:
   1) The addition shall comply with the requirements for new structures;
   2) The addition shall not increase the seismic forces in any structural elements of the existing structure by more than 5 per cent unless the capacity of the element subject to the increased force is still in compliance with this standard; and
   3) The addition shall not decrease the seismic resistance of any structural element of the existing structure unless reduced resistance is equal to or greater than that required for new structures.

5.3.1.8 *Change in occupancy*

When a change of occupancy results in a structure being reclassified to a higher importance factor (I), the structure shall conform to the seismic requirements for a new structure with the higher importance factor.

5.3.2 *Assumptions*

The following assumptions shall be made in the earthquake-resistant design of structures:

a) Earthquake causes impulsive ground motions, which are complex and irregular in character, changing in period and amplitude each lasting for a small duration. Therefore, resonance of the type as visualized under steady-state sinusoidal excitations, will not occur as it would need time to build up such amplitudes.

NOTE However, there are exceptions where

resonance-like conditions have been seen to occur between long distance waves and tall structures founded on deep soft soils.

b) Earthquake is not likely to occur simultaneously with wind or maximum flood or maximum sea waves.

c) The value of elastic modulus of materials, wherever required, may be taken as for static analysis unless a more definite value is available for use in such condition (*see* Part 6 'Structural Design, Section 5 Concrete and Section 6 Steel'.

5.3.3 *Load Combination and Increase in Permissible Stresses*

5.3.3.1 *Load combinations*

When earthquake forces are considered on a structure, these shall be combined as per **5.3.3.1.1** and **5.3.3.1.2** where the terms *DL*, *IL* and *EL* stand for the response quantities due to dead load, imposed and designated earthquake load respectively.

5.3.3.1.1 *Load factors for plastic design of steel structures*

In the plastic design of steel structures, the following load combinations shall be accounted for:

a) 1.7 (*DL* + *IL*)
b) 1.7 (*DL* ± *EL*)
c) 1.3 (*DL*+ *IL* ± *EL*)

5.3.3.1.2 *Partial safety factors for limit state design of reinforced concrete and prestressed concrete structures*

In the limit state design of reinforced and prestressed concrete structures, the following load combinations shall be accounted for:

a) 1.5 (*DL* + *IL*)
b) 1.2 (*DL*+ *IL* ± *EL*)
c) 1.5 (*DL* ± *EL*)
d) 0.9 *DL* ± 1.5 *EL*

5.3.3.2 *Design horizontal earthquake load*

5.3.3.2.1 When the lateral load resisting elements are oriented along orthogonal horizontal direction, the structure shall be designed for the effects due to full design earthquake load in one horizontal direction at time.

5.3.3.2.2 When the lateral load resisting elements are not oriented along the orthogonal horizontal directions, the structure shall be designed for the effects due to full design earthquake load in one horizontal direction plus 30 percent of the design earthquake load in the other direction.

NOTE — For instance, the building should be designed for ($\pm EL_x \pm 0.3\ EL_y$) as well as ($\pm 0.3\ EL_x \pm EL_y$), where *x* and *y* are two orthogonal horizontal direction, *EL* in **5.3.3.1.1** and **5.3.3.1.2** shall be replaced by ($EL_x \pm 0.3\ EL_y$) or ($EL_y \pm 0.3\ EL_x$).

5.3.3.3 *Design vertical earthquake load*

When effects due to vertical earthquake loads are to be considered, the design vertical force shall be calculated in accordance with **5.3.4.5**.

5.3.3.4 *Combination for two or three component motion*

5.3.3.4.1 When responses from the three earthquake components are to be considered, the responses due to each components may be combined using the assumption that when the maximum response from one component occurs, the responses from the other two component are 30 percent of their maximum. All possible combinations of the three components (EL_x, EL_y and EL_z) including variations in sign (plus or minus) shall be considered. Thus, the response due earthquake force (*EL*) is the maximum of the following three cases:

a) $\pm EL_x \pm 0.3\ EL_Y \pm 0.3\ EL_z$
b) $\pm EL_y \pm 0.3\ EL_x \pm 0.3\ EL_z$
c) $\pm EL_z \pm 0.3\ EL_x \pm 0.3\ EL_y$

Where *x* and *y* are two orthogonal directions and z is vertical direction.

5.3.3.4.2 As an alternative to the procedure in **5.3.3.4.1**, the response (*EL*) due to the combined effect of the three components can be obtained on the basis of 'square root of the sum of the square (SRSS)' that is

$$EL = \sqrt{(EL_x)^2 + (EL_y)^2 + (EL_z)^2}$$

NOTE — The combination procedure of **5.3.3.4.1** and **5.3.3.4.2** apply to the same response quantity (say, moment in a column about its major axis, or storey shear in a frame) due to different components of the ground motion.

5.3.3.4.3 When two component motions (say one horizontal and one vertical, or only two horizontal) are combined, the equations in **5.3.3.4.1** and **5.3.3.4.2** should be modified by deleting the term representing the response due to the component of motion not being considered.

5.3.3.5 *Increase in permissible stresses*

5.3.3.5.1 *Increase in permissible stresses in materials*

When earthquake forces are considered along with other normal design forces, the permissible stresses in material, in the elastic method of design, may be increased by one-third. However, for steels having a definite yield stress, the stress be limited to the yield stress; for steels without a definite yield point, the stress will be limited to 80 percent of the ultimate strength or 0.2 percent proof stress, whichever is smaller; and that in prestressed concrete members, the tensile stress in the extreme fibres of the concrete may be permitted so as not to exceed two-thirds of the modulus of rupture of concrete.

5.3.3.5.2 *Increase in allowable pressure in soils*

When earthquake forces are included, the allowable bearing pressure in soils shall be increased as per Table 1, depending upon type of foundation of the structure and the type of soil.

In soil deposits consisting of submerged loose sands and soils falling under classification SP with standard penetration N values less than 15 in seismic Zones III, IV, V and less than 10 in seismic Zone II, the vibration caused by earthquake may cause liquefaction or excessive total and differential settlements. Such sites should preferably be avoided while locating new settlements or important projects. Otherwise, this aspect of the problem needs to be investigated and appropriate methods of compaction or stabilization adopted to achieve suitable N values as indicated in Note 3 under Table 30. Alternatively, deep pile foundation may be provided and taken to depths well into the layer which is not likely to liquefy. Marine clays and other sensitive clays are also known to liquefy due to collapse of soil structure and will need special treatment according to site condition.

NOTE — Specialist literature may be referred for determining liquefaction potential of a site.

Table 30 Percentage of Permissible Increase in Allowable Bearing Pressure or Resistance of Soils

(*Clause* 5.3.3.5.2)

Sl No.	Foundation	Type of Soil Mainly Constituting the Foundation		
		Type I Rock or Hard Soil: Well graded gravel and sand gravel mixtures with or without clay binder, and clayey sands poorly graded or sand clay mixtures (GB, CW, SB, SW and SC)[1] having[2] above 30, where N is the standard penetration value	Type II Medium Soils All soils with N between 10 an 30, and poorly graded sands or gravelly sands with little or no fines (SP[1]) with $N > 15$	Type III Soft Soils: All soils other than SP[1] with $N < 10$
(1)	(2)	(3)	(4)	(5)
i)	Piles passing through any soil but resting on solid type I	50	50	50
ii)	Piles not covered under item (i)	—	25	25
iii)	Raft foundations	50	50	50
iv)	Combined isolated RCC footing with tie beams	50	25	—
v)	Isolated RCC footing without tie beams, or unreinforced strip foundations	50	25	—
vi)	Well foundations	50	25	25

NOTES

1 The allowable bearing pressure shall be determined in accordance with good practice [6-1(6)].

2 If any increase in bearing pressure has already been permitted for forces other than seismic forces, the total increase in allowable bearing pressure when seismic force is also included shall not exceed the limits specified above.

3 Desirable minimum field values of N — If soils of smaller N-values are met, compacting may be adopted to achieve these values or deep pile foundations going to stronger strata should be used.

4 The values of N (corrected values) are at the founding level and the allowable bearing pressure shall be determined in accordance with good practice [6-1(6)].

Seismic Zone Level	*Depth Below Ground* m	*N-Values*	*Remark*
III, IV and V	≤ 5	15	For values of depths between 5 m and 10 m, linear interpolation is recommended.
	≥ 10	25	
II (for important structures only)	≤ 5	15	
	≥ 10	20	

5 The piles should be designed for lateral loads neglecting lateral resistance of soil layers liable to liquefy.

6 Accepted standard [6-1(7)] and good practice [6-1(8)] may also be referred.

7 Isolated R.C.C. footing without tie beams, or unreinforced strip foundation shall not be permitted in soft soils with N<10.

[1] *See* accepted standard [6-1(7)].

[2] *See* good practice [6-1(8)].

5.3.4 *Design Spectrum*

5.3.4.1 For the purpose of determining seismic forces, the country is classified into four seismic zones as shown in Fig. 11.

5.3.4.2 The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = \frac{ZI}{2R} \frac{S_a}{g}$$

Provided that for any structure with $T \geq 0.1$ sec, the value of A_h will not be less than $Z/2$ whatever be the value of I/R

where

Z = Zone factor given in Table 31, is for the maximum considered earthquake (MCE) and service life of structure in a zone. The factor 2 in the denominator of $\geq$ is used so as to reduce the maximum considered earthquake (MCE) zone factor to the factor for design basis earthquake (DBE).
Zone factor for some important towns are given at Annex J.

I = Importance factor, depending upon the functional use of the structures, characterised by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance (Table 35).

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0 (Table 36). The values of R for buildings are given in Table 36.

S_a/g = Average response acceleration coefficient for rock or soil sites as given by Fig. 12 and Table 32 based on appropriate natural periods and damping of the structure. These curves represent free field ground motion.

NOTE — For various types of structures, the values of Importance Factor I, Response Reduction Factor R, and damping values are given in the respective parts of this standard. The method (empirical or otherwise) to calculate the natural periods of the structure to be adopted for evaluating S_a/g is also given in the respective parts of this Code.

Table 31 Zone Factor, Z

(*Clause* 5.3.4.2)

Seismic Zone	II	III	IV	V
Seismic Intensity	Low	Moderate	Severe	Very Severe
Z	0.10	0.16	0.24	0.36

5.3.4.3 Where a number of modes are to be considered for dynamic analysis, the value of A_h as defined in **5.3.4.2** for each mode shall be determined using the natural period of vibration of that mode.

5.3.4.4 For underground structures and foundations at depths of 30 m or below, the design horizontal acceleration spectrum value shall be taken as half the value obtained from **5.3.4.2**. For structures and foundations placed between the ground level and 30 m depth, the design horizontal acceleration spectrum value shall be linearly interpolated between A_h and 0.5 A_h, where A_h is as specified in **5.3.4.2**.

5.3.4.5 The design acceleration spectrum for vertical motions, when required, may be taken as two-thirds of the design horizontal acceleration spectrum specified in **5.3.4.2**.

Figure 12 shows the proposed 5 percent spectra for rocky and soils sites and Table 32 gives the multiplying factors for obtaining spectral values for various other dampings.

For Rocky, or hard soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \leq T \leq 0.10 \\ 2.50 & 0.10 \leq T \leq 0.40 \\ 1.00/T & 0.40 \leq T \leq 4.00 \end{cases}$$

For Medium soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \leq T \leq 0.10 \\ 2.50 & 0.10 \leq T \leq 0.55 \\ 1.36/T & 0.55 \leq T \leq 4.00 \end{cases}$$

For Soft soil sites

$$\frac{S_a}{g} = \begin{cases} 1+15T; & 0.00 \leq T \leq 0.10 \\ 2.50 & 0.10 \leq T \leq 0.67 \\ 1.67/T & 0.67 \leq T \leq 4.00 \end{cases}$$

Table 32 Multiplying Factors for Obtaining Values for Other Damping

(*Clause* 5.3.4.2)

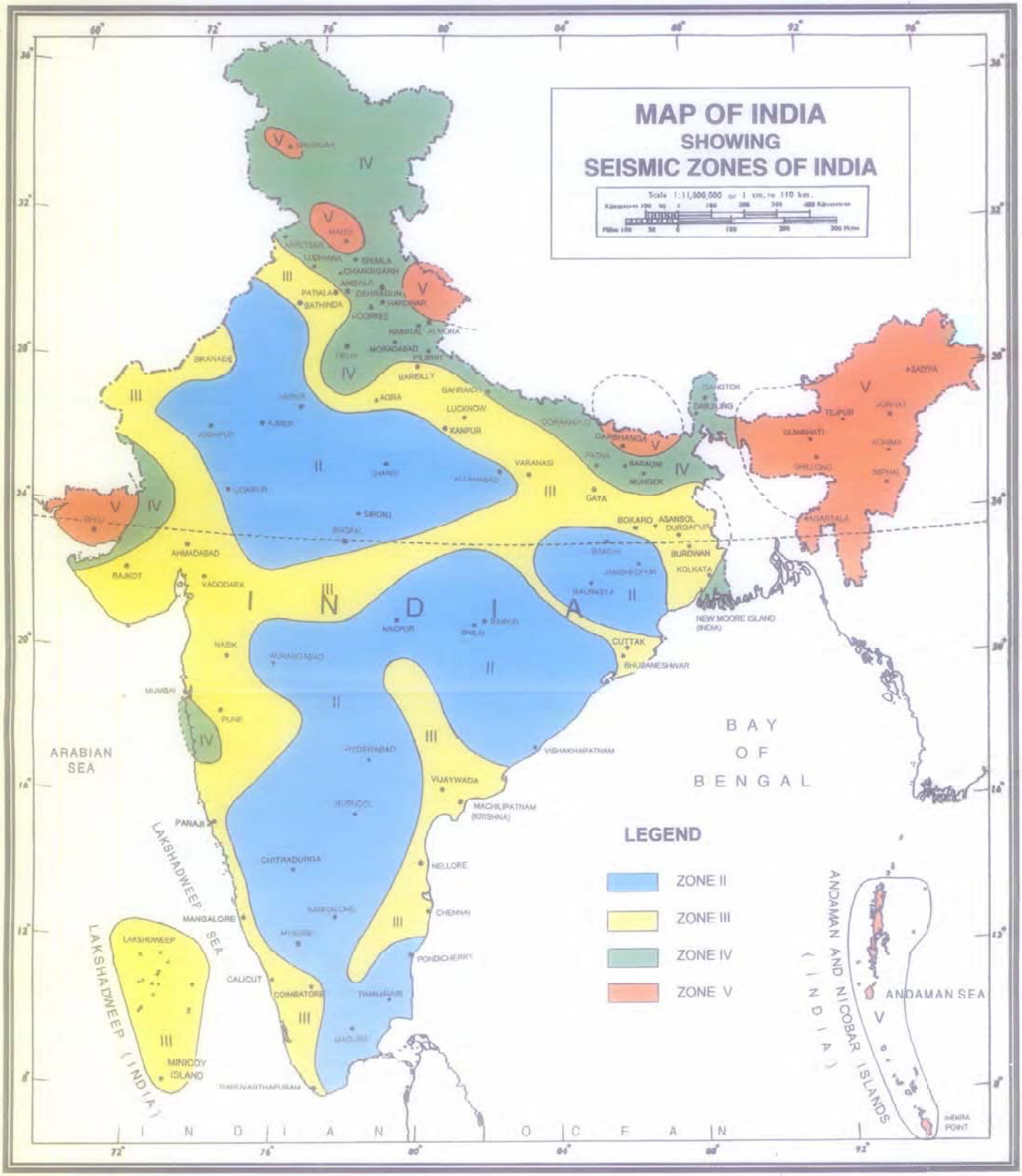
Damping percent	0	2	5	7	10	15	20	25	30
Factors	3.20	1.40	1.00	0.90	0.80	0.70	0.60	0.55	0.50

5.3.4.6 In case design spectrum is specifically prepared for a structure at a particular project site, the same may be used for design at the discretion of the project authorities.

5.4 Buildings

5.4.1 *Regular and Irregular Configuration*

To perform well in an earthquake, a building should possess four main attributes, namely, simple and regular configuration, and adequate lateral strength, stiffness and ductility. Buildings having simple regular in plan as well as in elevation, suffer much less damage



Based upon Survey of India Outline Map printed in 1993.

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

NOTE — Towns falling at the boundary of zones demarcation line between two zones shall be considered in higher zone.

FIG. 11 SEISMIC ZONES

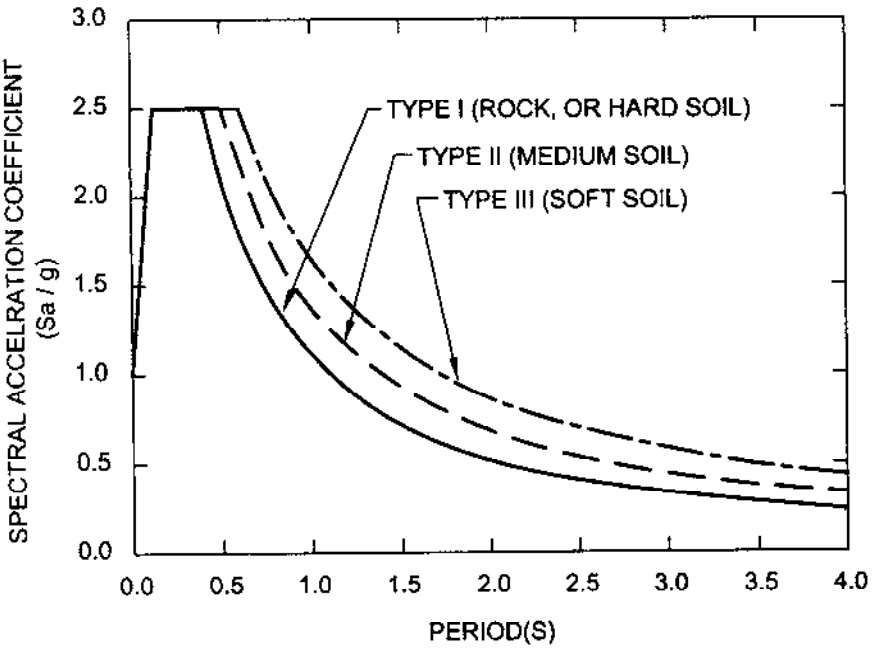


FIG. 12 RESPONSE SPECTRA FOR ROCK AND SOIL SIGHT FOR 5 PERCENT DAMPING

than buildings with irregular configurations. A building shall be considered as irregular for the purposes of this standard, if at least one of the conditions given in Tables 33 and 34 is applicable.

Table 33 Definitions of Irregular Buildings — Plan Irregularities (Fig. 13)

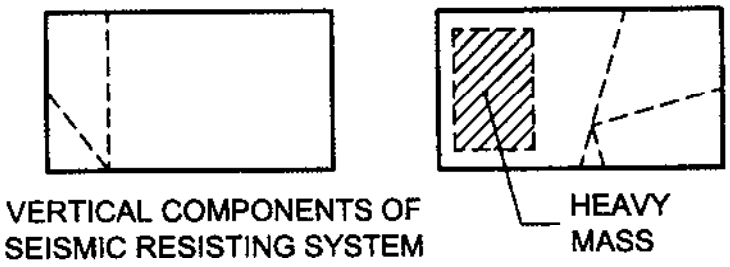
(*Clause* 5.4.1)

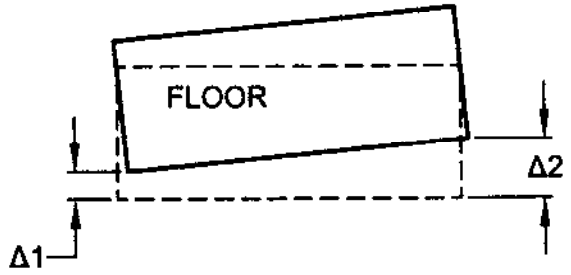
Sl No.	Irregularity Type and Description
i)	*Torsion Irregularity* To be considered when floor diaphragms are rigid in their own plan in relation to the vertical structural elements that resist the lateral forces. Torsional irregularity to be considered to exist when the maximum storey drift, computed with design eccentricity, at one end of the structures transverse to an axis is more than 1.2 times the average of the storey drifts at the two ends of the structure.
ii)	*Re-entrant Corners* Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction.
iii)	*Diaphragm Discontinuity* Diaphragms with abrupt discontinuities or variations in stiffness, including those having cut-out or open areas greater than 50 percent of the gross enclosed diaphragm area, or changes in effective diaphragm stiffness of more than 50 percent from one storey to the next.
iv)	*Out- of- Plane Offsets* Discontinuities in a lateral force resistance path, such as out-of-plane offsets of vertical elements.
v)	*Non-parallel Systems* The vertical elements resisting the lateral force are not parallel to or symmetric about the major orthogonal axes or the lateral force resisting elements.

Table 34 Definition of Irregular Buildings — Vertical Irregularities (Fig. 14)

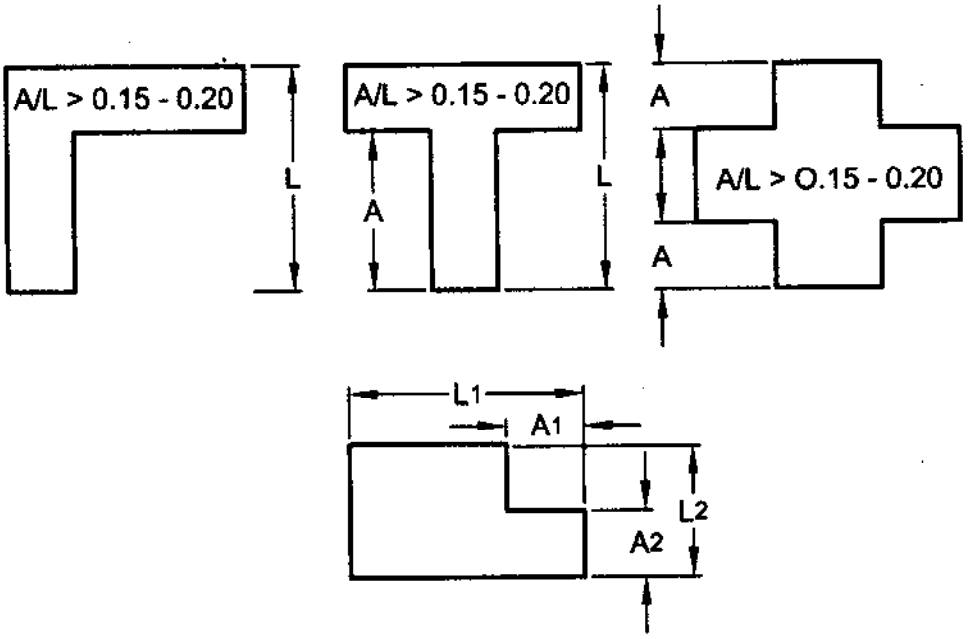
(*Clause* 5.4.1)

Sl No.	Irregularity Type and Description
i)	a) *Stiffness Irregularity — Soft Storey* A soft storey is one in which the lateral stiffness is less than 70 percent of that in the storey above or less than 80 percent of the average lateral stiffness of the three storeys above. b) *Stiffness Irregularity — Extreme Soft Storey* An extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above. For example, buildings on STILTS will fall under this category.
ii)	*Mass Irregularity* Mass irregularity shall be considered to exist where the seismic weight of any storey is more than 200 percent of that of its adjacent storeys. The irregularity need not be considered in case of roofs.
iii)	*Vertical Geometric Irregularity* Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral force resisting system in any storey is more than 150 percent of that in its adjacent storey.
iv)	*In-Plane Discontinuity in Vertical Elements Resisting Lateral Force* An in-plane offset of the lateral force resisting elements greater than the length of those elements.
v)	*Discontinuity in Capacity — Weak Strorey* A weak storey is one in which the storey lateral strength is less than 80 percent of that in the storey above. The storey lateral strength is the total strength of all seismic force resisting elements sharing the storey shear in the considered direction.



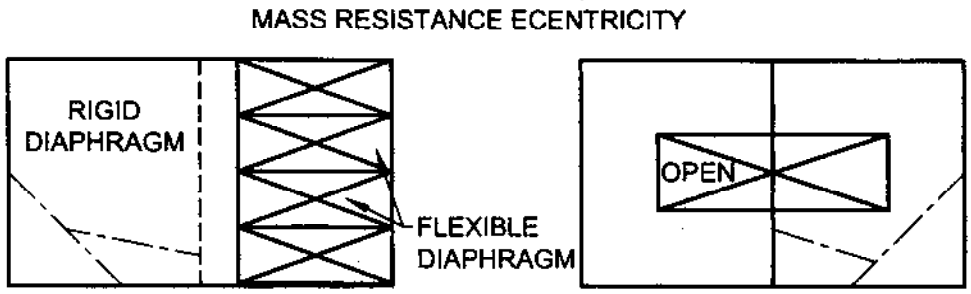


13 A TORSIONAL IRREGULARITY

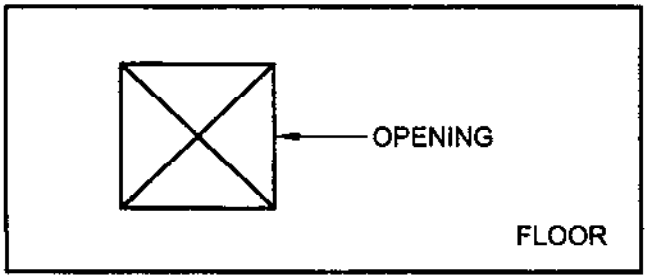


13 B RE - ENTRANT CORNER

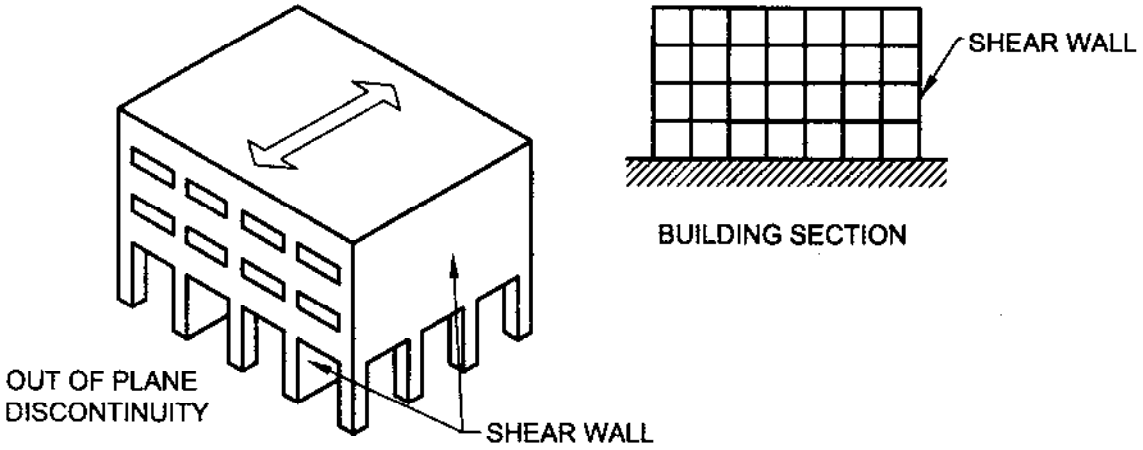
FIG. 13 PLAN IRREGULARITIES — *Continued*



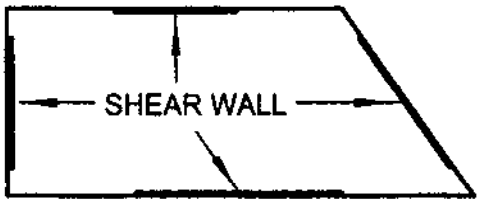
VERTICAL COMPONENTS OF SEISMIC RESISTING SYSTEM



13 C DIAPHRAGM DISCONTINUITY

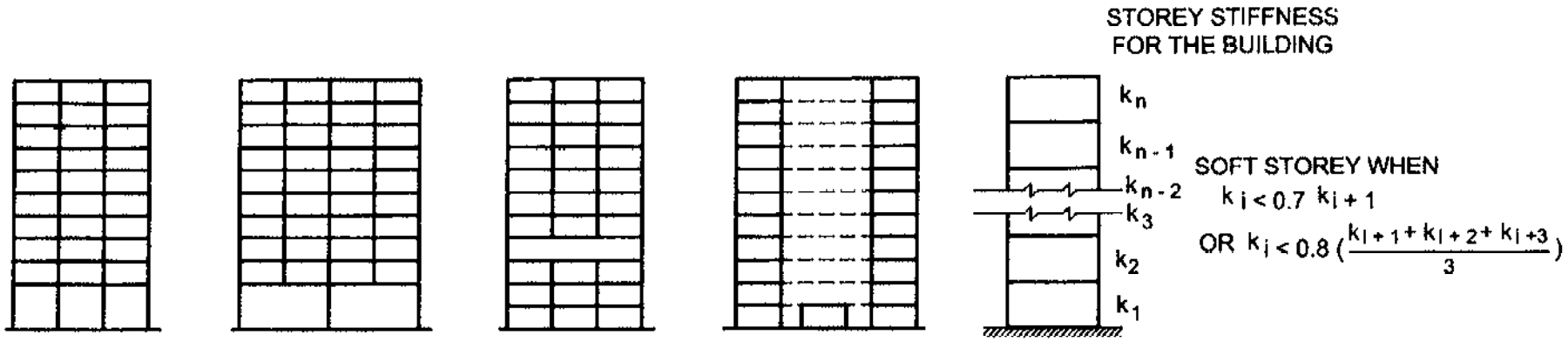


13 D OUT - OF - PLANE OFFSETS

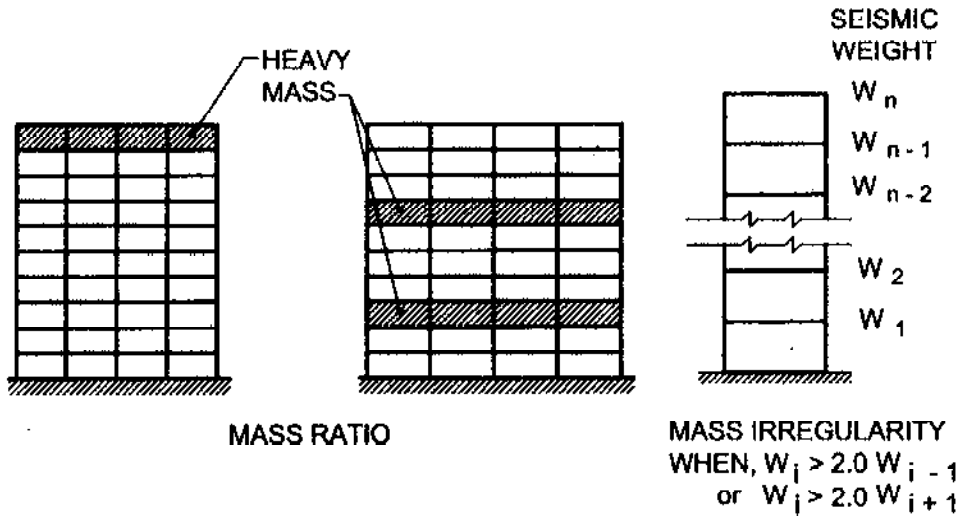


13 E NON - PARALLEL SYSTEM

FIG. 13 PLAN IRREGULARITIES

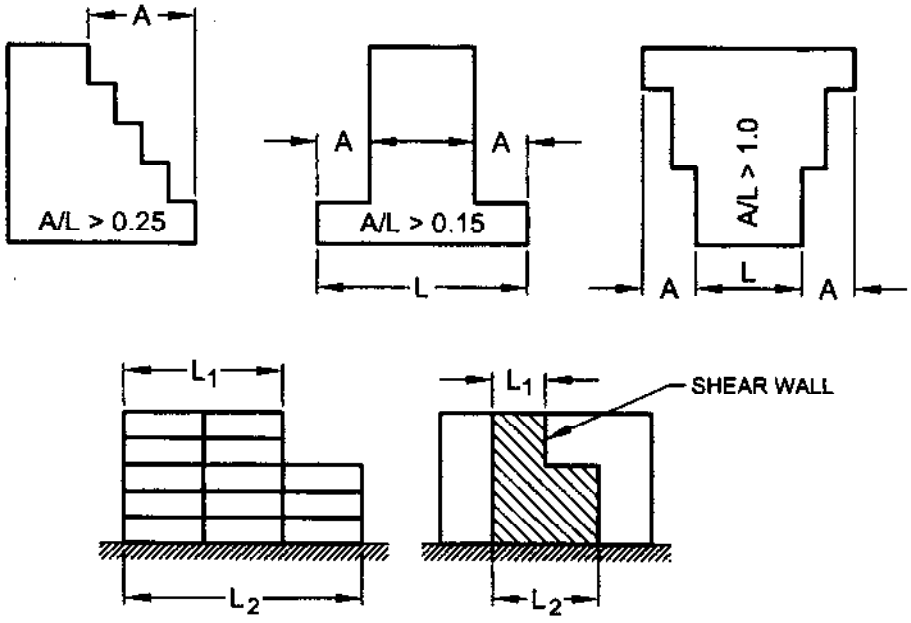


14 A STIFFNESS IRREGULARITY

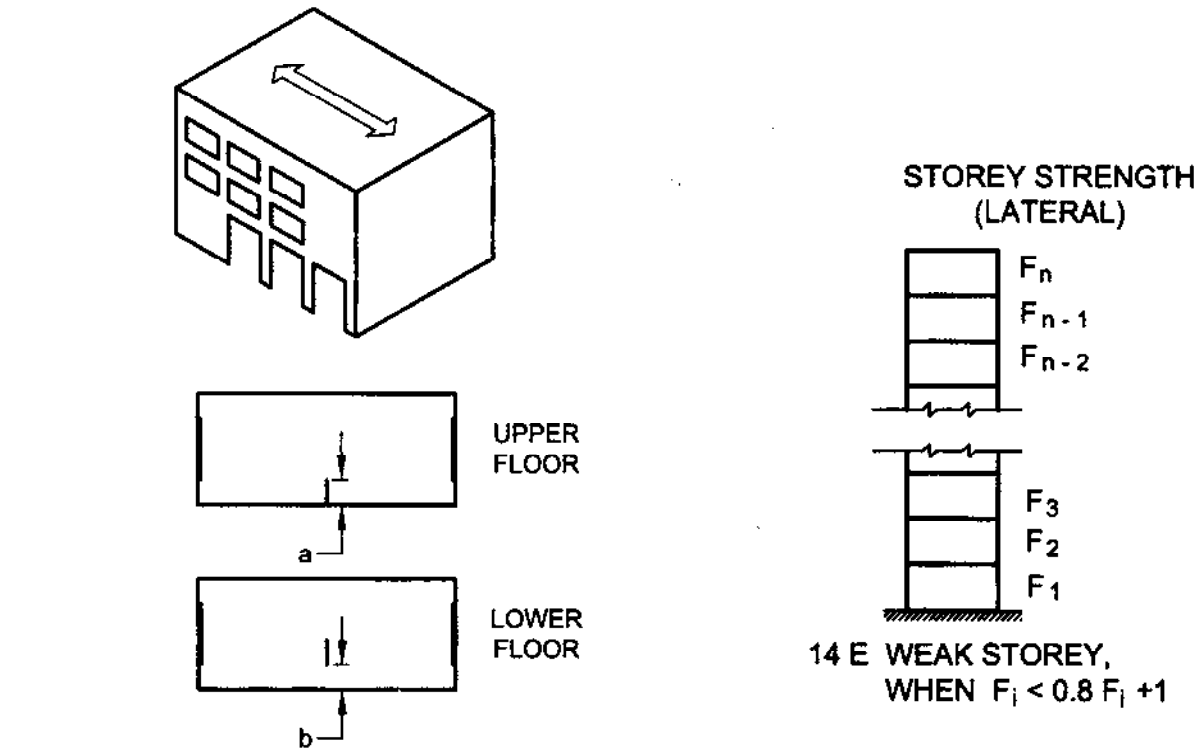


14 B MASS IRREGULARITY

FIG. 14 VERTICAL IRREGULARITIES — *Continued*



14 C VERTICAL GEOMETRIC IRREGULARITY, WHEN $L_2 > 1.5\ L_1$



14 D IN - PLANE DISCONTINUITY VERTICAL ELEMENTS RESISTING LATERAL FORCE, WHEN b > a

14 E WEAK STOREY, WHEN $F_i < 0.8\ F_i + 1$

FIG. 14 VERTICAL IRREGULARITIES

5.4.2 *Importance Factor I and Response Reduction Factor R*

The minimum value of importance factor, I, for different building systems shall be as given in Table 35. The response reduction factor, R, for different building systems shall be as given in Table 36.

5.4.3 *Design Imposed Loads for Earthquake Force Calculation*

5.4.3.1 For various loading classes as specified in IS 875 (Part 2), the earthquake force shall be calculated for the full dead load plus the percentage of imposed load as given in Table 37.

5.4.3.2 For calculating the design seismic forces of the structure, the imposed load on roof need not be considered.

5.4.3.3 The percentage of imposed loads given in **5.3.3.1** and **5.3.3.2** shall also be used for 'Whole frame loaded' condition in the load combinations specified in **5.3.3.1.1** and **5.3.3.1.2** where the gravity loads are combined with the earthquake loads [that is in load combinations (a) in **5.3.3.1.1**, and (b) in **5.3.3.1.2**]. No further reduction in the imposed load will be used as envisaged in **3** for number of storeys above the one under consideration or for large spans of beams or floors.

5.4.3.4 The proportions of imposed load indicated above for calculating the lateral design forces for earthquakes are applicable to average conditions. Where the probable loads at the time of earthquake are more accurately assessed, the designer may alter the proportions indicated or even replace the entire

Table 35 Importance Factors, *I*

(*Clauses* 5.3.4.2 *and* 5.4.2)

Sl No.	Structure	Importance Factor
i)	Important service and community buildings, such as hospitals; schools; monumental structures; emergency buildings like telephone exchange, television stations, radio stations, railway stations, fire station buildings; large community halls like cinemas, assembly halls and subway stations, power stations.	1.5
ii)	All other buildings.	1.0

NOTES

1 The design engineer may choose values of importance factor I greater than those mentioned above.

2 Buildings not covered in Sl No. (i) and (ii) above may be designed for higher value of I, depending on economy, strategy considerations like multi-storey buildings having several residential units.

3 This does not apply to temporary structures like excavations, scaffolding etc of short duration.

Table 36 Response Reduction Factor[1] *R*, for Building Systems

(*Clauses* 5.3.4.2 *and* 5.4.2)

Sl No.	Lateral Load Resisting System	R
	Building Frame Systems	
i)	Ordinary RC Moment-Resisting Frame (OMRF)[2]	3.0
ii)	Special RC Moment-Resisting Frame (SMRF)[3]	5.0
iii)	Steel Frame with	
	a) Concentric Braces	4.0
	b) Eccentric Braces	5.0
iv)	Steel Moment Resisting Frame designed as per SP: 6(6)	5.0
	Building with Shear Walls [4]	
v)	Load Bearing Masonry Wall Buildings [5]	
	a) Unreinforced	1.5
	b) Reinforced with horizontal RC Bands	2.5
	c) Reinforced with horizontal RC bands and vertical bars at corners of rooms and jambs of openings	3.0
vi)	Ordinary Reinforced Concrete Shear Walls [6]	3.0
vii)	Ductile Shear Walls [7]	4.0
	Buildings with Dual Systems [8]	
viii)	Ordinary Shear Wall with OMRF	3.0
ix)	Ordinary Shear Wall with SMRF	4.0
x)	Ductile Shear Wall with OMRF	4.5
xi)	Ductile Shear Wall with SMRF	5.0

[1] The above values of response reduction factors are to be used for buildings with lateral load resisting elements, and not just for the lateral load resisting elements built in isolation.

[2] OMRF are those designed and detailed as per IS 456 or IS 800 but not meeting ductile detailing requirement as per IS 13920.

[3] SMRF defined in **4.15.2**.

[4] Buildings with shear walls also include buildings having shear walls and frames, but where

a) frames are not designed to carry lateral loads, or

b) frames are designed to carry lateral loads but do not fulfil the requirements of 'dual systems'.

[5] Reinforcement should be as per IS 4326.

[6] Prohibited in Zones IV and V.

[7] Ductile shear walls are those designed and detailed as per IS 13920

[8] Buildings with dual systems consist of shear walls (or braced frames) and moment resisting frames such that

a) the two systems are designed to resist the total design force in proportion to their lateral stiffness considering the interaction of the dual system at all floor levels; and

b) the moment resisting frames are designed to independently resist at least 25 percent of the design seismic base shear.

Table 37 Percentage of Imposed Load to be Considered in Seismic Weight Calculation

(*Clause* 5.4.3.1)

Imposed Uniformity Distributed Floor Loads (kN/sq.m)	Percentage of Imposed Load
Up to and including 3.0	25
Above 3.0	50

imposed load proportions by the actual assessed load. In such cases, where the imposed load is not assessed as per **5.4.3.1** and **5.4.3.2** only that part of imposed load, which possesses mass, shall be considered. Lateral design force for earthquakes shall not be calculated on contribution of impact effects from imposed loads.

5.4.3.5 Other loads apart from those given above (for example, snow and permanent equipment) shall be considered as appropriate.

5.4.4 *Seismic Weight*

5.4.4.1 *Seismic weight of floors*

The seismic weight of each floor is its full dead load plus appropriate amount of imposed load, as specified in **5.4.3.1** and **5.4.3.2**. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be equally distributed to the floors above and below the storey.

5.4.4.2 *Seismic weight of building*

The seismic weight of the whole building is the sum of the seismic weights of all the floors.

5.4.4.3 Any weight supported in between storeys shall be distributed to the floors above and below in inverse proportion to its distance from the floors.

5.4.5 *Design Lateral Force*

5.4.5.1 Buildings and portions thereof shall be designed and constructed, to resist the effects of design lateral force specified in **5.4.5.3** as a minimum.

5.4.5.2 The design lateral force shall first be computed for the building as a whole. This design lateral force shall then be distributed to the various floor levels. The overall design seismic force thus obtained at each floor level, shall then be distributed to individual lateral load resisting elements depending on the floor diaphragm action.

5.4.5.3 *Design seismic base shear* — The total design lateral force or seismic base shear (V_B) along any principal direction shall be determined by the following expression:

$$V_B = A_h W$$

where

A_h = Design horizontal acceleration spectrum value as per **5.3.4.2**, using the fundamental natural period as per **5.4.6** in the considered direction of vibration; and

W = Seismic weight of the building as per **5.4.4.2**.

5.4.6 *Fundamental Natural Period*

5.4.6.1 The approximate fundamental natural period of vibration (T_a), in seconds, of a moment-resisting frame building without brick infill panels may be estimated by the empirical expression:

$$T_a = 0.075\ h^{0.75} \qquad \text{for RC Frame Building}$$

$$= 0.085\ h^{0.75} \qquad \text{for Steel Frame Building}$$

where

h = Height of building, in metres. This excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns. But, it includes the basement storeys, when they are not so connected.

5.4.6.2 The approximate fundamental natural period of vibration (T_a), in seconds, of all other buildings, including moment-resisting frame buildings with brick infill panels, may be estimated by the empirical expression:

$$T_a = \frac{0.09\,h}{\sqrt{d}}$$

where

h = Height of building, in metres, as defined in **5.4.6.1**; and

d = Base dimension of the building at the plinth level, in metres; and along the considered direction of the lateral force.

5.4.7 *Distribution of Design Force*

5.4.7.1 *Vertical distribution of base shear to different floor levels*

The design base shear (V_B) computed in **5.4.5.3** shall be distributed along the height of the building as per the following expression:

$$Q_i = V_B \frac{W_i\ h_i^2}{\sum_{j=1}^{n} W_j\ h_j^2}$$

where

Q_i = Design lateral force at floor i,

W_i = Seismic weight of floor i,

h_i = Height of floor i measured from base, and

n = Number of storeys in the building is the number of levels at which the masses are located.

5.4.7.2 *Distribution of horizontal design lateral force to different lateral force resisting elements*

5.4.7.2.1 In case of buildings whose floors are capable of providing rigid horizontal diaphragm action, the total

shear in any horizontal plane shall be distributed to the various vertical elements of lateral force resisting system, assuming the floors to be infinitely rigid in the horizontal plane.

5.4.7.2.2 In case of building whose floor diaphragms cannot be treated as infinitely rigid in their own plane, the lateral shear at each floor shall be distributed to the vertical elements resisting the lateral forces, considering the in-plane flexibility of the diaphragms.

NOTES

1 A floor diaphragm shall be considered to be flexible, if it deforms such that the maximum lateral displacement measured from the chord of the deformed shape at any point of the diaphragm is more than 1.5 times the average displacement of the entire diaphragm.

2 Reinforced concrete monolithic slab-beam floors or those consisting of Prefabricated/Precast elements with topping reinforced screed can be taken a rigid diaphragms.

5.4.8 *Dynamic Analysis*

5.4.8.1 Dynamic analysis shall be performed to obtain the design seismic force, and its distribution to different levels along the height of the building and to the various lateral load resisting elements, for the following buildings:

a) *Regular buildings* — Those greater than 40 m in height in Zones IV and V, and those greater than 90 m in height in Zones II and III. Modelling as per **5.4.8.4.5** can be used.

b) *Irregular buildings (as defined in* **5.4.1***)* — All framed buildings higher than 12 m in Zones IV and V, and those greater than 40 m in height in Zones II and III.

The analytical model for dynamic analysis of buildings with unusual configuration should be such that it adequately models the types of irregularities present in the building configuration. Buildings with plan irregularities, as defined in Table 33 (as per **5.4.1**), cannot be modelled for dynamic analysis by the method given in **5.4.8.4.5**

NOTE — For irregular buildings, lesser than 40 m in height in Zones II and III, dynamic analysis, even though not mandatory, is recommended.

5.4.8.2 Dynamic analysis may be performed either by the Time History Method or by the Response Spectrum Method. However, in either method, the design base shear (V_B) shall be compared with a base shear (V_B) calculated using a fundamental period T_a, where T_a is as per **5.4.6**. Where V_B is less than V_B, all the response quantities (for example, member forces, displacements, storey forces, storey shears and base reactions) shall be multiplied by $\overline{V_B}/V_B$).

5.4.8.2.1 The value of damping for buildings may be taken as 2 and 5 percent of the critical, for the purposes of dynamic analysis of steel and reinforced concrete buildings, respectively.

5.4.8.3 *Time history method*

Time history method of analysis, when used, shall be based on an appropriate ground motion and shall be performed using accepted principles of dynamics.

5.4.8.4 *Response spectrum method*

Response spectrum method of analysis shall be performed using the design spectrum specified by **5.3.4.2**, or by a site-specific design spectrum mentioned in **5.3.4.6**.

5.4.8.4.1 *Free vibration analysis*

Undamped free vibration analysis of the entire building shall be performed as per established methods of mechanics using the appropriate masses and elastic stiffness of the structural system, to obtain natural periods (T) and mode shapes {Ø} of those of its modes of vibration that need to be considered as per **5.4.8.4.2**.

5.4.8.4.2 *Modes to be considered*

The number of modes to be used in the analysis should be such that the sum total of modal masses of all modes considered is at least 90 percent of the total seismic mass and missing mass correction beyond 33 percent. If modes with natural frequency beyond 33 Hz are to be considered, modal combination shall be carried out only for modes up to 33 Hz. The effect of higher modes shall be included by considering missing mass correction following well established procedures.

5.4.8.4.3 *Analysis of building subjected to design forces*

The building may be analysed by accepted principles of mechanics for the design forces considered as static forces.

5.4.8.4.4 *Modal Combination*

The peak response quantities (for example, member forces, displacements, storey forces, storey shears and base reactions) shall be combined as per Complete Quadratic Combination (CQC) method.

$$\lambda = \sqrt{\sum_{i=1}^{r} \sum_{j=1}^{r} \lambda_i \ \rho_{ij} \ \lambda_j}$$

where

r = Number of modes being considered,

λ_i = Response quantity in i th mode,

ρ_{ij} = Cross-modal coefficient i (including sign), and

λ_j = Response quantity in mode j (including sign).

$$\rho_{ij} = \frac{8\varsigma^2 \ (1+\beta) \ \beta^{1.5}}{(1-\beta^2)^2 + 4\varsigma^2\beta(1+\beta)^2}$$

ς = Modal damping ratio (in fraction) as specified in **5.4.8.2.1**,

β = Frequency ratio = ω_j/ω_i

ω_i = circular frequency in ith mode, and

ω_j = circular frequency in jth mode.

Alternatively, the peak response quantities may be combined as follows:

a) If the building does not have closely-spaced modes, then the peak response quantity (λ) due to all modes considered shall be obtained as

$$\lambda = \sqrt{\sum_{K=1}^{r} (\lambda_K)^2}$$

where

λ_k = Absolute value of quantity in mode k.

b) If the building has a few closely-spaced modes (*see* **5.3.3.2**), then the peak response quantity (λ^*) due to these modes shall be obtained as

$$\lambda^* = \sum_c \lambda_c,$$

where the summation is for the closely-spaced modes only. This peak response quantity due to the closely spaced modes (λ^*) is then combined with those of the remaining well-separated modes by the method described in **5.4.8.4.4** (a).

5.4.8.4.5 Buildings with regular, or nominally irregular, plan configurations may be modelled as a system of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. In such a case, the following expressions shall hold in the computation of the various quantities:

a) *Modal Mass* — The modal mass (M_k) of mode k is given by

$$M_K = \frac{\left[\sum_{i=1}^{N} W_i \ \phi_{ik}\right]^2}{g \sum_{i=1}^{N} W_i \ (\phi_{ik})^2}$$

where

g = Acceleration due to gravity,

ϕ_{ik} = Mode shape coefficient at floor i in mode k, and

W_i = Seismic weight of floor i.

b) *Modal Participation Factors* — The modal participation factor (P_K) of mode k is given by

$$P_K = \frac{\sum_{i=1}^{n} W_i \ \phi_{ik}}{\sum_{i=1}^{n} W_i \ (\phi_{ik})^2}$$

c) *Design lateral Force at Each Floor in Each Mode* — The peak lateral force (Q_{ik}) at floor i in mode k is given by

$$Q_{ik} = A_K \ \phi_{ik} \ P_K \ W_i$$

where

A_K = Design horizontal acceleration spectrum value as per **5.3.4.2** using the natural period of vibration (T_k) of mode k.

c) *Storey Shear Forces in Each Mode* — The peak shear force (V_{iK}) acting in storey i in mode k is given by

$$V_{iK} = \sum_{j=i+1}^{n} Q_{iK}$$

d) *Storey Shear Forces due to All Modes Considered* — The peak storey shear force (V_i) in storey i due to all modes considered is obtained by combining those due to each mode in accordance with **5.4.8.4.4**.

e) *Lateral Forces at Each Storey due to All Modes Considered* — The design lateral forces, F_{roof} and F_i, at roof and at floor i:

$$F_{roof} = V_{roof} \text{ and}$$

$$F_i = V_i - V_{i+1}$$

5.4.9 *Torsion*

5.4.9.1 Provision shall be made in all buildings for increase in shear forces on the lateral force resisting elements resulting from the horizontal torsional moment arising due to eccentricity between the centre of mass and centre of rigidity. The design forces calculated as in **5.4.8.4.5** are to be applied at the centre of mass appropriately displaced so as to cause design eccentricity (**5.4.9.2**) between the displaced centre of mass and centre of rigidity. However, negative torsional shear shall be neglected.

5.4.9.2 The design eccentricity, e_{di} to be used at floor i shall be taken as

$$e_{di} = \begin{cases} 1.5 \ e_{si} + 0.05 \ b_i \\ \text{or} \quad e_{si} - 0.05 \ b_i \end{cases}$$

whichever of these gives the more severe effect in the shear of any frame where

e_{di} = static eccentricity at floor i defined as the distance between centre of mass and centre of rigidity and

b_i = floor plan dimension of floor i, perpendicular to the direction of force.

NOTE — The factor 1.5 represents dynamic amplification factor, while the factor 0.05 represents the extent of accidental eccentricity.

5.4.9.3 In case of highly irregular buildings analysed according to **5.4.8.4.5**, additive shears will be superimposed for a statically applied eccentricity of $\pm 0.05b_i$ with respect to the centre of rigidity.

5.4.10 *Buildings with Soft Storey*

5.4.10.1 In case buildings with a flexible storey, such as the ground storey consisting of open spaces for parking that is stilt buildings, special arrangement needs to be made to increase the lateral strength and stiffness of the soft/open storey.

5.4.10.2 Dynamic analysis of building is carried out including the strength and stiffness effects of infills and inelastic deformations in the members, particularly, those in the soft storey, and the members designed accordingly.

5.4.10.3 Alternatively, the following design criteria are to be adopted after carrying out the earthquake analysis, neglecting the effect of infill walls in other storeys:

a) the columns and beams of the soft storey are to be designed for 2.5 times the storey shears and moments calculated under seismic loads specified in the other relevant clauses; or,

b) besides the columns designed and detailed for the calculated shears and moments, shear walls placed symmetrically in both directions of the building as far away from the centre of the building as feasible; to be designed exclusively for 1.5 times the lateral shear force calculated as before.

5.4.11 *Deformations*

5.4.11.1 *Storey drift limitation*

The storey drift in any storey due to the minimum specified design lateral force, with partial load factor of 1.0, shall not exceed 0.004 times the storey height.

For the purposes of displacement requirements only (that is, in **5.4.11.1**, **5.4.11.2** and **5.4.11.3** only), it is permissible to use seismic force obtained from the computed fundamental period (T) of the building without the lower bound limit on design seismic force specified in **5.4.8.2**.

There shall be no drift limit for single storey building which has been designed to accommodate storey drift.

5.4.11.2 *Deformation compatibility of non-seismic members*

For building located in seismic Zones IV and V, it shall be ensured that the structural components, that are not a part of the seismic force resisting system in the direction under consideration, do not lose their vertical load-carrying capacity under the induced moments resulting from storey deformations equal to R times the storey displacements calculated as per **5.4.11.1**, where R is specified in Table 36.

NOTE — For instance, consider a flat-slab building in which lateral load resistance is provided by shear walls. Since the lateral load resistance of the slab-column system is small, these are often designed only for the gravity loads, while all the seismic force is resisted by the shear walls. Even though the slabs and columns are not required to share the lateral forces, these deform with rest of the structure under seismic force. The concern is that under such deformations, the slab-column system should not lose its vertical load capacity.

5.4.11.3 *Separation between adjacent units*

Two adjacent buildings, or two adjacent units of the same building with separation joint in between shall be separated by a distance equal to the amount R times the sum of the calculated storey displacements as per **5.4.11.1** of each of them, to avoid damaging contact when the two units deflect towards each other. When floor levels of two similar adjacent units or buildings are at the same elevation levels, factor R in this requirement may be replaced by $R/2$.

5.4.12 *Miscellaneous*

5.4.12.1 *Foundations*

The use of foundations vulnerable to significant differential settlement due to ground shaking shall be avoided for structures in seismic Zones III, IV and V. In seismic Zones IV and V, individual spread footings or pile caps shall be interconnected with ties, (*see* **5.2.3.4.1** of IS 4326) except when individual spread footings are directly supported on rock. All ties shall be capable of carrying, in tension and in compression, an axial force equal to $A_h/4$ times the larger of the column or pile cap load, in addition to the otherwise computed forces. Here, A_h is as per **5.3.4.2**.

5.4.12.2 *Cantilever projections*

5.4.12.2.1 *Vertical projections*

Tower, tanks, parapets, smoke stacks (chimneys) and other vertical cantilever projections attached to buildings and projecting above the roof, shall be designed and checked for stability for five times the design horizontal seismic coefficient A_h specified in **5.3.4.2**. In the analysis of the building, the weight

5.4.12.2.2 *Horizontal projection*

All horizontal projections like cornices and balconies shall be designed and checked for stability for five times the design vertical coefficient specified in **5.3.4.5**.

5.4.12.2.3 The increased design forces specified in **5.4.11.2.1** and **5.4.12.2.2** are only for designing the projecting parts and their connections with the main structures. For the design of the main structure, such increase need not be considered.

5.4.12.3 *Compound walls*

Compound walls shall be designed for the design horizontal coefficient A_h with Importance Factor $I = 1.0$ specified in **6.4.2**

5.4.12.4 *Connections between parts*

All parts of the building, except between the separation sections, shall be tied together to act as integrated single unit. All connections between different parts, such as, beams to columns and columns to their footings, should be made capable of transmitting a force, in all possible directions, of magnitude (Q_i/W_i) times but not less than 0.05 times the weight of the smaller part or the total of dead and imposed load reaction. Frictional resistance shall not be relied upon for fulfilling these requirements.

6 SNOW LOAD

6.1 This clause deals with snow loads on roofs of buildings. Roofs should be designed for the actual load due to snow or for the imposed loads specified in **3** whichever is more severe.

NOTE — Mountainous regions in northern parts of India are subjected to snow fall.

In India, part of Jammu and Kashmir (Baramulah District, Srinagar District, Anantnag District and Ladakh District); Punjab and Himachal Pradesh (Chamba, Kulu Kinnaur District, Mahasu District, Mandi District, Sirmur District and Simla District); and Uttaranchal (Dehra Dun District, Tehri Garhwal District, Almora District and Nainital District) experience snow fall of varying depths two or three times in a year.

6.2 Notations

(Dimensionless) — Nominal values of the shape coefficients, taking tin account snow draft, sliding snow, etc, with subscripts, if necessary.

l_i (metres) — Horizontal dimension with numerical subscripts, if necessary.

h_i (metres) — Vertical dimensions with numerical subscripts, if necessary.

s_i (pascals) — Snow load on roofs.

6.3 Snow Load in Roof(s)

6.3.1 The minimum design snow load on a roof area or any other area above ground which is subjected to snow accumulation is obtained by multiplying the snow load on ground, s_o by the shape coefficient μ, as applicable to the particular roof area considered:

$$s = \mu s_o$$

where

s = Design snow load in Pa on plan area of roof,

μ = Shape coefficient (*see* **5.4**), and

s_o = Ground snow load in Pa (1 Pa=1 N/m^2)

NOTE — Ground snow load at any place depends on the critical combination of the maximum depth of undisturbed aggregate cumulative snow fall and its average density. In due course the characteristic snow load on ground for different regions will be included based on studies. Till such time the users of this code are advised to contact either Snow and Avalanches Study Establishment (Defence Research and Development Organization), Manali (HP) or Indian Meteorological Department (IMD), Pune in the absence of any specific information for any location.

6.4 Shape Coefficients

6.4.1 *General Principles*

In perfectly calm weather, falling snow would cover roofs and the ground with a uniform blanket of snow, and the design snow load could be considered as a uniformly distributed load. Truly uniform loading conditions, however, are rare and have usually only been observed in areas that are sheltered on all sides by high trees, buildings, etc. In such a case, the shape coefficient would be equal to unity.

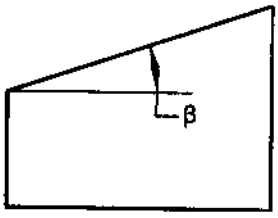
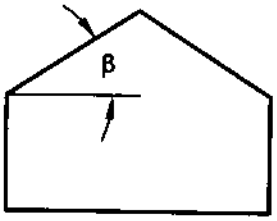
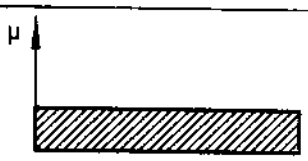
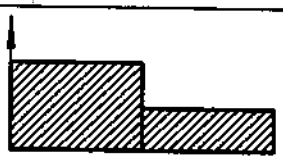
In most regions, snow-falls are accompanied or followed by winds. The winds will re-distribute the snow, and on some roofs especially multilevel roofs, the accumulated drift load may reach a multiple of the ground load. Roofs which are sheltered by other buildings, vegetation, etc, may collect more snow load than the ground level. The phenomenon is of the same nature as that illustrated for multi-level roofs in **6.4.2.4**.

So far sufficient data are not available to determine the shape coefficient on a statistical basis. Therefore, a nominal value is given. A representative sample of roofs is shown in **6.4.2**. However, in special cases such as strip loading, cleaning of the roof periodically by deliberate heating of the roof, etc, have to be treated separately.

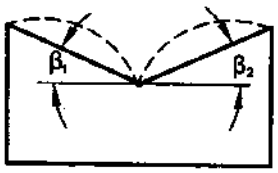
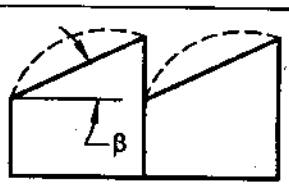
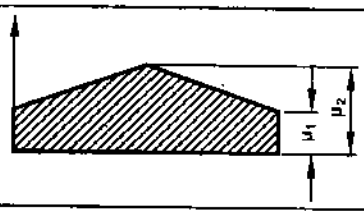
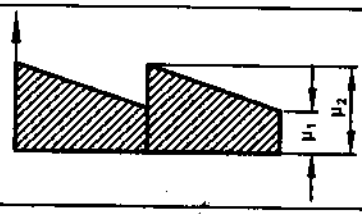
The distribution of snow in the direction parallel to the caves is assumed to be uniform.

6.4.2 *Shape Coefficients for Selected Types of Roofs*

6.4.2.1

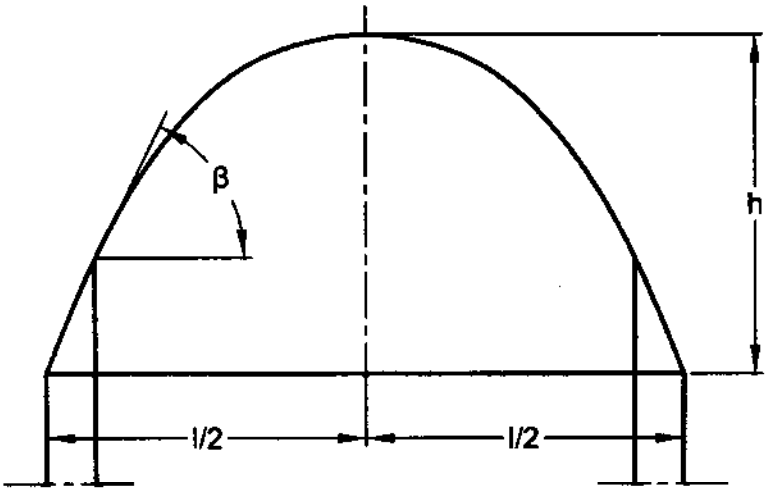
	Simple Flat and Monopitch Roofs	Simple Pitched Roofs (Positive Roof Slope)[1)]
		
		
$0° < \beta \leq 30°$	$\mu_1 = 0.8$	$\mu_2 = \mu_1 = 0.8$
$15° < \beta \leq 30°$		$\mu_2 = 0.8 + 0.4\left(\frac{\beta - 15}{15}\right)$ $\mu_1 = 0.8$
$30° < \beta \leq 60°$	$\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$	$\mu_2 = 1.2\left(\frac{60 - \beta}{30}\right)$ $\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$
$\beta > 60°$	$\mu_1 = 0$	$\mu_2 = \mu_1 = 0$

6.4.2.2

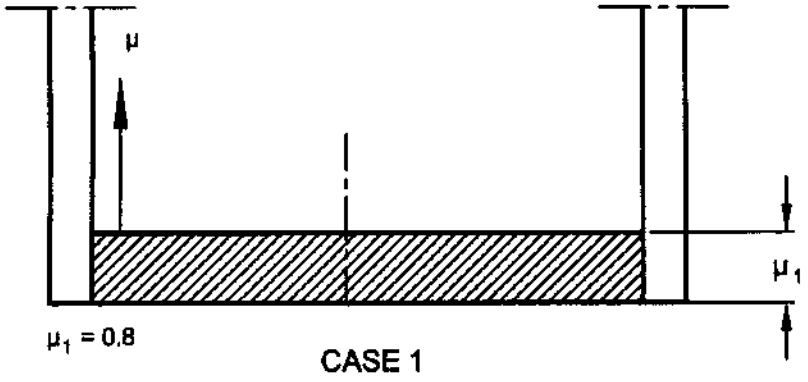
	Simple or Multiple Pitched Roofs (Negative Roof Slope)	Two-Span or Multispan Roofs
	 $\beta = \frac{\beta_1 + \beta_2}{2}$	
		
$0° < \beta < 30°$	$\mu_1 = 0.8\left(\frac{30 + \beta}{30}\right)$ $\mu'_1 = 0.8$	$\mu_1 = 0.8\left(\frac{30 + \beta}{30}\right)$ $\mu_1 = 0.8$
$30° < \beta < 60°$	$\mu_2 = 1.6$ $\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$	$\mu_2 = 1.6$ $\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$
$\beta > 60°$	$\mu_2 = 1.6$ $\mu_1 = 0$	$\mu_2 = 1.6$ $\mu_1 = 0$

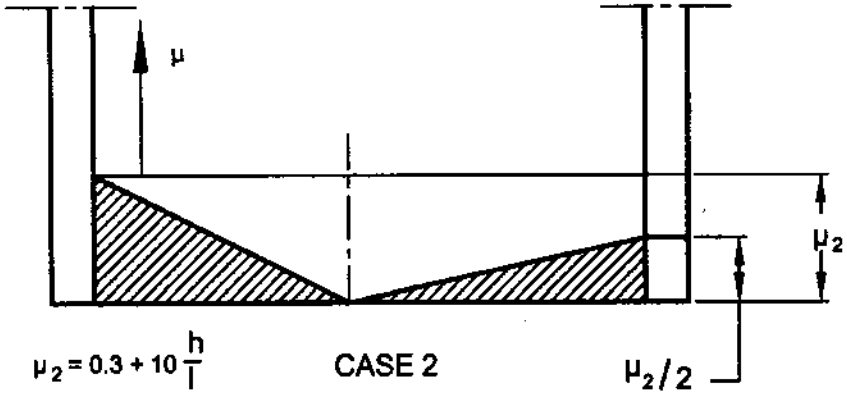
[1)] For asymmetrical simple pitched roofs, each side of the roof shall be treated as one half of corresponding symmetrical roofs.

6.4.2.3 *Simple curved roofs*



THE FOLLOWING CASES 1 AND 2 MUST BE EXAMINED



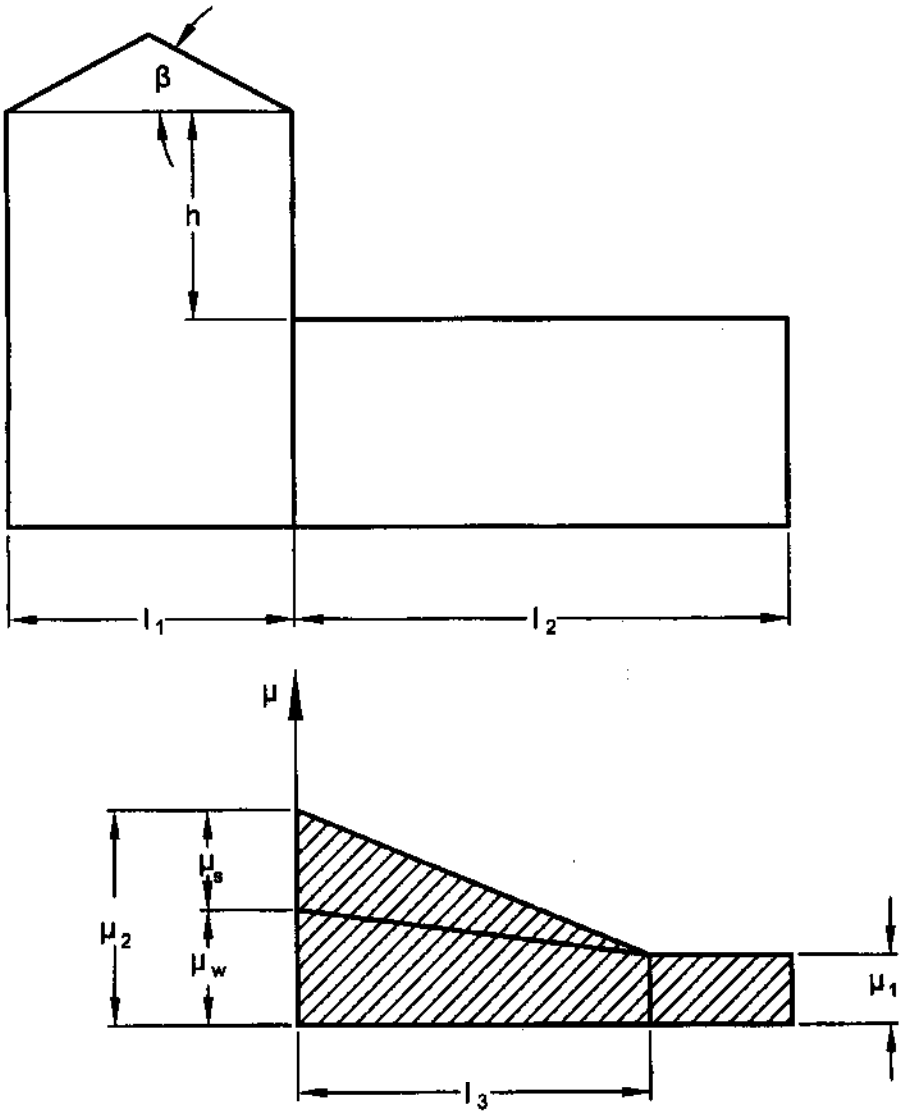


Restriction:

$m_2 \leq 2.3$

$m = 0$ if $b > 60°$

6.4.2.4 *Multi-level roofs*[1)]



$\mu_1 = 0.8$

$\mu_2 = \mu_s + \mu_w$

where

μ_s = due to sliding

μ_w = due to wind

l_3 = $2h$[2)] but is restricted as follows:

$$5 \text{ m} \le l_3 \le 15 \text{ m}$$

$$\mu_w = \frac{l_1 + l_2}{2h} \le \frac{kh}{s_o}$$

with the restriction $0.8 \le \mu_w \le 4.0$

where

h is in metres

s_o is in kilopascals (kilonewtons per square metre)

$k = 2$ kN/m^2

$\beta \ge 15°$: μ_s is determined from an additional load amounting to 50 percent of the maximum total load on the adjacent slope of the upper roof[1)], and is distributed linearly as shown in the figure.

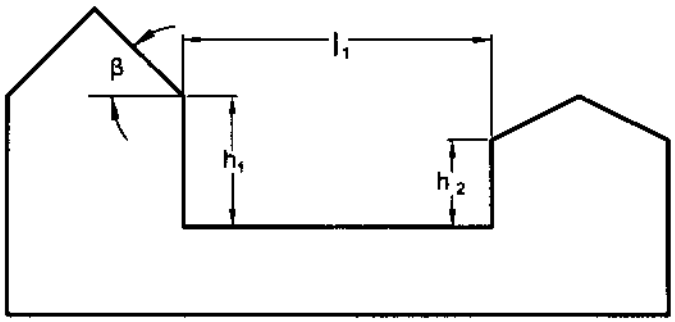
$$\beta \le 15° : \mu_s = 0$$

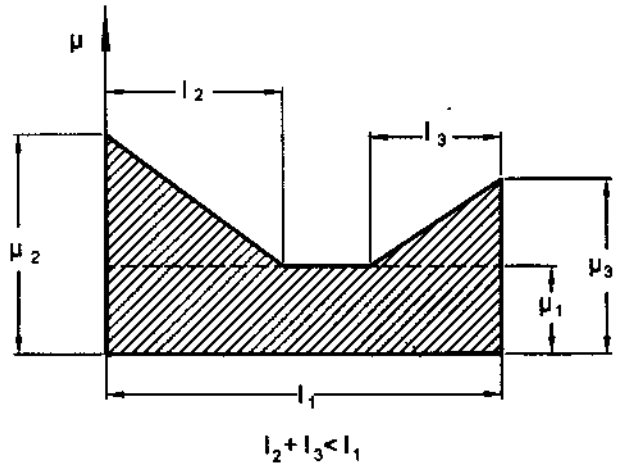
[1)] A more extensive formula for μ_w is described in Annex A.

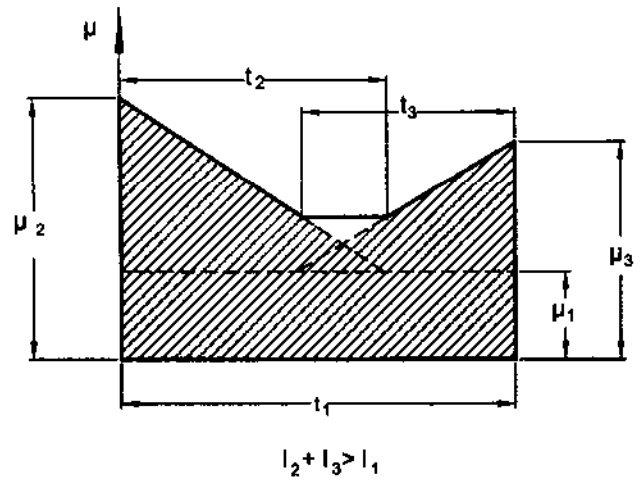
[2)] If $l_2 < l_3$, the coefficient μ is determined by interpolation between μ_1 and μ_2.

[1)] The load on the upper roof is calculated according to **6.4.2.1** or **6.4.2.2**.

6.4.2.5 *Complex multi-level roofs*







$l_2 = 2h_1$: $l_3 = 2h_2$: $\mu_1 = 0.8$

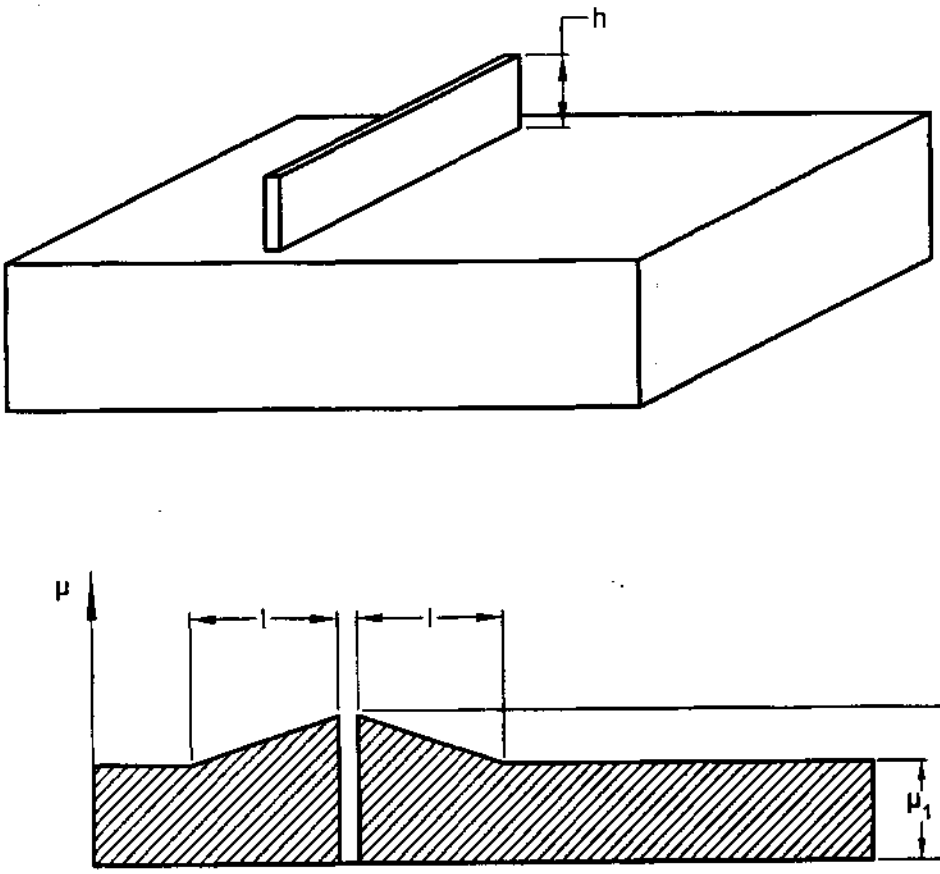
Restriction:

$5\text{ m} < l_2 \leq 15\text{ m}$;

$5\text{ m} < l_3 \leq 15\text{ m}$;

μ_2 and $\mu_3 = (\mu_s + \mu_w)$, are calculated according to **6.4.2.1**, **6.4.2.2** and **6.4.2.4**.

6.4.2.6 *Roofs with local projections and obstructions*



$$\mu_2 = \frac{kh}{s_o}$$

h = is in metres

s_o = is in kilopascals (kilonewtons per square metre)

k = 2 kN/m^2

μ = 0.8

Restrictions:

$0.8 \leq \mu_w \leq 2.0$

$5 \text{ m} \leq l \leq 15 \text{ m}$

6.4.3 *Shape Coefficients in Areas Exposed to Wind*

The shape coefficients given in **6.4.2** and Annex K may be reduced by 15 percent, provided the designer has demonstrated that the following conditions are fulfilled:

a) The building is located in an exposed location, such as open level terrain with only scattered buildings, trees or other obstructions so that the roof is exposed to the winds on all sides and is not likely to become shielded in the future by obstructions higher than the roof within a distance from the building equal to ten times the height of the obstruction above the roof level; and

b) The roof does not have any significant projections, such as, parapet walls which may prevent snow from being blow off the roof.

NOTE — In some areas, winter climate may not be of such a nature as to produce a significant reduction of roof loads from the snow load on the ground these areas area:

a) Winter calm valleys in the mountains where sometimes layer after layer of snow accumulates

on roofs without any appreciable removal of snow by wind; and

b) Areas (that is, high temperature) where the maximum snow load may be the result of single snowstorm, occasionally without appreciable wind removal.

In such area, the determination of the shape coefficients shall be based on local experience with due regard to the likelihood of wind drifting and sliding.

7 SPECIAL LOADS

7.1 This clause gives guidance on loads and load effects due to temperature changes, soil and hydrostatic pressures, internally generating stresses (due to creep, shrinkage, differential settlement, etc), accidental loads, etc, to be considered in the design of buildings as appropriate. This clause also includes guidance on load combinations. The nature of loads to be considered for a particular situation is to be based on engineering judgement (*see also* **3.6**)

7.2 Temperature Effects

7.2.1 Expansion and contraction due to changes in temperature of the materials of a structure shall be considered in design. Provision shall be made either to relieve the stress by the provision of expansion/ contraction joints in accordance with good practice [6-1(10)] or design the structure to carry additional stresses due to temperature effects as appropriate to the problem.

7.2.1.1 The temperature range varies for different regions and under different diurinal and seasonal conditions. The absolute maximum and minimum temperature which may be expected in different localities in Annex B of Part 6 'Structural Design, Section 6 Steel' respectively. These figures may be used for guidance in assessing the maximum variations of temperature.

7.2.1.2 The temperatures indicated are the air temperatures in the shade. The range of variation in temperature of the building materials may be appreciably greater or less than the variation of air temperature and is influenced by the condition of exposure and the rate at which the materials composing the structure absorb or radiate heat. This difference in temperature variations of the material and air should be given due consideration.

7.2.1.3 The structural analysis must take account of changes of the mean (through the section) temperature in relation to the initial (st) and the temperature gradient through the section.

a) It should be borne in mind that the changes of mean temperature in relation to the initial are liable to differ as between one structural element and another in buildings or structures, as for example, between the external walls and the internal elements of a building. The distribution of temperature through section of single-leaf structural elements may be assumed linear for the purpose of analysis.

b) The effect of mean temperature changes t_1 and t_2, and the temperature gradients ν_1 and ν_2 in the hot and cold seasons for single-leaf structural elements shall be evaluated on the basis of analytical principles.

NOTES

1 For portions of the structure below ground level, the variation of temperature is generally insignificant. However, during the period of construction, when the portions of the structure are exposed to weather elements, adequate provision should be made to encounter adverse effects, if any.

2 If it can be shown by engineering principles, or if it is known from experience, that neglect of some or all the effects of temperature do not affect the structural safety and serviceability, they need not be considered in design.

7.3 Hydrostatic and Soil Pressure

7.3.1 In the design of structures of parts or structures below ground level, such as, retaining walls and other walls in basement floors, the pressure exerted by the soil or water or both shall be duly accounted for on the basis of established theories. Due allowance shall be made for possible surcharge from stationary or moving loads. When a portion or whole of the soil is blow the free water surface, the lateral earth pressure shall be evaluated for weight of soil diminished by buoyancy and the full hydrostatic pressure.

7.3.1.1 All foundation slabs and other footings subjected to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure. Checking of overturning of foundation under submerged condition shall be done considering buoyant weight of foundation.

7.3.2 While determining the lateral soil pressure on column like structural members, such as, pillars which rest in sloping soils, the width of the member shall be taken as follows (*see* Fig. 15).

Actual Width of Member	*Ratio of Effective Width to Actual Width*
Less than 0.5 m	3.0
Beyond 0.5 m and up to 1 m	3.0 to 2.0
Beyond 1 m	2.0

The relieving pressure of soil in front of the structural member concerned may generally not be taken into account.

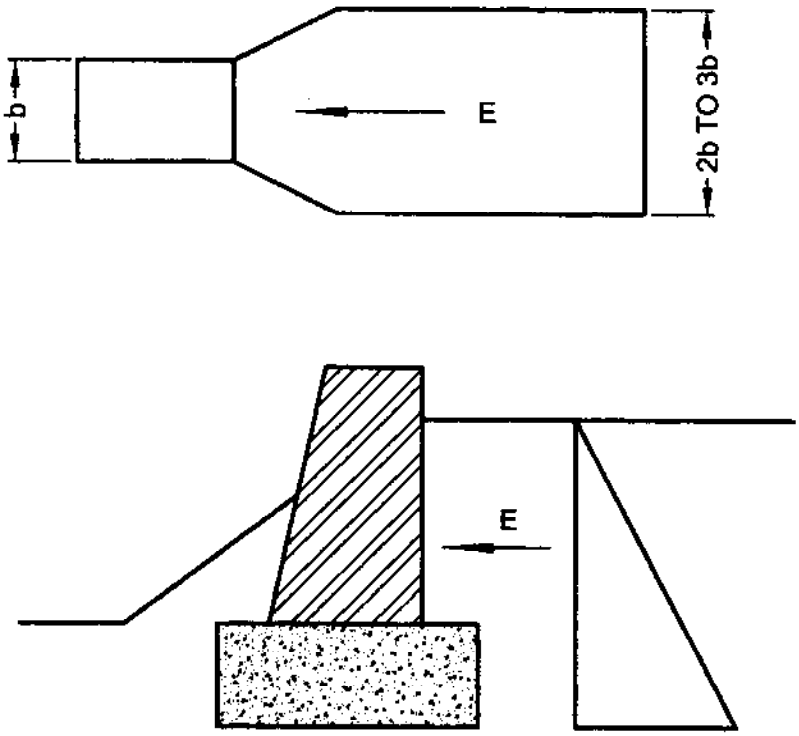


FIG. 15 SKETCH SHOWING EFFECTIVE WIDTH OF PILAR FOR CALCULATING SOIL PRESSURE

7.3.3 Safe-guarding of structures and structural members against overturning and horizontal sliding shall be verified. Imposed loads having favourable effect shall be disregarded for the purpose. Due consideration shall be given to the possibility of soil being permanently or temporarily removed.

7.4 Fatigue

7.4.1 *General*

Fatigue cracks are usually initiated at points of high stress concentration. These stress concentrations may be caused by or associated with holes (such as, bolt or rivet holes in steel structures), welds including stray or fusions in steel structures, defects in materials, and local and general changes in geometry of members. The cracks usually propogate, if loading is continuous.

Where there is such loading cycles, sudden changes of shape of a member or part of a member, especially in regions of tensile stress and/or local secondary bending, shall be avoided. Suitable steps shall be taken to avoid critical vibrations due to wind and other causes.

7.4.2 Where necessary, permissible stresses shall be reduced to allow for the effects of fatigue. Allowance for fatigue shall be made for combinations of stresses due to dead load and imposed load. Stresses due to wind and earthquakes may be ignored when fatigue is being considered, unless otherwise specified in relevant codes of practice.

Each element of the structure shall be designed for the number of stress cycles of each magnitude to which it is estimated that the element is liable to be subjected during the expected life of the structure. The number of cycles of each magnitude shall be estimated in the light of available date regarding the probable frequency of occurrence of each type of loading.

NOTE — Apart from the general observations made herein, the section is unable to provide any precise guidance in estimating the probabilistic behaviour and response of structures of various types arising out of repetitive loading approaching fatigue conditions in structural members, joints, materials, etc.

7.5 Structural Safety During Construction

7.5.1 All loads required to be carried by the structures or any part of it due to storage or positioning of construction materials and erection equipment including all loads due to operation of such equipment, shall be considered as erection loads. Proper provision shall be made, including temporary bracings, to take care of all stresses due to erection loads. The conjunction with the temporary bracings shall be capable of sustaining these erection loads, without exceeding the permissible stresses specified in respective codes of practice. Dead load, wind load and such parts of imposed load, as would be imposed on

the structure during the period of erection, shall be taken as acting together with erection loads.

7.6 Accidental Loads

The occurrence of which, with a significant value, is unlikely on a given structure over the period of time under consideration, and also in most cases, is of short duration. The occurrence of an accidental load could, in many cases, be expected to cause severe consequences, unless special measures are taken.

The accidental loads arising out of human action include the following:

a) Impacts and collisions,
b) Explosions, and
c) Fire.

Characteristic of the above stated loads are that they are not a consequence of normal use and that they are undesired, and that extensive effects are made to avoid them. As a result, the probability of occurrence of an accidental load is small whereas the consequences may be severe.

The causes of accidental loads may be:

a) inadequate safety of equipment (due to poor design or poor maintenance); and
b) wrong operation (due to insufficient teaching or training, indisposition, negligence or unfavouable external circumstances).

In most cases, accidental loads only develop under a combination of several unfavourable occurrence. In practical applications, it may be necessary to neglect the most unlikely loads. The probability of occurrence of accidental loads, which are neglected, may differ for different consequences of a possible failure. A data base for a detailed calculation of the probability will seldom be available.

7.6.1 *Impact and Collisions*

7.6.1.1 *General*

During an impact, the kinetic impact energy has to be absorbed by the vehicle hitting the structure and by the structure itself. In an accurate analysis, the probability of occurrence of an impact with a certain energy object hitting the structure and the structure itself at the actual place must be considered. Impact energies for dropped object should be based on the actual loading capacity and lifting height.

Common sources of impact are:

a) Vehicles;
b) Dropped objects from cranes, fork lifts, etc;
c) Cranes out of control, crane failures; and
d) Flying fragments.

The codal requirements regarding impact from vehicles and cranes are given in **7.6.1.2** and **7.6.1.3**.

7.6.1.2 *Collisions between vehicles and structural elements*

In road traffic, the requirement that a structure shall be able to resist collision may be assumed to be fulfilled if it is demonstrated that the structural element is able to stop a fictitious vehicle, as described below. It is assumed that the vehicle strikes the structural element at a height of 1.2 m in any possible direction and at a speed of 10 m/s (36 km/h).

The fictitious vehicle shall be considered to consist of two masses m_1 and m_2 which during compression of the vehicle, produce an impact force increasing uniformly from zero, corresponding to the rigidities C_1 and C_2. It is assumed that the mass m_1 is broken completely before the breaking of mass m_2 begins.

The following numerical values should be used:

m_1 = 400 kg, C_1 = 10 000 kN/m, the vehicle is compressed.

m_2 = 12 000 kg, C_2 = 300 kN/m, the vehicle is compressed.

NOTE — The described fictitious collision corresponds in the case of a non-elastic structural element to a maximum static force of 630 kN for the mass m_1 and 600 kN for the mass m_2 irrespective of the elasticity, it will therefore be on the safe side to assume the static force to be 630 kN.

In addition, breaking of the mass m_1 will result in an impact wave, the effect of which will depend, to a great extent, on the kind of structural element concerned. Consequently, it will not always be sufficient to design for the static force.

7.6.1.3 *Safety railings*

With regard to safety, railings put up to protect structures against collision due to road traffic, it should be shown that the railings are able to resist the impact as described in **7.6.1.2**.

NOTE — When a vehicle collides with safety railings, the kinetic energy of the vehicle will be absorbed partly by the deformation of the railings and partly by the deformation of the vehicle. The part of the kinetic energy which the railings should be able to absorb without breaking down may be determined on the basis of the assumed rigidity of the vehicle during compression.

7.6.1.4 *Crane impact load on buffer stop*

The basic horizontal load P_y (tones), acting along the crane track produced by impact of the crane on the buffer stop, is calculated by the following formula:

$$P_y = MV^2/f$$

where

V = Speed at which the crane is travelling at the moment of impact (assumed equal to half the nominal value) (m/s).

f = Maximum shortening of the buffer, assumed equal to 0.1 m for light duty, medium-duty and heavy-duty cranes with flexible load suspension and loading capacity not exceeding 50 t, and 0.2 m in every other cranes.

M = Reduced crane mass, ($t.s^2/m$); and is obtained by the formula:

$$M = \frac{1}{g}\left[\frac{P_b}{2} + (P_t + kQ)\frac{L_k - l}{L_k}\right]$$

where

g = Acceleration due to gravity (9.81 m/s^2);

P_b = Crane bridge weight (t);

P_t = Crab bridge weight (t);

Q = Crane loading capacity (t);

k = Coefficient, assumed equal to zero for cranes with flexible load suspension and to one for cranes with rigid suspension;

L_k = Crane span (m); and

l = Nearness of crab (m).

7.6.2 *Explosions*

7.6.2.1 *General*

Explosions may cause impulsive loading on a structure. The following types of explosions are particularly relevant:

a) Internal gas explosions which may be caused by leakage of gas piping (including piping outside the room), evaporation from volatile liquids or unintentional evaporation from surface material (for example, fire);

b) Internal dust explosions;

c) Boiler failure;

d) External gas cloud explosions; and

e) External explosions of high explosives (TNT, dynamite).

The codal requirement regarding internal gas explosions is given in **7.6.2.2**.

7.6.2.2 *Explosion effect in closed rooms*

Gas explosion may be caused, for example by leaks in gas pipes (inclusive of pipes outside for room), evaporation from volatile liquids or unintentional evaporation of gas from wall sheathings (for example, caused by fire).

NOTES

1 The effect of explosions depends on the exploding medium, the concentration of the explosion, the shape of the room, possibilities of ventilation of the explosion, and the ductility and dynamic properties of the structure. In rooms with little possibility for relief of the pressure from the explosion, very large pressures may occur.

Internal over pressure from an internal gas explosion in rooms of sizes comparable to residential rooms and with ventilation areas consisting of window glass breaking at a pressure of 4 kN/m^2 (3-4 mm machine made glass) may be calculated from the following method:

a) The over pressure is assumed to depend on a factor A/V, where A is the total windows area in m^2 and V is the volume in m^3 of the room considered;

b) The internal pressure is assumed to act simultaneously upon all walls and floors in one closed room; and

c) The action q_o may be taken as static action.

If account is taken of the time curve of the action, the schematic correspondence between pressure and time is assumed (Fig. 16), where t_1 is the time from the start of combustion until maximum pressure is reached and t_2 is the time from maximum pressure to the end of combustion. For t_1 and t_2, the most unfavourable values should be chosen in relation to the dynamic properties of the structures. However, the values should be chosen within the intervals as given in Fig. 17.

2 Figure 16 is based on tests with gas explosions in room corresponding to ordinary residential flats and should, therefore, not be applied to considerably different conditions. The figure corresponds to an explosion caused by town gas and it might, therefore, be somewhat on the safe side in rooms where there is only the possibility of gases with a lower rate of combustion.

The pressure may be applied solely in one room or in more rooms at the same time. In the latter case, all rooms are incorporated in the volume V. Only windows or other similarly weak and light weight structural elements may be taken to be ventilation areas even though certain limited structural parts break at pressures less than q_o.

Figure 16 is given purely as guide and probability of occurrence of an explosion should be checked in each case using appropriate values.

7.6.3 *Vertical Load on Air Raid Shelters*

7.6.3.1 *Characteristic values*

As regards buildings in which the individual floors are acted upon by a total characteristic imposed action of up to 5.0 kN/m^2, vertical actions on air raid shelters generally located below ground level, for example, basement, etc, should be considered to have the following characteristic values:

Buildings up to 2 storeys	28 kN/m^2
Buildings with 3-4 storeys	34 kN/m^2
Buildings with more than 4 storeys	41 kN/m^2
Buildings of particularly stable construction irrespective of the number of storeys	28 kN/m^2

In the case of buildings with floors that are acted upon by a characteristic imposed action larger than 5.0 kN/m^2, the above values should be increased by the difference between the average imposed action on all storeys above the one concerned and 5.0 kN/m^2.

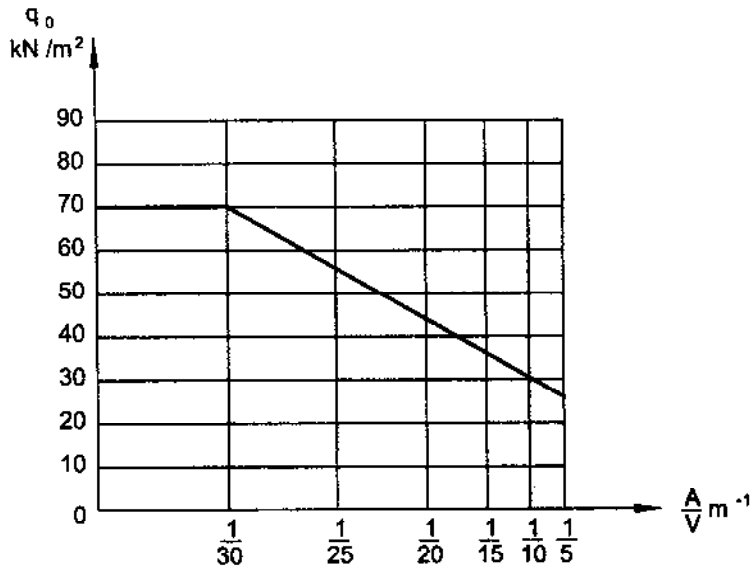


FIG. 16 SKETCH SHOWING RELATION BETWEEN PRESSURE AND TIME

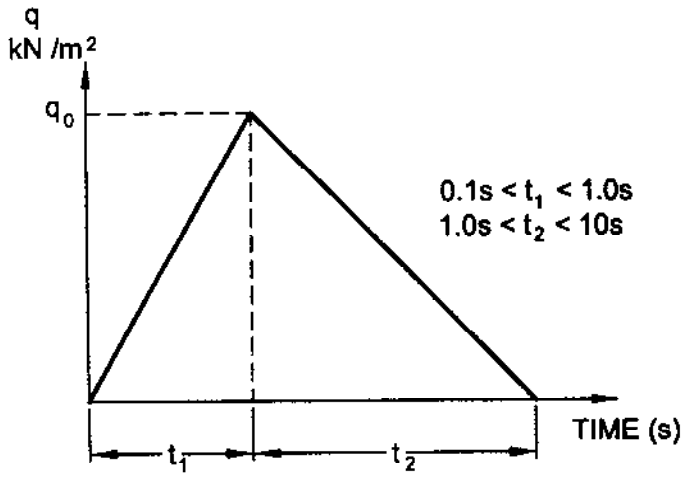


FIG. 17 SKETCH SHOWING TIME INTERVAL AND PRESSURE

NOTES

1 By storeys it is understood, every utilizable storey above the shelter.

2 By buildings of a particular stable construction, it is understood, buildings in which the load-bearing structures are made from reinforced *in-situ* concrete.

7.6.4 *Fire*

7.6.4.1 *General*

Possible extraordinary loads during a fire may be considered as accidental actions. Examples are loads from people along escape routes and loads on another structure from structure failing because of a fire.

7.6.4.2 *Thermal effects during fire*

The thermal effect during fire may be determined from one of the following methods:

a) the time-temperature curve and the required fire resistance (minutes), and

b) an energy balance method.

If the thermal effect during fire is determined from an energy balance method, the fire load is taken to be:

$$q = 12\, t_b$$

where

q = Fire action (kJ per m² floor), and

t_b = Required fire resistance (minutes) [*see* 6-1(11)].

NOTE — The fire action is defined as the total quantity of heat produced by complete combustion of all combustible material in the fire compartment, inclusive of stored goods and equipment together with building structures and building materials.

7.7 Vibrations

For general details on loads due to vibrations, reference may be made to Annex L.

7.8 Other Loads

Other loads not included in the Section, such as special loads due to technical process, moisture and shrinkage effects, etc, should be taken into account where stipulated by building design codes or established in accordance with the performance requirement of the structure.

7.9 For additional information regarding loads, forces and effects about cyclone resistant buildings and landslide control aspects, reference may be made to good practices [6-1(12)] and 6-1(13)] respectively.

8 LOAD COMBINATIONS

8.1 General

A judicious combination of the loads keeping in view the probability of:

a) their acting together; and

b) their disposition in relation to other loads and severity of stresses or deformations caused by the combinations of the various loads, is necessary to ensure the required safety and economy in the design of a structure.

8.2 Land Combinations

Keeping the aspect specified in **8.1**, the various loads should, therefore, be combined in accordance with the stipulation in the relevant design codes. In the absence of such recommendations, the following loading combinations, whichever combination produces the most unfavourable effect in the building, foundation or structural member concerned may be adopted (as a general guidance). It should also be recognized in load combinations that the simultaneous occurrence of maximum values of wind, earthquake, imposed and snow loads is not likely.

1) DL
2) $DL + IL$
3) $DL + WL$
4) $DL + EL$
5) $DL + TL$
6) $DL + IL + WL$
7) $DL + IL + EL$
8) $DL + IL + TL$
9) $DL + WL + TL$
10) $DL + EL + TL$
11) $DL + IL + WL + TL$
12) $DL + IL + EL + TL$

(DL = dead load, IL = imposed load, WL = wind load, EL = earthquake load and TL = temperature load).

NOTES

1 When snow load is present on roof's, replace imposed load by snow load for the purpose of above load combinations.

2 The relevant design codes shall be followed for permissible stresses when the structure is designed by working stress method and for partial safety factors when the structure is designed by limit state design method for each of the above load combinations.

3 Whenever imposed load (IL) is combined with earthquake load (EL), the appropriate part of imposed load as specified in **5** should be used, both for evaluating earthquake effect and also for combined load effects used in such combination.

4 For the purpose of stability of the structure as a whole against overturning, the restoring moment shall be not less than 1.2 times the maximum overturning moment due to dead load plus 1.4 times the maximum overturning moment due to imposed loads. In cases where dead load provides the restoring moment, only 0.9 times the dead load shall be considered. The restoring moments due to imposed loads shall be ignored.

5 The structure shall have a factor against sliding of not less than 1.4 under the most adverse combination of the applied loads/forces. In this case, only 0.9 times the dead load shall be taken into account.

6 Where the bearing pressure on soil due to wind alone is less than 25 percent of that due to dead load and imposed load, it may be neglected in design where this exceeds 25 percent, foundation may be so proportioned that the pressure due to combined effect of dead load, imposed load and wind load does not exceed the allowable bearing pressure by more than 25 percent. When earthquake effect is included, the permissible increase in allowable bearing pressure in the soil shall be in accordance with **5**.

Reduced imposed load specified in **3** for the design of supporting structures should not be applied in combination with earthquake forces.

7 Other loads and accidental load combination not included should be dealt with appropriately.

8 Crane load combinations are covered in **3.6.4.**

9 MULTI-HAZARD RISK IN VARIOUS DISTRICTS OF INDIA

9.1 Multi-Hazard Risk Concept

The commonly encountered hazards are:

a) earthquake,
b) cyclone,
c) wind storm,
d) floods,
e) landslides,
f) liquefaction of soils,
g) extreme winds,
h) cloud bursts, and
j) failure of slopes.

A study of the earthquake, wind/cyclone, and flood hazard maps of India indicate that there are several areas in the country which run the risk of being affected by more than one of these hazards.

Further there may be instances where one hazard may cause occurrence or accentuation of another hazard, such as landslides may be triggered/accelerated by earthquakes and wind storms and floods by the cyclones.

It is important to study and examine the possibility of occurrence of multiple hazards, as applicable to an area. However, it is not economically viable to design all the structures for multiple hazards. The special structures, such as, nuclear power plants, and life line structures, such as, hospitals and emergency rescue shelters may be designed for multiple hazards. For such special structures, site specific data have to be collected and the design be carried out based on the accepted levels of risk. The factors that have to be considered in determining this risk are:

a) The severity of the hazard characterized by M.M. (or M.S.K.) intensity in the case of earthquake; the duration and velocity of wind in the storms; and unprotected or protected situation of flood prone areas; and

b) The frequency of occurrence of the severe hazards.

Till such time that risk evaluation procedures are formalized, the special structures may be designed for multiple hazards using the historical data, that can be obtained for a given site and the available Code for loads already covered. The designer may have to consider the loads due to any one of the hazards individually or in combination as appropriate.

9.2 Multi-Hazard Prone Areas

The criteria adopted for identifying multi hazard prone areas may be as follows:

a) *Earthquake and Flood Risk Prone* — Districts which have seismic Zone of intensity 7 or more and also flood prone unprotected or protected area. Earthquake and flood can occur separately or simultaneously.

b) *Cyclone and Flood Risk Prone* — Districts which have cyclone and flood prone areas. Here floods can occur separately from cyclones, but simultaneous also along with prossibility of storm surge too.

c) *Earthquake, Cyclone and Flood Risk Prone* — Districts which have earthquake Zone of intensity 7 or more, cyclone prone as well as flood prone (protected or unprotected) areas. Here the three hazards can occur separately and also simultaneously as in (a) and (b) above but earthquake and cyclone will be assumed to occur separately only.

d) *Earthquake and Cyclone Risk Prone* — Districts which have earthquake zone of intensity 7 or more and prone to cyclone hazard too. The two will be assumed to occur separately.

Based on the approach given above, the districts with multi-hazard risk are given in Annex M.

9.3 Use of the List of the District with Multi-hazard Risk

The list provides some ready information for use of the authorities involved in the task of disaster mitigation, preparedness and preventive action. This information gives the district which are prone to high risk for more than one hazard. This information will be useful in establishing the need for developing housing design to resist the such multi-hazard situation.

ANNEX A

[*Clause* 3.3.2.1(b)]

ILLUSTRATIVE EXAMPLE SHOWING REDUCTION OF UNIFORMLY DISTRIBUTED IMPOSED FLOOR LOADS IN MULTI-STOREYED BUILDINGS FOR DESIGN OF COLUMNS

A-1 The total imposed loads from different floor levels (including the roof) combing on the central column of a multi-storeyed building (with mixed occupancy) is shown in Fig. 20. Calculate the reduced imposed load for the design of column members at different floor levels using **3.3.2.1**. Floor loads do not exceed 5.0 kN/m^2.

A-1.1 Applying reduction coefficients in accordance with **3.3.2.1**, total reduced floor loads on the column at different levels is indicated along with Fig. 18.

FLOOR No. FROM TOP INCLUDING ROOF	ACTUAL FLOOR LOAD COMING ON DIFFERENT FLOORS kN	LOADS FOR WHICH COLUMNS ARE TO BE DESIGNED kN
1	30	ROOF
2	40	30
3	50	(30 + 40) (1 - 0.1) = 63
4	50	(30 + 40 + 50) (1 - 0.2) = 96
5	40	(30 + 40 + 50 + 50) (1 - 0.3) = 119
6	45	(30 + 40 + 50 + 50 + 40) (1 - 0.4) = 126
7	50	(30 + 40 + 50 + 50 + 40 + 45) (1 - 0.4) = 153
8	50	(30 + 40 + 50 + 50 + 40 + 45 + 50) (1 - 0.4) = 183
9	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50) (1 - 0.4) = 213
10	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40) (1 - 0.4) = 237
11	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40) (1 - 0.4) = 261
12	55	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40) (1 - 0.5) = 237.5 < 261 adopt 261 for design
13	55	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55) (1 - 0.5) = 265
14	70	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55) (1 - 0.5) = 292.5
15	80	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55 + 70) (1 - 0.5) = 327.5
		(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55 + 70 + 80) (1 - 0.5) = 367.5

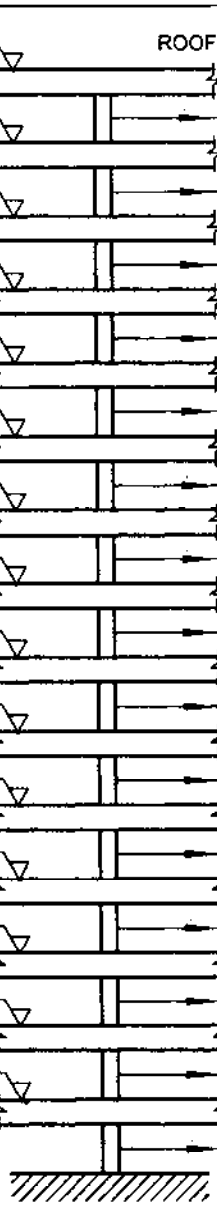


FIG. 18

ANNEX B

(*Clause* 4.2)

NOTATIONS

A = Surface area of a structure or part of a structure

A_e = Effective frontal area

A_z = An area at height Z

b = Breadth of a structure or structural member normal to be wind stream in the horizontal plane

C_f = Force coefficient/drag coefficient

C_{fn} = Normal force coefficient

C_{ft} = Transverse force coefficient

C'_f = Frictional drag coefficient

C_p = Pressure coefficient

C_{pe} = External pressure coefficient

C_{pi} = Internal pressure coefficient

d = Depth of a structure or structural member parallel to wind stream

D = Diameter of cylinder

F = Force normal to the surface

F_n = Normal force

F_t = Transverse force

F' = Frictional force

h = Height of structure above mean ground level

h_x = The height of development of a velocity profile at a distance x down wind from a change in terrain category

k_1, k_2, k_3 = Multiplication factors

K = Multiplication factor

l = Length of the member or greater horizontal dimension of a building

p_d = Design wind pressure

p_z = Design wind pressure at height Z

p_e = External pressure

p_i = Internal pressure

R_e = Reynolds number

S = Strouhal number

V_b = Regional basic wind speed

$\overline{V}_b$ = Mean hourly wind speed corresponding to 10 m height

V_z = Design wind velocity at height Z

$\overline{V}_z$ = Hourly mean wind speed at height Z

w = Lesser horizontal dimension of a building or a structural member

w' = Bay within multi-bay buildings

x = Distance down wind from a change in terrain category

θ = Wind angle from a given axis

α = Inclination of the roof to the horizontal

ϕ = Solidity ratio

Z = A height or distance above the ground

ε = Average height of the surface roughness

ANNEX C

(*Clause* 4.4.2)

BASIC WIND SPEED A 10 m HEIGHT FOR SOME IMPORTANT CITIES/TOWNS

City/Town	*Basic Wind Speed* m/s	*City/Town*	*Basic Wind Speed* m/s
Agra	47	Barauni	47
Ahmedabad	39	Bareilly	47
Ajmer	47	Bhatinda	47
Almora	47	Bhilai	39
Amritsar	47	Bhopal	39
Asansol	47	Bhubaneshwar	50
Aurangabad	39	Bhuj	50
Bahraich	47	Bikaner	47
Bangalore	33	Bokaro	47

City/Town	*Basic Wind Speed* m/s	*City/Town*	*Basic Wind Speed* m/s
Calicut	39	Mangalore	39
Chandigarh	47	Moradabad	47
Chennai	50	Mumbai	44
Coimbatore	39	Mysore	33
Cuttack	50	Nagpur	44
Darbhanga	55	Nainital	47
Darjeeling	47	Nasik	39
Dehra Dun	47	Nellore	50
Delhi	47	Panjim	39
Durgapur	47	Patiala	47
Gangtok	47	Patna	47
Guwahati	50	Pondicherry	50
Gaya	39	Portblair	44
Gorakhpur	47	Pune	39
Hyderabad	44	Raipur	39
Imphal	47	Rajkot	39
Jabalpur	47	Ranchi	39
Jaipur	47	Roorkee	39
Jamshedpur	47	Rourkela	39
Jhansi	47	Shimla	39
Jodhpur	47	Srinagar	39
Kanpur	47	Surat	44
Kohima	44	Tiruchchirappalli	47
Kolkata	50	Thiruvananthpuram	39
Kurnool	39	Udaipur	47
Lakshadweep	39	Vadodara	44
Lucknow	47	Varanasi	47
Ludhiana	47	Vijayawada	50
Madurai	39	Vishakhapatnam	50
Mandi	39		

ANNEX D

[*Clause* 4.4.3.2(d)]

CHANGES IN TERRAIN CATEGORIES

D-1 LOW TO HIGH NUMBER

D-1.1 In cases of transitions from a low category number (corresponding to a low terrain roughness) to a high category number (corresponding to a rougher terrain), the velocity profile over the rougher terrain shall be determined as follows:

a) Below height h_x, the velocities shall be determined in relation to the rougher terrain; and

b) Above height h_x, the velocities shall be determined in relation to the less rough (more distant) terrain.

D-2 HIGH TO LOW NUMBER

D-2.1 In cases of transitions from a more rough to a less rough terrain, the velocity profile shall be determined as follows:

a) Above height h_x, the velocities shall be determined in accordance with the rougher (more distant) terrain; and

b) Below height h_x, the velocities shall be taken as the lesser of the following:

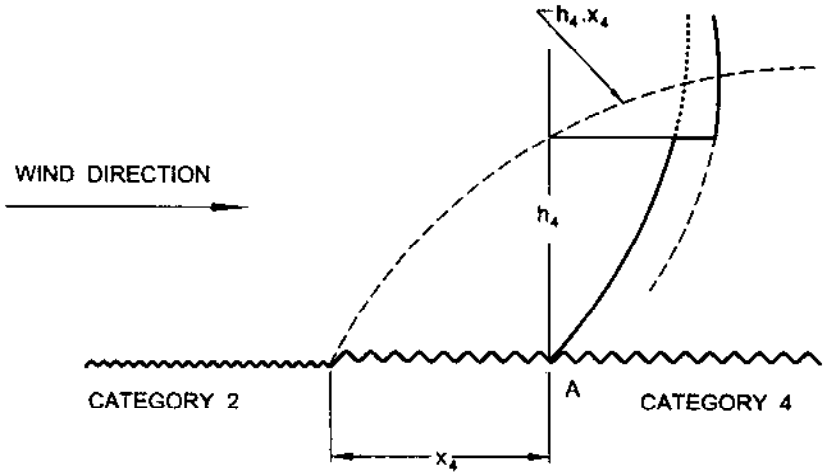
1) that determined in accordance with the less rough terrain; and
2) the velocity at height h_x as determined in relation to the rougher terrain.

NOTE — Examples of the determination of velocity profiles in the vicinity of a change in terrain category are shown in Fig. 19 (a) and (b).

D-3 MORE THAN ONE CATEGORY

D-3.1 Terrain changes involving more than one category shall be treated in similar fashion to that described in **A-1** and **A-2**.

NOTE — Examples involving three terrain categories are shown in Fig. 19(c).



x_4 = FETCH, h_4 = HEIGHT FOR CATEGORY 4

PROFILE FOR CATEGORY 4

PROFILE FOR CATEGORY 2

DESIGN PROFILE AT A

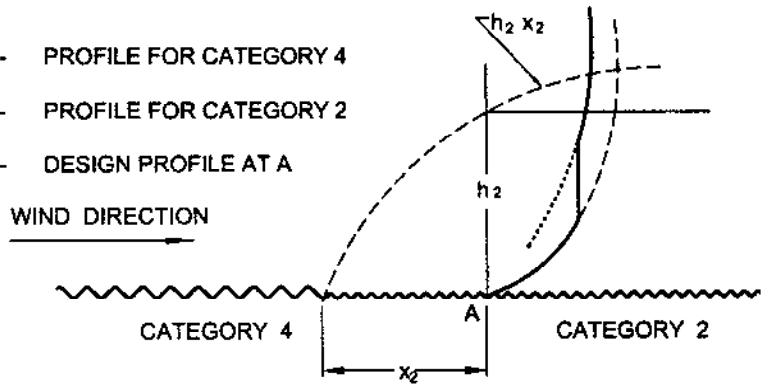
a) DETERMINATION OF VELOCITY PROFILE NEAR A CHANGE IN TERRAIN CATEGORY
(Less rough to more rough)

x_4 = FETCH, h_4 = HEIGHT FOR CATEGORY 2

PROFILE FOR CATEGORY 4

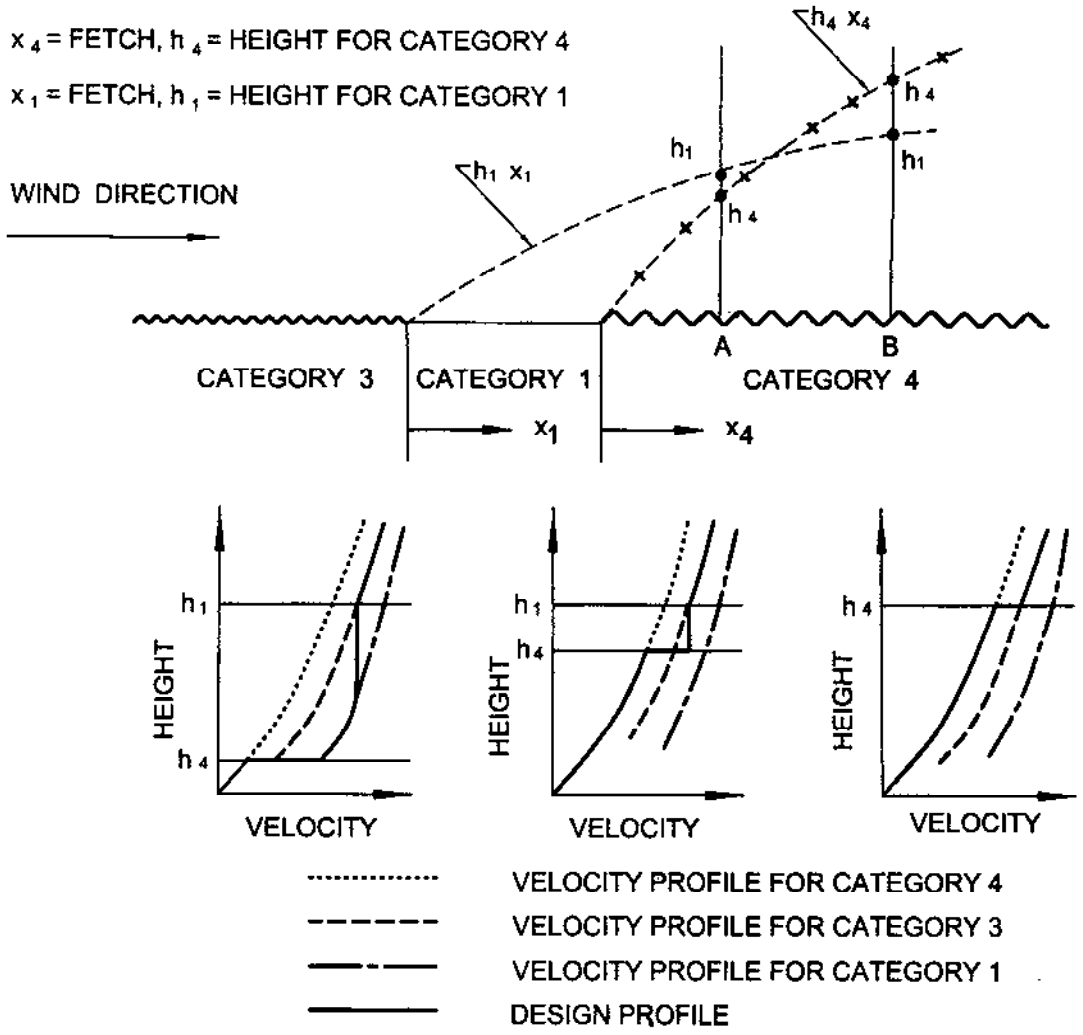
PROFILE FOR CATEGORY 2

DESIGN PROFILE AT A



b) DETERMINATION OF VELOCITY PROFILE NEAR A CHANGE IN TERRAIN CATEGOR
(More rough to less rough)

FIG. 19 VELOCITY PROFILES IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY — *Continued*



c) DETERMINATION OF DESIGN PROFILE INVOLVING MORE THAN ONE CHANGE TERRAIN CATEGORY

FIG. 19 VELOCITY PROFILES IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY

ANNEX E

(*Clause* 4.4.3.3)

EFFECT OF A CLIFF OR ESCARPMENT ON THE EQUIVALENT HEIGHT ABOVE GROUND (k_3 FACTOR)

E-1 The influence of the topographic feature is considered to extend 1.5 L_e is the effective horizontal length of the hill depending on slope as indicated below (*see* Fig. 20).

Slope	L_e
$3° < \theta \leq 17°$	L
$> 17°$	$\frac{Z}{0.3}$

where L is the actual length of the upwind slope in the wind direction, Z is the effective height of the feature, and θ is the upwind slope in the wind direction.

If the zone downwind from the crest of the feature is

relatively flat, ($\theta < 3°$) for a distance exceeding L_e, then the feature should be treated as an escarpment. If not then the feature should be treated as a hill or ridge. Examples of typical features are given in Fig. 20.

NOTES

1 No difference is made in evaluating k_3 between a three dimensional hill and two dimensional ridge.

2 In undulating terrain, it is often not possible to decide whether the local topography to the site is significant in terms of wind flow. In such cases, the average value of the terrain upwind of the site for a distance of 5 km should be taken as the base level from wind to assess the height L and the upwind slope θ of the feature.

E-2 TOPOGRAPHY FACTOR, k_3

The topography factor k_3 is given by the following:

$$k_3 = 1 + C\,s$$

where C has the following values:

Slope	C
$3° < \theta \leq 17°$	$1.2\left(\frac{Z}{L}\right)$
$> 17°$	0.36

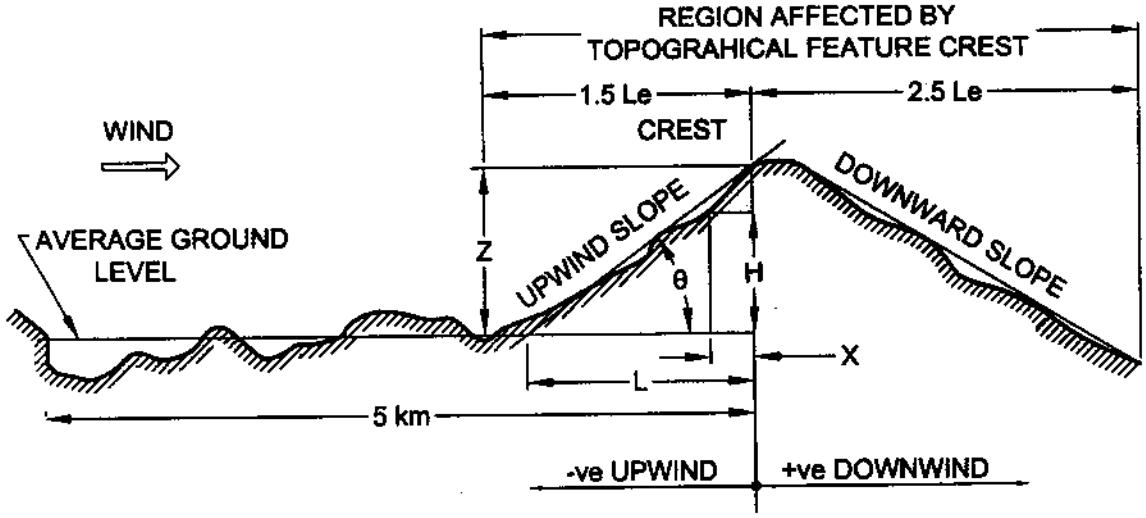
s is a factor derived in accordance with **E-2.1** appropriate to the height, H above mean ground level and the distance x from the summit or crest, relative to the effective length, L_e.

E-2.1 The factor s should be determined from:

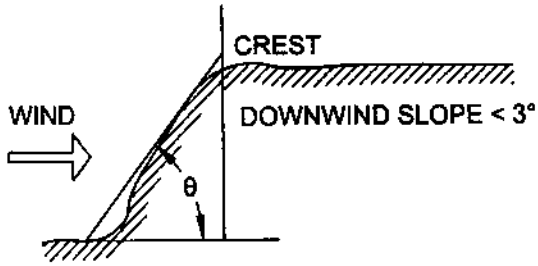
a) Figure 21 for cliffs and escarpments, and

b) Figure 22 for hills and ridges.

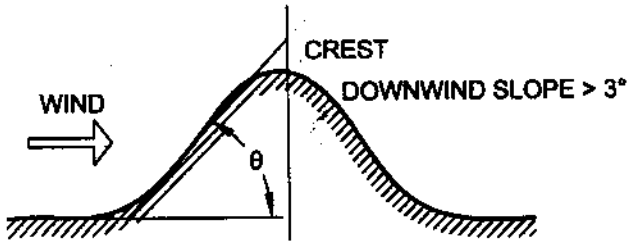
NOTE — Where the downwind slope of a hill or ridge is greater than 3°, there will be large regions of reduced accelerations or even shelter and it is not possible to give general design rules to cater for these circumstances. Values of s from Fig. 22 may be used as upper bound values.



20 (a) GENERAL NOTATIONS



20 (b) CLIFF AND ESCARPMENT



20 (c) HILL AND RIDGE

FIG. 20 DEFINITION OF TOPOGRAPHICAL DIMENSIONS

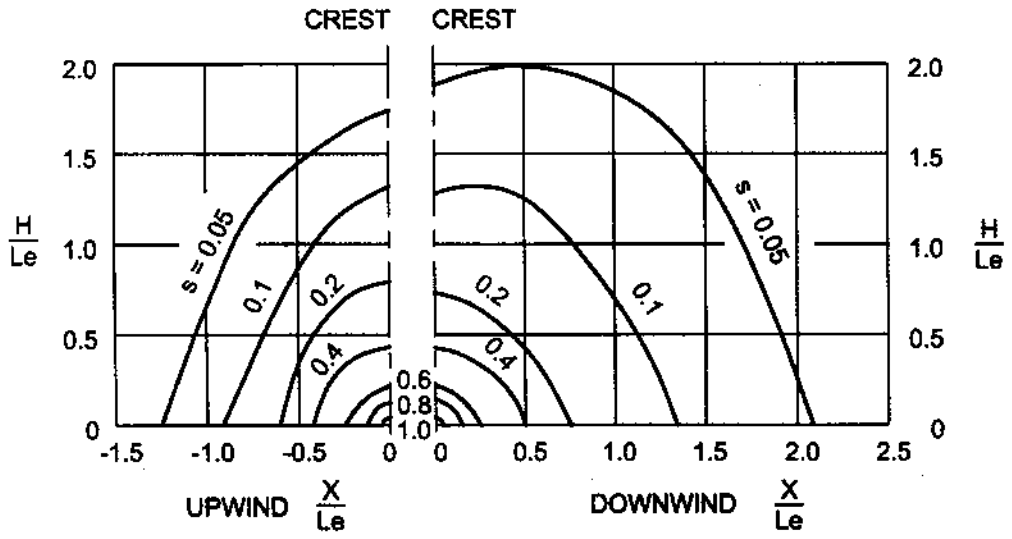


FIG. 21 FACTOR *s* FOR CLIFF AND ESCARPMENT

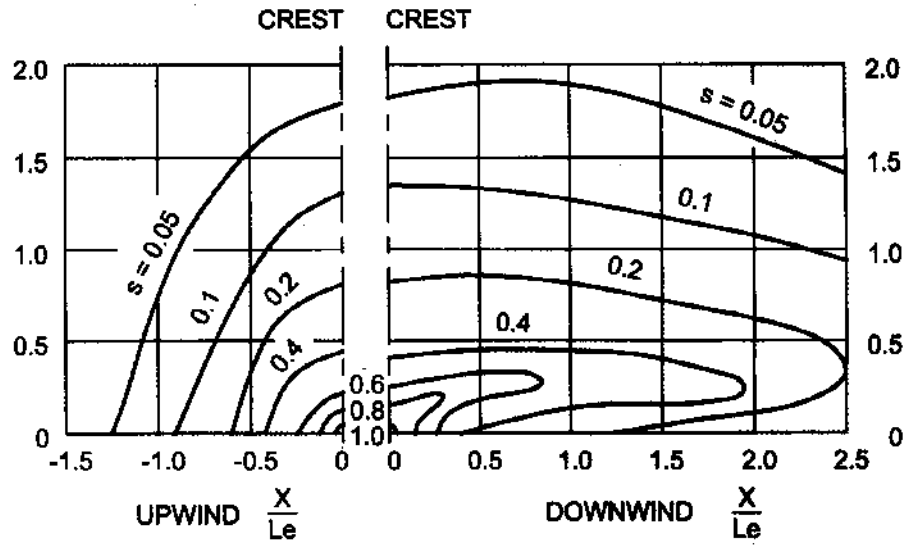


FIG. 22 FACTOR *s* FOR RIDGE AND HILL

ANNEX F

[*Clause* 4.5.3.2 (b)]

WIND FORCE ON CIRCULAR SECTIONS

F-1 The wind force on any object is given by:

$$F = C_f A_e \cdot p_d$$

where

C_f = Force coefficient,

A_e = Effective area of the object normal to the wind direction, and

p_d = Design pressure of the wind.

For most shapes, the force coefficient remains approximately constant over the whole range of wind speeds likely to be encountered. However, for objects of circular cross-section, it varies considerably.

For a circular section, the force coefficient depends upon the way in which the wind flows around it and is

dependent upon the velocity and kinematic viscosity of the wind and diameter of the section. The force coefficient is usually quoted against a non-dimensional parameter, called the Reynolds number, which takes account of the velocity and viscosity of the flowing medium (in the case the wind) and the member diameter.

$$\text{Reynolds number, } R_e = \frac{DV_d}{\gamma}$$

where

D = Diameter of the member;

V_d = Design wind speed; and

γ = Kinematic viscosity of the air which is 1.46×10^5 m²/s at 15°C and standard atmospheric pressure.

Since in most natural environments likely to be found in India, the kinematic viscosity of the air is fairly constant, it is convenient to use DV_d as the parameter instead of Reynolds numbers and this has been done in this Section.

The dependence of a circular section's force coefficient or Reynolds number is due to the change in the wake developed behind the body.

At a low Reynolds number, the wake is as shown in Fig. 23 and the force coefficient is typically 1.2. As the Reynolds number is increased, the wake gradually changes to that shown in Fig. 24, that is, the wake width d_w decreases and the separation point, S moves from the front to the back of the body.

As a result, the force coefficient shows a rapid drop at a critical value of Reynolds number, followed by a gradual rise and Reynolds number is increased still further.

The variation of C_f with parameter DV_d is shown in Fig. 5 for infinitely long circular cylinders having various values of relative surface roughness ε/D when subjected to wind having an intensity and scale of turbulence typical of built-up urban areas. The curve for a smooth cylinder $\varepsilon/D = 1 \times 10^{-5}$ in a steady air-stream, as found in a low-turbulence wind tunnel is shown for comparison.

It can be seen that the main effect of free-stream turbulence is to decrease the critical value of the parameter DV_d. For subcritical flows, turbulence can produce a considerable reduction in C_f below the steady air-stream values. For super-critical flows, this effect becomes significantly smaller.

If the surface of the cylinder is deliberately roughened, such as by incorporating flutes, riveted construction, etc then the data given in Fig. 5 for appropriate value of $\varepsilon/D > 0$ shall be used.

NOTE — In case of uncertainty regarding the value of ε to be used for small roughness, ε/D shall be taken as 0.001.

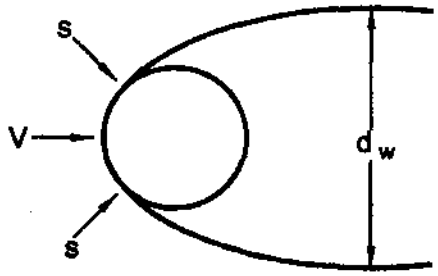


FIG. 23 WAKE IN SUBCRITICAL FLOW

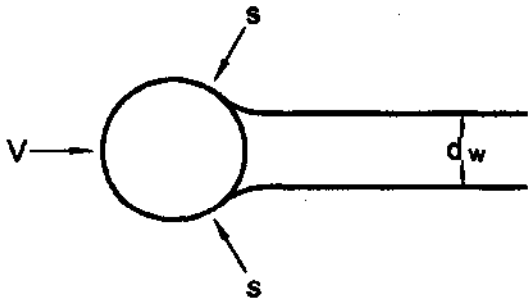


FIG. 24 WAKE IN SUPER-CRITICAL FLOW

ANNEX G

(*Clause* 5.0)

SYMBOLS

The symbols and notations given below apply to the provisions of this Code:

A_h Design horizontal seismic coefficient

A_k Design horizontal acceleration spectrum value for mode k of vibration

b_i ith Floor plan dimension of the building perpendicular to the direction of force

c Index for the closely-spaced

d Base dimension of the building, in metres, in the direction in which the seismic force is considered.

e_{di} Static eccentricity to be used at floor i calculated as per **5.4.8.2.**

e_{si} Static eccentricity at floor i defined as the distance between centre of mass and centre of rigidity

EL_x Response quantity due to earthquake load for horizontal shaking along x-direction

EL_y Response quantity due to earthquake load for horizontal shaking along y-direction

EL_z Response quantity due to earthquake load for vertical shaking along z-direction

F_{roof} Design lateral forces at the roof due to all modes considered

F_i Design lateral forces at the floor i due to all modes considered

g Acceleration due to gravity

h Height of structure, in metres

h_i Height measured from the base of the building to floor i

I Importance factor

IL Response quantity due to imposed load

M_k Modal mass of mode k

n number of storeys

N SPT value for soil

P_k Modal participation factor of mode k

Q_i Lateral force at floor i

Q_{ik} Design lateral force at floor i in mode k

r Number of modes to be considered as per **5.4.8.4.2**

R Response reduction factor

S_a/g Average response acceleration coefficient for rock or soil sites as given by Fig. 2 and Table 3 based on appropriate natural periods and damping of the structure

structure (in second)

T_a Approximate fundamental period (in second)

T_i Fundamental natural period of vibration (in second)

T_k Undamped natural period of mode k of vibration (in second)

V_B Design seismic base shear

$\bar{V}_B$ Design base shear calculated using the approximate fundamental period T_a

V_i Peak storey shear force in storey i due to all modes considered

V_{ik} Shear force in storey i in mode k

V_{roof} Peak storey shear force at the roof due to all modes considered

W Seismic weight of the structure

W_i Seismic weight of floor i

Z Zone factor

ϕ_{ik} Mode shape coefficient at floor i in mode k

λ Peak response (for example, member forces, displacements, storey forces, storey shears or base reactions) due to all modes considered

λ_k Absolute value of maximum response in mode k

λ_c Absolute value of maximum response in mode c, where mode c is a closely-spaced mode

λ^* Peak response due to the closely-spaced modes only

P_{ij} Coefficient used in the Complete Quadratic Combination (CQC) method while combining responses of modes i and j

ω_i Circular frequency in rad/second in the ith mode

ANNEX H

(*Clause* 5.1.15)

COMPREHENSIVE INTENSITY SCALE (MSK 64)

The scale was discussed generally at the inter-governmental meeting convened by UNESCO in April 1964. Though not finally approved the scale is more comprehensive and describes the intensity of earthquake more precisely. The main definitions used are followings:

a) *Type of Structures (Buildings)*

Type A — Building in field-stone, rural structures, unburnt-brick houses, clay houses.

Type B — Ordinary brick buildings, buildings of large block and prefabricated type, half timbered structures, buildings in natural hewn stone.

Type C — Reinforced buildings, well built wooden structures.

b) *Definition of Quantity*:

Single, few	About 5 percent
Many	About 50 percent
Most	About 75 percent

c) *Classification of Damage to Buildings*

Grade 1	Slight damage	Fine cracks in plaster: fall of small pieces of plaster
Grade 2	Moderate damage	Small cracks in plaster: fall of fairly large pieces of plaster; pantiles slip off; cracks in chimneys parts of chimneys fall down
Grade 3	Heavy damage	Large and deep cracks in plaster: fall of chimneys
Grade 4	Destruction	Gaps in walls: parts of buildings may collapse; separate parts of the buildings lose their cohension; and inner walls collapse
Grade 5	Total damage	Total collapse of the buildings

d) *Intensity Scale*

1. *Not noticeable* — The intensity of the vibration is below the limits of sensibility; the tremor is detected and recorded by seismograph only.
2. *Scarcely noticeable (very slight)* — Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.
3. *Weak, partially observed only* — The earthquake is felt indoors by a few people, outdoors only in favourable circumstances. The vibration is like that due to the passing of a light truck. Attentive observers notice a slight swinging of hanging objects, somewhat more heavily on upper floors.
4. *Largely observed* — The earthquake is felt indoors by many people, outdoors by few. Here and there people awake, but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. Windows, doors, and dishes rattle. Floors and walls crack. Furniture begins to shake. Hanging objects swing slightly. Liquid in open vessels are slightly disturbed. In standing motor cars the shock is noticeable.
5. *Awakening*
   i) The earthquake is felt indoors by all outdoors by many. Many people awake. A few run outdoors uneasy. Building tremble throughout. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Unstable objects overturn or shift. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The sensation of vibration is like that due to heavy objects falling inside the buildings.
   ii) Slight damages in buildings of Type A are possible.
   iii) Sometimes changes in flow of springs.
6. *Frightening*
   i) Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons loose their balance. Domestic animals run out of their stalls in few instances, dishes and glassware may break and books fall down. Heavy furniture may possibly move and small steeple bells may ring.
   ii) Damage of Grade 1 is sustained in single buildings of Type B and in many of Type A. Damage in few buildings of Type A is of Grade 2.
   iii) In few cases, cracks up to widths of 1 cm possible in wet ground; in mountains occasional landslips; change in flow of springs and in level of well water are observed.
7. *Damage of buildings*
   i) Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring.
   ii) In many buildings of Type C damage of Grade 1 is caused; in many buildings of Type B damage is of Grade 2. Most buildings of Type A suffer damage of Grade 3, few of

Grade 4. In single instances, landslides of roadway on steep slopes; crack in roads; seams of pipelines damaged; cracks in stone walls.

iii) Waves are formed on water, and is made turbid by mud stirred up. Water levels in wells change, and the flow of springs changes. Some times dry springs have their flow resorted and existing springs stop flowing. In isolated instances parts of sand and gravelly banks slip off.

8. *Destruction of buildings*

i) Fright and panic; also persons driving motor cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.

ii) Most buildings of Type C suffer damage of Grade 2, and few of Grade 3. Most buildings of Type B suffer damage of Grade 3. Most buildings of Type A suffer damage of Grade 4. Occasional breaking of pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.

iii) Small landslips in hollows and on banked roads on steep slopes; cracks in ground up to widths of several centimeters. Water in lakes become turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases, change in flow and level of water is observed.

9. *General damage of buildings*

i) General panic; considerable damage to furniture. Animals run to and fro in confusion, and cry.

ii) Many buildings of Type C suffer damage of Grade 3, and few of Grade 4. Most buildings of Type B show a damage of Grade 4 and a few of Grade 5. Many buildings of Type A suffer damage of Grade 5. Monuments and columns fall. Considerable damage to reservoirs; underground pipes partly broken. In individual cases, railway lines are bent and roadway damaged.

iii) On flat land overflow of water, sand and mud is often observed. Ground cracks in widths of up to 10 cm on slopes and river banks more than 10 cm. Further more a large number of slight cracks in ground; falls of rock, many land slides and earth flows; large waves in wate. Dry wells renew their flow and existing wells dry up.

10. *General destruction of buildings*

i) Many buildings of Type C suffer damage of Grade 4, and few of Grade 5. Many buildings of Type B show a damage of Grade 5. Most of Type A have destruction of Grade 5. Critical damage of dykes and dams. Severe damage to bridges. Railways lines are bent slightly. Underground pipes are bent on broken. Road paving and asphalt show waves.

ii) In ground, cracks up to widths of several centimetres, sometimes up to 1 m. Parallel to water courses occur broad fissures. Loose ground slides from steep slopes. From river banks and steep coasts considerable landslides are possible. In coastal areas displacement of sand and mud; change of water level in wells; water from canals; lakes; rivers; etc, thrown on land. New lakes occur.

11. *Destruction*

i) Severe damage even to well built buildings, bridges, water damps and railway lines. Highways become useless. Underground pipes destroyed.

ii) Ground considerably distorted by broad cracks and fissures, as well as movement in horizontal and vertical directions. Numerous landslips and falls of rocks. The intensity of the earthquake requires to be investigated specifically.

12. *Landscape changes*

i) Practically all structures above and below ground are greatly damaged or destroyed.

ii) The surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Falling of rock and slumping of river banks over wide areas, lakes are damaged, waterfalls appears and rivers are deflected. The intensity of the earthquake requires to be investigated specially.

ANNEX J

(*Clause* 5.3.4.2)

ZONE FACTORS FOR SOME IMPORTANT TOWNS

Town	*Zone*	*Zone Factor, Z*	*Town*	*Zone*	*Zone Factor, Z*
Agra	III	0.16	Goa	III	0.16
Ahmedabad	III	0.16	Gulbarga	II	0.10
Ajmer	II	0.10	Gaya	III	0.16
Allahabad	II	0.10	Gorakhpur	IV	0.24
Almora	IV	0.24	Hyderabad	II	0.10
Ambala	IV	0.24	Imphal	V	0.36
Amritsar	IV	0.24	Jabalpur	III	0.16
Asansol	III	0.16	Jaipur	II	0.10
Aurangabad	II	0.10	Jamshedpur	II	0.10
Bahraich	IV	0.24	Jhansi	II	0.10
Bangalore	II	0.10	Jodhpur	II	0.10
Barauni	IV	0.24	Jorhat	V	0.36
Bareilly	III	0.16	Kakrapara	III	0.16
Belgaum	III	0.16	Kalapakkam	III	0.16
Bhatinda	III	0.16	Kanchipuram	III	0.16
Bhilai	II	0.10	Kanpur	III	0.16
Bhopal	II	0.10	Karwar	III	0.16
Bhubaneshwar	III	0.16	Kohima	V	0.36
Bhuj	V	0.36	Kolkata	III	0.16
Bijapur	III	0.16	Kota	II	0.10
Bikaner	III	0.16	Kurnool	II	0.10
Bokaro	III	0.16	Lucknow	III	0.16
Bulandshahr	IV	0.24	Ludhiana	IV	0.24
Burdwan	III	0.16	Madurai	II	0.10
Calicut	III	0.16	Mandi	V	0.36
Chandigarh	IV	0.24	Mangalore	II	0.16
Chennai	III	0.16	Monghyr	IV	0.24
Chitradurga	II	0.10	Moradabad	IV	0.24
Coimbatore	III	0.16	Mumbai	III	0.16
Cuddalore	III	0.16	Mysore	II	0.10
Cuttack	III	0.16	Nagpur	II	0.10
Darbhanga	V	0.36	Nagarjunasagar	II	0.10
Darjeeling	IV	0.24	Nainital	IV	0.24
Dharwad	III	0.16	Nasik	III	0.16
Dehra Dun	IV	0.24	Nellore	III	0.16
Dharampuri	III	0.16	Osmanabad	III	0.16
Delhi	IV	0.24	Panjim	III	0.16
Durgapur	III	0.16	Patiala	III	0.16
Gangtok	IV	0.24	Patna	IV	0.24
Guwahati	V	0.36	Pilibhit	IV	0.24

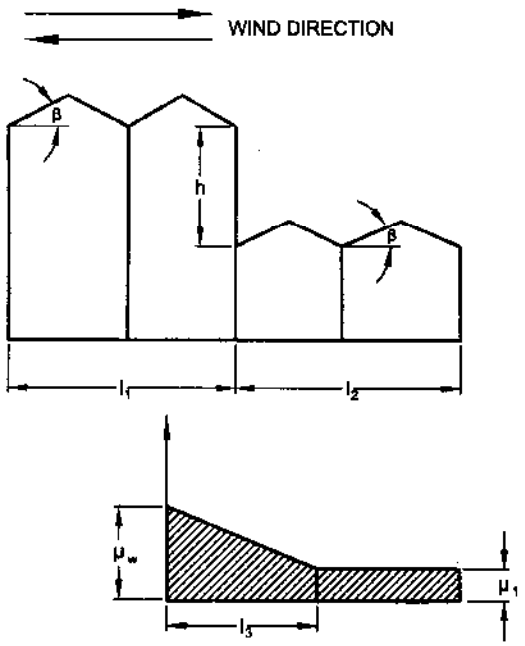
Town	*Zone*	*Zone Factor, Z*	*Town*	*Zone*	*Zone Factor, Z*
Pondicherry	II	0.10	Tarapur	III	0.16
Pune	III	0.16	Tezpur	V	0.36
Raipur	II	0.10	Thane	III	0.16
Rajkot	III	0.16	Thanjavur	II	0.10
Ranchi	II	0.10	Thiruvananthapuram	III	0.16
Roorkee	IV	0.24	Tiruchchirappalli	II	0.10
Rourkela	II	0.10	Tiruvennamalai	III	0.16
Sadiya	V	0.36	Udaipur	II	0.10
Salem	III	0.16	Vadodara	III	0.16
Shimla	IV	0.24	Varanasi	III	0.16
Sironj	II	0.10	Vellore	III	0.16
Solapur	III	0.16	Vijayawada	III	0.16
Srinagar	V	0.36	Vishakhapatnam	II	0.10
Surat	III	0.16			

ANNEX K

(*Clauses* 6.4.2.4 *and* 6.4.3)

SHAPE COEFFICIENTS FOR MULTILEVEL ROOFS

A more comprehensive formula for the shape coefficient for multilevel roofs



$$\mu_w = 1 + \frac{1}{h}(m_1 l_1 + m_2 l_2)(l_2 - 2h)$$

μ_1 = 0.8

l_3 = 2h

(h and l being in metres)

Restriction:

$$\mu_w \leq \frac{kh}{S_o}$$

where

S_o is in kilopascals (kilonewtons per square metre)

k is in newtons per cubic metre

$l_3 \leq 15$ m

Values of m_1 (m_2) for the higher (lower) roof depend on its profile and are taken as equal to:

0.5 for plane roofs with slopes $\beta \leq 20°$ and vaulted roofs with $\frac{f}{l} \leq \frac{1}{18}$

0.3 for plane roofs with slopes $\beta \leq 20°$ and vaulted roofs with $\frac{f}{l} \leq \frac{1}{18}$

The coefficients m_1 and m_2 may be adjusted to take into account conditions for transfer of snow on the roof surface (that is wind, temperature, etc).

NOTE — The other condition of loading shall also be tried.

ANNEX L

(*Clause* 7.7)

VIBRATIONS IN BUILDINGS

L-1 GENERAL

In order to design the buildings safe against vibrations, it is necessary to identify the source and nature of vibration. Vibrations may be included in the buildings due to various actions, such as:

a) human induced vibrations, for example, the walking or running or a single person or a number of persons or dancing or motions in stadia or concert halls;
b) machine induced vibrations;
c) wind induced vibrations;
d) blast induced vibrations;
e) traffic load, for example, due to rail, fork-lift, trucks, cars, or heavy vehicles;
f) airborne vibrations;
g) crane operations; and
h) other dynamic actions, such as, wave loads or earthquake actions.

The dynamic response of buildings for the above mentioned causes of vibration of buildings may have to be evaluated by adopting standard mathematical models and procedures.

The severity or otherwise of these actions have to be assessed in terms of the limits set for dynamic response (frequencies and amplitude of motion) of the buildings related to (a) human comfort, (b) serviceability requirements, such as, deflections and drifts and separation distances to avoid damage due to pounding, and (c) limits set on the frequencies and amplitude of motion for machines and other installations.

In order to verify that the set limits are not exceeded, the actions may be modelled in terms of force-time histories for which the structural responses may be determined as time histories of displacements or accelerations by using appropriate analytical/numerical methods.

L-2 SERVICEABILITY LIMIT STATE VERIFICATION OF STRUCTURE SUSCEPTIBLE TO VIBRATIONS

L-2.1 While giving guidance for serviceability limit state verification of structure susceptible to vibrations, here it is proposed to deal with the treatment of the action side, the determination of the structural response and the limits to be considered for the structural response to ensure that vibrations are not harmful or do not lead to discomfort.

L-2.2 Source of Vibrations

Vibrations may be included by the following sources:

a) by the movement of persons as in pedestrian bridges, floors where people walk, floors meant for sport or dancing activities, and floors with fixed seating and spectator galleries;
b) by working of machines as in machine foundations and supports, vibrations transmitted through the ground, and pile driving operations;
c) by wind blowing on buildings, towers, chimneys and masts, guyed masts, pylons, bridges, cantilevered roofs, airborne vibrations;
d) induced by traffic on rail or road bridges and car park structures and exhibition halls; and
e) by earthquakes.

L-2.3 Modelling of Actions and Structures

For serviceability limit states, the modelling of these actions and of the structure depends on how the serviceability limits are formulated. The serviceability limit states may refer to:

a) human comfort,

b) limits for the proper functioning of machines and other installations, and

c) maximum deformation limits to avoid damage or pounding.

In order to verify that these limits are not exceeded, the actions may be modelled in terms of force-time histories, for which the structural responses may be determined as time histories of displacements or accelerations by using appropriate analytical/ numerical methods. Where the structural response may significantly influence the force-time histories to be applied, these interactions have to be considered either in modelling a combined load-structure vibration system or by appropriate modifications of the force-time histories. In addition to the levels of vibration for which presently limits have been specified, the possible deformations of structural members and systems using different clauses in the relevant codes have to be evaluated by adopting standard mathematical models and procedures.

L-2.4 Force-Time Histories

The force-time histories used in the dynamic analysis should adequately represent the relevant loading situations for which the serviceability limits are to be verified. The force-time histories may model:

a) human induced vibrations, for example the walking or running of a single person or a number of persons or dancing or motions in stadia or concert halls;

b) machine induced vibrations, for example by force vectors due to mass eccentricities and frequencies, that may be variable with time;

c) wind induced vibrations;

d) blast induced vibrations;

e) traffic load, for example rail, fork-lift, trucks, cars, or heavy vehicles;

f) airborne vibrations;

g) crane operations; and

h) other dynamic actions such as wave loads or earthquake actions.

ANNEX M

(*Clause* 9.2)

SUMMARY OF DISTRICTS HAVING SUBSTANTIAL MULTI-HAZARD RISK AREAS

State	*Name of Districts Having Substantial Multi-hazard Prone Area*			
	E.Q. and Flood	Cyclone and Flood	E.Q. Cyclone and Flood	E.Q. and Cyclone
(1)	(2)	(3)	(4)	(5)
Andhra Pradesh	Adilabad, Karim Nagar, Khammam	Krishna, Nellore, Srikakulam, Vishakhapatnam, Vizianagram	East Godavari, Guntur, Prakasam, West Godavari	—
Assam	All 22 districts listed in Table 38 could have M.S.K. IX or more with flooding	No cyclone, but speed can be 50 m/s in districts of Table 38 causing local damage except Dhubri	—	—
Bihar	All 25 districts listed in Table 38	—	—	—
Goa		—	—	North and South Goa
Gujarat	Banaskantha, Danthe GS, Gandhinagar, Kheda, Mahesana, Panchmahals, Vadodara	—	Ahmedabad, Bharuch, Surat, Valsad	Amreli, Bhavnagar, Jamnagar, Rajkot, Junagad, Kachcha
Haryana	All 8 districts listed in Table 38	—	—	—

(1)	(2)	(3)	(4)	(5)
Kerala	Idduki, Kottayam, Palakkad, Pathanamthitta	—	Alappuzha, Ernakulum, Kannur, Kasargode, Kollam, Kozhikode, Malappuram, Thiruvanathapuram, Trissur	—
Maharashtra	—	—	—	Bombay, Rayagad, Ratnagiri, Sindhudurg, Thane
Orissa	—	Ganjam	Baleshwar, Cuttack, Puri	Dhenkanal
Punjab	All 12 districts listed in Table 38	—	—	—
Uttar Pradesh	All 50 districts listed in Table 38	—	—	—
West Bengal	Birbhum, Darjeeling, Jalpaiguri, Kooch Bihar, Malda, Murshidabad, West Dinajpur	—	Bardhaman, Calcutta, Hugli, Howra, Mednipur, Nadia, North and South 24 Parganas	Bankura
Union Territories	Delhi	—	Yanam (Py)	Diu
India	139 Districts	6 Districts	29 Districts	16 Districts

Table 38 Multi-Hazard Prone Districts

Assam

Barpeta, Bongaigaon, Cachar[1], Darrang, Dhemaji, Dhuburi, Dibrugarh, Goalpara, Golaghat, Hailaknadi[1], Jorhat, Kamrup, Karbianglong, Karimganj[1], Kokrajhar, Lakhimpur, Morigaon, Nagaon, Nalbari, Sibsagar, Sonitpur, Tinsukia

Bihar[2]

Araria, Begusarai, Bhagalpur, Bhojpur, Darbhanga, Gopalganj, Katihar, Khagaria, Kishanganj, Madhepura, Madhubani, Munger, Muzaffarpur, Nalanda, Nawada, Paschim Champaran, Patna, Purbachamparan, Purnia, Samastipur, Saran, Saharsa, Sitamarhi, Siwan, Vaishali

[3]Haryana

Ambala, Bhiwani, Faridabad, Gurgaon, Hissar, Jind, Kurukshetra, Rohtak

[4]Punjab

Amritsar, Bathinda, Faridkot, Firozpur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Patiala, Rup Nagar, Sangrur

[5]Uttar Pradesh

Agra, Aligarh, Allahabad, Azamgarh, Bahraich, Ballia, Barabanki, Bareilly, Basti, Bijnor, Budaun, Bulandshahr, Deoria, Etah, Etawah, Faizabad, Farrukhabad, Fatehpur, Firozabad, Ghaziabad, Ghazipur, Gonda, Gorakhpur, Hardoi, Haridwar, Jaunpur, Kanpur (Dehat), Kanpur (Nagar), Kheri, Lucknow, Maharajganj, Mainpuri, Mathura, Mau, Meerut, Mirzapur, Mordabad, Muzaffarnagar, Nainital, Pilibhit, Partapgarh, Raebareli, Rampur, Saharanpur, Shahjahanpur, Siddarth Nagar, Sitapur, Sultanpur, Unnao, Varanasi

[1] Districts liable to cyclonic storm but No Storm Surge
[2] No cyclonic storm in Bihar
[3] No cyclonic storm in Haryana
[4] No cyclonic storm in Punjab
[5] No cyclonic storm in Uttar Pradesh

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

IS No.	*Title*
(1) 875 (Part 1) : 1987	Code of practice for design loads (other than earthquake) for buildings and structures Part 1 Dead loads — Unit weights of building material and stored materials (*second revision*)
(2) 8888 (Part 1) : 1993	Guide for requirements of low income housing: Part 1 Urban area (*first revision*)
(3) 807 : 1976	Code of practice for design, manufacture, erection and testing (structural portion) of cranes and hoists (*first revision*)
3177 : 1999	Code of practice for electric overhead travelling cranes and gantry cranes other than steelwork cranes (*second revision*)
(4) 13920 : 1993	Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces
(5) 1893 (Part 4) : 2005	Criteria for earthquake resistant design of structures: Part 4 Industrial structures including stack-like structures
(6) 1888 : 1982	Method of load test on soils (*second revision*)
6403 : 1981	Code of practice for determination of bearing capacity of shallow foundations (*first revision*)
(7) 1498 : 1970	Classification and identification of soils for general engineering purposes (*first revision*)
(8) 2131 : 1981	Method for standard penetration test for soils (*first revision*)
(9) 4326 : 1993	Code of practice for earthquake resistant design and construction of buildings (*second revision*)
(10) 3414 : 1968	Code of practice for design and installation of joints in buildings
(11) 1642 : 1989	Code of practice for fire safety of buildings (general): Details of construction (*first revision*)
(12) 15498 : 2004	Guidelines for improving cyclone resistance of low rise houses and other buildings/ structures
(13) 14458 (Part 1) : 1998	Guidelines for retaining wall for hill area: Part 1 Selection of type of wall
(14) 14458 (Part 2) : 1997	Guidelines for retaining wall for hill area: Part 2 Design of retaining/breast walls
(15) 14458 (Part 3) : 1998	Guidelines for retaining wall for hill area: Part 3 Construction of dry stone
(16) 14496 (Part 2) : 1998	Guidelines for preparation of landslide-hazard zonation maps in mountainous terrains: Part 2 Macro-zonation
(17) 14680 : 1999	Guidelines for landslide control

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 2 Soils and Foundations

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section deals with the structural design aspects of foundations and mainly covers the design principles involved in different types of foundations.

This Section was published in 1970, and subsequently revised in 1983. In the first revision design considerations in respect of shallow foundation were modified, provisions regarding pier foundation were added and provisions regarding draft foundation and pile foundation were revised and elaborated.

As a result of experience gained in implementation of 1983 version of the Code and feed back received as well as revision of standards and preparation of new standards in the field of soils and foundations, a need to revise this Section was felt. This revision has therefore been prepared to take into account these developments. The significant changes incorporated in this revision include:

a) Design considerations in respect of shallow foundations have been modified.
b) Method for determining depth of fixity, lateral deflection and maximum moment have been modified.
c) Reference has been made to ground improvement techniques.
d) References to Indian Standards made in the text have been updated.

For detailed information regarding structural analysis and soil mechanics aspects of individual foundations, reference should be made to standard textbooks and available literature.

The information contained in this Section is mainly based on the following Indian Standards:

IS No.	*Title*
1080 : 1985	Code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell) (*second revision*)
1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
2911 (Part 1/Sec 1) : 1979	Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*first revision*)
2911 (Part 1/Sec 2) : 1979	Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 2 Bored cast *in-situ* piles (*first revision*)
2911 (Part 1/Sec 3) : 1979	Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 3 Driven precast concrete piles (*first revision*)
2911 (Part 1/Sec 4) : 1984	Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 4 Bored precast concrete piles
2911 (Part 3) : 1980	Code of practice for design and construction of pile foundations: Part 3 Under-reamed piles (*first revision*)
2950 (Part 1) : 1981	Code of practice for design and construction of raft foundations: Part 1 Design (*second revision*)
9456 : 1980	Code of practice for design and construction of conical hyperbolic paraboidal types of shell foundations

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 6 STRUCTURAL DESIGN

Section 2 Soils and Foundations

1 SCOPE

This Section covers structural design (principles) of all building foundations such as raft, pile and other foundation systems to ensure safety and serviceability without exceeding the permissible stresses of the materials of foundations and the bearing capacity of the supporting soil.

2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions shall apply.

2.1 General

2.1.1 *Clay* — An aggregate of microscopic and sub-microscopic particles derived from the chemical decomposition and disintegration of rock constituents. It is plastic within a moderate to wide range of water content. The particles are less than 0.002 mm in size.

2.1.2 *Clay, Firm* — A clay which at its natural water content can be moulded by substantial pressure with the fingers and can be excavated with a spade.

2.1.3 *Clay, Soft* — A clay which at its natural water content can be easily moulded with the fingers and readily excavated.

2.1.4 *Clay, Stiff* — A clay which at its natural water content cannot be moulded with the fingers and requires a pick or pneumatic spade for its removal.

2.1.5 *Foundation* — That part of the structure which is in direct contact with and transmits loads to the ground.

2.1.6 *Gravel* — Cohesionless aggregates of angular rounded or semi-rounded, fragments of more or less unaltered rocks or minerals, 50 percent or more of the particles having size greater than 4.75 mm and less than 80 mm.

2.1.7 *Peat* — A fibrous mass of organic matter in various stages of decomposition generally dark brown to black in colour and of spongy consistency.

2.1.8 *Sand* — Cohesionless aggregate of rounded, sub-rounded, angular, sub-angular or flat fragments of more or less unaltered rock or minerals, 50 percent or more of particles greater than 0.075 mm or less than 4.75 mm in size.

2.1.9 *Sand, Coarse* — Sand which contains 50 percent or more of particles of size greater than 2 mm and less than 4.75 mm.

2.1.10 *Sand, Fine* — Sand which contains 50 percent of particles of size greater than 0.075 mm and less than 0.425 mm.

2.1.11 *Sand, Medium* — Sand which contains 50 percent of particles of size greater than 0.425 mm and less than 2.0 mm.

2.1.12 *Silt* — A fine grained soil with little or no plasticity. The size of particles ranges from 0.075 mm to 0.002 mm.

2.1.13 *Soft Rock* — A rocky cemented material which offers a high resistance to picking up with pick axes and sharp tools but which does not normally require blasting or chiselling for excavation.

2.1.14 *Soil, Black Cotton* — Inorganic clays of medium to high compressibility. They form a major soil group in India. They are predominately montmorillonitic in structure and yellowish black or blackish grey in colour. They are characterized by high shrinkage and swelling properties.

2.1.15 *Soil, Coarse Grained* — Soils which include the coarse and largely siliceous and unaltered products of rock weathering. They possess no plasticity and tend to lack cohesion when in dry state.

2.1.16 *Soil, Fine Grained* — Soils consisting of the fine and altered products of rock weathering, possessing cohesion and plasticity in their natural state, the former even when dry and both even when submerged. In these soils, more than half of the material by weight is smaller than 75-micron IS Sieve size.

2.1.17 *Total Settlement* — The total downward movement of the foundation unit under load.

2.2 Shallow Foundation

2.2.1 *Back Fill* — Materials used or re-used to fill an excavation.

2.2.2 *Bearing Capacity, Safe* — The maximum intensity of loading that the soil will safely carry with a factor of safety without risk of shear failure of soil irrespective of any settlement that may occur.

2.2.3 *Bearing Capacity, Ultimate* — The intensity of loading at the base of a foundation which would cause shear failure of the supporting soil.

2.2.4 *Bearing Pressure, Allowable (Gross or Net)* — The maximum allowable loading intensity on the ground in any given case (with full cognizance of surcharge) taking into account the maximum safe bearing capacity, the amount and kind of settlement expected and the capability of the structure to take up

this settlement. It is, therefore, a combined function of both the site conditions and characteristics of the particular structure.

The net allowable bearing pressure is the gross allowable bearing pressure minus the surcharge intensity.

NOTE — The concept of 'gross' and 'net' used in defining the allowable bearing pressure could also be extended to safe bearing capacity, safe bearing pressure and ultimate bearing capacity.

2.2.5 *Factor of Safety (with Respect to Bearing Capacity)* — A factor by which the ultimate bearing capacity (net) must be reduced to arrive at the value of safe bearing capacity (net).

2.2.6 *Footing* — A spread constructed in brick work, masonry or concrete under the base of a wall or column for the purpose of distributing the load over a larger area.

2.2.7 *Foundation, Raft* — A substructure supporting an arrangement of columns or walls in a row or rows transmitting the loads to the soil by means of a continuous slab, with or without depressions or openings.

2.2.8 *Make-up Ground* — Refuse, excavated soil or rock deposited for the purpose of filling a depression or raising a site above the natural surface level of the ground.

2.2.9 *Offset* — The projection of the lower step from the vertical face of the upper step.

2.2.10 *Permanent Load* — Loads which remain on the structure for a period, or a number of periods, long enough to cause time dependent deformation/ settlement of the soil.

2.2.11 *Shallow Foundation* — A foundation whose width is generally equal to or greater than its depth.

NOTE — These cover such types of foundations in which load transference is primarily through shear resistance of the bearing strata (the frictional resistance of soil above bearing strata is not taken into consideration) and are laid normally to depth of 3 m.

2.2.12 *Spread Foundation* — A foundation which transmits the load to the ground through one or more footings.

2.3 Pile Foundation

2.3.1 *Batter Pile (Raker Pile)* — The pile which is installed at an angle to the vertical.

2.3.2 *Bearing Pile* — A pile formed in the ground for transmitting the load of a structure to the soil by the resistance developed at its tip and/or along its surface. It may be formed either vertically or at an inclination (Batter Pile) and may be required to take uplift pressure.

If the pile supports the load primarily by resistance developed at the pile point or base, it is referred to as 'End Bearing Pile', if support is provided primarily by friction along its surface, it is referred to as 'Friction Pile'.

2.3.3 *Bored Cast* in-situ *Pile* — The pile formed within the ground by excavating or boring a hole within it, with or without the use of a temporary casing and subsequently filling it with plain or reinforced concrete. When the liner is left permanently it is termed as cased pile and when the casing is taken out it is termed as uncased pile.

In installing a bored pile the sides of the borehole (when it does not stand by itself) are required to be stabilized with the aid of a temporary casing, or with the aid of drilling mud of suitable consistency. For marine situations such piles are formed with permanent casing (liner).

2.3.4 *Bored Compaction Pile* — A bored cast *in-situ* pile with or without bulb(s) in which the compaction of the surrounding ground and freshly filled concrete in pile bore is simultaneously achieved by a suitable method. If the pile is with bulb(s), it is known as under-reamed bored compaction pile.

2.3.5 *Bored Pile* — A pile formed with or without casing by excavating or boring a hole in the ground and subsequently filling it with plain or reinforced concrete.

2.3.6 *Bored Precast Pile* — A pile constructed in reinforced concrete in a casting yard and subsequently lowered in the pre-bored holes and the space around grouted.

2.3.7 *Cut-off Level* — It is the level where the installed pile is cut-off to connect the pile caps or beams or any other structural components at that level.

2.3.8 *Driven Cast* in-situ *Pile* — A pile formed within the ground by driving a casing of permanent or temporary type and subsequently filling in the hole so formed with plain or reinforced concrete. For displacing the subsoil, the casing is installed with a plug or a shoe at the bottom end. When the casing is left permanently, it is termed as cased pile and when the casing is taken out, it termed as uncased pile.

2.3.9 *Driven Precast Pile* — A pile constructed in concrete (reinforced or prestressed) in a casting yard and subsequently driven in the ground when it has attained sufficient strength.

2.3.10 *Efficiency of a Pile Group* — It is the ratio of the actual supporting value of a group of piles to the supporting value arrived at by multiplying the pile resistance of an isolated pile by their number in the group.

2.3.11 *Factor of Safety* — It is the ratio of the ultimate load capacity of a pile to the safe load of a pile.

2.3.12 *Multi-Under-Reamed Pile* — An under-reamed pile having more than one bulb. The piles having two bulbs may be called double under-reamed piles.

2.3.13 *Negative Skin Friction* — Negative skin friction is the force developed through the friction between the pile and the soil in such a direction as to increase the loading on the pile, generally due to drag of a consolidating soft layer around the pile resting on a stiffer bearing stratum such that the surrounding soil settles more than the pile.

2.3.14 *Ultimate Load Capacity* — The maximum load which a pile can carry before failure of ground when the soils fails by shear or failure of pile materials.

2.3.15 *Under-Reamed Pile* — A bored cast *in-situ* or bored compaction concrete pile with enlarged bulb(s) made by either cutting or scooping out the soil or by any other suitable process.

3 SITE INVESTIGATION

3.1 General

In areas which have already been developed, information should be obtained regarding the existing local knowledge, records of trial pits, bore holes, etc, in the vicinity, and the behaviour of the existing structures, particularly those of a similar nature to those proposed. This information may be made use of for design of foundation of lightly loaded structures of not more than two storeys and also for deciding scope of further investigation for other structures.

3.1.1 If the existing information is not sufficient or is inconclusive, the site should be explored in detail as per good practice [6-2(1)] so as to obtain a knowledge of the type, uniformity, consistency, thickness, sequence and dip of the strata, hydrology of the area and also the engineering properties. In the case of lightly loaded structures of not more than two storeys, the tests required to obtain the above information are optional, mainly depending on site conditions. Geological maps of the area give valuable information of the site conditions. The general topography will often give some indications of the soil conditions and their variations. In certain cases the earlier uses of the site may have a very important bearing on the proposed new structures.

3.2 Methods of Site Exploration

3.2.1 The common methods of site exploration are given below:

a) *Open trial pits* — The method consists of excavating trial pits and thereby exposing the subsoil surface thoroughly, enabling undisturbed samples to be taken from the sides and bottom of the trial pits. This is suitable for all types of formations, but should be used for small depths (up to 3 m). In the case of cuts which cannot stand below water table, proper bracing should be given.

b) *Auger boring* — The auger is either power of hand operated with periodic removal of the cuttings.

c) *Shell and auger boring* — Both manual and mechanized rig can be used for vertical borings. The tool normally consists of augers for soft to stiff clays, shells for very stiff and hard clays, and shells or sand pumps for sandy strata attached to sectional boring rods.

d) *Wash boring* — In wash boring, the soil is loosened and removed from the bore hole by a stream of water or drilling mud is worked up and down or rotated in the bore hole. The water or mud flow carries the soil up the annular space between the wash pipe and the casing, and it overflows at ground level, where the soil in suspension is allowed to settle in a pond or tank and the fluid is re-circulated as required. Samples of the settled out soil can be retained for identification purposes but this procedure is often unreliable. However, accurate identification can be obtained if frequent 'dry' sampling is resorted to using undisturbed sample tubes.

e) *Sounding/Probing including standard penetration test, dynamic and static cone penetration test*

f) *Geophysical method*

g) *Percussion boring and rotary boring*

h) *Pressure meter test*

3.2.2 *Number and Disposition of Test Locations*

The number and disposition of various tests shall depend upon type of structure/buildings and the soil strata variations in the area. General guidelines are, however, given below:

a) For a compact building site covering an area of about 0.4 hectare, one bore hole or trial pit in each corner and one in the centre should be adequate.

b) For smaller and less important buildings, even one bore hole or trial pit in the centre will suffice.

c) For very large areas covering industrial and residential colonies, the geological nature of the terrain will help in deciding the number of bore holes or trial pits. For plant and other main structures, number of bore holes and/or trial pits should be decided considering importance of structure and type as well as uniformity of

strata. In general, dynamic or static cone penetration tests may be performed at every 100 m by dividing the area in a grid pattern and the number of bore holes or trial pits may be decided by examining the variation in the penetration curves. The cone penetration tests may not be possible at sites having generally bouldery strata. In such cases, geophysical methods should be resorted to.

3.2.3 *Depth of Exploration*

The depth of exploration required depends on the type of proposed structure, its total weight, the size, shape and disposition of the loaded areas, soil profile, and the physical properties of the soil that constitutes each individual stratum. Normally, it should be one and a half times the width of the footing below foundation level. In certain cases, it may be necessary to take at least one bore hole or cone test or both to twice the width of the foundation. If a number of loaded areas are in close proximity the effect of each is additive. In such cases, the whole of the area may be considered as loaded and exploration should be carried out up to one and a half times the lower dimension. In weak soils, the exploration should be continued to a depth at which the loads can be carried by the stratum in question without undesirable settlement and shear failure. In any case, the depth to which seasonal variations affect the soil should be regarded as the minimum depth for the exploration of sites. But where industrial processes affect the soil characteristics this depth may be more. The presence of fast growing and water seeking trees also contributes to the weathering processes.

NOTE — Examples of fast growing and water seeking trees are Banyan (*Ficus bengalensis*), Pipal (*Ficus religiosa*) and Neem (*Azadirachta indica*).

3.2.3.1 An estimate of the variation with depth of the vertical normal stress in the soil arising from foundation loads may be made on the basis of elastic theory. The net loading intensity at any level below a foundation may be obtained approximately by assuming a spread of load of two vertical to one horizontal from all sides of the foundations, due allowance being made for the overlapping effects of load from closely spaced footings. As a general guidance, the depth of exploration at the start of the work may be decided as given in Table 1, which may be modified as exploration proceeds, if required. However, for plant and other main structures, the depth of exploration may be decided depending upon importance of structure, loading conditions and type as well as uniformity of strata.

3.3 Choice of Method for Site Exploration

The choice of the method depends on the following factors.

3.3.1 *Nature of Ground*

a) *Soils* — In clayey soils, borings are suitable for deep exploration and pits for shallow exploration. In case of soft sensitive clayey soils field vane shear test may be carried out with advantage.

   In sandy soils, special equipments may be required for taking representative samples below the water table. Standard penetration test, dynamic cone penetration test and static cone penetration test are used to assess engineering properties.

b) *Gravel-boulder deposits* — In the deposits where gravel-boulder proportion is large (>30 percent), the sub-soil strata should be explored by open trial pits of about 5 m × 5 m but in no case less than 2 m × 2 m. The depth of excavation may be up to 6 m. For determining strata characteristics, *in-situ* tests should be preferred. For shear characteristics and allowable soil pressure dynamic cone penetration tests, load tests on cast *in-situ* footing and *in-situ* shear tests that is, boulder-boulder test or concrete-boulder test are more appropriate. For detailed information on these tests reference may be made to good practice [6-2(2)]. Depending on the structure, if required, the strata may be explored by drilling bore hole using suitable method.

c) *Rocks* — Drillings are suitable in hard rocks and pits in soft rocks. Core borings are suitable for the identification of types of rock, but they cannot supply data on joints and fissures which can be examined only in pits and large diameter borings.

3.3.2 *Topography*

In hilly country, the choice between vertical openings (for example, borings and trial pits) and horizontal openings (for example, headings) may depend on the geological structure, since steeply inclined strata are most effectively explored by headings and horizontal strata by trial pits or borings. Swamps and areas overlain by water are best explored by borings which may require use of a floating craft.

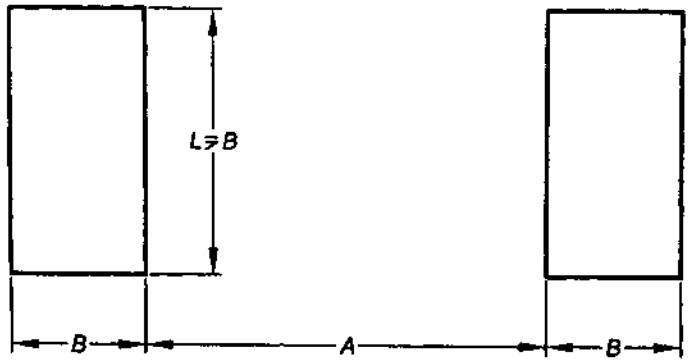
3.3.3 *Cost*

For deep exploration, borings are usual, as deep shafts are costly. For shallow exploration in soil, the choice between pits and borings will depend on the nature of the ground and the information required for shallow exploration in rock; the cost of bringing a core drill to the site will be justified only if several holes are required; otherwise, trial pits will be more economical.

Table 1 Depth of Exploration

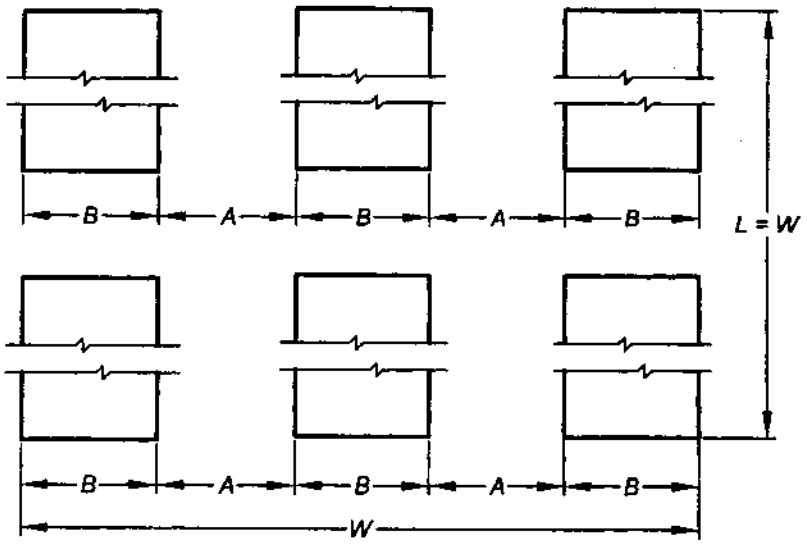
(*Clause* 3.2.3.1)

Sl No.	Type of Foundation	Depth of Exploration *D*
(1)	(2)	(3)
i)	Isolated spread footing or raft	One and a half times the width (*B*) (*see* Fig. 1)
ii)	Adjacent footings with clear spacing less than twice the width	One and a half times the length (*L*) of the footing (*see* Fig. 1)
iii)	Adjacent rows of footings	*See* Fig. 1
iv)	Pile and well foundations	To a depth of one and a half times the width of structure from the bearing (toe of pile or bottom of well)
v)	a) Road cuts	Equal to the bottom width of the cut
	b) Fill	Two metres below ground level or equal to the height of the fill whichever is greater



$D = 1\frac{1}{2} B$ FOR $A \geq 4B$

$D = 1\frac{1}{2} L$ FOR $A < 2B$



$D = 4\frac{1}{2} B$ FOR $A < 2B$

$D = 3B$ FOR $A > 2B$

$D = 1\frac{1}{2} B$ FOR $A \geq 4B$

FIG. 1 DEPTH OF EXPLORATION

3.4.1 *Methods of Sampling*

a) *Disturbed samples* — These are taken by methods which modify or destroy the natural structure of the material though with suitable precautions the natural moisture content can be preserved.

b) *Undisturbed samples* — These are taken by methods which preserve the structure and properties of the material. Such samples are easily obtained from most rocks, but undisturbed samples of soil can be obtained only by special methods. Thin walled tube samples may be used for undisturbed samples in soils of medium strength and tests for the same may be carried out in accordance with good practice {6-2(1)}.

NOTE — In case of loose sandy soils and soft soils, specially below water table it may not be possible to take undisturbed sample, in which case other suitable methods may be adopted for exploration.

c) *Representative samples* — These samples have all their constituent parts preserved, but may or may not be structurally disturbed.

3.4.1.1 The methods usually employed are:

Nature of Ground	*Type of Sample*	*Method of Sampling*
(1)	(2)	(3)
Soil	Disturbed	Chunk samples
		Auger samples (for example, in clay)
		Shell samples (for example, in sand)
	Undisturbed	Chunk samples
		Tube samples
Rock	Disturbed	Wash samples from percussion of rotary drilling
	Undisturbed	Core barrel sampling

a) *Disturbed soil samples* — The mass of sample generally required for testing purposes is given in Table 2.

b) *Undisturbed soil samples* — The minimum diameter of the sample shall be 38 mm with the minimum length/diameter ratio of 2.

3.4.3 *Rock Sample*

a) *Disturbed samples* — The sludge from percussion borings, or from rotary borings which have failed to yield a core, may be taken as a disturbed sample.

b) *Undisturbed samples*

1) *Block samples* — Such samples taken from the rock formation shall be dressed to a size convenient for packing to about 90 mm × 75 mm × 50 mm.

2) *Core sample; see also* good practice [6-2(3)]

3.4.4 *Protection, Handling and Labelling of Samples*

Care should be taken in protecting, handling and subsequent transport of samples and in their full labelling, so that samples can be received in a fit state for examination and testing, and can be correctly recognized as coming from a specified trial pit or boring.

3.4.5 *Examination and Testing of Samples*

3.4.5.1 The following tests shall be carried out in accordance with good practice [6-2(4)].

a) Particle size distribution,

b) Density,

c) Natural moisture content,

d) Consistency limits,

e) Consolidation characteristics,

f) Strength characteristics,

g) Sulphate, chloride and *p*H content of soil and ground water, and

Table 2 Mass of Soil Sample Required

[*Clause* 3.4.2(a)]

Sl No.	Purpose of Sample	Type	Mass of Sample Required kg
(1)	(2)	(3)	(4)
i)	Soil identification, natural moisture content tests, mechanical analysis, and index properties	Cohesive soil	1
	Chemical tests	Sands and gravels	3
ii)	Compaction tests	Cohesive soils and sands	12.5
		Gravely soils	25
iii)	Comprehensive examination of construction materials including stabilization	Cohesive soils and sands	25 to 50
		Gravely soils	50 to 100

h) Differential free swelling and swelling pressure.

4 CLASSIFICATION AND IDENTIFICATION OF SOILS

The classification and identification of soils for engineering purposes shall be in accordance with good practice [6-2(5)].

5 MATERIALS

5.1 Cement, coarse aggregate, fine aggregate, lime, *SURKHI*, steel, timber and other materials go into the construction of foundations shall conform to the requirements of Part 5 'Building Materials'.

5.2 Protection Against Deterioration of Materials

Where a foundation is to be in contact with soil, water or air, that is, in a condition conducive to the deterioration of the materials of the foundation, protective measures shall be taken to minimize the deterioration of the materials.

5.2.1 *Concrete*

In the case of concrete placed against a soil containing harmful chemicals (sulphates, chlorides), among other protective measures, it shall be ensured to provide nominal cover required as prescribed in Part 6 'Structural Design, Section 5 Concrete for the Applicable Environment Exposure Condition'.

5.2.1.1 Preferably concrete of higher grade shall be used in situations subject to aggressive environment.

5.2.2 *Timber*

Where timber is exposed to soil, it shall be treated in accordance with good practice [6-2(6)].

6 TYPE OF FOUNDATIONS

6.1 Types of foundations covered in this Section are:

a) *Shallow Foundations*
   1) Pad or spread and strip foundations,
   2) Raft foundations, and
   3) Ring and shell foundations.

b) *Pile Foundations*
   1) Driven cast *in-situ* concrete piles,
   2) Bored cast *in-situ* concrete piles,
   3) Driven precast concrete piles,
   4) Bored precast concrete piles,
   5) Under-reamed concrete piles, and
   6) Timber piles.

c) *Other Foundations*
   Pier foundations.

7 SHALLOW FOUNDATIONS

7.0 Design Information

For the satisfactory design of foundations, the following information is necessary:

a) The type and condition of the soil or rock to which the foundation transfers the loads;
b) The general layout of the columns and load-bearing walls showing the estimated loads, including moments and torques due to various loads (dead load, imposed load, wind load, seismic load) coming on the foundation units;
c) The allowable bearing pressure of the soils;
d) The changes in ground water level, drainage and flooding conditions and also the chemical conditions of the subsoil water, particularly with respect to its sulphate content;
e) The behaviour of the buildings, topography and environment/surroundings adjacent to the site, the type and depths of foundations and the bearing pressure assumed; and
f) Seismic zone of the region.

7.1 Design Considerations

7.1.1 *Design Loads*

The foundation shall be proportioned for the following combination of loads:

a) Dead load + imposed load; and
b) Dead load + imposed load + wind load or seismic loads, whichever is critical.

For details, reference shall be made to Part 6 'Structural Design, Section 1 Loads, Forces and Effects'.

NOTES

1 For load, imposed, wind, seismic and other loads, *see* Part 6 'Structural Design, Section 1 Loads, Forces and Effects'.

2 For coarse grained soils, settlements shall be estimated corresponding to **7.1.1** (b) and for fine grained soils settlement shall be estimated corresponding to permanent loads only.

7.1.2 *Allowable Bearing Pressure*

The allowable bearing pressure shall be taken as either of the following, whichever is less:

a) The safe bearing capacity on the basis of shear strength characteristics of soil, or
b) The allowable bearing pressure that the soil can take without exceeding the permissible settlement (*see* **7.1.3**).

7.1.2.1 *Bearing capacity by calculation*

Where the engineering properties of the soil are available, that is, cohesion, angle of internal friction, density, etc the bearing capacity shall be calculated

from stability considerations of shear; factor of safety of 2.5 shall be adopted for safe bearing capacity. The effect of interference of different foundations should be taken into account. The procedure for determining the ultimate bearing capacity and allowable bearing pressure of shallow foundations based on shear and allowable settlement criteria shall be in accordance with good practice [6-2(7)].

7.1.2.2 *Field method for determining allowable bearing pressure*

Where appropriate, plate load tests can be performed and allowable pressure determined as per good practice [6-2(8)]. The allowable bearing pressure for sandy soils may also be obtained by loading tests. When such tests cannot be done, the allowable bearing pressure for sands may be determined using penetration test.

7.1.2.3 Where the bearing materials directly under a foundation over-lie a stratum having smaller safe bearing capacity, these smaller values shall not be exceeded at the level of such stratum.

7.1.2.4 *Effect of wind and seismic force*

Where the bearing pressure due to wind is less than 25 percent of that due to dead and live loads, it may be neglected in design. Where this exceeds 25 percent foundations may be so proportioned that the pressure due to combined dead, live and wind loads does not exceed the allowable bearing pressure by more than 25 percent.

When earthquake forces are considered for the computation of design loads, the permissible increase in allowable bearing pressure of pertaining soil shall be as given in Table 3, depending upon the type of foundation of the structure.

7.1.2.5 *Bearing capacity of buried strata*

If the base of a foundation is close enough to a strata of lower bearing capacity, the latter may fail due to excess pressure transmitted to it from above. Care should be taken to see that the pressure transmitted to the lower strata is within the prescribed safe limits. When the footings are closely spaced, the pressure transmitted to the underlying soil will overlap. In such cases, the pressure in the overlapped zones will have to be considered. With normal foundations, it is sufficiently accurate to estimate the bearing pressure on the underlying layers by assuming the load to be spread at a slope of 2 (vertical) to 1 (horizontal).

7.1.3 *Settlement*

The permissible values of total and differential settlement for a given type of structure may be taken as given in Table 4. Total settlements of foundation due to net imposed loads shall be estimated in accordance with good practice [6-2(10)]. The following causes responsible for producing the settlement shall be investigated and taken into account.

a) *Causes of settlement*
   1) Elastic compression of the foundation and the underlying soil;
   2) Consolidation including secondary compression;
   3) *Ground water lowering* — Specially repeated lowering and raising of water level in loose granular soils tend to compact the soil and cause settlement of the footings. Prolonged lowering of the water table in fine grained soils may introduce settlement because of the extrusion of water from the voids. Pumping water or draining water by tiles or pipes from granular soils without an adequate mat of filter material as protection may, in a period of time, carry a sufficient amount of fine particles away from the soil and cause settlement;
   4) Seasonal swelling and shrinkage of expansive clays;
   5) Ground movement on earth slope, for example, surface erosion, slow creep or landslides; and
   6) Other causes, such as adjacent excavation, mining, subsidence and underground erosion.

b) *Causes of differential settlements*
   1) Geological and physical non-uniformity or anomalies in type, structure, thickness, and density of the soil medium (pockets of sand in clay, clay lenses in sand, wedge like soil strata, that is, lenses in soil), an admixture of organic matter, peat, mud;
   2) Non-uniform pressure distribution from foundation to the soil due to non-uniform loading and incomplete loading of the foundations;
   3) Water regime at the construction site,
   4) Overstressing of soil at adjacent site by heavy structures built next to light ones;
   5) Overlap of stress distribution in soil from adjoining structures;
   6) Unequal expansion of the soil due to excavation for footing;
   7) Non-uniform development of extrusion settlements; and
   8) Non-uniform structural disruptions or disturbance of soil due to freezing and thawing, swelling and softening and drying of soils.

Table 3 Percentage of Permissible Increase in Allowable Bearing Pressure or Resistance of Soils

(*Clauses* 7.1.2.4 *and* 8.2.7)

Sl No.	Foundation	Type of Soil Mainly Constituting the Foundation		
		Type I — Rock or Hard Soil: Well graded gravel and sand gravel mixtures with or without clay binder, and clayey sands poorly graded or sand clay mixtures (GB, CW, SB, SW, and SC)[1] having N[2] above 30, where N is the standard penetration value	Type II — Medium Soils: All soils with N between 10 and 30, and poorly graded sands or gravelly sands with little or no fines (SP[1]) with $N > 15$	Type III — Soft Soils: All soils other than SP[1] with $N < 10$
(1)	(2)	(3)	(4)	(5)
i)	Piles passing through any soil but resting on soil type I	50	50	50
ii)	Piles not covered under item (i)	—	25	25
iii)	Raft foundations	50	50	50
iv)	Combined isolated RCC footing with tie beams	50	25	25
v)	Isolated RCC footing without tie beams, or unreinforced strip foundations	50	25	—
vi)	Well foundations	50	25	25

NOTES

1 The allowable bearing pressure shall be determined in accordance with good practice [6-2(7)] and [6-2(8)].

2 If any increase in bearing pressure has already been permitted for forces other than seismic forces, the total increase in allowable bearing pressure when seismic force is also included shall not exceed the limits specified above.

3 Desirable minimum field values of N — If soils of smaller N-values are met, compacting may be adopted to achieve these values or deep pile foundations going to stronger strata should be used.

4 The values of N (corrected values) are at the founding level and the allowable bearing pressure shall be determined in accordance with good practice [6-2(7)] and [6-2(8)].

Seismic Zone	*Depth Below Ground Level (in m)*	*N Values*	*Remark*
(1)	(2)	(3)	(4)
III, IV and V	≤ 5	15	For values of depths between 5 m and 10 m, linear interpolation is recommended
	≥ 5	25	
II (for important structures only)	≤ 5	15	
	≥ 10	25	

5 The piles should be designed for lateral loads neglecting lateral resistance of soil layers liable to liquefy.

6 Good practice [6-2(5)] and [6-2(9)] may also be referred.

7 Isolated RCC footing without tie beams, or unreinforced strip foundation shall not be permitted in soft soils with $N < 10$.

[1] *See* good practice [6-2(5)].

[2] *See* good practice [6-2(9)].

Table 4 Permissible Differential Settlements and Tilt (Angular Distortion) for Shallow Foundations in Soils

(Clause 7.1.3)

Sl No.	Type of Structure	Isolated Foundations						Raft Foundations					
		Sand and Hard Clay			Plastic Clay			Sand and Hard Clay			Plastic Clay		
		Maximum settlement mm	Differential settlement mm	Angular distortion mm	Maximum settlement mm	Differential settlement mm	Angular distortion mm	Maximum settlement mm	Differential settlement mm	Angular distortion mm	Maximum settlement mm	Differential settlement mm	Angular distortion mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	For steel structure	50	.003 3L	1/300	50	.003 3L	1/300	75	.003 3L	1/300	100	.003 3L	1/300
ii)	For reinforced concrete structures	50	.001 5L	1/666	75	.001 5L	1/666	75	.002 1L	1/500	100	.002 0L	1/500
iii)	For multistoreyed buildings												
	a) RC or steel framed buildings with panel walls	60	.002L	1/500	75	.002L	1/500	75	.002 5L	1/400	125	.003 3L	1/300
	b) For load bearing walls												
	1) $L/H = 2$*	60	.000 2L	1/5 000	60	.000 2L	1/5000	← Not likely to be encountered →					
	2) $L/H = 7$*	60	.000 4L	1/2 500	60	.000 4L	1/2500						
iv)	For water towers and silos	50	.001 5L	1/666	75	.001 5L	1/666	100	.002 5L	1/400	125	.002 5L	1/400

NOTE — The values given in the table may be taken only as a guide and the permissible total settlement/different settlement and tilt (angular distortion) in each case should be decided as per requirements of the designer.

L denotes the length of deflected part of wall/raft or centre-to-centre distance between columns.

H denotes the height of wall from foundation footing.

* For intermediate ratios of L/H, the values can be interpolated.

7.1.4 *Depth of Foundations*

7.1.4.1 The depth to which foundations should be carried depends upon the following principal factors:

a) The securing of adequate allowable capacity.
b) In the case of clayey soils, penetration below the zone where shrinkage and swelling due to seasonal weather changes, and due to trees and shrubs are likely to cause appreciable movements.
c) In fine sands and silts, penetration below the zone in which trouble may be expected from frost.
d) The maximum depth of scour, wherever relevant, should also be considered and the foundation should be located sufficiently below this depth.
e) Other factors such as ground movements and heat transmitted from the building to the supporting ground may be important.

7.1.4.2 All foundations shall extend to a depth of at least 500 mm below natural ground level. On rock or such other weather resisting natural ground, removal of the top soil may be all that is required. In such cases, the surface shall be cleaned and, if necessary, stepped or otherwise prepared so as to provide a suitable bearing and thus prevent slipping or other unwanted movements.

7.1.4.3 Where there is excavation, ditch pond, water course, filled up ground or similar condition adjoining or adjacent to the subsoil on which the structure is to be erected and which is likely to impair the stability of structure, either the foundation of such structure shall be carried down to a depth beyond the detrimental influence of such conditions, or retaining walls or similar works shall be constructed for the purpose of shielding from their effects.

7.1.4.4 A foundation in any type of soil shall be below the zone significantly weakened by root holes or cavities produced by burrowing animals or works. The depth shall also be enough to prevent the rainwater scouring below the footings.

7.1.4.5 Clay soils, like black cotton soils, are seasonally affected by drying, shrinkage and cracking in dry and hot weather, and by swelling in the following wet weather to a depth which will vary according to the nature of the clay and the climatic condition of the region. It is necessary in these soils, either to place the foundation bearing at such a depth where the effects of seasonal changes are not important or to make the foundation capable of eliminating the undesirable effects due to relative movement by providing flexible type of construction or rigid foundations. Adequate load counteracting against swelling pressures also provide satisfactory foundations.

7.1.5 *Foundation at Different Levels*

7.1.5.1 Where footings are adjacent to sloping ground or where the bottoms of the footings of a structure are at different levels or at levels different from those of the footings of adjoining structures, the depth of the footings shall be such that the difference in footing elevations shall be subject to the following limitations:

a) When the ground surface slopes downward adjacent to a footing, the sloping surface shall not intersect a frustum of bearing material under the footing having sides which make an angle of 30° with the horizontal for soil and horizontal distance from the lower edge of the footing to the sloping surface shall be at least 600 mm for rock and 900 mm for soil (*see* Fig. 2).
b) In the case of footings in granular soil, a line drawn between the lower adjacent edges of adjacent footings shall not have a steeper slope than one vertical to two horizontal (*see* Fig. 3).
c) In case of footing of clayey soils a line drawn between the lower adjacent edge of the upper footing and the upper adjacent edge of lower footing shall not have a steeper slope than one vertical to two horizontal (*see* Fig. 4).

7.1.5.2 The requirement given in **7.1.5.1** shall not apply under the following conditions:

a) Where adequate provision is made for the lateral support (such as, with retaining walls) of the material supporting the higher footing.
b) When the factor of safety of the foundation soil against shearing is not less than four.

7.1.6 *Effect of Seasonal Weather Changes*

During periods of hot, dry weather a deficiency of water develops near the ground surface and in clay soils, that is associated with a decrease of volume or ground shrinkage and the development of cracks. The shrinkage of clay will be increased by drying effect produced by fast growing and water seeking trees. The range of influence depends on size and number of trees and it increase during dry periods. In general, it is desirable that there shall be a distance of at least 8 m between such trees. Boiler installations, furnaces, kilns, underground cables and refrigeration installations and other artificial sources of heat may also cause increased volume changes of clay by drying out the ground beneath them, the drying out can be to a substantial depth. Special precautions either in the form of

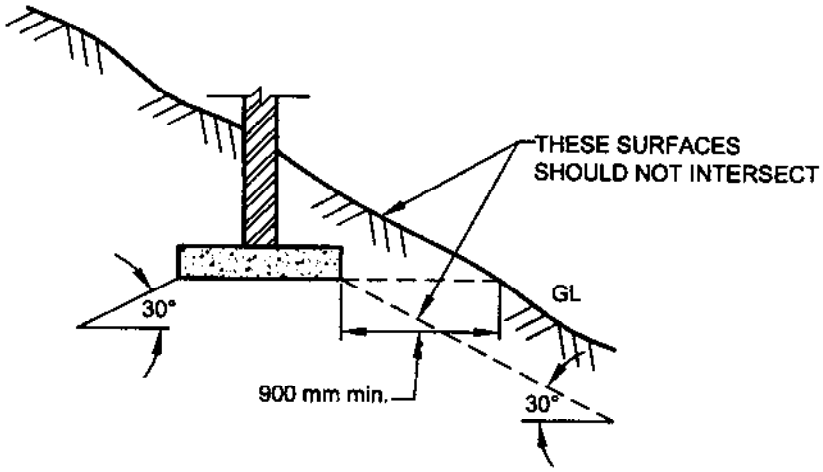


FIG. 2 FOOTING IN SLOPING GROUND

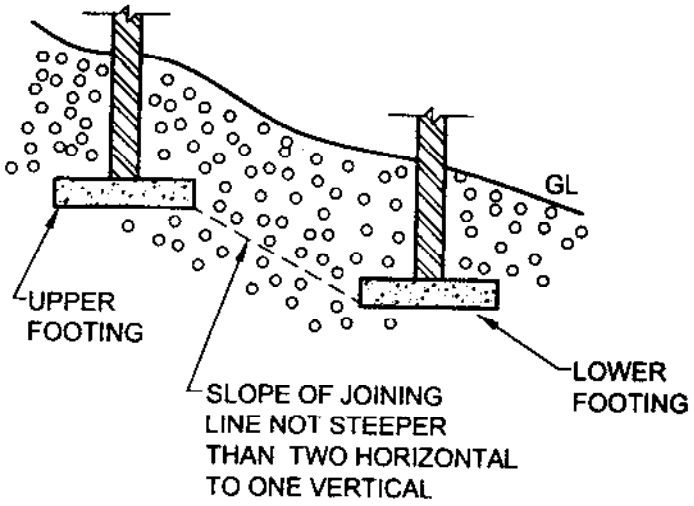


FIG. 3 FOOTING IN GRANULAR SOIL

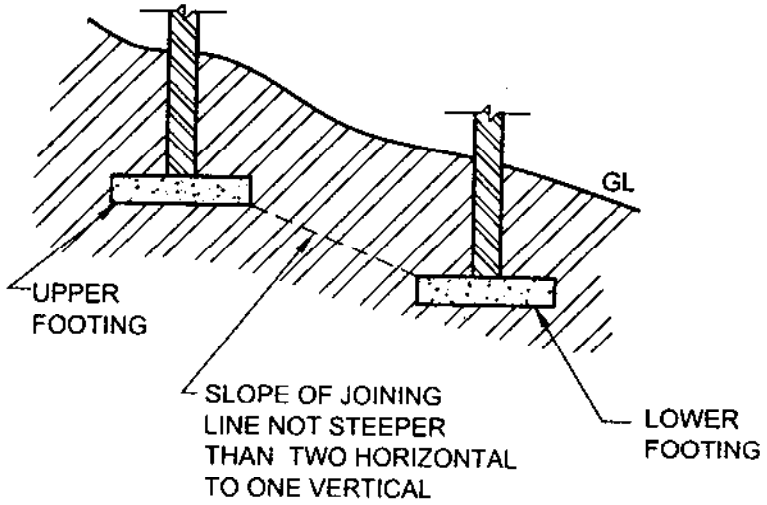


FIG. 4 FOOTING IN CLAYEY SOIL

wet weather, clay soils swell and the cracks tend to close, the water deficiency developed in the previous dry periods may be partially replenished and a sub-surface zone or zones deficient in water may persist for many years. Leakage from water mains and underground sewers may also result in large volume changes. Therefore, special care must be taken to prevent such leakages.

7.1.7 *Effect of Mass Movements of Ground in Unstable Areas*

7.1.7.1 In certain areas mass movements of the ground are liable to occur from causes independent of the loads applied by the foundations of structures. These include mining subsidence, landslides on unstable slopes and creep on clay slopes.

7.1.7.2 *Mining subsidence*

In mining areas, subsidence of the ground beneath a building or any other structure is liable to occur. The magnitude of the movement and its distribution over the area are likely to be uncertain and attention shall, therefore, be directed to make the foundations and structures sufficiently rigid and strong to withstand the probable worst loading condition.

7.1.7.3 *Landslide prone areas*

The construction of structures on slopes which are suspected of being unstable and are subject to landslip shall be avoided.

On sloping ground on clay soils, there is always a tendency for the upper layers of soil to move downhill, depending on type of soil, the angle of slope, climatic conditions, etc. In some cases, the uneven surface of the slope on a virgin ground will indicate that the area is subject to small land slips and, therefore, if used for foundation, will obviously necessitate special design consideration.

Where there may be creep of the surface layer of the soil, protection against creep may be obtained by following special design considerations.

On sloping sites, spread foundations shall be on a horizontal bearing and stepped. At all changes of levels, they shall be lapped at the steps for a distance at least equal to the thickness of the foundation or twice the height of the step, whichever is greater. The steps shall not be of greater height than the thickness of the foundation, unless special precautions are taken.

Cuttings, excavations or sloping ground near and below foundation level may increase the possibility of shear failure of the soil. The foundation shall be well beyond the zone of such shear failure.

wall or other revetment, the latter shall be made strong enough to resist any unbalanced thrust. In case of doubt as to the suitability of the natural slopes or cuttings, the structure shall be kept well away from the top of the slopes, or the slopes shall be stabilized.

Cuttings and excavations adjoining foundations reduce stability and increase the likelihood of differential settlement. Their effect should be investigated not only when they exist but also when there is possibility that they are made subsequently.

Where a structure is to be placed on sloping ground, additional complications are introduced. The ground itself, particularly if of clay, may be subject to creep or other forms of instability, which may be enhanced if the strata dip in the same direction as the ground surface. If the slope of the ground is large, the overall stability of the slope and substructure may be affected. These aspects should be carefully investigated.

7.1.8 *Precautions for Foundations on Inclined Strata*

In the case of inclined strata, if they dip towards a cutting of basement, it may be necessary to carry foundation below the possible slip planes, land drainage also requires special consideration, particularly on the uphill side of a structure to divert the natural flow of water away from the foundations.

7.1.9 *Strata of Varying Thickness*

Strata of varying thickness, even at appreciable depth, may increase differential settlement. Where necessary, calculations should be made of the estimated settlement from different thickness of strata and the structure should be designed accordingly. When there is large change of thickness of soft strata, the stability of foundation may be affected. Site investigations should, therefore, ensure detection of significant variations in strata thickness.

7.1.10 *Layers of Softer Material*

Some soils and rocks have thin layers of softer material between layers of harder material, which may not be detected unless thorough investigation is carried out. The softer layers may undergo marked changes in properties if the loading on them is increased or decreased by the proposed construction or affected by related changes in ground water conditions. These should be taken into account.

7.1.11 *Spacing Between Existing and New Foundation*

The deeper the new foundation and the nearer to the existing it is located, the greater the damage is likely to be. The minimum horizontal spacing between existing and new footings shall be equal to the width of the wider one. While the adoption of such provision

shall help minimizing damage to adjacent foundation, an analysis of bearing capacity and settlement shall be carried out to have an appreciation of the effect on the adjacent existing foundation.

7.1.12 *Alterations During Construction*

a) Where during construction the soil or rock to which foundation is to transfer loads is found not to be the type or in the condition assumed, the foundation shall be re-designed and constructed for the existing type or conditions and the Authority notified.

b) Where a foundation bears on gravel, sand or silt and where the highest level of the ground water is or likely to be higher than an elevation defined by bearing surface minus the width of the footing, the bearing pressure shall be altered in accordance with Note 4 in Table 3.

c) Where the foundation has not been placed or located as indicated earlier or is damaged or bears on a soil whose properties may be adversely changed by climatic and construction conditions, the error shall be corrected, the damaged portion repaired or the design capacity of the affected foundation recalculated to the satisfaction of the Authority.

d) Where a foundation is placed, and if the results of a load test so indicate, the design of the foundation shall be modified to ensure structural stability of the same.

7.2 Pad or Spread and Strip Foundations

7.2.1 In such type of foundations wherever the resultant of the load deviates from the centre line by more than 1/6 of its least dimension at the base of footing, it should be suitably reinforced.

7.2.2 For continuous wall foundations (plain or reinforced) adequate reinforcement should be provided particularly at places where there is abrupt change in magnitude of load or variation in ground support.

7.2.3 On sloping sites the foundation should have a horizontal bearing and stepped and lapped at changes of levels for a distance at least equal to the thickness of foundation or twice the height of step whichever is greater. The steps should not be of greater height than thickness of the foundations.

7.2.4 *Ground Beams*

The foundation can also have the ground beam for transmitting the load. The ground beam carrying a load bearing wall should be designed to act with the wall forming a composite beam, when both are of reinforced concrete and structurally connected by reinforcement. The ground beam of reinforced concrete structurally connected to reinforced brick work can also be used.

7.2.5 *Dimensions of Foundation*

The dimensions of the foundation in plan should be such as to support loads as given in good practice [6-2(11)]. The width of the footings shall be such that maximum stress in the concrete or masonry is within the permissible limits. The width of wall foundation (in mm) shall not be less than that given by:

$$B = W + 300$$

where

B = Width at base in mm, and

W = Width of supported wall in mm.

7.2.6 In the base of foundations for masonry foundation it is preferable to have the steps in multiples of thickness of masonry unit.

7.2.7 The plan dimensions of excavation for foundations should be wide enough to ensure safe and efficient working with good practice [6-2(12)].

7.2.8 Unreinforced foundation may be of concrete or masonry (stone or brick) provided that angular spread of load from the base of column/wall or bed plate to the outer edge of the ground bearing is not more than 1 vertical to ½ horizontal to masonry or 1 vertical to 1 horizontal for cement concrete and 1 vertical to 2/3 horizontal for lime concrete. The minimum thickness of the foundation of the edge should not be less than 150 mm. In case the depth to transfer the load to the ground bearing is less than the permissible angle of spread, the foundations should be reinforced.

7.2.9 If the bottom of a pier is to be belled so as to increase its load carrying capacity such bell should be at least 300 mm thick at its edge. The sides should be sloped at an angle of not less than 45° with the horizontal. The least dimension should be 600 mm (circular, square or rectangular). The design should allow for the vertical tilt of the pier by 1 percent of its height.

7.2.10 If the allowable bearing capacity is available only at a greater depth, the foundation can be rested at a higher level for economic considerations and the difference in level between the base of foundation and the depth at which the allowable bearing capacity occurs can be filled up with either: (a) concrete of allowable compressive strength not less than the allowable bearing pressure, (b) in compressible fill material, for example, sand, gravel, etc, in which case the width of the fill should be more than the width of the foundation by an extent of dispersion of load from the base of the foundation on either side at the rate of 2 vertical to 1 horizontal.

reinforced) should be designed in accordance with good practice [6-2(13)] and masonry foundation in accordance with good practice [6-2(14)].

7.2.12 *Thickness of Footing*

The thickness of different types of footings, if not designed according to **7.1**, should be as given in Table 5.

7.2.13 *Land Slip Area*

On a sloping site, spread foundation shall be on a horizontal bearing and stepped. At all changes of levels, they shall be lapped at the steps for a distance at least equal to the thickness of the foundation or twice the height of the step, whichever is greater. The steps shall not be of greater height than the thickness of the foundation unless special precautions are taken. On sloping ground on clay soils, there is always a tendency for the upper layers of soil to move downhill, depending on type of soil, the angle of slope, climatic conditions, etc. Special precautions are necessary to avoid such a failure.

7.2.14 In the foundations, the cover to the reinforcement shall be as prescribed in Part 6 'Structural Design, Section 5 Concrete for the Applicable Environment Exposure Condition'.

7.2.15 For detailed information regarding preparation of ground work, reference may be made to good practice [6-2(15)].

7.3 Raft Foundations

7.3.1 *Design Considerations*

Design provisions given in **7.1** shall generally apply.

7.3.1.1 The structural design of reinforced concrete rafts shall conform to Part 6 'Structural Design, Section 5 Concrete'.

directly on an rock concrete, the cover to the reinforcement shall be as prescribed in Part 6 'Structural Design, Section 5 Concrete' for the applicable environment exposure condition.

7.3.1.3 In case the structure supported by the raft consists of several parts with varying loads and heights, it is advisable to provide separation joints between these parts. Joints shall also be provided wherever there is a change in the direction of the raft.

7.3.1.4 Foundations subject to heavy vibratory loads should preferably be isolated.

7.3.1.5 The minimum depth of foundation shall generally be not less than 1 m.

7.3.1.5 *Dimensional parameters*

The size and shape of the foundation adopted affect the magnitude of subgrade modulus and long-term deformation of the supporting soil and this, in turn, influences the distribution of contact pressure. This aspect needs to be taken into consideration in the analysis.

7.3.1.7 *Eccentricity of loading*

A raft generally occupies the entire area of the building and often it is not feasible and rather uneconomical to proportion it coinciding the centroid of the raft with the line of action of the resultant force. In such cases, the effect of the eccentricity on contact pressure distribution shall be taken into consideration.

7.3.1.8 *Properties of supporting soil*

Distribution of contact pressure underneath a raft is affected by the physical characteristics of the soil supporting it. Consideration must be given to the increased contact pressure developed along the edges of foundation on cohesive soils and the opposite effect

Table 5 Thickness of Footings

(*Clause* 7.2.12)

Sl No.	Type of Footings	Thickness of Footings, *Min*	Remarks
(1)	(2)	(3)	(4)
i)	Masonry	a) 250 mm b) Twice the maximum projection from the face of the wall	Select the greater of the two values
ii)	Plain concrete		
	For normal structures	a) 200 mm b) Twice the maximum offset in a stepped footing c) 300 mm	For footings resting on top of the pile For footings resting on soil
	For lightly loaded structures	a) 150 mm b) 200 mm	Resting on soil Resting on pile
iii)	Reinforced concrete	a) 150 mm b) 300 mm	Resting on soil Resting on pile

on granular soils. Long-term consolidation of deep soil layers shall be taken into account in the analysis. This may necessitate evaluation of contact pressure distribution both immediately after construction and after completion of the consolidation process. The design must be based on the worst conditions.

7.3.1.9 *Rigidity of foundations*

Rigidity of the foundation tends to iron out uneven deformation and thereby modifies the contact pressure distribution. High order of rigidity is characterized by long moments and relatively small, uniform settlements. A rigid foundation may also generate high secondary stresses in structural members. The effect of rigidity shall be taken into account in analysis.

7.3.1.10 *Rigidity of the superstructure*

Free response of the foundations to soil deformation is restricted by the rigidity of the superstructure. In the extreme case, a stiff structure may force a flexible foundation to behave as rigid. This aspect shall be considered to evaluate the validity of the contact pressure distribution.

7.3.1.11 *Modulus of elasticity and modulus of subgrade reaction*

Annex A enumerates the methods of determination of modulus of elasticity (E_s). The modulus of subgrade reaction (k) may be determined in accordance with Annex B.

7.3.2 *Necessary Information*

The following information is necessary for a satisfactory design and construction of a raft foundation:

a) Site plan showing the location of the proposed as well as the neighbouring structures;

b) Plan and cross-sections of building showing different floor levels, shafts and openings, etc, layout of loading bearing walls, columns, shear walls, etc;

c) Loading conditions, preferably shown on a schematic plan indicating combination of design loads transmitted to the foundation;

d) Information relating to geological history of the area, seismicity of their area, hydrological information indicating ground water conditions and its seasonal variations, etc;

e) Geotechnical information giving subsurface profile with stratification details, engineering properties of the founding strata (namely, index properties, effective shear parameters determined under appropriate drainage conditions, compressibility characteristics, swelling properties, results of field tests like static and dynamic penetration tests, pressure meter tests etc); and

f) A review of the performance of similar structure, if any, in the locality.

7.3.3 *Choice of Raft Type*

7.3.3.1 For fairly small and uniform column spacing and when the supporting soil is not too compressible a flat concrete slab having uniform thickness throughout (a true mat) is most suitable (*see* Fig. 5A).

7.3.3.2 A slab may be thickened under heavy loaded columns to provide adequate strength for shear and negative moment. Pedestals may also be provided in such cases (*see* Fig. 5B).

7.3.3.3 A slab and beam type of raft is likely to be more economical for large column spacing and unequal column loads particularly when the supporting soil is very compressive (*see* Fig. 5C and 5D).

7.3.3.4 For very heavy structures, provision of cellular raft or rigid frames consisting of slabs and basement walls may be considered.

7.3.4 *Methods of Analysis*

The essential task in the analysis of a raft foundation is the determination of the distribution of contact pressure underneath the raft which is a complex function of the rigidity of the superstructure, the supporting soil and the raft itself, and cannot be determined with exactitude, except in very simple cases. This necessitates a number of simplifying assumptions to make the problem amenable to analysis. Once the distribution of contact pressure is determined, design bending moments and shears can be computed based on statics. The methods of analysis suggested are distinguished by the assumptions involved. Choice of a particular method should be governed by the validity of the assumptions in the particular case.

7.3.4.1 *Rigid foundation (conventional method)*

This method is based on the assumption of linear distribution of contact pressure. The basic assumptions of this method are:

a) the foundations rigid relative to the supporting soil and the compressible soil layer is relatively shallow; and

b) the contact pressure variation is assumed as planar, such that the centroid of the contact pressure coincides with the line of action of the resultant force of all loads acting on the foundation.

This method may be used when either of the following conditions is satisfied:

a) The structure behaves as rigid (due to the

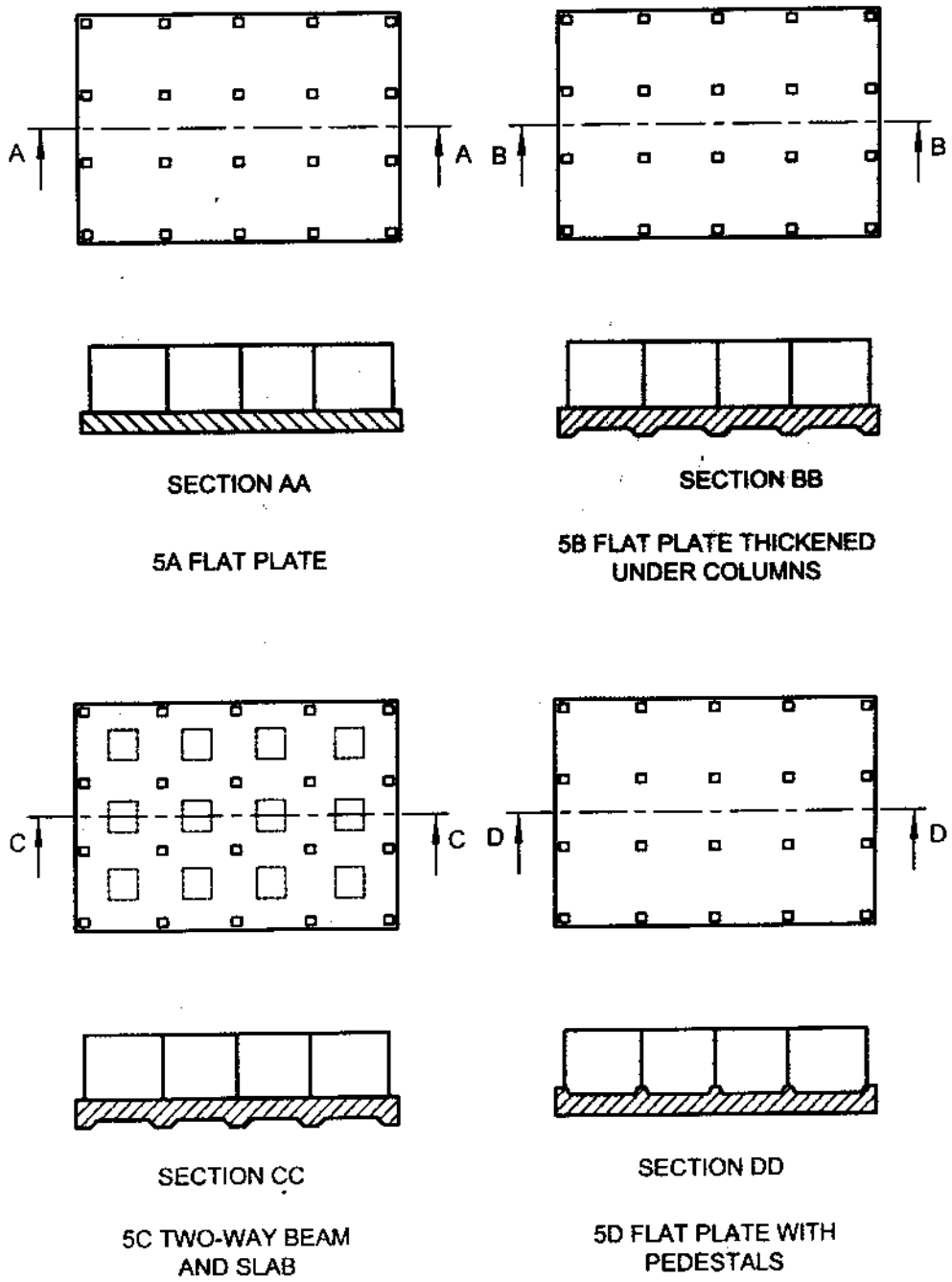


FIG. 5 COMMON TYPES OF RAFT FOUNDATION

combined action of the superstructure and the foundation) with relative stiffness factor $K > 0.5$ (for evaluation of K *see* Annex C); and

b) The column spacing is less than $1.75/\lambda$ (*see* Annex C).

The raft is analysed as a whole in each of the two perpendicular directions. The contact pressure distribution is determined by the procedure outlined in Annex D. Further analysis is also based on statics.

In the case of uniform conditions when the variations in adjacent column loads and column spacings do not exceed 20 percent of the higher value, the raft may be divided into perpendicular strips of widths equal to the distance between midspans and each strip may be analysed as an independent beam with known column loads and known contact pressures. Such beams will not normally satisfy statics due to shear transfer between adjacent strips and design may be based on suitable moment coefficients, or by moment distribution.

NOTE – On soft soils, for example, normally consolidated clays, peat, muck, organic silts, etc, the assumptions involved in the conventional method are commonly justified.

7.3.4.2 *Flexible foundations*

a) *Simplified method* — In this method, it is assumed that the subgrade consists of an infinite array of individual elastic springs each of which is not affected by others. The spring constant is equal to the modulus of subgrade reaction (k). The contact pressure at any point under the raft is, therefore, linearly proportional to the settlement at the point. Contact pressure may be determined as given in Annex E. This method may be used when all the following conditions are satisfied:
   1) The structure (combined action of superstructure and raft) may be considered as flexible (relative stiffness factor $K > 0.5$, *see* Annex C).
   2) Variation in adjacent column load does not exceed 20 percent of the higher value.

b) *General method* — For the general case of a flexible foundation not satisfying the requirements of (a), the method based on closed form solution of elastic plate theory may be used. This method is based on the theory of plates on winkler foundation which takes into account the restraint on deflection of a point provided by continuity of the foundation in orthogonal foundation. The distribution of deflection and contact pressure on the raft due to a column load is determined by the plate theory. Since the effect of a column load on an elastic foundation is damped out rapidly, it is possible to determine the total effect at a point of all column loads within the zone of influence by the method of superimposition. The computation of effect at any point may be restricted to columns of two adjoining bays in all directions. The procedure is outlined in Annex F.

7.4 Ring Foundations

For provisions regarding ring foundations good practice [6-2(16)] shall be referred to.

8 DRIVEN/BORED CAST *IN-SITU* CONCRETE PILES

8.0 General

Piles find application in foundations to transfer load from a structure to competent sub-surface strata having adequate load bearing capacity. The load transfer mechanism from a pile to the surrounding ground is complicated and is yet to be fully understood, although application of pile foundations is in practice over many decades. Broadly, piles transfer axial loads either substantially by friction along their shafts and/or substantially by the end bearing. Construction of a pile foundation requires a careful choice of piling system, depending upon the subsoil conditions, the load characteristics of a structure and the limitation of total settlement, differential settlements and any other special requirement of a project.

8.1 Material

8.1.1 *Concrete*

The minimum grade of concrete to be used shall not be less than that arrived at in accordance with Part 6 'Structural Design, Section 5 Concrete'.

8.1.1.1 *For bored and driven cast-in-situ concrete piles including under-reamed piles*

The minimum cement content shall be 400 kg/m^3 in all conditions. For piles up to 6 m, minimum cement content of 350 kg/m^3 without provision for under water concreting may be used under favourable non-aggressive subsoil condition and where concrete of higher strength is not needed structurally or due to aggressive site conditions. For concreting in aggressive surroundings due to presence of sulphates, etc the provisions given in Part 6 'Structural Design, Section 5 Concrete' shall be followed.

8.1.2 *Steel Reinforcement*

Steel reinforcement shall conform to any one of the types of steel specified in Part 6 'Structural Design, Section 5 Concrete'.

8.2 Design Considerations

Pile foundation shall be designed in such a way that the load from the structure it supports can be transmitted to the soil without causing any soil failure and without causing such settlement, differential or total under permanent/transient loading as may result in structural damage and/or functional distress. The pile shaft should have adequate structural capacity to withstand all loads (vertical, axial or otherwise) and moments which are to be transmitted to the subsoil.

NOTE — When working near existing structures, care shall be taken to avoid any damage to structures.

8.2.1 *Soil Resistance*

The bearing capacity of a pile is dependent on the properties of the soil in which it is embedded. Axial load from a pile is normally transmitted to the soil through skin friction along the shaft and end bearing at its tip. A horizontal load on a vertical pile is transmitted to the subsoil primarily by horizontal subgrade reaction generated in the upper part of the

along its axis. The transverse load bearing capacity of a single pile depends on the soil reaction developed and the structural capacity of the shaft under bending. In case the horizontal loads are of higher magnitude, it is essential to investigate the phenomena using principles of horizontal subsoil reaction adopting appropriate values for horizontal modulus of the soil. Alternatively, piles may be installed in rake. The feasibility of constructing bored piles in rake under a given subsoil condition should, however, be examined critically.

8.2.1.1 The ultimate bearing capacity of a pile may be estimated approximately by means of a static formula on the basis of soil test results or by test loading. The settlement of pile obtained at safe load/ working load from load test results on a single pile shall not be directly used in forecasting the settlement of a structure unless experience from similar foundations on its settlement behaviour is available. The average settlement may be assessed on the basis of subsoil data and loading details of the structure as a whole using the principle of soil mechanics.

8.2.1.2 *Static formula*

By using static formula, the estimated value of the ultimate bearing capacity of a typical pile is obtained, the accuracy being dependent on the reliability of the formula and the reliability of the soil properties for various strata available. The soil properties to be adopted in such a formula may be assigned from results of laboratory tests and field tests as per good practice [6-2(1)]. Two separate static formulae commonly applicable for cohesive and non-cohesive soils are indicated in Annex G, to serve only as a guide. Other alternative formulae may be applicable, depending on the subsoil characteristics and method of installation of piles.

8.2.1.3 *Dynamic formula*

For driven piles in non-cohesive soils, such as gravels, coarse sand and other similar deposits, an approximate value of the bearing capacity may be determined by a dynamic pile formula as per good practice [6-2(17)]. Dynamic formulae are not directly applicable to cohesive soil deposits, such as saturated silts and clays, as the resistance to impact of the toe of the casing will be exaggerated by their low permeability, while the frictional resistance on the sides is reduced by lubrication. If as a result of test loadings on a given area a suitable coefficient can be applied to a dynamic formula, the results may then be considered as reasonable.

8.2.1.4 *Load test results*

The ultimate load capacity of a single pile is determined

practice [6-2(18)]. The load test on a pile shall not be carried out earlier than four weeks from the time of casting the pile.

8.2.1.5 *Non-destructive testing*

For quality assurance of concrete piles, non-destructive integrity test may be carried out prior to laying of beam/ caps, in accordance with good practice [6-2(19)].

8.2.2 *Negative Skin Friction or Dragdown Force*

When a soil stratum, through which a pile shaft has penetrated into an underlying hard stratum, compresses as a result of either its being unconsolidated or its being under a newly placed fill or as a result of re-moulding during driving of the pile, a dragdown force is generated along the pile shaft up to a point in depth where the surrounding soil does not move downwards relative to the pile shaft. Recognition of the existence of such a phenomenon shall be made and a suitable reduction shall be made to the allowable load, where appropriate.

8.2.3 *Structural Capacity*

The piles shall have the necessary structural strength to transmit the loads imposed on them ultimately to the soil.

8.2.3.1 *Axial capacity*

Where a pile is fully embedded in the soil (having an undrained shear strength not less than 10 kN/m^2) its axial carrying capacity is not limited by its strength as a long column. Where piles are installed through very weak soils (having an undrained shear strength less than 10 kN/m^2), special consideration shall be given to determine whether the shaft would behave as a long column or not; if necessary suitable reductions shall be made in its structural strength considering the buckling phenomenon.

When the finished pile projects above ground level and is not secured against buckling by adequate bracing, the effective length will be governed by the fixity conditions imposed on it by the structure it supports and by the nature of the soil into which it is installed. The depth below the ground surface to the lower point of contraflexure varies with the type of soil. In good soil the lower point of contraflexure may be taken at a depth of 1 m below ground surface subject to a minimum of three times the diameter of the shaft. In weak soil (undrained shear strength less than 10 kN/m^2) such as soft clay and soft silt, this point may be taken at about half the depth of penetration into such stratum but not more than 3 m or 10 times the diameter of the shaft, whichever is less. A stratum of liquid mud should be treated as if it was water. The degree of fixity of the position and inclination

of the pile top and the restraint provided by any bracing shall be estimated following accepted structural principles.

8.2.3.2 *Uplift capacity*

Total uplift capacity of pile will be the sum of the frictional resistance and weight of the pile (buoyant or total as relevant). The uplift capacity from the static formula (Annex G) can be approximately estimated by ignoring end bearing but adding weight of pile (buoyant or total as relevant). The safe uplift capacity can be obtained by applying a factor of safety 3. However, more reliance should be given to that obtained from test loading as per good practice [6-2(18)].

8.2.3.3 *Lateral load capacity*

A pile may be subjected to transverse forces for a number of causes, such as wind, earthquake, water current, earth pressure, effect of moving vehicles or ships, plant and equipment, etc. The lateral load carrying capacity of a single pile depends not only on the horizontal subgrade modulus of the surrounding soil but also on the structural strength of the pile shaft against bending consequent upon the application of a lateral load. While considering lateral load on piles, the effect of other co-existent loads, including the axial load on the pile, should be taken into consideration for checking the structural capacity of the shaft. A method for the determination of the depth of fixity of piles for driven cast *in-situ* and depth of fixity, lateral deflection and maximum moment for driven precast, bored cast-*in-situ* and bored precast piles required for design is given in Annex H. Other accepted methods, such as the method of Reese and Matlock or finite element analysis using linear/non-linear springs to represent the resistance of soil. A pile in a group of three or more piles connected by a rigid cap shall be designed considering as 'fixed head condition'. In caps of single piles interconnected by ground beams in two directions and for two piles by ground beams in a line transverse to the common axis of the piles is also to be considered as 'fixed head condition'. In all other conditions the pile shall be designed by treating it 'free head condition'.

NOTE — Because of limited information on horizontal modulus of soil, and requirements in the theoretical analysis, it is suggested that the adequacy of a design should be checked by an actual field load test.

8.2.3.4 *Raker piles*

Raker piles are normally provided where vertical piles cannot resist the required applied horizontal forces. In the preliminary design, the load on a raker pile is generally considered to be axial. The distribution of load between raker and vertical piles in a group may be determined graphically or by analytical methods. Where necessary, due consideration should be given to secondary bending induced as a result of the pile cap movement, particularly when the cap is rigid. Free-standing raker piles are subjected to bending moments due to their own weight, or external forces from other causes. Raker piles embedded in loose fill or consolidating deposit may become laterally loaded owing to the settlement of the surrounding soil. In consolidating clay special precautions, like provision of permanent casing, should be taken for raker piles.

8.2.4 *Spacing of Piles*

The centre to centre spacing of a pile is considered from two aspects as follows:

a) Practical aspects of installing the piles; and
b) The nature of the load transfer to the soil and possible reduction in bearing capacity of a group of piles thereby.

8.2.4.1 In the case of piles founded on a very hard stratum and deriving their capacity mainly from end bearing, the spacing will be governed by the competency of the end bearing strata. The minimum spacing in such cases shall be 2.5 times the diameter of the shaft. In case of piles resting on rock, a spacing of two times the diameter may be adopted.

8.2.4.2 Piles deriving their bearing capacity mainly from friction shall be sufficiently apart to ensure that the zones of soil from which the piles derive their support do not overlap to such an extent that their bearing values are reduced. Generally, the spacing in such cases shall not be less than three times the diameter of the shaft.

8.2.4.3 In the case of loose sand or filling, closer spacing than in dense sand may be possible, in driven piles since displacement during the piling may be absorbed by vertical and horizontal compaction of the strata. The minimum spacing in such strata may be two times the diameter of the shaft.

NOTE — In the case of piles of non-circular cross-section, the diameter of the circumscribing circle shall be adopted.

8.2.5 *Pile Grouping*

In order to determine the bearing capacity of a group of piles, a number of efficiency equations are in use. However, it is very difficult to establish the accuracy of these efficiency equations, as the behaviour of pile group is dependent on many complex factors. It is desirable to consider each case separately on its own merits.

8.2.5.1 The bearing capacity of a pile group may be either of the following:

a) Equal to the bearing capacity of individual piles multiplied by the number of piles in group; or
b) It may be less.

The former holds true in the case of friction piles, cast or driven into progressively stiffer materials or in end-bearing piles. In friction piles in soft and clayey soils, it is normally smaller. For driven piles in loose sandy soils, the group value may be higher due to the effect of compaction. In such a case, a load test should be made on a pile from the group after all the piles have been installed. The group capacity may then be decided by taking into account the interference effects. This would be done by multiplying the total capacity of a pile group with the group efficiency factor.

8.2.5.2 In the case of piles deriving their support mainly from friction and connected by a rigid pile cap, the group may be visualized to transmit load to the soil, as if from a column of soil, enclosed by the piles. The ultimate capacity of the group may be computed following this concept, taking into account the frictional capacity along the perimeter of the column of soil as above and the end bearing of the said column using the accepted principles of soil mechanics.

8.2.5.3 When the cap of the pile group is cast directly on a reasonably firm stratum which supports the piles, it may contribute to the bearing capacity of the group. This additional capacity along with the individual capacity of the piles multiplied by the number of piles in the group shall not be more than the capacity worked out as per **8.2.5.2**.

8.2.5.4 When a moment is applied on the pile group either from the superstructure or as a consequence of unavoidable inaccuracies of installation, the adequacy of the pile group in resisting the applied moment should be checked. In the case of a single pile subjected to moments due to lateral forces or eccentric loading, beams may be provided to restrain the pile caps effectively from lateral or rotational movement.

8.2.5.5 In the case of a structure supported on a single pile/group of piles, resulting in large variation in the number of piles from column to column, it is likely, depending on the type of subsoil supporting the piles, to result in a high order of differential settlement. Such high order of differential settlement may be either catered for in the structural design or it may be suitably reduced by judicious choice of variations in the actual pile loadings. For example, a single pile cap may be loaded to a level higher than that of a pile in a group in order to achieve reduced differential settlement between the adjacent pile caps supported on different number of piles.

8.2.6 *Factor of Safety*

8.2.6.1 The factor of safety should be judiciously chosen after considering the following:

a) The reliability of the value of the ultimate bearing capacity of a pile,
b) The type of superstructure and the type of loading, and
c) Allowable total/differential settlement of the structure.

8.2.6.2 When the ultimate bearing capacity is compound from either static formula or dynamic formula, the factor of safety would depend on the reliability of the formulae, depending on a particular site and locality and the reliability of the subsoil parameters employed in such computation. The minimum factor of safety on static formula shall be 2.5. The final solution of a factor of safety shall take into consideration the load settlement characteristics of the structure as a whole on a given site.

8.2.6.3 The factor of safety for assessing the safe load on piles from load test data should be increased in unfavourable conditions where:

a) settlement is to be limited or unequal settlement avoided as in the case of accurately aligned machinery or a superstructure with fragile finishings;
b) large impact or vibrating loads are expected;
c) the properties of the soil may be expected to deteriorate with time; and
d) the live load on a structure carried by friction piles is a considerable portion of the total and approximates to the dead load in its duration.

8.2.7 *Transient Loading*

The maximum permissible increase over the safe load of a pile as arising out of wind loading is 25 percent. In the case of loads and moments arising out of earthquake effects, the increase of safeload shall be as given in Table 3.

8.2.8 *Overloading*

When a pile in a group, designed for a certain safe load is found, during or after execution, to fall just short of the load required to be carried by it, an overload of up to 10 percent of the pile capacity may be allowed on each pile. The total overloading on the group should not be more than 10 percent of the capacity of the group nor more than 40 percent of the allowable load on a single pile.

8.2.9 *Reinforcement*

8.2.9.1 The design of the reinforcing cage varies depending upon the driving and installation conditions,

the nature of the subsoil and the nature of load to be transmitted by the shaft-axial, or otherwise. The minimum area of longitudinal reinforcement (any type or grade) within the pile shaft shall be 0.4 percent of the sectional area calculated on the basis of the outside area of the casing of the shaft.

8.2.9.2 The curtailment of reinforcement along the depth of the pile, in general, depends on the type of loading and subsoil strata. In the case of piles subjected to compressive load only, the designed quantity of reinforcement may be curtailed at an appropriate level as per the design requirements. For piles subjected to uplift load, lateral load and moments, separately or with compressive loads, it may be necessary to provide reinforcement for the full depth of pile. In soft clays or loose sands, or where there is likelihood of danger to green concrete due to driving of adjacent piles, the reinforcement should be provided up to the full pile depth, regardless of whether or not it is required from uplift and lateral load considerations. However, in all cases, the minimum reinforcement specified in **8.2.9.1** should be provided in the full length of the pile.

Piles shall always be reinforced with a minimum amount of reinforcement as dowels, keeping the minimum bond length into the pile shaft and with adequate projection into the pile cap.

NOTE — In some cases the cage may lift at bottom or at the top during withdrawal of casing. This can be minimized by making the reinforcement 'U' shaped at the bottom and up to well secured joints. Also the lifting 5 percent of the length should be considered not to affect the quality of pile.

8.2.9.3 Clear cover to all main reinforcements in pile shaft shall be not less than 50 mm. The laterals of a reinforcing cage may be in the form of links or spirals. The diameter and spacing of the same are so chosen as to impart adequate rigidity to the reinforcing cage during its handling and installation. The minimum diameter of the links or spirals shall be 6 mm and the spacing of the links or spirals shall be not less than 150 mm.

8.2.10 *Design of Pile Cap*

8.2.10.1 The pile caps may be designed considering that the reaction from any pile is concentrated at the centre of the pile. The critical section for shear in diagonal tension is taken at a distance equal to half the effective depth of cap from the face of column/pedestal or wall. For bending moment and shear for bond, the critical section is taken at the face of column/pedestal or wall for cap supporting a concrete column, pedestal or wall; half way between the centre line and the edge of the wall for caps under masonry walls and half-way between the face of the column or pedestal and the edge of the gusseted base for caps under gusseted bases. In computing the external shear or the critical section, the entire action of any pile of diameter D whose centre is located $D/2$ or more outside the section shall be assumed as producing no shear on the section. For intermediate positions of the pile centre, the portion of the pile reaction to be assumed as producing shear on the section shall be based on straight-line interpolation between full value at $D/2$ outside the section and zero value at $D/2$ inside the section. Further, design may be carried out as specified in Part 6 'Structural Design, Section 5 Concrete'.

8.2.10.2 The pile cap shall be deep enough to allow for necessary anchorage of the column and pile reinforcement and the minimum thickness shall be 300 mm.

8.2.10.3 The pile cap should normally be rigid enough, so that the imposed load could be distributed on the piles in a group equitably.

8.2.10.4 In the case of a large cap, where differential settlement may be imposed between piles under the same cap, due consideration should be given to the consequential moment.

8.2.10.5 The clear overhang of the pile cap beyond the outer most pile in the group shall normally be 100 mm to 150 mm, depending upon the pile size.

8.2.10.6 The cap is generally cast over a 75 mm thick levelling course of concrete. The clear cover for the main reinforcement in the cap slab shall not be less than 60 mm.

8.2.10.7 The pile should project 50 mm into the cap concrete.

8.2.11 *Grade Beams*

8.2.11.1 The grade beams supporting the walls shall be designed taking due account of arching effect due to masonry above the beam. The beam with masonry due to composite action behaves as a deep beam.

For the design of beams, a maximum bending moment of $\frac{wl^2}{50}$, where w is uniformly distributed load per metre run (worked out by considering a maximum height of two storeys in structures with load bearing walls and one storey in framed structures) and l is the effective span in metres, will be taken if the beams are supported during construction till the masonry above it gains strength. The value of bending moment shall be increased to $\frac{wl^2}{30}$, if the beams are not supported. For considering composite action, the minimum height of wall shall be 0.6 times the beam span. The brick strength should not be less than 3 N/mm^2. For concentrated and other loads which come directly over the beam, full bending moment should be considered.

8.2.11.2 The minimum overall depth of grade beams shall be 150 mm. The reinforcement at the bottom should be kept continuous and an equal amount may be provided at top to a distance of a quarter span both ways from pile centres. The longitudinal reinforcement both at top and bottom should not be less than three bars of 10 mm diameter mild steel (or equivalent deformed steel) and stirrups of 6 mm diameter bars should be spaced at a minimum of 300 mm spacing.

8.2.11.3 In expansive soils, the grade beams shall be kept a minimum of 80 mm clear off the ground. In other soils, beams may rest on ground over a levelling concrete course of about 80 mm (*see* Fig. 6).

8.2.11.4 In the case of exterior beams over piles in expensive soils, an edge projection of 75 mm thickness and extending 80 mm into ground (*see* Fig. 6) shall be provided on the outer side of the beam.

8.3 For detailed information on driven/bored cast *in-situ* concrete piles regarding control of piling, installation, defective pile and recording of data, reference may be made to good practice [6-2(17)].

9 DRIVEN PRECAST CONCRETE PILES

9.1 Provisions of **8** except **8.2.9** shall generally apply.

9.2 Design of Piles

9.2.1 The design of pile section shall be such as to ensure the strength and soundness of the pile against lifting from the casting bed, transporting, handling, driving stresses without damage.

9.2.2 Any shape having radial symmetry will be satisfactory for precast piles. The most common cross-sections used are square and octagonal or circular.

9.2.3 Where exceptionally long lengths of piles are required, hollow sections may advantageously be used. If the final conditions require a larger cross-sectional area, the hollow sections may be filled with concrete after driving in position.

9.2.4 Excessive whippiness in handling precast pile may generally be avoided by limiting the length of pile to a maximum of 50 times the least width.

9.2.5 *Lifting and Handling Stresses*

Stresses induced by bending in the cross-section of a precast pile during lifting and handling may be estimated just as for any reinforced concrete section in accordance with relevant provisions of good practice [6-2(13)]. The calculations with regard to moments depending on the method of support during handling will be as given below. Excessive whippiness in handling precast pile may generally be avoided by limiting the length of pile to a maximum of 50 times the least width.

Number of Points of Pick Up	*Location of Point of Support from in Terms of Length of Pile for Minimum Moments*	*Bending Moment to be Allowed for Design*
One	0.293 L	$\frac{WL}{23.3}$
Two	0.207 L	$\frac{WL}{46.6}$
Three	0.145 L, the middle point will be at the centre	$\frac{WL}{95}$

where

W = Mass of pile in kg, and

L = Length in metres.

During hoisting the pile will be suspended at one point near the head and the bending moment will be the least when it is pulled in a distance of 0.293 L, and the value of bending moment will be:

$$\frac{WL}{23.3}$$

9.3 Reinforcement

9.3.1 The longitudinal reinforcement shall be provided in precast reinforced concrete piles for the entire length. All the main longitudinal bars shall be of the same length with lap welded at joints and should fit tightly into the pile shoe if there is one. Shorter rods to resist local bending moments may be added, but the same should be carefully detailed to avoid any sudden discontinuity of the steel which may lead to cracks during heavy driving. The area of the main longitudinal reinforcement shall not be less than the following percentages of the cross-sectional area of the piles:

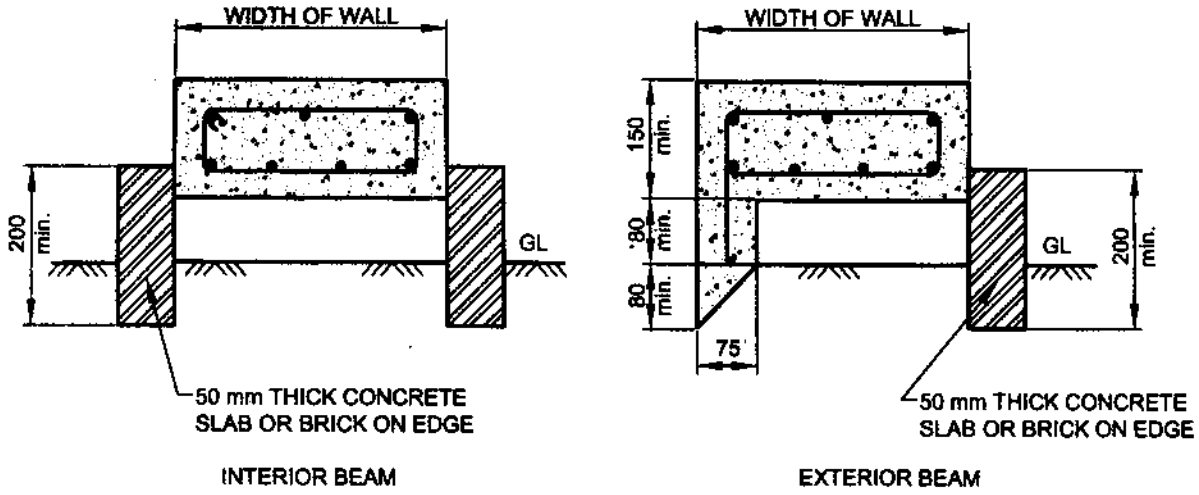
a) For piles with length less than 30 times the least width — 1.25 percent

b) For piles with length 30 to 40 times the least width — 1.5 percent, and

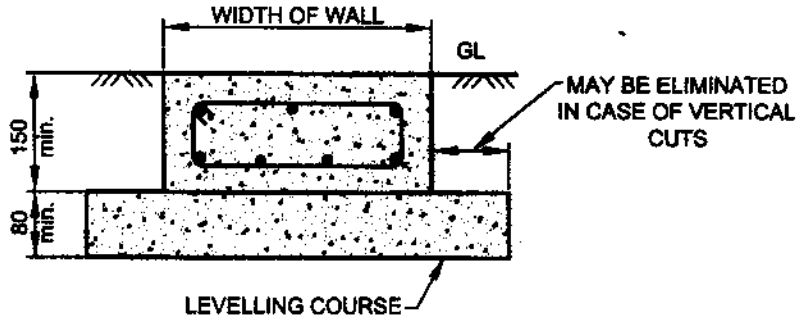
c) For piles with length greater than 40 times the least width — 2 percent.

9.3.2 The lateral reinforcement is of particular importance in resisting the driving stresses induced in the piles and should be in the form of hoops or links and of diameter not less than 6 mm. The volume of lateral reinforcement shall not be less than the following:

a) At each end of the pile for a distance of about 3 times the least width — not less than 0.6 percent of the gross volume of that part of the pile; and



6A BEAMS IN EXPANSIVE SOILS



6B BEAMS IN NON - EXPANSIVE SOILS

All dimensions in millimetres.

FIG. 6 TYPICAL SECTIONS OF GRADE BEAMS

b) In the body of the pile — not less than 0.2 percent of the gross volume of the pile.

The spacing shall be such as to permit free flow of concrete around it. The transition between the close spacing of lateral reinforcement near the ends and the maximum spacing shall be gradually over a length of 3 times the least width of the pile.

9.3.3 The cover of concrete over all the reinforcement, including ties, should not be less than 40 mm. But where the piles are exposed to sea-water or water having other corrosive content, the cover should be nowhere less than 50 mm. Cover should be measured clear from the main or longitudinal reinforcement.

NOTE — Where concrete of the pile is liable to be exposed to the attack of sulphates and chlorides present in the ground water, the piles may be coated with a suitable material.

9.3.4 Piles should be provided with flat or pointed co-axial shoes if they are driven into or through ground, such as rock, coarse gravel, clay with cobbles and other soils likely to damage the concrete at the tip of the pile. The shoe can be of steel or cast iron. In uniform clay or sand, the shoe may be omitted.

Where jetting is necessary for concrete piles, a jet tube may be cast into the pile, the tube, being connected to the pile shoe which is provided with jet holes. Generally, a central jet is inadvisable, as it is liable to become choked. At least two jet holes will be necessary on opposite sides of the shoe, four holes giving best results. Alternatively, two or more jet pipes may be attached to the sides of the pile.

9.4 For detailed information regarding casting and curing, storing and handling, control of pile driving and recording of data, reference may be made to good practice [6-2(20)].

10 BORED PRECAST CONCRETE PILES

10.1 Provisions of **9** except **9.3** shall generally apply.

10.2 For grouting the space around the pile, the precast

pile should be provided with a central duct/hole or suitable jet holes to pump the grouting material. The bottom end of the pile shall have proper arrangements for flushing/cleaning for grouting.

10.3 Reinforcement

The longitudinal reinforcement shall be provided in for the entire length preferably of high yield strength to withstand the handling stresses to the extent to meet requirement as given in **9.2.5**. All the main longitudinal bars shall be of the same length. The area of the main longitudinal reinforcement of any type and grade shall not be less than 0.4 percent of the cross-section area of the piles or as required to cater for handling stresses whichever is greater. The lateral reinforcement shall be links or spirals preferably of not less than 6 mm diameter bars. The cover of concrete over all the reinforcement including bending wire should not be less than 40 mm, but where the piles are exposed to the sea-water or water having other corrosive contents the cover should be no where less than 50 mm. A thin gauge sheathing pipe of approximately 40 mm diameter may be attached to the reinforcement cage, in case of solid piles, to form the central duct for pumping grout to the bottom of the bore.

10.4 For detailed information regarding casting and curing, storing and handling, control of pile installation and recording of data, reference may be made to good practice [6-2(21)].

11 UNDER-REAMED PILES

11.0 General

Under-reamed piles are bored cast *in-situ* and bored compaction concrete types having one or more bulbs formed by enlarging the borehole for the pile stem. These piles are suited for expansive soils which are often subjected to considerable ground movements due to seasonal moisture variations. These also find wide application in other soil strata where economics are favourable. When the ground consists of expansive soil, for example, black cotton soils, the bulb of under-reamed pile provide anchorage against uplift due to swelling pressure, apart from the increased bearing, provided topmost bulb is formed close to or just below the bottom of active zone. Negative slopes may not be stable in certain strata conditions, for example, in pure sands (clean sands with fines less than five per cent) and very soft clayey strata having N of SPT less than 2 (undrained shear strength of less than 12.5 kN/m^2). Hence formation of bulb(s) in such strata is not advisable. In subsoil strata above water table, the maximum number of bulbs in underreamed pile should be restricted to four. In the strata such as clay, silty clay and clayey silt with high water table where sides of bore hole stand by itself without needing any stabilization by using drilling mud or otherwise, the maximum number of bulbs in under-reamed piles should be restricted to two. In strata, for example, clayey sand, silty sand and sandy silt with high water table where bore hole needs stabilization by using drilling mud, under-reamed piles with more than one bulb shall not be used. In loose to medium pervious strata such as clayey sand, silty sand and sandy silt strata, compaction under-reamed piles can be used as the process of compaction, increases the load carrying capacity of piles. From practical considerations, under-reamed piles of more than 10 m depth shall not be used without ensuring their construction feasibility and load carrying capacity by initial load tests in advance. In view of additional anchorage available with the provision of bulbs, under-reamed piles can be used with advantage to resist uplift loads.

11.1 Materials

11.1.1 Provisions of **8.1** shall generally apply.

11.2 Design Considerations

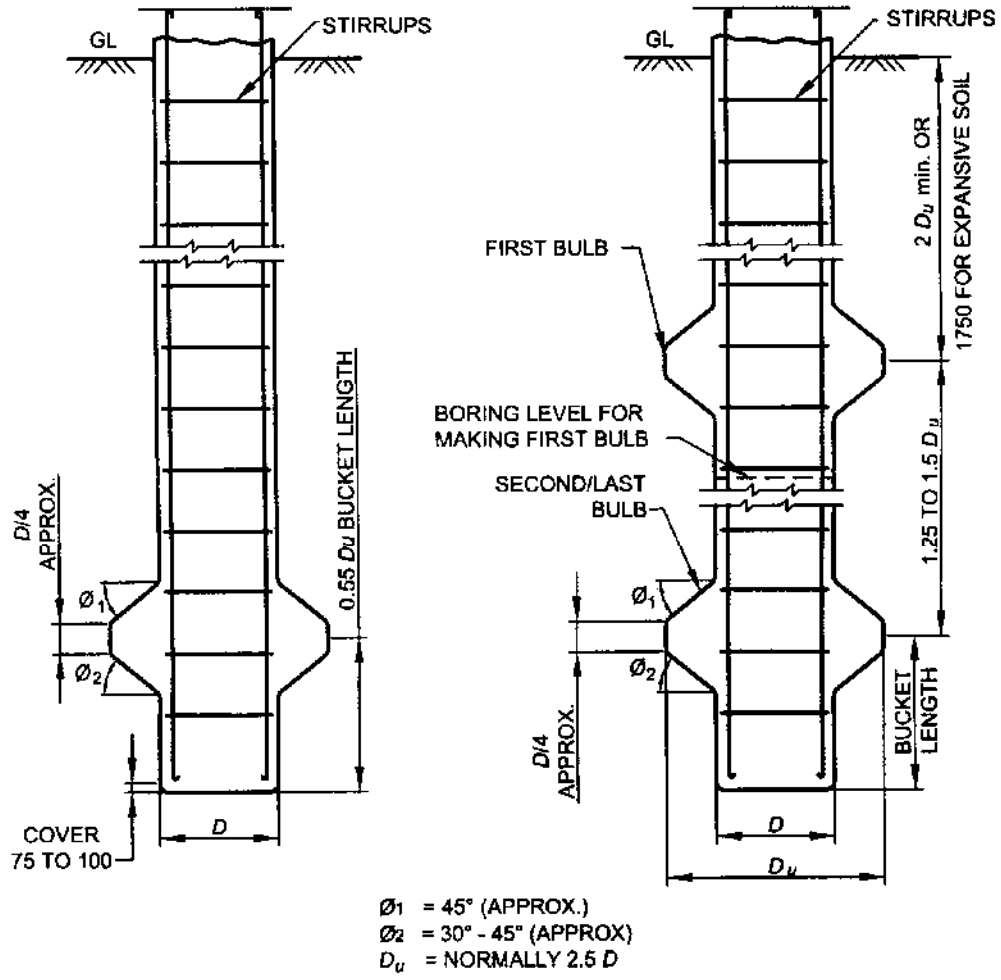
11.2.1 *General*

Under-reamed pile foundation shall be designed in such a way that the load from the structure they support can be transmitted to the soil without causing failure of soil or failure of pile material and without causing settlement (differential or total) under permanent transient loading as may result in structural damage and/or functional distress (*see* Fig. 7).

11.2.1.1 In deep deposits of expansive soils the minimum length of piles, irrespective of any other considerations, shall be 3.5 m below ground level. If the expansive soil deposits are of shallow depth and overlying on non-expansive soil strata of good bearing or rock, piles of smaller length can also be provided. In recently filled up grounds or other strata or poor bearing the piles should pass through them and rest in good bearing strata.

11.2.1.2 The minimum stem diameter of under-reamed pile can be 200 mm up to 5 m depth in dry conditions, that is strata with low water table. The minimum stem diameter for piles up to 5 m depth in strata with high water table within pile depth, shall be 300 mm for normal under-reamed pile and 250 mm for compaction under-reamed pile. For piles of more than 5 m depth, the minimum diameter in two cases shall be 375 mm and 300 mm respectively. The minimum diameter of stem for strata consisting of harmful constituents, such as sulphates, should also be 375 mm.

11.2.1.3 The diameter of under-reamed bulbs may vary from 2 to 3 times the stem diameter, depending,



7A SECTION OF SINGLE - UNDER - REAMED PILE

7B SECTION OF MULTI-UNDER-REAMED PILE

All dimensions in millimetres.

FIG. 7 TYPICAL DETAILS OF BORED CAST *IN-SITU* UNDER-REAMED PILE FOUNDATION

upon the feasibility of construction and design requirements. In bored cast *in-situ* under-reamed piles and under-reamed compaction piles, the bulb diameter shall be normally 2.5 and 2 times the stem diameter respectively.

11.2.1.4 For piles of up to 300 mm diameter, the spacing of the bulbs should not exceed 1.5 times the diameter of the bulb. For piles of diameter greater than 300 mm, spacing can be reduced to 1.25 times the bulb diameter.

11.2.1.5 The topmost bulb should be at a minimum depth of two times the bulb diameter. In expansive soils it should also be not less than 2.75 m below ground level. The minimum clearance below the underside of pile cap embedded in the ground and the bulb should be a minimum of 1.5 times the bulb diameter.

11.2.1.6 Under-reamed piles with more than one bulb are not advisable without ensuring their feasibility in strata needing stabilization of bore holes by drilling mud. The number of bulbs in the case of bored compaction piles should also not exceed one in such strata.

11.2.1.7 Under-reamed batter piles without lining in dry conditions, that is, strata with low water table can be constructed with batter not exceeding 15°.

11.2.2 *Safe Load*

Safe load on a pile can be determined:

a) by calculating the ultimate load from soil properties and applying a suitable factor of safety as given in Annex J;

b) by load test on pile as good practice [6-2(18)]; and

c) from safe load tables.

11.2.2.1 *Load test and non-destructive testing*

Provisions of **8.2.1.4** and **8.2.1.5** shall generally apply.

11.2.2.2 In the absence of detailed sub-soil investigations and pile load tests for minor and less important structures, a rough estimate of safe load on piles may be made from the Safe Load Table in accordance with good practice [6-2(22)].

11.2.3 *Negative Skin Friction or Dragdown Force*

Provisions of **8.2.2** shall generally apply subject to the condition that the under-reamed bulb is provided below the strata susceptible to negative skinfriction.

11.2.4 *Structural Capacity*

Provisions of **8.2.3** shall generally apply except that the under-reamed pile stem is designed for axial capacity as a short column. Under-reamed piles under lateral loads and moments tend to behave more as rigid piles due the presence of bulbs and therefore the analysis can be done on rigid pile basis. Nominally reinforced long single bulb piles which are not rigid may be analyzed as per the method given in Annex H or as per other accepted methods.

11.2.5 *Spacing*

11.2.5.1 Generally the centre to centre spacing for bored cast *in-situ* under-reamed piles in a group should be two times the bulb diameter (2 D_u). It shall not be less than 1.5 D_u. For under-grade beams, the maximum spacing of piles should generally not exceed 3 m. In under-reamed compaction piles, generally the spacing should not be less than 1.5 D_u. If the adjacent piles are of different diameter, an aveage value of bulb diameter should be taken for spacing.

11.2.6 *Group Efficiency*

For bored cast *in-situ* under-reamed piles at a usual spacing of 2 D_u, the group efficiency will be equal to the safe load of an individual pile multiplied by the number of piles in the group. For piles at a spacing of 1.5 D_u, the safe load assigned per pile in a group should be reduced by 10 percent.

In under-reamed compaction piles, at the usual spacing of 1.5 D_u, the group capacity will be equal to the safe load on an individual pile multiplied by the number of piles in the group.

11.2.7 *Transient and Overloading*

Provisions of **8.2.7** and **8.2.8** shall generally apply.

11.2.8 *Reinforcement*

11.2.8.1 The minimum area of longitudinal reinforcement (any type or grade) within the pile shaft shall be 0.4 percent of the sectional area calculate on the basis of outside area of the shaft or casing if used. Reinforcement is to be provided in full length and further a minimum of 3 bars of 10 mm diameter mild steel or three 8 mm diameter high strength steel bars shall be provided. Transverse reinforcement shall not be less than 6 mm diameter at a spacing of not more than the stem diameter or 300 mm, whichever is less.

In under-reamed compaction piles, a minimum number of four 12 mm diameter bars shall be provided. For piles of lengths exceeding 5 m and of 375 mm diameter, a minimum number of six 12 mm diameter bars shall be provided. For piles exceeding 400 mm diameter, a minimum number of six 12 mm diameter bars shall be provided. The circular stirrups for piles of lengths exceeding 5 m and diameter exceeding 375 mm shall be minimum 8 mm diameter bars.

For piles in earthquake prone areas, a minimum number of six bars of 10 mm diameter shall be provided. Also transverse reinforcement in the form of stirrups or helical should be at 150 mm centre-to-centre in top few metre depth.

11.2.8.2 The minimum clear cover over the longitudinal reinforcement shall be 40 mm. In aggressive environment of sulphates etc, it may be increased to 75 mm.

11.2.9 The design of pile cap and grade beams shall conform to the requirements specified in **8.2.10** and **8.2.11** respectively.

11.2.10 For detailed information on under-reamed piles regarding control of pile, installation, reference may be made to good practice [6-2(22)].

12 TIMBER PILES

12.1 Materials

12.1.1 *Timber*

The timber shall have the following characteristics:

a) Only structural timber shall be used for piles (*see* Part 6 'Structural Design, Section 3 Timber and Bamboo, 3A Timber');

b) The length of an individual pile shall be:
   1) the specified length ± 300 mm for piles up to and including 12 m in length, and
   2) the specified length ± 600 mm for piles above 12 m in length;

c) The ratio of heartwood diameter to the pile butt diameter shall be not less than 0.8; and

d) Piles to be used untreated shall have as little sapwood as possible.

12.2 Design Considerations

12.2.1 *General — See* **8.0**.

12.2.2 *Soil Resistance — See* **8.2.1.**

12.2.3 *Structural Capacity*

The pile shall have the necessary structural strength to transmit the load imposed on it to the soil. Load tests shall be conducted on a single pile or preferably on a group of piles. For compaction piles, test should be done on a group of piles with their caps resting on the ground as good practice [6-2(18)]. If such test data is not available, the load carried by the pile shall be determined by the Engineering News formula (*see* Note).

NOTE — For timber piles, the load carried shall be determined by the Engineering News formula given below. Care shall be taken that while counting the number of blows, the head of the timber pile is not broomed or brushed and in case of interrupted driving counting shall be done after 300 mm of driving.

For piles driven with drop hammer,

$$P = \frac{160\,WH}{S+25}$$

For piles driven with single-acting steam hammer,

$$P = \frac{160\,WH}{S+2.5}$$

where

P = Safe load on pile in kN,
W = Weight of monkey in kN,
H = Free fall of monkey in m, and
S = Penetration of pile in mm to be taken as the average of the last three blows.

12.2.4 For detailed information on timber piles regarding spacing, classification, control of pile driving, storing and handling, reference may be made to good practice [6-2(23)].

13 OTHER FOUNDATIONS

13.1 Pier Foundations

13.1.1 *Design Considerations*

13.1.1.1 *General*

The design of concrete piers shall conform to the requirements for columns specified in Part 6 'Structural Design, Section 5 Concrete'. If the bottom of the pier is to be belled so as to increase its load carrying capacity, such bell shall be at least 300 mm thick at its edge. The sides shall slope at an angle of not less than 60° with the horizontal. The least permissible dimensions shall be 600 mm, irrespective of the pier being circular, square or rectangular. Piers of smaller dimensions if permitted shall be designed as piles (*see* **8** and **9**).

13.1.1.2 *Plain concrete piers*

The height of the pier shall not exceed 6 times the least lateral dimension. When the height exceeds 6 times the least lateral dimension, buckling effect shall be taken into account, but in no case shall the height exceed 12 times the least lateral dimension.

When the height exceeds 6 times the least lateral dimension, the deduction in allowable stress shall be given by the following formula:

$$f_c' = f_c\left(1.3 - \frac{H}{20D}\right)$$

where

f_c' = Reduced allowable stress,
f_c = Allowable stress,
H = Height of pier, and
D = Least lateral dimension.

NOTE — The above provision shall not apply for piers where the least lateral dimension is 1.8 m or greater.

13.1.1.3 *Reinforced concrete piers*

When the height of the pier exceeds 18 times its least dimension, the maximum load shall not exceed:

$$P' = P\left(1.5 - \frac{H}{36D}\right)$$

where

P' = Permissible load;
P = Permissible load when calculated as axially loaded short column,
H = Height of the pier measured from top of bell, if any, to the level of cut-off of pier; and
D = Least lateral dimension.

13.2 Design of foundation units not already covered by this section, such as well foundations, machine foundations, shell foundations, etc, may be designed and constructed in accordance with good practice [6-2(24)].

14 GROUND IMPROVEMENT

In poor and weak subsoils, the design of conventional shallow foundation for structures and equipment may present problems with respect to both sizing of foundation as well as control of foundation settlements. A viable alternative in certain situations, developed over the recent years is to improve the subsoil to an extent such that the subsoil would develop an adequate bearing capacity and foundations constructed after subsoil improvement would have resultant settlements within acceptance limits. Selection of ground improvement techniques may be done in accordance with good practice [6-2(25)].

Use of suitable geo-synthetics/geo-textiles may be made in an approved manner for ground improvement, where applicable; *see also* good practice [6-2(26)].

ANNEX A

(Clause 7.3.1.11)

DETERMINATION OF MODULUS OF ELASTICITY (E_s) AND POISSON'S RATIO (μ)

A-1 DETERMINATION OF MODULUS OF ELASTICITY (E_s)

A-1.1 The modulus of elasticity is a function of composition of the soil, its void ratio, stress history and loading rate. In granular soils it is a function of the depth of the strata, while in cohesive soil it is markedly influenced by the moisture content. Due to its great sensitivity to sampling disturbance, accurate evaluation of the modulus in the laboratory is extremely difficult. For general cases, therefore, determination of the modulus may be based on field tests (**A-2**). Where properly equipped laboratory and sampling facility is available, E_s may be determined in the laboratory (*see* **A-3**).

A-2 FIELD DETERMINATION

A-2.1 The value of E_s shall be determined from plate load test in accordance with good practice [6-2(8)].

$$E_s = q B \frac{(1-\mu^2)}{s} I_w$$

where

q = Intensity of contact pressure,
B = Least lateral dimension of test plate,
s = Settlement,
μ = Poisson's ratio, and
I_w = Influence ratio
= 0.82 for a square plate.

A-2.1.1 The average value of E_s shall be based on a number of plate load tests carried out over the area, the number and location of the tests, depending upon the extent and importance of the structure.

A-2.1.2 *Effect of Size*

In granular soils the value of E_s corresponding to the size of the raft shall be determined as follows:

$$E_s = E_p \frac{B_f}{B_p} \left[\frac{B_f + B_p}{2 B_f} \right]^2$$

where B_f, B_p represent sizes of foundation and plate and E_p is the modulus determined by the plate load test.

A-2.2 For stratified deposits or deposits with lenses of different materials, results of plate load test will be unreliable and static cone penetration tests may be carried out to determine E_s.

A-2.2.1 Static cone penetration tests shall be carried out in accordance with good practice [6-2(1)]. Several tests shall be carried out at regular depth intervals up to a depth equal to the width of the raft and the results plotted to obtain an average value of E_s.

A-2.2.2 The value of E_s may be determined from the following relationship:

$$E_s = 2\ C_{kd}$$

where

C_{kd} = Cone resistance in kN/m^2.

A-3 LABORATORY DETERMINATION OF E_s

A-3.1 The value of E_s shall be determined by conducting triaxial test in the laboratory in accordance with good practice [6-2(4)] on samples collected with least disturbances.

A-3.2 In the first phase of the tri-axial test, the specimen shall be allowed to consolidate fully under an all-round confining pressure equal to the vertical effective overburden stress for the specimen in the field. In the second phase, after equilibrium has been reached, further drainage shall be prevented and the deviator stress shall be increased from zero value to the magnitude estimated for the field loading condition. The deviator stress shall then be reduced to zero and the cycle of loading shall be repeated.

A-3.3 The value of E_s shall be taken as the tangent modulus at the stress level equal to one-half the maximum deviator stress applied during the second cycle of loading.

ANNEX B
(*Clause* 7.3.1.1)

DETERMINATION OF MODULUS OF SUBGRADE REACTION

B-1 GENERAL

B-1.1 The modulus of subgrade reaction (k) as applicable to the case of load through a plate of size 300 mm × 300 mm or beams 300 mm wide on the soils is given in Table 6 for cohesionless soils and in Table 7 for cohesive soils. Unless more specific determination of k is done (*see* **B-2** and **B-3**) these values may be used for design of raft foundation in cases where the depth of the soil affected by the width of the footing may be considered isotropic and the extra-polation of plate load test results is valid.

B-2 FIELD DETERMINATION

B-2.1 In cases where the depth of the soil affected by the width of the footing may be considered as isotropic, the value of k may be determined in accordance with good practice [6-2(27)]. The test shall be carried out with a plate of size not less than 300 mm.

B-2.2 The average value of k shall be based on a number of plate load tests carried out over the area, the number and location of the tests depending upon the extent and importance of the structure.

B-3 LABORATORY DETERMINATION

B-3.1 For stratified deposits or deposits with lenses of different materials, evaluation of k from plate load test will be unrealistic and its determination shall be based on laboratory tests [*see* 6-2(4)].

B-3.2 In carrying out the test, the continuing cell pressure may be so selected as to be representative of the depth of the average stress influence zone (about 0.5 B to B).

B-3.3 The value of k shall be determined from the following relationship:

$$k = 0.65 \times \left(\frac{E_s B^4}{EI} \right)^{1/12} \frac{E_s}{(1-\mu^2)} \frac{1}{B}$$

Table 6 Modulus of Subgrade Reaction (k) for Cohesionless Soils

(*Clause* B-1.1)

Soil Characteristic		[1] Modulus of Subgrade Reaction (k) kN/m^3	
Relative Density	Standard Penetration Test Value (N) (Blows per 300 mm)	For Dry or Moist State	For Submerged State
(1)	(2)	(3)	(4)
Loose	< 10	15 000	9 000
Medium	10 to 30	15 000 to 47 000	9 000 to 29 000
Dense	30 and over	47 000 to 180 000	29 000 to 108 000

[1] The above values apply to a square plate 300 mm × 300 mm or beams 300 mm wide.

Table 7 Modulus of Subgrade Reaction (k) for Cohesive Soils

(*Clause* B-1.1)

Soil Characteristic		[1] Modulus of Subgrade Reaction (k) kN/m^3
Consistency	Unconfined Compressive Strength, kN/m^2	
(1)	(2)	(3)
Stiff	100 to 200	27 000
Very Stiff	200 to 400	27 000 to 54 000
Hard	400 and over	54 000 to 108 000

[1] The values apply to a square plate 300 mm × 300 mm. The above values are based on the assumption that the average loading intensity does not exceed half the ultimate bearing capacity.

where

E_s = Modulus of elasticity of soil (*see* Annex A),
E = Young's modulus of foundation material,
μ = Poisson's ratio of soil,
I = Moment of inertia of the foundation, and
B = Width of the footing.

B-4 CALCULATIONS

When the structure is rigid (*see* Annex C), the average modulus of subgrade reaction may also be determined as follows:

$$k_s = \frac{\text{Average contact pressure}}{\text{Average settlement of the raft}}$$

ANNEX C

(*Clauses* 7.3.4.1, 7.3.4.2 *and* B-4)

RIGIDITY OF SUPERSTRUCTURE AND FOUNDATION

C-1 DETERMINATION OF THE RIGIDITY OF THE STRUCTURE

C-1.1 The flexural rigidity EI of the structure of any section may be estimated according to the relation given below (*see also* Fig. 8)

$$EI = \frac{E_1 I_i b^2}{2H^2} + \sum E_2 I_b \left[1 + \frac{(I'_u + I'_l) b^2}{(I'_b + I'_u + I'_f) I^2} \right]$$

where

E_1 = Modulus of elasticity of the infilling material (wall material) in kN/m^2,
I_i = Moment of inertia of the infilling in m^4,
b = Length or breadth of the structure in the direction of bending in m,
H = Total height of the infilling in m,
E_2 = Modulus of elasticity of the frame material in kN/m^2,
I_b = Moment of inertia of the beam in m^4,

$I'_u = \frac{I_u}{h_u}$

$I'_l = \frac{I_l}{h_l}$

$I'_b = \frac{I_b}{I}$

I = Spacing of the columns in m,
h_u = Length of the upper column in m,
h_l = Length of the lower column in m,

$I'_f = \frac{I_f}{L}$

I_u = Moment of inertia of the upper column in m^4,
I_l = Moment of inertia of the lower column in m^4, and
I_f = Moment of inertia of the foundation beam or raft in m^4.

NOTE — The summation is to be done over all the storeys including the foundation beam or raft. In the case of the foundation, I'_f replaces I'_b and I_l becomes zero, whereas for the topmost beam I'_u becomes zero.

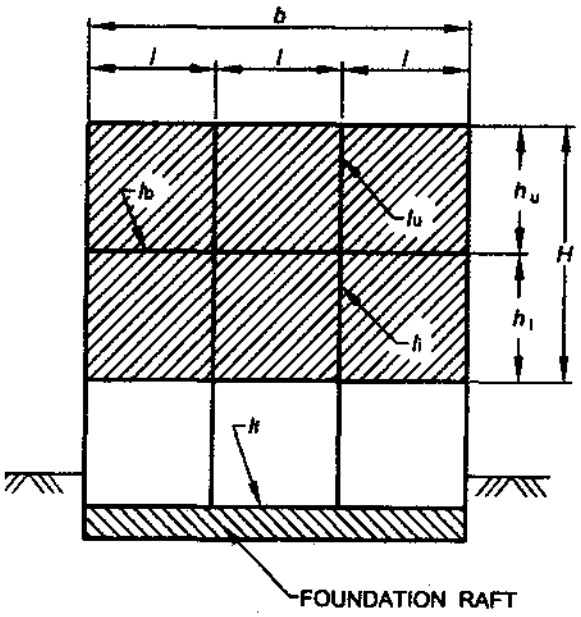


FIG. 8 DETERMINATION OF RIGIDITY OF STRUCTURE

C-2 RELATIVE STIFFNESS FACTOR, K

C-2.1 Whether a structure behaves as rigid or flexible depends on the relative stiffness of the structure and the foundation soil. This relation is expressed by the relative stiffness factor K given below:

a) For the whole structure, $K = \frac{EI}{E_s b^3 a}$

b) For rectangular rafts, $K = \frac{E}{12 E_s} \left(\frac{d}{b} \right)^3$

c) For circular rafts, $K = \frac{E}{12\,E_s}\left(\frac{d}{2R}\right)^3$

where

EI = Flexural rigidity of the structure over the length (a) in kN/m^2,

E_s = Modulus of compressibility of the foundation soil in kN/m^2,

b = Length of the section in the bending axis in m,

a = Length perpendicular to the section under investigation in m,

d = Thickness of the raft or beam in m, and

R = Radius of the raft in m.

C-2.1.1 For $K > 0.5$, the foundation may be considered as rigid.

C-3 DETERMINATION OF CRITICAL COLUMN SPACING

C-3.1 Evaluation of the characteristics λ is made as follows:

$$\lambda = \left(\frac{kB}{4\,E_c I}\right)^{1/4}$$

where

k = Modulus of subgrade reaction in kN/m^3 for footing of width B in m (*see* Annex B),

B = Width of raft B in m,

E_c = Modulus of elasticity of concrete in kN/m^2, and

I = Moment of inertia of raft in m^4.

ANNEX D

(*Clause* 7.3.4.1)

CALCULATION OF PRESSURE DISTRIBUTION BY CONVENTIONAL METHOD

D-1 DETERMINATION OF PRESSURE DISTRIBUTION

D-1.1 The pressure distribution (q) under the raft shall be determined by the following formula:

$$q = \frac{Q}{A} \pm \frac{Qe'_y}{I'_x}\,y \pm \frac{Qe'_x}{I'_y}\,x$$

where

Q = Total vertical load on the raft,

A = Total area of the raft,

e'_x, e'_y, I'_x, I'_y = Eccentricities and moments of inertia about the principal axes through the centroid of the section, and

x, y = Co-ordinates of any given point on the raft with respect to the x and y axes passing through the centroid of the area of the raft.

I'_x, I'_y, e'_x, e'_y may be calculated from the following equations:

$$I'_x = I_x - \frac{I_{xy}^2}{I_y}$$

$$I'_y = I_y - \frac{I_{xy}^2}{I_x}$$

$$e'_x = e_x - \frac{I_{xy}}{I_x}e_y$$

$$e'_y = e_y - \frac{I_{xy}}{I_y}e_x$$

where

I_x, I_y = Moment of inertia of the area of the raft respectively about the x and y axes through the centroid,

I_{xy} = $\int xy\,dA$ for the whole area about x and y axes through the centroid, and

e_x, e_y = Eccentricities in the x and y directions of the load from the centroid.

For a rectangular raft, the equation simplifies to:

$$q = \frac{Q}{A}\left(1 \pm \frac{12\,e_y y}{b^2} \pm \frac{12\,e_x x}{a^2}\right)$$

where

a and b = the dimensions of the raft in the x and y directions respectively.

NOTE — If one or more of the values of (q) are nagative as calculated by the above formula, it indicates that the whole area of foundation is not subject to pressure and only a part of the area is in contact with the soil, and the above formula will still hold good, provided the appropriate values of I_x, I_y, I_{xy}, e_x and e_y, are used with respect to the area in contact with the soil instead of the whole area.

ANNEX E

(Clause 7.3.4.2)

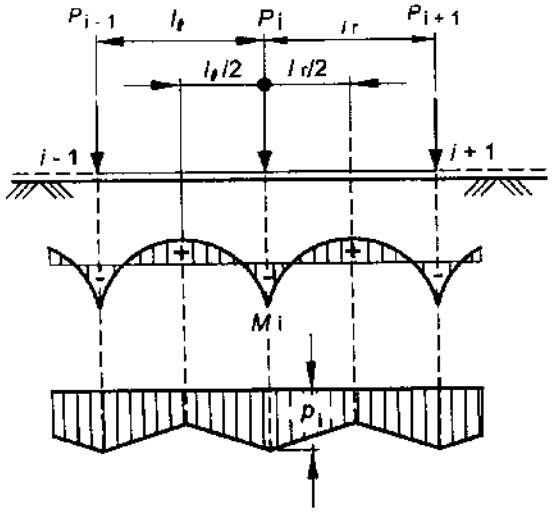
CONTACT PRESSURE DISTRIBUTION AND MOMENTS BELOW FLEXIBLE FOUNDATION

E-1 CONTACT PRESSURE DISTRIBUTION

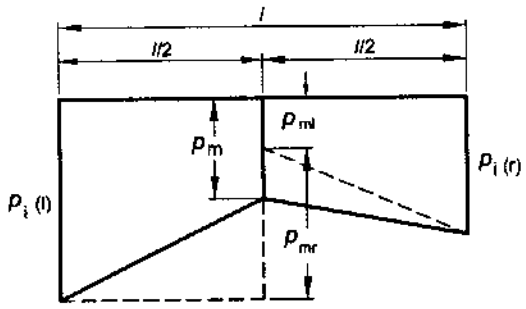
E-1.1 The distribution of contact pressure is assumed to be linear with the maximum value attained under the columns and the minimum value at mid span.

E-1.2 The contact pressure for the full width of the strip under an interior column load located at a point i can be determined as (*see* Fig. 9 A):

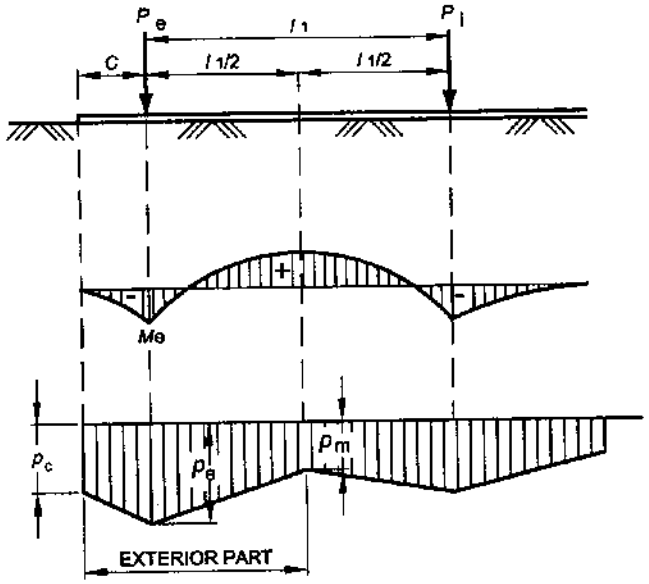
$$p_i = \frac{5\,P_i}{\bar{l}} + \frac{48\,M_i}{(\bar{l})^2}$$



9A MOMENT AND PRESSURE DISTRIBUTION AT INTERIOR COLUMN



9B PRESSURE DISTRIBUTION OVER AN INTERIOR SPAN



9C MOMENT AND PRESSURE DISTRIBUTION AT EXTERIOR COLUMNS

FIG. 9 MOMENT AND PRESSURE DISTRIBUTION AT COLUMNS

where

$\bar{l}$ = Average length of adjacent span (m),

P_i = Column load at point i, and

M_i = Moment under an interior columns loaded at i.

E-1.3 The minimum contact pressure for the full width of the strip at the middle of the adjacent spans can be determined as (*see* Fig. 9A and 9B).

$$p_{ml} = 2P_i\left(\frac{l_r}{l_l + \bar{l}}\right) - p_i\left(\frac{\bar{l}}{l_l}\right)$$

$$p_{mr} = 2P_i\left(\frac{l_r}{l_r + \bar{l}}\right) - p_i\left(\frac{\bar{l}}{l_r}\right)$$

$$p_m = \frac{p_{mr} + p_{ml}}{2}$$

E-1.4 If **E-2.3** (a) governs the moment under the exterior columns, contact pressures under the exterior columns and at end of strip can be determined as (*see* Fig. 9C):

$$p_e = \frac{4p_c + \frac{6M_e}{C} - p_m l_l}{C + l_l}$$

$$p_c = -\frac{3M_e}{C^2} - \frac{p_2}{2}$$

E-1.5 If **E-2.3** (b) governs the moment under the exterior columns, the contact pressures are determined as (*see* Fig. 9C):

$$p_e = p_c = \frac{4p_c - p_m l_r}{4C + l_l}$$

E-2 BENDING MOMENT DIAGRAM

E-2.1 The bending moment under an interior column located at i (*see* Fig. 9A) can be determined as:

$$M_i = \frac{P_i}{4\lambda}(0.24\lambda\bar{l} + 0.16)$$

E-2.2 The bending moment at mid span is obtained as (*see* Fig. 9A):

$$M_m = M_o + M_i$$

where

M_o = Moment of simply supported beam

$$= \frac{(\bar{l})^2}{48}[p_i(l) + 4p_m + p_i(r)]$$

M_i = Average of negative moments M_i at each end of the bay.

E-2.3 The bending moment M_e under exterior columns can be determined as the least of (*see* Fig. 9C):

a) $$M_{e1} = -\frac{P_e}{4\lambda}(0.13\lambda l_l + 1.06\lambda C - 0.50)$$

b) $$M_{e2} = -\frac{(4P_e - p_m l_l)}{(4C + l_l)}\frac{C^2}{2}$$

ANNEX F

(*Clause* 7.3.4.2)

FLEXIBLE FOUNDATION — GENERAL CONDITION

F-1 CLOSED FORM SOLUTION OF ELASTIC PLATE THEORY

F-1.1 For a flexible raft foundation with non-uniform column spacing and load intensity, solution of the differential equation governing the behaviour of plates on elastic foundation (Winkler Type) gives radial moment (M_r) tangential moment (M_t) and deflection (w) at any point by the following expressions:

$$M_r = -\frac{P}{4}\left[Z_4\left(\frac{r}{L}\right) - (1-\mu)\frac{Z_3'\left(\frac{r}{L}\right)}{\left(\frac{r}{L}\right)}\right]$$

$$M_t = -\frac{P}{4}\left[\mu Z_4\left(\frac{r}{L}\right) + (1-\mu)\frac{Z_3'\left(\frac{r}{L}\right)}{\left(\frac{r}{L}\right)}\right]$$

$$w = \frac{PL^2}{4D} \cdot Z_3\left(\frac{r}{L}\right)$$

where

P = Column load,

r = Distance of the point under investigation from column load along radius, and

L = Radius of effective stiffness

$$\left(\frac{D}{k}\right)^{1/4}$$

where

k = Modulus of subgrade reaction for footing of width B,

D = Flexural rigidity of the foundation,

$$P = \frac{Et^2}{12(1-\mu^2)},$$

t = Raft thickness,

E = Modulus of elasticity of the foundation material,

μ = Possion's ratio of the foundation material, and

$Z_3\left(\frac{r}{L}\right)$, $Z'_3\left(\frac{r}{L}\right)$, $Z_4\left(\frac{r}{L}\right)$ = Functions of shear, moment and deflection (*see* Fig. 10)

F-1.2 The radial and tangential moments can be converted to rectangular co-ordinates:

$$M_x = M_r \cos^2\phi + M_t \sin^2\phi$$

$$M_y = M_r \sin^2\phi + M_t \cos^2\phi$$

where

ϕ = Angle with x-axis to the line jointing origin to the point under consideration.

F-1.3 The shear Q per unit width of raft can be determined by:

$$Q = -\frac{P}{4L} Z'_4\left(\frac{r}{L}\right)$$

$Z'_4\left(\frac{r}{L}\right)$ = function for shear (*see* Fig. 10).

F-1.4 When the edge of the raft is located within the radius of influence, the following corrections are to be applied. Calculate moments and shears perpendicular to the edge,of the raft within the radius of influence, assuming the raft to be infinitely large. Then apply opposite and equal moments and shears on the edge of the mat. The method for beams on elastic foundation may be used.

F-1.5 Finally, all moments and shears calculated for each individual column and wall are superimposed to obtain the total moment and shear values.

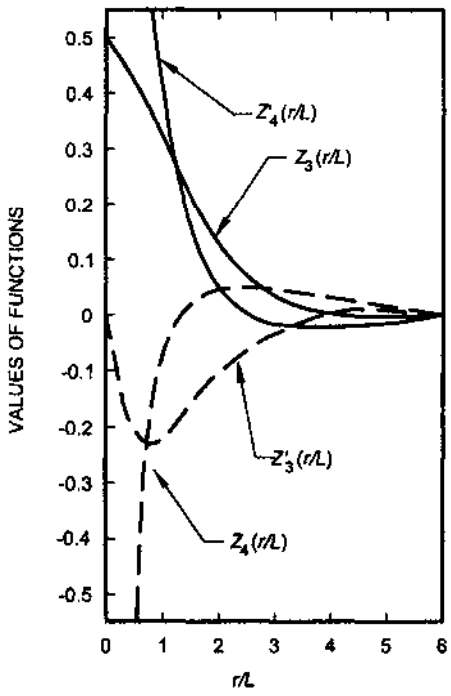


FIG. 10 FUNCTIONS FOR SHEAR MOMENT AND DEFLECTION

ANNEX G

(*Clauses* 8.2.1.2 *and* 8.2.3.2)

LOAD CARRYING CAPACITY — STATIC FORMULA

G-1 PILES IN GRANULAR SOILS

G-1.1 The ultimate bearing capacity (Q_u) of piles in granular soils is given by the following formula:

$$Q_u = A_p(\tfrac{1}{2} D.\gamma.N_\gamma + P_D.N_q) + \sum_{i=1}^{n} K.P_{Di}.\tan\delta.A_{si}$$

where

A_p = Cross-sectional area of pile toe in m²;

D = Stem diameter in m;

γ = Effective unit weight of soil at pile toe in kN/m³;

P_D = Effective overburden pressure at pile toe in kN/m²;

N_γ, N_q = Bearing capacity factors and depending upon the angle of internal friction ø, at toe;

$\sum_{i=1}^{n}$ = Summation for n layers in which pile is installed;

K = Coefficient of earth pressure;

P_{Di} = Effective overburden pressure in kN/m² for the ith layer, where i varies from 1 to n;

δ = Angle of wall friction between pile and soil, in degrees (may be taken equal to ϕ); and

A_{si} = Surface area of pile stem in m² in the *i*th layer, where *i* varies from 1 to *n*.

NOTES

1 For N_γ factors refer to good practice [6-2(7)].

2 N_q factor will depend, apart from nature of soil on the type of pile and the method of its construction and the values are given in Fig. 11 and Fig. 12 for bored and driven piles respectively.

3 The earth pressure coefficient K depends on the nature of soil strata, type of pile and the method of its construction. For driven piles in loose to medium sands, K values of 1 to 3 should be used. For bored piles, k values can be taken between 1 and 2.

4 The angle of wall friction may be taken equal to the angle of shear resistance of soil.

5 In working out pile capacities using static formula, for piles larger than 15 to 20 pile diameters, the maximum effective overburden at the pile tip should correspond to pile length equal to 15 to 20 times of the diameters.

G-2 PILES IN COHESIVE SOILS

G-2.1 The ultimate bearing capacity of piles (Q_u) in cohesive soil is given by the following formula:

$$Q_u = A_p N_c . C_p + \alpha \bar{C} . A_s$$

where

A_p = Cross-sectional area of pile toe in m²,

N_c = Bearing capacity factor usually taken as 9,

C_p = Average cohesion at pile tip in kN/m²,

α = Reduction factor,

$\bar{C}$ = Average cohesion throughout the length of pile in kN/m², and

A_s = Surface area of pile shaft in m².

NOTES

1 The following values of α may be taken, depending upon the consistency of the soils:

Consistency	*N Value*	*Value of α*	
		Bored piles	Driven cast *in-situ* piles
(1)	(2)	(3)	(4)
Soft to very soft	< 4	0.7	1
Medium	4 to 8	0.5	0.7
Stiff	8 to 15	0.4	0.4
Stiff to hard	>15	0.3	0.3

2 a) Static formula may be used as a guide only for bearing capacity estimates. Better reliance may be put on load test on piles.

b) For working out safe load, a minimum factor of safety 2.5 should be used on the ultimate bearing capacity estimated by static formulae.

3 In case of soft to very soft soils which are not sensitive, the value of α can be taken up to 1.

G-3 When full static penetration data is available for the entire depth, the following correlations may be used as a guide for the determination of shaft resistance of a pile:

Type of Soil	*Local Side Friction* f_s
Clays and peats where $q_c < 1$	$\frac{q_c}{3} < f_s < \frac{q_c}{1}$
Clays	$\frac{q_c}{2.5} < f_s < \frac{2\,q_c}{2.5}$
Silty clays and silty sands	$\frac{q_c}{10} < f_s < \frac{q_c}{2.5}$
Sands	$\frac{q_c}{10} < f_s < \frac{2\,q_c}{10}$
Coarse sands and gravels	$f_s < \frac{q_c}{15}$

where

q_c = Static point resistance in N/mm², and

f_s = Local side friction in N/mm².

For non-homogeneous soils, the ultimate point bearing capacity may be calculated using the following relationships:

$$q_u = \frac{\frac{q_{c0} + q_{c1}}{2} + q_{c2}}{2}$$

where

q_u = Ultimate point bearing capacity,

q_{c0} = Average static cone resistance over a depth of 2 *d* below the base level of the pile,

q_{c1} = Minimum static cone resistance over the same 2 *d* below the pile tip,

q_{c2} = Average of the minimum cone resistance values in the diagram over a height of 8 *d* above the base level of the pile, and

d = Diameter of the pile base or the equivalent diameter for a non-circular cross-section.

G-3.1 The correlation between standard penetration test value N and static point resistance q_c (in N/mm²) given below may be used for working out the shaft resistance and skin friction of piles:

Soil type	q_c/N
Clays, silts, sandy silts and slightly cohesive silt-sand mixtures	0.2
Clean fine to medium sands and slightly silty sands	0.3-0.4
Coarse sands and sands with little gravel	0.5-0.6
Sandy gravels and gravel	0.8-0.10

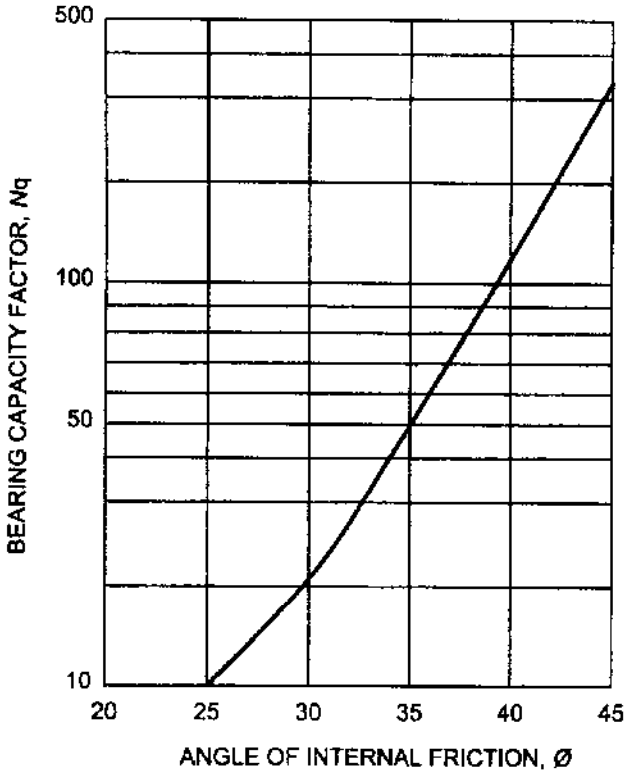


FIG. 11 BEARING CAPACITY FACTOR, N_q FOR BORED PILES

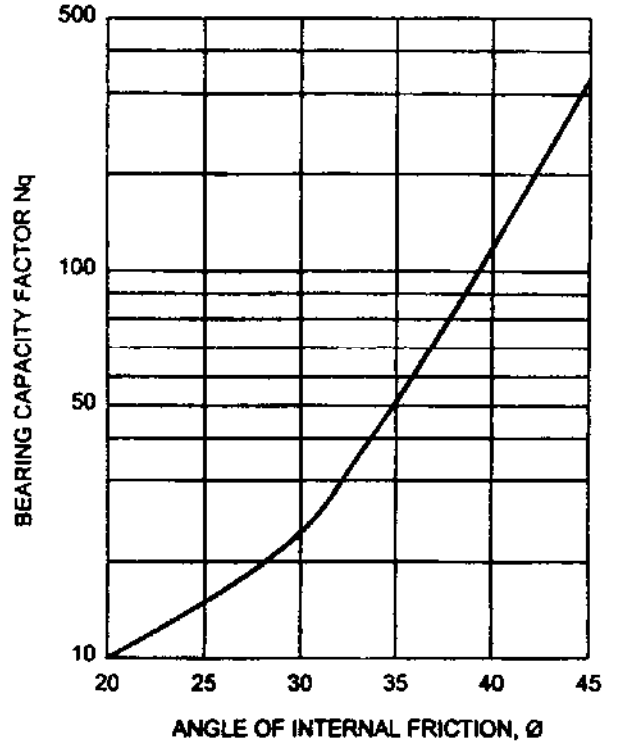


FIG. 12 BEARING CAPACITY FACTOR, N_q FOR DRIVEN PILES

ANNEX H

(*Clauses* 8.2.3.3 *and* 11.2.4)

DETERMINATION OF DEPTH OF FIXITY, LATERAL DEFLECTION AND MAXIMUM MOMENT OF LATERALLY LOADED PILES

H-1 DETERMINATION OF LATERAL DEFLECTION AT THE PILE HEAD AND DEPTH OF FIXITY

H-1.1 The long flexible pile, fully or partially embedded, is treated as a cantilever fixed at some depth below the ground level (*see* Fig. 13).

H-1.2 Determine the depth of fixity and hence the equivalent length of the cantilever using the plots given in Fig. 13.

where

$$T = 5\sqrt{\frac{EI}{K_1}} \quad \text{and} \quad R = 4\sqrt{\frac{EI}{K_2}}$$

(K_1 and K_2 are constants given in Tables 8 and 9, E is the Young's modulus of the pile material in kN/m^2 and I is the moment of inertia of the pile cross-section in m^4).

NOTE — Figure 12 is valid for long flexible piles where the embedded length L_e is $\geq 4R$ or $4T$.

Table 8 Values of Constant K_1 (kN/m^3)

(*Clause* H-1.2)

Type of Soil	Value	
	Dry	Submerged
(1)	(2)	(3)
Loose sand	2 600	1 460
Medium sand	7 750	5 250
Dense sand	20 750	12 450
Very loose sand under repeated loading or normally loading clays		400

Table 9 Values of Constant K_1 (kN/m^3)

(*Clause* H-1.2)

Unconfined Compressive Strength kN/m^2	Value
(1)	(2)
20 to 40	7.75×10^4
100 to 200	48.80×10^4
200 to 400	97.75×10^4
More than 400	195.50×10^4

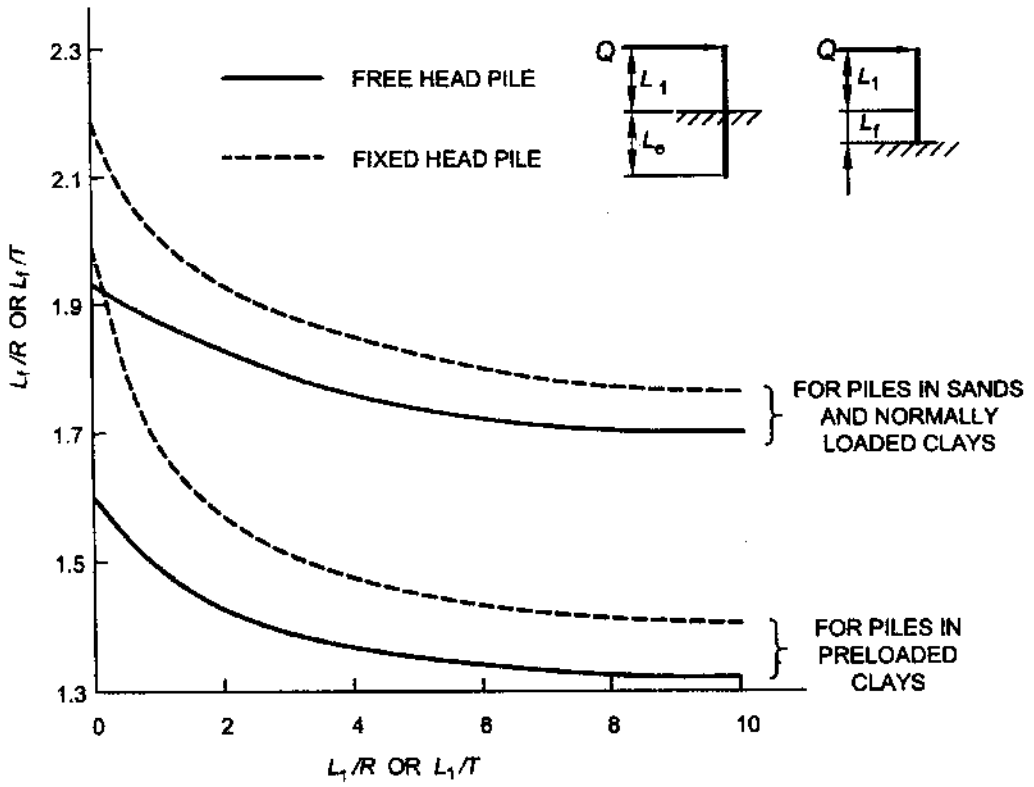


FIG. 13 DETERMINATION OF DEPTH FIXITY

H-1.3 Knowing the length of the equivalent cantilever the pile head deflection (Y) shall be computed using the following equations:

$$Y(\text{in } m) = \frac{Q(L_1 + L_f)^3}{3EI} \quad \text{..... for free head pile}$$

$$= \frac{Q(L_1 + L_f)^3}{12EI} \quad \text{..... for fixed head pile}$$

where Q is the lateral load in kN.

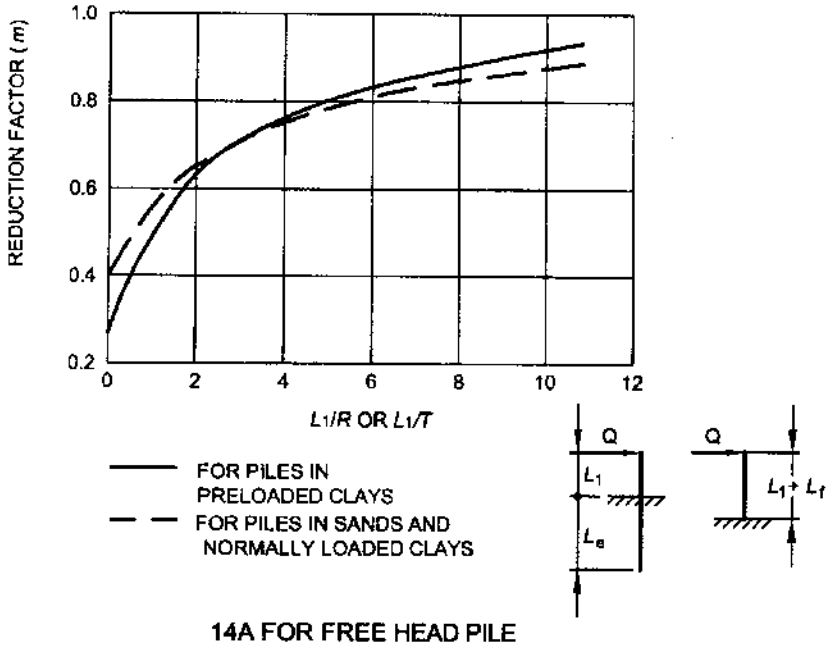
H-2 DETERMINATION OF MAXIMUM MOMENT IN THE PILE

H-2.1 The fixed end moment (M_f) of the equivalent cantilever is higher than the actual maximum moment (M) of the pile. The actual maximum moment is obtained by multiplying the fixed end moment of the equivalent cantilever by a reduction factor, m given in Fig. 14. The fixed end moment of the equivalent cantilever is given by:

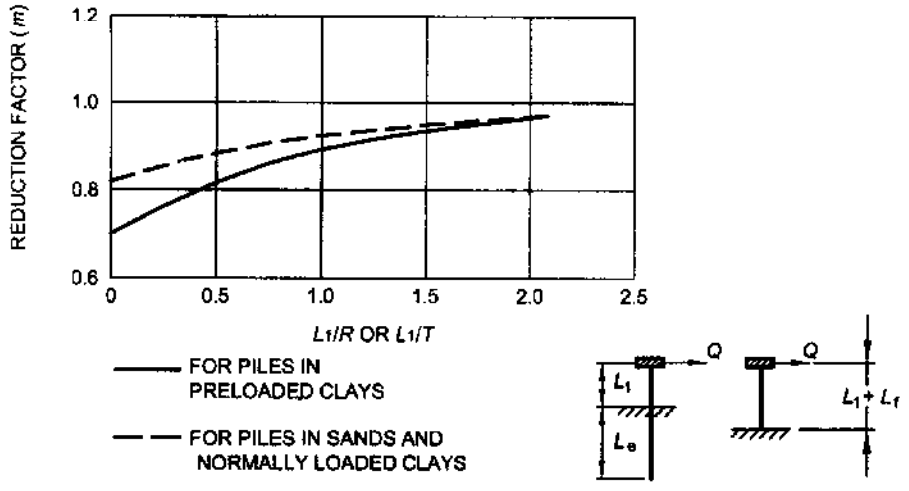
$$M_f = Q(L_1 + L_f) \quad \text{..... for free head pile}$$

$$= \frac{Q(L_1 + L_f)^3}{12EI} \quad \text{..... for fixed head pile}$$

The actual maximum moment (M) = m (M_F).



14A FOR FREE HEAD PILE



14B FOR FIXED HEAD PILE

FIG. 14 DETERMINATION OF REDUCTION FACTORS FOR COMPUTATION OF MAXIMUM MOMENT IN PILE

ANNEX J

(*Clause* 11.2.2)

LOAD CARRYING CAPACITY OF UNDER-REAMED PILES FROM SOIL PROPERTIES

J-1 ULTIMATE LOAD CAPACITY

The ultimate load capacity of a pile can be calculated from soil properties. The soil properties required are strength parameters, cohesion, angle of internal friction and soil density.

a) *Clayey Soils* — For clayey soils, the ultimate load carrying capacity of an under-reamed pile may be worked out from the following expression:

$$Q_u = A_p N_c C_p + A_a N_c C'_a + C'_a A'_s + \alpha C_a A_s$$

where

Q_u = Ultimate bearing capacity of pile in kN;

A_p = Cross-sectional area of the pile stem at the toe level in m^2;

N_c = Bearing capacity factor, usually taken as 9;

C_p = Cohesion of the soil around toe in kN/m^2;

A_a = $(\pi/4)(D_u^2 - D^2)$, where D_u and D are the under-reamed and stem diameter, respectively in m;

C_a = Average cohesion of the soil along the pile stem in kN/m^2;

A_s = Surface area of the stem in m^2;

A'_s = Surface area of the cylinder circumscribing the under-reamed bulbs in m^2;

C'_a = Average cohesion of the soil around the under-reamed bulbs; and

α = Reduction factor (usually taken 0.5 for clays).

NOTES

1 The above expression holds for the usual spacing of under-reamed bulbs spaced at not more than one and a half times their diameter.

2 If the pile is with one bulb only, the third term will not occur. For calculating uplift load, the first term will not occur in the formula.

3 In case of expansive soil top 2 m strata should be neglected for computing skin friction.

b) *Sandy Soils*

$$Q_u = A_p(\tfrac{1}{2} D_\gamma N_\gamma + \gamma d_f N_q) + A_a(\tfrac{1}{2} D_u n \gamma N_\gamma)$$

$$+ \gamma N_q \sum_{r=1}^{r=n} d_r + \tfrac{1}{2}\pi D_\gamma K \tan\delta\,(d_1^2 + d_1^2 + d_n^2)$$

where

A_p = $\pi D^2/4$, where D is stem diameter in m;

A_a = $\pi/4\,(D_u^2 - D^2)$ where D_u is the under-reamed bulb diameter in m;

n = Number of under-reamed bulbs;

γ = Average unit weight of soil (submerged unit weight in strata below water table) in kN/m^3;

N_γ, N_q = Bearing capacity factors, depending upon the angle of internal friction;

d_r = Depth of the centre of different under-reamed bulbs below ground level in m;

d_f = Total depth of pile below ground level in m;

K = Earth pressure coefficient (usually taken as 1.75 for sandy soils);

δ = Angle of wall friction (may be taken as equal to the angle of internal friction Ø);

d_1 = Depth of the centre of the first under-reamed bulb in m; and

d_n = Depth of the centre of the last under-reamed bulb in m.

NOTES

1 For uplift bearing on pile tip, A_p will not occur.

2 N_γ will be as specified in good practice [6-2(7)] and N_q will be taken from Fig. 11.

c) *Soil Strata having both Cohesion and Friction* — In soil strata having both cohesion and friction or in layered strata having two types of soil, the bearing capacity may be estimated using both the formulae. However, in such cases load test will be a better guide.

d) *Compaction Piles in Sandy Strata* — For bored compaction piles in sandy strata, the formula in (b) shall be applied but with the modified value of ϕ_1 as given below:

$$\phi_1 = (\phi + 40)/2$$

where

ϕ = Angle of internal friction of virgin soil.

The values of N_γ, N_q and δ are taken corresponding to ϕ_1. The value of the earth pressure coefficient K will be 3.

e) *Piles Resting on Rock* — For piles resting on rock, the bearing component will be obtained by multiplying the safe bearing capacity of rock with bearing area of the pile stem plus the bearing provided by the bulb portion.

NOTE — To obtain safe load in compression and uplift from ultimate load capacity generally the factors of safety will be 2.5 and 3 respectively.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 1892 : 1979	Code of practice for subsurface investigation for foundation (*first revision*)
2131 : 1981	Method of standard penetration test for soils (*first revision*)
2132 : 1986	Code of practice for thin walled tube sampling of soils (*second revision*)
4434 : 1978	Code of practice for *in-situ* vane shear test for soils (*first revision*)
4968	Method for sub-surface sounding for soils:
(Part 1) : 1976	Dynamic method using 50 mm cone without bentonite slurry (*first revision*)
(Part 2) : 1976	Dynamic method using cone and bentonite slurry (*first revision*)
(Part 3) : 1976	Static cone penetration test (*first revision*)
8763 : 1978	Guide for undisturbed sampling of sands and sandy soils
9214 : 1979	Method for determination of modulus of subgrade reaction (*k*-value) of soils in the field
(2) 10042 : 1981	Code of practice for site-investigations for foundation in gravel boulder deposits
(3) 13365 (Part 1) : 1998	Guidelines for quantitative classification systems of rock mass: Part 1 RMR for predicting of engineering properties
(4) 2720 (Part 1) : 1983	Methods of tests for soils: Preparation of dry soil samples for various tests (*second revision*)
(Part 2) : 1973	Determination of water content (*second revision*)
(Part 3/Sec 1) : 1980	Determination of specific gravity, Section 1 Fine grained soils (*first revision*)
(Part 3/Sec 2) : 1980	Determination of specific gravity, Section 2 Fine, medium and coarse grained soils (*first revision*)
(Part 4) : 1985	Grain size analysis (*second revision*)
(Part 5) : 1985	Determination of liquid and plastic limits (*second revision*)
(Part 10) : 1991	Determination of unconfined compressive strength (*second revision*)
(Part 13) : 1986	Direct shear test (*second revision*)
(Part 15) : 1986	Determination of consolidation properties (*first revision*)
(Part 28) : 1974	Determination of dry density of soils in place, by the sand replacement method (*first revision*)
(Part 29) : 1975	Determination of dry density of soils in place, by the core cutter method (*first revision*)
(Part 33) : 1971	Determination of the density in-place by the ring and water replacement method
(Part 34) : 1972	Determination of density of soils in-place by rubber-balloon method
(Part 39/Sec 1) : 1977	Direct shear test for soils containing gravel, Section 1 Laboratory test
(5) 1498 : 1970	Classification and identification of soils for general engineering purposes (*first revision*)
(6) 401 : 2001	Code of practice for preservation of timber (*fourth revision*)
(7) 6403 : 1981	Code of practice for determination of bearing capacity of shallow foundations (*first revision*)
(8) 1888 : 1982	Method of load tests on soils (*second revision*)
(9) 2131 : 1981	Method for standard penetration test for soils (*first revision*)

IS No.	Title
(10) 8009 (Part 1) : 1976	Code of practice for calculation of settlement of foundations: Part 1 Shallow foundations subjected to symmetrical static vertical loads
(11) 1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
(12) 3764 : 1992	Code of safety for excavation work (*first revision*)
(13) 456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
(14) 1905 : 1987	Code of practice for structural use of unreinforced masonry (*third revision*)
(15) 1080 : 1985	Code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell) (*second revision*)
(16) 11089 : 1984	Code of practice for design and construction of ring foundations
(17) 2911	Code of practice for design and construction of pile foundations:
(Part 1/Sec 1): 1979	Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*first revision*)
(Part 1/Sec 2) : 1979	Concrete piles, Section 2 Bored cast *in-situ* piles (*first revision*)
(18) (Part 4) : 1985	Load test on piles (*first revision*)
(19) 14893 : 2001	Guidelines for non-destructive integrity testing of piles
(20) 2911	Code of practice for design and construction of pile foundations:
(Part 1/Sec 3) : 1979	Concrete piles, Section 3 Driven precast concrete piles (*first revision*)
(21) (Part 1/Sec 4) : 1979	Concrete piles, Section 4 Bored precast concrete piles
(22) (Part 3) : 1980	Under-reamed pile foundation (*first revision*)
(23) (Part 2) : 1980	Timber piles (*first revision*)
(24) 2974	Code of practice for design and construction of machine foundation
(Part 1) : 1982	Foundations for reciprocating type machine (*second revision*)
(Part 2) : 1980	Foundations for impact type machines (hammer foundations) (*first revision*)
(Part 3) : 1992	Foundations for rotary type machines (medium and high frequency) (*second revision*)
(Part 4) : 1979	Foundations for rotary type machines of low frequency (*first revision*)
(Part 5) : 1987	Foundations for impact machines other than hammers (forging and stamping press; pig breakers, drop crusher and jetter) (*first revision*)
13301 : 1992	Guidelines for vibration isolation for machine foundations
9556 : 1980	Code of practice for design and construction of diaphragm walls
(25) 13094 : 1992	Guidelines for selection of ground improvement techniques for foundation in weak soils
(26) 13162 (Part 2) : 1991	Geotextiles — Methods of test: Part 2 Determination of resistance to exposure of ultra-violet light and water (Xenon arc type apparatus)
13321 (Part 1) : 1992	Glossary of terms for geo-synthetics: Part 1 Terms used in materials and properties
13325 : 1992	Method of test for the determination of tensile properties of extruded polymer geogrids using the wide strip
13326 (Part 1) : 1992	Method of test for the evaluation of interface friction between geosynthetics and soil: Part 1 Modified direct shear technique
14293 : 1995	Geotextiles — Method of test for trapezoid tearing strength
14294 : 1995	Geotextiles — Method for determination of apparent opening size by dry sieving technique
14324 : 1995	Geotextiles — Methods of test for determination of water permeability-permittivity

IS No.	*Title*
14706 : 1999	Geotextiles — Sampling and preparation of test specimens
14714 : 1999	Geotextiles — Determination of abrasion resistance
14715 : 2000	Woven jute geotextiles — Specification
14716 : 1999	Geotextiles — Determination of mass per unit area
14739 : 1999	Geotextiles — Methods for determination of creep
14986 : 2001	Guidelines for application of jute geo-grid for rain water erosion control in road and railway embankments and hill slopes
15060 : 2001	Geotextiles — Tensile test for joints/seams by wide width method
(27) 9214 : 1979	Method of determination of subgrade reaction (K-value) of soils in the field

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3A Timber

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section deals with the structural design aspect of timber structures. In this section, the various Species of Indian timber, classified into three groups depending on the structural properties influencing the design, most are included.

In the previous version of the Code, timber was covered under Section 3 of Part 6 under the title 'Wood', which did not cover bamboo. Now this Section 3 has been enlarged as Section 3 Timber and Bamboo, which has been sub-divided into sub-section 3A Timber and sub-section 3B Bamboo. This sub-section pertains to 3A Timber.

This Section was first published in 1970 which was subsequently revised in 1983. In the first revision provisions of this Section were updated and design of nailed laminated timber beams were included and information on bolted construction joints was added. As a result of experience gained in implementation of 1983 version of this Code and feedback received as well as formulation of new standards in the field and revision of some of the existing standards, a need to revise this Section was felt. This revision has, therefore, been brought out to take care of these aspects. The significant changes incorporated in this revision include the following:

a) A number of terminologies related to timber for structural purpose have been added.
b) Strength data of additional species of timber have been included.
c) Requirements for structural timber and preferred cut sizes thereof have been modified.
d) Requirements for glued laminated construction and finger joints have been introduced.
e) Requirements for laminated veneer lumber have been introduced.
f) Brief details have been included for structural sandwiches, glued laminated beams, lamella roofing, nail and screw holding power of timber, structural use of plywood and trussed rafter; these are proposed to be further elaborated in future revisions of this Section.
g) Guidelines for protection against termite attack in buildings have been added.
h) Reference to all the concerned Indian Standards have been updated.

In the present day context of dwindling forest resources, all efforts are being made to effect judicious use of timber. In this context, the Indian Standards now permit use of plantation timbers including certain fast growing species and suitable guidelines in terms of their seasoning, sawing, treatment, etc have been made available. In the same way, use of finger jointing and glued laminated timber is important and standardization on the same is desirable and is under due consideration. However, in the absence of detailed Indian Standard Specifications and Codes of practice in these areas at present, general details on the same have been incorporated in the revision of this part.

The information contained in this Section is largely based on the following Indian Standards:

IS No.	*Title*
399 : 1963	Classification of commercial timbers and their zonal distribution (*revised*)
883 : 1994	Code of practice for design of structural timber in building (*fourth revision*)
1150 : 2000	Trade names and abbreviated symbols for timber species (*third revision*)
2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
4891 : 1988	Specification for preferred cut sizes of structural timber (*first revision*)
4983 : 1968	Code of practice for design and construction of nailed laminated timber beams
11096 : 1984	Code of practice for design and construction of bolt-jointed timber construction
14616 : 1999	Specification for laminated veneer lumber

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3A Timber

1 SCOPE

1.1 This Section relates to the use of structural timber in structures or elements of structures connected together by fasteners/fastening techniques.

1.2 This shall not be interpreted to prevent the use of material or methods of design or construction not specifically mentioned herein; and the methods of design may be based on analytical and engineering principles, or reliable test data, or both, that demonstrate the safety and serviceability of the resulting structure. Nor is the classification of timber into strength groups to be interpreted as preventing the use of design data desired for a particular timber or grade of timber on the basis of reliable tests.

2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions and those in accordance with accepted standard [6-3A(1)], shall apply.

2.1 Structural Purpose Definitions

2.1.1 *Beam, Built-Up-Laminated* — A beam made by joining layers of timber together with mechanical fastenings, so that the grain of all layers is essentially parallel.

2.1.2 *Beam, Glued-Laminated* — A beam made by bonding layers of veneers or timber with an adhesive, so that grain of all laminations is essentially parallel.

2.1.3 *Diaphragm, Structural* — A structural element of large extent placed in a building as a wall, or roof, and made use of to resist horizontal forces such as wind or earthquakes-acting parallel to its own plane.

2.1.4 *Duration of Load* — Period during which a member or a complete structure is stressed as a consequence of the loads applied.

2.1.5 *Edge Distance* — The distance measured perpendicular to grain from the centre of the connector to the edge of the member.

2.1.6 *End Distance* — The distance measured parallel to grain of the member from the centre of the connector to the closest end of timber.

2.1.7 *Finger Joint* — Joint produced by connecting timber members end-to-end by cutting profiles (tapered projections) in the form of V-shaped grooves to the ends of timber planks or scantlings to be joined, glueing the interfaces and then mating the two ends together under pressure.

2.1.8 *Fundamental or Ultimate Stress* — The stress which is determined on small clear specimen of timber, in accordance with good practice [6-3A(2)]; and does not take into account the effect of naturally occurring characteristics and other factors.

2.1.9 *Inside Location* — Position in buildings in which timber remains continuously dry or protected from weather.

2.1.10 *Laminated Veneer Lumber* — A structural composite made by laminating veneers, 1.5 mm to 4.2 mm thick, with suitable adhesive and with the grain of veneers in successive layers aligned along the longitudinal (length) dimension of the composite.

2.1.11 *Loaded Edge Distance* — The distance measured from the centre to the edge towards which the load induced by the connector acts, and the unloaded edge distance is the one opposite to the loaded edge.

2.1.12 *Location* — A term generally referred to as exact place where a timber is used in building.

2.1.13 *Outside Location* — Position in buildings in which timbers are occasionally subjected to wetting and drying as in the case of open sheds and outdoor exposed structures.

2.1.14 *Permissible Stress* — Stress obtained by applying factor of safety to the ultimate stress.

2.1.15 *Sandwich, Structural* — A layered construction comprising a combination or relatively high-strength facing material intimately bonded to and acting integrally with a low density core material.

2.1.16 *Spaced Column* — Two column sections adequately connected together by glue, bolts, screws or otherwise.

2.1.17 *Structure, Permanent* — Structural units in timber which are constructed for a long duration and wherein adequate protection and design measures have initially been incorporated to render the structure serviceable for the required life.

2.1.18 *Structure, Temporary* — Structures which are erected for a short period, such as hutments at project sites, for rehabilitation, temporary defence constructions, exhibition structures, etc.

2.1.19 *Structural Element* — The component timber members and joints which make up a resulting structural assembly.

2.1.20 *Structural Grades* — Grades defining the maximum size of strength reducing natural characteristics (knots, sloping grain, etc) deemed

permissible in any piece of structural timber within designated structural grade classification.

2.1.21 *Structural Timber* — Timber in which strength is related to the anticipated in-service use as a controlling factor in grading and selection and/or stiffness.

2.1.22 *Termite* — An insect of the order *Isoptera* which may burrow in the wood or wood products of a building for food or shelter.

2.1.23 *Wet Location* — Position in buildings in which timbers are almost continuously damp or wet in contact with the earth or water, such as piles and timber foundations.

2.2 Definitions of Defects in Timber

2.2.1 *Check* — A separation of fibres extending along the grain which is confined to one face of a piece of wood.

2.2.2 *Compression Wood* — Abnormal wood which is formed on the lower sides of branches and inclined stems of coniferous trees. It is darker and harder than normal wood but relatively low in strength for its weight. It can be usually identified by wide eccentric growth rings with abnormally high proportion of growth latewood.

2.2.3 *Dead Knot* — A knot in which the layers of annual growth are not completely intergrown with those of the adjacent wood. It is surrounded by pitch or bark. The encasement may be partial or complete.

2.2.4 *Decay or Rot* — Disintegration of wood tissue caused by fungi (wood destroying) or other micro-organisms.

2.2.5 *Decayed Knot* — A knot softer than the surrounding wood and containing decay.

2.2.6 *Diameter of Knot* — The maximum distance between the two points farthest apart on the periphery of a round knot, on the face on which it becomes visible. In the case of a spike or a splay knot, the maximum width of the knot visible on the face on which it appears shall be taken as its diameter.

2.2.7 *Discolouration* — A change from the normal colour of the wood which does not impair the strength of the wood.

2.2.8 *Knot* — A branch base or limb embedded in the tree or timber by natural growth.

2.2.9 *Knot Hole* — A hole left as a result of the removal of a knot.

2.2.10 *Live Knot* — A knot free from decay and other defects, in which the fibres are firmly intergrown with those of the surrounding wood. Syn. 'Integrown knot'; *cf.* 'Dead Knot'.

2.2.11 *Loose Grain (Loosened Grain)* — A defect on a flat sawn surface caused by the separation or raising of wood fibres along the growth rings; *cf.* 'Raised Grain'.

2.2.12 *Loose Knot* — A knot that is not held firmly in place by growth or position, and that cannot be relied upon to remain in place; *cf.* 'Tight Knot'.

2.2.13 *Mould* — A soft vegetative growth that forms on wood in damp, stagnant atmosphere. It is the least harmful type of fungus, usually confined to the surface of the wood.

2.2.14 *Pitch Pocket* — Accumulation of resin between growth rings of coniferous wood as seen on the cross section.

2.2.15 *Sap Stain* — Discolouration of the sapwood mainly due to fungi.

2.2.16 *Sapwood* — The outer layer of log, which in the growing tree contain living cells and food material. The sapwood is usually lighter in colour and is readily attacked by insects and fungi.

2.2.17 *Shake* — A partial or complete separation between adjoining layers of tissues as seen in end surfaces.

2.2.18 *Slope of Grain* — The inclination of the fibres to the longitudinal axis of the member.

2.2.19 *Sound Knot* — A tight knot free from decay, which is solid across its face, and at least as hard as the surrounding wood.

2.2.20 *Split* — A crack extending from one face of a piece of wood to another and runs along the grain of the piece.

2.2.21 *Tight Knot* — A knot so held by growth or position as to remain firm in position in the piece of wood; *cf.* 'Loose Knot'.

2.2.22 *Wane* — The original rounded surface of a tree remaining on a piece of converted timber.

2.2.23 *Warp* — A deviation in sawn timber from a true plane surface or distortion due to stresses causing departure from a true plane.

2.2.24 *Worm Holes* — Cavities caused by worms.

3 SYMBOLS

3.1 For the purpose of this Section, the following letter symbols shall have the meaning indicated against each:

a = Projected area of bolt in main member ($t' \times d_3$), mm^2

B = Width of the beam, mm

C = Concentrated load, N

D = Depth of beam, mm

D_1 = Depth of beam at the notch, mm

D_2 = Depth of notch, mm

d = Dimension of least side of column, mm

d_1 = Least overall width of box column, mm

d_2 = Least overall dimension of core in box column, mm

d_3 = Diameter of bolt, mm

d_f = Bolt-diameter factor

e = Length of the notch measured along the beam span from the inner edge of the support to the farthest edge of the notch, mm

E = Modulus of elasticity in bending, N/mm^2

F = Load acting on a bolt at an angle to grain, N

f_{ab} = Calculated bending stress in extreme fibre, N/mm^2

f_{ac} = Calculated average axial compressive stress, N/mm^2

f_{at} = Calculated axial tensile stress, N/mm^2

f_b = Permissible bending stress on the extreme fibre, N/mm^2

f_c = Permissible stress in axial compression, N/mm^2

f_{cn} = Permissible stress in compression normal (perpendicular) to grain, N/mm^2

f_{cp} = Permissible stress in compression parallel to grain, N/mm^2

f_c^{Θ} = Permissible compressive stress in the direction of the line of action of the load, N/mm^2

f_t = Permissible stress in tension parallel to grain, N/mm^2

H = Horizontal shear stress, N/mm^2

I = Moment of inertia of a section, mm^4

K = Coefficient in deflection depending upon type and criticality of loading on beam

K_1 = Modification factor for change in slope of grain

K_2 = Modification factor for change in duration of loadings

K_3, K_4, K_5, and K_6 = Form factors

K_7 = Modification factor for bearing stress

K_8 = Constant equal to $0.584\sqrt{\frac{E}{f_{cp}}}$

K_9 = Constant equal to $\frac{\pi}{2}\sqrt{\frac{U\,E}{5q\,f_{cp}}}$

K_{10} = Constant equal to $0.584\sqrt{\frac{2.5E}{f_{cp}}}$

L = Span of a beam or truss, mm

M = Maximum bending moment in beam, N/mm^2

N = Total number of bolts in the joint

n = Shank diameter of the nail, mm

P = Load on bolt parallel to grain, N

p_1 = Ratio of the thickness of the compression flange to the depth of the beam

Q = Statical moment of area above or below the neutral axis about neutral axis, mm^3

q = Constant for particular thickness of plank

q_1 = Ratio of the total thickness of web or webs to the overall width of the beam

R = Load on bolt perpendicular (normal) to grain, N

S = Unsupported overall length of column, mm

t = Nominal thickness of planks used in forming box type column, mm

t' = Thickness of main member, mm

U = Constant for a particular thickness of the plank

V = Vertical end reaction or shear at a section, N

W = Total uniform load, N

x = Distance from reaction to load, mm

γ = A factor determining the value of form factor K_4

δ = Deflection at middle of beam, mm

θ = Angle of load to grain direction

Z = Section modulus of beam, mm^3

λ_1 = Percentage factor for t'/d_3 ratio, parallel to grain

λ_2 = Percentage factor for t'/d_3 ratio, perpendicular to grain

4 MATERIALS

4.1 Species of Timber

The species of timber recommended for structural purposes are given in Table 1.

4.1.1 *Grouping*

Species of timber recommended for constructional purposes are classified in three groups on the basis of their strength properties, namely, modulus of elasticity (E) and extreme fibre stress in bending and tension (f_b).

The characteristics of these groups are as given below:

Group A — E above 12.6×10^3 N/mm^2 and f_b above 18.0 N/mm^2.

Group B — E above 9.8×10^3 N/mm^2 and up to 12.6×10^3 N/mm^2 and f_b above 12.0 N/mm^2 and up to 18.0 N/mm^2.

Group C — E above 5.6×10^3 N/mm^2 and up to 9.8×10^3 N/mm^2 and f_b above 8.5 N/mm^2 and up to 12.0 N/mm^2.

NOTE — Modulus of elasticity given above is applicable for all locations and extreme fibre stress in bending is for inside location.

4.1.2 Timber species may be identified in accordance with good practice [6-3A(3)].

4.2 The general characteristics like durability and treatability of the species are also given in Table 1. Species of timber other than those recommended in Table 1 may be used, provided the basic strength properties are determined and found in accordance with **4.1.1**.

NOTE For obtaining basic stress figures of the unlisted species, reference may be made to the Forest Research Institute, Dehra Dun.

4.3 The permissible lateral strength (in double shear) of mild steel wire shall be as given in Table 2 and Table 3 for different species of timber.

4.4 Moisture Content in Timber

The permissible moisture content of timber for various positions in buildings shall be as given in Table 4.

4.5 Sawn Timber

4.5.1 *Sizes*

Preferred cut sizes of timber for use in structural components shall be as given in Tables 5 to 7.

4.5.2 *Tolerances*

Permissible tolerances in measurements of cut sizes of structural timber shall be as follows:

a) For width and thickness:

1) Up to and including 100 mm $^{+3}_{-0}$ mm

2) Above 100 mm $^{+6}_{-3}$ mm

b) For length $^{+10}_{-0}$ mm

4.6 Grading of Structural Timber

4.6.1 Cut sizes of structural timber shall be graded, after seasoning, into three grades based on permissible defects given in Table 8:

a) Select Grade
b) Grade I
c) Grade II

4.6.2 The prohibited defects given in **4.6.2.1** and permissible defects given in **4.6.2.2** shall apply to structural timber.

4.6.2.1 *Prohibited defects*

Loose grains, splits, compression wood in coniferous species, heartwood rot, sap rot, crookedness, worm holes made by powder post beetles and pitch pockets shall not be permitted in all the three grades.

4.6.2.2 *Permissible defects*

Defects to the extent specified in Table 8 shall be permissible.

NOTE — Wanes are permitted provided they are not combined with knots and the reduction in strength on account of the wanes is not more than the reduction with maximum allowable knots.

4.6.3 *Location of Defects*

The influence of defects in timber is different for different locations in the structural element. Therefore, these should be placed during construction in such a way so that they do not have any adverse effect on the members, in accordance with good practice [6-3A(5)].

4.7 Suitability

4.7.1 *Suitability in Respect of Durability and Treatability for Permanent Structures*

There are two choices as given in **4.7.1.1** and **4.7.1.2**.

4.7.1.1 *First choice*

The species shall be any one of the following:

a) Untreated heartwood of high durability. Heartwood if containing more than 15 percent sap wood, may need chemical treatment for protection;
b) Treated heartwood of moderate and low durability and class 'a' and class 'b' treatability;
c) Heartwood of moderate durability and class 'c' treatability after pressure impregnation; and
d) Sapwood of all classes of durability after thorough treatment with preservative.

4.7.1.2 *Second choice*

The species of timber shall be heartwood of moderate durability and class 'd' treatability.

4.7.2 Choice of load-bearing temporary structures or semi-structural components at construction site

a) Heartwood of low durability and class 'e' treatability; or
b) The species whose durability and/or treatability is yet to be established, as listed in Table 1.

4.8 Fastenings

All structural members shall be framed, anchored, tied and braced to develop the strength and rigidity necessary for the purposes for which they are used.

Table 1 Safe Permissible Stresses for the Species of Timber

[*Clauses* 4.1, 4.2, 4.7.2 (b), 5.4.1, 5.4.2 *and* 6.5.8.3.1 (b)]

Species		Locality from Where Tested	Average Density at 12 percent Moisture Content	Modulus of Elasticity (All Grades and All Locations $\times 10^3$	Permissible Stress in N/mm^2 for Grade I											Preservative Characters		
					Bending and Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			†Durability Class	‡Treatability Grade	§Refracteriness to All Seasoning
Botanical Name	Trade Name		kg/m^3	N/mm^2	Inside Location	Outside Location	Wet Location	Horizontal	Along Grain	Inside Location	Outside Location	Wet Location	Inside Location	Outside Location	Wet Location			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
GROUP A																		
Acacia catecthu	Khair (KHA)	U.P.	1 009	13.44	20.1	16.8	13.4	1.6	2.2	13.8	12.3	10.1	7.7	6.0	4.9	I	—	A
Acacia chundra	Red kutch	M.P.	1 086	16.79	26.5	22.0	17.6	2.2	3.2	17.9	15.9	13.0	10.9	8.4	6.9	—	—	A
Albizia odoratissima	Kala siris (KSI)	Chennai	737	13.54	18.7	15.6	12.5	1.5	2.2	13.3	11.8	9.6	7.3	5.6	4.6	I	e	B
Bruguiera spp.	Bruguiera (BSV) (Mangrove)	Andmans	897	17.68	21.9	18.3	14.6	1.2	1.7	14.3	12.7	10.4	5.5	4.3	3.5	III	—	—
Grewia tilifolia	Dhaman (DHA)	Chennai	788	14.82	18.3	15.2	12.2	1.3	1.9	12.0	10.7	8.7	6.0	4.7	3.8	III	d	B
Hopea utilis (Balano carpus utilis)	Karung	Chennai	987	16.91	25.1	20.9	16.7	1.5	2.2	16.4	14.6	11.9	9.3	7.3	5.9	—	—	—
Hopea glabra	Hopea (HOP)	Chennai	1 081	14.79	21.3	17.8	14.2	1.5	2.2	14.5	12.9	10.6	9.9	7.7	6.3	I	—	A
Hopea parviflora	Hopea (HOP)	Chennai	923	13.03	18.6	15.5	12.4	1.3	1.8	13.2	11.8	9.6	9.2	7.3	6.0	I	e	A
Manilota polyandra (Syn. Cynometra polyandra)	Ping (PIG)	Assam	903	13.20	19.1	15.9	12.7	1.3	1.8	1.2	10.4	8.5	5.7	4.4	3.6	III	b	A
Mesua ferrea	Mesua (MES)	Assam	965	16.30	23.3	19.4	15.5	1.2	1.8	15.5	13.8	11.3	5.9	4.6	3.7	I	—	A
Mimusops littoralis	Bullet-wood (BUL)	S. Andaman	1 103	17.39	22.7	18.9	15.1	1.5	2.1	14.2	12.7	10.4	11.3	8.8	7.2	I	—	A
Pesciloneuron indicum	Ballagi (BAL)	Chennai	1 139	16.29	22.4	18.7	15.0	1.5	2.2	14.7	13.1	10.7	8.7	6.8	5.5	I	e	A
Pterocarpus Scantalinus	Red sanders (MA)	Chennai	1 121	12.73	25.0	20.9	16.7	1.7	2.5	18.1	16.1	13.2	11.8	9.2	7.5	—	—	A
Sageraea elliptica	Chooi (COC)	Andmans	869	15.06	21.5	17.9	14.3	1.1	1.5	12.5	11.1	9.1	5.3	4.1	3.4	—	—	A
Stereospermun celonoides	Padri (PAD)	Chennai	731	12.94	19.0	15.8	12.7	1.1	1.6	11.9	10.6	8.7	4.0	3.1	2.6	III	—	B
Vitex altissima	Milla (MIL)	Maharashtra	937	13.01	18.2	15.2	12.1	1.2	1.7	12.6	11.2	9.2	9.5	7.4	6.1	I	e	A
GROUP B																		
Albizzia lebbeck	Kokko (KOK)	Andaman	642	11.17	13.4	11.2	9.0	1.1	1.5	9.0	8.0	6.5	4.4	3.4	2.8	I	e	B

Table 1 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Anogeissus latifolia	Dhaura, Axle wood (AXL) (Bakli)	U.P.	892	10.55	16.1	13.4	10.7	1.1	1.6	9.1	8.1	6.6	4.7	3.7	3.0	I	e	A
Artocarpus hirsulus	Aini (AIH)	Chennai	600	10.45	15.0	12.5	10.0	0.7	1.1	10.4	9.2	7.5	3.3	2.6	2.1	I	—	B
Acacia nilotica	Babul (BAB)	U.P.	797	—	—	12.9	10.3	1.4	2.1	8.9	7.9	6.4	5.2	4.0	3.3	I	b	B
Acacia ferruginea	Safed khair	Maharashtra	993	12.28	23.0	19.2	15.3	1.7	2.4	13.9	12.4	10.1	9.9	7.7	6.3	—	—	—
Acrocarpus fraxinifolius	Mundani (MUN)	Chennai	690	12.59	16.1	13.4	10.8	1.2	1.8	10.5	9.4	7.7	4.6	3.6	2.9	III	c	B
Aglaia odulis	Aglaia (AGL)	Assam	815	12.56	18.2	15.2	12.1	1.4	2.0	10.1	8.9	7.3	4.4	3.4	2.8	—	—	A
Anogeissus acuminota	Yon	Orissa	844	11.67	17.6	14.7	11.7	1.3	1.8	10.8	9.6	7.9	5.1	4.0	3.3	—	—	A
Atalantia monophylla	Jungli-nimbu (JHI)	Orissa	897	10.31	16.7	13.9	11.1	1.5	2.1	11.3	10.0	8.2	6.3	4.9	4.0	—	—	—
Altingia excelsa	Jutili (JUT)	Assam	795	11.37	17.1	14.3	11.4	1.2	1.8	11.0	9.8	8.0	6.8	5.3	4.4	II	e	A
Amoora spp.	Amari (AMA)	W. Bengal	625	1.05	13.4	1.1	9.2	0.9	1.3	8.4	7.4	6.0	3.7	2.9	2.4	II	d	B
Bucklandia populnea (Syn Exbucklandia populnea)	Pipli (PIP)	W. Bengal	672	9.89	12.8	10.7	8.6	1.1	1.5	7.9	7.0	5.7	3.5	2.7	2.2	III	e	C
Cassia fistula	Amaltas (AMT)	U.P.	865	11.80	19.2	16.0	12.8	1.4	2.0	12.3	10.9	8.9	7.2	5.6	4.6	I	—	A
Carallia lucida	Maniawaga	Assam	748	12.60	18.4	15.3	12.3	1.2	1.7	11.4	10.1	8.3	5.9	4.6	3.8	—	—	—
Canarium strictum	Dhup	Chennai	655	11.86	13.3	11.1	8.9	0.9	1.2	8.1	7.2	5.9	2.8	2.2	1.8	III	—	C
Cassia sienea	Kasod	M.P.	820	10.50	15.4	12.8	10.9	1.0	1.4	10.8	9.6	7.9	5.5	4.3	3.5	—	—	—
Casuerina equisetifolia	Casuarina (CAS)	Orissa	769	11.44	14.6	12.2	9.8	1.3	1.8	8.2	7.3	5.9	4.0	3.1	2.5	III	e	A
Celophyllum temculosum	Poon (POO)	Maharashtra	657	9.77	13.4	11.2	9.0	0.8	1.1	8.6	7.7	6.3	2.8	2.2	1.8	II	—	B
Chloroxylon swielenia	Satin wood (CFI)	M.P.	865	11.69	18.2	15.1	12.1	1.4	2.0	10.9	9.7	8.0	6.3	4.9	4.0	III	—	A
Cullenia resayoana (Syn C. execelsa)	Karani (KAP)	Chennai	625	12.43	14.7	12.3	9.8	0.6	0.9	9.0	8.0	6.6	2.7	2.1	1.7	III	b	C
Diploknema butyracea (Syn Bassia butyrance)	Hill mahua (HMA)	S. Andaman	780	10.64	15.3	12.8	10.2	1.0	1.5	9.9	8.8	7.2	6.6	5.2	4.2	—	—	—
Dyscxylum malebaricum	White ceda (WCE)	Chennai	745	10.92	13.2	11.0	8.8	1.0	1.4	8.0	7.1	5.8	3.1	2.4	1.9	I	—	B
Dipterocarpus grandiflorus	Gurjan (GUR)	N. Andaman	758	11.71	12.5	10.5	8.4	0.8	1.1	7.9	7.1	5.8	2.7	2.1	1.7	I	—	B
Dipterocarpus macrocarpus	Hollong (HOL)	Assam	726	13.34	14.5	12.0	9.6	0.8	1.1	8.8	7.9	6.4	3.5	2.7	2.2	III	a	B
Dichopsis polyantha (Syn Palaquium polyanthum)	Tali (TAL)	Assam	734	11.24	14.9	12.4	10.0	1.1	1.6	9.9	8.8	7.2	4.7	3.7	3.0	—	—	B
Dichopsis elliptica (Syn Palaquium ellipticum)	Pali (PAL)	Chennai	606	11.86	13.9	11.6	9.3	0.7	1.0	8.5	7.5	6.2	2.9	2.2	1.8	I	e	B
Diospyros micropylla	Ebony (EBO)	Maharashtra	776	12.15	14.2	11.9	9.5	0.9	1.3	8.3	7.3	6.0	3.3	2.6	2.1	—	—	A
Diospyros pyrrhocarpus	Ebony (EBO)	N. Andaman	843	9.93	13.5	11.2	9.0	1.0	1.4	7.9	7.0	5.7	4.0	3.1	2.5	III	—	A
Dipterocarpus bourdilloni	Gurjan (GUR)	Kerala	699	12.71	13.6	11.3	9.0	0.7	1.0	7.8	6.9	5.7	2.5	1.9	1.6	—	—	B
Eucalyptus globulus	Eucalyptus (Blue gum) (BLN)	Chennai	912	14.83	15.9	13.2	10.6	10.3	1.5	9.0	8.0	6.5	3.4	2.6	2.1	I	e	A
Eucalyptus ougenioides	Eucalyptus	Chennai	853	11.47	16.4	13.6	10.9	1.2	1.7	11.3	10.0	8.2	7.6	5.9	4.8	—	—	—

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Eugenia gardnery	Jaman (JAM)	Chennai	952	11.94	14.8	12.3	9.8	1.1	1.6	9.2	8.2	6.7	5.8	4.5	3.7	III	d	--
Eugenia jambolana	Jaman (JAM)	U.P.	778	10.94	16.0	13.3	10.6	1.2	1.7	9.7	8.6	7.1	4.7	3.7	3.0			
Gluta travancorice	Gluta (GLU)	Chennai	726	12.73	13.5	11.3	9.0	0.9	1.3	9.0	8.0	6.6	4.0	3.1	2.5	I	—	A
Grewia veslita	Dhaman (DHA)	W. Bengal	758	12.00	15.4	12.6	10.3	1.4	2.0	9.1	8.1	6.6	4.1	3.2	2.6	III	d	B
Heritiera spp.	Sundri (SUN)	Assam	872	13.37	17.9	14.9	11.9	1.3	1.8	11.0	9.8	8.0	6.5	5.0	4.1	I	—	A
Kingiodendron pinnatum (Syn Hardwickia pinnata)	Piney (PIN)	Chennai	617	10.62	13.2	11.0	8.8	0.4	1.3	8.2	7.3	6.0	2.9	2.2	1.8	—	—	B
Kayea floribund	Karal	Assam	813	10.88	16.8	14.0	1.1	1.1	1.6	10.1	9.0	7.3	4.4	3.4	2.8	III	—	—
Lagerstromia lanceolata	Benteak (BEN)	Chennai	617	10.76	12.7	10.6	8.5	0.8	1.2	8.2	7.3	5.9	3.4	2.6	2.2	I	e	B
Lagerstromia parviflora	Lendi (LEN)	U.P.	734	10.97	14.3	11.9	9.5	1.1	1.6	8.7	7.7	6.3	3.7	2.9	2.4	I	e	A
Mimusops elengi	Bakul (BKL)	Chennai	885	12.39	17.3	14.4	11.5	1.3	1.8	11.0	9.8	8.0	5.6	4.3	3.6	I	—	A
Machilus macrantha	Machilus (MAC)	W. Bengal	692	10.00	12.4	10.3	8.3	1.0	1.5	8.2	7.3	6.0	3.5	2.7	2.2	III	e	B/C
Miliuse tyomentosa (Syn Saccopapetalum tomentosum)	Hoom (HOO)	Maharashtra	745	11.06	14.8	12.3	9.9	0.9	1.3	9.7	8.6	7.0	3.5	2.7	2.2	III	—	B
Pommetia pinnata	—	Andaman	788	12.90	14.3	11.9	9.5	1.1	1.6	9.1	8.0	6.6	4.0	3.1	2.5	—	—	—
Pterocarpus dolbergioides	Padauk (PAD)	N. Andaman	721	11.24	17.1	14.3	11.4	1.0	1.5	12.0	10.7	8.7	5.5	4.3	3.5	I	c	B
Mesua assamica	Kayea	Assam	842	12.83	17.4	14.5	11.6	1.0	1.4	11.7	10.4	8.5	5.3	4.1	3.3	II	e	—
Pterocarpus marsupium	Bijasal (BIJ)	Maharashtra	803	10.25	14.9	12.4	9.9	0.9	1.3	9.1	8.1	6.6	4.1	3.2	2.6	I	e	B
Fraxinus macrantha	Ash (ASH)	U.P.	712	10.69	15.0	12.5	10.0	1.2	1.7	8.5	7.6	6.2	4.3	3.3	2.7	III	—	B
Fraxinus execlsior	Ash (ASH)	Punjab	719	10.41	14.8	12.3	9.8	1.2	1.7	8.1	7.2	5.8	3.3	2.6	2.1	III	—	B
Planchonia valida (Syn P. andamanica)	Red bombwe (RBO)	Andaman	913	13.10	16.1	13.4	10.7	1.0	1.4	10.8	9.6	7.9	4.9	3.8	3.1	III	—	—
Quercus lamellosa	Oak	W. Bengal	87	12.44	14.5	12.1	9.7	1.2	1.7	8.7	7.8	6.4	3.8	2.9	2.4	II	c	A
Quercus griffithii	Oak	Meghalaya	974	10.06	13.1	10.9	8.8	1.1	1.6	8.0	7.1	5.8	4.6	3.6	2.9	—	—	A
Quercus incana	Oak	Punjab	1008	10.82	15.8	13.1	10.5	1.2	1.8	8.7	7.8	6.3	5.0	3.9	3.2	—	—	A
Quercus lineate	Oak	W. Bengal	874	12.63	15.2	12.7	10.1	1.2	1.7	9.6	8.6	7.0	5.3	4.1	3.4	II	c	A
Quercus semecarpifolia	—	Punjab	834	11.58	15.8	13.1	10.5	1.3	1.8	8.3	7.3	6.0	3.8	2.9	2.4	—	—	A
*Shorea robusta**	Sal (SAL)	M.P.	805	12.67	16.9	14.0	11.2	0.9	1.3	10.6	9.4	7.7	4.6	3.5	2.9	I	e	A
Soymida fabrifuga	Rohini (ROH)	Chennai	1116	12.22	21.5	17.9	14.4	1.6	2.3	15.0	13.3	10.9	12.9	10.0	8.2	I	—	A
Shorea talura	—	Maharashtra	721	12.20	16.8	14.0	11.2	1.1	1.6	12.6	11.2	9.2	6.8	5.3	4.3	—	—	—
Plerygota alata (Syn. Sterculia alata)	Nariket (NAR)	Assam	593	10.95	13.4	11.8	8.9	0.8	1.2	8.2	7.3	6.0	2.7	2.1	1.7	III	—	C
Syzygium cumini	Jaman (JAM)	Assam	841	10.55	14.8	12.4	9.9	1.1	1.6	9.0	8.0	6.5	6.9	5.4	4.4	II	e	A
Terminalia bellirica	Bahera (BAH)	U.P.	729	10.19	13.6	11.3	9.0	1.0	1.4	8.4	.7.5	6.1	3.7	2.8	2.3	III	b	B
Terminalia chebula	Myrobalan (MYR)	—	918	12.37	17.1	14.2	11.4	1.1	1.6	1.2	10.4	8.5	6.7	5.2	4.3	II	c	A

Table 1 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Terminalia citrina	—	Assam	755	11.89	17.1	14.3	11.4	1.1	1.6	10.8	9.6	7.9	5.0	3.9	3.2	—	—	—
Terminalia manii	Black-chuglam (BCH)	S. Andaman	822	12.66	16.8	14.0	11.2	1.1	1.6	10.3	9.2	7.5	5.1	4.0	3.2	II	a	B
Tectona grandis	Teak (TEA)	U.P.	660	9.97	15.5	12.9	10.3	1.2	1.6	9.4	8.3	6.8	4.5	3.5	2.8	I	e	B
Terminalia paniculate	Kindal (KIN)	Maharashtra	765	10.57	13.1	10.9	8.7	0.9	1.3	8.6	7.7	6.3	3.6	2.8	2.3	I	c	A
Alreminalia alata	Laurel (LAU), Sain	Chennai	906	10.54	15.1	12.5	10.0	1.1	1.6	9.4	8.4	6.8	6.2	4.8	4.0	I	b	A
Terminalia bilata	White-chuglam (WCH)	S. Andaman	690	12.38	15.5	13.0	10.4	0.9	1.2	9.8	8.7	7.1	3.6	2.8	2.3	III	e	B
Thespesia populnea	Bhendi (BHE)	Maharashtra	766	10.36	18.9	15.8	12.6	1.3	1.9	11.3	10.0	8.2	4.4	3.4	2.8	—	—	B
Xylia xylocarpa	Irul (IRU)	Maharashtra	839	11.63	16.2	13.5	10.8	1.3	1.8	10.9	9.7	7.9	7.8	6.0	4.9	I	e	A
Zanthoxylum budranga	Mullilam (MUL)	W. Bengal	587	10.65	14.7	12.2	9.8	0.9	1.2	9.5	8.4	6.9	3.4	2.6	2.1	I	e	B
Adina oligocephala	—	Arunachal	715	11.17	15.2	12.7	10.1	1.2	1.7	10.3	9.2	7.5	4.0	3.1	2.4	—	—	—
Castanopsis indica	Chestnut	Meghalaya	688	12.54	14.8	12.3	9.9	1.0	1.4	9.8	8.7	7.1	3.4	2.7	2.2	—	—	B
Eucalyptus citriodara	Eucalyptus	Nilgiri	831	12.12	17.3	14.4	11.5	1.4	2.0	11.0	9.8	8.0	4.2	3.3	2.7	—	—	—
Eucalyptus citriodata	Eucalyptus	Ooty	725	9.35	15.4	12.9	10.3	1.0	1.4	8.6	7.6	6.3	3.0	2.4	2.0	—	—	—
Eucalytus tereticornis	Eucalyptus	Chennai	777	11.05	16.7	13.9	11.1	1.0	1.4	9.7	8.6	7.1	3.4	2.6	2.2	III	c	—
GROUP C																		
Tbizia procera	White siris	U.P.	643	9.02	13.4	11.2	8.9	1.0	1.4	8.5	7.6	6.2	4.3	3.3	2.7	I	c	B
Artocarpus lakocha	Lakooch (LAK)	U.P.	647	6.14	10.0	8.3	6.7	1.0	1.4	5.3	4.7	3.8	2.8	2.2	1.8	I	—	B
Artocarpus hetarophyllus (Syn. A. Integrifolia)	Jack, kathal (KAT)	Chennai	617	9.46	13.9	11.6	9.2	1.0	1.5	9.3	8.3	6.8	4.5	3.5	2.9	I	d	B
Aphanamixis polystachya (Syn. Amoora rehituka)	Pitraj (PIT)	West Bengal	668	8.98	12.3	10.2	8.2	1.1	1.5	8.0	7.1	5.8	4.0	3.1	2.6	I	—	B
*Adina cordifolia**	Haldu (HAL)	U.P.	663	8.54	13.3	11.1	8.9	1.0	1.4	8.7	7.7	6.3	4.4	3.4	2.8	III	a	B
Anthocephyalus chinensis (Syn. A. Cadamba)	Kadam (KAD)	—	485	1.88	9.7	8.1	5.4	0.7	1.0	5.9	5.3	4.3	1.9	1.5	1.2	III	a	—
Arlocarpus chaplasha	Chaplash (CHP)	Assam	515	9.11	13.2	11.0	8.8	0.9	1.2	8.5	7.5	6.2	3.6	2.8	2.3	III	d	B
Acacia leucophloea	Hiwar (HIW)	M.P.	737	7.85	13.4	11.2	9.0	1.0	1.5	7.5	6.7	5.4	4.5	3.5	2.8	—	—	A
Acacia melanoxylone	Black wood	Chennai	630	9.45	13.0	10.8	8.7	1.1	1.5	7.6	6.8	5.5	3.2	2.5	2.0	—	—	—
Acacia mearnsii (Syn. A. mollissima)	Black wattle	Chennai	669	6.10	10.4	8.6	6.9	0.8	1.2	6.0	5.4	4.4	2.3	1.8	1.5	—	—	—
Accer spp.	Maple (MAP)	Punjab, U.P.	551	7.35	9.9	8.2	6.5	0.9	1.3	5.5	4.9	4.0	2.1	1.7	1.4	III	—	B
Aegla marmalos (Syn. Intsia bijuga)	Bael (BEL)	U.P.	890	8.81	13.5	11.2	9.0	1.4	2.0	8.8	7.8	6.4	6.8	5.3	4.3	III	—	B
Afzelia bijuga	—	Andaman	705	9.16	13.2	11.0	8.8	1.1	1.5	7.9	7.1	5.8	4.0	3.1	2.6	—	—	—
Ailanthus grandis	Gokul (GOK)	W. Bengal	404	7.94	8.3	6.9	5.5	0.6	0.8	5.3	4.7	3.9	1.1	0.9	0.7	III	—	C
Anogeissus pendula	Kardhai (KAH)	U.P.	929	9.75	17.0	14.2	11.4	1.3	1.8	9.8	8.7	7.1	6.5	5.1	4.2	III	—	A
Areca nut	—	Kerala	833	9.48	15.2	12.7	10.2	1.2	1.6	10.8	9.6	7.8	7.3	5.7	4.7	—	—	—

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Albizia lucida	—	Arunachal, A.P.	566	8.51	10.7	8.9	7.1	8.2	1.2	7.3	6.3	5.3	2.3	1.8	1.5	—	—	—
Azadirachta indica	Neem (NEE)	U.P.	836	8.52	14.6	12.1	9.7	1.3	1.8	10.0	8.9	7.3	5.0	3.9	3.2	—	—	—
Boswellia seriata	Salai (SAA)	Bihar	551	7.21	9.4	7.9	6.3	0.7	1.1	5.5	4.9	4.0	2.1	1.6	1.3	I	e	C
Bridelia retusa	Kassi (KAS)	Bihar	584	9.42	11.6	9.7	7.7	0.9	1.3	7.1	6.3	5.1	4.0	3.1	2.6	I	e	B
Betula lnoides	Birch (BIR)	West Bengal	625	9.23	9.6	8.0	6.4	0.8	1.1	5.7	5.0	4.1	2.2	1.7	1.4	—	—	B
Bischofia javanica	Uriam Bishopwood (URI)	Chennai	769	8.84	9.6	8.2	6.5	0.8	1.1	5.9	5.3	4.3	3.6	2.8	2.3	III	—	A
Burserra serrata (Syn. Protium serratum)	Muntenga (MUR)	A.P.	756	1.17	15.5	13.3	10.5	0.9	1.3	10.1	9.0	7.4	5.3	4.1	3.4	II	c	—
Careya arbersa	Kumbi (KUM)	U.P.	889	8.37	13.1	10.9	8.8	1.0	1.5	7.7	6.8	5.6	5.3	4.1	3.4	I	e	A
Cedrus deodara	Deodar (DEO)	H.P.	557	9.48	10.2	8.7	7.2	0.7	1.0	7.8	6.9	5.7	2.7	2.1	1.7	I	c	C
Cupressus torulosa	Cypress (CYP)	U.P.	506	8.41	8.8	7.6	6.2	0.6	0.8	6.9	6.2	5.0	2.4	1.8	1.5	I	e	C
Castanopsis hystrix	Indian chestnut (ICH)	West Bengal	624	9.85	10.6	8.8	7.0	0.8	1.2	6.4	5.7	4.6	2.7	2.1	1.7	II	b	B
Chukrasia velutina (Syn. C. Tabularis)	Chickrassy (CHI)	West Bengal	666	8.35	11.8	9.8	7.9	1.1	1.5	7.1	6.3	5.2	3.9	3.1	2.5	II	c	B
Calophyllum wightianum	Poon (POO)	Maharashtra	689	8.68	13.5	11.2	9.0	1.0	1.4	8.7	7.8	6.4	4.0	3.1	2.5	II	—	B
Canarium strictum	White dhup	Assam	569	10.54	10.1	8.4	6.7	0.7	1.1	6.2	5.5	4.5	2.1	1.6	1.3	III	—	C
Chlorophora excelsa	—																	
Cocosnucifera	Coconut (COC)	Kerala	761	7.34	9.2	7.7	6.1	0.7	1.1	9.5	8.4	6.9	3.9	3.0	2.5	—	—	—
Dalbergia latifolia	Rosewood (ROS)	M.P.	884	8.39	12.9	10.8	8.6	1.1	1.6	8.0	7.1	5.8	4.2	3.3	2.7	I	—	B
Dalbergia sissee	Sisso (SIS)	Punjab	799	7.14	12.8	10.7	8.5	1.3	1.8	8.2	7.3	6.0	4.2	3.3	2.7	I	e	B
Dillemia indica	Dillenia (DIL)	West Bengal	617	8.61	12.1	10.0	8.0	0.8	1.2	7.3	6.5	5.3	2.7	2.1	1.7	III	a	B
Dillenia pentagyne	Dillenia (DIL)	West Bengal	622	7.56	11.8	9.9	7.9	0.9	1.3	7.1	6.3	5.2	3.5	2.7	2.2	III	d	B
Diospyres melanoxylon	Ebony (EBO)	Maharashtra	818	7.69	10.9	9.1	7.3	0.9	1.2	7.0	6.2	5.1	3.3	2.6	2.1	II	—	A
Duabanga grandiflora (Syn. D. Sonneratioides)	Lampati (LAP)	West Bengal	485	8.38	9.8	8.2	6.5	0.6	0.9	6.4	5.7	4.7	1.8	1.4	1.1	III	c	C
Elesocarpus tuberculatus	Rudrak (RUD)	Chennai	466	8.74	9.7	8.1	6.4	0.7	1.0	6.3	5.6	4.6	2.0	1.5	1.3	—	—	C
Eucalyptus hybrid	Mysore gum (MGU)	Chennai	753	6.00	10.2	8.5	6.8	0.9	1.2	7.3	6.5	5.3	4.0	3.1	2.5	III	e	—
Calitres rhomboidea (Syn. Frenela rhomboidea)	—	Chennai	607	6.48	9.2	7.7	6.1	0.7	1.0	6.9	6.1	5.0	4.0	3.1	2.6	—	—	—
Garuga pinnata	Garuga (GAU)	U.P.	571	7.58	11.7	9.7	7.8	1.0	1.5	7.2	6.4	5.3	3.4	2.6	2.1	I	e	B
gGmeline arborea	Gamari (GAM)	U.P.	501	7.02	9.8	8.2	6.6	0.8	1.2	5.7	5.0	4.1	4.2	3.2	2.7	I	e	B
Gardonia latifolia	Gardenia (GAI)	M.P.	705	7.13	14.1	11.7	9.4	1.2	1.7	8.4	7.4	6.1	4.6	3.6	3.0	—	—	—
Hardwickis binata	Anjan (ANJ)	M.P.	852	6.64	14.1	11.8	9.4	1.3	1.8	9.0	8.0	6.5	7.4	5.6	4.7	I	e	—
Heloptelea integrifolia	Kanju (KAN)	U.P.	592	7.46	12.0	10.0	8.0	0.9	1.3	6.7	6.0	4.9	2.8	2.2	1.8	III	b	B

Table 1 — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Heterrophragma rexburghii	Palang (PAL)	M.P.	616	8.69	12.3	10.2	8.2	0.7	1.0	7.9	7.0	5.7	3.4	2.6	2.1	—	—	—
Juglans spp.	Walnut (WAL)	U.P.	565	9.00	9.9	8.3	6.6	0.9	1.2	5.8	5.2	4.2	2.2	1.7	1.4	III	—	B
Lagerstrosmia speciosa (Syn. L. flesregihal)	Jarul (JAAR)	N. Andaman	622	8.53	12.1	10.1	8.1	0.8	1.8	7.7	6.8	5.6	3.4	2.6	2.2	II	e	B
Lannea grandis (Syn. L.coromandelica)	Jhingan (JHI)	U.P.	557	5.63	8.5	7.1	5.7	0.6	0.9	4.9	4.4	3.6	2.2	1.7	1.4	III	e	B
Leucanena leucocephala	Subabul (SUB)	U.P.	673	6.32	11.6	9.7	7.8	1.0	1.5	7.4	6.6	5.4	3.8	3.0	2.4	—	—	
Lophopatalum wightianum	Banati (BAN)	Chennai	460	7.33	8.5	7.5	5.6	0.5	0.8	5.3	4.7	3.8	1.8	1.4	1.1	III	—	C
Madhuca longifolia varlatifolia (Syn. Bassia latifolia)	Mahua (MAU)	M.P.	936	8.82	13.0	10.8	8.7	1.0	1.4	7.5	6.7	5.5	6.3	4.9	4.0	I	e	A
Mangifera indica	Mango, Aam (MAN)	Orissa	661	9.12	12.2	10.2	8.2	1.0	1.4	7.3	6.5	5.3	3.1	2.4	2.0	III	a	C
Machilus macrantha	Machilus (MAC)	Chennai	521	7.63	10.2	8.5	6.8	0.7	1.0	6.3	5.6	4.6	2.4	1.9	1.5	III	e	B
Mallotus philippinensis	Raini (RAI)	U.P.	662	7.51	10.8	9.0	7.2	1.0	1.4	6.0	5.4	4.4	2.9	2.3	1.8	III	—	B
Manglietia insignia	—	Assam	449	10.37	10.9	9.1	7.3	0.7	1.0	8.0	7.1	5.8	3.4	2.6	2.1	—	—	—
Michelia montana	Champ (CHM)	West Bengal	512	8.25	10.9	9.1	7.3	0.7	1.0	6.6	5.9	4.8	2.8	2.2	1.8	I	—	B
Mitragyna pervifolia (Syn. Stephagyne pervifolia)	Kaim (KAI)	U.P.	651	7.82	12.6	10.5	8.4	1.0	1.5	7.9	7.0	5.7	3.7	2.9	2.4	III	b	B
Michelia excelsa	Champ (CHM)	West Bengal	513	10.12	9.8	8.2	6.5	0.7	1.0	6.1	5.5	4.5	1.6	1.3	1.0	II	e	B
Miliusa velutnia	Domsal (DOM)	U.P.	747	7.92	11.7	9.7	7.8	1.1	1.6	7.0	6.3	5.1	3.7	2.9	2.4	III	—	—
Morus alba	Mulberry (MUL)	U.P.	743	8.20	11.8	9.8	7.9	1.0	1.4	6.6	5.8	4.8	3.8	2.9	2.4	II	—	B
Morus serrata	Mulberry (MUL)	H.P.	657	7.03	10.2	8.5	6.8	0.9	1.3	5.6	5.0	4.1	2.6	2.0	1.6	III	—	B
Morus laevigata	Bola (BOL)	Andaman	588	8.61	12.3	10.2	8.2	1.0	1.5	7.2	6.4	5.3	3.3	2.5	2.1	—	—	B
Ougeinia eejeinensis (Syn. O. delbergioides)	Sandan (SAD)	M.P.	784	8.54	13.3	11.1	8.9	1.2	1.7	8.5	7.5	6.2	5.1	3.9	3.2	I	—	B
Phoebe hainesiana	Bonsum (BOH)	Assam	566	9.50	13.2	11.0	8.8	0.8	1.2	8.8	7.8	6.4	2.8	2.1	1.8	II	c	B
Pinus roxburghii (Syn. P. longifolia)	Chir (CHR)	U.P.	525	9.82	8.5	7.3	6.0	0.6	0.9	6.0	5.3	4.4	2.0	1.5	1.3	III	b	C
Pinus wallichiana	Kail (KAL)		515	6.80	6.6	5.6	5.0	0.6	0.8	5.2	4.6	3.8	1.7	1.3	1.0	II	c	C
Phoebe goalperansis	Bonsum (BOH)	Assam	511	7.65	9.7	8.1	6.5	0.7	1.0	6.6	5.9	4.8	2.2	1.7	1.4	II	c	B
Parretiopsis jacquementiena	Rohu Parrotia	H.P.	761	5.77	12.5	10.4	8.3	1.2	1.7	6.8	6.1	5.0	4.0	3.1	2.5	III	—	B
Pinus kesia (Syn. Pinus insularis)	Khasi pine (KPI)	North East	513	7.38	8.9	7.4	5.9	0.6	0.7	5.8	5.2	4.3	1.5	1.2	1.0	III	a	B
Pistacia integerrima	Kikar singhi	J&K	881	7.32	13.1	10.9	8.7	1.2	1.7	8.0	7.1	5.8	4.3	3.4	2.8	—	—	—
Podocarpus nerrifolius	Thitmin (THT)	S. Andaman	533	9.41	12.5	10.4	8.3	6.1	0.9	8.0	7.1	5.8	2.6	2.0	1.6	II	—	—
Polyalthia fragrances	Debdaru (DEB) (Nedunar)	Maharashtra	752	9.15	11.9	9.9	7.9	0.8	1.2	6.7	6.0	4.9	3.0	2.3	1.9	III	—	B
Polyalthia coreoides		M.P.	700	9.29	13.2	11.0	8.8	1.0	1.4	7.1	6.3	5.2	3.2	2.5	2.0	—	—	—

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Prunus napeulensis	Arupati	West Bengal	548	9.41	104.4	8.7	69.6	0.9	1.2	6.7	6.0	4.9	2.4	1.9	1.6	—	—	—
Pterespermum acerifolium	Hattipaila (HAT)	West Bengal	607	9.55	13.5	11.3	9.0	0.9	1.2	8.7	7.7	6.3	3.2	2.5	2.0	III	c	B
Quercus spp.	Oak	North East	657	11.65	11.4	9.5	7.6	0.8	1.2	6.7	5.9	4.8	2.0	1.6	1.3	II	c	B
Raderomachera xylocarpe (Syn. Sterosperam xylocarpum)	Vedankonnai	Chennai	696	8.52	13.2	11.0	8.8	1.1	1.5	9.0	8.0	6.6	4.3	3.3	2.7	II	a	—
Schleichera oleosa (Syn. S. trijuga)	Kusum (KUS)	Bihar	1032	12.12	15.5	13.0	10.4	1.5	2.1	10.9	9.7	7.9	6.1	4.2	3.9	II	a	A
Schima wallichii	Chilauni (CHL)	West Bengal	693	9.57	11.1	9.3	7.4	0.9	1.3	6.6	5.9	4.8	2.3	1.8	1.4	III	d	B
Shotea assamica	Makai (MAK)	Assam	548	9.27	11.1	9.2	7.4	0.9	1.3	7.1	6.3	5.2	2.9	2.2	1.8	III	c	B
Sonneralia apetale	Keora (KEO)	West Bengal	617	8.63	12.8	10.7	8.5	0.9	1.3	7.4	6.6	5.4	4.8	3.7	3.0	II	—	B
Stereospermum suaveolans	Padri (PAD)	U.P.	721	8.86	13.3	11.1	8.9	0.9	1.3	7.3	7.0	5.7	3.5	2.7	2.2	III	—	B
Tactona grandis	Teak (TEA)	M.P.	617	8.49	12.8	10.7	8.5	0.8	1.3	7.9	7.0	5.7	4.0	3.1	2.6	I	e	B
Terminalia arjuna	Arjun (ARJ)	Bihar	794	7.71	12.2	10.2	8.2	1.1	1.6	7.4	6.6	5.4	5.2	4.1	3.3	II	b	B
Terminalia myriocarpa	Hollock (HOC)	Assam	615	9.62	11.9	9.9	8.0	0.9	1.2	7.6	6.7	5.5	2.9	2.2	1.8	III	a	B
Terminalia procera	White bombwae (WBO)	N.Andaman	626	8.99	11.8	9.8	7.9	0.9	1.3	7.2	6.4	5.3	3.0	2.3	1.9	III	b	B
Taxus buccata	Yew (YEW)	West Bengal	705	7.79	14.3	11.9	9.5	1.2	1.7	8.7	7.8	6.4	4.7	3.7	3.0	—	—	—
Tamarindus indica	Imli (IML)	Chennai	913	5.63	11.4	9.5	7.6	1.2	1.7	7.0	6.2	5.1	5.3	4.1	3.4	—	—	B
Toena ciliata	Toon (TOO)	U.P.	487	6.40	8.7	7.3	5.8	0.7	1.0	5.4	4.8	3.9	2.4	1.8	1.5	II	c	B
Vateria indica	Vellapine (VEL)	Chennai	535	10.95	11.5	9.6	7.6	0.7	1.1	7.5	6.7	5.5	2.3	1.8	1.4	III	e	C
Aeculas indica	Horse chestnut (HCH)	U.P.	484	7.55	8.5	7.1	5.7	0.8	1.1	4.8	4.2	3.5	1.8	1.4	1.1	—	—	B
Borassus flabelsfer	Tad (Palmyra) (TAD)	A.P.	838	8.79	10.5	8.8	7.0	0.7	1.0	10.0	8.8	7.2	4.7	3.6	2.7	—	—	—
Eucalyptus cemaldulensis	Eucalyptus	Karnataka	804	9.53	12.8	10.6	8.5	0.8	1.1	7.2	6.4	5.2	3.5	2.7	2.2	—	—	A
Eucalyptus camaldulenis	Eucalyptus	U.P.	781	7.03	12.4	10.4	8.3	1.1	1.6	7.9	7.0	5.7	3.5	2.8	2.3	—	—	A
Eucalyptus pilularia	Eucalyptus	T.N.	713	9.22	14.8	12.3	11.1	1.0	1.4	8.5	7.6	6.2	2.8	2.2	1.8	—	—	A
Eucalyptus propingus	Eucalyptus	T.N.	584	7.93	12.8	10.7	8.5	0.8	1.2	8.0	5.4	4.4	2.5	1.9	1.6	—	—	A
Eucalyptus saligna	Eucalyptus	U.P.	819	8.24	11.5	9.6	7.6	1.5	2.1	8.2	7.3	6.0	6.2	4.8	4.0	—	—	A

* Species thus marked and tested from other localities show higher strength to enable their categorization in higher group.

For Example

i) Sal tested from West Bengal, Bihar, U.P. and Assam can be classified as Group 'A' species;

ii) Haldu tested from Bihar can be classified as Group 'B' species;

iii) Morus laevigate (Bole) of Assam can be classified in Group 'B' species.

Table 1 — *Concluded*

† Classification for preservation based on durability tests, etc.

Class

I – Average life more than 120 months;

II – Average life 60 months and above but less than 120 months; and

III – Average life less than 60 months.

‡ Treatability Grades

a – Heartwood easily treatable;

b – Heartwood treatable, but complete penetration not always obtained; in case where the least dimension is more than 60 mm;

c – Heartwood only partially treatable;

d – Heartwood refractory to treatment; and

e – Heartwood very refractory to treatment, penetration of preservative being practically nil even from the ends;

Data based on strength properties at three years of age of tree.

§ Classifications based on seasoning behaviour of timber and refractoriness *w.r.t.* cracking, spliting and drying rate:

A – Highly refractory (slow and difficulty to season free from surface and end cracking);

B – Moderately refractory (may be seasoned free from surface and end cracking within reasonably short periods, given a little protection against rapid drying conditions); and

C – Non-refractory may be rapidly seasoned free from surface and end-cracking even in the open air and sun. If not rapidly dried, they develop blue stain and mould on the surface.

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength per Nail (for Both Lengthening Joints and Node Joints)
	Botanical Name	Trade Name	Lengthening Joints $N \times 10^2$	Node Joints $N \times 10^2$	$N \times 10^2$
(1)	(2)	(3)	(4)	(5)	(6)
1.	*Albies pindrow*[1]	Fir	8	2	12
2.	*Acacia nilotica*	Babul	15	11	34
3.	*Acrocarpus fraxinifolius*	Mundani	18	9.5	19.5
4.	*Adina cordifolia*	Haldu	23.5	10	22
5.	*Albizia lebbeck*	Kokko	20	7	24
6.	*Albizia odoratissima*	Kala Siris	14	5	22
7.	*Anogeissus latifolia*	Axlewood	20	10	29
8.	*Aphanamixis polystachya*	Pitraj	19	9	19
9.	*Calophyllum spp.*[1]	Poon	16	9	21
10.	*Canarium euphyllum*	White dhup	9	8	10.5
11.	*Castanopsis spp.*	Indian chestnut	18	10.5	23.5
12.	*Cedrus deodara*[1]	Deodar	9	4	15
13.	*Chukrasia tabularis*	Chikrassy	24	8	27
14.	*Cinnamomum spp.*[1]	Cinnomon	12	9	13
15.	*Cupressus torulosa*	Cypress	6	5	18
16.	*Dipterocarpus macrocarpus*	Hollong	17	7	20
17.	*Dipterocarpus spp.*	Gurjan	19	9	19
18.	*Dillenia pertagyna*	Dillenia	16.5	12	16
19.	*Diospyros melanoxylon*	Ebony	26.5	10	30.5
20.	*Eucalyptus eugenioides*	Eucalyptus	17	10	30
21.	*Grewia tilifolia*[1]	Dhaman	13	5	24
22.	*Lagerstroemia spp.*	Jarul	24.5	21.5	22.5
23.	*Hopea parviflora*	Hopea	31.5	13	28.5
24.	*Lagerstroemia spp.*[1]	Lendi	19	5	26
25.	*Mangifera indica*	Mango	11	9	16
26.	*Manilkoa polyandra*	Ping	26	23.5	32
27.	*Mesua ferrea*	Mesua	26	8	41
28.	*Michelia spp.*	Champ	13	9	20
29.	*Millingtonia spp.*[1]	—	10.5	6	17
30.	*Morus alba*	Mulberry	13	10.5	22.5
31.	*Melia azedarach*	Persian lilac (bakain)	10.5	2.5	9
32.	*Ougeinia oojeinensis*	Sandan	17	11	18
33.	*Phoebe spp.*[1]	Bonsum	12	6	13
34.	*Pinus roxburghii*[1]	Chir	11	10	16
35.	*Pinus wallichiana*[1]	Kail	7	3	9
36.	*Pterocarpus marsupium*	Bijasal	15	12	27
37.	*Pterocarpus dalbergioides*	Padauk	19	14	23
38.	*Planchonia andamanica*	Red bombwe	14	13	29
39.	*Quercus spp.*	Oak	11	11	27
40.	*Schleichera oleosa*	Kusum	23	16	40
41.	*Shorea roubusta*	Sal (M.P.)	23	15.5	19.5
42.	*Shorea robusta*	Sal	10	5	19
43.	*Stereospenmum*	Padriwood	16	8	19.5
44.	*Syzygium spp.*	Jamun	15	12	25
45.	*Tectona grandis*	Teak	14	8	13
46.	*Terminalia Bellirica*	Bahera	10	10	14
47.	*Terminalia biolata*	White chuglam	18	9	21
48.	*Terminalia procera*	Badam	18	10.5	20
49.	*Terminalia manii*[1]	Black chuglam	23	10	33
50.	*Terminalia myriocarpa*	Hollock	13	10	19
51.	*Terminalia alata*	Sain	16	16	29
52.	*Toona spp.*	Toona	10	8	21
53.	*Xylia xylacarpa*	Irul	23	6	33
54.	*Toona ciliata*	Toon	16	9	21

NOTES

1 Nails of 3.55 mm diameter are most commonly used. The above values can also be used for 4 mm diameter 100 mm long nails.

2 The values in N are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9.806 65 N.

[1] Species requiring no preboring for nail penetration.

Table 3 Permissible Lateral Strengths (in Double Shear) of Nails 5.00 mm Dia, 125 mm and 150 mm Long

(*Clause* 4.3)

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength per Nail (for Both Lengthening Joints and Node Joints)
	Botanical Name	Trade Name	Lengthening Joints	Node Joints	
			$N \times 10^2$	$N \times 10^2$	$N \times 10^2$
(1)	(2)	(3)	(4)	(5)	(6)
1.	*Abies pindrow*[1]	Fir	16.5	4.5	21
2.	*Acacia catechu*	Khair	42	25	71.5
3.	*Acacia nilotica*[1]	Babul	27	13.5	53
4.	*Albizia procera*	Safed siris	35	18	—
5.	*Albizia odoratissima*[1]	Kala siris	27.5	17.5	45
6.	*Alstonia scholaris*	Chatian	9.5	5.5	27
7.	*Anogeissus latifolia*	Axlewood	22.5	13	46.5
8.	*Cupressus torulosa*	Cypress	20	7	27
9.	*Cullenia rosayroana*	Karani	11	9.5	30
10.	*Dalbergia sissoo*	Sissoo	17	15	43
11.	*Diptrocarous spp.*	Gurjan	19.5	9.5	33
12.	*Hardwickia binata*	Anjan	32	19	59
13.	*Hopea perviflora*	Hopea	60.5	25	61.5
14	*Holoptelea integrifolia*	Kanju	18	12.5	37.5
15.	*Mangifera indica*[1]	Mango	22.5	15	32
16.	*Mesua ferrea*	Mesua	24	15.5	57.5
17.	*Michelia champaca*[1]	Champ	26	12.5	39
18.	*Pterocarpus marsupium*	Bijasal	20.5	15	43
19.	*Pinus roxburghii*[1]	Chir	9	6	24
20.	*Shorea robusta (U.P.)*	Sal	19.5	17	37
21.	*Shorea robusta*	Sal	30.5	20	41
22.	*Schleichera oleosa*	Kusum	15	14	55
23.	*Stereospimum personatum*	Padriwood	22	8	34
24.	*Syzygium cumini*	Jamum	18	14.5	38.5
25.	*Terminalia myriocarpa*	Hollock	27.5	9	41
26.	*Tectona grandis*	Teak	28	13	30
27.	*Hopea utilis*	Karung kangoo	31	10	58
28.	*Phoebe spp*[1]	Bonsum	20	7.5	30

NOTES

1 Nails of 5.00 mm diameter are most commonly used.

2 The values in N are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9.806 65 N.

[1] Species requires no preboring for nail penetration.

Table 4 Permissible Percentage Moisture Content Values

(*Clause* 4.4)

Sl No.	Use	Zones (*see* Note)			
		I	II	III	IV
(1)	(2)	(3)	(4)	(5)	(6)
i)	Structural elements	12	14	17	20
ii)	Doors and windows				
	a) 50 mm and above in thickness	10	12	14	16
	b) Thinner than 50 mm	8	10	12	14
iii)	Flooring strips for general purposes	8	10	10	12
iv)	Flooring strips for tea gardens	12	12	14	16

NOTE — The country has been broadly divided into the following four zones based on the humidity variations in the country:

Zone I — Average annual relative humidity less than 40 percent.

Zone II — Average annual relative humidity 40 to 50 percent.

Zone III — Average annual relative humidity 50 to 67 percent.

Zone IV — Average annual relative humidity more than 67 percent.

For detailed zonal classification, tolerances, etc reference may be made to good practice [6-3A(4)].

(*Clause* 4.5.1)

Thickness mm	Width mm							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
20	40	50	60	80	*100*	—	—	—
25	40	50	60	80	100	120	140	160
30	40	50	60	80	100	120	140	160
35	—	—	60	80	100	120	140	160
40	—	—	60	80	100	120	140	160
50	—	—	60	80	100	120	140	160
60	—	—	—	80	100	120	140	160
80	—	—	—	—	100	120	140	160

NOTES

1 For truss spans marginally above 20 m, preferred cut sizes of structural timber may be allowed.

2 Preferred lengths of timber: 1, 1.5, 2, 2.5 and 3 m.

Table 6 Preferred Cut Sizes of Structural Timber for Roof Purlins, Rafters, Floor Beams, Etc

(*Clause* 4.5.1)

Thickness mm	Width mm						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
50	80	100	120	140	—	—	—
60	80	100	120	140	160	—	—
80	—	100	120	140	160	—	—
100	—	—	—	140	160	180	200

NOTE — Preferred lengths of timber: 1.5, 2, 2.5 and 3 m.

Table 7 Preferred Cut Sizes of Structural Timbers for Partition Framing and Covering, and for Centering

(*Clause* 4.5.1)

Thickness mm	Width mm								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
10	40	50	60	80	—	—	—	—	—
15	40	50	60	80	100	—	—	—	—
20	40	50	60	80	100	120	160	200	—
25	40	50	60	80	100	120	160	200	240
30	40	50	60	80	100	120	160	200	240
40	40	—	60	80	100	120	160	200	240
50	—	50	—	80	100	120	160	200	240
60	—	—	60	80	100	120	160	200	240
80	—	—	—	80	100	120	160	200	240

NOTE — Preferred lengths of timber: 0.5, 1, 1.5, 2, 2.5 and 3 m.

Table 8 Permissible Defects for Cut Sizes of Timber for Structural Use

(Clauses 4.6.1 *and* 4.6.2.2)

All dimensions in millimetres.

Sl No.	Defects	Select Grade	Grade I	Grade II
(1)	(2)	(3)	(4)	(5)
i)	Wane	Shall be permissible at its deepest portion up to a limit of 1/8 of the width of the surface on which it occurs	Shall be permissible at its deepest portion up to a limit of 1/6 of the width of the surface on which it occurs	Shall be permissible at its deepest portion up to a limit of 1/4 of the width of the surface on which it occurs
ii)	Worm holes	Other than those due to powder post beetles are permissible	Other than those due to powder post beetles are permissible	Other than those due to powder post beetles are permissible
iii)	Slope of grain	Shall not be more than 1 in 20	Shall not be more than 1 in 15	Shall not be more than 1 in 12

iv) Live knots:

Width of Wide Faces of Cut Sizes of Timber	*Permissible Maximum Size of Live Knot on*		*Permissible Maximum Size of Live Knot on*		*Permissible Maximum Size of Live Knot on*	
Max	Narrow faces and ¼ of the width face close to edges of cut size of timber	Remaining central half of the width of the wide faces	Narrow faces and ¼ of the width face close to edges of cut size of timber	Remaining central half of the width of the wide faces	Narrow faces and ¼ of the width face close to edges of cut size of timber	Remaining central half of the width of the wide faces
(1)	(2)	(3)	(4)	(5)	(6)	(7)
75	10	10	19	19	29	30
100	13	13	25	25	38	39
150	19	19	38	38	57	57
200	22	25	44	50	66	75
250	25	29	50	57	66	87
300	27	38	54	75	81	114
350	29	41	57	81	87	123
400	32	44	63	87	96	132
450	33	47	66	93	99	141
500	35	50	69	100	105	150
550	36	52	72	103	108	156
600	38	53	75	106	114	159

v) Checks and shakes:

Width of the Face of the Timber	*Permissible Depth*	*Permissible Depth*	*Permissible Depth*
Max	*Max*	*Max*	*Max*
(1)	(2)	(3)	(4)
75	12	25	36
100	18	35	54
150	25	50	75
200	33	65	99
250	40	81	120
300	50	100	150
350	57	115	171
400	66	131	198
450	76	150	225
500	83	165	249
550	90	181	270
600	100	200	300

Allowable stresses or loads on joints and fasteners shall be determined in accordance with recognized principles. Common mechanical fastenings are of bar type such as nails and spikes, wood screws and bolts, and timber connectors including metallic rings or wooden disc-dowels. Chemical fastenings include synthetic adhesives for structural applications.

5 PERMISSIBLE STRESSES

5.1 Fundamental stress values of different groups of timber are determined on small clear specimen according to good practice [6-3A(1)]. These values are then divided by the appropriate factors of safety to obtain the permissible stresses. In these values, are then applied, appropriate safety factors given in the relevant table of the accepted standard [6-3A(5)] to obtain the permissible stress.

5.2 The permissible stresses for Groups A, B and C for different locations applicable to Grade I structural timber shall be as given in Table 9 provided that the following conditions are satisfied:

a) The timbers should be of high or moderate durability and be given the suitable treatment where necessary.

b) Timber of low durability shall be used after proper preservative treatment to good practice [6-3A(6)], and

c) The loads should be continuous and permanent and not of impact type.

Table 9 Minimum Permissible Stress Limits (N/mm^2) in Three Groups of Structural Timbers (for Grade I Material)

(*Clauses* 5.2 *and* 5.3)

Sl No.	Strength Character	Location of Use	Group A	Group B	Group C
(1)	(2)	(3)	(4)	(5)	(6)
i)	Bending and tension along grain	Inside [1]	18.0	12.0	8.5
ii)	Shear [2] Horizontal	All locations	1.05	0.64	0.49
	Along grain	All locations	15	0.91	0.70
iii)	Compression parallel to grain	Inside [1]	11.7	7.8	4.9
iv)	Compression perpendicular to grain	Inside [1]	4.0	2.5	1.1
v)	Modulus of elasticity (× 10^3 N/mm^2)	All locations and grade	12.6	9.8	5.6

[1] For working stresses for other locations of use, that is, outside and wet, generally factors of 5/6 and 2/3 are applied.

[2] The values of horizontal shear to be used only for beams. In all other cases shear along grain to be used.

5.3 The permissible stresses (excepting E) given in Table 9 shall be multiplied by the following factors to obtain the permissible stresses for other grades provided that the conditions laid down in **5.2** are satisfied:

a)	For Select Grade Timber	1.16
b)	For Grade II Timber	0.84

5.3.1 When low durability timbers are to be used [*see* **5.2**(b)] on outside locations, the permissible stresses for all grades of timber, arrived at by **5.2** and **5.3** shall be multiplied by 0.80.

5.4 Modification Factors for Permissible Stresses

5.4.1 *Due to Change in Slope of Grain*

When the timber has not been graded and has major defects like slope of grain, knots and checks or shakes but not beyond permissible value, the permissible stress given in Table 1 shall be multiplied by modification factor K_1 for different slopes of grain as given in Table 10.

Table 10 Modifications Factor K_1 to Allow for Change in Slope of Grain

(*Clause* 5.4.1)

Slope	Modification Factor K_1	
	Strength of Beams, Joists and Ties	Strength of Posts or Columns
(1)	(2)	(3)
1 in 10	0.80	0.74
1 in 12	0.90	0.82
1 in 14	0.98	0.87
1 in 15 and flatter	1.00	1.00

NOTE — For intermediary slopes of grains, values of modification factor may be obtained by interpolation.

5.4.2 *Due to Duration of Load*

For different durations of design load, the permissible stresses given in Table 1 shall be multiplied by the modification factor K_2 given in Table 11.

NOTE — The strength properties of timber under load are time-dependent.

Table 11 Modifications Factor K_2, for Change in Duration of Loading

(*Clause* 5.4.2)

Duration of Loading	Modification Factor K_2
(1)	(2)
Continuous (Normal)	1.0
Two months	1.15
Seven days	1.25
Wind and earthquake	1.33
Instantaneous or impact	2.00

5.4.2.1 The factor K_2 is applicable to modulus of elasticity when used to design timber columns, otherwise they do not apply thereto.

5.4.2.2 If there are several duration of loads (in addition to the continuous) to be considered, the modification factor shall be based on the shortest duration load in the combination, that is, the one yielding the largest increase in the permissible stresses, provided the designed section is found adequate for a combination of other larger duration loads.

[*Explanation*: In any structural timber design for dead loads, snow loads and wind or earthquake forces, members may be designed on the basis of total of stresses due to dead, snow and wind loads using $K_2 = 1.33$, factor for the permissible stress (of Table 1) to accommodate the wind load, that is, the shortest of duration and giving the largest increase in the permissible stresses. The section thus found is checked to meet the requirements based on dead loads alone with modification $K_2 = 1.00$].

5.4.2.3 Modification factor K_2 shall also be applied to allowable loads for mechanical fasteners in design of joints, when the wood and not the strength of metal determines the load capacity.

6 DESIGN CONSIDERATIONS

6.1 All structural members, assemblies or framework in a building, in combination with the floors, walls and other structural parts of the building shall be capable of sustaining, with due stability and stiffness the whole dead and imposed loadings as per Part 6 'Structural Design, Section 1 Loads, Forces and Effects', without exceeding the limits of relevant stresses specified in this Section.

6.2 Buildings shall be designed for all dead and imposed loads or forces assumed to come upon them during construction or use, including uplifts or horizontal forces from wind and forces from earthquakes or other loadings. Structural members and their connections shall be proportioned to provide a sound and stable structure with adequate strength and stiffness. Wooden components in construction generally include panels for sheathing and diaphragms, siding, beams, girder, columns, light framings, masonry wall and joist construction, heavy-frames, glued laminated structural members, structural sandwiches, prefabricated panels, lamella arches, portal frames and other auxiliary constructions.

6.3 Net Section

6.3.1 The net section is obtained by deducting from the gross sectional area of timber the projected area of all material removed by boring, grooving or other means at critical plane. In case of nailing, the area of the prebored hole shall not be taken into account for this purpose.

6.3.2 The net section used in calculating load carrying capacity of a member shall be at least net section determined as above by passing a plane or a series of connected planes transversely through the members.

6.3.3 Notches shall be in no case remove more than one quarter of the section.

6.3.4 In the design of an intermediate or a long column, gross section shall be used in calculating load carrying capacity of the column.

6.4 Loads

6.4.1 The loads shall conform to those given in Part 6 'Structural Design, Section 1 Loads, Forces and Effects'.

6.4.2 The worst combination and location of loads shall be considered for design. Wind and seismic forces shall not be considered to act simultaneously.

6.5 Flexural Members

6.5.1 Such structural members shall be investigated for the following:

a) Bending strength,
b) Maximum horizontal shear,
c) Stress at the bearings, and
d) Deflection.

6.5.2 *Effective Span*

The effective span of beams and other flexural members shall be taken as the distance from face of supports plus one-half of the required length of bearing at each end except that for continuous beams and joists the span may be measured from centre of bearing at those supports over which the beam is continuous.

6.5.3 Usual formula for flexural strength shall apply in design:

$$f_{ab} = \frac{M}{Z} \leq f_b$$

6.5.4 *Form Factors for Flexural Members*

The following form factors shall be applied to the bending stress:

a) *Rectangular Section* — For rectangular sections, for different depths of beams, the form factor K_3 shall be taken as:

$$K_3 = 0.81\left(\frac{D^2 + 89\,400}{D^2 + 55\,000}\right)$$

NOTE — Form factor (K_3) shall not be applied for beams having depth less than or equal to 300 mm.

obtained by using the formula:

$$K_4 = 0.8 + 0.8y\left(\frac{D^2 + 89\,400 - 1}{D^2 + 55\,000}\right)$$

where

$$y = p_1^2\ (6 - 8\,p_1 + 3p_1^2)\ (1 - q_1) + q_1$$

c) *Solid Circular Cross-Sections* — For solid circular cross sections the form factor K_5 shall be taken as 1.18.

d) *Square Cross-Sections* — For square cross-sections where the load is in the direction of diagonal, the form factor K_6 shall be taken as 1.414.

6.5.5 *Width*

The minimum width of the beam or any flexural member shall not be less than 50 mm or 1/50 of the span, whichever is greater.

6.5.6 *Depth*

The depth of beam or any flexural member shall not be taken more than three times of its width without lateral stiffening.

6.5.6.1 *Stiffening*

All flexural members having a depth exceeding three times its width or a span exceeding 50 times its width or both shall be laterally restrained from twisting or buckling and the distance between such restraints shall not exceed 50 times its width.

6.5.7 Shear

6.5.7.1 The following formulae shall apply:

a) The maximum horizontal shear, when the load on a beam moves from the support towards the centre of the span, and the load is at a distance of three to four times the depth of the beam from the support, shall be calculated from the following general formula:

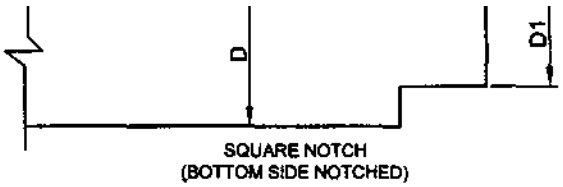
$$H = \frac{VQ}{Ib}$$

b) For rectangular beams:

$$H = \frac{3V}{2bD}$$

c) For notched beams, with tension notch at supports (*see* **6.5.7.3**):

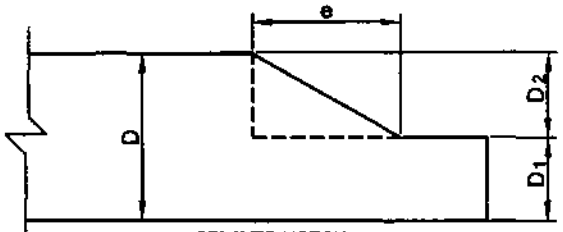
$$H = \frac{3VD}{2bD_1^2}$$



SQUARE NOTCH
(BOTTOM SIDE NOTCHED)

d) For notched at upper (compression) face, where $e > D$:

$$H = \frac{3V}{2bD_1}$$



SPLAYED NOTCH
(UPPER SIDE NOTCHED)

e) For notched at upper (compression) face, where $e < D$:

$$H = \frac{3V}{2b\left[D - \left(\frac{D_2}{D}\right)e\right]}$$

6.5.7.2 For concentrated loads:

$$V = \frac{10\,C(I - x)\,(x/D)^2}{9I[2 + (x/D)^2]}$$

and for uniformly distributed loads,

$$V = \frac{W}{2}\left(1 - \frac{2D}{I}\right)$$

After arriving at the value of V, its value will be substituted in the formula:

$$H = \frac{V\,Q}{I\,b}$$

6.5.7.3 In determining the vertical reaction V, the following deductions in loads may be made:

a) Consideration shall be given to the possible distribution of load to adjacent parallel beams, if any;

b) All uniformly distributed loads within a distance equal to the depth of the beam from the edge of the nearest support may be neglected except in case of beam hanging downwards from a particular support; and

c) All concentrated loads in the vicinity of the

supports may be reduced by the reduction factor applicable according to Table 12.

Table 12 Reduction Factor for Concentrated Loads in the Vicinity of Supports

[*Clause* 6.5.7.3 (c)]

Distance of Load from the Nearest Support	1.5 *D* or Less	2 *D*	2.5 *D*	3 *D* or More
(1)	(2)	(3)	(4)	(5)
Reduction factor	0.60	0.40	0.20	No reduction

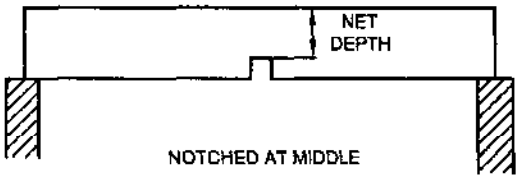
NOTE — For intermediate distances, factor may be obtained by linear interpolation.

6.5.7.4 Unless the local stress is calculated and found to be within the permissible stress, flexural member shall not be cut, notched or bored except as follows:

a) Notches may be cut in the top or bottom neither deeper than one-fifth of the depth of the beam nor farther from the edge of the support than one-sixth of the span;

b) Holes not larger in diameter than one quarter of the depth may be bored in the middle third of the depth and length; and

c) If holes or notches occur at a distance greater than three times the depth of the member from the edge of the nearest support, the net remaining depth shall be used in determining the bending strength.



NOTCHED BEAMS

6.5.8 *Bearing*

6.5.8.1 The ends of flexural members shall be supported in recesses which provide adequate ventilation to prevent dry rot and shall not be enclosed. Flexural members except roof timbers which are supported directly on masonry or concrete shall have a length of bearing of not less than 75 mm. Members supported on corbels, offsets and roof timbers on a wall shall bear immediately on and be fixed to wall-plate not less than 75 mm × 40 mm.

6.5.8.2 Timber joists or floor planks shall not be supported on the top flange of steel beams unless the bearing stress, calculated on the net bearing as shaped to fit the beam, is less than the permissible compressive stress perpendicular to the grain.

6.5.8.3 *Bearing stress*

6.5.8.3.1 *Length and position of bearing*

a) At any bearing on the side grain of timber, the permissible stress in compression perpendicular to the grain, f_{cn}, is dependent on the length and position of the bearing.

b) The permissible stresses given in Table 1 for compression perpendicular to the grain are also the permissible stresses for any length at the ends of a member and for bearings 150 mm or more in length at any other position.

c) For bearings less than 150 mm in length located 75 mm or more from the end of a member as shown in Fig. 1, the permissible stress may be multiplied by the modification factor K_7 given in Table 13.

d) No allowance need be made for the difference in intensity of the bearing stress due to bending of a beam.

e) The bearing area should be calculated as the net area after allowance for the amount of wane.

f) For bearings stress under a washer or a small plate, the same coefficient specified in Table 13 may be taken for a bearing with a length equal to the diameter of the washer or the width of the small plate.

g) When the direction of stress is at angle to the direction of the grain in any structural member, then the permissible bearing stress in that member shall be calculated by the following formula:

$$f_c\theta = \frac{f_{cp} \times f_{cn}}{f_{cp} \sin^2\theta + f_{cn} \cos^2\theta}$$

6.5.9 *Deflection*

The deflection in the case of all flexural members supporting brittle materials like gypsum ceilings, *slates*, tiles and asbestos sheets shall not exceed 1/360 of the span. The deflection in the case of other flexural members shall not exceed 1/240 of the span and 1/150 of the freely hanging length in the case of cantilevers.

6.5.9.1 Usual formula for deflection shall apply:

$$\delta = \frac{KWL^3}{EI}$$ (ignoring deflection due to shear strain)

K-values = 1/3 for cantilevers with load at free end,

1/8 for cantilevers with uniformly distributed load,

Table 13 Modification Factor K_7 for Bearing Stresses

(*Clause* 6.5.8.3.1)

Length of Bearing, in mm	15	25	40	50	75	100	150 or more
Modification Factor, K_7	1.67	1.40	1.25	1.20	1.13	1.10	1.00

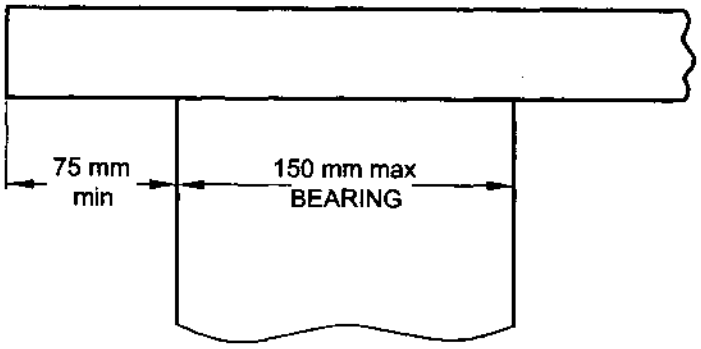


FIG. 1 POSITION OF END BEARINGS

1/48 for beams supported at both ends with point load at centre, and

5/384 for beams supported at both ends with uniformly distributed load.

6.5.9.2 In order to allow the effect of long duration loading on E, for checking deflection in case of beams and joists the effective loads shall be twice the dead load if timber is initially dry.

6.5.9.3 Self weight of beam shall be considered in design.

6.6 Columns

NOTE — The formulae given are for columns with pin end conditions and the length shall be modified suitably with other end conditions.

6.6.1 *Solid Columns*

Solid columns shall be classified into short, intermediate and long columns depending upon their slenderness ratio (S/d) as follows:

a) *Short columns* — where S/d does not exceed 11.

b) *Intermediate columns* — where S/d is between 11 and K_8, and

c) *Long columns* — where S/d is greater than K_8.

6.6.1.1 For short columns, the permissible compressive stress shall be calculated as follows:

$$f_c = f_{cp}$$

6.6.1.2 For intermediate columns, the permissible compressive stress is calculated by using the following formula:

$$f_c = f_{cp}\left[1-\frac{1}{3}\left(\frac{S}{K_8 d}\right)^4\right]$$

6.6.1.3 For long columns, the permissible compressive stress shall be calculated by using the following formula:

$$f_c = \frac{0.329\,E}{(S/d)^2}$$

6.6.1.4 In case of solid columns of timber, S/d ratio shall not exceed 50.

6.6.1.5 The permissible load on a column of circular cross-section shall not exceed that permitted for a square column of an equivalent cross-sectional area.

6.6.1.6 For determining S/d ratio of a tapered column, its least dimension shall be taken as the sum of the corresponding least dimensions at the small end of the column and one-third of the difference between this least dimension at the small end and the corresponding least dimension at the large end, but in no case shall the least dimension for the column be taken as more than one and a half times the least dimension at the small end. The induced stress at the small end of the tapered column shall not exceed the permissible compressive stress in the direction of grain.

6.6.2 *Built-up Columns*

6.6.2.1 *Box column*

Box columns shall be classified into short, intermediate and long columns as follows:

a) *Short columns* — where $\frac{S}{\sqrt{d_1^2+d_2^2}}$ is less than 8;

b) *Intermediate columns* — where $\frac{S}{\sqrt{d_1^2+d_2^2}}$ is between 8 and K_9; and

c) *Long columns* — where $\frac{S}{\sqrt{d_1^2+d_2^2}}$ is greater than K_9.

6.6.2.2 For short columns, the permissible compressive stress shall be calculated as follows:

$$f_c = qf_{cp}$$

6.6.2.3 For intermediate columns, the permissible compressive stress shall be obtained using the following formula:

$$f_c = qf_{cp}\left[1-\frac{1}{3}\left(\frac{S}{k_9\sqrt{d_1^2+d_1^2}}\right)^4\right]$$

6.6.2.4 For long columns, the permissible compressive stress shall be calculated by using the following formula:

$$f_c = \frac{0.329\,UE}{\left(\frac{S}{\sqrt{d_1^2+d_2^2}}\right)^2}$$

6.6.2.5 The following values of U and q, depending upon plank thickness (t) in **6.6.2.3** and **6.6.2.4**, shall be used:

t mm	U	q
25	0.80	1.00
50	0.60	1.00

6.6.3 *Spaced Columns*

6.6.3.1 The formulae for solid columns as specified in **6.6.1** are applicable to spaced columns with a restraint factor of 2.5 or 3, depending upon distances of end connectors in the column.

NOTE — A restrained factor of 2.5 for location of centroid group of fasteners at $S/20$ from end and 3 for location at $S/10$ to $S/20$ from end shall be taken.

6.6.3.2 For intermediate spaced column, the permissible compressive stress shall be:

$$f_c = f_{cp}\left[1-\frac{1}{3}\left(\frac{S}{k_{10}d}\right)^4\right]$$

6.6.3.3 For long spaced columns, the formula shall be:

$$f_c = \frac{0.329\,E\times 2.5}{(S/d)^2}$$

6.6.3.4 For individual members of spaced columns, S/d ratio shall not exceed 80.

6.6.4 Compression members shall not be notched. When it is necessary to pass services through such a member, this shall be effected by means of a bored hole provided that the local stress is calculated and found to be within the permissible stress specified. The distance from the edge of the hole to the edge of the member shall not be less than one quarter of width of the face.

6.7 Structural Members Subject to Bending and Axial Stresses

6.7.1 Structural members subjected both to bending and axial compression shall be designed to comply with the following formula:

$$\frac{f_{ac}}{f_c}+\frac{f_{ab}}{f_b} \text{ is not greater than 1.}$$

6.7.2 Structural members subjected both to bending and axial tension shall be designed to comply with the following formula:

$$\frac{f_{at}}{f_t}+\frac{f_{ab}}{f_b} \text{ is not greater than 1.}$$

7 DESIGN OF COMMON STEEL WIRE NAIL JOINTS

7.1 General

Nail jointed timber construction is suitable for light and medium timber framings (trusses, etc) up to 15 m spans. With the facilities of readily available materials and simpler workmanship in mono-chord and split chord constructions, this type of fabrication has a large scope.

7.2 Dimensions of Members

7.2.1 The dimension of an individual piece of timber (that is, any single member) shall be within the range given below:

a) The minimum thickness of the main members in mono-chord construction shall be 30 mm.

b) The minimum thickness of an individual piece of members in split-chord construction shall

be 20 mm for web members and 25 mm for chord members.

c) The space between two adjacent pieces of timber shall be restricted to a maximum of 3 times the thickness of the individual piece of timber of the chord member. In case of web members, it may be greater for joining facilities.

7.3 No lengthening joint shall preferably be located at a panel point. Generally not more than two, but preferably one, lengthening joint shall be permitted between the two panel points of the members.

7.4 Specification and Diameter of Nails

7.4.1 The nails used for timber joints shall conform to Part 5 'Building Materials'. The nails shall be diamond pointed.

7.4.2 The diameter of nail shall be within the limits of one-eleventh to one-sixth of the least thickness of members being connected.

7.4.3 Where the nails are exposed to be saline conditions, common wire nails shall be galvanized.

7.5 Arrangement of Nails in the Joints

The end distances, edge distances and spacings of nails in a nailed joint should be such as to avoid undue splitting of the wood and shall not be less than those given in **7.5.1** and **7.5.2.**

7.5.1 *Lenthening Joints*

The requirement of spacing of nails in a lengthening joint shall be as follows (*see also* Fig. 2):

Sl No.	*Spacing of Nails*	*Type of Stress in the Joint*	*Requirement, Min*
(1)	(2)	(3)	(4)
i)	End distance	Tension	12 *n*
		Compression	10 *n*
ii)	In direction of grain	Tension	10 *n*
		Compression	5 *n*
iii)	Edge distance	—	5 *n*
iv)	Between row of nails perpendicular to the grain	—	5 *n*

NOTES

1 *n* is shank diameter of nails.

2 The 5 *n* distance between rows perpendicular to the grain may be increased subject to the availability of width of the member keeping edge distance constant.

7.5.2 *Node Joints*

The requirement for spacing of nails in node joints shall be as specified in Fig. 3 where the members are at right angle and as in Fig. 4 where the members are inclined to one another at angles other than 90° and subjected to either pure compression or pure tension.

7.6 Penetration of Nails

7.6.1 For a lap joint when the nails are driven from the side of the thinner member, the length of penetration of nails in the thicker member shall be one and a half times the thickness of the thinner member subject to maximum of the thickness of the thicker member.

7.6.2 For butt joints the nails shall be driven through the entire thickness of the joint.

7.7 Design Considerations

7.7.1 Where a number of nails are used in a joint, the allowable load in lateral resistance shall be the sum of the allowable loads for the individual nails, provided that the centroid of the group of these nails lies on the axis of the member and the spacings conform to **7.5**. Where a large number of nails are to be provided at a joint, they should be so arranged that there are more of rows rather than more number of nails in a row.

7.7.2 Nails shall, as far as practicable, be arranged so that the line of force in a member passes through the centroid of the group of nails. Where this is not practicable, allowance shall be made for any eccentricity in computing the maximum load on the fixing nails as well as the loads and bending moment in the member.

7.7.3 Adjacent nails shall preferably be driven from opposite faces, that is, the nails are driven alternatively from either face of joint.

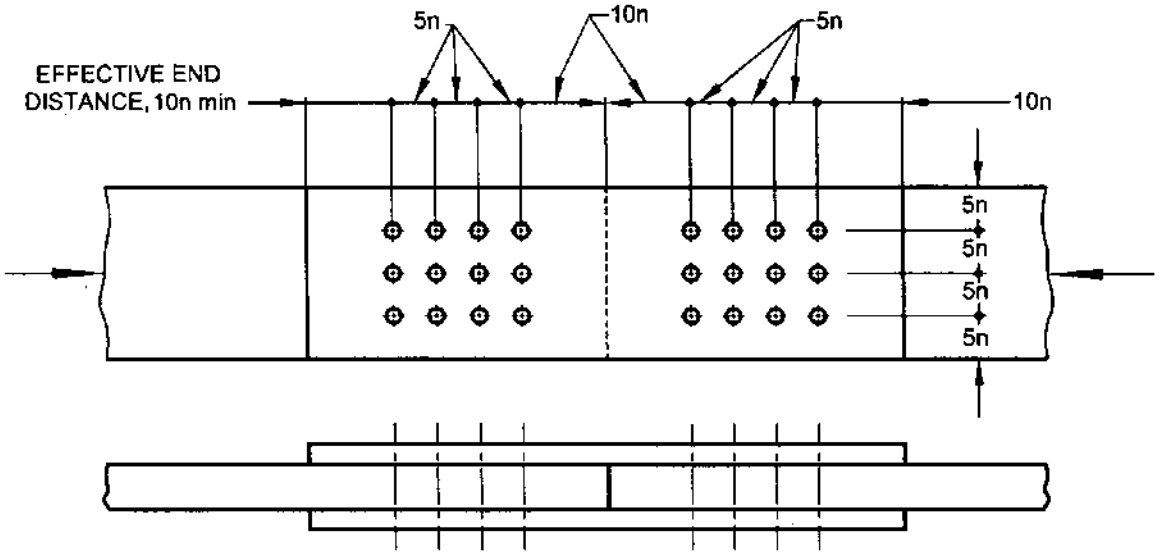
7.7.4 For a rigid joint, a minimum of 2 nails for nodal joints and 4 nails for lengthening joint shall be driven.

7.7.5 Two nails in a horizontal row are better than using the same number of nails in a vertical row.

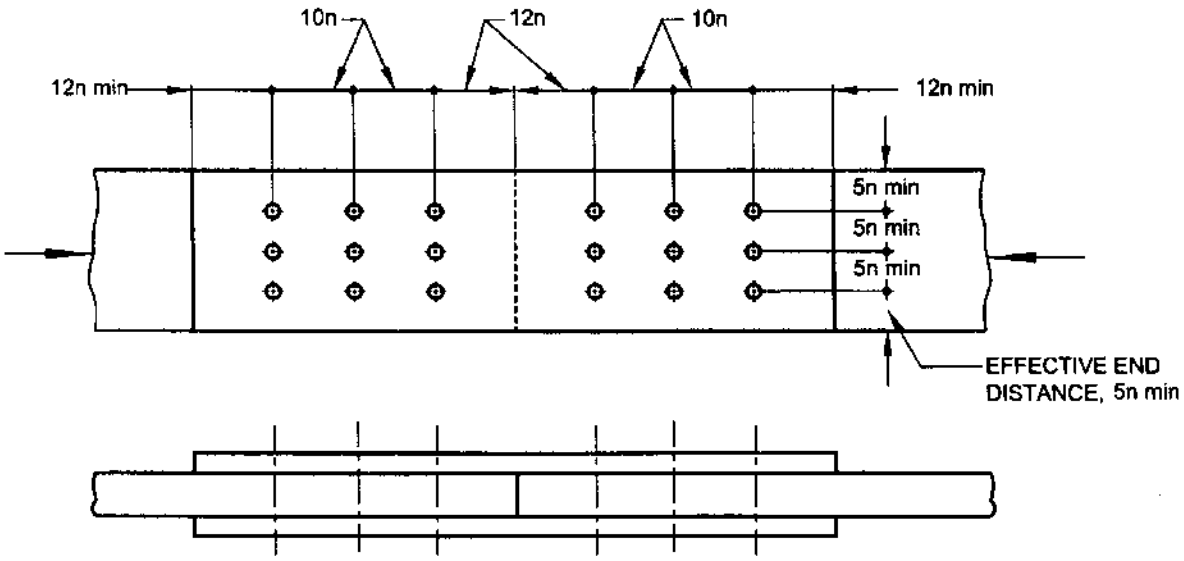
7.8 Special Consideration in Nail-Jointed Truss Construction

7.8.1 The initial upward camber provided at the centre of the lower chord of nail-jointed timber trusses shall be not less than 1/200 of the effective span for timber structures using seasoned wood and 1/100 for unseasoned or partially seasoned wood.

7.8.2 The total combined thickness of the gusset or splice plates on either side of the joint in a mono-chord type construction shall not be less than one and a half times the thickness of the main members subject to a minimum thickness of 25 mm of individual gusset plate.



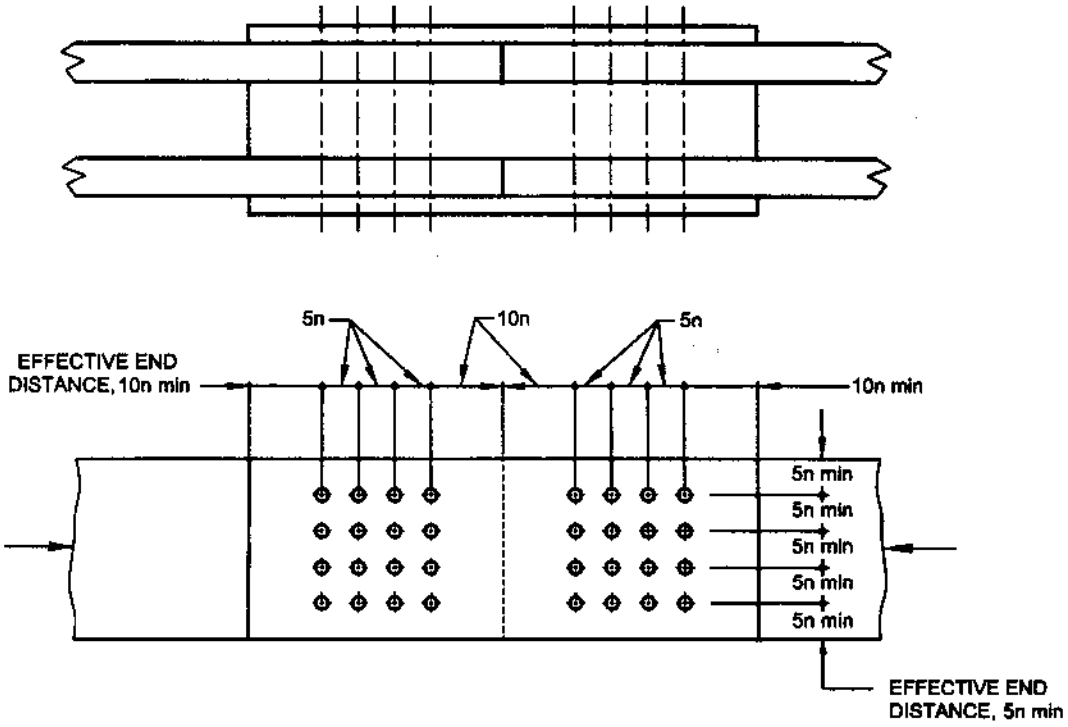
2A MONOCHORD TYPE BUTT JOINT SUBJECT TO COMPRESSION



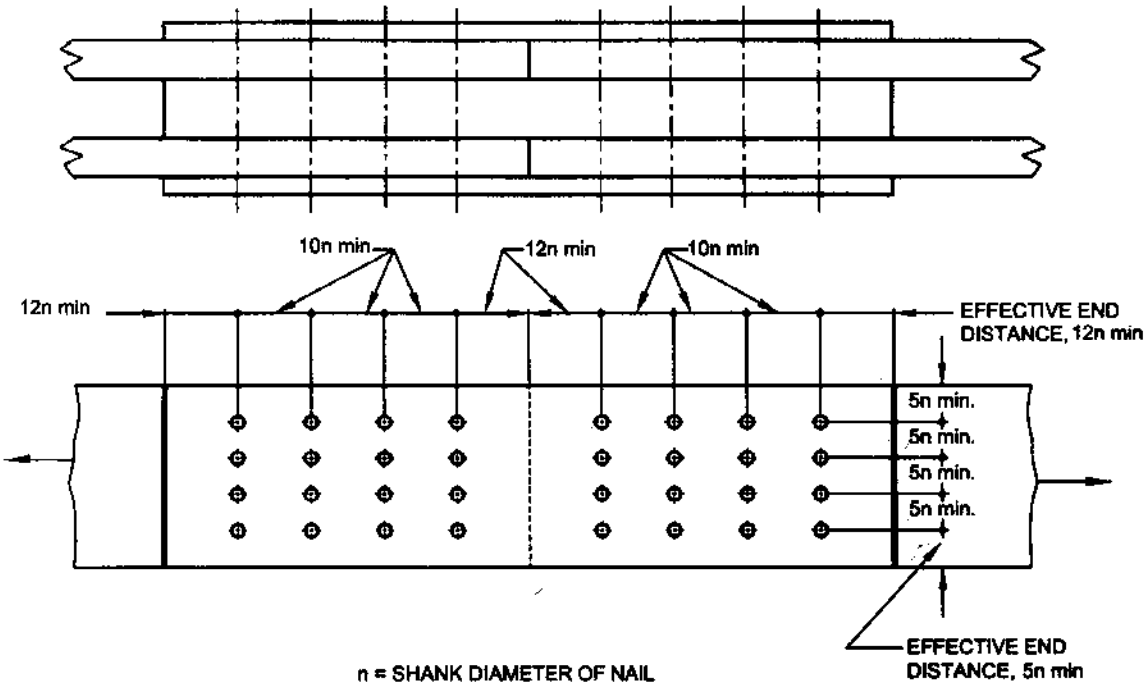
n = SHANK DIAMETER OF NAIL

2B MONOCHORD TYPE BUTT JOINT SUBJECT TO TENSION

FIG. 2 SPACING OF NAILS IN A LENGTHENING JOINT — *Continued*



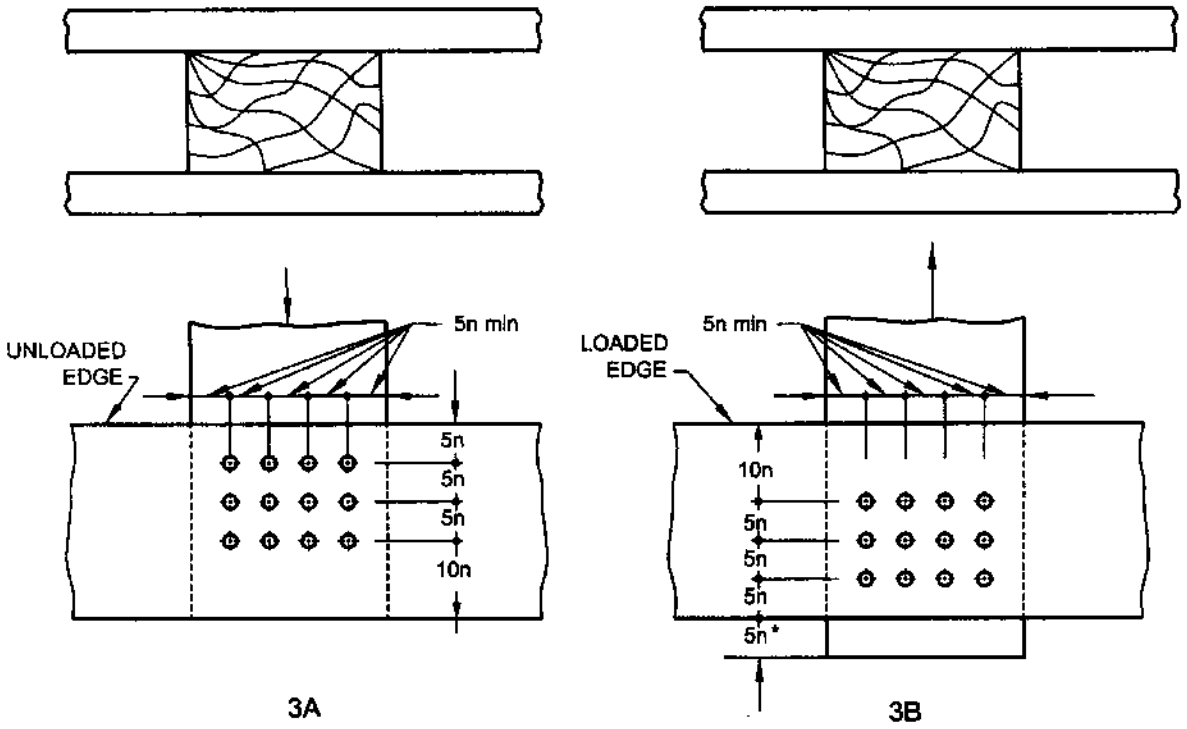
2C SPLIT - CHORD TYPE BUTT JOINT SUBJECT TO COMPRESSION

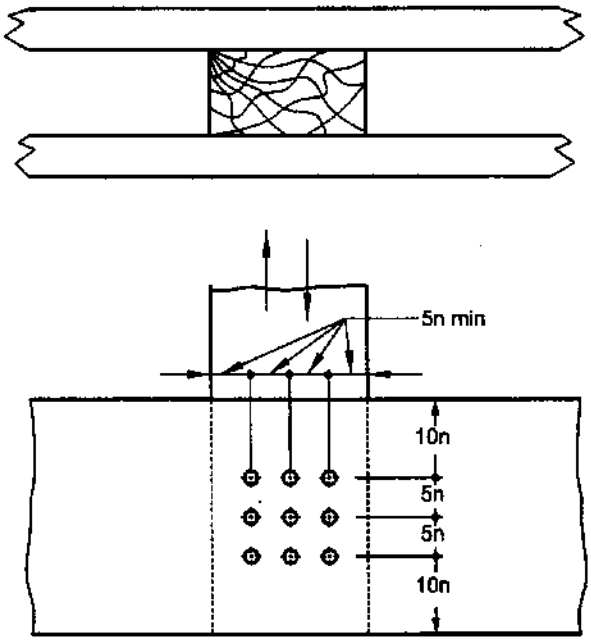


n = SHANK DIAMETER OF NAIL

2D SPLIT - CHORD TYPE BUTT JOINT SUBJECT TO TENSION

FIG. 2 SPACING OF NAILS IN A LENGHTHENING JOINT



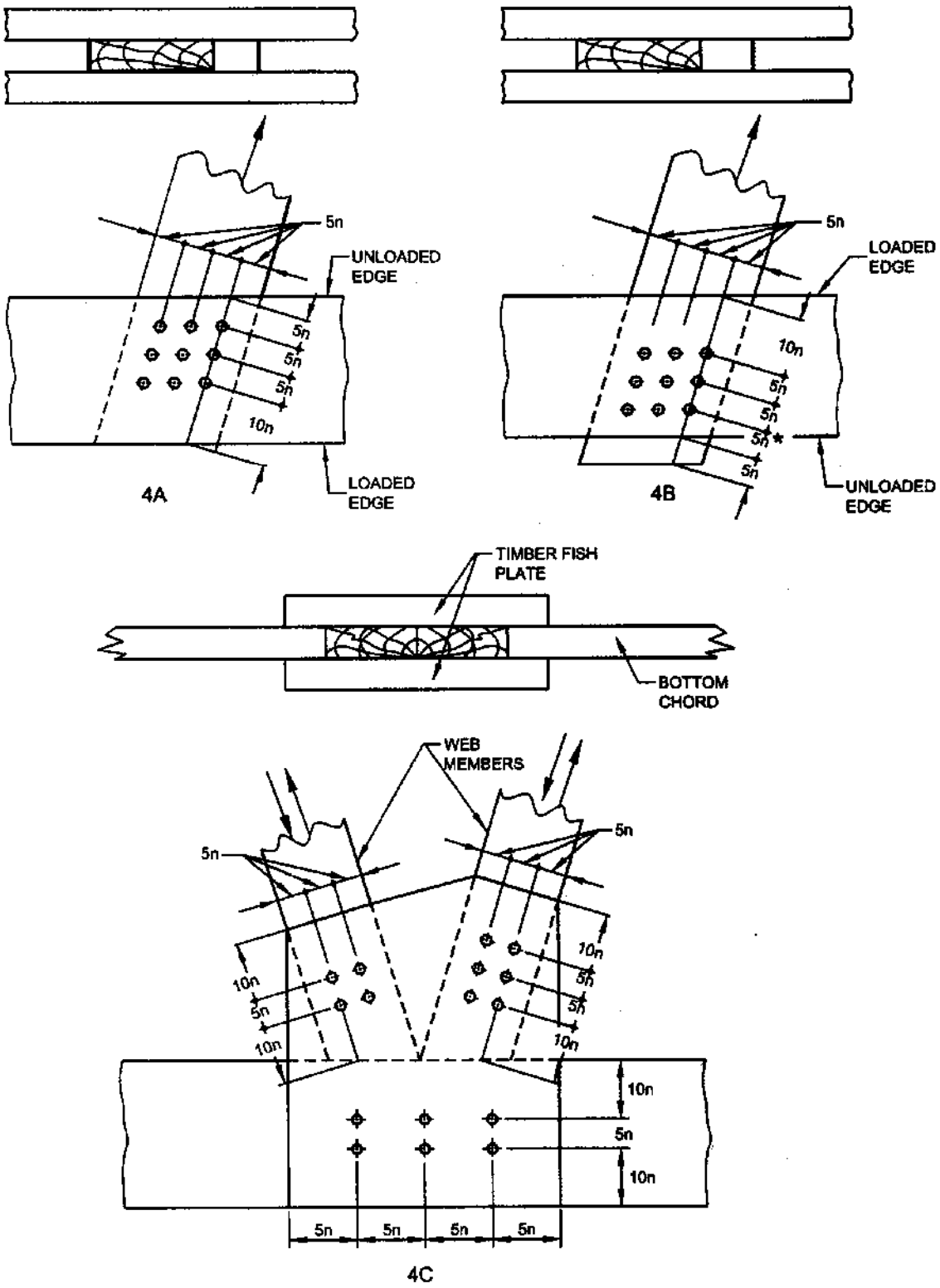


n = SHANK DIAMETER OF NAIL

*5n MAY BE INCREASED TO 10n, IF THE DESIGNED WIDTH OF CORD MEMBER PERMITS. OTHERWISE THE END OF THE LOADED WEB MEMBER MAY BE EXTENDED BY 5n min

3C

FIG. 3 SPACING OF NAILS WHERE MEMBERS ARE AT RIGHT ANGLES TO ONE ANOTHER



*5n MAY BE INCREASED TO 10n, IF THE DESIGNED WIDTH OF CHORD MEMBER PERMITS. OTHERWISE THE END OF THE LOADED WEB MEMBER MAY BE EXTENDED BY 5n min
n = SHANK DIAMETER OF NAIL

FIG. 4 SPACING OF NAILS AT NODE JOINTS WHERE MEMBERS ARE INCLINED TO ONE ANOTHER

NOTES

1 The allowable load or lateral strength values of nails shall be those as given in Table 13.

2 The strength data for joints given in the section apply to gusset or splice or fish plates of solid wood; however, materials other than solid wood may be used for gusset when field tests are made and their strength requirements have been established.

7.8.3 The total combined thickness of all spacer blocks or plates or both including outer splice plates, at any joint in a split-chord type construction shall not be less than one and a half times the total thickness of all the main members at that joint.

7.9 Fabrication

The fabrication of nail-jointed timber construction shall be done in accordance with good practice [6-3A(7)].

8 DESIGN OF NAIL LAMINATED TIMBER BEAMS

8.1 Method of Arrangement

8.1.1 The beam is made up of 20 mm to 30 mm thick planks placed vertically with joints staggered in the adjoining planks with a minimum distance of 300 mm. The planks are laminated with the help of wire nails at regular intervals to take up horizontal shear developed in the beam besides keeping the planks in position (*see* Fig. 5).

8.1.2 The advantage in laminations lies in dimensional stability, dispersal of defects and better structural performance.

8.2 Sizes of Planks and Beams

8.2.1 The plank thickness for fabrication of nailed laminated beams recommended are 20, 25 and 30 mm.

8.2.2 In case of nailed laminated timber beam the maximum depth and length of planks shall be limited to 250 mm and 2 000 mm, respectively.

8.2.3 In order to obtain the overall width of the beam, the number and thickness of planks to form vertical nailed laminated beams, and also type and size of wire nail shall be as mentioned in Table 14. The protruding portion of the nail shall be cut off or clenched across the grains.

8.3 Design Considerations

8.3.1 Nail laminated beams shall be designed in accordance with **6**.

8.3.1.1 The deflection in the case of nailed laminated timber beams, joists, purlins, battens and other flexural members supporting brittle materials like gypsum, ceiling slates, tiles and asbestos sheets shall not exceed 1/480 of the span. The deflection in case of other flexural members shall not exceed 1/360 of the span in the case of beams and joists, and 1/225 of the freely hanging length in case of cantilevers.

8.3.2 Permissible lateral strength of mild steel wire nails shall be as given in Table 2 and Table 3 for Indian Species of timber, which shall apply to nails that have their points cut flush with the faces. For nails clenched across the grains the strength may be increased by 20 percent over the values for nails with points cut flush.

8.3.3 *Arrangement of Nails*

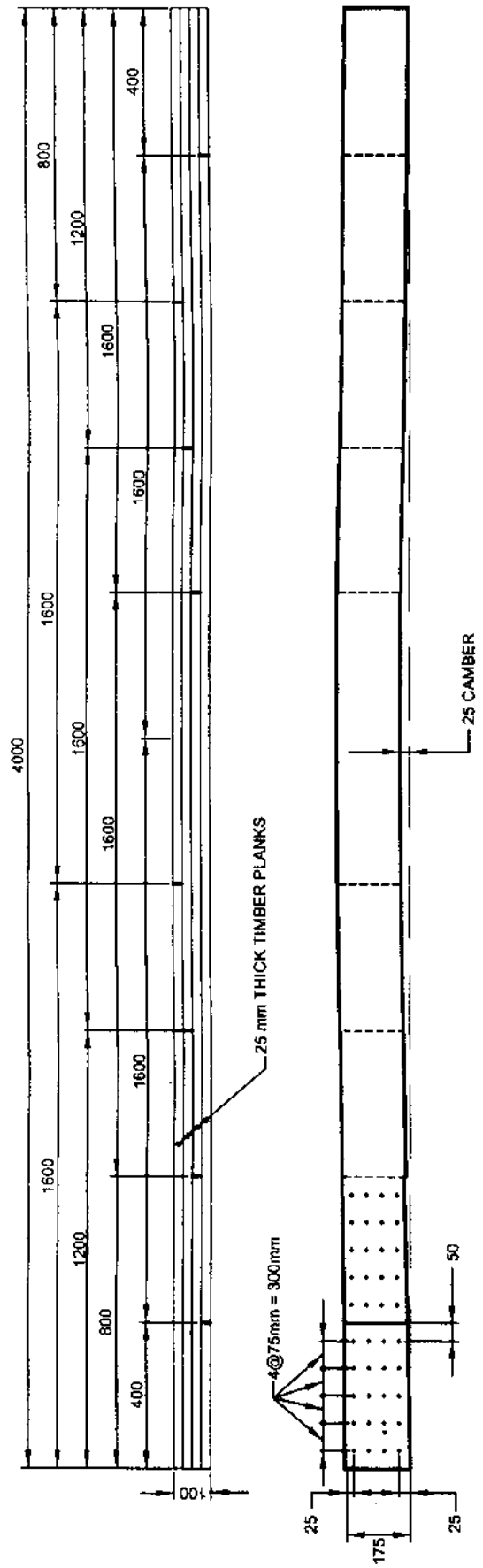
8.3.3.1 A minimum number of four nails in a vertical row at regular interval not exceeding 75 mm to take up horizontal shear as well as to keep the planks in position shall be used. Near the joints of the planks this distance may, however, be limited to 5 cm instead of 75 mm.

Table 14 Number and Size of Planks and Nails for Nailed Laminated Beams

(*Clause* 8.2.3)

Sl No.	Overall Width of Beam mm	No. of Planks	Thickness of Each Plank mm	Type and Size of Nail to be Used mm
(1)	(2)	(3)	(4)	(5)
i)	50	2	25	80 long 3.55 dia
ii)	60	3	20	- do -
iii)	70	3	(2 × 25) (1 × 20)	- do -
iv)	80	4	20	100 long 4.0 dia
v)	90	3	30	- do -
vi)	100	4	25	125 long 5.0 dia
vii)	110	4	(3 × 30) (1 × 20)	- do -
viii)	120	4	30	- do -
ix)	150	5	30	150 long 5.0 dia

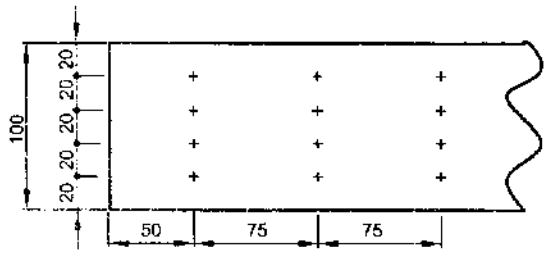
NOTE — A number of combinations of the different thickness of planks may be adopted as long as the minimum and maximum thickness of the planks are adhered to.



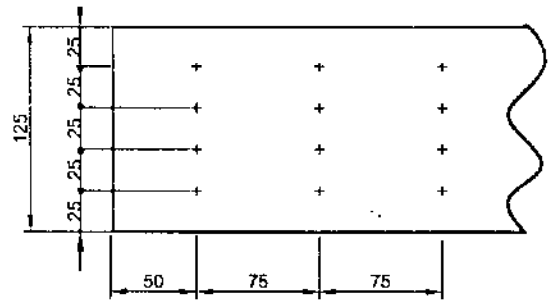
All dimensions in millimetres.

FIG. 5 PLAN AND ELEVATION OF A TYPICAL NAILED LAMINATED TIMBER BEAM

8.3.3.2 Shear shall be calculated at various points of the beam and the number of nails required shall be accommodated within the distance equal to the depth of the beam, with a minimum of 4 nails in a row at a standard spacing as shown in Fig. 6.



6A FOR 3.55 mm AND 4 mm DIAMETER NAILS



6B FOR 5 mm DIAMETER NAILS

All dimensions in millimetres.

FIG. 6 STANDARD LENGTHWISE SPACING IN NAILED LAMINATED BEAM

8.3.3.3 If the depth of the beam is more, then the vertical intermediate spacing of nails may be increased proportionately.

8.3.3.4 If the nails required at a point are more than that can be accommodated in a row, then these shall be provided lengthwise of the beam within the distance equal to the depth of the beam at standard lengthwise spacing.

8.3.3.5 For nailed laminated beam minimum depth of 100 mm for 3.55 mm and 4 mm diameter nails, and 125 mm for 5 mm diameter nails shall be provided.

8.4 Fabrication

8.4.1 The fabrication of nailed laminated timber beams shall be done in accordance with good practice [6-3A(8)].

9 DESIGN OF BOLTED CONSTRUCTION JOINTS

9.1 General

Bolted joints suit the requirements of prefabrication in small and medium span timber structures for speed and economy in construction. Bolt jointed construction units offer better facilities as regards to workshop ease, mass production of components, transport convenience and re-assembly at site of work particularly in defence sector for high altitudes and far off situations. Designing is mainly influenced by the species, size of bolts, moisture conditions and the inclination of loadings to the grains. In principle bolted joints follow the pattern of rivetted joints in steel structures.

9.2 Design Considerations

9.2.1 Bolted timber construction shall be designed in accordance with **6**. The concept of critical section, that is, the net section obtained by deducting the projected area of bolt-holes from the cross-sectional area of member is very important for the successful design and economy in timber.

9.2.2 *Bolt Bearing Strength of Wood*

The allowable load for a bolt in a joint consisting of two members (single shear) shall be taken as one half the allowable loads calculated for a three member joint (double shear) for the same t'/d_3 ratio. The percentage of safe working compressive stress of timber on bolted joints for different t'/d_3 ratios shall be as given in Table 15.

Table 15 Percentage of Safe Working Compressive Stress of Timber for Bolted Joints in Double Shear

(*Clause* 9.2.2)

t'/d_3 Ratio	Stress Percentage	
	Parallel to Grain	Perpendicular to Grain
	λ_1	λ_2
(1)	(2)	(3)
1.0	100	100
1.5	100	96
2.0	100	88
2.5	100	80
3.0	100	72
3.5	100	66
4.0	96	60
4.5	90	56
5.0	80	52
5.5	72	49
6.0	65	46
6.5	58	43
7.0	52	40
7.5	46	39
8.0	40	38
8.5	36	36
9.0	34	34
9.5	32	33
10.0	30	31
10.5	—	31
11.0	—	30
11.5	—	30
12.0	—	28

9.2.2.1 Where a number of bolts are used in a joint, the allowable loads shall be the sum of the allowable loads for the individual bolts.

9.2.2.2 The factors for different bolt diameter used in calculating safe bearing stress perpendicular to grain in the joint shall be as given in Table 16.

Table 16 Bolt Diameter Factor

(*Clause* 9.2.2.2)

Sl No.	Diameter of Bolt mm	Diameter Factor (d_f)
(1)	(2)	(3)
i)	6	5.70
ii)	10	3.60
iii)	12	3.35
iv)	16	3.15
v)	20	3.05
vi)	22	3.00
vii)	25	2.90

9.2.3 *Dimensions of Members*

a) The minimum thickness of the main member in mono-chord construction shall be 40 mm.

b) The minimum thickness of side members shall be 20 mm and shall be half the thickness of main members.

c) The minimum individual thickness of spaced member in split-chord construction shall be 20 mm and 25 mm for webs and chord members respectively.

9.2.4 *Bolts and Bolting*

a) The diameter of bolt in the main member shall be so chosen to give larger slenderness (l'/d_3) ratio of bolt.

b) There shall be more number of small diameter bolts rather than small number of large diameter bolts in a joint.

c) A minimum of two bolts for nodal joints and four bolts for lengthening joints shall be provided.

d) There shall be more number of rows rather than more bolts in a row.

e) The bolt holes shall be of such diameter that the bolt can be driven easily.

f) Washers shall be used between the head of bolt and wood surface as also between the nut and wood.

9.3 Arrangement of Bolts

9.3.1 The following spacings in bolted joints shall be followed (*see* Fig. 7):

a) *Spacing of Bolts in a Row* — For parallel and perpendicular to grain loading = 4 d_3

b) *Spacing Between Rows of Bolts*

1) *For perpendicular to grain loading* — 2.5 d_3 to 5 d_3 (2.5 d_3 for l'/d_3 ratio of 2 and 5 d_3 for l'/d_3 ratio of 6 or more. For ratios between 2 to 6 the spacing shall be obtained by interpolation.

2) *For parallel to grain loading* — At least $(N-4)\,d_3$ with a minimum of 2.5 d_3. Also governed by net area at critical section which should be 80 percent of the total area in bearing under all bolts.

c) *End Distance* — $7d_3$ for soft woods in tension, 5 d_3 for hardwoods in tension and 4 d_3 for all species in compression.

d) *Edge Distance*

1) For parallel to grain loading 1.5 d_3 or half the distance between rows of bolts, whichever is greater.

2) For perpendicular to grain loading, (loaded edge distance) shall be at least 4 d_3.

9.3.2 For inclined members, the spacing given above for perpendicular and parallel to grain of wood may be used as a guide and bolts arranged at the joint with respect to loading direction.

9.3.3 The bolts shall be arranged in such a manner so as to pass the centre of resistance of bolts through the inter-section of the gravity axis of the members.

9.3.4 Staggering of bolts shall be avoided as far as possible in case of members loaded parallel to grain of wood. For loads acting perpendicular to grain of wood, staggering is preferable to avoid splitting due to weather effects.

9.3.5 *Bolting*

The bolt holes shall be bored or drilled perpendicular to the surface involved. Forcible driving of the bolts shall be avoided which may cause cracking or splitting of members. A bolt hole of 1.0 mm oversize may be used as a guide for preboring.

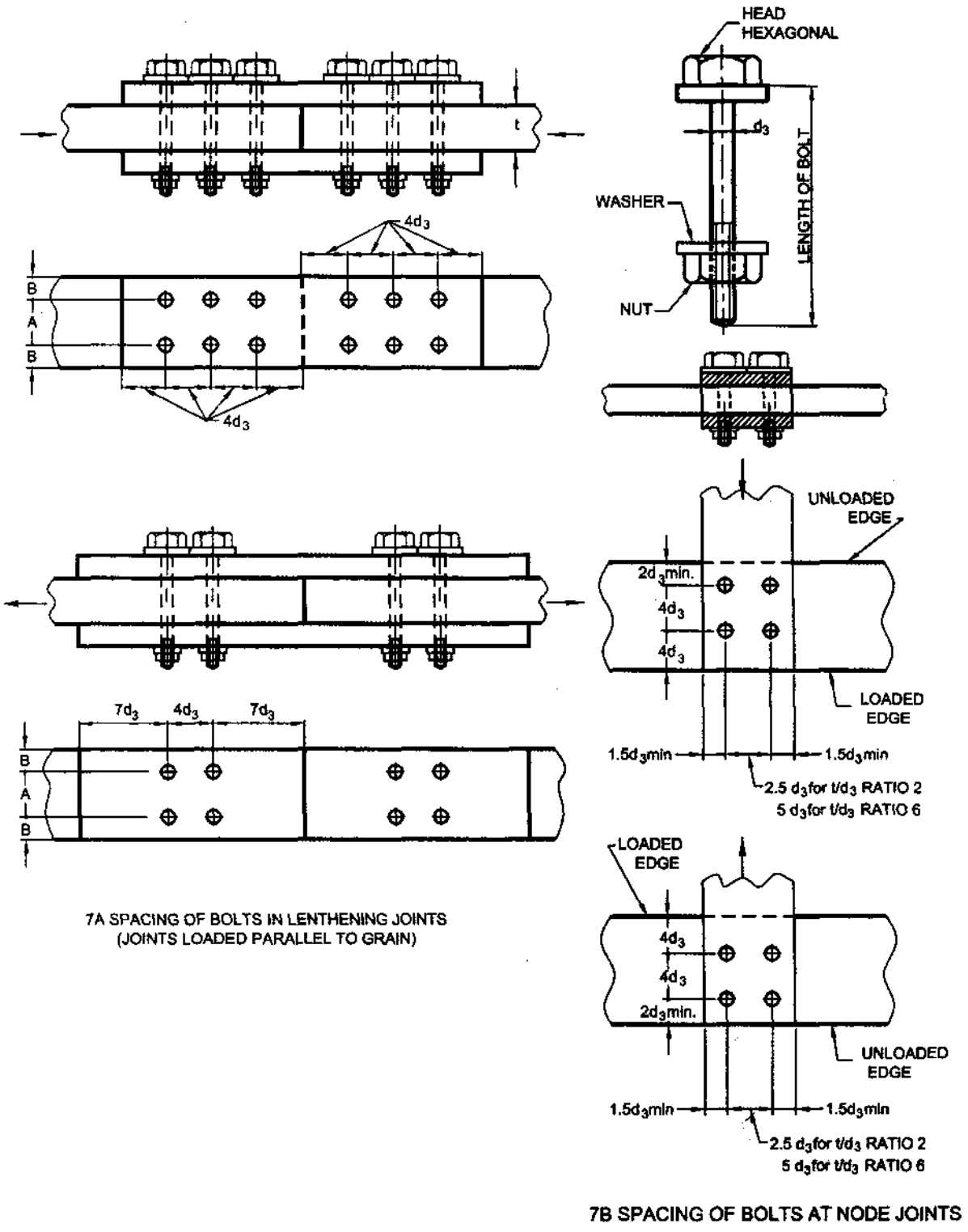
9.3.5.1 Bolts shall be tightened after one year of completion of structure and subsequently at an interval of two to three years.

9.4 Outline for Design of Bolted Joints

Allowable load on one bolt (unit bearing stress) in a joint with wooden splice plates shall not be greater than value of P, R, F as determined by one of the following equations:

a) *For Loads Parallel to Grain*

$$P = f_{cp}\, a\, \lambda_1$$



7A SPACING OF BOLTS IN LENTHENING JOINTS
(JOINTS LOADED PARALLEL TO GRAIN)

7B SPACING OF BOLTS AT NODE JOINTS

FIG. 7 TYPICAL SPACING OF BOLTS IN STRUCTURAL JOINTS

b) *For Loads Perpendicular to Grain*

$$R = f_{cn}\ a\lambda_2 d_f,$$

c) *For Loads at an Angle to Grain*

$$F = \frac{PR}{P\sin^2\theta + R\cos^2\theta}$$

9.5 Fabrication

The fabrication of bolt jointed construction shall be in accordance with good practice [6-3A(9)].

10 DESIGN OF TIMBER CONNECTOR JOINTS

10.1 In large span structures, the members have to transmit very heavy stresses requiring stronger jointing techniques with metallic rings or wooden disc-dowels. Improvized metallic ring connector is a split circular band of steel made from mild steel pipes. This is placed in the grooves cut into the contact faces of the timber members to be joined, the assembly being held together by means of a connecting bolt.

10.1.1 *Dimensions of Members*

Variation of thickness of central (main) and side members affect the load carrying capacity of the joint. The thickness of main member shall be at least 57 mm and that of side member 38 mm with length and width of members governed by placement of connector at joint.

The metallic connector shall be so placed that the loaded edge distance is not less than the diameter of the connector and the end distance not less than 1.75 times the diameter on the loaded side.

10.1.2 *Design Considerations*

Figure 8 illustrates the primary stresses in a split ring connector joint under tension. The shaded areas represent the part of wood in shear, compression and tension. Related formulae for the same are indicated in Fig. 8.

For fabrication of structural members, a hole of the required size of the bolt is drilled into the member and a groove is made on the contact faces of the joint.

Theoretical safe loads in design shall be corroborated with sample tests done in accordance with good practice [6-3(10)].

NOTE — A pilot study on determination of strength of ring connector joint in a compression test for a specific design problem yielded the data as given below:

Strength of Improvized Split Ring Connectors in Mesua (*Mesua ferra*) (Pilot Study)

No. and Diameter of Ring used in a Joint		*No. and Size of Bolt used in a Joint*		*Side Member*		*Central Member*		*Load Direction w.r.t. Grains of Wood*	*End Distance*	*Inter-mediate Distance*	*Load per Pair of Connector*
No.	Size	No.	Size	Thick-ness	Width	Thick-ness	Width		mm	mm	kgf
	mm		mm	mm	mm	mm	mm				
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2	63	1	12 × 125	31	92	38	92	Parallel	63	—	3 930
2	63	1	12 × 125	31	92	38	92	Parallel	75	—	4 185
2	63	1	12 × 150	38	92	63	92	Parallel	75	—	4 010
2	63	1	12 × 150	38	117	63	117	Parallel	75	—	4 450
2	63	1	12 × 125	31	138	38	92	Perpendicular	69	—	2 520
2	63	1	12 × 125	38	138	38	92	Perpendicular	69	—	3 515
2	100	1	19 × 175	38	138	66	138	Parallel	100	—	7 075
2	100	1	19 × 175	38	138	66	138	Parallel	125	—	7 370
2	100	1	19 × 175	41	138	75	138	Parallel	100	—	7 220
2	100	1	19 × 175	41	138	75	138	Parallel	125	—	7 645
4	100	2	19 × 200	38	138	66	138	Parallel	100	150	5 655
4	100	2	19 × 200	41	138	75	138	Parallel	100	150	5 925
4	100	2	19 × 200	41	138	75	138	Parallel	125	200	7 135

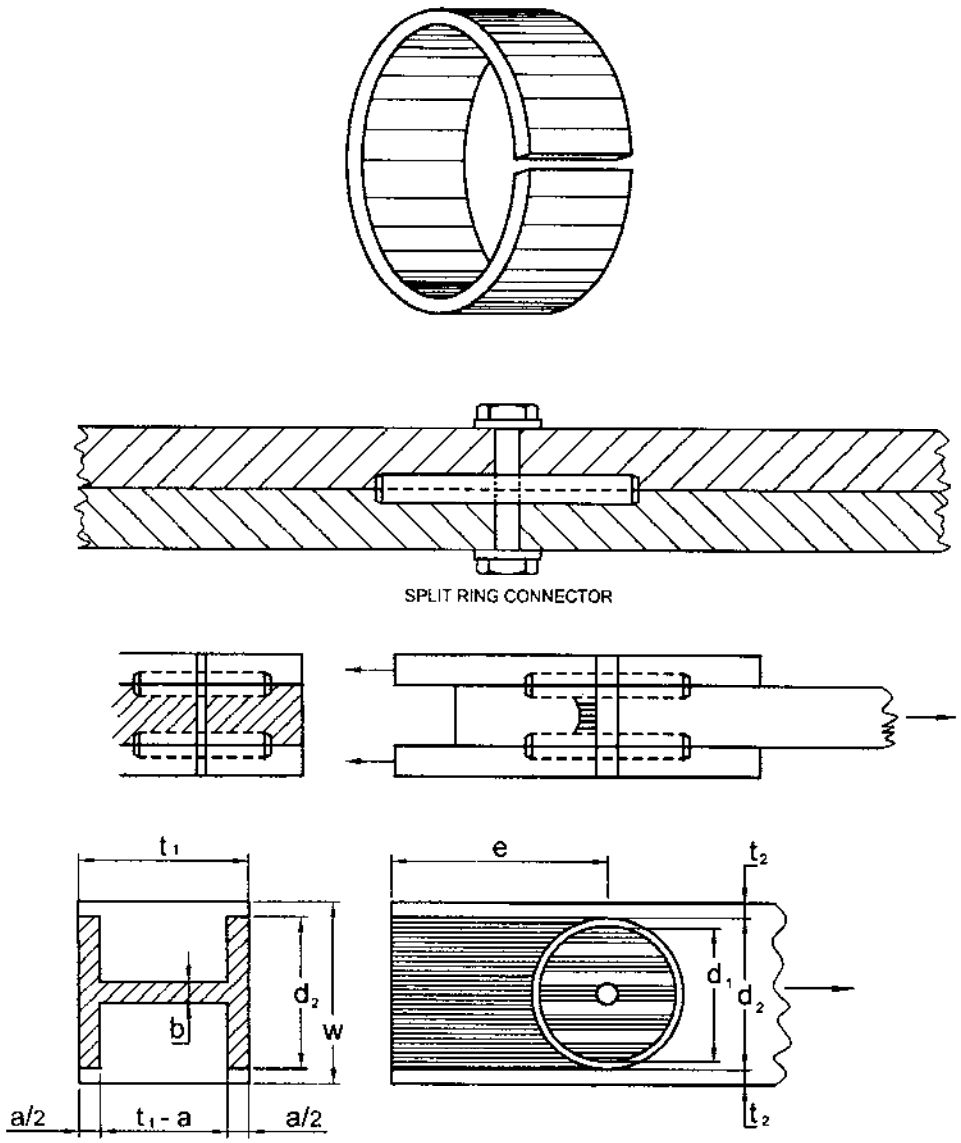


FIG. 8 STRESS DISTRIBUTION IN A SPLIT RING CONNECTOR

10.2 Wooden Disc-Dowel

10.2.1 It is a circular hardwood disc generally tapered each way from the middle so as to form a double conical frustum. Such a disc is made to fit into preformed holes (recesses), half in one member and the other half in another, the assembly being held by one mild steel bolt through the centre of the disc to act as a coupling for keeping the jointed wooden members from spreading apart.

10.2.2 *Dimensions of Members*

The thickness of dowel may vary from 25 mm to 35 mm and diameter from 50 mm to 150 mm. The diameter of dowel shall be 3.25 to 3.50 times the thickness.

The edge clearance shall range from 12 mm to 20 mm as per the size of the dowel. The end clearance shall be at least equal to the diameter of dowel for joints subjected to tension and three-fourth the diameter for compression joints. Disc-dowel shall be turned from quarter sawn planks of seasoned material.

10.2.3 *Choice of Species*

Wood used for making dowels shall be fairly straight grained, free from excessive liability to shrink and warp, and retain shape well after seasoning species recommended include:

Babul
Dhaman
Irul

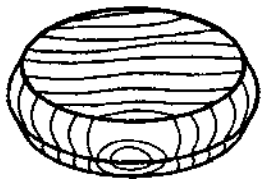
Sissoo
Rose wood
Sandal
Axle-wood
Padauk
Pyinkado
Yon

NOTE — Data on the above species as per Table 1 except for the species *Pyinkado*, which is not an indigenous species.

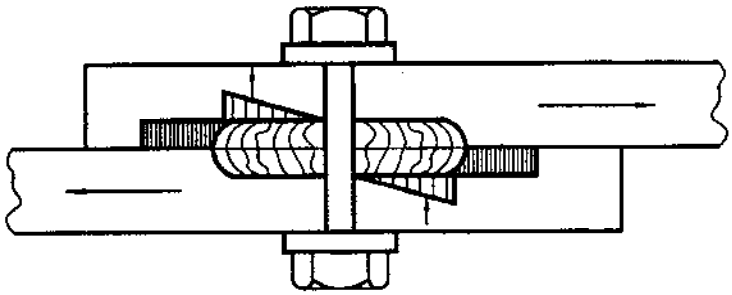
10.2.4 *Design Considerations*

Figure 9 illustrates the forces on dowel in a lap joint and butt joint. Dowel is subjected to shearing at the mid-section, and compression along the grain at the bearing surfaces. For equal strength in both the forces, formula equations are given in Fig. 9 to determine the size of dowel.

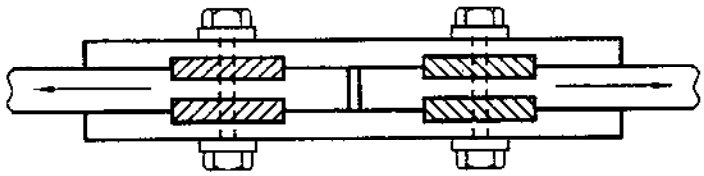
The making of wooden discs may present some problems in the field, but they may be made in small



DOWEL



LAP JOINT



BUTT JOINT

Lap Joint: Bolt in simple tension due to clockwise turning moment on dowel:

Butt Joint: No tilting moment in dowel due to balancing effect [dowels are in shear (no bending, shearing and tensile stress on bolts)]

Size of dowel for equal strength in both shearing and bearing.

$$\pi d^2/4 \times S = d \times t/2 \times c$$

where

d = Mid diameter of the dowel,
t = Thickness of dowel,
s = Safe working stress in shear along grain, and
c = Safe compressive stress along grain.

NOTE — Symbols are exclusive to this figure.

FIG. 9 DISTRIBUTION OF FORCES IN DOWEL JOINT

workshop to the specifications of the designer. This is also economically important. Once the wood fittings are shop tailored and made, the construction process in the field is greatly simplified.

Theoretical safe loads in design shall be confirmed through sample tests.

NOTE — Some experimental studies have indicated the following safe loads in kgf for dowels bearing parallel to the grain.

Members	*Dowels*	*62 × 25*	*75 × 25*	*87 × 25*	*100 × 31*	*112 × 37*	*125 × 37*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Sal	Babul	680	1 000	1 360	1 815	2 270	2 810
Sal	Sissoo	545	770	1 045	1 360	1 725	2 130

11 GLUED LAMINATED CONSTRUCTION AND FINGER JOINTS

11.1 Developments in the field of synthetic adhesive have brought glueing techniques within the range of engineering practice. Timber members of larger cross-sections and long lengths can be fabricated from small sized planks by the process of gluelam. The term glued laminated timber construction as applied to structural members refers to various laminations glued together, either in straight or curved form, having grain of all laminations essentially parallel to the lengths of the member.

11.1.1 *Choice of Glue*

The adhesive used for glued laminated assembly are 'gap filling' type. A 'filler' in powder form is introduced in the adhesive. Structural adhesives are supplied either in powder form to which water is added or in resin form to which a hardener or catalyst is added. For choice of glues, reference may be made to good practice [6-3A(11)]. However, it is important that only boiling water proof (BWP) grade adhesives shall be used for fabrication of gluelam in tropical, high humid climates like India.

11.1.2 *Manufacturing Schedule*

In absence of a systematic flow-line in a factory, provisions of intermediate technology shall be created for manufacturing structural elements. The schedule involves steps:

a) Drying of planks;
b) Planning;
c) End-jointing by scarfs or fingers;
d) Machining of laminations;
e) Setting up dry assembly of structural unit;
f) Application of glue;
g) Assembly and pressing the laminations;
h) Curing the glue lines, as specified; and
j) Finishing, protection and storage.

11.2 Finger joints are glued joints connecting timber members end-to-end (Fig. 10). Such joints shall be produced by cutting profiles (tapered projections) in the form of V-shaped grooves to the ends of timber planks or scantling to be joined, glueing the interfaces and then meeting the two ends together under pressure. Finger joints provide long lengths of timber, ideal for upgrading timber by permitting removal of defects, minimizing warping and reducing wastage by avoiding short off-cuts.

11.2.1 In finger joints the glued surfaces are on the side grain rather than on the end grain and the glue line is stressed in shear rather in tension.

11.2.1.1 The figures can be cut from edge-to-edge or from face-to-face. The difference is mainly in appearance, although bending strength increases if several fingers share the load. Thus a joist is slightly stronger with edge-to-edge finger joints and a plank is stronger with face-to-face finger joint.

11.2.1.2 For structural finger jointed members for interior dry locations, adhesives based on melamine formaldehyde cross linked polyvinyl acetate (PVA) are suited. For high humid and exterior conditions, phenol formaldehyde and resorcinol formaldehyde type adhesives are recommended. Proper adhesives should be selected in consultation with the designer and adhesive manufacturers and assessed in accordance with accepted standard [6-3A(11)].

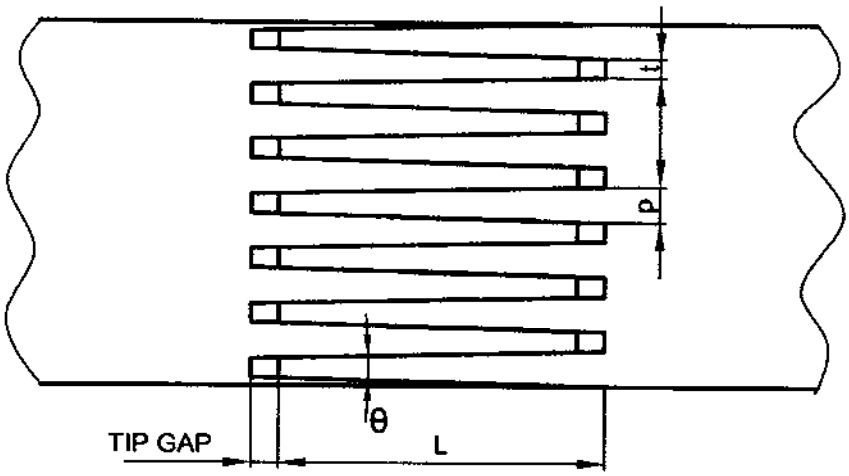
11.2.2 *Manufacturing Process*

In the absence of sophisticated machinery, the finger joints shall be manufactured through intermediate technology with the following steps:

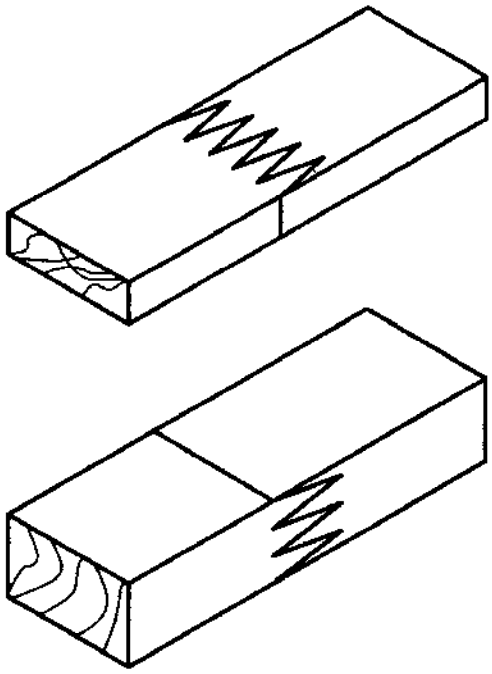
a) Drying of wood,
b) Removal of knots and other defects,
c) Squaring the ends of the laminating planks,
d) Cutting the profile of finger joint in the end grain,
e) Applying adhesives on the finger interfaces,
f) Pressing the joint together at specified pressure,
g) Curing of adhesive line at specified temperature, and
h) Planning of finger-jointed planks for smooth surface.

11.2.3 *Strength*

Strength of finger joints depends upon the geometry of the profile for structural purpose; this is generally 50 mm long, 12 mm pitch.



L = FINGER LENGTH
p = PITCH
t = TIP THICKNESS
θ = 6°



ORIENTATION OF FINGER JOINTS

FIG. 10 TYPICAL FINGER JOINT GEOMETRY

11.2.3.1 End joints shall be scattered in adjacent laminations, which shall not be located in very highly stressed outer laminations.

11.2.4 Tip thickness will be as small as practically possible.

12 LAMINATED VENEER LUMBER

12.1 Certain reconstituted lignocellulosic products with fibre oriented along a specific direction have been developed and are being adopted for load bearing applications. Laminated veneer lumber is one such product developed as a result of researches in plantation grown species of wood. Density of laminated veneer lumber ranges from 0.6 to 0.75 which is manufactured in accordance with good practice [6-3A(12)].

12.1.1 *Dimensions*

Sizes of laminated veneer lumber composite shall be inclusive of margin for dressing and finishing unless manufactured to order. The margin for dressing and finishing shall not exceed 3 mm in the width and thickness and 12 mm in the length.

12.1.2 *Permissible Defects*

Jointing gaps — Not more than 3 mm wide, provided they are well staggered in their spacing and position between the successive plies.

Slope of grain — Not exceeding 1 in 10 in the face layers.

Tight knot — Three numbers up to 25 mm diameter in one square metre provided they are spaced 300 mm or more apart.

Warp — Not exceeding 1.5 mm per metre length.

12.1.3 *Strength Requirements*

The strength requirements for laminated veneer lumber shall be as per Table 17.

13 DESIGN OF GLUED LAMINATED BEAMS

13.1 General

Glued laminated structural members shall be fabricated only where there are adequate facilities for accurate sizing and surfacing of planks, uniform application of glue, prompt assembly, and application of adequate pressure and prescribed temperature for setting and curing of the glue. Design and fabrication shall be in accordance with established engineering principles and good practice. A glued laminated beam is a straight member made from a number of laminations assembled both ways either horizontally or vertically. While vertical laminations have limitations in restricting the cross-section of a beam by width of the plank, horizontally laminated section offers wider scope to the designer in creating even the curved members. Simple straight beams and joists are used for many structures from small domestic rafters or ridges to the light industrial structures.

13.2 Design

The design of glue laminated wood elements shall be in accordance with good engineering practice and shall take into consideration the species and grade of timber used, presence of defects, location of end joints in laminations, depth of beams and moisture contents expected while in service. Beams of large spans shall be designed with a suitable camber to assist in achieving the most cost effective section where deflection governs the design. The strength and stiffness of laminated beams is often governed by the quality of outer laminations. Glued laminated beams can be tapered to follow specific roof slopes across a building and/or to commensurate with the varying bending moments.

13.3 Material

Laminating boards shall not contain decay, knots or other strength reducing characteristics in excess of those sizes or amounts permitted by specifications. The moisture content shall approach that expected in service and shall in no case exceed 15 percent at the time of glueing. The moisture content of individual

Table 17 Requirements of Laminated Veneer Lumber

(*Clause* 12.1.3)

Sl No.	Properties	Requirement
(1)	(2)	(3)
i)	Modulus of rupture (N/mm^2), *Min*	50
ii)	Modulus of elasticity (N/mm^2), *Min*	7 500
iii)	Compressive strength parallel to grain (N/mm^2), *Min*	35
iv)	Compressive strength perpendicular to grain:	
	a) Parallel to grain (N/mm^2), *Min*	35
	b) Perpendicular to grain (N/mm^2), *Min*	50
v)	Horizontal shear:	
	a) Parallel to laminae (N/mm^2), *Min*	6
	b) Perpendicular to laminae (N/mm^2), *Min*	8
vi)	Tensile strength parallel to grain (N/mm^2), *Min*	55
vii)	Screw holding power:	
	a) Edge (N), *Min*	2 300
	b) Face (N), *Min*	2 700
viii)	Thickness swelling in 2 h water soaking (percent), *Max*	3

laminations in a structural member shall not differ by more than 3 percent at the time of glueing. Glue shall be of type suitable for the intended service of a structural member.

13.4 Fabrication/Manufacture

In order to assure a well-bonded and well-finished member of true shape and size, all equipments, end-jointing, glue spread, assembly, pressing, curing or any other operation in connection with the manufacture of glued structural members shall be in accordance with the available good practices and as per glue manufacturers' instructions as applicable.

13.5 Testing

For examining the quality of glue and its relative strength *vis-à-vis* species of timber in glued laminated construction, it is necessary to conduct block shear and other related tests in accordance with accepted standard [6-3A(11)].

Structural loading tests on prototype sizes provide information on the strength properties, stiffness or rigidity against deflection of a beam.

14 STRUCTURAL USE OF PLYWOOD

Unlike sawn timber, plywood is a layered panel product comprising veneers of wood bonded together with adjacent layers usually at right angles. As wood is strongest when stressed parallel to grain, and weak perpendicular to grain, the lay up or arrangement of veneers in the panel determines its properties. When the face grain of the plywood is parallel to the direction of stress, veneers parallel to the face grain carry almost all the load. Some information/guidelines for structural use of plywood which would be manufactured in accordance with accepted standard [6-3A(13)] are given in **14.1** to **14.3**.

14.1 The plywood has a high strength to weight ratio, and is dimensionally stable material available in sheets of a number of thicknesses and construction. Plywood can be sawn, drilled and nailed with ordinary wood working tools. The glues used to bond these veneers together are derived from synthetic resins which are set and cured by heating. The properties of adhesives can determine the durability of plywood.

14.2 In glued plywood construction, structural plywood is glued to timber resulting in highly efficient and light structural components like web beams (I and box sections), (Fig. 11 and Fig. 12) stressed skin panels (Fig. 13) used for flooring and walling and pre-fabricated houses, cabins, etc. Glueing can be carried out by nail glueing techniques with special clamps. High shear strength of plywood in combination with high flexural strength and stiffness of wood result in structures characterized by high stiffness for even medium spares. Plywood can act as web transmitting shear stress in web bearing or stressed skin or sandwich construction. The effective moment of inertia of web beam and stressed skin construction depends on modular ratio that is, E of wood to E of plywood.

14.3 Structural plywood is also very efficient as cladding material in wood frame construction, such as houses. This type of sheathing is capable of resisting racking due to wind and quack forces. Structural plywood has been widely used as diaphragm (horizontal) as in roofing and flooring in timber frame construction. It has been established that 6 mm thick plywood can be used for sheathing and even for web and stressed skin construction, 9-12 mm thick plywood is suitable for beams, flooring diaphragms, etc. Phenol formaldehyde (PF) and PRF adhesive are suitable for fabrication of glued plywood components. 6 mm-12 mm thick structural plywood can be very well used as nailed or bolded gussets in fixing members of trusses or lattice griders or trussed rafters.

Normally, scarf joints are used for fixing plywood to required length and timber can be joined by using either finger or scarf joints. Arch panels, folded plates, shelves are other possibilities with this technique.

15 TRUSSED RAFTER

15.1 General

A roof truss is essentially a plane structure which is very stiff in the plane of the members, that is, the plane in which it is expected to carry loads, but very flexible in every other direction. Thus it can virtually be seen as a deep, narrow girder liable to buckling and twisting under loads. In order, therefore, to reduce this effect, eccentricity of loading and promote prefabrication for economy, low-pitched trussed rafters are designed with bolt ply/nail ply joints. Plywood as gussets, besides being simple have inherent constructional advantage of grain over solid wood for joints, and a better balance is achievable between the joint strength and the member strength.

Trussed rafters are light weight truss units spaced at close centres for limited spans to carry different types of roof loads. They are made from timber members of uniform thickness fastened together in one plane. The plywood gussets may be nailed or glued to the timber to form the joints. Conceptually a trussed rafter is a triangular pin jointed system, traditionally meant to carry the combined roof weight, cladding services and wind loads. There is considerable scope for saving timber by minimizing the sections through proper design without affecting structural and functional requirements.

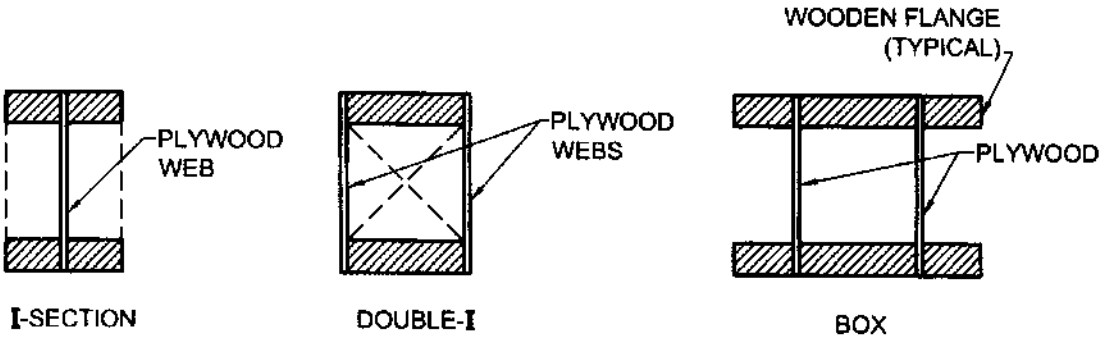
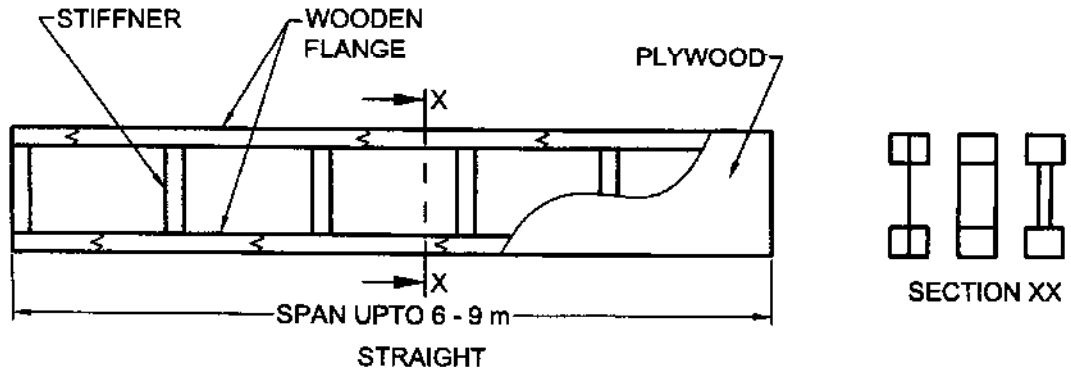
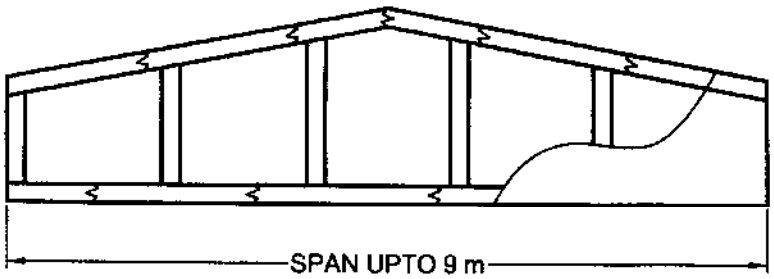


FIG. 11 TYPICAL CROSS-SECTION OF WEB BEAMS





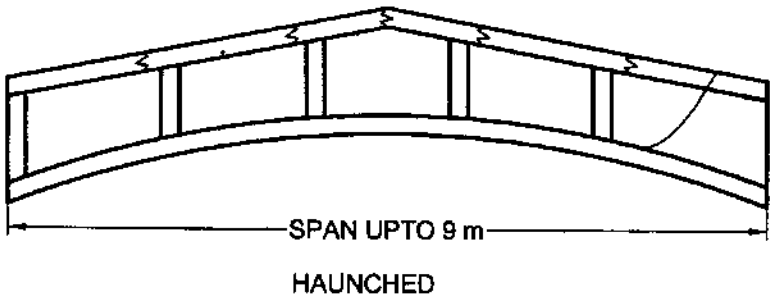


FIG. 12 WEB BEAM CONFIGURATIONS

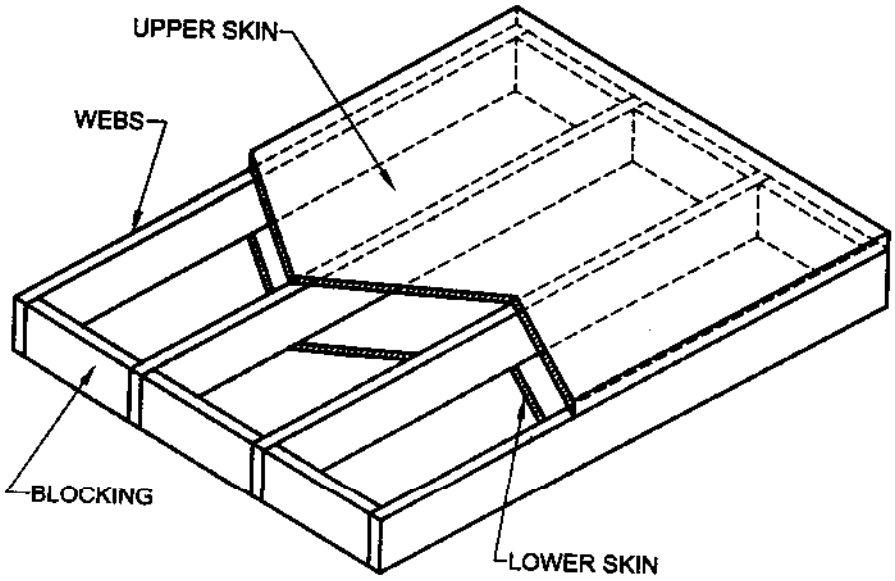


FIG. 13 STRESSED SKIN PANEL CONSTRUCTION (SINGLE SKIN OR DOUBLE SKIN)

Trussed rafters require to be supported only at their ends so that there is no need to provide load bearing internal walls, Purlins, etc are dispensed with and in comparison with traditional methods of construction they use less timber and considerably reduces of site labour, Mass production or reliable units can be carried out under workshop controls.

15.2 Design

Trussed rafter shall be designed to sustain the dead and imposed loads specified in Part 6 'Structural Design: Section 1 Loads, Forces and Effects' and the combinations expected to occur. Extra stresses/ deflections during handling, transportation and erection shall be taken care of. Structural analysis, use of load-slip and moment, rotation characteristics of the individual joints may be used if feasible. Alternatively the maximum direct force in a member may be assessed to be given by an idealized pin-jointed framework, fully loaded with maximum dead and imposed load in the combination in which they may reasonably be expected to occur.

15.3 Timber

The species of timber including plantation grown species which can be used for trussed rafter construction and permissible stresses thereof shall be in accordance with Table 1. Moisture contents to be as per zonal requirements in accordance with **4.4**.

15.4 Plywood

Boiling water resistant (BWR) grade preservative treated plywood shall be used in accordance with accepted standard [6-3A(13)]. Introduction of a plywood gusset simplifies the jointing and in addition provides rigidity to the joint. Preservation of plywood and other panel products shall be done in accordance with good practice [6-3A(14)].

16 STRUCTURAL SANDWICHES

16.1 General

Sandwich constructions are composites of different materials including wood based materials formed by bonding two thin facings of high strength material to a light weight core which provides a combination of desirable properties that are not attainable with the individual constituent materials (Fig. 14). The thin facings are usually of strong dense material since that are the principal load carrying members of the construction. The core must be stiff enough to ensure the faces remain at the correct distance apart. The sandwiches used as structural elements in building construction shall be adequately designed for their intended services and shall be fabricated only where there are adequate facilities for glueing or otherwise bonding cores to facings to ensure a strong and durable product. The entire assembly provides a structural element of high strength and stiffness in proportion to its mass.

Non-structural advantages can also be derived by proper selection of facing and core material for example, an impermeable facings can be used to serve as a moisture barrier for walls and roof panels and core may also be selected to provide thermal and/or acoustic insulation, fire resistance, etc, besides the dimensional stability.

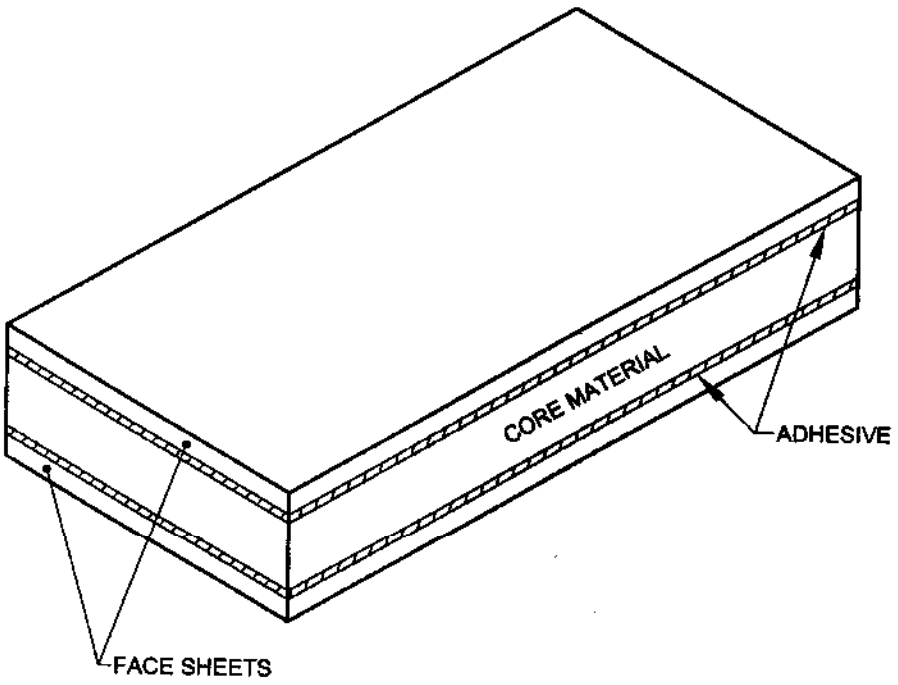


FIG. 14 STANDWICH CONSTRUCTION IN STRUCTURAL APPLICATIONS

16.2 Cores

Sandwich cores shall be of such characteristics as to give to the required lateral support to the stressed facings to sustain or transmit the assumed loads or stresses. Core generally carries shearing loads and to support the thin facings due to compressive loads. Core shall maintain the strength and durability under the conditions of service for which their use is recommended. A material with low E and small shear modulus may be suitable.

16.3 Facings

Facings shall have sufficient strength and rigidity to resist stresses that may come upon them when fabricated into a sandwich construction. They shall be thick enough to carry compressive and tensile stresses and to resist puncture or denting that may be expected in normal usages.

16.4 Designing

Structural designing may be comparable to the design of I-beams, the facings of the sandwich represent the flanges of the I-beam and the sandwich core I-beam web.

16.5 Tests

Panels of sandwich construction shall be subject to testing in accordance with accepted standards [6-3A(15)]. Tests shall include, as applicable, one or more of the following:

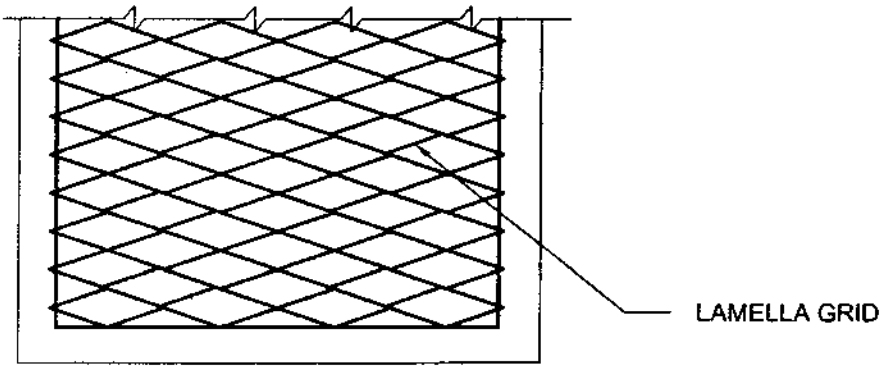
a) Flexural strength/stiffness,
b) Edge-wise compressions,
c) Flat-wise compression,
d) Shear in flat-wise plane,
e) Flat-wise tensions,
f) Flexural creep (creep behaviour of adhesive),
g) Cantilever vibrations (dynamic property), and
h) Weathering for dimensional stability.

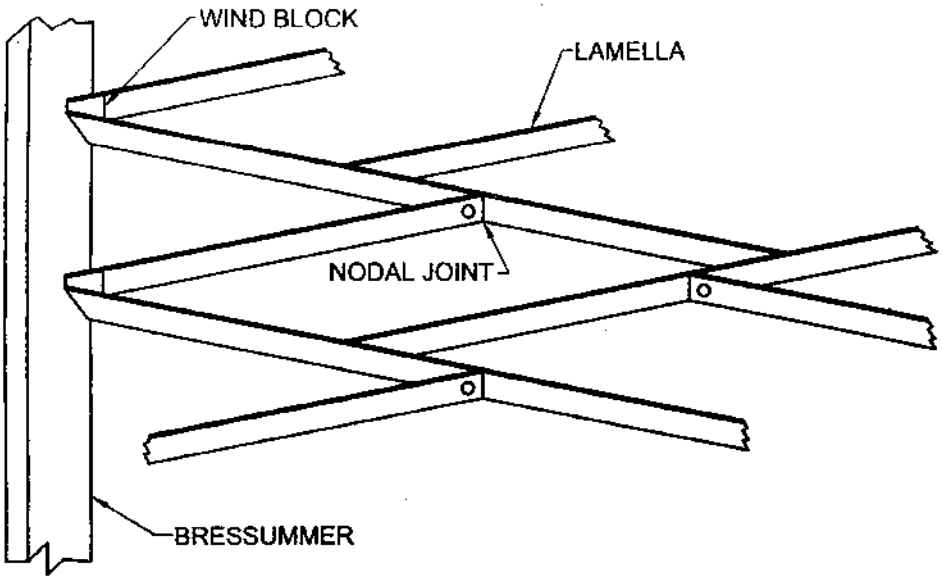
17 LAMELLA ROOFING

17.1 General

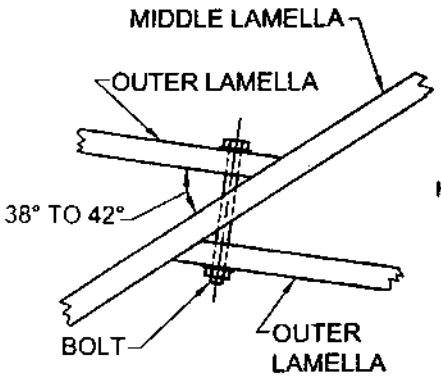
The Lamella roofing offers an excellent architectural edifice in timber, amenable to prefabrication, light weight structure with high central clearance. It is essentially an arched structure formed by a system of intersecting skewed arches built-up of relatively short timber planks of uniform length and cross-section. Roof is designed as a two hinged arch with a depth equal to the depth of an individual lamella and width equal to the span of the building. The curved lamellas (planks) are bevelled and bored at the ends and bolted together at an angle, forming a network (grid) pattern of mutually braced and stiffened members (Fig. 15).

The design shall be based on the balanced or unbalanced assumed load distribution used for roof arches. Effect of deformation or slip of joints under load on the induced stresses shall be considered in design. Thrust components in both transverse and

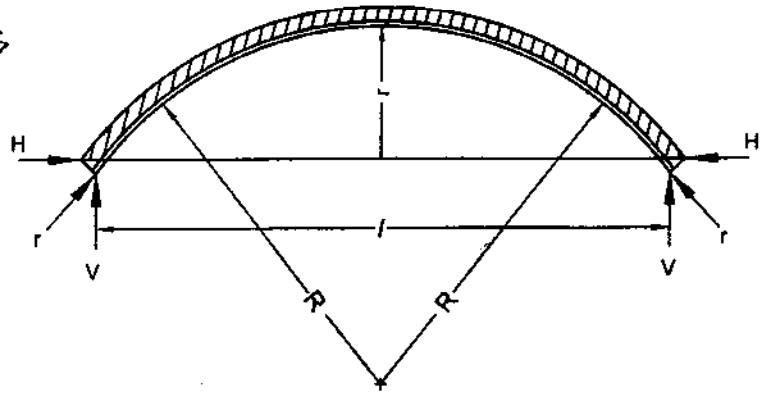




LAMELLA GRID



LAMELLA NODAL JOINT



LOAD REACTION DIAGRAM

FIG. 15 TYPICAL ARRANGEMENT OF LAMELLA ROOFING

longitudinal directions of the building due to skewness of the lamella arch shall be adequately resisted. Thrust at lamella joints shall be resisted by the moment of inertia in the continuous lamella and roof sheathening (decking) of lamella roofing. The interaction of arches in two directions adds to the strength and stability against horizontal forces. For design calculations several assumption tested and observed derivations, long-duration loading factors, seasoning advantages and effects of defects are taken into account.

17.2 Lamellas

Planking shall be of a grade of timber that is adequate in strength and stiffness to sustain the assumed loads, forces, thrust and bending moments generated in Lamella roofing. Lamella planks shall be seasoned to a moisture content approximating that they will attain in service. Lamella joints shall be proportioned so that allowable stresses at bearings of the non-continuous lamellas on the continuous lamellas or bearings under the head or washer of bolts are not exceeded.

17.3 Construction

Design and construction of lamella roofs in India assumes the roof surfaces to be cylindrical with every individual lamella an elliptic segment of an elliptical arch of constant curved length but of different curvature. Lamella construction is thus more of an art than science as there is no analytical method available for true generation of schedule of cutting lengths and curvature of curved members forming the lamella grid. Dependence of an engineer on the practical ingenuity of master carpenter is almost final. All the lamella joints shall be accurately cut and fitted to give full bearing without excessive deformation or slip. Bolts at lamella splices shall be adequate to hold the members in their proper position and shall not be over tightened to cause bending of the lamellas or mashing of wood under the bolt heads. Connection of lamellas to the end arches shall be adequate to transmit the thrust or any other force. Sufficient false work or sliding jig shall be provided for the support of lamella roof during actual construction/erection.

18 NAIL AND SCREW HOLDING POWER OF TIMBER

18.1 General

One of the most common ways of joining timber pieces to one another is by means of common wire nails and wood screws. Timber is used for structural and non-structural purposes in form of scantlings, rafters, joists, boarding, crating and packing cases, etc needing suitable methods of joining them. Nevertheless it is the timber which holds the nails or screws and as such pulling of the nails/screws is the chief factor which come into play predominantly. In structural nailed joints, nails are essentially loaded laterally, the design data for which is already available as standard code of practice. Data on holding power of nails/screws in different species is also useful for common commercial purposes. The resistance of mechanical fastenings is a function of the specific gravity of wood, direction of penetration with respect to the grain direction, depth of penetration and the diameter of fastener assuming that the spacing of fasteners should be adequate to preclude splitting of wood.

18.2 Nails

Nails are probably the most common and familiar fastener. They are of many types and sizes in accordance with the accepted standards [6-3A(16)]. In general nails give stronger joints when driven into the side grain of wood than into the end grain. Nails perform best when loaded laterally as compared to axial withdrawal so the nailed joints should be designed for lateral nail bearing in structural design. Information on withdrawal resistance of nails is available and joints may be designed for that kind of loading as and when necessary.

18.3 Screw

Next to the hammer driven nails, the wood screw may be the most commonly used fastener. Wood screws are seldom used in structural work because of their primary advantage is in withdrawal resistance, for example, for fixing of ceiling boards to joists, purlin cleats, besides the door hinges etc. They are of considerable structural importance in fixture design and manufacture. Wood screws are generally finished in a variety of head shapes and manufactured in various lengths for different screw diameters or gauges in accordance with the accepted standard [6-3A(17)].

The withdrawal resistance of wood screws is a function of screw diameter, length of engagement of the threaded portion into the member, and the specific gravity of the species of wood. Withdrawal load capacity of wood screws are available for some species and joints may be designed accordingly. End grain load on wood screws are unreliable and wood screws shall not be used for that purpose.

19 PROTECTION AGAINST TERMITE ATTACK IN BUILDINGS

19.1 Two groups of organisms which affect the mechanical and aesthetic properties of wood in houses are fungi and insects. The most important wood destroying insects belong to termites and beetles. Of about 250 species of wood destroying termites recorded in India, not more than a dozen species attack building causing about 90 percent of the damage to timber and

other cellulosic materials. Subterranean termites are the most destructive of the insects that infest wood in houses justifying prevention measures to be incorporated in the design and construction of buildings.

19.1.1 Control measures consist in isolating or sealing off the building from termites by chemical and non-chemical construction techniques. It is recognized that 95 percent damage is due to internal travel of the termites from ground upwards rather than external entry through entrance thus calling upon for appropriate control measures in accordance with good practices [6-3A(18)].

19.2 Chemical Methods

Termites live in soil in large colonies and damage the wooden structure in the buildings by eating up the wood or building nests in the wood. Poisoning the soil under and around the building is a normal recommended practice. Spraying of chemical solution in the trenches of foundations in and around walls, areas under floors before and after filling of earth, etc. In already constructed building the treatment can be given by digging trenches all around the building and then giving a liberal dose of chemicals and then closing the trenches.

19.3 Wood Preservatives

Natural resistance against organisms of quite a few wood species provides durability of timber without special protection measure. It is a property of heartwood while sapwood is normally always susceptible to attack by organisms. Preservatives should be well applied with sufficient penetration into timber. For engineers, architects and builders, the following are prime considerations for choice of preservatives:

a) Inflammability of treated timber is not increased and mechanical properties are not decreased;
b) Compatibility with the glue in laminated wood, plywood and board material;
c) Water repellent effect is preferred;
d) Possible suitability for priming coat;
e) Possibility of painting and other finishes;
f) Non-corrosive nature in case of metal fasteners; and
g) Influence on plastics, rubber, tiles and concrete.

19.4 Constructional Method

Protection against potential problem of termite attack can simply be carried out by ordinary good construction which prevents a colony from gaining access by:

a) periodic visual observations on termite galleries to be broken off;
b) specially formed and properly installed metal shield at plinth level; and
c) continuous floor slabs, apron floors and termite grooves on periphery of buildings.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of the enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 707 : 1976	Glossary of terms applicable to timber technology and utilization (*second revision*)
(2) 1708 (Parts 1 to 18) : 1986	Methods of testing small clear specimens of timber (*second revision*)
2408 : 1963	Methods of static tests of timbers in structural sizes
2455 : 1990	Methods of sampling of model trees and logs for timber testing and their conversion (*second revision*)
(3) 4970 : 1973	Key for identification of commercial timbers (*first revision*)
(4) 287 : 1993	Recommendations for maximum permissible moisture content of timber used for different purposes (*third revision*)
(5) 3629 : 1986	Specification for structural timber in building (*first revision*)
(6) 401 : 2001	Code of practice for preservation of timber (*fourth revision*)
(7) 2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)

IS No.	*Title*
(8) 4983 : 1968	Code of practice for design and construction of nail laminated timber beam (*first revision*)
(9) 11096 : 1984	Code of practice for design construction of bolt-jointed construction
(10) 4907 : 1968	Methods of testing timber connectors
(11) 9188 : 1979	Performance requirements for adhesive for structural laminated wood products for use under exterior exposure condition
(12) 14616 : 1999	Specification for laminated veneer lumber
(13) 10701 : 1983	Specification for structural plywood
4990 : 1993	Specification for plywood for concrete shuttering work (*second revision*)
(14) 12120 : 1987	Code of practice for preservation of plywood and other pane products
(15) 9307	Methods of test for wood
(Parts 1 to 7) : 1979	based structural sandwich construction
(16) 723 : 1972	Specification for steel countersunk head wire nails (*first revision*)
(17) 451 : 1999	Technical supply conditions for wood screws (*fourth revision*)
6736 : 1972	Specification for slotted countersunk head wood screw
6739 : 1972	Specification for slotted round head wood screw
6760 : 1972	Specification for slotted countersunk head wood screws
(18) 6313	Code of practice for anti-termite measures in buildings:
(Part 1) : 1981	Constructional measures (*first revision*)
(Part 2) : 2001	Pre-constructional chemical treatment measures (*second revision*)
(Part 3) : 2001	Treatment for existing buildings (*second revision*)

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3B Bamboo

BUREAU OF INDIAN STANDARDS

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FOREWORD

Bamboo is versatile resource characterized by high strength to weight ratio and ease in working with simple tools. It has a long and well established tradition as a building material throughout the tropical and sub-tropical regions. It is used in many forms of construction, particularly, for housing in rural areas. But, enough attention had not been paid towards research and development in bamboo as had been in the case with other materials of construction including timber. However, of late bamboo is being given its due importance and realization by national and international organizations. A need is being felt for design and construction code in bamboo for a number of social and trade advantages, engineering recognition and improved respectability. Forest Research Institute, Dehra Dun and some other organizations have been engaged in bamboo research to establish its silviculture, botanical nomenclature, entomological and pathological aspects and utilization base.

Some of the suitable species grown in India and neighbouring countries are enlisted in Annex A along with their local names and source, for general information.

Analogous to some constructional timbers, bamboo possesses better strength-to-mass and cost ratio. Resilience coupled with lightness makes bamboo suitable for housing in disaster-prone areas such as areas prone to earthquake. It has the capacity to absorb more energy and show larger deflections before collapse and as such is safer under earth tremors. At present, the application of bamboo as an engineering material is largely based on practical and engineering experience as the design guidelines are inadequate.

The bamboo culm has a tubular structure consisting essentially of nodes and inter-nodes. In the inter-nodes the cells are axially oriented while the nodes provide the transverse inter-connection. The disposition of the nodes and the wall thickness are significant in imparting strength to bamboo against bending and crushing. In a circular cross-section, bamboo is generally hollow and for structural purposes this form is quite effective and advantageous. Each of the species of bamboo has widely different characteristics affecting its usefulness as constructional material. The strength of bamboo culms, their straightness, lightness combined with hardness, range and size of hollowness make them potentially suitable for a variety of applications both structural and non-structural. With good physical and mechanical properties, low shrinkage and good average density, bamboo is well suited to replace wood in several applications, especially in slats and panel form.

In the earlier version of this Code, timber was covered under Section 3 of Part 6 under the title Wood, which did not cover Bamboo. In this revision, this Section has been enlarged and titled as Section 3 Timber and Bamboo. This has been sub-divided into sub-section 3A Timber and sub-section 3B Bamboo. Bamboo has found a place in this draft revision of the Code for the first time. This subsection pertains to bamboo and may be read in conjunction with sub-section 3A Timber.

The information contained in this Section is largely based on the works carried out at Forest Research Institute, Dehra Dun, Indian Plywood Industries Research and Training Institute, Bangalore, INBAR documents and the following Indian Standards:

IS No.	*Title*
6874 : 1973	Method of test for round bamboo
8242 : 1976	Method of test for split bamboo
9096 : 1979	Code of practice for preservation of bamboo for structural purposes
13958 : 1994	Specification for bamboo mat board for general purposes

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3B Bamboo

1 SCOPE

This Section relates to the use of bamboo for constructional purposes in structures or elements of the structure, ensuring quality and effectiveness of design and construction using bamboo. It covers minimum strength data, dimensional and grading requirements, seasoning, preservative treatment, design and jointing techniques with bamboo which would facilitate scientific application and long-term performance of structures. It also covers guidelines so as to ensure proper procurement, storage, precautions and design limitations on bamboo.

2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions shall apply.

2.1 Anatomical Purpose Definitions

2.1.1 *Bamboo* — Tall perennial grasses found in tropical and sub-tropical regions. They belong to the family *Poaceae* and sub-family *Bambusoidae*.

2.1.2 *Bamboo Culm* — A single shoot of bamboo usually hollow except at nodes which are often swollen.

2.1.3 *Bamboo Clump* — A cluster of bamboo culms emanating from two or more rhizomer in the same place.

2.1.4 *Cellulose* — A carbohydrate, forming the fundamental material of all plants and a main source of the mechanical properties of biological materials.

2.1.5 *Cell* — A fundamental structural unit of plant and animal life, consisting of cytoplasma and usually enclosing a central nucleus and being surrounded by a membrane (animal) or a rigid cell wall (plant).

2.1.6 *Cross Wall* — A wall at the node closing the whole inside circumference and completely separating the hollow cavity below from that above.

2.1.7 *Hemi Cellulose* — The polysaccharides consisting of only 150 to 200 sugar molecules, also much less than the 10 000 of cellulose.

2.1.8 *Lignin* — A polymer of phenyl propane units, in its simple form ($C_6H_5CH_3CH_2CH_3$).

2.1.9 *Sliver* — Thin strips of bamboo processed from bamboo culm.

2.1.10 *Tissue* — Group of cells, which in higher plants consist of (a) *Parenchyma* — a soft cell of higher plants as found in stem pith or fruit pulp, (b) *Epidermis* — the outermost layer of cells covering the surface of a plant, when there are several layers of tissue.

2.2 Structural Purpose Definitions

2.2.1 *Bamboo Mat Board* — A board made of two or more bamboo mats bonded with an adhesive.

2.2.2 *Beam* — A structural member which supports load primarily by its internal resistance to bending.

2.2.3 *Breaking Strength* — A term loosely applied to a given structural member with respect to the ultimate load it can sustain under a given set of conditions.

2.2.4 *Bundle-Column* — A column consisting of three or more number of culm bound as integrated unit with wire or strap type of fastenings.

2.2.5 *Centre Internode* — A test specimen having its centre between two nodes.

2.2.6 *Characteristic Load* — The value of loads which has a 95 percent probability of not exceeding during the life of the structure.

2.2.7 *Characteristic Strength* — The strength of the material below which not more than 5 percent of the test results are expected to fall.

2.2.8 *Cleavability* — The ease with which bamboo can be split along the longitudinal axis. The action of splitting is known as cleavage.

2.2.9 *Column* — A structural member which supports axial load primarily by inducing compressive stress along the fibres.

2.2.10 *Common Rafter* — A roof member which supports roof battens and roof coverings, such as boarding and sheeting.

2.2.11 *Curvature* — The deviation from the straightness of the culm.

2.2.12 *Delamination* — Separation of mats through failure of glue.

2.2.13 *End Distance* — The distance measured parallel to the fibres of the bamboo from the centre of the fastener to the closest end of the member.

2.2.14 *Flatten Bamboo* — Bamboo consisting of culms that have been cut and unfolded till it is flat. The culm thus is finally spread open, the diaphragms (cross walls) at nodes removed and pressed flat.

2.2.15 *Full Culm* — The naturally available circular section/shape.

2.2.16 *Fundamental or Ultimate Stress* — The stress which is determined on a specified type/size of culms of bamboo, in accordance with standard practice and does not take into account the effects of naturally occurring characteristics and other factors.

2.2.17 *Inner Diameter* — Diameter of internal cavity of a hollow piece of bamboo.

2.2.18 *Inside Location* — Position in buildings in which bamboo remains continuously dry or protected from weather.

2.2.19 *Joint* — A connection between two or more bamboo structural elements.

2.2.20 *Joist* — A beam directly supporting floor, ceiling or roof of a structure.

2.2.21 *Length of Internode* — Distance between adjacent nodes.

2.2.22 *Loaded End or Compression End Distance* — The distance measured from the centre of the fastner to the end towards which the load induced by the fastener acts.

2.2.23 *Matchet* — A light cutting and slashing tool in the form of a large knife.

2.2.24 *Mat* — A woven sheet made using thin slivers.

2.2.25 *Mortise and Tenon* — A joint in which the reduced end (tenon) of one member fits into the corresponding slot (mortise) of the other.

2.2.26 *Net Section* — Section obtained by deducting from the gross cross-section (*A*), the projected areas of all materials removed by boring, grooving or other means.

2.2.27 *Node* — The place in a bamboo culm where branches sprout and a diaphragm is inside the culm and the walls on both sides of node are thicker.

2.2.28 *Outer Diameter* — Diameter of a cross-section of a piece of bamboo measured from two opposite points on the outer surface.

2.2.29 *Outside Location* — Position in building in which bamboos are occasionally subjected to wetting and drying as in case of open sheds and outdoor exposed structures.

2.2.30 *Permissible Stress* — Stress obtained after applying factor of safety to the ultimate or basic stress.

2.2.31 *Principal Rafter* — A roof member which supports purlins.

2.2.32 *Purlins* — A roof member directly supporting roof covering or common rafter and roof battens.

2.2.33 *Roof Battens* — A roof member directly supporting tiles, corrugated sheets, slates or other roofing materials.

2.2.34 *Roof Skeleton* — The skelton consisting of bamboo truss or rafter over which solid bamboo purlins are laid and lashed to the rafter or top chord of a truss by means of galvanized iron wire, cane, grass, bamboo leaves, etc.

2.2.35 *Slenderness Ratio* — The ratio of the length of member to the radius of gyration is known as slenderness ratio of member. (The length of the member is the equivalent length due to end conditions).

2.2.36 *Splits* — The pieces made from quarters by dividing the quarters radially and cutting longitudinally.

2.2.37 *Taper* — The ratio of difference between minimum and maximum outer diameter to length.

2.2.38 *Unloaded End Distance* — The end distance opposite to the loaded end.

2.2.39 *Wall Thickness* — Half the difference between outer diameter and inner diameter of the piece at any cross-section.

2.2.40 *Wet Location* — Position in buildings in which the bamboos are almost continuously damp, wet or in contact with earth or water, such as piles and bamboo foundations.

2.3 Definitions Relating to Defects

2.3.1 *Bamboo Bore/GHOON Hole* — The defect caused by bamboo *GHOON* beetle (*Dinoderus* spp. *Bostrychdae*), which attacks felled culms.

2.3.2 *Crookedness* — A localized deviation from the straightness in a piece of bamboo.

2.3.3 *Discolouration* — A change from the normal colour of the bamboo which does not impair the strength of bamboo or bamboo composite products.

2.4 Definitions Relating to Drying Degrades

2.4.1 *Collapse* — The defect occurring on account of excessive shrinkage, particularly in thick walled immature bamboo. When the bamboo wall shrinks, the outer layers containing a larger concentration of strong fibro-vascular bundles set the weaker interior portion embedded in parenchyma in tension, causing the latter to develop cracks. The interior crack develops into a wide split resulting in a depression on the outer surface. This defect also reduces the structural strength of round bamboo.

2.4.2 *End Splitting* — A split at the end of a bamboo. This is not so common a defect as drying occurs both

from outer and interior wall surfaces of bamboo as well as the end at the open ends.

2.4.3 *Surface Cracking* — Fine surface cracks not detrimental to strength. However, the cracking which occurs at the nodes reduces the structural strength.

2.4.4 *Wrinkled and Deformed Surface* — Deformation in cross-section, during drying, which occurs in immature round bamboos of most species; in thick walled pieces, besides this deformation the outer surface becomes uneven and wrinkled. Very often the interior wall develops a crack below these wrinkles, running parallel to the axis.

3 SYMBOLS

3.1 For the purpose of this Section, the following letter symbols shall have the meaning indicated against each, unless otherwise stated:

A = Cross-sectional area of bamboo (perpendicular to the direction of the principal fibres and vessels), mm²

$$A = \frac{\pi}{4}(D^2 - d^2)$$

D = Outer diameter, mm

d = Inner diameter, mm

E = Modulus of elasticity in bending, N/mm²

f_c = Calculated stress in axial compression, N/mm²

f_{cp} = Permissible stress in compression along the fibres, N/mm²

I = Moment of inertia, mm⁴

$$= \frac{\pi}{64}(D^4 - d^4)$$

l = Unsupported length of column

M = Moisture content, percent

r = Radius of gyration

$= \sqrt{(I/A)}$

R' = Modulus of rupture, N/mm²

w = Wall thickness, mm

Z = Section modulus, mm³

δ = Deflection or deformation, mm.

4 MATERIALS

4.1 Species of Bamboo

More than 100 species of bamboo are native to India and a few of them are solid but most of them are hollow in structure. Physical and mechanical properties of 20 species of bamboo so far tested in green and dry conditions in round form are given in Table 1.

4.1.1 *Grouping*

Sixteen species of bamboo found suitable for structural applications and classified into three groups, namely, Group A, Group B and Group C are given in Table 2.

The characteristics of these groups are as given below:

Limiting Strength Values (in Green Condition)

	Modulus of Rupture (R′) N/mm²	*Modulus of Elasticity (E) in Bending* 10^3 N/mm²
(1)	(2)	(3)
Group A	$R' > 70$	$E > 9$
Group B	$70 \geq R' > 50$	$9 \geq E > 6$
Group C	$50 \geq R' > 30$	$6 \geq E > 3$

4.1.2 Bamboo species may be identified using suitable methods.

NOTE — Methods of identification of bamboo through anatomical characters have not been perfected so far. Identification through morphological characters could be done only on full standing culm by experienced sorters.

4.1.3 *Dendrocalamus strictus* and *Bambusa arundinacea* are the two principal economic species of which the former occupies the largest area and is the most common owing to the vast expanse and suitability as a raw material for industrial uses.

4.2 Species of bamboo other than those listed in the Table 2 may be used, provided the basic strength characteristics are determined and found more than the limits mentioned therein. However, in the absence of testing facilities and compulsion for use of other species, and for expedient designing, allowable stresses may be arrived at by multiplying density with factors as given below:

Allowable Long-Term Stress (N/mm²) per Unit Density (kg/m³)

Condition	*Axial Compression* (no buckling)	*Bending*	*Shear*
Green	0.011	0.015	—
Air dry (12%)	0.013	0.020	0.003

NOTE — In the laboratory regime, the density of bamboo is conveniently determined. Having known the density of any species of bamboo, permissible stresses can be worked out using factors indicated above. For example, if green bamboo has a density of 600 kg/m³, the allowable stress in bending would be 0.015 × 600 = 9 N/mm².

4.3 Moisture Content in Bamboo

With decrease of moisture content (M) the strength of

Table 1 Physical and Mechanical Properties of Indian Bamboos (in Round Form)

(*Clauses* 4.1 *and* 5.1.2)

Sl No.	Species	Properties						
		In Green Condition				In Air Dry Conditions		
		Density kg/m³	Modulus of Rupture N/mm²	Modulus of Elasticity 10^3 N/mm²	Maximum Compressive Strength N/mm²	Density kg/m³	Modulus of Rupture N/mm²	Modulus of Elasticity 10^3 N/mm²
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	*Bambusa auriculata*	594	65.1	15.01	36.7	670	89.1	21.41
ii)	*B. balcooa*	783	65.4	7.31	46.7	—	—	—
iii)	*B. bambos (Syn.B.arundinacea)*	559	58.3	5.95	35.3	663	80.1	8.96
iv)	*B. burmanica*	570	59.7	11.01	39.9	672	105.0	17.81
v)	*B. glancescens (Syn.B.nana)*	691	82.8	14.77	53.9	—	—	—
vi)	*B. nutans*	603	52.9	6.62	45.6	673	52.4	10.72
vii)	*B. pallida*	731	55.2	12.90	54.0	—	—	—
viii)	*B. polymorpha*	619	28.3	3.12	32.1	659	35.5	4.40
ix)	*B. tulda*	658	51.1	7.98	40.7	722	66.7	10.07
x)	*B. ventricosa*	626	34.1	3.38	36.1	—	—	—
xi)	*B. vulgaris*	626	41.5	2.87	38.6	—	—	—
xii)	*Cephalostachyum pergracile*	601	52.6	11.16	36.7	640	71.3	19.22
xiii)	*Dendrocalamus giganteous*	597	17.2	0.61	35.2	—	—	—
xiv)	*D. hamiltonii*	515	40.0	2.49	43.4	—	—	—
xv)	*D. longispathus*	711	33.1	5.51	42.1	684	47.8	6.06
xvi)	*D. membranaceus*	551	26.3	2.44	40.5	664	37.8	3.77
xvii)	*D. strictus*	631	73.4	11.98	35.9	728	119.1	15.00
xviii)	*Melocanna baccifera*	817	53.2	11.39	53.8	751	57.6	12.93
xix)	*Oxytenanthera abyssinicia*	688	83.6	14.96	46.6	—	—	—
xx)	*Thyrsostachys oliveri*	733	61.9	9.72	46.9	758	90.0	12.15

NOTES

1 As the strength of split bamboo is more than that of round bamboo, the results of tests on round bamboo can be safely used for designing with spit bamboo.

2 The values of stress in N/mm² have been obtained by converting the values in kgf/cm² by dividing the same by 10.

Table 2 Safe Working Stresses of Bamboos for Structural Designing[1)]

(*Clauses* 4.1.1, 4.2, 5.3 *and* 5.4)

Sl No.	Species	Extreme Fibre Stress in Bending N/mm²	Modulus of Elasticity 10^3 N/mm²	Allowable Compressive Stress N/mm²
(1)	(2)	(3)	(4)	(5)
	GROUP A			
i)	*Bambusa glancescens (syn. B. nana)*	20.7	3.28	15.4
ii)	*Dendrocalamus strictus*	18.4	2.66	10.3
iii)	*Oxytenanthera abyssinicia*	20.9	3.31	13.3
	GROUP B			
iv)	*Bambusa balcooa*	16.4	1.62	13.3
v)	*B. pallida*	13.8	2.87	15.4
vi)	*B. nutans*	13.2	1.47	13.0
vii)	*B. tulda*	12.8	1.77	11.6
viii)	*B. auriculata*	16.3	3.34	10.5
ix)	*B. burmanica*	14.9	2.45	11.4
x)	*Cephalostachyum pergracile*	13.2	2.48	10.5
xi)	*Melocanna baccifera (Syn. M. bambusoides)*	13.3	2.53	15.4
xii)	*Thyrsotachys oliveri*	15.5	2.16	13.4
	GROUP C			
xiii)	*Bambusa arundinacea (Syn. B. bambos)*	14.6	1.32	10.1
xiv)	*B. ventricosa*	8.5	0.75	10.3
xv)	*B. vulgaris*	10.4	0.64	11.0
xvi)	*Dendrocalamus longispathus*	8.3	1.22	12.0

NOTE — The values of stress in N/mm² have been obtained by converting the values in kgf/cm² by dividing the same by 10.

[1)] The values given pertain to testing of bamboo in green condition.

bamboo increases exponentially and bamboo has an intersection point (fibre saturation point) at around 25 percent moisture content depending upon the species. A typical moisture-strength relationship is given at Fig. 1. The moisture content of bamboo shall be determined in accordance with good practice [6-3B(1)]. Matured culms shall be seasoned to about 20 percent moisture content before use.

4.3.1 Air seasoning of split or half-round bamboo does not pose much problem but care has to be taken to prevent fungal discolouration and decay. However, rapid drying in open sun can control decay due to fungal and insect attack. Seasoning in round form presents considerable problem for several of Indian species of bamboo as regards mechanical degrade due to drying defects.

NOTE — A general observation has been that immature bamboo gets invariably deformed in cross-section during seasoning and thick walled immature bamboo generally collapses. Thick mature bamboo tends to crack on the surface, with the cracks originating at the nodes and at the decayed points. Moderately thick immature and thin and moderately thick mature bamboos season with much less degrade. Bamboo having poor initial condition on account of decay, borer holes, etc generally suffers more drying degrades.

4.3.2 Accelerated air seasoning method gives good results. In this method, the nodal diaphragm (septa) are punctured to enable thorough passage of hot air from one end of the resulting bamboo tube to the other end.

NOTE — For details, reference may be made to relevant publications of Forest Research Institute, Dehra Dun.

4.4 Grading of Structural Bamboo

4.4.1 Grading is sorting out bamboo on the basis of characteristics important for structural utilization as under:

a) Diameter and length of culm,
b) Taper of culm,
c) Straightness of culm,
d) Inter nodal length,
e) Wall thickness,
f) Density and strength, and
g) Durability and seasoning.

One of the above characteristics or sometimes combination of 2 or 3 characteristics form the basis of grading. The culms shall be segregated species-wise.

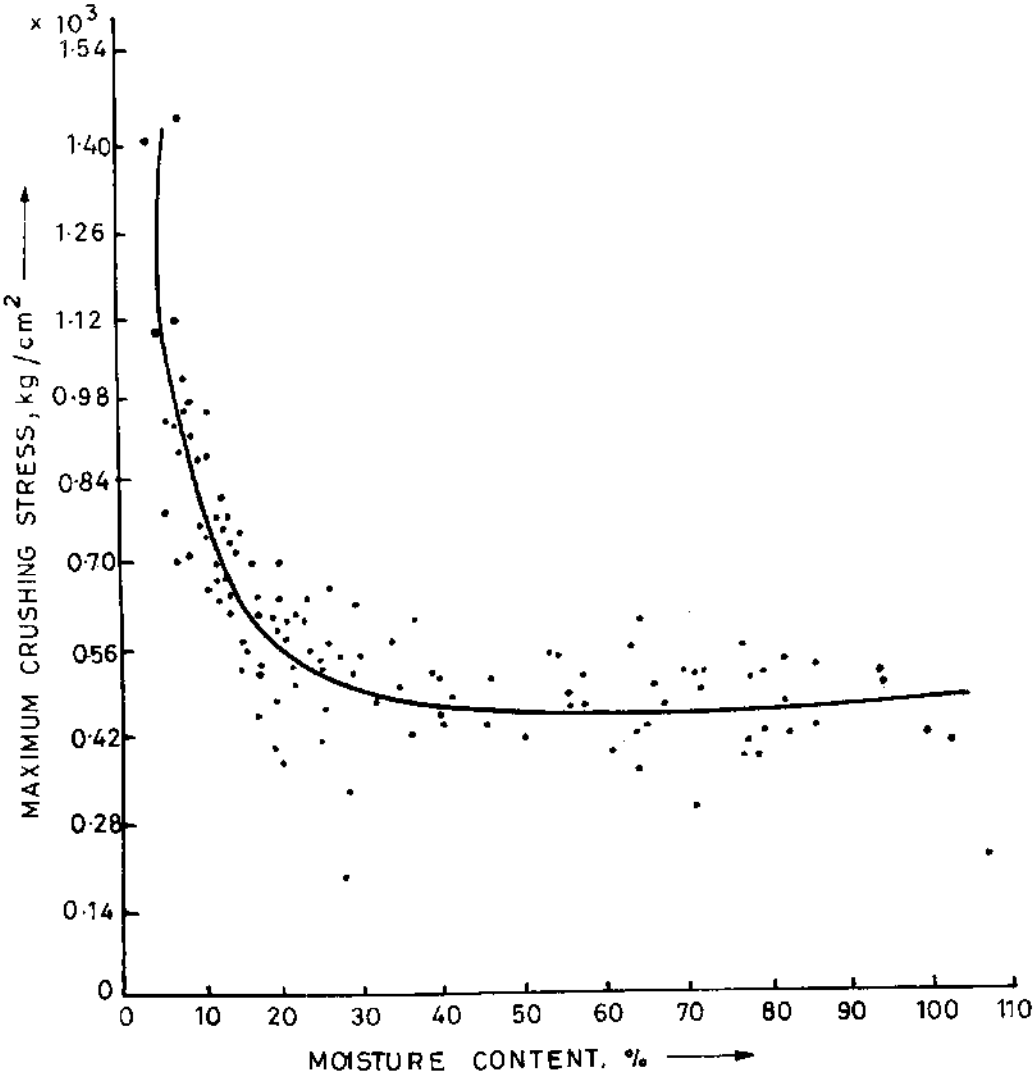


FIG. 1 MOISTURE STRENGTH RELATIONSHIP BAMBUSA NUTANS (BAMBOO)

4.4.2 *Diameter and Length*

4.4.2.1 *Gradation according to the mean outer diameter*

For structural Group A and Group B species, culms shall be segregated in steps of 10 mm of mean outer diameter as follows:

Special Grade	70 mm < Diameter ≤ 100 mm
Grade I	50 mm < Diameter ≤ 70 mm
Grade II	30 mm < Diameter ≤ 50 mm
Grade III	Diameter ≤ 30 mm

For structural Group C species culms shall be segregated in steps of 20 mm of mean outer diameter

Grade I	80 mm < Diameter ≤ 100 mm
Grade II	60 mm < Diameter ≤ 80 mm
Grade III	Diameter ≤ 60 mm

4.4.2.2 The minimum length of culms shall be preferably 6 m for facilitating close fittings at joints, etc.

4.4.3 *Taper*

The taper shall not be more than 5.8 mm per metre length (or 0.58 percent) of bamboo in any grade of bamboo.

4.4.4 *Curvature*

The maximum curvature shall not be more than 75 mm in a length of 6 m of any grade of bamboo.

4.4.5 *Wall Thickness*

Preferably minimum wall thickness of 8 mm shall be used for load bearing members.

4.4.6 *Defects and Permissible Characteristics*

4.4.6.1 Dead and immature bamboos, bore/*GHOON*

holes, decay, collapse, checks more than 3 mm in depth, shall be avoided.

4.4.6.2 Protruded portion of the nodes shall be flushed smooth. Bamboo shall be used after at least six weeks of felling. Bamboo shall be properly treated in accordance with good practice [6-3B(2)].

4.4.6.3 Broken, damaged and discoloured bamboo shall be rejected.

4.4.6.4 Matured bamboo of at least 4 years of age shall be used.

4.5 Durability and Treatability

4.5.1 *Durability*

The natural durability of bamboo is low and varies between 12 months and 36 months depending on the species and climatic conditions. In tropical countries the biodeterioration is very severe. Bamboos are generally destroyed in about one to two years' time when used in the open and in contact with ground while a service life of two to five years can be expected from bamboo when used under cover and out of contact with ground. The mechanical strength of bamboo deteriorates rapidly with the onset of fungal decay in the sclerenchymatous fibres. Split bamboo is more rapidly destroyed than round bamboo. For making bamboo durable, suitable treatment shall be given.

4.5.2 *Treatability*

Due to difference in the anatomical structure of bamboo as compared to timber, bamboo behaves entirely differently from wood during treatment with preservative. Bamboos are difficult to treat by normal preservation methods in dry condition and therefore treatment is best carried out in green condition in accordance with good practice [6-3B(2)].

4.5.2.1 *Boucherie Process*

In this process of preservative treatment, water borne preservative is applied to end surface of green bamboo through a suitable chamber and forced through the bamboo by hydrostatic or other pressure.

4.5.2.2 *Performance of treated bamboo*

Trials with treated bamboos have indicated varied durability depending upon the actual location of use. The performance in partially exposed and under covered conditions is better.

4.5.2.3 For provisions on safety of bamboo structures against fire, *see* Part 7 'Constructional Practices and Safety'.

5 PERMISSIBLE STRESSES

5.1 Basic stress values of different species and groups of bamboo shall be determined according to good practice [6-3B(3)]. These values shall then be divided by appropriate factors of safety to obtain permissible stresses.

5.1.1 The safety factor for deriving safe working stresses of bamboo shall be as under:

Extreme fibre stress in beams	–	4
Modulus of elasticity	–	4.5
Maximum compressive stress parallel to grain/fibres	–	3.5

5.1.2 The coefficient of variation (in percent), which has been arrived based on data of test-results of at least 15 consignments of bamboo in green conditions, shall be as under:

Property	*Mean*	*Range*	*Maximum Expected Value*
(1)	(2)	(3)	(4)
Modulus of rupture	15.9	5.7 – 28.3	23.4
Modulus of elasticity	21.1	12.7 – 31.7	27.4
Maximum compressive stress	14.9	7.6 – 22.8	20.0

The maximum expected values of coefficient of variation which are the upper confidence limits under normality assumption such that with 97.5 percent confidence the actual strength of the bamboo culm will be at least 53 percent of the average reported value of modulus of rupture in Table 1.

5.2 Solid bamboos or bamboos whose wall thickness (w) is comparatively more and bamboos which are generally known as male bamboos having nodes very closer and growing on ridges are often considered good for structural purposes.

5.3 The safe working stresses for 16 species of bamboos are given in Table 2.

5.4 For change in duration of load other than continuous (long-term), the permissible stresses given in Table 2 shall be multiplied by the modification factors given below:

For imposed or medium term loading	–	1.25
For short-term loading	–	1.50

6 DESIGN CONSIDERATIONS

6.1 All structural members, assemblies or framework in a building shall be capable of sustaining, without

exceeding the limits of stress specified, the worst combination of all loadings. A fundamental aspect of design will be to determine the forces to which the structure/structural element might be subjected to, starting from the roof and working down to the soil by transferring the forces through various components and connections. Accepted principles of mechanics for analysis and specified design procedures shall be applied (*see* Part 6 'Structural Design, Sub-section 3A Timber').

6.2 Unlike timber, bamboo properties do not relate well to species, being dependent among other factors, on position of the culm, geographic location and age. The practice in timber engineering is to base designs on safe working stresses and the same may be adopted to bamboo with the limitations that practical experience rather than precise calculations generally govern the detailing.

6.3 Net Section

It is determined by passing a plane or a series of connected planes transversely through the members. Least net sectional area is used for calculating load carrying capacity of a member.

6.4 Loads

6.4.1 The loads shall be in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects'.

6.4.2 The worst combination and location of loads shall be considered for design. Wind and seismic forces shall not be considered to act simultaneously.

6.5 Structural Forms

6.5.1 Main structural components in bamboo may include roof and floor diaphragms, shear walls, wall panellings, beams, piles, columns, etc. Both from the point of view of capacity and deformation, trusses and framed skeltons are much better applications of bamboo.

6.5.2 *Schematization of Bamboo as a Structural Material*

This shall be based on the principles of engineering mechanics involving the following assumptions and practices:

a) The elastic behaviour of bamboo, till failure; (plastic behaviour being considered insignificant);

b) Bamboo culms are analysed on mean wall thickness basis as hollow tube structure (not perfectly straight) member on mean diameter basis;

c) The structural elements of bamboo shall be appropriately supported near the nodes of culm as and where the structural system demands. The joints in the design shall be located near nodes; and

d) Bamboo structures be designed like any other conventional structural elements taking care of details with regards to supports and joints; they shall be considered to generally act as a hinge, unless substantiating data justify a fixed joint.

6.6 Flexural Members

6.6.1 All flexural members may be designed using the principles of beam theory.

6.6.2 The deflection shall be within the prescribed limits. The tendency of bamboo beams to acquire a large deflection under long continuous loadings due to possible plastic flow, if any shall be taken care of. Permanent load may be doubled for calculation of deflection under sustained load (including creep) in case of green bamboo having moisture content exceeding 15 percent.

6.6.3 Bamboo is not naturally reinforced for shear, because, compared to reinforced cement concrete beam, the stirrups are located on the longitudinal instead of the transverse direction in a bamboo culm.

6.6.4 The moment of inertia, I shall be determined as follows:

a) The outside diameter and the wall thickness shall be measured at both ends, correct up to 1 mm for diameter of culm and 0.1 mm for the wall thickness. (For each cross-section the diameter shall be taken twice, in direction perpendicular to each other and so the wall thickness shall be taken as four times, in the same places as the diameter has been taken twice.)

b) With these values the mean diameter and the mean thickness for the middle of the beam shall be calculated and moment of inertia determined.

6.6.4.1 The maximum bending stress shall be calculated and compared with the allowable stress.

6.6.4.2 The deflection shall be calculated, and compared with the allowable deflection. The initial curvature shall be considered in the calculation of the deflection.

6.6.4.3 The shear stress in the neutral layer at the small end shall be checked, if the length of the beam is less

than 25 times the diameter at that end. For shear checks, conventional design procedure in accordance with Part 6 'Structural Design, Sub-section 3A Timber' shall be followed.

NOTE — The basic shear stress values (N/mm²) for at least five species of bamboo in split form in green condition have been determined as under:

Bambusa pallida	9.77
B. Vulgaris	9.44
Dedrocalamus giganteous	8.86
D.hamiltonii	7.77
Oxytenanthera abyssinicia	11.2

6.6.4.4 Forces acting on a beam, being loads or reaction forces at supports, shall act in nodes or as near to nodes as by any means possible.

6.7 Bamboo Columns (Predominantly Loaded in Axial Direction)

6.7.1 Columns and struts are essential components sustaining compressive forces in a structure. They transfer load to the supporting media.

6.7.2 Design of columns shall be based on one of the following two criteria:

a) Full scale buckling tests on the same species, size and other relevant variables.

b) Calculations, based on the following:
   1) The moment of inertia shall be as per **6.6.4**.
   2) For bamboo columns the best available straight bamboo culms shall be selected. Structural bamboo components in compression should be kept under a slenderness ratio of 50.
   3) The bending stresses due to initial curvature, eccentricities and induced deflection shall be taken into account, in addition to those due to any lateral load.

6.7.3 Buckling calculation shall be according to Euler, with a reduction to 90 percent of moment of inertia, to take into account the effect of the taper provided it is not less than 0.6 percent.

6.7.4 For strength and stability, larger diameter thick walled sections of bamboo with closely spaced nodes shall be used. Alternatively, smaller sections may be tied together as a bundle-column.

6.8 Assemblies, Roof Trusses

6.8.1 Elements in structure are generally built-up in the form of assembled members for which a triangle is a simple figure of stability. Besides sloped chords, parallel chord construction is also appropriate as external profile.

6.8.2 A truss is essentially a plane structure which is very stiff in the plane of the members, that is the plane in which it is expected to carry load, but very flexible in every other direction. Roof truss generally consists of a number of triangulated frames, the members of which are fastened at ends and the nature of stresses at joints are either tensile or compressive and designed as pin-ended joints (*see* Fig. 2A). Bamboo trusses may also be formed using bamboo mat board or bamboo mat-veneer composite or plywood gusset (*see* Fig. 2B).

6.8.3 Truss shall be analysed from principles of structural mechanics for the determination of axial forces in members. For the influence of eccentricities, due allowance shall be made in design.

6.8.4 The truss height shall exceed 0.15 times the span in case of a triangular truss (pitched roofing) and 0.10 times the span in case of a rectangular (parallel) truss.

6.8.5 For members in compression, the effective length for in-plane strength verification shall be taken as the distance between two adjacent points of contraflexure. For fully triangulated trusses, effective length for simple span members without especially rigid end-connection shall be taken as the span length.

6.8.6 For strength verification of members in compression and connections, the calculated axial forces should be increased by 10 percent.

6.8.7 The spacing of trusses shall be consistent with use of bamboo purlins (2 m to 3 m).

6.8.8 The ends in open beams, joists, rafters, purlins shall be suitably plugged. Bamboo roof coverings shall be considered as non-structural in function. The common roof covering shall include bamboo mat board, bamboo mat corrugated sheet, bamboo tiles/ strings, plastered bamboo reeds, thatch, corrugated galvanized iron sheeting, plain clay tiles or pan tiles, etc.

7 DESIGN AND TECHNIQUES OF JOINTS

7.1 Connecting the load-bearing elements together for effective transfer of stress is one of the serious problems confronted by the engineers. The size of the members in a structure depends not only on the direct loads they are required carry, but also on the ability to join the members together. Joints are quite critical in assemblies, and these should be stable in relation to time. The main objective is to achieve continuity between elements with controlled displacements. As joints are a source of weakness in any bamboo structure, they have to be made as strong and rigid as possible.

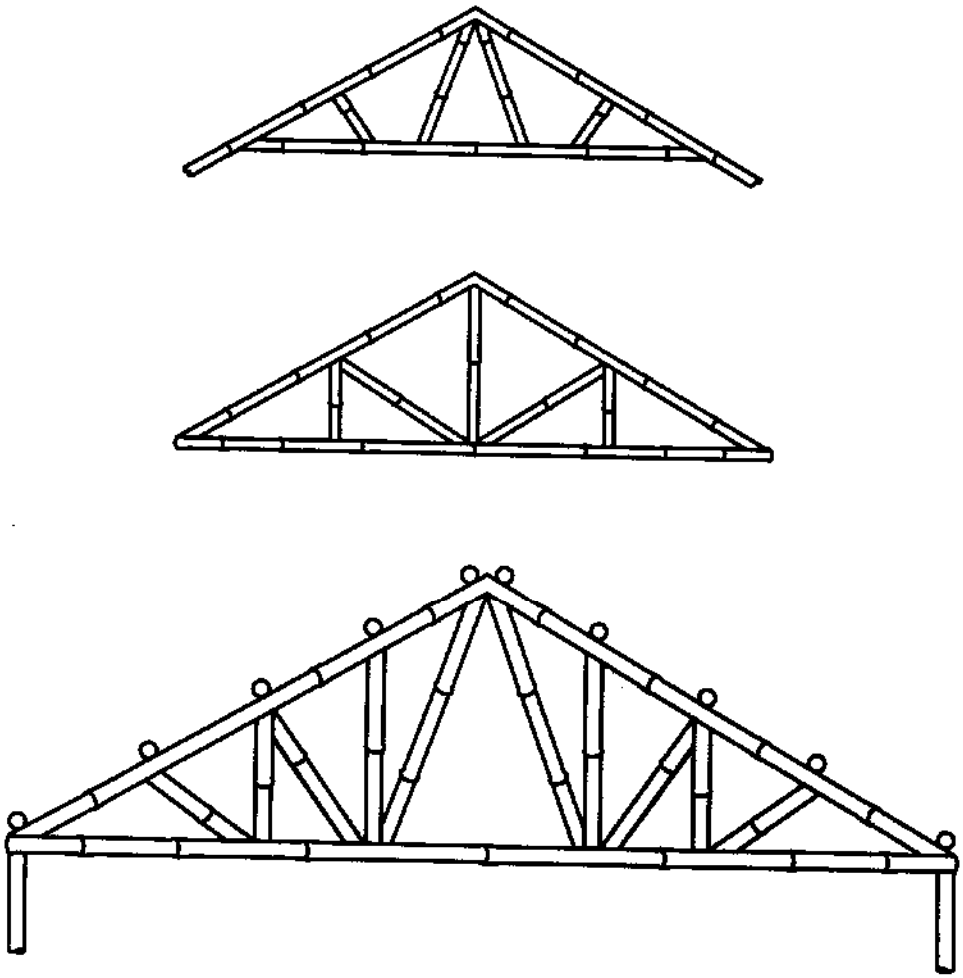


FIG. 2 SOME TYPICAL CONFIGURATIONS FOR SMALL AND LARGE TRUSSES IN BAMBOO

7.2 Bamboo Joints

Efficient jointing is basic to the structural adequacy of a framed construction, may it be of any cellulosic material. Round, tubular form of bamboo requires an approach different to that used for sawn timber. Susceptibility to crushing at the open ends, splitting tendency, variation in diameter, wall thickness and straightness are some of the associated issues which have to be taken care of while designing and detailing the connections with bamboo.

7.2.1 *Traditional Practices*

Such joining methods revolve around lashing or tying by rope or string with or without pegs or dowels. Such joints lack stiffness and have low efficiency.

7.2.1.1 *Lengthening joints (end jointing)*

7.2.1.1.1 *Lap joint*

In this case, end of one piece of bamboo is made to lap over that of the other in line and the whole is suitably fastened. It may be full lapping or half lapping. Full section culms are overlapped by at least one internode and tied together in two or three places. Efficiency could be improved by using bamboo or hardwood dowels. In half lapping, culms shall preferably be of similar diameter and cut longitudinally to half depth over at least one internode length and fastened as per full lap joint (*see* Fig. 3).

7.2.1.1.2 *Butt joints*

Culms of similar diameter are butted end to end, interconnected by means of side plates made of quarter-round culm of slightly large diameter bamboo, for two or more internode lengths. Assembly shall be fixed and tied preferably with dowel pins. This joint transfers both compressive and tensile forces equally well (*see* Fig. 4).

7.2.1.1.3 *Sleeves and inserts*

Short length of bamboo of appropriate diameter may be used either externally or internally to join two culms together (*see* Fig. 5).

7.2.1.1.4 *Scarf joints*

A scarf joint is formed by cutting a sloping plane 1 in 4 to 6 on opposite sides from the ends of two similar diameter bamboo culms to be joined. They shall be lapped to form a continuous piece and the assembly suitably fastened by means of lashings. Using hooked splays adds to the strength and proper location of joints (*see* Fig. 6).

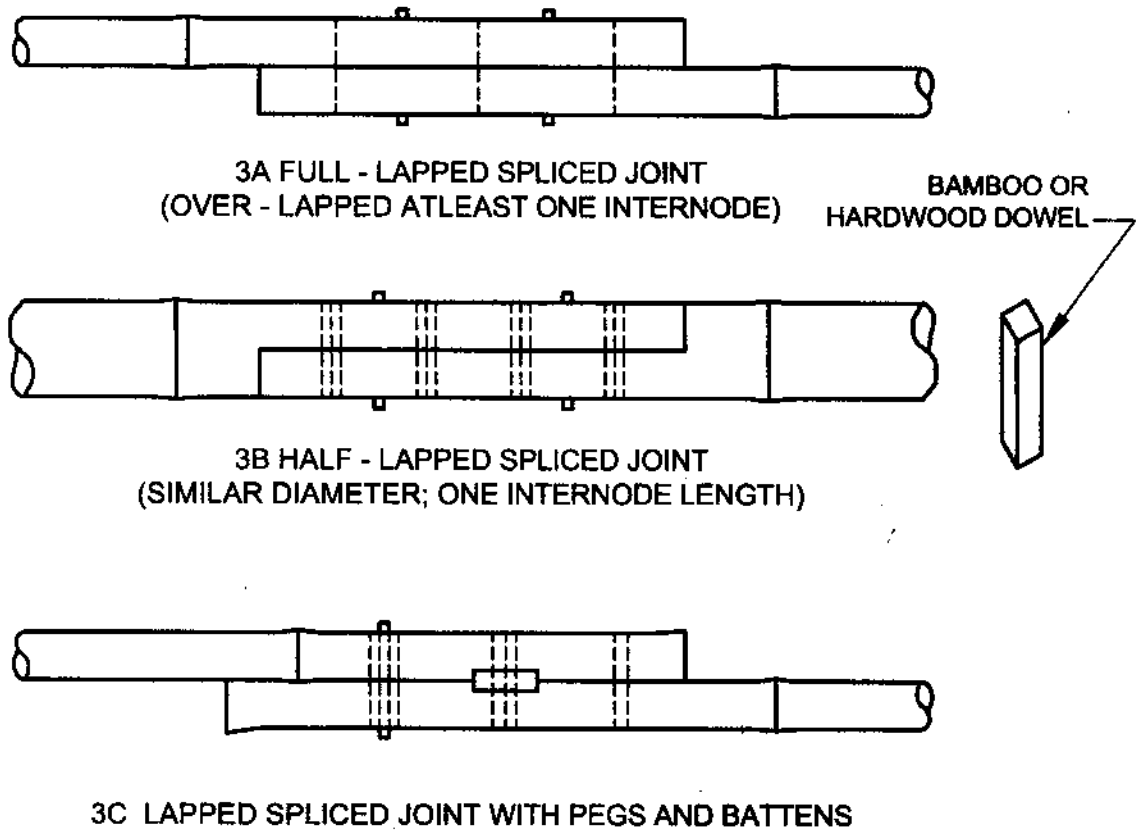


FIG. 3 LAP JOINTS IN BAMBOO

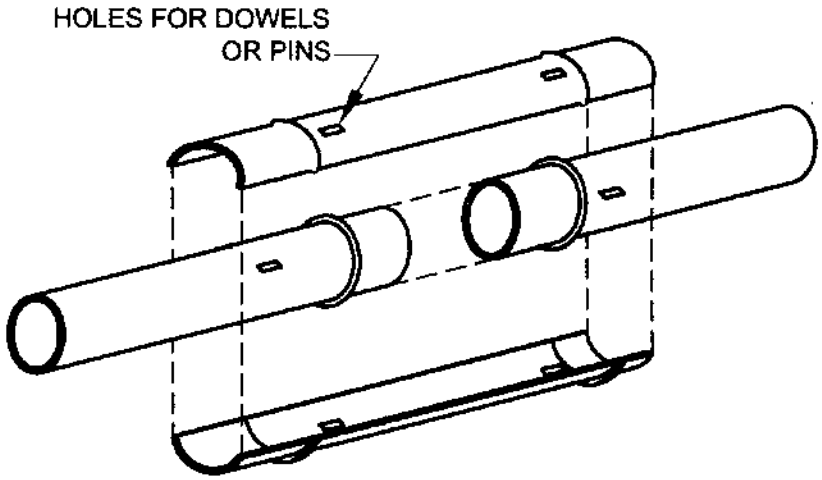


FIG. 4 BUTT JOINT WITH SIDE PLATES IN BAMBOO

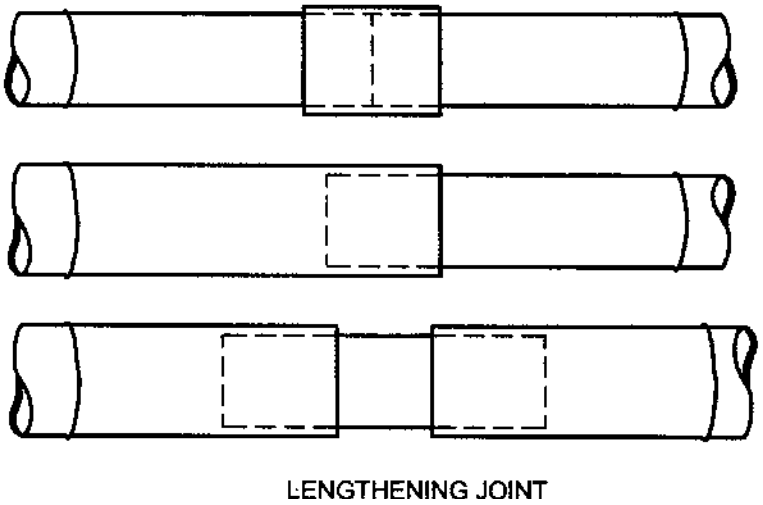


FIG. 5 SLEEVES AND INSERTS FOR BAMBOO JOINTS

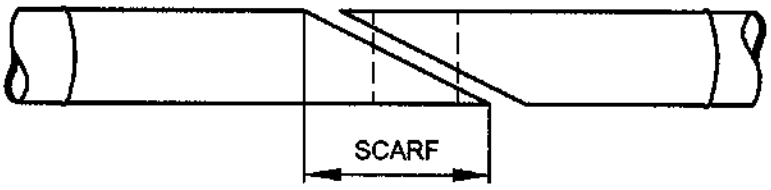


FIG. 6 SCARF JOINT

7.2.1.2 *Bearing joints*

For members which either bear against the other or cross each other and transfer the loads at an angle other than parallel to the axis, bearing joints are formed.

7.2.1.2.1 *Butt joints*

The simplest form consists of a horizontal member supported directly on top of a vertical member. The top of the post may be cut to form a saddle to ensure proper seating of beam for good load transfer. The saddle should be close to a node to reduce risk of splitting (*see* Fig. 7).

7.2.1.2.2 *Tenon joint*

It is formed by cutting a projection (tenon) in walls of one piece of bamboo and filling it into corresponding holes (mortise) in another and keyed. It is a neat and versatile joint for maximum strength and resistance to separation (*see* Fig. 8).

7.2.1.2.3 *Cross over joint*

It is formed when two or more members cross at right angles and its function is to locate the members and to provide lateral stability. In case of the joint connecting floor beam to post, it may be load bearing

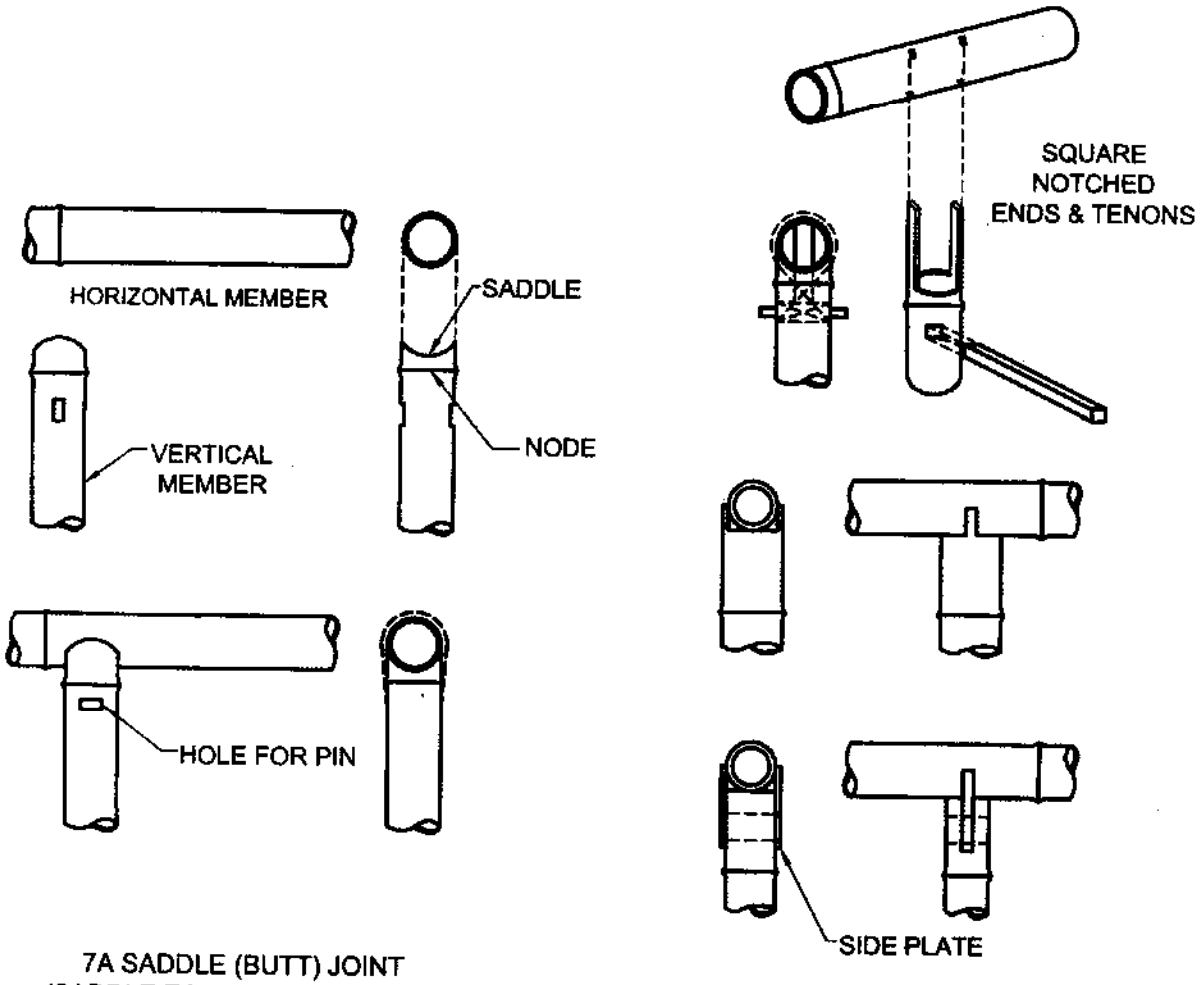
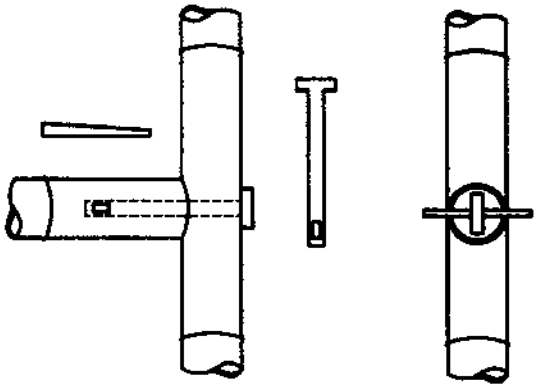
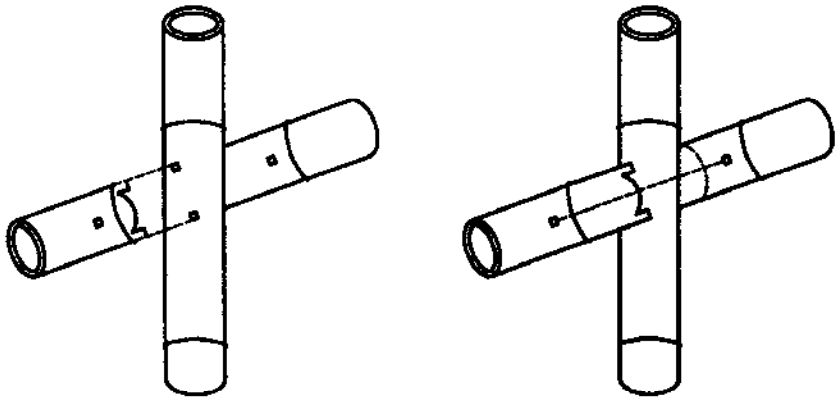


FIG. 7 BUTT JOINTS IN BAMBOO



TENON AND KEY JOINT



INTEGRAL TENON (HORNED) JOINT

FIG. 8 TENON JOINT

(*see* Fig. 9). Such joints are also used to transmit angle thrust.

7.2.1.3 *Angled joints*

When two or more members meet or cross other than at right angles, angled joints are formed. For butt joints, the ends of the members may be shaped to fit in as saddle joints. Tenons would help in strengthening such joints (*see* Fig. 10).

7.2.2 *Modern Practices* (*see* Fig. 11)

Following are some of the modern practices for bamboo jointing:

a) Plywood or solid timber gusset plates may be used at joint assemblies of web and chord connection in a truss and fixed with bamboo pins or bolts. Hollow cavities of bamboo need to be stuffed with wooden plugs.

b) Use of wooden inserts to reinforce the ends of the bamboo before forming the joints. Alternatively steel bands clamps with integral bolt/eye may be fitted around bamboo sections for jointing.

7.2.3 *Fixing Methods and Fastening Devices*

In case of butt joints the tie may be passed through a pre-drilled hole or around hardwood or bamboo pegs or dowels inserted into preformed holes to act as horns. Pegs are driven from one side, usually at an angle to increase strength and dowels pass right through the member, usually at right angles.

7.2.3.1 Normally 1.60 mm diameter galvanized iron wire may be used for tight lashing.

7.2.3.2 *Wire bound joints*

Usually galvanized iron 2.00 mm diameter galvanized iron wire is tightened around the joints by binding the respective pieces together. At least two holes are drilled in each piece and wire is passed through them for good results.

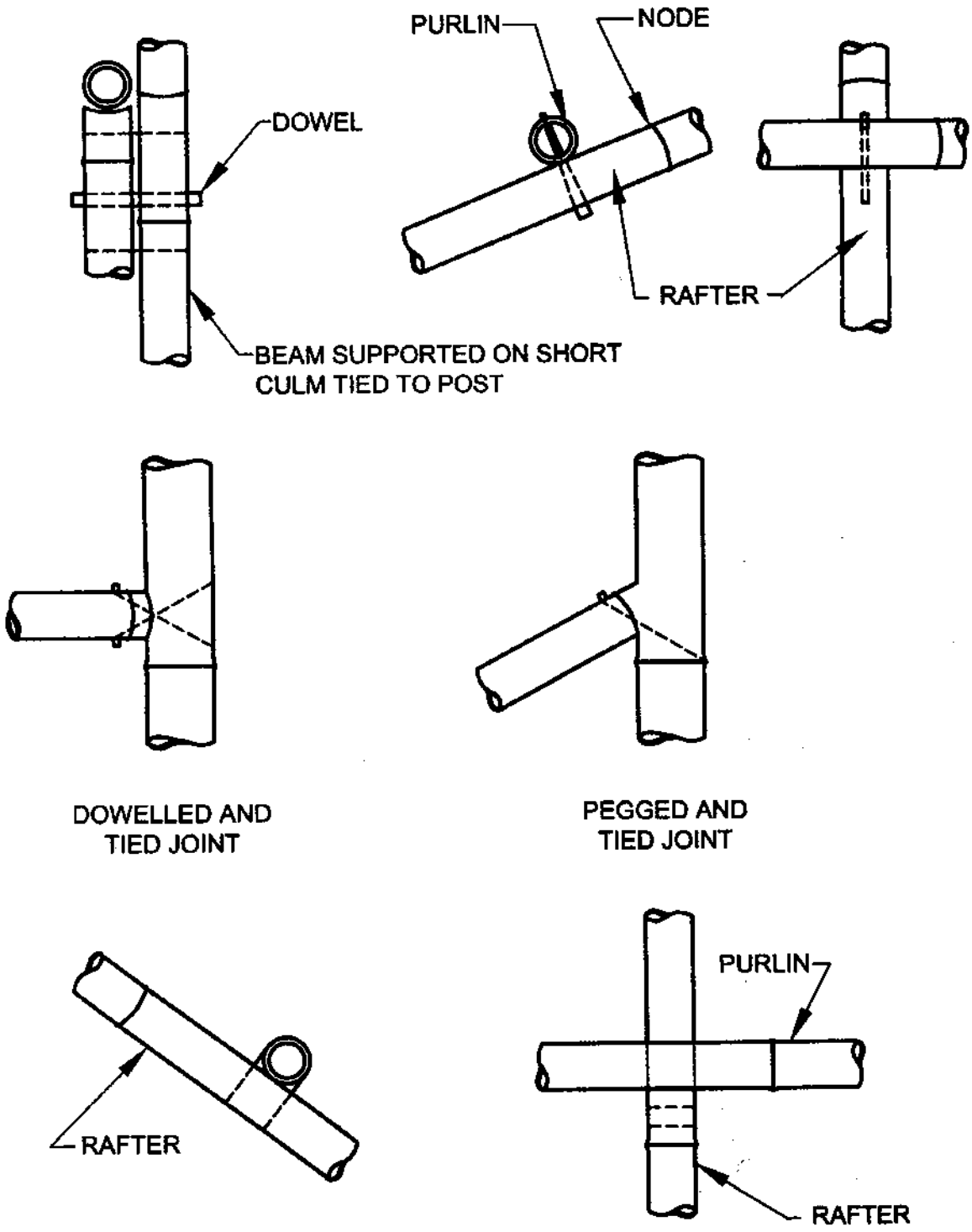


FIG. 9 CROSS OVER JOINTS (BEARING JOINTS)

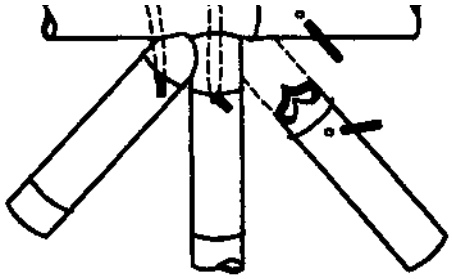


FIG. 10 ANGLED JOINT WITH INTEGRAL TENONS

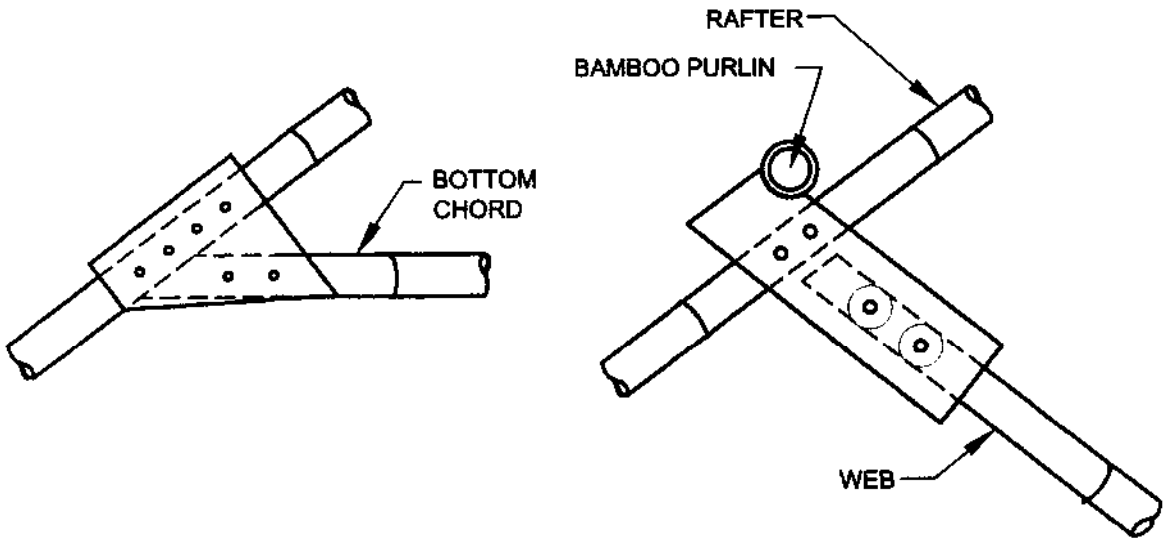


FIG. 11 GUSSET PLATED JOINTS

7.2.3.3 *Pin and wire bound joints*

Generally 12 mm dia bamboo pins are fastened to culms and bound by 2.00 mm diameter galvanized iron wire.

7.2.3.4 *Fish plates/gusset plated joints*

At least 25 mm thick hardwood splice plate or 12 mm thick structural grade plywood are used. Solid bamboo pins help in fastening the assembly.

7.2.3.5 *Horned joints*

Two tongues made at one end of culm may be fastened with a cross member with its mortise grooves to receive horns, the assembly being wire bound.

7.2.4 For any complete joint alternative for a given load and geometry, description of all fastening elements, their sizes and location shall be indicated. Data shall be based on full scale tests.

7.2.5 Tests on full scale joints or on components shall be carried out in a recognized laboratory.

7.2.6 In disaster high wind and seismic areas, good construction practice shall be followed taking care of joints, their damping and possible ductility. Bracings in walls shall be taken care of in bamboo structures.

8 STORAGE OF BAMBOO

Procurement and storage of bamboo stocks are essential for any project work and shall be done in accordance with Part 7 'Constructional Practices and Safety'.

ANNEX A

(Foreword)

SOURCE AND LOCAL NAMES OF SOME OF THE SPECIES OF BAMBOO

Sl No.	*Species*	*Source/Local Names*
(1)	(2)	(3)
1.	*Bambusa auriculata*	Assam, Bangladesh, Myanmar; introduced in Calcutta Botanic Garden.
2.	*B. balcooa*	Asm — Baluka; Ben — Balku bans; Duars — Bora bans; Garo — Wamnah, beru; Tripura — Barak.
3.	*B. bambos (Syn. B. arundinacea)*	Asm — Kotoba; Ben — Baroowa, behor; ketuas; ketwa Manip — Saneibi; Mah — Katang bamboo, oowga; Oriya — Daba, katuig; Tel — Mulkas veduru, Mullu vedurn; English — Spiny bamboo.
4.	*B. burmanica*	Asm — Thaikawa.
5.	*B. multiplex* *Syn. B. glancescens (Syn. B. nana)*	Sans — keu-fa; Burmese — Pa-lau-pinan-wa; Malay — Bamboo tjeenah; China — Bamboo hower tjeenah.
6.	*B. nutans*	Assam — Deobans, jotia-makal; Asm — Bidhuli, mukial; Ben — Makia; Bhutia — Jiu; Hin — Malabans; Kangra — Nal; Khasi — Seringjai; Kuki — Wa malang; Lepcha — Malubans, mahlu, mallo; Oriya — Badia bansa; Sylhet (Banglaesh) — Peechli; Tripura — Kali
7.	*B. pallida*	Asm — Bijli, jowa, makal, walkthai; Cachar — Bakhal, burwal; Khasi — Seskien, skhen, ineng, usker; Lepcha — Pashipo, pshi, pushee; Mikir — Loto; Naga — Tesero, watoi; Tripura — Makal.
8.	*B. polymorpha*	Asm — Jama betwa, betwa; Ben — Batua, jaibarouwa, jama; Burma — Kyathaung-wa; MP-Korku — Narangi bhas; Tripura — Basi.
9.	*B. tulda*	Asm — Wamunna, wagi, nal-bans; Beng — Tulda, jowa; Duars — Karanti, matela; Garo — Watti; Hin — Peka; Kamrup — Bijuli, jati, joo, ghora; Tripura — Mirtinga

10.	*B. vulgaris*	Ben and Manipuri — Bakal; Oriya — Sunarkania bans.
11.	*B. Wamin Syn. B. ventricosa (Syn. B. Vulgaris var. Wamin)*	Common name — Pitcher bamboo.
12.	*Cephalostachyum pergacile*	MP — Bhalan bans; Manipuri — Wootang; Naga — Latang; Oriya — Darrgi.
13.	*Dendrocalamus giganteous*	English — Giant Bamboo; Asm — Worra; Manipuri — Maroobeb.
14.	*D. hamiltonii*	Nep — Tamo; Asm — Kokwa; Tripura — Pecha.
15.	*D. longispathus*	Tripura — Rupai.
16.	*D. membranaceus*	Native of Myanmar; introduced in Kerala.
17.	*D. strictus*	English — Male bamboo; Ben — Karail; Guj — Nakur bans; Kan — Kiri bidiru; Mah — Male bamboo, nanvel; Oriya — Salia; Tam — Kalmungil; Tel — Sadanapa vedur; Tripura — Lathi bans; Hin — Bans Kaban, nav bans;
18.	*Melocanna baccifera*	Asm — Tarai; Ben — Muli; Cachar — Wati; Garo — Watrai; Manipuri — Moubi; Mikir — Artem; Naga — Turiah.
19.	*Oxytenanthera abyssinicia*	Native of tropical Africa; cultivated at FRI, Dehra Dun.
20.	*Thyrsostachys oliveri*	Native of Myanmar; Planted in Haldwani (Uttaranchal); Arunachal Pradesh, Kerala and Tamil Nadu.

NOTES

1 The following abbreviations have been used in the above table:

Asm	—	Assam
Ben	—	Bengali
Guj	—	Gujarati
Hin	—	Hindi
Kan	—	Kannada
Mah	—	Maharashtra
Manip	—	Manipur
MP	—	Madhya Pradesh
Nep	—	Nepali
Sans	—	Sanskrit

2 The above table does not provide an exhaustive list. It only attempts to enlist some of the information readily available in regard to species of bamboo from India and some of the neighbouring countries, and some connected information.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of this Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

	IS No.	*Title*
(1)	6874 : 1973	Method of test for round bamboo
(2)	9096 : 1979	Code of practice for preservation of bamboo for structural purposes
(3)	6874 : 1973	Method of test for round bamboo
	8242 : 1976	Method of test for split bamboo

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 4 Masonry

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section primarily covers the structural design of unreinforced masonry elements in buildings. However, provisions on reinforced brick and reinforced brick concrete floors and roofs have also been included.

This Section was first published in 1970 and revised in 1983. Subsequently the first revision of this Section was modified in 1987 through Amendment No. 2 to bring this Section in line with the latest revised masonry Code. In this amendment, certain provisions were updated following the revision of IS 1905 'Code of practice for structural use of unreinforced masonry' on which the earlier version was based. In the amendment, requirements of masonry element for stability were modified; in the design of free standing wall, provisions were made for taking advantage of the tensile resistance in masonry under certain conditions; provision regarding effective height of masonry wall between openings was modified; method of working out effective height of wall with a membrane type DPC was modified; the criteria for working out effective length of wall having openings was modified; some general guidelines for dealing with concentrated loads for design of walls were included; and provision of cutting and chases in walls were amplified.

As a result of experience gained in the implementation of this Section and feedback received, as well as in view of revision of IS 4326 'Code of practice for earthquake resistant design and construction of buildings' and formulation of some new standards in this field, a need to revise this Section has been felt. This revision has, therefore, been prepared to take care of these aspects. The significant changes incorporated in this revision include the following:

a) The provision of special considerations in earthquake zones have been aligned in line with IS 4326 : 1993.
b) A new clause covering guidelines for improving earthquake resistance of low strength masonry buildings has been added.
c) Reference to design of reinforced brick and reinforced brick concrete floors and roofs has been included.
d) Reference to all the concerned Indian Standards have been updated.

Structural design requirements of this Section are based on IS 1905 : 1987 'Code of practice for structural use of unreinforced masony (*third revision*)' and IS 4326 : 1993 'Code of practice for earthquake resistant design and construction of buildings (*second revision*)'.

A reference to SP 20 : 1991 'Handbook on masonry design and construction (*first revision*)' may be useful.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 6 STRUCTURAL DESIGN

Section 4 Masonry

1 SCOPE

1.1 This Section primarily covers the structural design aspects of unreinforced load bearing and non-load bearing walls, constructed with masonry units permitted in accordance with this Section. This, however, also covers provisions for design of reinforced brick and reinforced brick concrete floors and roofs. It also covers guidelines regarding earthquake resistance of low strength masonry buildings.

1.2 The recommendations of the Section do not apply to walls constructed in mud mortars.

2 TERMINOLOGY

2.1 For the purpose of this Section, the following definitions shall apply.

2.1.1 *Bed Block* — A block bedded on a wall, column or pier to disperse a concentrated load on a masonry element.

2.1.2 *Bond* — Arrangement of masonry units in successive courses to tie the masonry together both longitudinally and transversely; the arrangement is usually worked out to ensure that no vertical joint of one course is exactly over the one in the next course above or below it, and there is maximum possible amount of lap.

2.1.3 *Column, Pier and Buttress*

a) *Column* — An isolated vertical load bearing member, width of which does not exceed four times the thickness.

b) *Pier* — A thickened section forming integral part of a wall placed at intervals along the wall, to increase the stiffness of the wall or to carry a vertical concentrated load. Thickness of a pier is the overall thickness including the thickness of the wall or, when bonded into a leaf of a cavity wall, the thickness obtained by treating that leaf as an independent wall (*see* Fig. 1).

c) *Buttress* — A pier of masonry built as an integral part of wall and projecting from either or both surfaces, decreasing in cross-sectional area from base to top.

2.1.4 *Cross-Sectional Area of Masonry Unit* — Net cross-sectional area of a masonry unit shall be taken as the gross cross-sectional area minus the area of cellular space. Gross cross-sectional area of cored units shall be determined to the outside of the coring but cross-sectional area of grooves shall not be deducted from the gross cross-sectional area to obtain the net cross-sectional area.

2.1.5 *Curtain Wall* — A non-load bearing wall subject to lateral loads. It may be laterally supported by vertical or horizontal structural members where necessary (*see* Fig. 2).

2.1.6 *Effective Height* — The height of a wall or column, to be considered for calculating slenderness ratio.

2.1.7 *Effective Length* — The length of a wall to be considered for calculating slenderness ratio.

2.1.8 *Effective Thickness* — The thickness of a wall or column to be considered for calculating slenderness ratio.

2.1.9 *Hollow Unit* — A masonry unit of which net cross-sectional area in any plane parallel to the bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane.

2.1.10 *Grout* — Mortar of pourable consistency.

2.1.11 *Joint* — A junction of masonry units.

a) *Bed joint* — A horizontal mortar joint upon which masonry units are laid.

b) *Cross joint* — A vertical joint, normal to the face of the wall.

c) *Wall joint* — A vertical joint parallel to the face of the wall.

2.1.12 *Leaf* — Inner or outer section of a cavity wall.

2.1.13 *Lateral Support* — A support which enables a masonry element to resist lateral load and/or restrains lateral deflection of a masonry element at the point of support.

2.1.14 *Load Bearing Wall* — A wall designed to carry an imposed vertical load in addition to its own weight, together with any lateral load.

2.1.15 *Masonry* — An assemblage of masonry units properly bonded together with mortar.

2.1.16 *Masonry Unit* — Individual units which are bonded together with the help of mortar to form a masonry element such as wall, column, pier, buttress, etc.

2.1.17 *Partition Wall* — An interior non-load bearing wall, one storey or part storey in height.

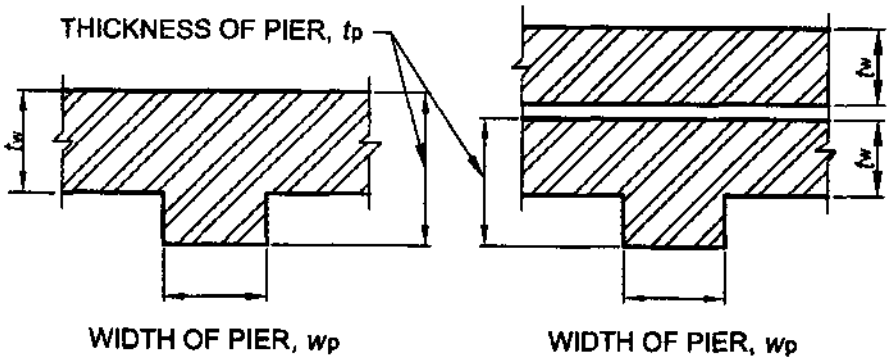


FIG. 1 DEFINITION OF PIER

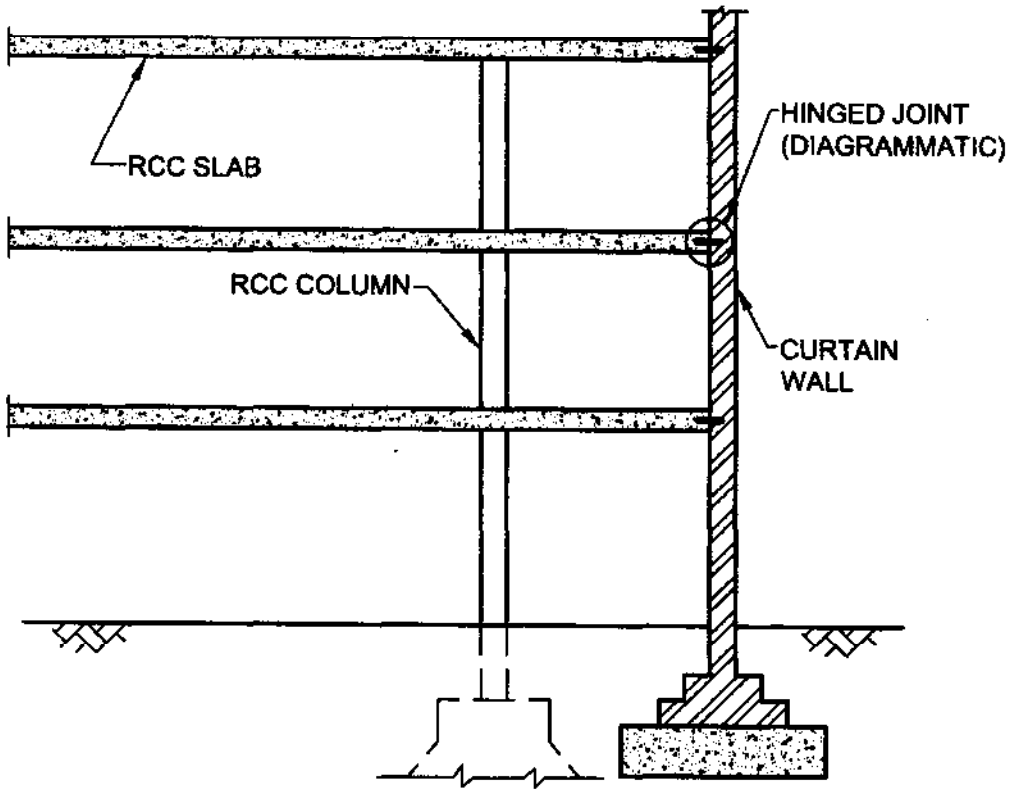


FIG. 2 MASONRY CURTAIN WALL

2.1.18 *Panel Wall* — An exterior non-load bearing wall in framed construction, wholly supported at each storey but subjected to lateral loads.

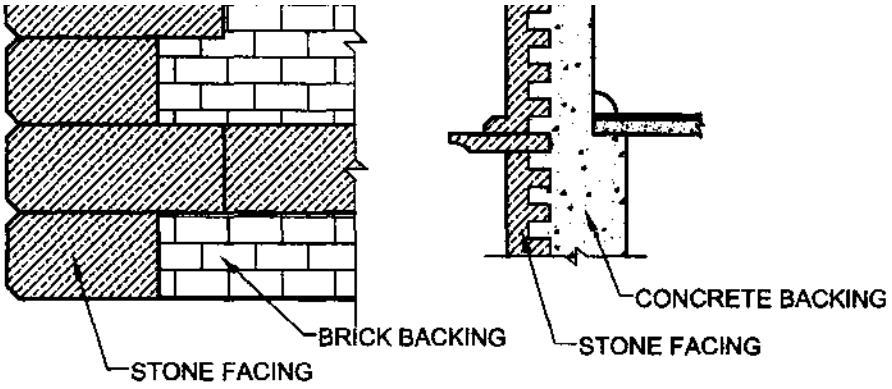
2.1.19 *Shear Wall* — A wall designed to carry horizontal forces acting in its plane with or without vertical imposed loads.

2.1.20 *Slenderness Ratio* — Ratio of effective height or effective length to effective thickness of a masonry element.

2.1.21 *Types of Walls*

a) *Cavity wall* — A wall comprising two leaves, each leaf being built of masonry units and separated by a cavity and tied together with metal ties or bonding units to ensure that the two leaves act as one structural unit, the space between the leaves being either left as continuous cavity or filled with a non-load bearing insulating and water-proofing material.

b) *Faced wall* — A wall in which facing and backing of two different materials are bonded together to ensure common action under load (*see* Fig. 3).



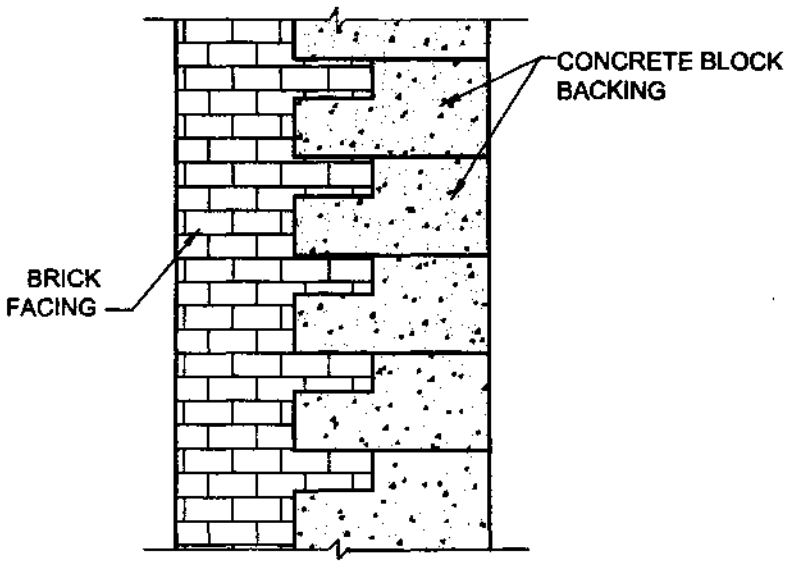


FIG. 3 TYPICAL FACED WALL

NOTE — To ensure monolithic action in faced walls, shear strength between the facing and the backing shall be provided by toothing, bonding or other means.

c) *Veneered wall* — A wall in which the facing is attached to the backing but not so bonded as to result in a common action under load.

3 MATERIALS

3.1 General

The materials used in masonry construction shall be in accordance with Part 5 'Building Materials'.

3.2 Masonry Units

Masonry units used in construction shall conform to accepted standards [6-4(1)].

3.2.1 Masonry units may be of the following types:

a) Common burnt clay building bricks,
b) Burnt clay fly ash building bricks,
c) Pulverized fuel ash lime bricks,
d) Stones (in regular sized units),
e) Sand-lime bricks,
f) Concrete blocks (solid and hollow),
g) Lime based blocks,
h) Burnt clay hollow blocks,
j) Gypsum partition blocks,
k) Autoclaved cellular concrete blocks, and
m) Concrete stone masonry blocks.

NOTES

1 Gypsum partition blocks are used only for construction of non-load bearing partition walls.

2 Use of other masonry units, such as, precise stone blocks, fly-ash-lime-gypsum bricks, stabilized mud blocks and other bricks/blocks not covered by the above specifications may also be permitted based on test results.

3.2.2 Masonry units that have been previously used shall not be re-used in brickwork or blockwork construction, unless they have been thoroughly cleaned and conform to this Section for similar new masonry units.

3.3 Mortar

Mortar for masonry shall conform to accepted standard [6-4(2)].

3.3.1 Mix proportions and compressive strengths of some of the commonly used mortars are given in Table 1.

Table 1 Mix Proportions and Strength of Mortars for Masonry

(*Clause* 3.3.1)

Sl No.	Grade of Mortar	Mix Proportions (by Loose Volume)					Minimum Compressive Strength at 28 Days in N/mm^2
		Cement	Lime	Lime Pozzolana Mixture	Pozzolana	Sand	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	H1	1	¼ C or B	0	0	3	10
2(a)	H2	1	¼ C or B	0	0	4	7.5
2(b)		1	½ C or B	0	0	4½	6.0
3(a)	M1	1		0	0	5	5.0
3(b)		1	1 C or B	0	0	6	3.0
3(c)		0	0	1 (LP-40)	0	1½	3.0
4(a)	M2	1	0	0	0	6	3.0
4(b)		1	2 B	0	0	9	2.0
4(c)		0	1 A	0	0	2	2.0
4(d)		0	1 B	0	1	1	2.0
4(e)		0	1 C or B	0	2	0	2.0
4(f)		0	0	1 (LP-40)	0	1¾	2.0
5(a)	M3	1	0	0	0	7	1.5
5(b)		1	3 B	0	0	12	1.5
5(c)		0	1 A	0	0	3	1.5
5(d)		0	1 B	0	2	1	1.5
5(e)		0	1 C or B	0	3	0	1.5
5(f)		0	0	1 (LP-40)	0	2	1.5
6(a)	L1	1	0	0	0	8	0.7
6(b)		0	1 B	0	1	2	0.7
6(c)		0	1 C or B	0	2	1	0.7
6(d)		0	0	1 (LP-40)	0	2¼	0.7
6(e)		0	0	1 (LP-20)	0	1½	0.7
7(a)	L2	0	1 B	0	0	3	0.5
7(b)		0	1 C or B	0	1	2	0.5
7(c)		0	0	1 (LP-7)	0	1½	0.5

NOTES

1 Sand for making mortar should be well graded. In case sand is not well graded, its proportion shall be reduced in order to achieve the minimum specified strength.

2 For mixes in Sl No. 1 and 2, use of lime is not essential from consideration of strength as it does not result in increase in strength. However, its use is highly recommended since it improves workability.

3 For mixes in Sl No. 3(a), 4(a), 5(a) and 6(a), either lime C or B to the extent of ¼ part of cement (by volume) or some plasticizer should be added for improving workability.

4 For mixes in Sl No. 4(b) and 5(b), lime and sand should first be ground in mortar mill and then cement added to coarse stuff.

5 It is essential that mixes in Sl No. 4(c), 4(d), 4(e), 5(d), 5(e), 6(b), 6(c), 7(a) and 7(b) are prepared by grinding in a mortar mill.

6 Mix in Sl No. 2(b) has been classified to be of same grade as that of Sl No. 2(a), mixes in Sl No. 3(b) and 3(c) same as that in Sl No. 3(a), mixes in Sl No. 4(b) to 4(f) same as that in Sl No. 4(a), even though their compressive strength is less. This is from consideration of strength of masonry using different mix proportions.

7 A, B and C denote eminently hydraulic lime, semi-hydraulic lime and fat lime respectively, as specified in appropriate standards listed in Part 5 'Building Materials'.

4 DESIGN CONSIDERATIONS

4.1 General

Masonry structures gain stability from the support offered by cross walls, floors, roof and other elements, such as, piers and buttresses. Load bearing walls are structurally more efficient when the load is uniformly distributed and the structure is so planned that eccentricity of loading on the members is as small as possible. Avoidance of eccentric loading by providing adequate bearing of floor/roof on the walls providing adequate stiffness in slabs and avoiding fixity at the supports, etc, is especially important in load bearing walls in multi-storey structures. These matters should receive careful consideration during the planning stage of masonry structures.

4.2 Lateral Supports and Stability

4.2.1 *Lateral Supports*

Lateral supports for a masonry element, such as, load bearing wall or column are intended:

a) to limit slenderness of a masonry element so as to prevent or reduce possibility of buckling of the member due to vertical loads; and

b) to resist horizontal components of forces so as to ensure stability of a structure against overturning.

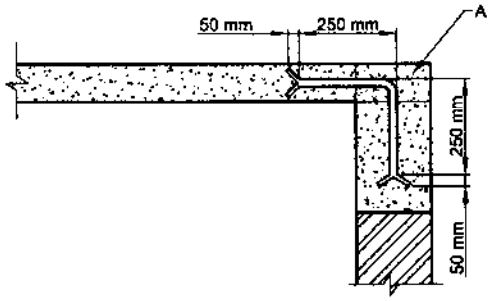
4.2.1.1 Lateral support may be in the vertical or horizontal direction, the former consisting of floor/roof bearing on the wall or properly anchored to the same and latter consisting of cross walls, piers or buttresses.

4.2.1.2 Requirements of **4.2.1**(a) from consideration of slenderness may be deemed to have been met with, if:

a) In case of a wall, where slenderness ratio is based on effective height, any of the following constructions are provided:

1) RCC floor/roof slab (or beams and slab) irrespective of the direction of span, bears on the supported wall as well as cross walls, to the extent of at least 90 mm;

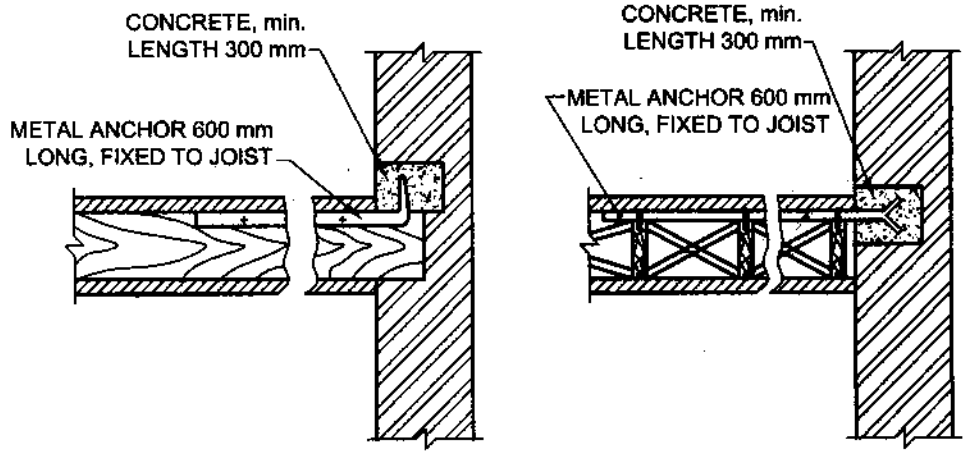
2) RCC floor/roof slab not bearing on the supported wall or cross wall is anchored to it with non-corrodible metal ties of 600 mm length and of section not less than 6 mm × 30 mm, and at intervals not exceeding 2 m, as shown in Fig. 4; and



A = Cement concrete only at places where anchors are provided (200 mm in width in the direction perpendicular to the plane of paper)

FIG. 4 ANCHORING OF RCC SLAB WITH MASONRY WALL (WHEN SLAB DOES NOT BEAR ON WALL)

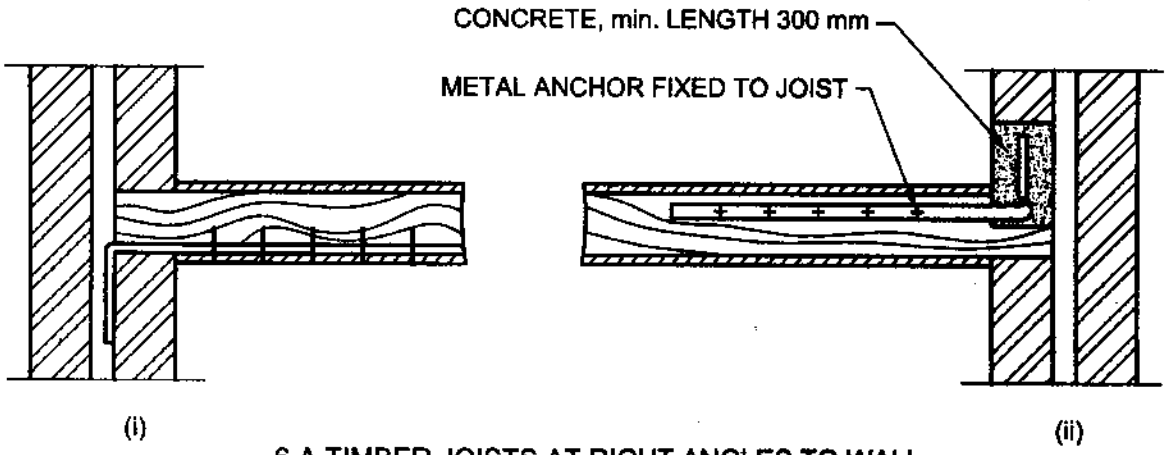
3) Timber floor/roof, anchored by non-corrodible metal ties of length 600 mm and of minimum section 6 mm × 30 mm, securely fastened to joists and built into walls as shown in Fig. 5 and Fig. 6. The



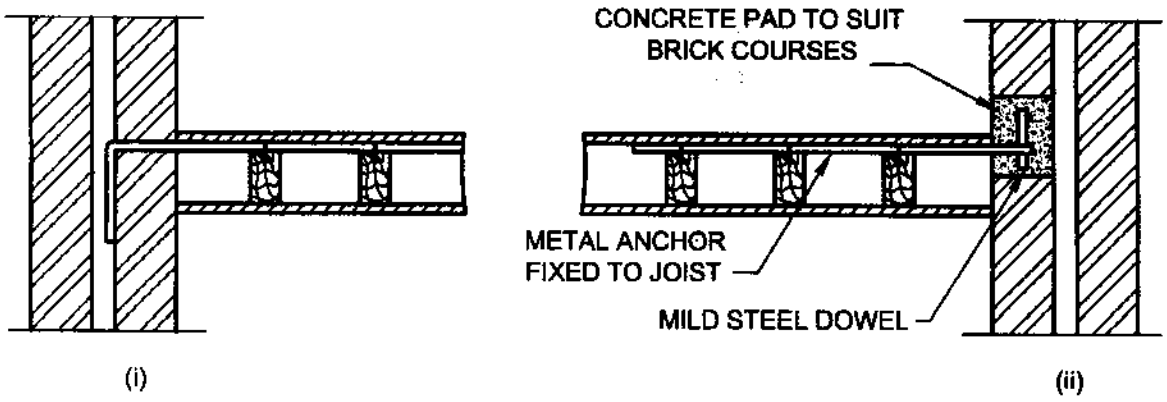
5A JOISTS AT RIGHT ANGLE TO WALL

5B JOISTS PARALLEL TO WALL

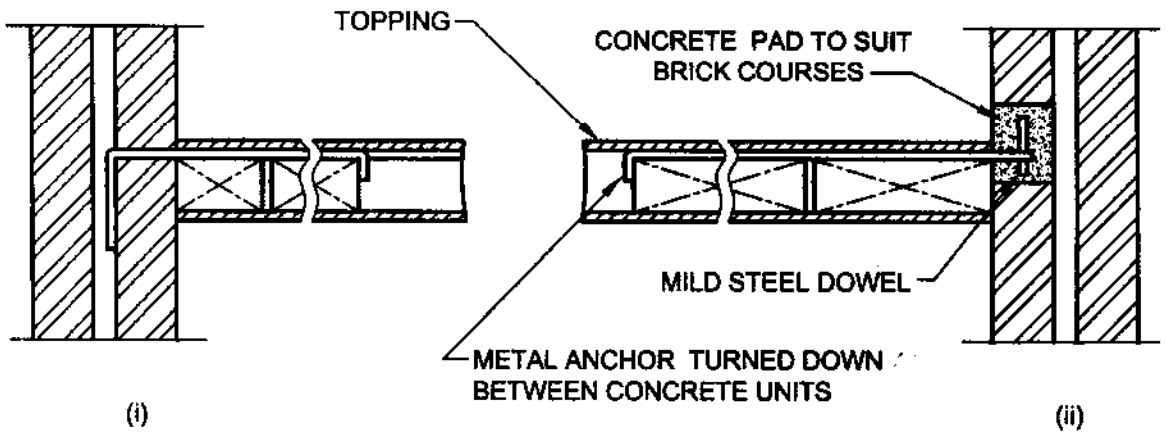
FIG. 5 TYPICAL DETAILS FOR ANCHORAGE OF SOLID WALLS



6 A TIMBER JOISTS AT RIGHT ANGLES TO WALL



6 B TIMBER JOISTS PARELLEL TO WALL



6 C PRECAST CONCRETE FLOOR UNITS PARALLEL TO WALL

FIG. 6 TYPICAL DETAILS FOR ANCHORAGE OF CAVITY WALLS

anchors shall be provided in the direction of span of timber joists as well as in its perpendicular direction, at intervals of not more than 2 m in buildings up to two storeys and 1.25 m for buildings more than two storeys in height.

NOTES

1 In case precast RCC units are used for floors and roofs, it is necessary to interconnect them and suitably anchor them to the cross walls so that they can transfer lateral forces to the cross walls.

2 In case of small houses of conventional designs, not exceeding two storeys in height, stiffening effect of partitions and cross walls is such that metal anchors are normally not necessary in case of timber floor/roof and precast RCC floor/roof units.

b) In case of a wall, when slenderness ratio is based on its effective length; a cross wall/pier/buttress of thickness equal to or more than half the thickness of the supported wall or 90 mm, whichever is more, and length equal to or more than one-fifth of the height of wall, is built at right angle to the wall (*see* Fig. 7) and bonded to it according to provision of **4.2.2.2** (d);

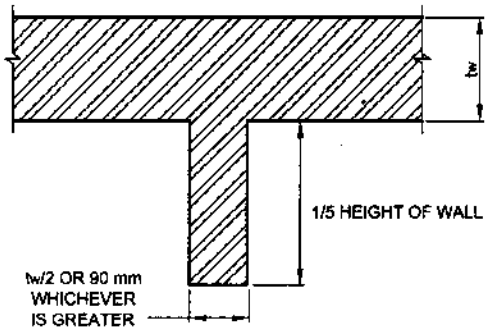


FIG. 7 MINIMUM DIMENSION FOR MASONRY WALL OR BUTTRESS EFFECTIVE LATERAL SUPPORT

c) In case of a column, an RCC or timber beam/R S joist/roof truss, is supported on the column. In this case, the column will not be deemed to be laterally supported in the direction at right angle to it; and

d) In case of a column, an RCC beam forming a part of beam and slab construction, is supported on the column, and slab adequately bears on stiffening walls. This construction will provide lateral support to the column, in the direction of both horizontal axes.

4.2.2 *Stability*

A wall or column subject to vertical and lateral loads may be considered to be provided with adequate lateral support from consideration of stability, if the construction providing the support is capable of resisting some of the following forces:

a) Simple static reactions at the point of lateral support to all the lateral loads; plus

b) 2.5 percent of the total vertical load that the wall or column is designed to carry at the point of lateral support.

4.2.2.1 For the purpose specified in **4.2.2**, if the lateral supports are in the vertical direction, these should meet the requirements given in **4.2.1.2**(a) and should also be capable of acting as horizontal girders duly anchored to the cross wall so as to transmit the lateral loads to the foundations without exceeding the permissible stresses in the cross walls.

4.2.2.2 In case of load bearing buildings up to four storeys, stability requirements of **4.2.2** may be deemed to have been met with, if:

a) height to width ratio of building does not exceed 2;

b) cross walls acting as stiffening walls continuous from outer wall to outer wall or outer wall to a load bearing inner wall, and of thickness and spacings as given in Table 2 are provided. If stiffening wall or walls that are in a line, are interrupted by openings, length of solid wall or walls in the zone of the wall that is to be stiffened shall be at least one-fifth of height of the opening as shown in Fig. 8;

c) floors and roof either bear on cross walls or are anchored to those walls as in **4.2.1.2** such that all lateral loads are safely transmitted to those walls and through them to the foundation; and

Table 2 Thickness and Spacing of Stiffening Walls

[*Clause* 4.2.2.2(b)]

Sl No.	Thickness of Load Bearing Wall to be Stiffened	Height [1] of Storey Not to Exceed	Stiffening Wall [1]		
			Thickness not less than		Maximum Spacing
			1 to 3 storeys	4 to 6 storeys	
	mm	m	mm	mm	m
(1)	(2)	(3)	(4)	(5)	(6)
i)	100	3.2	100	—	4.5
ii)	200	3.2	100	200	6.0
iii)	300	3.4	100	200	8.0
iv)	Above 300	5.0	100	200	8.0

[1] Storey height and maximum spacings as given are centre-to-centre dimensions.

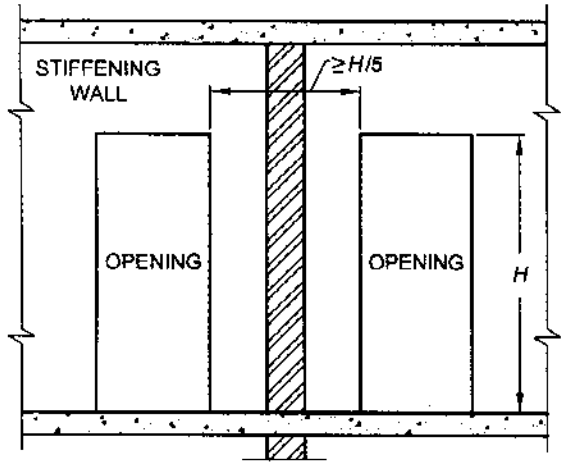


FIG. 8 OPENING IN STIFFENING WALL

d) cross walls are built jointly with the bearing walls and are jointly mortared, or the two interconnected by toothing. Alternatively, cross walls may be anchored to walls to be supported by ties of non-corrodible metal of minimum section 6 mm × 35 mm and length 600 mm with ends bend at least 50 mm; maximum vertical spacing of ties being 1.2 m (*see* Fig. 9).

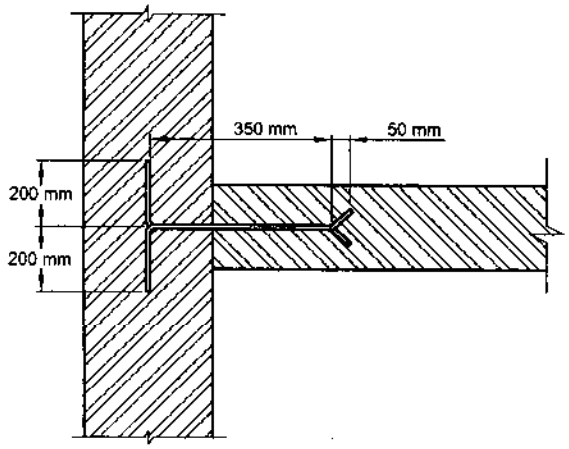


FIG. 9 ANCHORING OF STIFFENING WALL WITH SUPPORT WALL

4.2.2.3 In case of halls exceeding 8.0 m in length, safety and adequacy of lateral supports shall always be checked by structural analysis.

4.2.2.4 A trussed roofing may not provide lateral support unless special measures are adopted to brace and anchor the roofing. However, in case of residential and similar buildings of conventional design with trussed roofing having cross walls, it may be assumed that stability requirements are met with by the cross walls and structural analysis for stability may be dispensed with.

4.2.2.5 Capacity of a cross wall, also called shear wall, sometimes to take horizontal loads and consequently bending moments increases, when parts of bearing walls act as flanges to the cross wall. Maximum overhanging length of bearing wall which could effectively function as a flange should be taken as 12 *t* or *H*/6, whichever is less in case of *T*/*I* shaped walls, and 6 *t* or *H*/16, whichever is less in case of *L*/*U* shaped walls, where *t* is the thickness of bearing wall and *H* is the total height of wall above the level being considered, as shown in Fig. 10.

4.2.2.6 *External walls of basement and plinth*

In case of external walls of basement and plinth, stability requirements of **4.2.2** may be deemed to have been met with, if:

a) bricks used in basement and plinth have a minimum crushing strength of 5 N/mm² and mortar used in masonry is of Grade M1 or better;

b) clear height of ceiling in basement does not exceed 2.6 m;

c) walls are stiffened according to provisions of **4.2.2.1**;

d) in the zone of action of soil pressure on basement walls, traffic load excluding any surcharge due to adjoining buildings does not exceed 5 kN/m² and terrain does not rise; and

e) minimum thickness of basement walls is in accordance with Table 3.

NOTE — In case there is surcharge on basement walls from adjoining buildings, thickness of basement walls shall be based on structural analysis.

Table 3 Minimum Thickness of Basement Walls

[*Clause* 4.2.2.6(e)]

Sl No.	Height of the Ground Above Basement Floor Level		Minimum Nominal Thickness of Basement
	Wall loading (permanent load) less than 50 kN/m	Wall loading (permanent load) more than 50 kN/m	
(1)	(2)	(3)	(4)
i)	Up to 1.4 m	Up to 1.75 m	300 mm
ii)	Up to 2 m	Up to 2.5 m	400 mm

4.2.2.7 *Walls mainly subjected to lateral loads*

a) *Free standing wall* — A free standing wall such as compound wall or parapet wall is acted upon by wind force which tends to overturn it. This tendency to over-turning is resisted by gravity force due to self-weight of wall, and also by flexural moment of resistance on account of tensile strength of

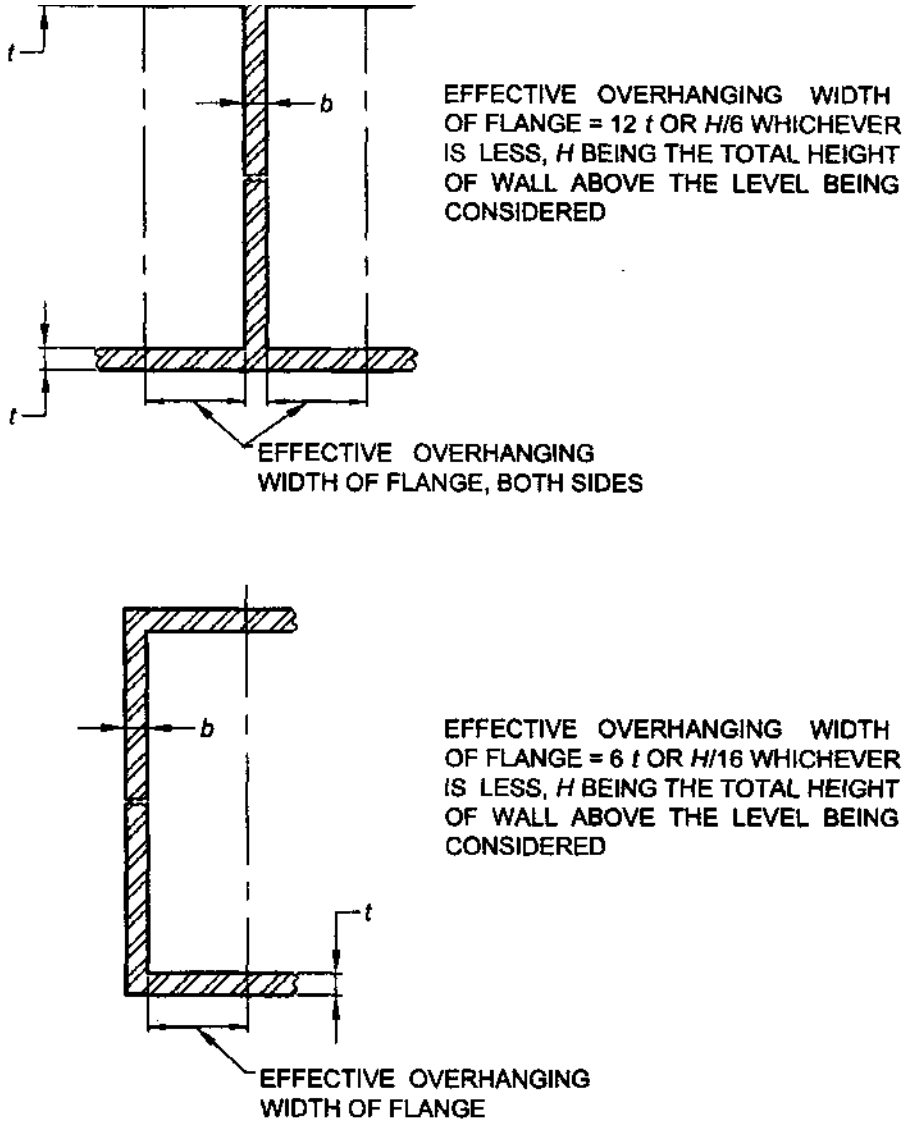


FIG. 10 TYPICAL DETAILS FOR ANCHORAGE OF SOLID WALLS

masonry. Free standing walls shall thus be designed as in **5.5.2.1**. If mortar used for masonry cannot be relied upon for taking flexural tension (*see* **5.4.2**), stability of free standing wall shall be ensured such that stability moment of wall due to self-weight equals or exceeds 1.5 times the overturning moment.

b) *Retaining wall* — Stability for retaining walls shall normally be achieved through gravity action but flexural moment of resistance could also be taken advantage of under special circumstances at the discretion of the designer (*see* **5.4.2**).

4.3 Effective Height

4.3.1 *Wall*

Effective height of a wall shall be taken as shown in Table 4 (*see* Fig. 11).

NOTE — A roof truss or beam supported on a column meeting the requirements of **4.2.2.1** is deemed to provide lateral support to the column only in the direction of the beam/truss.

4.3.2 *Column*

In case of a column, effective height shall be taken as actual height for the direction it is laterally supported and twice the actual height for the direction it is not laterally supported (*see* Fig. 12).

Table 4 Effective Height of Walls

(*Clause* 4.3.1)

Sl No.	Condition of Support	Effective Height
(1)	(2)	(3)
i)	Lateral as well as rotational restraint (that is, full restraint) at top and bottom. For example, when the floor/roof spans on the walls so that reaction to load of floor/roof is provided by the walls, or when an RCC floor/roof has bearing on the wall (minimum 9 cm), irrespective of the direction of the span foundation footings of a wall give lateral as well as rotational restraint	0.75 *H*
ii)	Lateral as well as rotational restraint (that is, full restraint) at one end and only lateral restraint (that is, partial restraint) at the other. For example, RCC floor/roof at one end spanning or adequately bearing on the wall and timber floor/roof not spanning on wall, but adequately anchored to it, on the other end	0.85 *H*
iii)	Lateral restraint, without rotational restraint (that is, partial restraint) on both ends. For example, timber floor/roof, not spanning on the wall but adequately anchored to it on both ends of the wall, that is, top and bottom	1.00 *H*
iv)	Lateral restraint as well as rotational restraint (that is, full restraint) at bottom but have no restraint at the top. For example, parapet walls with RCC roof having adequate bearing on the lower wall, or a compound wall with proper foundation on the soil.	1.50 *H*

NOTES

1 *H* is the height of wall between centres of support in case of RCC slabs and timber floors. In case of footings or foundation block, height (*H*) is measured from top of footing or foundation block. In case of roof truss, height (*H*) is measured up to bottom of the tie beam. In case of beam and slab construction, height should be measured from centre of bottom slab to centre of top beam. All these cases are illustrated by means of examples shown in Fig. 11.

2 For working out effective height, it is assumed that concrete DPC, when properly bonded with masonry, does not cause discontinuity in the wall.

3 Where memberane type damp-proof course or termite shield causes a discontinuity in bond, the effective height of wall may be taken to be greater of the two values calculated as follows:

a) consider *H* from top of footing ignoring DPC and take effective height as 0.75 *H*.

b) consider *H* from top of DPC and take effective height as 0.85 *H*.

4 When assessing effective height of walls, floors not adequately anchored to walls shall not be considered as providing lateral support to such walls.

5 When thickness of a wall bonded to a pier is at least two-thirds of the thickness of the pier measured in the same direction, the wall and pier may be deemed to act as one structural element.

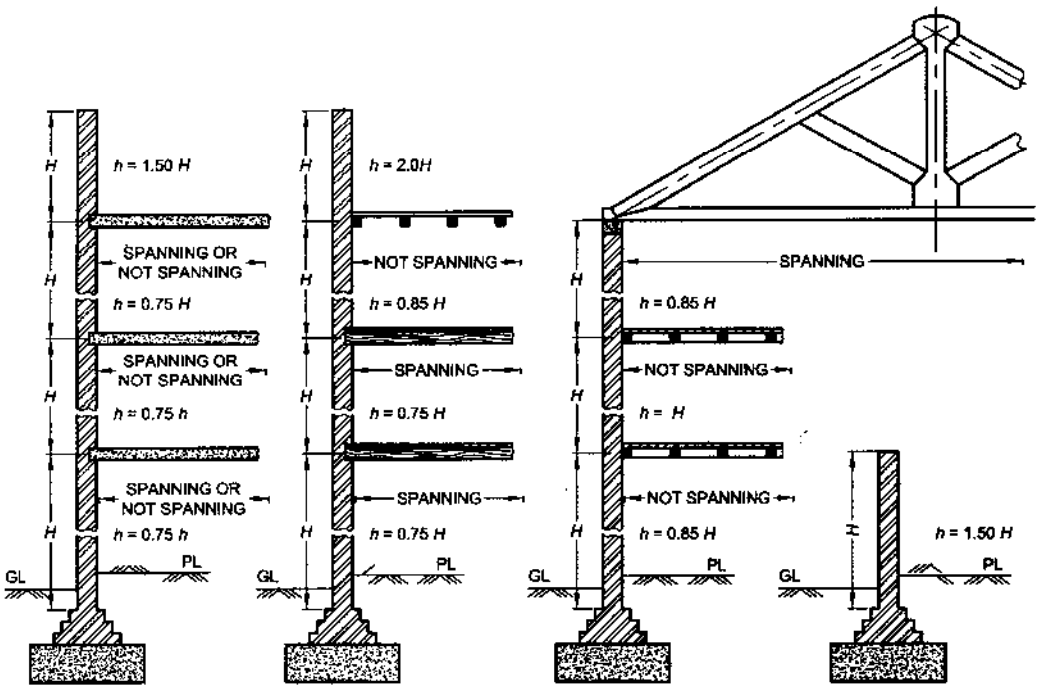
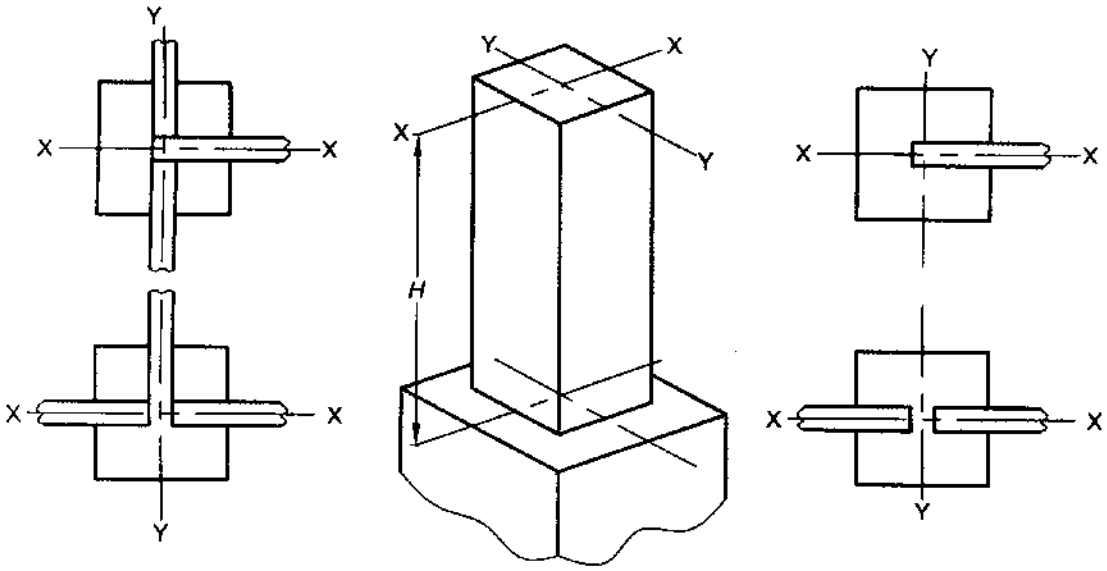


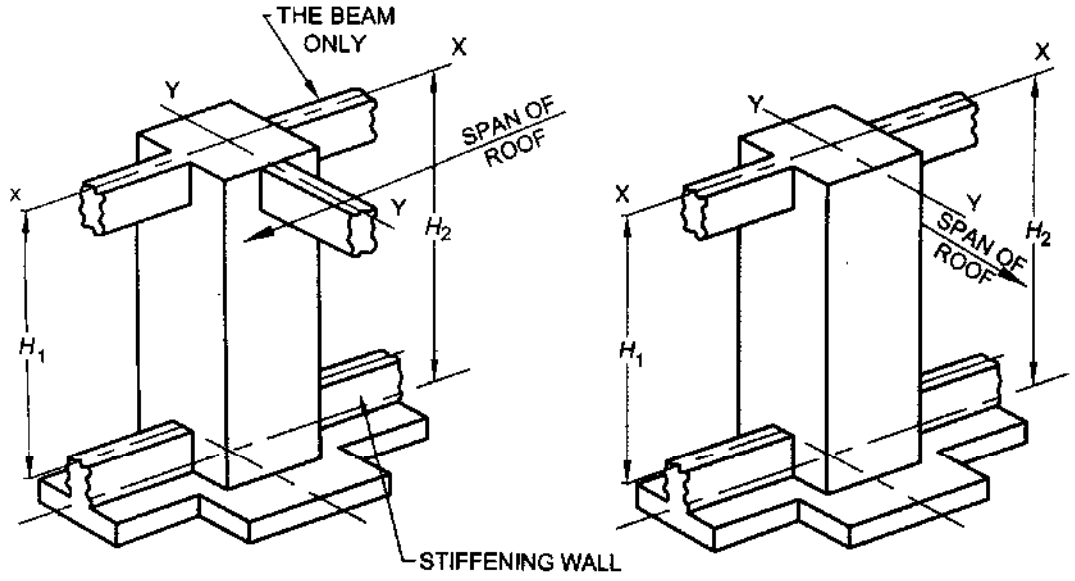
FIG. 11 EFFECTIVE HEIGHT OF WALL



EFFECTIVE HEIGHT
ABOUT AXIS
X - X = 1.0 *H*
Y - Y = 1.0 *H*

12 A

EFFECTIVE HEIGHT
ABOUT AXIS
X - X = 2.0 *H*
Y - Y = 1.0 *H*



12 B

12 C

Roof Construction	*Effective Height About Axis Fig. 12B*	*Effective Height About Axis Fig. 12C*
With precast concrete units of *in-situ* concrete floor or roof	$X - X = 1.0\ H_2$ $Y - Y = 1.0\ H_1$ $Y - Y = 1.5\ H_1$ (No ties)	$X - X = 1.5\ H_2$ $Y - Y = 1.0\ H_1$
With light deck or similar roof	$X - X = 1.0\ H_2$ $Y - Y = 1.0\ H_1$ $Y - Y = 2.0\ H_1$ (No ties)	$X - X = 2.0\ H_2$ $Y - Y = 1.0\ H_1$

FIG. 12 EXAMPLE OF EFFECTIVE HEIGHT OF COLUMNS

NOTES

1 A roof truss or beam supported on a column meeting the requirements of **4.2.2.1** is deemed to provide lateral support to the column only in the direction of the beam/truss.

2 When floor or roof consisting of RCC beams and slabs is supported on columns, the columns would be deemed to be laterally supported in both directions.

4.3.3 *Openings in Walls*

When openings occur in a wall such that masonry between the openings is by definition a column, effective height of masonry between the openings shall be reckoned as follows:

a) When wall has full restraint at the top:
   1) Effective height for the direction perpendicular to plane of wall equals $0.75\,H$ plus $0.25\,H_1$, where H is the distance between supports and H_1 is the height of the taller opening; and
   2) Effective height for the direction parallel to the wall equals H, that is, the distance between the supports.

b) When wall has partial restraint at the top and bottom:
   1) Effective height for the direction perpendicular to plane of wall equals H when height of neither opening exceeds $0.5\,H$ and it is equal to $2\,H$ when height of any opening exceeds $0.5\,H$; and
   2) Effective height for the direction parallel to the plane of the wall equals $2\,H$.

4.4 Effective Length

Effective length of a wall shall be as given in Table 5.

4.5 Effective Thickness

Effective thickness to be used for calculating slenderness ratio of a wall or column shall be obtained as in **4.5.1** to **4.5.5**.

4.5.1 For solid walls, faced walls or columns, effective thickness shall be the actual thickness.

4.5.2 For solid walls adequately bonded into piers, buttresses, effective thickness for determining slenderness ratio based on effective height shall be the actual thickness of wall multiplied by stiffening coefficient as given in Table 6. No modification in effective thickness, however, shall be made when slenderness ratio is to be based on effective length of walls.

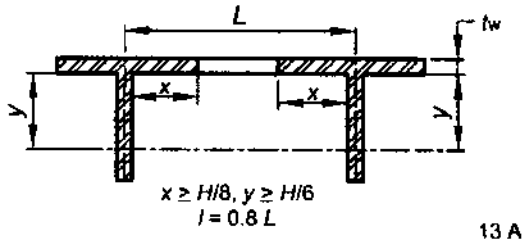
4.5.3 For solid walls or faced walls stiffened by cross walls, appropriate stiffening coefficient may be

Table 5 Effective Length of Walls

(*Clause* 4.4)

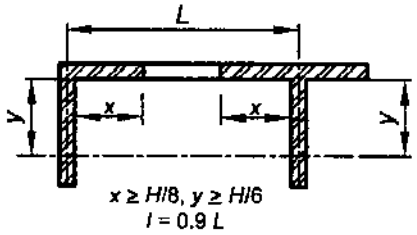
Sl No.	Conditions of Support (*See* Fig. 13)	Effective Length
(1)	(2)	(3)
i)	Where a wall is continuous and is supported by cross wall and there is no opening within a distance of $H/8$ from the face of cross wall (*see* Fig. 13)	$0.8\,L$
	or	
	Where a wall is continuous and is supported by piers/buttresses conforming to **4.2.1.2(b)**	
ii)	Where a wall is supported by a cross wall at one end and continuous with cross wall at other end	$0.9\,L$
	or	
	Where a wall is supported by a pier/buttress at one end and continuous with pier/buttress at other end conforming to **4.2.1.3**(b)	
iii)	Where a wall is supported at each end by cross wall	$1.0\,L$
	or	
	Where a wall is supported at each end by a pier/buttress conforming to **4.2.1.2**(b)	
iv)	Where a wall is free at one end and continuous with a pier/buttress at the other end	$1.5\,L$
	or	
	Where a wall is free at one end and continuous with a pier/buttress at the other end conforming to **4.2.1.2(b)**	
v)	Where a wall is free at one end and supported at the other end by a cross wall	$2.0\,L$
	or	
	Where a wall is free at one end and supported at the other end by a pier/buttress conforming to **4.2.1.2**(b)	
	where L = Length of wall from or between centres of cross wall, piers or buttress; and H = Actual height of wall between centres of adequate lateral support.	

NOTE — In case there is an opening taller than $0.5\,H$ in a wall, ends of the wall at the opening shall be considered as free. Cross walls shall conform to **4.2.2.1**(d).



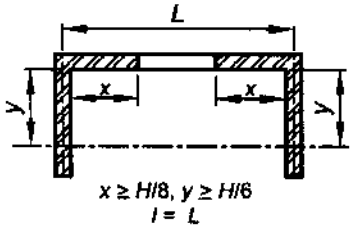
Wall is continuous at both ends and is supported by cross walls of thickness *tw*/2 or 100 mm whichever is more, length of cross wall is not less than *H*/6,opening in wall is not less than *H*/8 from cross wall

13 A CASE 1



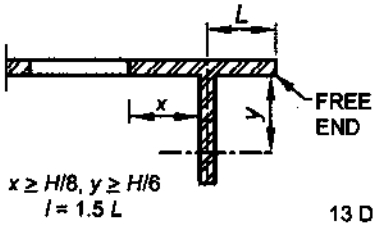
Same as case 1 except that one end of the wall is discontinuous

13 B CASE 2



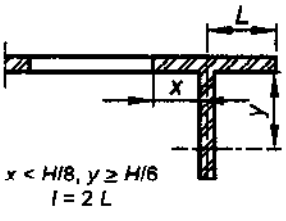
Same as case 1 except that wall is discontinuous on both ends

13 C CASE 3



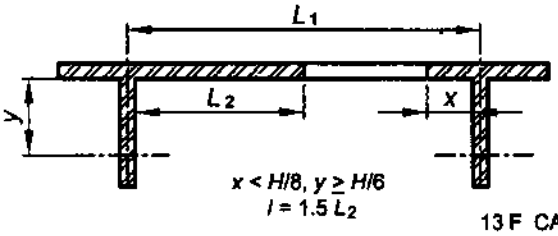
One end of the wall is free, other is supported by a cross wall and is continuous. There being no opening within *H*/8 from cross wall.

13 D CASE 4



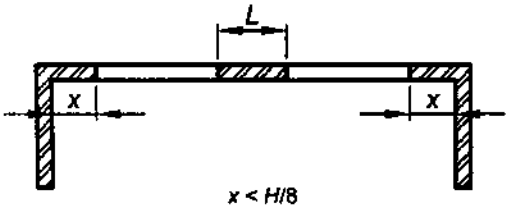
Same as case 4 but opening is within *H*/8 from cross wall and thus that end is taken as discontinuous

13 E CASE 5



This illustration is with an opening which is within *H*/8 from cross wall

13 F CASE 6



Wall length is between two opening which are closer than *H*/8 from cross walls

13 G CASE 7

FIG. 13 EFFECTIVE LENGTH OF WALL

determined from Table 6 on the assumption that the cross walls are equivalent to piers of width equal to the thickness of the cross wall and of thickness equal to three times the thickness of stiffened wall.

Table 6 Stiffening Coefficient for Walls Stiffened by Piers, Buttresses or Cross Walls

(*Clauses* 4.5.2 *and* 4.5.3)

Sl No.	Ratio $\frac{S_p}{w_p}$	Stiffening Coefficient		
		$\frac{t_p}{t_w} = 1$	$\frac{t_p}{t_w} = 2$	$\frac{t_p}{t_w} = 3$ or more
(1)	(2)	(3)	(4)	(5)
i)	6	1.0	1.4	2.0
ii)	8	1.0	1.3	1.7
iii)	10	1.0	1.2	1.4
iv)	15	1.0	1.1	1.2
v)	20 or more	1.0	1.0	1.0

where

S_p = Centre-to-centre spacing of the pier or cross wall,

t_p = Thickness of pier as defined in **2.3.2** (*see* Fig. 1),

t_w = Actual thickness of the wall proper (*see* Fig. 1), and

w_p = Width of the pier in the direction of the wall or the actual thickness of the cross wall.

NOTE — Linear interpolation between the values given in this table is permissible but not extrapolation outside the limits given.

4.5.4 For cavity walls with both leaves of uniform thickness throughout, effective thickness shall be taken as two-thirds of the sum of the actual thickness of the two leaves.

4.5.5 For cavity walls with one or both leaves adequately bonded into piers, buttresses or cross walls at intervals, the effective thickness of the cavity wall shall be two-thirds of the sum of the effective thickness of each of the two leaves; the effective thickness of each leaf being calculated using **4.5.1** or **4.5.2** as appropriate.

4.6 Slenderness Ratio

4.6.1 *Walls*

For a wall, slenderness ratio shall be effective height divided by effective thickness or effective length divided by the effective thickness, whichever is less. In case of a load bearing wall, slenderness ratio shall not exceed that given in Table 7.

Table 7 Maximum Slenderness Ratio for a Load Bearing Wall

(*Clause* 4.6.1)

Number of Storeys	Maximum Slenderness Ratio	
	Using Portland Cement or Portland Pozzolana Cement in Mortar	Using Lime Mortar
(1)	(2)	(3)
Not exceeding 2	27	20
Exceeding 2	27	13

4.6.2 *Columns*

For a column, slenderness ratio shall be taken to be the greater of the ratios of effective heights to the respective effective thickness, in the two principal directions. Slenderness ratio for a load bearing column shall not exceed 12.

4.7 Eccentricity

Eccentricity of vertical loading at a particular junction in a masonry wall shall depend on factors, such as extent of bearing, magnitude of loads, stiffness of slab or beam, fixity at the support and constructional details at junctions. No exact calculations are possible to make accurate assessment of eccentricity. Extent of eccentricity under any particular circumstances has, therefore, to be decided according to the best judgement of the designer. Some guidelines for assessment of eccentricity are given in Annex A.

5 STRUCTURAL DESIGN

5.1 General

The building as a whole shall be analyzed by accepted principles of mechanics to ensure safe and proper functioning in service of its component parts in relation to the whole building. All component parts of the structure shall be capable of sustaining the most adverse combinations of loads, which the building may be reasonably expected to be subjected to during and after construction.

5.2 Design Loads

Loads to be taken into consideration for designing masonry components of a structure are:

a) dead loads of walls, columns, floors and roofs;

b) live loads of floors and roof;

c) wind loads on walls and sloping roof; and

d) seismic forces.

NOTE — When a building is subjected to other loads, such as vibration from railways; machinery, etc, these should be taken into consideration accordingly to the best judgement of the designer (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

5.2.1 The design loads and other forces to be taken for the design of masonry structures shall conform to Part 6 'Structural Design, Section 1 Loads, Forces and Effects'.

NOTE — During construction, suitable measures shall be taken to ensure that masonry is not liable to damage or failure due to action of wind forces, back filling behind walls or temporary construction loads.

5.3 Load Dispersion

5.3.1 *General*

The angle of dispersion of vertical load on walls shall be taken as not more than 30° from the vertical.

Account may also be taken of the arching action of well-bonded masonry walls supported on lintels and beams, in accordance with established practice. Increased axial stresses in the masonry associated with arching action in this way, shall not exceed the permissible stresses given in **5.4**.

5.3.3 *Lintels*

Lintels that support masonry construction shall be designed to carry loads from masonry (allowing for arching and dispersion), where applicable and loads received from any other part of the structure. Length of bearing of lintel at each end shall not be less than 90 mm or one-tenth of the span, whichever is more and area of the bearing shall be sufficient to ensure that stresses in the masonry (combination of wall stresses, stresses due to arching action and bearing stresses from the lintel) do not exceed the stresses permitted in **5.4** (*see* Annex C).

5.4 Permissible Stresses

5.4.1 *Permissible Compressive Stress*

Permissible compressive stress in masonry shall be based on value of basic compressive stress (f_b) as given in Table 8 and multiplying this value by factors known as stress reduction factor (k_s), area reduction factor (k_a) and shape modification factor (k_p) as detailed in **5.4.1.1**

Table 8 take into consideration crushing strength of masonry unit and grades of mortar and hold good for values of slenderness ratio not exceeding 6, zero eccentricity and masonry unit having height to width ratio (as laid) equal to 0.75 or less.

Alternatively, basic compressive stress may be based on results of prism test given in Annex B on masonry made from masonry units and mortar to be actually used in a particular job.

5.4.1.1 *Stress reduction factor*

This factor, as given in Table 9, takes into consideration the slenderness ratio of the element and also the eccentricity of loading.

5.4.1.2 *Area reduction factor*

This factor takes into consideration smallness of the sectional area of the element and is applicable when sectional area of the element is less than 0.2 m^2. The factor $k_a = 0.7 + 1.5A$, A being the area of section in m^2.

5.4.1.3 *Shape modification factor*

This factor takes into consideration the shape of the unit, that is, height to width ratio (as laid) and is given in Table 10. This factor is applicable for units for crushing strength up to 15 N/mm^2.

Table 8 Basic Compressive Stresses for Masonry (After 28 days)

(*Clauses* 5.4.1 *and* 6.3.1)

Sl No.	Mortar Type (Ref Table 1)	Basic Compressive Stresses in N/mm^2 Corresponding to Masonry Units of which Height to Width Ratio does not Exceed 0.75 and Crushing Strength, in N/mm^2, is not Less than											
		3.5	5.0	7.5	10	12.5	15	17.5	20	25	30	35	40
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	H1	0.35	0.50	0.75	1.00	1.16	1.31	1.45	1.59	1.91	2.21	2.5	3.05
ii)	H2	0.35	0.50	0.74	0.96	1.09	1.19	1.30	1.41	1.62	1.85	2.1	2.5
iii)	M1	0.35	0.50	0.74	0.96	1.06	1.13	1.20	1.27	1.47	1.69	1.9	2.2
iv)	M2	0.35	0.44	0.59	0.81	0.94	1.03	1.10	1.17	1.34	1.51	1.65	1.9
v)	M3	0.25	0.41	0.56	0.75	0.87	0.95	1.02	1.10	1.25	1.41	1.55	1.78
vi)	L1	0.25	0.36	0.53	0.67	0.76	0.83	0.90	0.97	1.11	1.26	1.4	1.06
vii)	L2	0.25	0.31	0.42	0.53	0.58	0.61	0.65	0.69	0.73	0.78	0.85	0.95

NOTES

1 The table is valid for slenderness ratio up to 6 and loading with zero eccentricity.

2 The values given for basic compressive stress are applicable only when the masonry is properly cured.

3 Linear interpolation is permissible for units having crushing strengths between those given in the table.

4 The permissible stress for random rubble masonry may be taken as 75 percent of the corresponding stress for coarsed walling of similar materials.

5 The strength of ashlar masonry (natural stone masonry of massive type with thin joints) is closely related to intrinsic strength of the stone and allowable working stress in excess of those given in the table may be allowed for such masonry at the discretion of the designer.

6 For calculation of basic compressive stress of stabilized mud block having thickness 100 mm or more, reference to specialist literature may be made.

Table 9 Stress Reduction Factor for Slenderness Ratio and Eccentricity

(*Clause* 5.4.1.1)

Slenderness Ratio	Eccentricity of Loading Divided by the Thickness of the Member					
	0	1/24	1/12	1/6	1/4	1/3
(1)	(2)	(3)	(4)	(5)	(6)	(7)
6	1.00	1.00	1.00	1.00	1.00	1.00
8	0.95	0.95	0.94	0.93	0.92	0.91
10	0.89	0.88	0.87	0.85	0.83	0.81
12	0.84	0.83	0.81	0.78	0.75	0.72
14	0.78	0.76	0.74	0.70	0.66	0.66
16	0.73	0.71	0.68	0.63	0.58	0.53
18	0.67	0.64	0.61	0.55	0.49	0.43
20	0.62	0.59	0.55	0.48	0.41	0.34
22	0.56	0.52	0.48	0.40	0.32	0.24
24	0.51	0.47	0.42	0.33	0.24	—
26	0.45	0.40	0.35	0.25	—	—
27	0.43	0.38	0.33	0.22	—	—

NOTES

1 Linear interpolation between values is permitted.

2 Where in special cases the eccentricity of loading lies between 1/3 and 1/2 of the thickness of the member, the stress reduction factor should vary linearly between unity and 0.20 for slenderness ratio of 6 and 20 respectively.

3 Slenderness ratio of a member for sections within 1/8 of the height of the member above or below a lateral support may be taken to be 6.

Table 10 Shape Modification Factor for Masonry Units

(*Clause* 5.4.1.3)

Height to Width Ratio of Units (as Laid)	Shape Modification Factor (k_p) for Units Having Crushing Strength in N/mm^2 is			
	5.0	7.5	10.0	15.0
(1)	(2)	(3)	(4)	(5)
Up to 0.75	1.0	1.0	1.0	1.0
1.0	1.2	1.1	1.1	1.0
1.5	1.5	1.3	1.2	1.1
2.0 to 4.0	1.8	1.5	1.3	1.2

NOTE — Linear interpolation between values is permissible.

5.4.1.4 *Increase in permissible compressive stresses allowed for eccentric vertical loads, lateral loads under certain conditions*

In members subjected to eccentric and/or lateral loads, increase in permissible compressive stress is allowed as follows:

a) When resultant eccentricity ratio exceeds 1/24 but does not exceed 1/6, 25 percent increase in permissible compressive stress is allowed in design.

b) When resultant eccentricity ratio exceeds 1/6, 25 percent increase in permissible stress is allowed but the area of the section under tension shall be disregarded for computing the load carrying capacity of the member.

NOTE — When resultant eccentricity ratio of loading is 1/24 or less, compressive stress due to bending shall be ignored and only axial stress need be computed for the purpose of design.

5.4.1.5 *Increase in permissible compressive stress for walls subjected to concentrated loads*

When a wall is subjected to a concentrated load (a load being taken to be concentrated when area of supporting wall equals or exceeds three times the bearing area), certain increase in permissible compressive stress may be allowed because of dispersal of the load. Since, according to the present state of art, there is diversity of views in regard to manner and extent of dispersal, design of walls subjected to concentrated loads may, therefore, be worked out as per the best judgement of the designer. Some guidelines in this regard are given in Annex C.

5.4.2 *Permissible Tensile Stress*

As a general rule, design of masonry shall be based on the assumption that masonry is not capable of taking any tension. However, in case of lateral loads normal to the plane of wall, which causes flexural tensile stress, as for example, panel, curtain partition and free standing walls, flexural tensile stresses as follows may be permitted in the design for masonry:

Grade M1 or better mortar	– 0.07 N/mm² for bending in the vertical direction where tension developed is normal to bed joints.
	– 0.14 N/mm² for bending in the longitudinal direction where tension developed is parallel to bed joints, provided crushing strength of masonry units is not less than 10 N/mm².
Grade M2 mortar	– 0.05 N/mm² for bending in the vertical direction where tension developed is normal to bed joints.
	– 0.10 N/mm² for bending in the longitudinal direction where tension developed is parallel to bed joints, provided crushing strength of masonry units is not less than 7.5 N/mm².

NOTES

1 No tensile stress is permitted in masonry in case of water-retaining structures in view of water in contact with masonry. Also no tensile stress is permitted in earth-retaining structures, in view of the possibility of presence of water at the back of such walls.

2 Allowable tensile stress in bending in the vertical direction may be increased to 0.1 N/mm² for M1 mortar and 0.07 N/mm² for M2 mortar in case of boundry walls/compound at the discretion of the designer, since there is not much risk to life and property in the event of failure of such walls.

5.4.3 *Permissible Shear Stress*

In case of walls built in mortar not leaner than Grade M1 (*see* Table 1) and resisting horizontal forces in the plane of the wall, permissible shear stress calculated on the area of bed joints, shall not exceed the value obtained by the formula given below, subject to a maximum of 0.5 N/mm²:

$$f_s = 0.1 + f_d/6$$

f_d = Compressive stress due to dead loads in N/mm², and

f_s = Permissible shear stress in N/mm².

5.4.4 If there is tension in any part of a section of masonry, the area under tension shall be ignored while working out shear stress on the section.

5.5 Design Thickness/Cross-Section

5.5.1 *Walls and Columns Subjected to Vertical Loads*

Walls and columns bearing vertical loads shall be designed on the basis of permissible compressive stress. Design consists in determining thickness in case of walls and section in case of columns in relation to strength of masonry units and grade of mortar to be used, taking into consideration various factors, such as slenderness ratio, eccentricity, area of section, workmanship, quality of supervision, etc, subject further to provisions of **5.5.1.1** to **5.5.1.4**.

5.5.1.1 *Solid walls*

Thickness used for design calculation shall be the actual thickness of masonry computed as the sum of the average dimensions of the masonry units specified in the relevant standard, together with the specified joint thickness. In masonry with raked joints, thickness shall be reduced by the depth of raking, of joints for plastering/pointing.

5.5.1.2 *Cavity walls*

a) Thickness of each leaf of a cavity wall shall not be less than 75 mm.

b) Where the outer leaf is half masonry unit in thickness, the uninterrupted height and length of this leaf shall be limited so as to avoid undue loosening of ties due to differential movements between the two leaves. The outer leaf shall, therefore, be supported at least at every third storey or at every 10 m of height whichever is less, and at every 10 m or less along the length.

c) Where the load is carried by both leaves of a wall of a cavity construction, the permissible stress shall be based on the slenderness ratio derived from the effective thickness of the wall as given in **4.5.4** or **4.5.5**. The eccentricity of the load shall be considered with respect to the centre of gravity of the cross-section of the wall.

d) Where the load is carried by one leaf only, the permissible stress shall be the greater of values calculated by the following two alternative methods:

1) The slenderness ratio is based on the effective thickness of the cavity wall as a whole as given in **4.5.4** or **4.5.5** and on the eccentricity of the load with respect to the centre of gravity of the cross-section of the whole wall (both leaves). (This is the same method as where the load is carried by both the leaves but the eccentricity will be more when the load is carried by one leaf only.)

2) The slenderness ratio is based on the effective thickness of the loaded leaf only using **4.5.1** and **4.5.2**, and the eccentricity of the load will also be with respect to the centre of gravity of the loaded leaf only.

In either alternative, only the actual thickness of the load bearing leaf shall be used in arriving at the cross-sectional area resisting the load (*see* **5.5.1.1**).

5.5.1.3 *Faced wall*

The permissible load per length of wall shall be taken as the product of the total thickness of the wall and the permissible stress in the weaker of the two materials. The permissible stress shall be found by using the total thickness of the wall when calculating the slenderness ratio.

5.5.1.4 *Veneered wall*

The facing (veneer) shall be entirely ignored in calculations of strength and stability. For the purpose of determining the permissible stress in the backing, the slenderness ratio shall be based on the thickness of the backing alone.

5.5.2 *Walls and Columns Mainly Subjected to Lateral Loads*

5.5.2.1 *Free standing walls*

a) Free standing walls, subjected to wind pressure or seismic forces shall be designed on the basis of permissible tensile stress in masonry or stability as in **4.2.2.4**. However, in seismic Zones II, free-standing walls may be apportioned without making any design calculations with the help of Table 11 provided the mortar used is of grade not leaner than M1.

b) If there is a horizontal damp-proof course near the base of the wall, that is, not capable of developing tension vertically, the minimum wall thickness should be the greater of that calculated from either:

   1) the appropriate height to thickness ratio given in Table 11 reduced by 25 percent, reckoning the height from the level of the damp-proof course; or

   2) the appropriate height to thickness ratio given in Table 11 reckoning the height from the lower level at which the wall is restrained laterally.

5.5.2.2 *Retaining walls*

Normally masonry of retaining walls shall be designed on the basis of zero-tension, and permissible compressive stress. However, in case of retaining walls for supporting horizontal thrust from dry materials, retaining walls may be designed on the basis of permissible tensile stress at the discretion of the designers.

Table 11 Height to Thickness Ratio of Free Standing Walls Related to Wind Speed

(*Clause* 5.5.2.1)

Design Wind Pressure N/mm² (1)	Height to Thickness Ratio (2)
Up to 285	10
575	7
860	5
1 150	4

NOTES

1 For intermediate values, linear interpolation is permissible.

2 Height is to be reckoned from 150 mm below ground level or top of footing/foundation block, whichever is higher, and up to the top edge of the wall.

3 The thickness should be measured including the thickness of the plaster.

5.5.3 *Walls and Columns Subjected to Vertical as well as Lateral Loads*

For walls and columns, stress worked out separately for vertical loads as in **5.5.1** and lateral loads as in **5.5.2** shall be combined and elements designed on the basis of permissible stress.

5.5.4 *Walls Subjected to In-Plane Bending and Vertical Loads (Shear Walls)*

Walls subjected to in-plane bending and vertical loads, that is, shear walls shall be designed on the basis of no tension with permissible shear stress and permissible compressive stress.

5.5.5 *Non-Load Bearing Walls*

Non-load bearing walls, such as panel walls, curtain walls and partition walls which are mainly subjected to lateral loads, according to present state of art, are not capable of precise design and only approximate methods based on some tests are available. Guidelines for approximate design of these walls are given in Annex D.

6 GENERAL REQUIREMENTS

6.1 Methods of Construction

6.1.1 *General*

Construction of the following types of load bearing and non-load bearing masonry walls shall be carried out in accordance with good practice [6-4(3)].

a) Brickwork,
b) Stone masonry,
c) Hollow concrete block masonry,
d) Gypsum partition blocks,
e) Autoclaved cellular concrete block masonry, and
f) Lightweight concrete block masonry.

6.1.2 *Construction of Buildings in Seismic Zones*

No special provisions on construction are necessary for buildings constructed in Zones II. Special features of construction for earthquake resistant masonry buildings in Zones III, IV and V shall be applicable according to good practice [6-4(3)].

6.2 Minimum Thickness of Walls from Consideration other than Structural

Thickness of walls determined from consideration of strength and stability may not always be adequate in respect of other requirements, such as resistance to fire, thermal insulation, sound insulation and resistance to damp penetration for which reference may be made to the appropriate Parts/Sections of the Code, and thickness suitably increased, where found necessary.

6.3 Workmanship

6.3.1 *General*

Workmanship has considerable effect on strength of masonry and bad workmanship may reduce the strength of brick masonry to as low as half the intended strength. The basic compressive stress values for masonry as given in Table 8 would hold good for commercially obtainable standards of workmanship with reasonable degree of supervision. If the work is inadequately supervised, strength should be reduced to three-fourth or less at the discretion of the designer.

6.3.2 *Bedding of Masonry Units*

Masonry units shall be laid on a full bed of mortar with frog, if any, upward such that cross-joints and wall joints are completely filled with mortar. Masonry units which are moved after initial placement shall be relaid in fresh mortar, discarding the disturbed mortar.

6.3.3 *Bond*

Cross-joints in any course of one brick thick masonry wall shall be not less than one-fourth of a masonry unit in horizontal direction from the cross-joints in the course below. In masonry walls more than one brick in thickness, bonding through the thickness of wall shall be provided by either header units or by other equivalent means in accordance with good practice [6-4(4)].

6.3.4 *Verticality and Alignment*

All masonry shall be built true and plumb within the tolerances prescribed below; care shall be taken to keep the perpends properly aligned:

a) Deviation from vertical within a storey shall not exceed 6 mm per 3 m height.

b) Deviation in verticality in total height of any wall of a building more than one storey in height shall not exceed 12.5 mm.

c) Deviation from position shown on plan of any brickwork shall not exceed 12.5 mm.

d) Relative displacement between load bearing walls in adjacent storeys intended to be in vertical alignment shall not exceed 6 mm.

e) Deviation of bed-joint from horizontal in a length of 12 m shall not exceed 6 mm subject to a maximum deviation of 12 mm.

f) Deviation from the specified thickness of bed joints, cross-joints and perpends shall not exceed one-fifth of the specified thickness.

NOTE — These tolerances have been specified from the point of view of their effect on the strength of masonry. The permissible stress recommended in **5.3** may be considered applicable only if these tolerances are adhered to.

6.4 Joints to Control Deformation and Cracking

Special provision shall be made to control or isolate thermal and other movements so that damage to the fabric of the building is avoided and its structural sufficiency preserved. Design and installation of joints shall be done according to the appropriate recommendations in accordance with good practice [6-4(5)].

6.5 Chases, Recesses and Holes

6.5.1 Chases, recesses and holes are permissible in masonry only if these do not impair strength and stability of the structure.

6.5.2 In masonry, designed by structural analysis, all chases, recesses and holes shall be considered in structural design and detailed in building plans.

6.5.3 When chases, recesses and holes have not been considered in structural design and are not shown in drawings, these may be provided, subject to the constraints and precautions specified in **6.5.3.1** to **6.5.3.10**.

6.5.3.1 As far as possible, services should be planned with the help of vertical chases and use of horizontal chases should be avoided.

6.5.3.2 For load bearing walls, depth of vertical and horizontal chases shall not exceed one-third and one-sixth of the wall thickness respectively.

6.5.3.3 Vertical chases shall not be closer than 2 m in any stretch of wall and shall not be located within 345 mm of an opening or within 230 mm of a cross wall that serves as a stiffening wall for stability. Width of a vertical chase shall not exceed thickness of wall in which it occurs.

6.5.3.4 When unavoidable horizontal chases of width not exceeding 60 mm in a wall having slenderness ratio not exceeding 15 may be provided. These shall be located in the upper or lower middle third height of wall at a distance not less than 600 mm from a lateral support. No horizontal chase shall exceed 1 m in length and there shall not be more than 2 chases in any one wall. Horizontal chases shall have minimum mutual separation distance of 500 mm. Sum of lengths of all chases and recesses in any horizontal plane shall not exceed one-fourth the length of the wall.

6.5.3.5 Holes for supporting put-logs of scaffolding shall be kept away from bearings of beams, lintels, and other concentrated loads. If unavoidable, stresses in the affected area shall be checked to ensure that these are within safe limits.

6.5.3.6 No chase, recess or hole shall be provided in any stretch of a masonry wall, the length of which is less than four times the thickness of wall, except when found safe by structural analysis.

6.5.3.7 Masonry directly above a recess or a hole, if wider than 300 mm, shall be supported on a lintel. No lintel, however, is necessary in case of a circular recess or hole exceeding 300 mm in diameter provided upper half of the recess or hole is built as a semi-circular arch of adequate thickness and there is a adequate length of masonry on the sides of openings to resist the horizontal thrust.

6.5.3.8 As far as possible chases, recesses and holes in masonry should be left (inserting sleeves, where necessary) at the time of construction of masonry so as to obviate subsequent cutting. If cutting is unavoidable, it should be done without damage to the surrounding or residual masonry. It is desirable to use such tools for cutting which depend upon rotary and not on heavy impact for cutting action.

6.5.3.9 No chase, recess or hole shall be provided in half-brick load bearing wall, excepting the minimum number of holes needed for scaffolding.

6.5.3.10 Chases, recesses or holes shall not be cut into walls made of hollow or perforated units, after the units have been incorporated in masonry.

6.6 Corbelling

6.6.1 Where corbelling is required for the support of some structural element, maximum projection of masonry unit should not exceed one-half of the height of the unit or one-half of the built-in part of the unit and the maximum horizontal projection of the corbel should not exceed one-third of the wall thickness.

6.6.2 The load per unit length on a corbel shall not be greater than half of the load per unit length on the wall above the corbel. The load on the wall above the corbel, together with four times the load on the corbel, shall not cause the average stress in the supporting wall or leaf to exceed the permissible stresses given in **5.4**.

6.6.3 It is preferable to adopt header courses in the corbelled portion of masonry from considerations of economy and stability.

7 SPECIAL CONSIDERATION IN EARTHQUAKE ZONES

7.0 Special features of design and construction for earthquake resistant masonry buildings are given in **7.2** to **7.8.2.** Reference may also be made to good practice [6-4(6)] for detailed information.

7.1 Categories of Buildings

For the purpose of specifying the earthquake resistant features in masonry and wooden buildings, the buildings have been categorized in five categories A to E based on the seismic zone and the importance of building *I*,

where

I = Importance factor applicable to the building (*see* Table 35 of Part 6, Section 1)

7.1.1 The building categories are given in Table 12.

Table 12 Building Categories for Earthquake Resisting Features

(*Clauses* 7.1.1 *and* 8.1.2)

Importance Factor	Seismic Zone			
	II	III	IV	V
(1)	(2)	(3)	(4)	(5)
1.0	A	B	C	D
1.5	B	C	D	E

7.2 Masonry Units

Bricks/Blocks as per the accepted standards [6-4(1)] having a crushing strength not less than 3.5 MPa shall be used. However, higher strength of masonry units may be required depending upon number of storeys and thickness of walls in accordance with provisions of this Section.

7.3 Mortar

7.3.1 Mortars, such as those given in Table 13 or of equivalent specification, shall preferably be used for masonry construction for various categories of buildings.

Table 13 Recommended Mortar Mixes

(*Clauses* 7.3.1 *and* 7.4.6)

Category of Construction[1]	Proportion of Cemet-Lime-Sand[2]
(1)	(2)
A	M2 (Cement-sand 1:6) or
	M3 (Lime-cinder [3] 1:3) or richer
B, C	M2 (Cement-lime-sand 1:2:9 or
	Cement-sand 1:6) or richer
D, E	H2 (Cement-sand 1:4) or
	M1 (Cement-lime-sand 1:1:6) or richer

NOTE — Though the equivalent mortar with lime will have less strength at 28 days, their strength after one year will be comparable to that of cement mortar.

[1] Category of construction is defined in Table 12.

[2] Mortar grades and specification for types of limes etc, shall be in accordance with Table 1.

[3] In this case some other pozzolanic material like *SURKHI* (burnt brick fine powder) may be used in place of cinder.

7.3.2 Where steel reinforcing bars are provided in masonry the bars shall be embedded with adequate cover in cement sand mortar not leaner than 1:3 (minimum clear cover 10 mm) or in cement concrete of grade M15 (minimum clear cover 15 mm or bar diameter whichever more), so as to achieve good bond and corrosion resistance.

7.4 Walls

7.4.1 Masonry bearing walls built in mortar, as specified in **7.3.1** unless rationally designed as reinforced masonry shall not be built of greater height than 15 m subject to a maximum of four storeys when measured from the mean ground level to the roof slab or ridge level. The masonry bearing walls shall be reinforced in accordance with **7.6.1**.

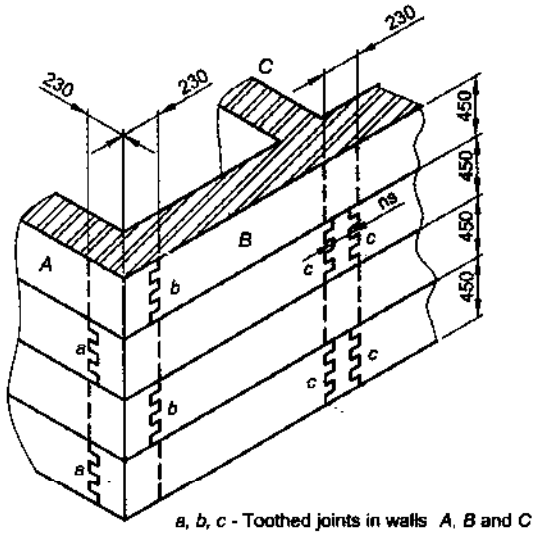
7.4.2 The bearing walls in both directions shall be straight and symmetrical in plan as far as possible.

7.4.3 The wall panels formed between cross walls and floors or roof shall be checked for their strength in bending as a plate or as a vertical strip subjected to the earthquake force acting on its own mass.

NOTE — For panel walls of 200 mm or larger thickness having a storey height not more than 3.5 m and laterally supported at the top, this check need not be exercised.

7.4.4 *Masonry Bond*

For achieving full strength of masonry, the usual bonds specified for masonry should be followed so that the vertical joints are broken properly from course to course. To obtain full bond between perpendicular walls, it is necessary to make a slopping (stepped) joint by making the corners first to a height of 600 mm and then building the wall in between them. Otherwise, the toothed joint should be made in both the walls alternatively in lifts of about 450 mm (*see* Fig. 14).



All dimensions in millimetres.

FIG. 14 ALTERNATING TOOTHED JOINTS IN WALLS AT CORNER AND T-JUNCTION

7.4.5 Ignoring tensile strength, free standing walls shall be checked against overturning under the action of design seismic coefficient α_h allowing for a factor of safety of 1.5.

7.4.6 Panel or filler walls in framed buildings shall be properly bonded to surrounding framing members by means of suitable mortar (*see* Table 13) or connected through dowels. If the walls are so bonded they shall be checked according to **7.4.3** otherwise as in **7.4.5**.

7.5 Openings in the Bearing Walls

7.5.1 Door and window openings in walls reduce their lateral load resistance and hence, should preferably be small and more centrally located. The guidelines on the size and position of opening are given in Table 14 and Fig. 15.

7.5.2 Openings in any storey shall preferably have their top at the same level so that a continuous band could be provided over them, including the lintels throughout the building.

7.5.3 Where openings do not comply with the guidelines of Table 14, they should be strengthened by providing reinforced concrete or reinforcing the brickwork, as shown in Fig. 16 with high strength deformed steel bars of 8 mm diameter but the quantity of steel shall be increased at the jambs to comply with **7.6.9**, if so required.

7.5.4 If a window or ventilator is to be projected out, the projection shall be in reinforced masonry or concrete and well anchored.

Table 14 Size and Position of Openings in Bearing Walls

(*Clause* 7.5.1 and *Fig.* 15)

Sl No.	Position of Opening	Details of Opening for Building Category		
		A and B	C	D and E
(1)	(2)	(3)	(4)	(5)
i)	Distance b_5 from the inside corner of outside wall, *Min*	0	230 mm	450 mm
ii)	For total length of openings, the ratio $(b_1 + b_2 + b_3)/l_1$ or $(b_6 + b_7)/l_2$ shall not exceed:			
	a) one-storeyed building	0.60	0.55	0.50
	b) two-storeyed building	0.50	0.46	0.42
	c) three or four-storeyed building	0.42	0.37	0.33
iii)	Pier width between consecutive openings b_4, *Min*	340 mm	450 mm	560 mm
iv)	Vertical distance between two openings one above the other h_4, *Min*	600 mm	600 mm	600 mm
v)	Width of opening of ventilator b_8, *Max*	900 mm	900 mm	900 mm

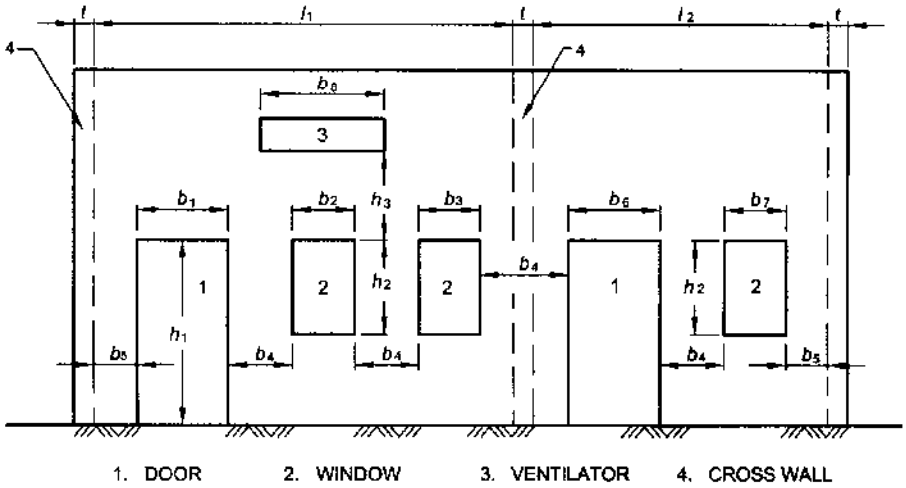


FIG. 15 RECOMMENDED DIMENSIONS OF OPENINGS AND PIERS (*see* Table 14)

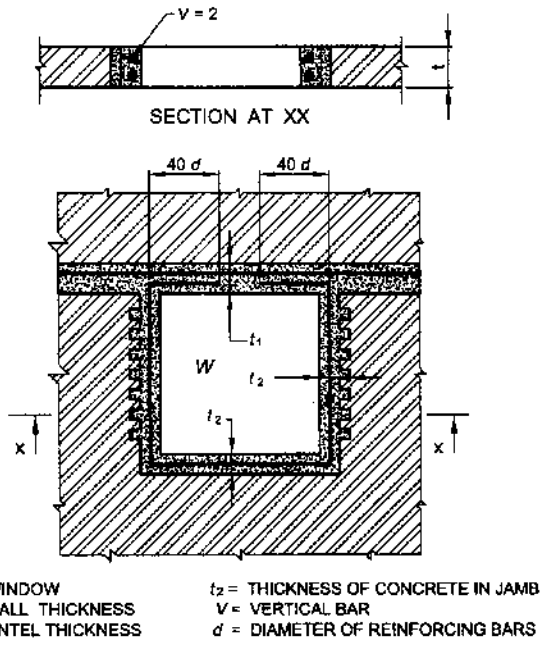


FIG. 16 STRENGTHENING MASONARY AROUND OPENING

7.5.5 If an opening is tall from bottom to almost top of a storey, thus dividing the wall into two portions, these portions shall be reinforced with horizontal reinforcement of 6 mm diameter bars at not more than 450 mm intervals, one on inner and one on outer face, properly tied to vertical steel at jambs, corners or junction of walls, where used.

7.5.6 The use of arches to span over the openings is a source of weakness and shall be avoided. Otherwise, steel ties should be provided.

7.6 Seismic Strengthening Arrangements

7.6.1 All masonry buildings shall be strengthened by the methods, as specified for various categories of buildings, as listed in Table 15, and detailed in subsequent clauses. Figures 17 and 18 show, schematically, the overall strengthening arrangements to be adopted for category D and E buildings which consist of horizontal bands of reinforcement at critical levels, vertical reinforcing bars at corners, junctions of walls and jambs of opening.

Table 15 Strengthening Arrangements Recommended for Masonry Buildings (Rectangular Masonry Units)

(*Clause* 7.6.1)

Building Category (1)	Number of Storeys (2)	Strengthening to be Provided in all Storeys (3)
A	i) 1 to 3	*a*
	ii) 4	*a, b, c*
B	i) 1 to 3	*a, b, c, f, g*
	ii) 4	*a, b, c, d, f, g*
C	i) 1 and 2	*a, b, c, f, g*
	ii) 3 and 4	*a* to *g*
D	i) 1 and 2	*a* to *g*
	ii) 3 and 4	*a* to *h*
E	1 to 3[1)]	*a* to *h*

where

a – Masonry mortar (*see* **7.3**)

b – Lintel band (*see* **7.6.2**)

c – Roof band and gable band where necessary (*see* **7.6.3** and **7.6.4**),

d – Vertical steel at corners and junctions of walls (*see* **7.6.8**)

e – Vertical steel at jambs of openings (*see* **7.6.9**)

f – Bracing in plan at tie level of roofs

g – Plinth band where necessary (*see* **7.6.6**), and

h – Dowel bars (*see* **7.6.7**)

[1)] Fourth storey not allowed in category E.

NOTE — In case of four storey buildings of category B, the requirements of vertical steel may be checked through a seismic analysis using a design seismic coefficient equal to four times the one given in good practice [6-4(8)] (this is because the brittle behaviour of masonry in the absence of a vertical steel results in much higher effective seismic force than that envisaged in the seismic coefficient, provided in the Code). If this analysis shows that vertical steel is not required the designer may take the decision accordingly.

7.6.2 Lintel band is a band provided at lintel level on all load bearing internal, external longitudinal and cross walls. The specifications of the band are given in **7.6.3**.

NOTE — Lintel band if provided in panel or partition walls also will improve their stability during severe earthquake.

7.6.3 Roof band is a band provided immediately below the roof or floors. The specifications of the band are given in **7.6.5**. Such a band need not be provided underneath reinforced concrete or brick-work slabs resting on bearing walls, provided that the slabs are continuous over the intermediate wall up to the crumple sections, if any, and cover the width of end walls, fully or at least ¾ of the wall thickness.

7.6.4 Gable band is a band provided at the top of gable masonry below the purlins. The specifications of the band are given in **7.6.5**. This band shall be made continuous with the roof band at the eaves level.

7.6.5 *Section and Reinforcement of Band*

The band shall be made of reinforced concrete of grade not leaner than M15 or reinforced brick work in cement mortar not leaner than 1:3. The bands shall be of the full width of the wall, not less than 75 mm in depth and reinforced with steel, as indicated in Table 16.

NOTE — In coastal areas, the concrete grade shall be M20 concrete and the filling mortar of 1:3 (cement sand with water proofing admixture).

Table 16 Recommended Longitudinal Steel in Reinforced Concrete Bands

(*Clauses* 7.6.5 *and* 7.8.1 **and** *Table* 17)

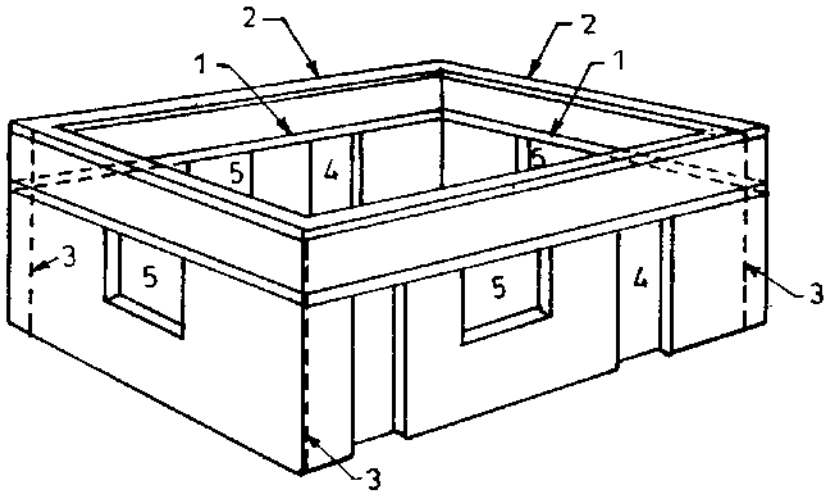
Span	Building Category B		Building Category C		Building Category D		Building Category E	
	No. of Bars	Dia	No. of Bars	Dia	No. of Bars	Dia	No. of Bars	Dia
m		mm		mm		mm		mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
5 or less	2	8	2	8	2	8	2	10
6	2	8	2	8	2	10	2	12
7	2	8	2	10	2	12	4	10
8	2	10	2	12	4	10	4	12

NOTES

1 Span of wall will be the distance between centre lines of its cross walls or buttresses. For spans greater than 8 m it will be desirable to insert pilasters or buttresses to reduce the span or special calculations shall be made to determine the strength of wall and section of band.

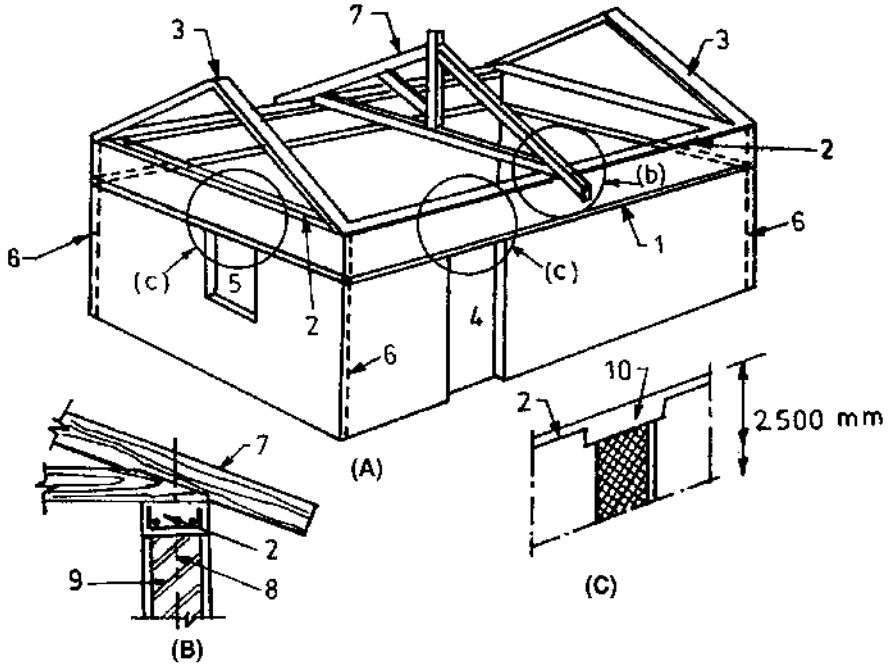
2 The number and diameter of bars given above pertain to high strength deformed bars. If plain mild steel bars are used keeping the same number, the following diameters may be used:

High strength deformed steel bar diameter	8	10	12	16	20



1. LINTEL BAND
2. ROOF FLOOR BAND
3. VERTICAL BAR
4. DOOR
5. WINDOW

FIG. 17 OVERALL ARRANGEMENT OF REINFORCING MASONRY BUILDINGS



1. LINTEL BAND
2. EAVE LEVEL (ROOF) BAND
3. CABLE BAND
4. DOOR
5. WINDOW
6. VERTICAL STEEL BAR
7. RAFTER
8. HOLDING DOWN BOLT
9. BRICK/STONE WALL
10. DOOR LINTEL INTEGRATE WITH ROOF BAND

18 A PERSPECTIVE VIEW
18 B DETAILS OF TRUSS CONNECTION WITH WALL
18 C DETAILS OF INTEGRATING DOOR LINTEL WITH ROOF BAND

FIG. 18 OVERALL ARRANGEMENT OF REINFORCING MASONRY BUILDING HAVING PITCHED ROOF

Table 16 — *Concluded*

Mild steel plain deformed bar diameter	10	12	16	20	25

3 Width of RC band is assumed same as the thickness of the wall. Wall thickness shall be 200 mm minimum. A clear cover of 20 mm from face of wall will be maintained.

4 The vertical thickness of RC band be kept 75 mm minimum, where two longitudinal bars are specified, one on each face; and 150 mm, where four bars are specified.

5 Concrete mix shall be of grade M15 or 1:2:4 by volume.

6 The longitudinal steel bars shall be held in position by steel links or stirrups 6 mm dia spaced at 150 mm apart.

7.6.5.1 In case of reinforced brickwork, the thickness of joints containing steel bars shall be increased so as to have a minimum mortar cover of 10 mm around the bar. In bands of reinforced brickwork the area of steel provided should be equal to that specified above for reinforced concrete bands.

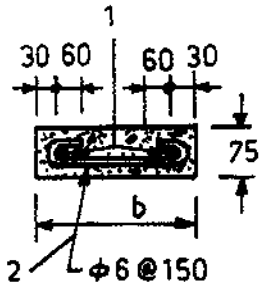
7.6.5.2 For full integrity of walls at corners and junctions of walls and effective horizontal bending resistance of bands continuity of reinforcement is essential. The details as shown in Fig. 19 are recommended.

7.6.6 Plinth band is a band provided at plinth level of walls on top of the foundation wall. This is to be provided where strip footings of masonry (other than reinforced concrete or reinforced masonry) are used and the soil is either soft or uneven in its properties, as frequently happens in hill tracts. Where used, its section may be kept same as in **7.6.5**. This band will serve as damp proof course as well.

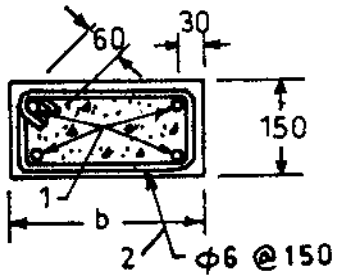
7.6.7 In category D and E buildings, to further iterate the box action of walls, steel dowel bars may be used at corners and T-junctions of walls at the sill level of windows to a length of 900 mm from the inside corner in each wall. Such dowel may be in the form of U stirrups of 8 mm diameter. Where used, such bars shall be laid in 1:3 cement-sand-mortar with a minimum cover of 10 mm on all sides to minimize corrosion.

7.6.8 *Vertical Reinforcement*

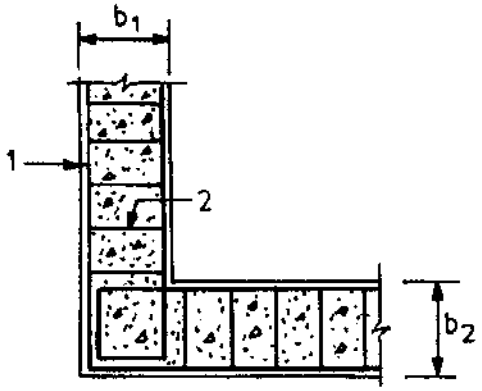
Vertical steel at corners and junctions of walls, which are up to 340 mm (1½ brick) thick, shall be provided as specified in Table 17. For walls thicker than 340 mm, the area of the bars shall be proportionately increased.



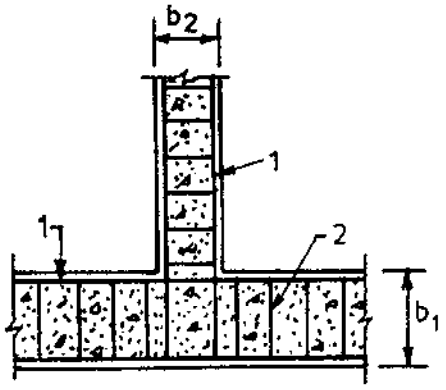
19A SECTION OF BAND WITH TWO BARS



19B SECTION OF BAND WITH FOUR BARS



19C STRUCTURAL PLAN OF CORNER JUNCTION



19D SECTION PLAN AT T-JUNCTION OF WALL

1. Longtudinal bars
2. Lateral ties

b_1, b_2 – Wall thickness

All dimensions in millimetres.

FIG. 19 REINFORCEMENT AND BENDING DETAIL IN R.C. BAND

Table 17 Vertical Steel Reinforcement in Masonry Walls with Rectangular Masonry Units

(*Clauses* 7.6.8, 7.6.9 *and* 8.7.2)

No. of Storeys	Storey	Diameter of HSD Single Bar in mm at Each Critical Section			
		Category B	Category C	Category D	Category E
(1)	(2)	(3)	(4)	(5)	(6)
One	—	Nil	Nil	10	12
Two	Top	Nil	Nil	10	12
	Bottom	Nil	Nil	12	16
Three	Top	Nil	10	10	12
	Middle	Nil	10	12	16
	Bottom	Nil	12	12	16
Four	Top	10	10	10	Four storeyed building not permitted
	Third	10	10	12	
	Second	10	12	16	
	Bottom	12	12	20	

NOTES

1 The diameters given above are for high strength deformed steel bars. For mild steel plain bars, use equivalent diameters as given in Table 16 (Note 2).

2 The vertical bars will be covered with concrete M 15 or mortar 1:3 grade in suitably created pockets around the bars. This will ensure their safety from corrosion and good bond with masonry.

3 In case of floors/roofs with small precast components, also refer good practice [6-4(8)] for floor/roof band details.

For earthquake resistant framed wall construction, (*see* **7.7**). No vertical steel need be provided in category A buildings.

7.6.8.1 The vertical reinforcement shall be properly embedded in the plinth masonry of foundations and roof slab or roof band so as to develop its tensile strength in bond. It shall be passing through the lintel bands and floor level bands in all storeys.

Bars in different storeys may be welded or suitably lapped.

NOTE – Typical details of providing vertical steel in brickwork masonry with rectangular solid units at corners and T-junctions are shown in Fig. 20.

7.6.9 Vertical reinforcement at jambs of window and door openings shall be provided as per Table 17. It may start from foundation of floor and terminate in lintel band (*see* Fig. 21).

7.7 Framing of Thin Load Bearing Walls (*see* Fig. 21)

Load bearing walls can be made thinner than 200 mm say 150 mm inclusive of plastering on both sides. Reinforced concrete framing columns and collar beams will be necessary to be constructed to have full bond with the walls. Columns are to be located at all corners and junctions of walls and spaced not more than 4.5 m apart but so located as to frame up the doors and windows. The horizontal bands or ring beams are located at all floors, roof as well as lintel levels of the openings. The sequence of construction between walls and columns will be first to build the wall up to 4 to 6 courses height leaving toothed gaps (tooth projection being about 40 mm only) for the columns and second to pour M15 (1:2:4) concrete to fill the columns against the walls using wood forms only on two sides. The column steel should be accurately held in position all along. The band concrete should be cast on the wall masonry directly so as to develop full bond with it.

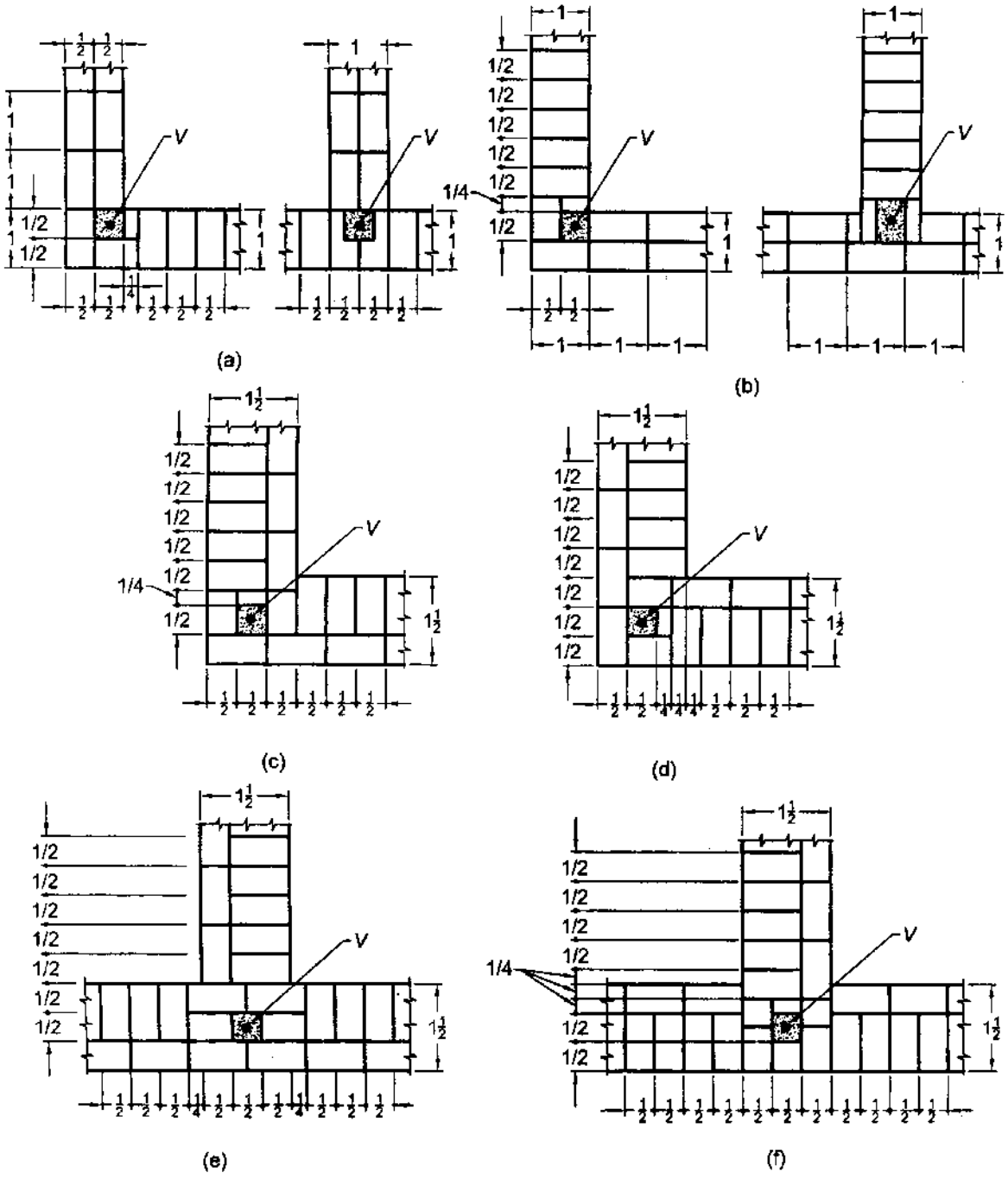
Such construction may be limited to only two storeys maximum in view of its vertical load carrying capacity. The horizontal length of walls between cross walls shall be restricted to 7 m and the storey height to 3 m.

7.8 Reinforcing Details for Hollow Block Masonry

The following details may be followed in placing the horizontal and vertical steel in hollow block masonry using cement-sand or cement-concrete blocks.

7.8.1 *Horizontal Band*

U-shaped blocks may be used for construction of horizontal bands in various levels of the storeys as shown in Fig. 22, where the amount of horizontal reinforcement shall be taken 25 percent more than that given in Table 16 and provided by using four bars and 6 mm dia stirrups. Other continuity details shall be followed, as shown in Fig. 19.



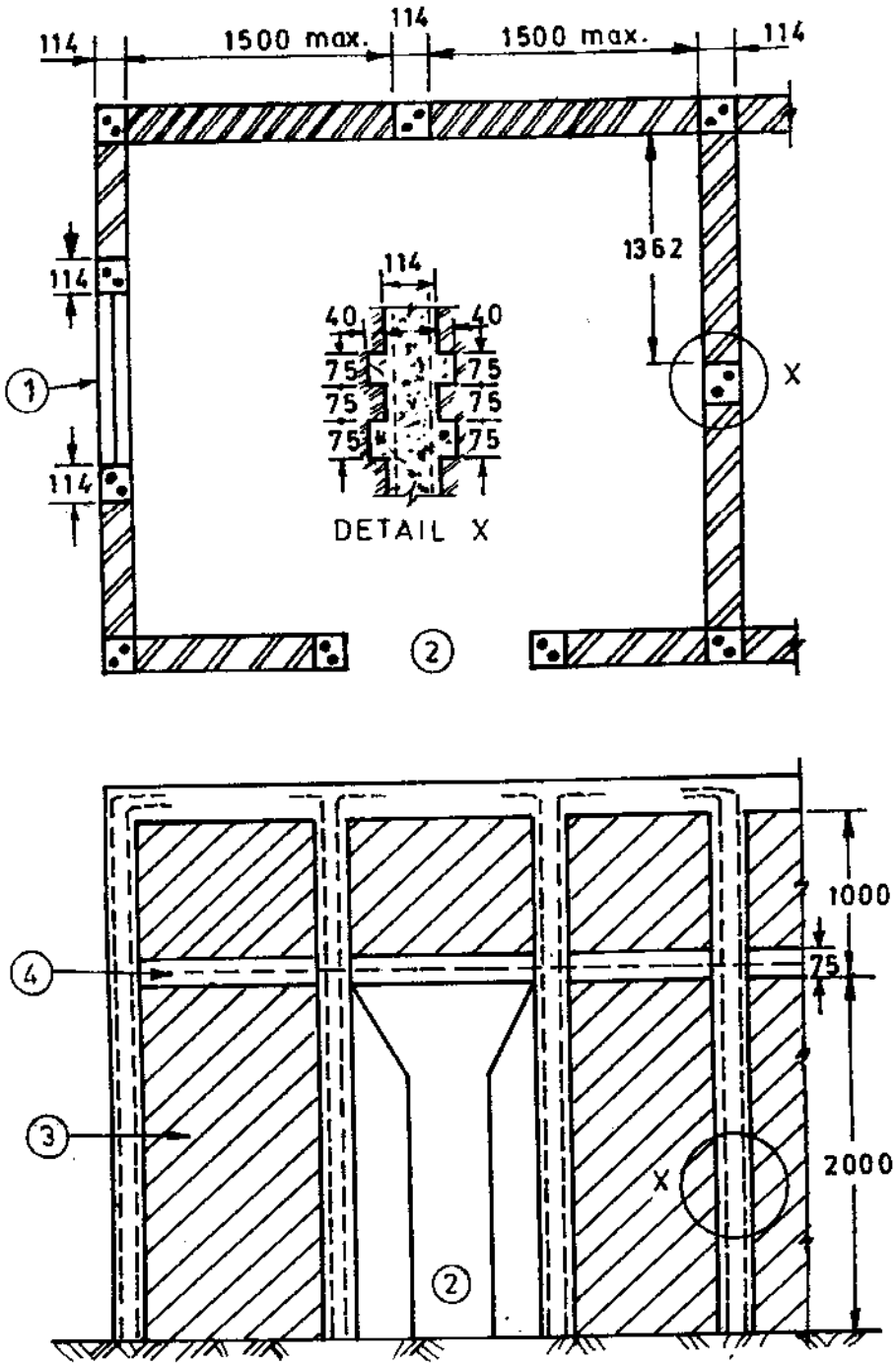
1 — One-brick length, ½ — Half brick length, *V* — Vertical steel bar with mortar/concrete filling in pocket

(a) and (b) — Alternate courses in one brick

(c) and (d) — Alternate courses at corner junction of 1½-brick wall

(e) and (f) — Alternate courses at T-junction of 1½-brick wall

FIG. 20 TYPICAL DETAILS OF PROVIDING VERTICAL STEEL BARS IN BRICK MASONRY



1. WINDOW
2. DOOR
3. BRICK PANEL
4. LINTEL BAND

All dimensions in millimetres.

FIG. 21 FRAMING OF THIN LOAD-BEARING BRICK WALLS

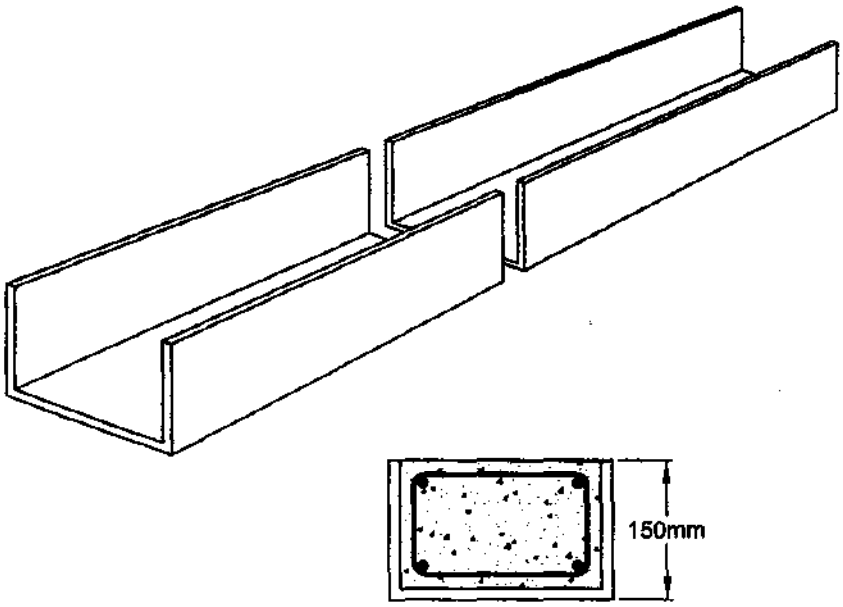


FIG. 22 U-BLOCKS FOR HORIZONTAL BANDS

7.8.2 *Vertical Reinforcement*

Bars, as specified in Table 17 shall be located inside the cavities of the hollow blocks, one bar in each cavity (*see* Fig. 23). Where more than one bar is planned these can be located in two or three consecutive cavities. The cavities containing bars are to be filled by using micro-concrete 1:2:3 or cement-coarse sand mortar 1:3, and properly rodded for compaction. The vertical bars should be spliced by welding or overlapping for developing full tensile strength. For proper bonding, the overlapped bars should be tied together by winding the binding wire over the lapped length. To reduce the number of overlaps, the blocks may be made U-shaped as shown in Fig. 23 which will avoid lifting and threading of bars into the hollows.

8 GUIDELINES FOR IMPROVING EARTHQUAKE RESISTANCE OF LOW STRENGTH MASONRY BUILDINGS

8.0 The term 'low strength masonry' includes fired brickwork laid in clay mud mortar and random rubble; uncoursed, undressed or semi-dressed stone masonry in weak mortars; such as cement sand, lime sand and clay mud. Special features of design and construction for improving earthquake resistance of buildings of low strength masonry are given in **8.1** to **8.4.7.** Reference may also be made to good practice [6-4(9)] for detailed information.

8.1 General

8.1.1 Two types of construction are included herein, namely:

a) Brick construction using weak mortar, and
b) Random rubble and half-dressed stone masonry construction using different mortars, such as, clay mud, lime-sand and cement sand.

8.1.2 These constructions should not be permitted for important buildings with $I \geq 1.5$ and should preferably be avoided for building category D and shall not be used for category E (*see* Table 12).

8.1.3 It will be useful to provide damp-proof course at plinth level to stop the rise of pore water into the superstructure.

8.1.4 Precautions should be taken to keep the rain water away from soaking into the wall so that the mortar is not softened due to wetness. An effective way is to take out roof projections beyond the walls by about 500 mm.

8.1.5 Use of a water-proof plaster on outside face of walls will enhance the life of the building and maintain its strength at the time of earthquake as well.

8.1.6 Ignoring tensile strength, free standing walls should be checked against overturning under the action of design seismic coefficient, a_h, allowing for a factor of safety of 1.5.

8.2 Brickwork in Weak Mortars

8.2.1 The fired bricks should have a compressive strength not less than 3.5 MPa. Strength of bricks and wall thickness should be selected for the total building height.

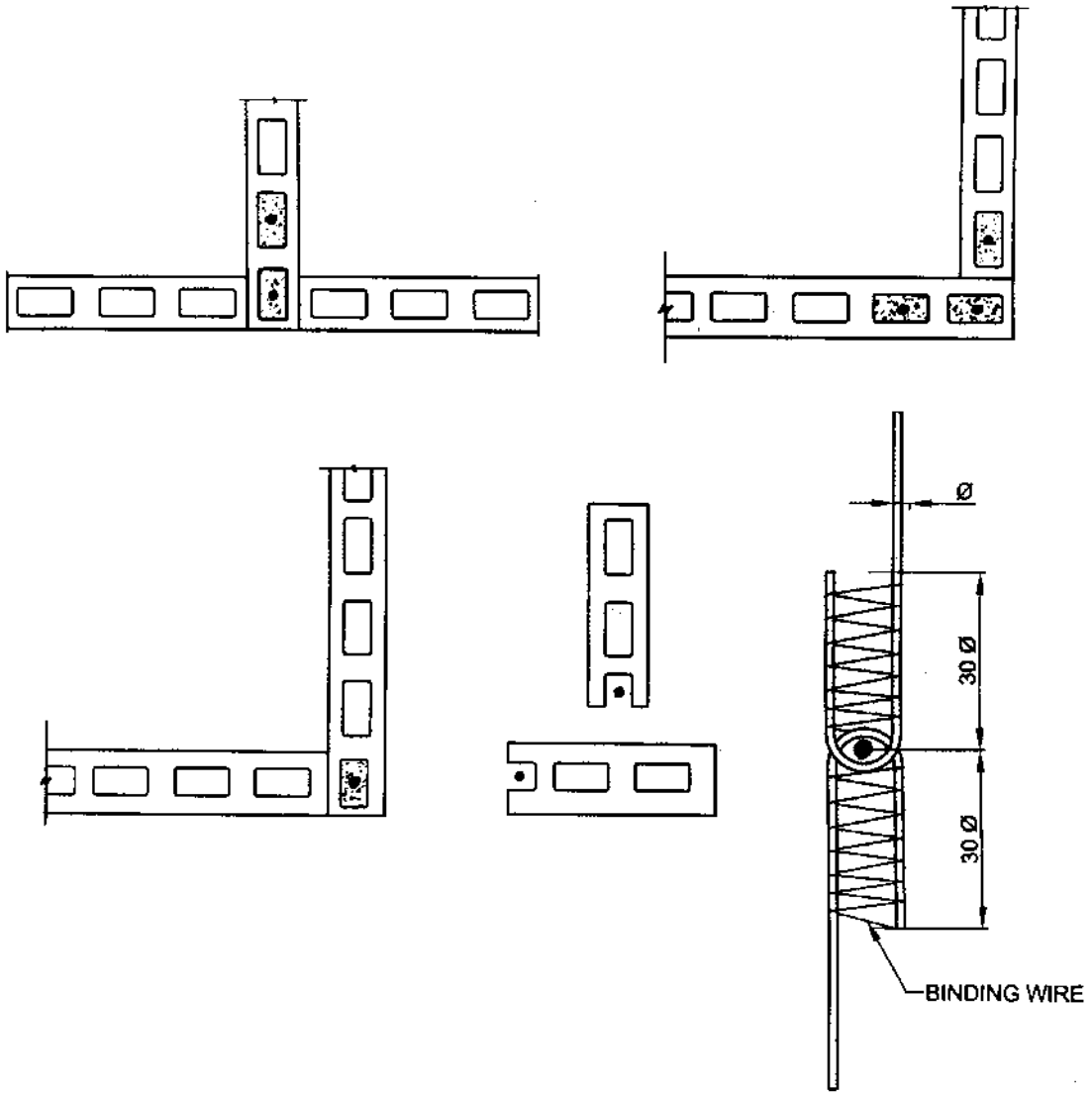


FIG. 23 VERTICAL REINFORCEMENT IN CAVITIES

8.2.2 The mortar should be lime-sand (1:3) or clay mud of good quality. Where horizontal steel is used between courses, cement-sand mortar (1:3) should be used with thickness so as to cover the steel with 6 mm mortar above and below it. Where vertical steel is used, the surrounding brickwork of 1 × 1 or 1½ × 1½ brick size depending on wall thickness should preferably be built using 1:6 cement-sand mortar.

8.2.3 The minimum wall thickness shall be one brick in one storey construction, and one brick in top storey and 1½ brick in bottom storeys of up to three storey construction. It should also not be less than 1/16 of the length of wall between two consecutive perpendicular walls.

8.2.4 The height of the building shall be restricted to the following, where each storey height shall not exceed 3.0 m:

a) *For Categories A, B and C* — three storeys with flat roof; and two storeys plus attic for pitched roof.

b) *For Category D* — two storeys with flat roof; and one storey plus attic for pitched roof.

8.2.5 *Special Bond in Brick Walls*

For achieving full strength of masonry, the usual bonds specified for masonry should be followed so that the vertical joints are broken properly from course to course. To obtain full bond between perpendicular walls, it is necessary to make a sloping (stepped) joint by making the corners first to a height of 600 mm and then building the wall in between them. Otherwise the toothed joint should be made in both the walls, alternatively in lifts of about 450 mm (*see* Fig. 14).

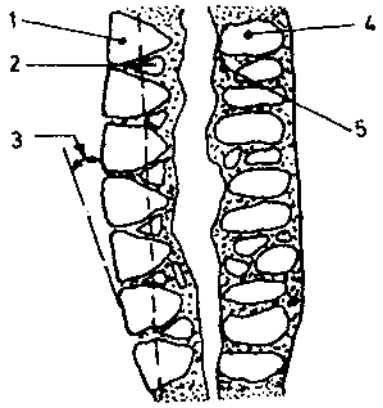
Dressed) ... and insect action.

8.3.1 The construction of stone masonry of random rubble or dressed stone type should generally follow good practice [6-4(3)].

8.3.2 The mortar should be cement-sand (1:6), lime sand (1:3) or clay mud of good quality.

8.3.3 The wall thickness '*t*' should not be larger than 450 mm. Preferably it should be about 350 mm, and the stones on the inner and outer wythes should be interlocked with each other.

NOTE — If the two wythes are not interlocked, they tend to delaminate during ground shaking bulge apart (*see* Fig. 24) and buckle separately under vertical load leading to complete collapse of the wall and the building.



1. Half-cressed conical stone
2. Small alignment stone
3. Rotation of wythe
4. Random rubble
5. Mud or weak lime mortar

FIG. 24 WALL DELAMINATED WITH BUCKLED WYTHES

8.3.4 The masonry should preferably be brought to courses at not more than 600 mm lift.

8.3.5 'Through' stones of full length equal to wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally. If full length stones are not available, stones in pairs each of about ¾ of the wall thickness may be used in place of one full length stone so as to provide an overlap between them (*see* Fig. 25).

8.3.6 In place of 'through' stones, 'bonding elements' of steel bars 8 mm to 10 mm diameter bent to S-shape or as hooked links may be used with a cover of 25 mm from each face of the wall (*see* Fig. 25). Alternatively, wood bars of 38 mm × 38 mm cross-section or concrete bars of 50 mm × 50 mm section with an 8 mm diameter rod placed centrally may be used in place of 'through' stones. The wood should be well treated with

8.3.7 Use of 'bonding' elements of adequate length should also be made at corners and junctions of walls to break the vertical joints and provide bonding between perpendicular walls.

8.3.8 Height of the stone masonry walls (random rubble or half-dressed) should be restricted as follows, with storey height to be kept 3.0 m maximum, and span of walls between cross walls to be limited to 5.0 m:

a) *For categories A and B* — Two storeys with flat roof or one storey plus attic, if walls are built in lime-sand or mud mortar; and one storey higher if walls are built in cement-sand 1:6 mortar.

b) *For categories C and D* — Two stroreys with flat roof or two storeys plus attic for pitched roof, if walls are built in 1:6 cement mortar; and one storey with flat roof or one storey plus attic, if walls are built in lime-sand or mud mortar, respectively.

8.3.9 If walls longer than 5 m are needed, buttresses may be used at intermediate points not farther apart than 4.0 m. The size of the buttress be kept of uniform thickness. Top width should be equal to the thickness of main wall, *t*, and the base width equal to one-sixth of wall height.

8.4 Opening in Bearing Walls

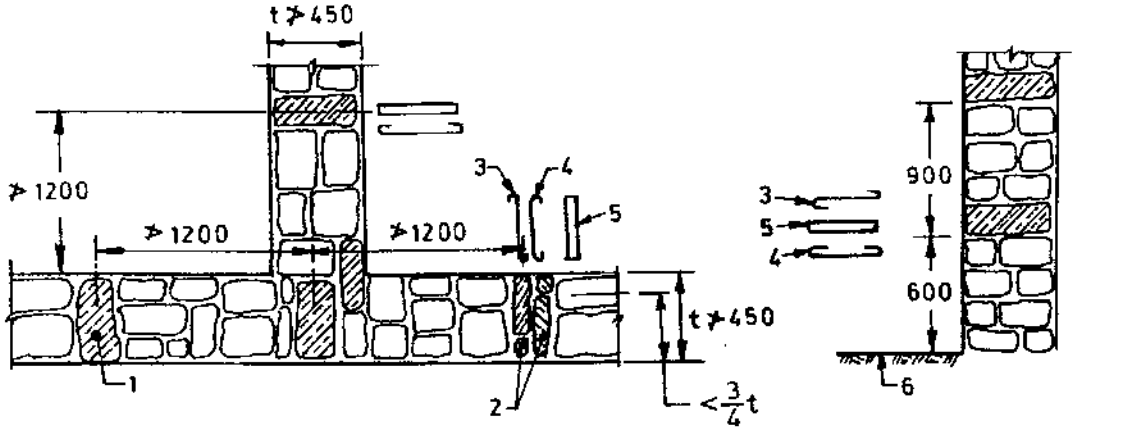
8.4.1 Door and window openings in walls reduce their lateral load resistance and hence should preferably, be small and more centrally located. The size and position of openings shall be as given in Table 18 and Fig. 15.

8.4.2 Openings in any storey shall preferably have their top at the same level so that a continuous band could be provided over them including the lintels throughout the building.

Table 18 Size and Position of Openings in Bearing Walls (*see* Fig. 15)

(*Clause* 8.4.1)

Sl No.	Description	Building Category	
		A, B & C	D
(1)	(2)	(3)	(4)
i)	Distance b_5 from the inside corner of outside wall, *Min*	230 mm	600 mm
ii)	Total length of openings, ratio; *Max*: $(b_1 + b_2 + b_3)/l_1$ or $(b_6 + b_7)/l_2$	0.46	0.42
	1) one storeyed building	0.37	0.33
	2) 2 and 3 storeyed building		
iii)	Pier width between consecutive openings b_4	450 mm	560 mm
iv)	Vertical distance between two openings one above the other, h_3, *Min*	600 mm	600 mm



25a SECTIONAL PLAN OF WALL

25b CROSS-SECTION OF WALL

1. Through stone
2. Pair of overlapping stone
3. S-Shape tie
4. Hooked tie
5. Wood plank
6. Floor level

All dimensions in millimetres.

FIG. 25 THROUGH STONE AND BAND ELEMENTS

8.4.3 Where openings do not comply with the guidelines of Table 18, they should be strengthened by providing reinforced concrete lining as shown in Fig. 16 with 2 high strength deformed steel bars of 8 mm diameter.

8.4.4 The use of arches to span over the openings is a source of weakness and shall be avoided, otherwise, steel ties should be provided.

8.5 Seismic Strengthening Arrangements

8.5.1 All buildings to be constructed of masonry shall be strengthened by the methods as specified for various categories of buildings, listed in Table 19 and detailed in subsequent clauses. Fig. 17 and Fig. 18 show, schematically, the overall strengthening arrangements to be adopted for category D buildings, which consist of horizontal bands of reinforcement at critical levels and vertical reinforcing bars at corners and junctions of walls.

8.5.2 Lintel band is a band provided at lintel level on all internal and external longitudinal as well as cross walls except partition walls. The details of the band are given in **8.5.5**.

8.5.3 Roof band is a band provided immediately below the roof or floors. The details of the band are given in **8.5.5**. Such a band need not be provided underneath reinforced concrete or reinforced brick slabs resting on bearing walls, provided that the slabs cover the width of end walls fully.

8.5.4 Gable band is a band provided at the top of gable

Table 19 Strengthening Arrangements Recommended for Low Strength Masonry Buildings

(*Clause* 8.5.1)

Building Category	Number of Storeys	Strengthening to be Provided
(1)	(2)	(3)
A	1	*b, c, f, g*
	2 and 3	*b, c, f, g*
B	1 and 2	*b, c, f, g*
	3	*b, c, d, f, g* (*see* Note 1)
C	1	*b, c, f, g*
	2 and 3	*b, c, d, f, g*
D	1 and 2	*b, c, d, f, g*

Strengthening Method

b – Lintel band (*see* **8.5.2**)

c – Roof band and gable band where necessary (*see* **8.5.3** *and* **8.5.4**)

d – Vertical steel at corners and junctions of walls (*see* **8.5.7**)

f – Bracing in plan at tie level of pitched roofs (*see* Note 2)

g – Plinth band where necessary (*see* **8.5.6**)

NOTES

1 For building of category B in two storeys constructed with stone masonry in weak mortar, it will be desirable to provide vertical steel of 10 mm dia in both storeys.

2 At tie level, all the trusses and the gable end should be provided with diagonal braces in plan so as to transmit the lateral shear due to earthquake force to the gable walls acting as shear walls.

masonry below the purlins. The details of the band are given in **8.5.5**. This band shall be made continuous with the roof band at the eaves level.

8.5.5 *Details of Band*

8.5.5.1 *Reinforced band*

The band should be made of reinforced concrete of grade not leaner than M15 or reinforced brickwork in cement mortar not leaner than 1:3. The bands should be of full width of the wall, not less than 75 mm in depth and should be reinforced with 2 high strength deformed steel bars of 8 mm diameter and held in position by 6 mm diameter bar links, installed at 150 mm apart as shown in Fig. 19.

NOTES

1 In coastal areas, the concrete grade shall be of grade in accordance with Part 6 'Structural Design, Section 5 Concrete' and the filling mortar of 1:3 ratio (cement-sand) with water proofing admixture.

2 In case of reinforced brickwork, the thickness of joints containing steel bars should be increased to 20 mm so as to have a minimum mortar cover of 6 mm around the bar. In bands of reinforced brickwork, the area of steel provided should be equal to that specified above for reinforced concrete bands.

3 For full integrity of walls at corners and junctions of walls and effective horizontal bending resistance of bands, continuity of reinforcement is essential. The details as shown in Fig. 19 are recommended.

8.5.5.2 *Wooden band*

As an alternative to reinforced band, the lintel band could be provided using wood beams in one or two parallel pieces with cross elements as shown in Fig. 26.

8.5.6 Plinth band is a band provided at plinth level of walls on top of the foundation wall. This is to be provided where strip footings of masonry (other than reinforced concrete or reinforced masonry) are used and the soil is either soft or uneven in its properties as frequently happens in hill tracts. Where used, its section may be kept same as in **8.5.5.1**. This band serves as damp proof course as well.

8.5.7 *Vertical Reinforcement*

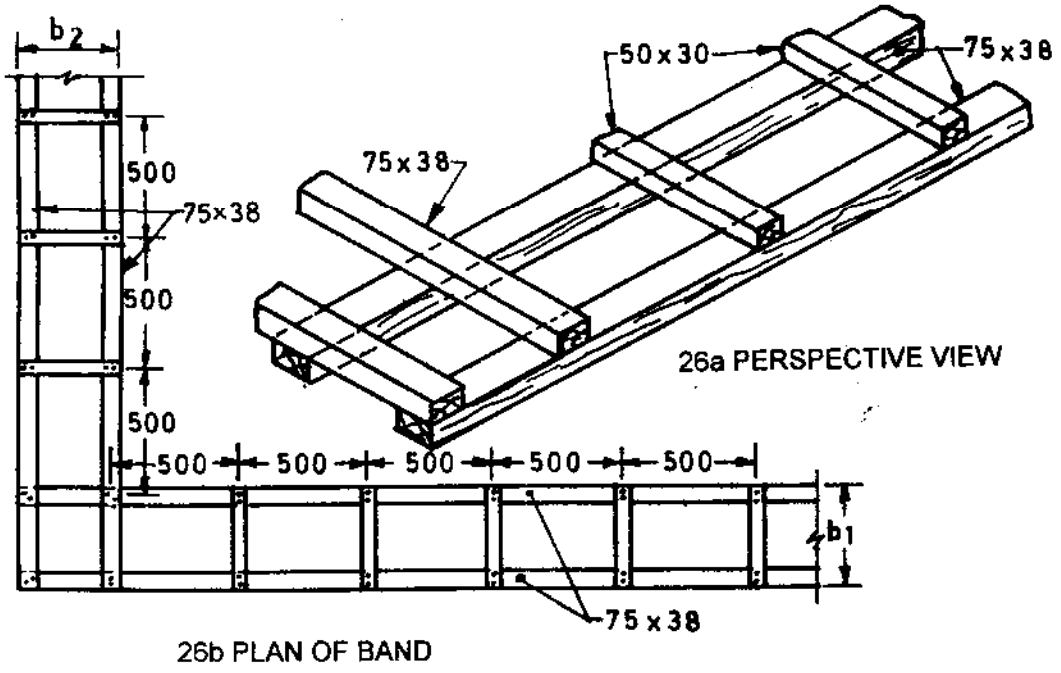
Vertical steel at corners and junctions of walls which are up to 350 mm thick should be provided as specified in Table 20. For walls thicker than 350 mm, the area of the bars should be proportionately increased.

8.5.7.1 The vertical reinforcement should be properly embedded in the plinth masonry of foundations and roof slab or roof band so as to develop its tensile strength in bond. It should pass through the lintel bands and floor slabs or floor level bands in all storeys. Bars in different storeys may be welded or suitably lapped.

NOTES

1 Typical details of providing vertical steel in brickwork at corners and T-junctions are shown in Fig. 20.

2 For providing vertical bar in stone masonry, use of a casing pipe is recommended around which masonry be built to height



All dimensions in millimetres.

FIG. 26 WOODEN BAND FOR LOW STRENGTH MASONRY BUILDINGS

Table 20 Vertical Steel Reinforcement in Low Strength Masonry Walls

(*Clause* 8.5.7)

No. of Storeys	Storey	Diameter of HSD Single Bar; in mm, at Each Critical Section for			
		Category A	Category B	Category C	Category D
(1)	(2)	(3)	(4)	(5)	(6)
One	—	Nil	Nil	Nil	10
Two	Top	Nil	Nil	10	10
	Bottom	Nil	Nil	10	12
Three	Top	Nil	10	10	10
	Middle	Nil	10	10	12
	Bottom	Nil	12	12	12

NOTES

1 The diameters given above are for High Strength Deformed bars with yield strength 415 MPa. For mild steel plain bars, use equivalent diameters.

2 The vertical bars should be covered with concrete of M15 grade or with mortar 1:3 (cement-sand) in suitably created pockets around the bars. This will ensure their safety from corrosion and good bond with masonry.

3 For category B two storey stone masonry buildings, *see* Note 1 under Table 19.

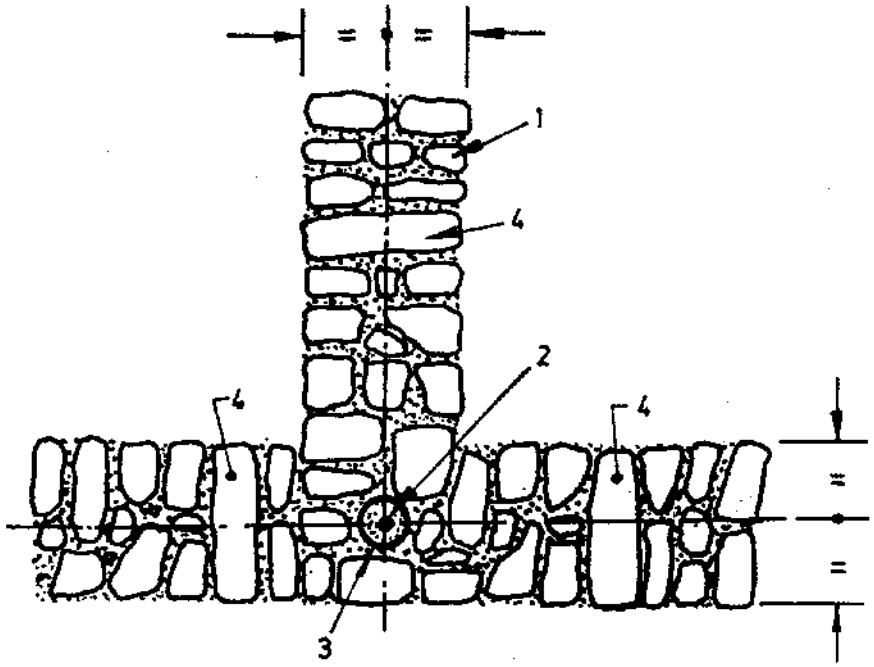
of 600 mm (see Fig. 27). The pipe is kept loose by rotating it during masonry construction. It is then raised and the cavity below is filled with M15 (or 1:2:4) grade of concrete mix and rodded to compact it.

9 REINFORCED BRICK AND REINFORCED BRICK CONCRETE FLOORS AND ROOFS

The construction and design of reinforced brick and reinforced brick concrete floors and roof shall be in accordance with good practices [6-4(10)].

10 NOTATIONS AND SYMBOLS

The various notations and letter symbols used in the text of this Section of the Code shall have the meaning as given in Annex E.



1. Stone wall
2. Vertical steel bar
3. Casing pipe
4. Through stone or bonding element

FIG. 27 TYPICAL CONSTRUCTION DETAIL FOR INSTALLING VERTICAL STEEL BAR IN RANDOM RUBBLE STONE MASONRY

ANNEX A

(*Clause* 4.7)

SOME GUIDELINES FOR ASSESSMENT OF ECCENTRICITY OF LOADING ON WALLS

A-1 Where a reinforced concrete roof and floor slab of normal span (not exceeding 30 times the thickness of wall) bear on external masonry walls, the point of application of the vertical loading shall be taken to be at the centre of the bearing on the wall. When the span is more than 30 times the thickness of wall, the point of application of the load shall be considered to be displaced from the centre of bearing towards the span of the floor to an extent of one-sixth the bearing width.

A-2 In case of a reinforced concrete slab of normal span (that is, less than 30 times the thickness of the wall), which does not bear on the full width of the wall and 'cover tiles or bricks' are provided on the external face, there is some eccentricity of load. The eccentricity may be assumed to be one-twelfth of the thickness of the wall.

A-3 Eccentricity of load from the roof/floor increases with the increase in flexibility and thus deflection of the slabs. Also, eccentricity of loading increases with the increase in fixity of slabs/beams at supports. Precast RCC slabs are better than *in-situ* slabs in this regard because of very little fixity. If supports are released before further construction on top, fixity is reduced.

A-4 Interior walls carrying continuous floors are assumed to be axially loaded except when carrying very flexible floor or roof systems. The assumption is valid also for interior walls carrying independent slabs spanning from both sides, provided the span of the floor on one side does not exceed that on the other by more than 15 percent. Where the difference is greater, the displacement of the point of application of each floor load shall be taken as one-sixth of its bearing width on the wall and the resultant eccentricity calculated therefrom.

A-5 For timber and other lightweight floors, even for full width bearing on wall, an eccentricity of about one-sixth may be assumed due to deflection. For timber floors with larger spans, that is, more than 30 times the thickness of the wall, eccentricity of one-third the thickness of the wall may be assumed.

A-6 In multi-storeyed buildings, fixity and eccentricity have normally purely local effect and are not cumulative. They just form a constant ripple on the downward increasing axial stress. If the ripple is large, it is likely to be more serious at upper levels where it can cause cracking of walls than lower down where it may or may not cause local over-stressing.

NOTE — The resultant eccentricity of the total loads on a wall at any level may be calculated on the assumption that immediately above a horizontal lateral support, the resultant eccentricity of all the vertical loads above that level is zero.

A-7 For a wall corbel to support some load, the point of application of the load shall be assumed to be at the centre of the bearing on the corbel.

ANNEX B

(*Clause* 5.4.1)

CALCULATION OF BASIC COMPRESSIVE STRESS OF MASONRY BY PRISM TEST

B-1 DETERMINATION OF COMPRESSIVE STRENGTH OF MASONRY BY PRISM TEST

When compressive strength of masonry (f'_m) is to be established by tests, it shall be done in advance of the construction, using prisms built of similar materials under the same conditions with the same bonding arrangement as for the structure. In building the prisms, moisture content of the units at the time of laying, the consistency of the mortar, the thickness of mortar joints and workmanship shall be the same as will be used in the structure. Assembled specimen shall be at least 400 mm high and shall have a height to thickness ratio (h/t) of at least 2 but not more than 5. If the h/t ratio of the prisms tested is less than 5 in case of brickwork and more than 2 in case of blockwork, compressive strength values indicated by the tests shall be corrected by multiplying with the factor indicated in Table 21.

(*Clause* B-1.1)

Ratio of Height to Thickness (h/t)	2.0	2.5	3.0	3.5	4.0	5.0
Correction Factors for Brickwork[1)]	0.73	0.80	0.86	0.91	0.95	1.00
Correction Factors for Blockwork[1)]	1.00	—	1.20	—	1.30	1.37

[1)] Interpolation is valid for intermediate values.

Prisms shall be tested after 28 days between sheets of nominal 4 mm plywood, slightly longer than the bed platform of which is spherically seated. The load shall be evenly distributed over the whole top and bottom surfaces of the specimen and shall be applied at the rate of 350 kN/m to 700 kN/m. The load at failure should be recorded.

B-2 CALCULATION OF BASIC COMPRESSIVE STRESS

Basic compressive stress of masonry shall be taken to be equal to $0.25 f'_m$ where f'_m is the value of compressive strength of masonry as obtained from prism test.

ANNEX C

(*Clauses* 5.3.3 *and* 5.4.1.5)

GUIDELINES FOR DESIGN OF MASONRY SUBJECTED TO CONCENTRATED LOADS

C-1 EXTENT OF DISPERSAL OF CONCENTRATED LOAD

For concentric loading, maximum spread of a concentrated load on a wall may be taken to be equal to $b+4t$ (b is width of bearing and t is thickness of wall), or stretch of wall supporting of load, or centre-to-centre distance between loads, whichever is less.

C-2 INCREASE IN PERMISSIBLE STRESS

C-2.1 When a concentrated load bears on a central strip of wall, not wider than half the thickness of the wall and is concentric, bearing stress in masonry may exceed the permissible compressive stress by 50 percent, provided the area of supporting wall is not less than three times the bearing area.

C-2.2 If the load bears on full thickness of wall and is concentric, 25 percent increase in stress may be allowed.

C-2.3 For loading on central strip wider than half the thickness of the wall but less than full thickness, increase in stress may be worked out by interpolation between values of increase in stresses as given in **C-2.1** and **C-2.2**.

C-2.4 In case concentrated load is from a lintel over an opening, an increase of 50 percent in permissible stress may be taken, provided the supporting area is not less than 3 times the bearing area.

C-3 CRITERIA OF PROVIDING BED BLOCK

C-3.1 If a concentrated load bears on one end of a wall, there is a possibility of masonry in the upper region developing tension. In such a situation, the load should be supported on an RCC bed block (of M15 Grade) capable of taking tension.

C-3.2 When any section of masonry wall is subjected to concentrated as well as uniformly distributed load and resultant stress, computed by making due allowance for increase in stress on account of concentrated load, exceeds the permissible stress in masonry, a concrete bed block (of M15 Grade) should be provided under the load in order to relieve stress in masonry. In concrete, angle of dispersion of concentrated load is taken to be 45° to the vertical.

C-3.3 In case of cantilevers and long span beams supported on masonry walls, indeterminate but very high edge stresses occur at the supports and in such cases it is necessary to relieve stress on masonry by providing concrete bed block of M15 Grade concrete. Similarly when a wall is subjected to a concentrated load from a beam which is not sensibly rigid (for example, a timber beam or an RS joist), a concrete bed block should be provided below the beam in order to avoid high edge stress in the wall because of excessive deflection of the beam.

GUIDELINES FOR APPROXIMATE DESIGN OF NON-LOAD BEARING WALL

D-1 PANEL WALLS

A panel wall may be designed approximately as under, depending upon its support conditions and certain assumptions:

a) When there are narrow tall windows on either side of panel, the panel spans in the vertical direction. Such a panel may be designed for a bending moment of $PH/8$, where P is the total horizontal load on the panel and H is the height between the centres of supports. Panel wall is assumed to be simply supported in the vertical direction.

b) When there are long horizontal windows between top support and the panel, the top edge of the panel is free. In this case, the panel should be considered to be supported on sides and at the bottom, and the bending moment would depend upon height to length ratio of panel and flexural strength of masonry. Approximate values of bending moments in the horizontal direction for this support condition, when ratio (μ) of flexural strength of wall in the vertical direction to that in horizontal direction is assumed to be 0.5, are given in Table 22.

Table 22 Bending Moments in Laterally Loaded Panel Walls, Free at Top Edge and Supported on Other Three Edges

Height of Panel, H / Length of Panel, L	0.30	0.50	0.75	1.00	1.25	1.50	1.75
Bending Moment	$\frac{P.L}{25}$	$\frac{P.L}{18}$	$\frac{P.L}{14}$	$\frac{P.L}{12}$	$\frac{P.L}{11}$	$\frac{P.L}{10.5}$	$\frac{P.L}{10}$

NOTE — For H/L ratio less than 0.30, the panel should be designed as a free-standing wall and for H/L ratio exceeding 1.75, it should be designed as a horizontally spanning member for a bending moment value of $PL/8$.

c) When either there are no window openings or windows are of 'hole-in-wall' type, the panel is considered to be simply supported on all four edges. In this case also, amount of maximum bending moment depends on height to length ratio of panel and ratio (μ) of flexural strength of masonry in vertical direction to that in the horizontal direction. Approximate values for maximum bending moment in the horizontal direction for masonry with $\mu = 0.50$, are given in Table 23.

Table 23 Bending Moments in Laterally Loaded Panel Walls Supported on All Four Edges

Height of Panel, H / Length of Panel, L	0.30	0.50	0.75	1.00	1.25	1.50	1.75
Bending Moment	$\frac{P.L}{72}$	$\frac{P.L}{36}$	$\frac{P.L}{24}$	$\frac{P.L}{18}$	$\frac{P.L}{15}$	$\frac{P.L}{13}$	$\frac{P.L}{12}$

NOTE — When H/L is less than 0.30, value of bending moment in the horizontal direction may be taken as nil and panel wall may be designed for a bending moment value of $PH/8$ in the vertical direction; when H/L exceeds 1.75, panel may be assumed to be spanning in the horizontal direction and designed for bending moment of $PL/8$.

D-2 CURTAIN WALLS

Curtain walls may be designed as panel walls taking into consideration the actual supporting conditions.

D-3 PARTITION WALLS

D-3.1 These are internal walls usually subjected to much smaller lateral forces. Behaviour of such wall is similar to that of panel wall and these could, therefore, be designed on similar lines. However, in view of smaller lateral loads, ordinarily these could be apportioned empirically as follows:

a) Walls with adequate lateral restraint at both ends but not at the top:
   1) The panel may be of any height, provided the length does not exceed 40 times the thickness; or
   2) The panel may be of any length, provided the height does not exceed 15 times the thickness (that is, it may be considered as a free-standing wall); or
   3) Where the length of the panel is over 40 times and less than 60 times the thickness, the height plus twice the length may not exceed 135 times the thickness;

b) Walls with adequate lateral restraint at both ends at the top:
   1) The panel may be of any height, provided the length does not exceed 40 times the thickness; or
   2) The panel may be of any length, provided the height does not exceed 30 times the thickness; or
   3) Where the length of the panel is over

40 times and less than 110 times the thickness, the length plus three times the height should not exceed 200 times the thickness; and

c) When walls have adequate lateral resistant at the top but not at the ends, the panel may be of any length, provided the height does not exceed 30 times the thickness.

D-3.2 Strength of bricks used in partition walls should not be less than 3.5 N/mm^2 or the strength of masonry units used in adjoining masonry, whichever is less. Grade of mortar should not be leaner than M2.

ANNEX E

(Clause 10)

NOTATIONS, SYMBOLS AND ABBREVIATIONS

E-1 The following notations, letter symbols and abbreviations shall have the meaning indicated against each, unless otherwise specified in the text of this Section of the Code:

A = Area of a section
b = Width of bearing
DPC = Damp proof course
e = Resultant eccentricity
f_b = Basic compressive stress
f_c = Permissible compressive stress
f_d = Compressive stress due to dead loads
f_s = Permissible shear stress
f_m = Compressive strength of masonry (in prism test)
GL = Ground level
H = Actual height between lateral supports
H' = Height of opening
$H1, H2$ = High strength mortars
h = Effective height between lateral supports
k_a = Area factor
k_p = Shape modification factor
k_s = Stress reduction factor
L = Actual length of wall
$L1, L2$ = Lower strength mortars
$M1, M2$ = Medium strength mortars
P = Total horizontal load
PL = Plinth level
RCC = Reinforced cement concrete
RS = Rolled steel
S_p = Spacing of piers/buttresses/cross walls
SR = Slenderness ratio
t = Actual thickness
t_p = Thickness of pier
t_w = Thickness of wall
W = Resultant load
W_1 = Axial load
W_2 = Eccentric load
w_p = Width of piers/buttresses/cross walls
μ = Ratio of flexural strength of wall in the vertical direction to that in the horizontal direction.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	1077 : 1992	Specification for common burnt clay building bricks (*fifth revision*)
	2180 : 1988	Specification for heavy duty burnt clay building bricks (*third revision*)
	2185	Specification for concrete masonry units:
	(Part 1) : 1979	Hollow and solid concrete blocks (*second revision*)

IS No.	*Title*
(Part 2) : 1983	Hollow and solid light weight concrete blocks (*first revision*)
(Part 3) : 1984	Autoclaved cellular aerated concrete blocks (*first revision*)
2222 : 1991	Specification for burnt clay perforated building bricks (*fourth revision*)
2849 : 1983	Specification for non-load bearing gypsum partition blocks (solid and hollow types) (*first revision*)
3115 : 1992	Specification for lime based blocks (*second revision*)
3316 : 1974	Specification for structural granite (*first revision*)
3620 : 1979	Specification for laterite stone block for masonry (*first revision*)
3952 : 1988	Specification for burnt clay hollow blocks for walls and partitions (*second revision*)
4139 : 1989	Specification for calcium silicate bricks (*second revision*)
12440 : 1988	Specification for precast concrete stone masonry blocks
12894 : 2002	Specification for pulverized fuel ash lime bricks (*first revision*)
13757 : 1993	Specification for burnt clay fly ash building bricks
(2) 2250 : 1981	Code of practice for preparation and use of masonry mortars (*first revision*)
(3) 1597	Code of practice for construction of stone masonry:
(Part 1) : 1992	Rubble stone masonry (*first revision*)
(Part 2) : 1992	Ashlar masonry (*first revision*)
2110 : 1980	Code of practice for *in-situ* construction of walls, in building with soil-cement (*first revision*)
2212 : 1991	Code of practice for brickwork (*first revision*)
2572 : 1963	Code of practice for construction of hollow concrete block masonry
2849 : 1983	Specification for non-load bearing gypsum partition blocks (solid and hollow types) (*first revision*)
3630 : 1992	Code of practice for construction of non-load bearing gypsum block partitions (*first revision*)
4326 : 1993	Code of practice for earthquake resistant design and construction of buildings (*second revision*)
6041 : 1985	Code of practice for construction of autoclaved cellular concrete block masonry (*first revision*)
6042 : 1969	Code of practice for construction of lightweight concrete block masonry
(4) 2212 : 1991	Code of practice for brickwork (*first revision*)
(5) 3414 : 1968	Code of practice for design and installation of joints in buildings
(6) 4326 : 1993	Code of practice for earthquake resistant design and construction of buildings (*second revision*)
(7) 1905 : 1987	Code of practice for structural use of un-reinforced masonry (*third revision*)
(8) 1893 (Part 1) : 2002	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*fifth revision*)
(9) 13828 : 1993	Guidelines for improving earthquake resistance of low strength masonry buildings
(10) 10440 : 1983	Code of practice for construction of RB and RBC floors and roofs

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 5 Concrete: 5A Plain and Reinforced Concrete

BUREAU OF INDIAN STANDARDS

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FOREWORD

Section 5 of Part 6 of the Code covers plain and reinforced concrete as also the prestressed concrete. The Section has been subdivided into the following sub-sections:

5 A Plain and Reinforced Concrete

5 B Prestressed Concrete

This sub-section 5A covers the structural design aspects of plain and reinforced concrete.

This sub-section 5A was first published in 1970 and was subsequently revised in 1983, to bring it in line with revised version of IS 456 : 1978 on which this chapter was based. Now this revision is intended to bring this subsection in line with the revised version of IS 456 : 2000.

This revision incorporates a number of important changes. The major thrust in the revision is on the following lines:

a) In recent years, durability of concrete structures have become the cause of concern to all concrete technologists. This has led to codify the durability requirements world over. In this revision of the Code, in order to introduce in-built protection from factors affecting a structure, earlier clause on durability has been elaborated and a detailed clause covering different aspects of design of durable structure has been incorporated.

b) Sampling and acceptance criteria for concrete have been revised. With this revision acceptance criteria has been simplified in line with the provisions given in BS 5328 (Part 4) : 1990 'Concrete: Part 4 Specification for the procedures to be used in sampling, testing and assessing compliance of concrete'.

Some of the significant changes incorporated in Section 5A (b) are as follows:

a) All the three grades of ordinary Portland cement, namely 33 grade, 43 grade and 53 grade and sulphate resisting Portland cement have been included in the list of types of cement used (in addition to other types of cement).

b) The permissible limits for solids in water have been modified keeping in view the durability requirements.

c) The clause on admixtures has been modified in view of the availability of new types of admixtures including superplasticizers.

d) In Table 2 'Grades of Concrete', grades higher than M 40 have been included.

e) It has been recommended that minimum grade of concrete shall be not less than M 20 in reinforced concrete work (*see also* **5.1.3**).

f) The formula for estimation of modulus of elasticity of concrete has been revised.

g) In the absence of proper correlation between compacting factor, vee-bee time and slump, workability has now been specified only in terms of slump in line with the provisions in BS 5328 (Parts 1 to 4).

h) Durability clause has been enlarged to include detailed guidance concerning the factors affecting durability. The table on 'Environmental Exposure Conditions' has been modified to include 'very severe' and 'extreme' exposure conditions. This clause also covers requirements for shape and size of member, depth of concrete cover, concrete quality, requirement against exposure to aggressive chemical and sulphate attack, minimum cement requirement and maximum water cement ratio, limits of chloride content, alkali silica reaction, and importance of compaction, finishing and curing.

j) A clause on 'Quality Assurance Measures' has been incorporated to give due emphasis to good practices of concreting.

k) Proper limits have been introduced on the accuracy of measuring equipments to ensure accurate batching of concrete.

m) The clause on 'Construction Joints' has been modified.

n) The clause on 'Inspection' has been modified to give more emphasis on quality assurance.

The significant changes incorporated in Section 5A (c) are as follows:

a) Requirements for 'Fire Resistance' have been further detailed.
b) The figure for estimation of modification factor for tension reinforcement used in calculation of basic values of span to effective depth to control the deflection of flexural member has been modified.
c) Recommendations regarding effective length of cantilever have been added.
d) Recommendations regarding deflection due to lateral loads have been added.
e) Recommendations for adjustments of support moments in restrained slabs have been included.
f) In the determination of effective length of compression members, stability index has been introduced to determine sway or no sway conditions.
g) Recommendations have been made for lap length of hooks for bars in direct tension and flexural tension.
h) Recommendations regarding strength of welds have been modified.
j) Recommendations regarding cover to reinforcement have been modified. Cover has been specified based on durability requirements for different exposure conditions. The term 'nominal cover' has been introduced. The cover has now been specified based on durability requirement as well as for fire requirements.

The significant change incorporated in Section 5A (d) is the modification of the clause on Walls. The modified clause includes design of walls against horizontal shear.

In Section 5 on limit state method a new clause has been added for calculation of enhanced shear strength of sections close to supports. Some modifications have also been made in the clause on Torsion. Formula for calculation of crack width has been added (separately given in Annex F).

Working stress method has now been given in Annex B so as to give greater emphasis to limit state design. In this Annex, modifications regarding torsion and enhanced shear strength on the same lines as in Section 5 have been made.

Whilst the common methods of design and construction have been covered in this Code, special systems of design and construction of any plain or reinforced concrete structure not covered by this Code may be permitted on production of satisfactory evidence regarding their adequacy and safety by analysis or test or both (*see* **18**).

In this Code it has been assumed that the design of plain and reinforced cement concrete work is entrusted to a qualified engineer and that the execution of cement concrete work is carried out under the direction of a qualified and experience supervisor.

This Section also introduces self-compacting concrete (*see* Annex A).

In the formulation of this subsection, assistance has been derived from the following publications:

BS 5328 (Part 1) : 1991 Concrete: Part 1 Guide to specifying concrete, British Standards Institution

BS 5328 (Part 2) : 1991 Concrete: Part 2 Methods for specifying concrete mixes, British Standards Institution

BS 5328 (Part 3) : 1990 Concrete: Part 3 Specification for the procedures to be used in producing and transporting concrete, British Standards Institution

BS 5328 (Part 4) : 1990 Concrete: Part 4 Specification for the procedures to be used in sampling, testing and assessing compliance of concrete, British Standards Institution

BS 8110 (Part 1) : 1985 Structural use of concrete: Part 1 Code of practice for design and construction, British Standards Institution

BS 8110 (Part 2) : 1985 Structural use of concrete: Part 2 Code of practice for special circumstances, British Standards Institution

ACI 318 : 1995 Building code requirements for reinforced concrete, American Concrete Institute

AS 3600 : 1988 Concrete structures, Standards Association of Australia

DIN 1045 July 1988 Structural use of concrete, design and construction, Deutsches Institut für Normung E.V.

CEB-FIP Model Code 1990, Comite Euro International Du Belon

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

SECTION 5A (a) GENERAL

1 SCOPE

1.1 This Section deals with the general structural use of plain and reinforced concrete.

1.1.1 For the purpose of this Section, plain concrete structures are those where reinforcement, if provided is ignored for determination of strength of the structure.

1.2 Design of special requirements of structures, such as shells, folded plates, arches, bridges, chimneys, blast resistant structures, hydraulic structures, liquid retaining structures and earthquake resistant structures, shall be done in accordance with good practice [6-5A(1)].

2 TERMINOLOGY

For the purpose of this Section, the definitions given in accepted standards [6-5A(2)].

3 SYMBOLS

For the purpose of this standard, the following letter symbols shall have the meaning indicated against each; where other symbols are used, they are explained at the appropriate place:

- A – Area
- b – Breadth of beam, or shorter dimension of a rectangular column
- b_{ef} – Effective width of slab
- b_f – Effective width of flange
- b_w – Breadth of web or rib
- D – Overall depth of beam or slab or diameter of column; dimension of a rectangular column in the direction under consideration
- D_f – Thickness of flange
- DL – Dead load
- d – Effective depth of beam or slab
- d' – Depth of compression reinforcement from the highly compressed face
- E_c – Modulus of elasticity of concrete
- EL – Earthquake load
- E_s – Modulus of elasticity of steel
- e – Eccentricity
- f_{ck} – Characteristic cube compressive strength of concrete
- f_{cr} – Modulus of rupture of concrete (flexural tensile strength)
- f_{ct} – Splitting tensile strength of concrete
- f_d – Design strength
- f_y – Characteristic strength of steel
- H_w – Unsupported height of wall
- H_{we} – Effective height of wall
- I_{ef} – Effective moment of inertia
- I_{gr} – Moment of inertia of the gross section excluding reinforcement
- I_r – Moment of intertia of cracked section
- K – Stiffness of member
- k – Constant or coefficient or factor
- L_d – Development length
- LL – Live load or imposed load
- l – Length of a column or beam between adequate lateral restraints or the unsupported length of a column
- l_{ef} – Effective span of beam or slab or effective length of column
- l_{ex} – Effective length about x-x axis
- l_{ey} – Effective length about y-y axis
- l_n – Clear span, face-to-face of supports
- l'_{ef} – l'_{ef} for shorter of the two spans at right angles
- l_x – Length of shorter side of slab
- l_y – Length of longer side of slab
- l_0 – Distance between points of zero moments in a beam
- l_1 – Span in the direction in which moments are determined, centre-to-centre of supports
- l_2 – Span transverse to l_1, centre-to-centre of supports
- l'_2 – l_2 for the shorter of the continuous spans
- M – Bending moment
- m – Modular ratio
- n – Number of samples
- P – Axial load on a compression member
- q_u – Calculated maximum bearing pressure
- q_0 – Calculated maximum bearing pressure of soil
- r – Radius
- s – Spacing of stirrups or standard deviation
- T – Torsional moment
- t – Wall thickness
- V – Shear force

W – Total load

WL – Wind load

w – Distributed load per unit area

w_d – Distributed dead load per unit area

w_i – Distributed imposed load per unit area

x – Depth of neutral axis

Z – Modulus of section

z – Lever arm

α, β – Angle or ratio

γ_f – Partial safety factor for load

γ_m – Partial safety factor for material

δ_m – Percentage reduction in moment

ϵ_{cc} – Creep strain of concrete

σ_{cbc} – Permissible stress in concrete in bending compression

σ_{cc} – Permissible stress in concrete in direct compression

σ_{mc} – Permissible stress in metal in direct compression

σ_{sc} – Permissible stress in steel in compression

σ_{st} – Permissible stress in steel in tension

σ_{sv} – Permissible stress in shear reinforcement

τ_{bd} – Design bond stress

τ_c – Shear stress in concrete

$\tau_{c,max}$ – Maximum shear stress in concrete with shear reinforcement

τ_v – Nominal shear stress

ϕ – Diameter of bar

SECTION 5A (b)
MATERIALS, WORKMANSHIP, INSPECTION AND TESTING

4 MATERIALS

4.1 Cement

The cement used shall be any of the following conforming to accepted standards [6-5A(3)] and the type selected should be appropriate for the intended use:

a) 33 grade ordinary Portland cement
b) 43 grade ordinary Portland cement
c) 53 grade ordinary Portland cement
d) Rapid hardening Portland cement
e) Portland slag cement
f) Portland pozzolana cement (fly ash based)
g) Portland pozzolana cement (calcined clay based)
h) Hydrophobic cement
j) Low heat Portland cement
k) Sulphate resisting Portland cement

Other combinations of Portland cement with mineral admixture (*see* **4.2**) of quality conforming with relevant Indian Standards laid down may also be used in the manufacture of concrete provided that there are satisfactory data on their suitability, such as performance test on concrete containing them.

4.1.1 Low heat Portland cement conforming to accepted standards [6-5A(3)] shall be used with adequate precautions with regard to removal of formwork, etc.

4.1.2 High alumina cement or supersulphated cement conforming to accepted standards [6-5A(4)] may be used only under special circumstances with the prior approval of the engineer-in-charge. Specialist literature may be consulted for guidance regarding the use of these types of cements.

4.1.3 The attention of the engineer-in-charge and users of cement is drawn to the fact that quality of various cements mentioned in **4.1** is to be determined on the basis of its conformity to the performance characteristics given in the respective Indian Standard Specification for that cement. Any trade-mark or any trade name indicating any special features not covered in the standard or any qualification or other special performance characteristics sometimes claimed/ indicated on the bags or containers or in advertisements alongside the 'Statutory Quality Marking' or otherwise have no relation whatsoever with the characteristics guaranteed by the Quality Marking as relevant to that cement. Consumers are, therefore, advised to go by the characteristics as given in the corresponding Indian Standard Specification or seek specialist advise to avoid any problem in concrete making and construction.

4.2 Mineral Admixtures

4.2.1 *Pozzolanas*

Pozzolanic materials conforming to relevant Indian Standards may be used with the permission of the engineer-in-charge, provided uniform blending with cement is ensured.

4.2.1.1 *Fly ash (pulverized fuel ash)*

Fly ash conforming to Grade I of accepted standards [6-5A(5)] may be used as part replacement of ordinary Portland cement provided uniform blending with cement is ensured.

4.2.1.2 *Silica fume*

Silica fume conforming to a standard approved by the deciding authority may be used as part replacement of

cement provided uniform blending with the cement is ensured.

NOTE — The silica fume (very fine non-crystalline silicon dioxide) is a by-product of the manufacture of silicon, ferrosilicon or the like, from quartz and carbon in electric are furnace. It is usually used in proportion of 5 to 10 percent of the cement content of a mix.

4.2.1.3 *Rice husk ash*

Rice husk ash giving required performance and uniformity characteristics may be used with the approval of the deciding authority.

NOTE — Rice husk ash is produced by burning rice husk and contain large proportion of silica. To achieve amorphous state, rice husk may be burnt at controlled temperature. It is necessary to evaluate the product from a particular source for performance and uniformity since it can be as deleterious as silt when incorporated in concrete. Water demand and drying shrinkage should be studied before using rice husk.

4.2.1.4 *Metakaoline*

Metakaoline having fineness between 700 to 900 m^2/kg may be used as pozzolanic material in concrete.

NOTE Metakaoline is obtained by clacination of pure or refined kaolintic clay at a temperature between 650°C and 850°C, followed by grinding to achieve a fineness of 700 to 900 m^2/kg. The resulting material has high pozzolanicity.

4.2.2 *Ground Granulated Blast Furnace Slag*

Ground granulated blast furnace slag obtained by grinding granulated blast furnace slag conforming to accepted standards [6-5A(6)] may be used as part replacement of ordinary Portland cements provided uniform blending with cement is ensured.

4.3 Aggregates

Aggregates shall comply with the requirements of accepted standards [6-5A(7)]. As far as possible preference shall be given to natural aggregates.

4.3.1 Other types of aggregates such as slag and crushed overburnt brick or tile, which may be found suitable with regard to strength, durability of concrete and freedom from harmful effects may be used for plain concrete members, but such aggregates should not contain more than 0.5 percent of sulphates as SO_3 and should not absorb more than 10 percent of their own mass of water.

4.3.2 Heavy weight aggregates or light weight aggregates such as bloated clay aggregates and sintered fly ash aggregates may also be used provided the engineer-in-charge is satisfied with the data on the properties of concrete made with them.

NOTE — Some of the provisions of the Code would require modification when these aggregates are used; specialist literature may be consulted for guidance.

4.3.3 *Size of Aggregate*

The nominal maximum size of coarse aggregate should be as large as possible within the limits specified but in no case greater than one-fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. For most work, 20 mm aggregate is suitable. Where there is no restriction to the flow of concrete into sections, 40 mm or larger size may be permitted. In concrete elements with thin sections, closely spaced reinforcement or small cover, consideration should be given to the use of 10 mm nominal maximum size.

Plums above 160 mm and up to any reasonable size may be used in plain concrete work up to a maximum limit of 20 percent by volume of concrete when specifically permitted by the engineer-in-charge. The plums shall be distributed evenly and shall be not closer than 150 mm from the surface.

4.3.3.1 For heavily reinforced concrete members as in the case of ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to the reinforcement whichever is smaller.

4.3.4 Coarse and fine aggregate shall be batched separately. All-in-aggregate may be used only where specifically permitted by the engineer-in-charge.

4.4 Water

Water use for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

Potable water is generally considered satisfactory for mixing concrete. As a guide the following concentrations represent the maximum permissible values:

a) To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml of 0.02 normal NaOH. The details of test are given in **7.1** of good practice [6-5A(8)].

b) To neutralize 100 ml sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal H_2SO_4. The details of test shall be as given in **7** of good practice [6-5A(8)].

c) Permissible limits for solids shall be as given in Table 1.

Table 1 Permissible Limit for Solids

(*Clause* 4.4)

Sl No.		Tested as per	Permissible Limit, *Max*
(1)	(2)	(3)	(4)
i)	Organic	Good practice [6-5A(8)]	200 mg/l
ii)	Inorganic	Good practice [6-5A(8)]	3 000 mg/l
iii)	Sulphates (as SO_3)	Good practice [6-5A(8)]	400 mg/l
iv)	Chlorides (as Cl)	Good practice [6-5A(8)]	2 000 mg/l for concrete not containing embedded steel and 500 mg/l for reinforced concrete work
v)	Suspended matter	Good practice [6-5A(8)]	2 000 mg/l

4.4.1 In case of doubt regarding development of strength, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time tests specified in **4.4.1.2** and **4.4.1.3**.

4.4.1.1 The sample of water taken for testing shall represent the water proposed to be used for concreting, due account being paid to seasonal variation. The sample shall not receive any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previously rinsed out with similar water.

4.4.1.2 Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90 percent of the average of strength of three similar concrete cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with good practice [6-5A(9)].

4.4.1.3 The initial setting time of test block made with the appropriate cement and the water proposed to be used shall not be less than 30 min and shall not differ by ± 30 min from the initial setting time of control test block prepared with the same cement and distilled water. The test blocks shall be prepared and tested in accordance with the good practice [6-5A(10)].

4.4.2 The *p*H value of water shall be not less than 6.

4.4.3 *Sea Water*

Mixing or curing of concrete with sea water is not recommended because of presence of harmful salts in sea water. Under unavoidable circumstances sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement system.

4.4.4 Water found satisfactory for mixing is also suitable for curing concrete. However, water used for curing should not produce any objectionable stain or unsightly deposit on the concrete surface. The presence of tannic acid or iron compounds is objectionable.

4.5 Chemical Admixtures

4.5.1 Admixture, if used shall comply with accepted standards [6-5A(11)]. Previous experience with and data on such materials should be considered in relation to the likely standards of supervision and workmanship to the work being specified.

4.5.2 Admixtures should not impair durability of concrete nor combine with the constituent to form harmful compounds nor increase the risk of corrosion of reinforcement.

4.5.3 The workability, compressive strength and the slump loss of concrete with and without the use of admixtures shall be established during the trial mixes before use of admixtures.

4.5.4 The relative density of liquid admixtures shall be checked for each drum containing admixtures and compared with the specified value before acceptance.

4.5.5 The chloride content of admixtures shall be independently tested for each batch before acceptance.

4.5.6 If two or more admixtures are used simultaneously in the same concrete mix, data should be obtained to assess their interaction and to ensure their compatibility.

4.6 Reinforcement

The reinforcement shall be any of the following conforming to the accepted standards [6-5A(12)]:

a) Mild steel and medium tensile steel bars.
b) High strength deformed steel bars.
c) Hard-drawn steel wire fabric.
d) Grade A of structural steel.

4.6.1 All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or any other substances which may destroy or reduce bond. Sand blasting or other treatment is recommended to clean reinforcement.

4.6.2 Special precautions like coating of reinforcement may be required for reinforced concrete elements in exceptional cases and for rehabilitation of structures. Specialist literature may be referred to in such cases.

4.6.3 The modulus of elasticity of steel shall be taken as 200 kN/mm^2. The characteristic yield strength of different steel shall be assumed as the minimum yield stress/0.2 percent proof stress specified in the relevant Indian Standard.

4.7 Storage of Materials

Storage of materials shall be as described in good practice [6-5A(13)].

5 CONCRETE

5.1 Grades

The concrete shall be in grades designated as per Table 2.

Table 2 Grades of Concrete

(*Clauses* 5.1, 8.2.2, 14.1.1 *and* 35.1)

Group	Grade Designation	Specified Characteristic Compressive Strength of 150 mm Cube at 28 days in N/mm^2
(1)	(2)	(3)
Ordinary Concrete	M 10	10
	M 15	15
	M 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High Strength Concrete	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

NOTES

1 In the designation of concrete mix M refers to the mix and the number of the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm^2.

2 For concrete of compressive strength greater than M 55, design parameters given in the standard may not be applicable and the values may be obtained from specialized literatures and experimental results.

5.1.1 The characteristic strength is defined as the strength of material below which not more than 5 percent of the test results are expected to fall.

5.1.2 The minimum grade of concrete for plain and reinforced concrete shall be as per Table 5.

5.1.3 Concrete of grades lower than those given in Table 5 may be used for plain concrete constructions, lean concrete, simple foundations, foundation for masonry walls and other simple or temporary reinforced concrete construction.

5.2 Properties of Concrete

5.2.1 *Increase of Strength with Age*

There is normally a gain of strength beyond 28 days. The quantum of increase depends upon the grade and type of cement, curing and environmental conditions, etc. The design should be based on 28 days characteristic strength of concrete unless there is an evidence to justify a higher strength for a particular structure due to age.

5.2.1.1 For concrete of grade M 30 and above, the rate of increase of compressive strength with age shall be based on actual investigations.

5.2.1.2 Where members are subjected to lower direct load during construction, they should be checked for stresses resulting from combination of direct load and bending during construction.

5.2.2 *Tensile Strength of Concrete*

The flexural and splitting tensile strengths shall be obtained in accordance with good practice [6-5A(14)]. When the designer wishes to use an estimate of the tensile strength from the compressive strength, the following formula may be used:

$$\text{Flexural strength, } f_{cr} = 0.7\sqrt{f_{ck}} \text{ N/mm}^2$$

where f_{ck} is the characteristic cube compressive strength of concrete in N/mm^2.

5.2.3 *Elastic Deformation*

The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to a lesser extent by the conditions of curing and age of the concrete, the mix proportions and the type of cement. The modulus of elasticity is normally related to the compressive strength of concrete.

5.2.3.1 The modulus of elasticity of concrete can be assumed as follows:

$$E_c = 5\,000\sqrt{f_{ck}}$$

where E_c is the short-term static modulus of elasticity in N/mm^2.

Actual measured values may differ by ±20 percent from the values obtained from the above expression.

5.2.4 *Shrinkage*

The total shrinkage of concrete depends upon the constituents of concrete, size of the member and environmental conditions. For a given humidity and temperature, the total shrinkage of concrete is most influenced by the total amount of water present in the concrete at the time of mixing and, to a lesser extent, by the cement content.

5.2.4.1 In the absence of test data, the approximate value of the total shrinkage strain for design may be taken as 0.000 3 (for more information, *see* accepted standard [6-5A(15)]).

5.2.5 *Creep of Concrete*

Creep of concrete depends, in addition to the factors

listed in **5.2.4**, on the stress in the concrete, age at loading and the duration of loading. As long as the stress in concrete does not exceed one-third of its characteristic compressive strength, creep may be assumed to be proportional to the stress.

5.2.5.1 In the absence of experimental data and detailed information on the effect of the variables, the ultimate creep strain may be estimated from the following values of creep coefficient (that is, ultimate creep strain/elastic strain at the age of loading); for long span structure, it is advisable to determine actual creep strain, likely to take place:

Age at Loading	*Creep Coefficient*
7 days	2.2
28 days	1.6
1 year	1.1

NOTE — The ultimate creep strain, estimated as described above does not include the elastic strain.

5.2.6 *Thermal Expansion*

The coefficient of thermal expansion depends on nature of cement, the aggregate, the cement content, the relative humidity and the size of sections.

The value of coefficient of thermal expansion for concrete with different aggregates may be taken as below:

Type of Aggregate	*Coefficient of Thermal Expansion for Concrete/°C*
Quartzite	1.2 to 1.3 to 10^{-5}
Sandstone	0.9 to 1.2 to 10^{-5}
Granite	0.7 to 0.95 to 10^{-5}
Basalt	0.8 to 0.95 to 10^{-5}
Limestone	0.6 to 0.9 to 10^{-5}

6 WORKABILITY OF CONCRETE

6.1 The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of workability of concrete measured in accordance with good practice [6-5A(16)] are given below:

Placing Conditions	*Degree of Workability*	*Slump* mm
(1)	(2)	(3)
Blinding concrete; Shallow sections; Pavements using pavers	Very low	*See* **6.1.1**
Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns	Medium	50-100
Slipform work; Pumped concrete	Medium	75-100
Trench fill; *in-situ* piling	High	100-150
Tremie concrete	Very high	*See* **6.1.2**

NOTE — For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars an thickness of sections. For tremie concrete, vibrators are not required to be used (*see also* **13.3**).

6.1.1 In the 'very low' category of workability where strict control is necessary, for example, pavement quality concrete, measurement of workability by determination of compacting factor will be more appropriate than slump (*see* accepted standard [6-5A(16)]) and a value of compacting factor of 0.75 to 0.80 is suggested.

6.1.2 In the 'very high' category of workability, measurement of workability by determination of flow will be appropriate (*see* accepted standard [6-5A(17)]).

7 DURABILITY OF CONCRETE

7.1 General

A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.

7.1.1 One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship used in making the concrete. With normal-weight aggregates a suitably low permeability is achieved by having an adequate cement content, sufficiently low free water/cement ratio, by ensuring complete compaction of the concrete, and by adequate curing.

The factors influencing durability include:

a) the environment;
b) the cover to embedded steel;
c) the type and quality of constituent materials;
d) the cement content and water/cement ratio of the concrete;

e) workmanship, to obtain full compaction and efficient curing; and

f) the shape and size of the member.

The degree of exposure anticipated for the concrete during its service life together with other relevant factors relating to mix composition, workmanship, design and detailing should be considered. The concrete mix to provide adequate durability under these conditions should be chosen taking account of the accuracy of current testing regimes for control and compliance as described in this Section.

7.2 Requirements for Durability

7.2.1 *Shape and Size of Member*

The shape or design details of exposed structures should be such as to promote good drainage of water and to avoid standing pools and rundown of water. Care should also be taken to minimize any cracks that may collect or transmit water. Adequate curing is essential to avoid the harmful effects of early loss of moisture (*see* **12.5**). Member profiles and their intersections with other members shall be designed and detailed in a way to ensure easy flow of concrete and proper compaction during concreting.

Concrete is more vulnerable to deterioration due to chemical or climatic attack when it is in thin sections, in sections under hydrostatic pressure from one side only, in partially immersed sections and at corners and edges of elements. The life of the structure can be lengthened by providing extra cover to steel, by chamfering the corners or by using circular cross-sections or by using surface coatings which prevent or reduce the ingress of water, carbon dioxide or aggressive chemicals.

7.2.2 *Exposure Conditions*

7.2.2.1 *General environment*

The general environment to which the concrete will be exposed during its working life is classified into five levels of severity, that is, mild, moderate, severe, very severe and extreme as described in Table 3.

7.2.2.2 *Abrasive*

Specialist literatures may be referred to for durability requirements of concrete surfaces exposed to abrasive action, for example, in case of machinery and metal tyres.

7.2.2.3 *Freezing and thawing*

Where freezing and thawing actions under wet conditions exist, enhanced durability can be obtained by the use of suitable air entraining admixtures. When concrete lower than grade M 50 is used under these conditions, the mean total air content by volume of the fresh concrete at the time of delivery into the construction should be:

Nominal Maximum Size Aggregate (mm)	*Entrained Air Percentage*
20	5 ± 1
40	4 ± 1

Since air entrainment reduces the strength, suitable adjustments may be made in the mix design for achieving required strength.

7.2.2.4 *Exposure to sulphate attack*

Table 4 gives recommendations for the type of cement, maximum free water/cement ratio and minimum cement content, which are required at different sulphate

Table 3 Environmental Exposure Conditions

(*Clauses* 7.2.2.1 *and* 34.3.2)

Sl No.	Environment	Exposure Conditions
(1)	(2)	(3)
i)	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area.
ii)	Moderate	Concrete surfaces sheltered from severe rain or freezing whilst wet. Concrete exposed to condensation and rain. Concrete continuously under water. Concrete in contact or buried under non-aggressive soil/ground water. Concrete surfaces sheltered from saturated salt air in coastal area.
iii)	Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation. Concrete completely immersed in sea water. Concrete exposed to coastal environment.
iv)	Very Severe	Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet. Concrete in contact with or buried under aggressive sub-soil/ground water.
v)	Extreme	Surface of members in tidal zone. Members in direct contact with liquid/solid aggressive chemicals.

Sl No.	Class	Concentration of Sulphates, Expressed as SO_3			Type of Cement	Dense, Fully Compacted Concrete. Made with 20 mm Nominal Maximum Size Aggregates in Accordance with Accepted Standard [6-5A(18)]	
		In Soil		In Ground Water			
		Total SO_3	SO_3 in 2:1 Water: Soil Extract			Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio
		Percent	g/l	g/l			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	1	Traces (<0.2)	Less than 1.0	Less than 0.3	Ordinary Portland cement or Portland slag cement or Portland pozzolana cement	280	0.55
ii)	2	0.2 to 0.5	1.0 to 1.9	0.3 to 1.2	Ordinary Portland cement or Portland slag cement or Portland pozzolana cement	330	0.50
					Supersulphated cement or sulphate resisting Portland cement	310	0.50
iii)	3	0.5 to 1.0	1.9 to 3.1	1.2 to 2.5	Supersulphated cement or sulphate resisting Portland cement	330	0.50
					Portland pozzolana cement or Portland slag cement	350	0.45
iv)	4	1.0 to 2.0	3.1 to 5.0	2.5 to 5.0	Supersulphated or sulphate resisting Portland cement	370	0.45
v)	5	More than 2.0	More than 5.0	More than 5.0	Sulphate resisting Portland cement or supersulphated cement with protective coatings	400	0.40

NOTES

1 Cement content given in this table is irrespective of grades of cement.

2 Use of supersulphated cement is generally restricted where the prevailing temperature is above 40°C.

3 Supersulphated cement gives an acceptable life provided that the concrete is dense and prepared with a water-cement ratio of 0.4 or less, in mineral acids, down to *p*H 3.5.

4 The cement contents given in col 6 of this table are the minimum recommended. For SO_3 contents near the upper limit of any class, cement contents above these minimum are advised.

5 For severe conditions, such as thin sections under hydrostatic pressure on one side only and sections partly immersed, considerations should be given to a further reduction of water-cement ratio.

6 Portland slag cement conforming to accepted standard [6-5A(3)] with slag content more than 50 percent exhibits better sulphate resisting properties.

7 Where chloride is encountered along with sulphates in soil or ground water, ordinary Portland cement with C_3A content from 5 to 8 percent shall be desirable to be used in concrete, instead of sulphate resisting cement. Alternatively, Portland slag cement conforming to accepted standard [6-5A(3)] having more than 50 percent slag or a blend of ordinary Portland cement and slag may be used provided sufficient information is available on performance of such blended cements in these conditions.

concentrations in near-neutral ground water having *p*H of 6 to 9.

For the very high sulphate concentrations in Class 5 conditions, some form of lining such as polyethylene or polychloroprene sheet; or surface coating based on asphalt, chlorinated rubber, epoxy; or polyurethane materials should also be used to prevent access by the sulphate solution.

7.2.3 *Requirement of Concrete Cover*

7.2.3.1 The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality concrete.

7.2.3.2 The nominal cover to the reinforcement shall be provided as per **25.4**.

7.2.4 *Concrete Mix Proportions*

7.2.4.1 *General*

The free water-cement ratio is an important factor in governing the durability of concrete and should always be the lowest value. Appropriate values for minimum cement content and the maximum free water-cement ratio are given in Table 5 for different exposure conditions. The minimum cement content and maximum water-cement ratio apply to 20 mm nominal

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 5.1.2, 5.1.3, 7.2.4.1 *and* 8.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	—	300	0.55	M 20
ii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very Severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in **4.2**. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolana and slag specified in accordance with accepted standard [6-5A(19)].

2 Minimum grade for plain concrete under mild exposure condition is not specified.

maximum size aggregate. For other sizes of aggregate they should be changed as given in Table 6.

Table 6 Adjustments to Minimum Cement Contents for Aggregates Other Than 20 mm Nominal Maximum Size

(*Clause* 7.2.4.1)

Sl No.	Nominal Maximum Aggregate Size	Adjustments to Minimum Cement Contents Given in Table 5
	mm	kg/m^3
(1)	(2)	(3)
i)	10	+ 40
ii)	20	0
iii)	40	–30

7.2.4.2 *Maximum cement content*

Cement content not including fly ash and ground granulated blast furnace slag in excess of 450 kg/m^3 should not be used unless special consideration has been given in design to the increased risk of cracking due to drying shrinkage in thin sections, or to early thermal cracking and to the increased risk of damage due to alkali silica reactions.

7.2.5 *Mix Constituents*

7.2.5.1 *General*

For concrete to be durable, careful selection of the mix and materials is necessary, so that deleterious constituents do not exceed the limits.

7.2.5.2 *Chlorides in concrete*

Whenever there is chloride in concrete there is an increased risk of corrosion of embedded metal. The higher the chloride content, or if subsequently exposed to warm moist conditions, the greater the risk of corrosion. All constituents may contain chlorides and concrete may be contaminated by chlorides from the external environment. To minimize the chances of deterioration of concrete from harmful chemical salts, the levels of such harmful salts in concrete coming from concrete materials, that is, cement, aggregates water and admixtures, as well as by diffusion from the environment should be limited. The total amount of chloride content (as Cl) in the concrete at the time of placing shall be as given in Table 7.

The total acid soluble chloride content should be calculated from the mix proportions and the measured chloride contents of each of the constituents. Wherever possible, the total chloride content of the concrete should be determined.

Table 7 Limits of Chloride Content of Concrete

(*Clause* 7.2.5.2)

Sl No.	Type or Use of Concrete	Maximum Total Acid Soluble Chloride Content Expressed as kg/m^3 of Concrete
(1)	(2)	(3)
i)	Concrete containing metal and steam cured at elevated temperature and prestressed concrete	0.4
ii)	Reinforced concrete or plain concrete containing embedded metal	0.6
iii)	Concrete not containing embedded metal or any material requiring protection from chloride	3.0

7.2.5.3 *Sulphates in concrete*

Sulphates are present in most cements and in some aggregates; excessive amounts of water-soluble sulphate from these or other mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as SO_3, should not exceed 4 percent by mass of the cement in the mix. The sulphate content should be calculated as the total from the various constituents of the mix.

The 4 percent limit does not apply to concrete made with supersulphated cement complying with accepted standard [6-5A(20)].

7.2.5.4 *Alkali-aggregate reaction*

Some aggregates containing particular varieties of silica may be susceptible to attack by alkalis (Na_2O and K_2O) originating from cement or other sources, producing an expansive reaction which can cause cracking and disruption of concrete. Damage to concrete from this reaction will normally only occur when all the following are present together:

a) A high moisture level, within the concrete;
b) A cement with high alkali content, or another source of alkali; and
c) Aggregate containing an alkali reactive constituent.

Where the service records of particular cement/ aggregate combination are well established, and do not include any instances of cracking due to alkali-aggregate reaction, no further precautions should be necessary. When the materials are unfamiliar, precautions should take one or more of the following form:

a) Use of non-reactive aggregate from alternate sources.
b) Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 percent (as Na_2O equivalent).

   Further advantage can be obtained by use of fly ash (Grade 1) conforming to accepted standard [6-5A(5)] or granulated blastfurnace slag conforming to accepted standard [6-5A(5)] as part replacement of ordinary Portland cement (having total alkali content as Na_2O equivalent not more than 0.6 percent), provided fly ash content is at least 20 percent or slag content is at least 50 percent.
c) Measures to reduce the degree of saturation of the concrete during service, such as use of impermeable membranes.
d) Limiting the cement content in the concrete mix and thereby limiting total alkali content in the concrete mix. For more guidance specialist literatures may be referred.

7.2.6 *Concrete in Aggressive Soils and Water*

7.2.6.1 *General*

The destructive action of aggressive waters on concrete is progressive. The rate of deterioration decreases as the concrete is made stronger and more impermeable, and increases as the salt content of the water increases. Where structures are only partially immersed or are in contact with aggressive soils or waters on one side only, evaporation may cause serious concentrations of salts with subsequent deterioration, even where the original salt content of the soil or water is not high.

NOTE — Guidance regarding requirements for concrete exposed to sulphate attack is given in **7.2.2.4**.

7.2.6.2 *Drainage*

At sites where alkali concentrations are high or may become very high, the ground water should be lowered by drainage so that it will not come into direct contact with the concrete.

Additional protection may be obtained by the use of chemically resistant stone facing or a layer of plaster of Paris covered with suitable fabric, such as jute thoroughly impregnated with bituminous material.

7.2.7 *Compaction, Finishing and Curing*

Adequate compaction without segregation should be ensured by providing suitable workability and by employing appropriate placing and compacting equipment and procedures. Full compaction is particularly important in the vicinity of construction and movement joints and of embedded water bars and reinforcement.

Good finishing practices are essential for durable concrete.

Overworking the surface and the addition of water/ cement to aid in finishing should be avoided; the resulting laitance will have impaired strength and durability and will be particularly vulnerable to freezing and thawing under wet conditions.

It is essential to use proper and adequate curing techniques to reduce the permeability of the concrete and enhance its durability by extending the hydration of the cement, particularly in its surface zone (*see* **12.5**).

7.2.8 *Concrete in Sea-water*

Concrete in sea-water or exposed directly along the sea-coast shall be at least M 20 Grade in the case of plain concrete and M 30 in case of reinforced concrete.

The use of slag or pozzolana cement is advantageous under such conditions.

7.2.8.1 Special attention shall be given to the design of the mix to obtain the densest possible concrete; slag, broken brick, soft limestone, soft sandstone, or other porous or weak aggregates shall not be used.

7.2.8.2 As far as possible, preference shall be given to precast members unreinforced, well-cured and hardened, without sharp corners, and having trowel-smooth finished surfaces free from crazing, cracks or other defects; plastering should be avoided.

7.2.8.3 No construction joints shall be allowed within 600 mm below low water-level or within 600 mm of the upper and lower planes of wave action. Where unusually severe conditions or abrasion are anticipated, such parts of the work shall be protected by bituminous or silico-flouride coatings or stone facing bedded with bitumen.

7.2.8.4 In reinforced concrete structures, care shall be taken to protect the reinforcement from exposure to saline atmosphere during storage, fabrication and use. It may be achieved by treating the surface of reinforcement with cement wash or by suitable methods.

8 CONCRETE MIX PROPORTIONING

8.1 Mix Proportion

The mix proportion shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish.

8.1.1 The determination of the proportions of cement, aggregates and water to attain the required strengths shall be made as follows:

a) By designing the concrete mix; such concrete shall be called 'Design mix concrete', or

b) By adopting nominal concrete mix; such concrete shall be called 'Nominal mix concrete'.

Design mix concrete is preferred to nominal mix. If design mix concrete cannot be used for any reason on the work for grades of M 20 or lower, nominal mixes may be used with the permission of engineer-in-charge, which, however, is likely to involve a higher cement content.

8.1.2 *Information Required*

In specifying a particular grade of concrete, the following information shall be included:

a) Type of mix, that is, design mix concrete or nominal mix concrete;

b) Grade designation;

c) Type of cement;

d) Maximum nominal size of aggregate;

e) Minimum cement content (for design mix concrete);

f) Maximum water-cement ratio;

g) Workability;

h) Mix proportion (for nominal mix concrete);

j) Exposure conditions as per Tables 4 and 5;

k) Maximum temperature of concrete at the time of placing;

m) Method of placing; and

n) Degree of supervision.

8.1.2.1 In appropriate circumstances, the following additional information may be specified;

a) Type of aggregate,

b) Maximum cement content, and

c) Whether an admixture shall or shall not be used and the type of admixture and the condition of use.

8.2 Design Mix Concrete

8.2.1 As the guarantor of quality of concrete used in the construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the employer within the limitations of parameters and other stipulations laid down by this standard.

8.2.2 The mix shall be designed to produce the grade of concrete having the required workability and a characteristic strength not less than appropriate values given in Table 2. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.

8.2.3 Mix design done earlier not prior to one year may be considered adequate for later work provided there is no change in source and the quality of the materials.

8.2.4 *Standard Deviation*

The standard deviation for each grade of concrete shall be calculated, separately.

8.2.4.1 Standard deviation based on test strength of sample

a) *Number of test results of samples* — The total number of test strength of samples required to constitute an acceptable record for calculation of standard deviation shall be not less than 30. Attempts should be made to obtain the 30 samples, as early as possible, when a mix is used for the first time.

b) *In case of significant changes in concrete* — When significant changes are made in the production of concrete batches (for example changes in the materials used, mix design, equipment or technical control), the standard deviation value shall be separately calculated for such batches of concrete.

c) *Standard deviation to be brought up to date* — The calculation of the standard deviation shall be brought up to date after every change of mix design.

8.2.4.2 *Assumed standard deviation*

Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation given in Table 8 may be assumed for design of mix in the first instance. As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix designed properly. However, when adequate past records for a similar grade exist and justify to the designer a value of standard deviation different from that shown in Table 8, it shall be permissible to use that value.

Table 8 Assumed Standard Deviation

(*Clause* 8.2.4.2 and *Table* 11)

Grade of Concrete	Assumed Standard Deviation N/mm²
(1)	(2)
M 10, M 15	3.5
M 20, M 25	4.0
M 30, M 35, M 40, M 45, M 50	5.0

NOTE — The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate gradings and moisture content; and periodical checking of workability and strength. Where there is deviation from the above the values given in the above table shall be increased by 1 N/mm².

8.3 Nominal Mix Concrete

Nominal mix concrete may be used for concrete of M 20 or lower. The proportions of materials for nominal mix concrete shall be in accordance with Table 9.

8.3.1 The cement content of the mix specified in Table 9 for any nominal mix shall be proportionately increased if the quantity of water in a mix has to be increased to overcome the difficulties of placement and compaction, so that the water-cement ratio as specified is not exceeded.

9 PRODUCTION OF CONCRETE

9.1 Quality Assurance Measures

9.1.1 In order that the properties of the completed structure be consistent with the requirements and the assumptions made during the planning and the design, adequate quality assurance measures shall be taken. The construction should result in satisfactory strength, serviceability and long-term durability so as to lower the overall life-cycle cost. Quality assurance in construction activity relates to proper design, use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately proper care during the use of structure including timely maintenance and repair by the owner.

9.1.2 Quality assurance measures are both technical and organizational. Some common cases should be specified in a general Quality Assurance Plan which shall identify the key elements necessary to provide fitness of the structure and the means by which they are to be provided and measured with the overall purpose to provide confidence that the realized project will work satisfactorily in service fulfilling intended needs. The job of quality control and quality assurance would involve quality audit of both the inputs as well as the outputs. Inputs are in the form of materials for concrete; workmanship in all stages of batching, mixing, transportation, placing, compaction and curing; and the related plant, machinery and equipments; resulting in the output in the form of concrete in place. To ensure proper performance, it is necessary that each step in concreting which will be covered by the next step is inspected as the work proceeds (*see also* **16**).

9.1.3 Each party involved in the realization of a project should establish and implement a Quality Assurance Plan, for its participation in the project. Supplier's and subcontractor's activities shall be covered in the plan. The individual Quality Assurance Plans shall fit into the general Quality Assurance Plan. A Quality Assurance Plan shall define the tasks and responsibilities of all persons involved, adequate control and checking procedures, and the organization and maintaining adequate documentation of the building process and its results. Such documentation should generally include:

a) test reports and manufacturer's certificate for materials, concrete mix design details;

b) pour cards for site organization and clearance for concrete placement;

c) record of site inspection of workmanship, field tests;

d) non-conformance reports, change orders;

Table 9 Proportions for Nominal Mix Concrete

(*Clauses* 8.3 *and* 8.3.1)

Grade of Concrete	Total Quantity of Dry Aggregates by Mass per 50 kg of Cement, to be Taken as the Sum of the Individual Masses of Fine and Coarse Aggregates, kg, *Max*	Proportion of Fine Aggregate to Coarse Aggregate (by Mass)	Quantity of Water per 50 kg of Cement, *Max*
(1)	(2)	(3)	(4)
M 5	800	Generally 1:2 but subject to an upper limit of 1:1½ and a lower limit of 1:2½	60
M 7.5	625		45
M 10	480		34
M 15	330		32
M 20	250		30

NOTE — The proportion of the fine to coarse aggregates should be adjusted from upper limit to lower limit progressively as the grading of fine aggregates becomes finer and the maximum size of coarse aggregate becomes larger. Graded coarse aggregate shall be used.

Example

For an average grading of fine aggregate (that is, Zone II of Table 4 of IS 383), the proportions shall be 1:1½, 1:2 and 1:2½ for maximum size of aggregates 10 mm, 20 mm and 40 mm respectively.

e) quality control charts; and

f) statistical analysis.

NOTE — Quality control charts are recommended wherever the concrete is in continuous production over considerable period.

9.2 Batching

To avoid confusion and error in batching, consideration should be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may, however, be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank (*see also* accepted standard [6-5A(21)]).

Ready-mixed concrete supplied by ready-mixed concrete plant shall be preferred. For large and medium project sites the concrete shall be sourced from ready-mixed concrete plants or from on site or off site batching and mixing plants (*see also* accepted standard [6-5A(21)]).

9.2.1 Except where it can be shown to the satisfaction of the engineer-in-charge that supply of properly graded aggregate of uniform quality can be maintained over a period of work, the grading of aggregate should be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions when required, the different sizes being stocked in separate stock-piles. The material should be stock-piled for several hours preferably a day before use. The grading of coarse and fine aggregate should be checked as frequently as possible, the frequency for a given job being determined by the engineer-in-charge to ensure that the specified grading is maintained.

9.2.2 The accuracy of the measuring equipment shall be within ± 2 percent of the quantity of cement being measured and within ± 3 percent of the quantity of aggregate, admixtures and water being measured.

9.2.3 Proportion/Type and grading of aggregates shall be made by trial in such a way so as to obtain densest possible concrete. All ingredients of the concrete should be used by mass only.

9.2.4 Volume batching may be allowed only where weigh-batching is not practical and provided accurate bulk densities of materials to be actually used in concrete have earlier been established. Allowance for bulking shall be made in accordance with accepted standard [6-5A(23)]. The mass volume relationship should be checked as frequently as necessary, the frequency for the given job being determined by engineer-in-charge to ensure that the specified grading is maintained.

9.2.5 It is important to maintain the water-cement ratio constant at its correct value. To this end, determination of moisture contents in both fine and coarse aggregates shall be made as frequently as possible, the frequency for a given job being determined by the engineer-in-charge according to weather conditions. The amount of the added water shall be adjusted to compensate for any observed variations in the moisture contents. For the determination of moisture content in the aggregates,

variation in their moisture content, suitable adjustments in the masses of aggregates shall also be made. In the absence of exact data, only in the case of nominal mixes, the amount of surface water may be estimated from the values given in Table 10.

Table 10 Surface Water Carried by Aggregate

(*Clause* 9.2.5)

Sl No.	Aggregate	Approximate Quantity of Surface Water	
		Percent by Mass	l/m³
(1)	(2)	(3)	(4)
i)	Very wet sand	7.5	120
ii)	Moderately wet sand	5.0	80
iii)	Moist sand	2.5	40
iv)	Moist gravel or crushed rock[1)]	1.25 – 2.5	20 – 40

[1)] Coarser the aggregate, less the water it will carry.

9.2.6 No substitutions in materials used on the work or alterations in the established proportions, except as permitted in **9.2.4** and **9.2.5** shall be made without additional tests to show that the quality and strength of concrete are satisfactory.

9.3 Mixing

Concrete shall be mixed in a mechanical mixer. The mixer should comply with accepted standard [6-5A(24)]. The mixers shall be fitted with water measuring (metering) devices. The mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete should be re-mixed.

9.3.1 For guidance, the mixing time shall be at least 2 min. For other types of more efficient mixers, manufacturers recommendations shall be followed; for hydrophobic cement it may be decided by the engineer-in-charge.

9.3.2 Workability should be checked at frequent intervals (*see* accepted standard [6-5A(16)]).

9.3.3 Dosages of retarders, plasticizers and superplasticizers shall be restricted to 0.5, 1.0 and 2.0 percent respectively by weight of cementitious materials, unless a higher value is agreed upon between the manufacturer and the constructor based on performance test.

10 FORMWORK

10.1 General

The formwork shall be designed and constructed so as loss of slurry from the concrete. For further details regarding design, detailing, etc, reference may be made to good practice [6-5A(25)]. The tolerances on the shapes, lines and dimensions shown in the drawing shall be within the limits given below:

a) Deviation from specified dimensions of cross-section of columns and beams $^{+12}_{-6}$ mm

b) Deviation from dimensions of footings

1) Dimensions in plan $^{+50}_{-12}$ mm

2) Eccentricity 0.02 times the width of the footing in the direction of deviation but not more than 50 mm

3) Thickness ± 0.05 times the specified thickness

These tolerances apply to concrete dimensions only, and not to positioning of vertical reinforcing steel or dowels.

10.2 Cleaning and Treatment of Formwork

All rubbish, particularly, chippings, shavings and sawdust shall be removed from the interior of the forms before the concrete is placed. The face of formwork in contact with the concrete shall be cleaned and treated with form release agent. Release agents should be applied so as to provide a thin uniform coating to the forms without coating the reinforcement.

10.3 Stripping Time

Forms shall not be released until the concrete has achieved a strength of at least twice the stress to which the concrete may be subjected at the time of removal of formwork. The strength referred to shall be that of concrete using the same cement and aggregates and admixture, if any, with the same proportions and cured under conditions of temperature and moisture similar to those existing on the work.

10.3.1 While the above criteria of strength shall be the guiding factor for removal of formwork, in normal circumstances where ambient temperature does not fall below 15°C and where ordinary Portland cement is used and adequate curing is done, following striking period may deem to satisfy the guideline given in **10.3**:

	Type of Formwork	*Minimum Period Before Striking Formwork*
a)	Vertical formwork to columns, walls, beams	16-24 h
b)	Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days
c)	Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days
d)	Props to slabs:	
	1) Spanning up to 4.5 m	7 days
	2) Spanning over 4.5 m	14 days
e)	Props to beams and arches:	
	1) Spanning up to 6 m	14 days
	2) Spanning over 6 m	21 days

For other cements and lower temperature, the stripping time recommended above may be suitably modified.

10.3.2 The number of props left under, their sizes and disposition shall be such as to be able to safely carry the full dead load of the slab, beam or arch as the case may be together with any live load likely to occur during curing or further construction.

10.3.3 Where the shape of the element is such that the formwork has re-entrant angles, the formwork shall be removed as soon as possible after the concrete has set, to avoid shrinkage cracking occurring due to the restraint imposed.

11 ASSEMBLY OF REINFORCEMENT

11.1 Reinforcement shall be bent and fixed in accordance with procedure specified in good practice [6-5A(26)]. The high strength deformed steel bars should not be re-bent or straightened without the approval of engineer-in-charge.

Bar bending schedules shall be prepared for all reinforcement work.

11.2 All reinforcement shall be placed and maintained in the position shown in the drawings by providing proper cover blocks, spacers, supporting bars, etc.

11.2.1 Crossing bars should not be tack-welded for assembly of reinforcement unless permitted by engineer-in-charge.

11.3 Placing of Reinforcement

Rough handling, shock loading (prior to embedment) and the dropping of reinforcement from a height should be avoided. Reinforcement should be secured against displacement outside the specified limits.

11.3.1 *Tolerances on Placing of Reinforcement*

Unless otherwise specified by engineer-in-charge, the reinforcement shall be placed within the following tolerances:

a) for effective depth 200 mm or less ± 10 mm

b) for effective depth more than 200 mm ± 15 mm

12.3.2 *Tolerance for Cover*

Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by $^{+10}_{-0}$ mm.

Nominal cover as given in **25.4.1** should be specified to all steel reinforcement including links. Spacers between the links (or the bars where no links exist) and the formwork should be of the same nominal size as the nominal cover.

Spacers, chairs and other supports detailed on drawings, together with such other supports as may be necessary, should be used to maintain the specified nominal cover to the steel reinforcement. Spacers or chairs should be placed at a maximum spacing of 1 m and closer spacing may sometimes be necessary.

Spacers, cover blocks should be of concrete of same strength or PVC.

11.4 Welded Joints or Mechanical Connections

Welded joints or mechanical connections in reinforcement may be used but in all cases of important connections, test shall be made to prove that the joints are of the full strength of bars connected. Welding of reinforcements shall be done in accordance with good practice [6-5A(27)].

11.5 Where reinforcement bars up to 12 mm for high strength deformed steel bars and up to 16 mm for mild steel bars are bent aside at construction joints and afterwards bent back into their original positions, care should be taken to ensure that at no time is the radius of the bend less than 4 bar diameters for plain mild steel or 6 bar diameters for deformed bars. Care shall also be taken when bending back bars, to ensure that the concrete around the bar is not damaged beyond the band.

11.6 Reinforcement should be placed and tied in such a way that concrete placement be possible without segregation of the mix. Reinforcement placing should allow compaction by immersion vibrator. Within the concrete mass, different types of metal in contact should be avoided to ensure that bimetal corrosion does not take place.

12 TRANSPORTING, PLACING, COMPACTION AND CURING

12.1 Transporting and Handling

After mixing, concrete shall be transported to the formwork as rapidly as possible by methods which will prevent the segregation or loss of any of the ingredients or ingress of foreign matter or water and maintaining the required workability.

12.1.1 During hot or cold weather, concrete shall be transported in deep containers. Other suitable methods to reduce the loss of water by evaporation in hot weather and heat loss in cold weather may also be adopted.

12.2 Placing

The concrete shall be deposited as nearly as practicable in its final position to avoid rehandling. The concrete shall be placed and compacted before initial setting of concrete commences and should not be subsequently disturbed. Methods of placing should be such as to preclude segregation. Care should be taken to avoid displacement of reinforcement or movement of formwork. As a general guidance, the maximum permissible free fall of concrete may be taken as 1.5 m.

12.3 Compaction

Concrete should be thoroughly compacted and fully worked around the reinforcement, around embedded fixtures and into corners of the formwork.

12.3.1 Concrete shall be compacted using mechanical vibrators complying with accepted standard [6-5A(28)]. Over vibration and under vibration of concrete are harmful and should be avoided. Vibration of very wet mixes should also be avoided.

Whenever vibration has to be applied externally, the design of formwork and the disposition of vibrators should receive special consideration to ensure efficient compaction and to avoid surface blemishes.

12.4 Construction Joints and Cold Joints

Joints are a common source of weakness and, therefore, it is desirable to avoid them. If this is not possible, their number shall be minimized. Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated by the designer. Construction joints should comply with accepted standard [6-5A(29)].

Construction joints shall be placed at accessible locations to permit cleaning out of laitance, cement slurry and unsound concrete, in order to create rough/ uneven surface. It is recommended to clean out laitance and cement slurry by using wire brush on the surface of joint immediately after initial setting of concrete and to clean out the same immediately thereafter. The prepared surface should be in a clean saturated surface dry condition when fresh concrete is placed, against it.

In the case of construction joints at locations where the previous pour has been cast against shuttering the recommended method of obtaining a rough surface for the previously poured concrete is to expose the aggregate with a high pressure water jet or any other appropriate means.

Fresh concrete should be thoroughly vibrated near construction joints so that mortar from the new concrete flows between large aggregates and develop proper bond with old concrete.

Where high shear resistance is required at the construction joints, shear keys may be provided.

Sprayed curing membranes and release agents should be thoroughly removed from joint surfaces.

12.5 Curing

Curing is the process of preventing the loss of moisture from the concrete whilst maintaining a satisfactory temperature regime. The prevention of moisture loss from the concrete is particularly important if the water-cement ratio is low, if the cement has a high rate of strength development, if the concrete contains granulated blast furnace slag or pulverized fuel ash. The curing regime should also prevent the development of high temperature gradients within the concrete.

The rate of strength development at early ages of concrete made with supersulphated cement is significantly reduced at lower temperatures. Supersulphated cement concrete is seriously affected by inadequate curing and the surface has to be kept moist for at least seven days.

12.5.1 *Moist Curing*

Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacking, canvas, hessian or similar materials and kept constantly wet for at least seven days from the date of placing concrete in case of ordinary Portland Cement and at least 10 days where mineral admixtures or blended cements are used. The period of curing shall not be less than 10 days for concrete exposed to dry and hot weather conditions. In the case of concrete where mineral admixtures or blended cements are used, it is recommended that above minimum periods may be extended to 14 days.

12.5.2 *Membrane Curing*

Approved curing compounds may be used in lieu of

moist curing with the permission of the engineer-in-charge. Such compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set. Impermeable membranes such as polyethylene sheeting covering closely the concrete surface may also be used to provide effective barrier against evaporation.

12.6 Supervision

It is exceedingly difficult and costly to alter concrete once placed. Hence, constant and strict supervision of all the items of the construction is necessary during the progress of the work, including the proportioning and mixing of the concrete. Supervision is also of extreme importance to check the reinforcement and its placing before being covered.

12.6.1 Before any important operation, such as concreting or stripping of the formwork is started, adequate notice shall be given to the construction supervisor.

13 CONCRETING UNDER SPECIAL CONDITIONS

13.1 Work in Extreme Weather Conditions

During hot or cold weather, the concreting should be done as per good practice [6-5A(30)].

13.2 Under-Water Concreting

13.2.1 When it is necessary to deposit concrete under water, the methods, equipment, materials and proportions of the mix to be used shall be submitted to and approved by the engineer-in-charge before the work is started.

13.2.2 Under-water concrete should have a slump recommended in **6.1**. The water-cement ratio shall not exceed 0.6 and may need to be smaller, depending on the grade of concrete or the type of chemical attack. For aggregates of 40 mm maximum particle size, the cement content shall be at least 350 kg/m^3 of concrete.

13.2.3 Coffer-dams or forms shall be sufficiently tight to ensure still water if practicable, and in any case to reduce the flow of water to less than 3 m/min through the space into which concrete is to be deposited. Coffer-dams or forms in still water shall be sufficiently tight to prevent loss of mortar through the walls. De-watering by pumping shall not be done while concrete is being placed or until 24 h thereafter.

13.2.4 Concrete cast under water should not fall freely through the water. Otherwise it may be leached and become segregated. Concrete shall be deposited continuously until it is brought to the required height. While depositing, the top surface shall be kept as nearly level as possible and the formation of seams avoided. The methods to be used for depositing concrete under water shall be one of the following:

a) *Tremie* — The concrete is placed through vertical pipes the lower end of which is always inserted sufficiently deep into the concrete which has been placed previously but has not set. The concrete emerging from the pipe pushes the material that has already been placed to the side and upwards and thus does not come into direct contact with water.

   When concrete is to be deposited under-water by means of tremie, the top section of the tremie shall be a hopper large enough to hold one entire batch of the mix or the entire contents the transporting bucket, if any. The tremie pipe shall be not less than 200 mm in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of the water in which it is suspended, even if a partial vacuum develops inside the pipe. Preferably, flanged steel pipe of adequate strength for the job should be used. A separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the pipe is equipped with an approved automatic check valve, the upper end of the pipe shall be plugged with a wadding of the gunny sacking or other approved material before delivering the concrete to the tremie pipe through the hopper, so that when the concrete is forced down from the hopper to the pipe, it will force the plug (and along with it any water in the pipe) down the pipe and out of the bottom end, thus establishing a continuous stream of concrete. It will be necessary to raise slowly the tremie in order to cause a uniform flow of the concrete, but the tremie shall not be emptied so that water enters the pipe. At all times after the placing of concrete is started and until all the concrete is placed, the lower end of the tremie pipe shall be below the top surface of the plastic concrete. This will cause the concrete to build up from below instead of flowing out over the surface, and thus avoid formation of laitance layers. If the charge in the tremie is lost while depositing, the tremie shall be raised above the concrete surface, and unless sealed by a check valve, it shall be re-plugged at the top end, as at the beginning, before refilling for depositing concrete.

b) *Direct placement with pumps* — As in the case of the tremie method, the vertical end piece of the pipe line is always inserted sufficiently

deep into the previously cast concrete and should not move to the side during pumping.

c) *Drop bottom bucket* — The top of the bucket shall be covered with a canvas flap. The bottom doors shall open freely downward and outward when tripped. The bucket shall be filled completely and lowered slowly to avoid backwash. The bottom doors shall not be opened until the bucket rests on the surface upon which the concrete is to be deposited and when discharged, shall be withdrawn slowly until well above the concrete.

d) *Bags* — Bags of at least 0.028 m^3 capacity of jute or other coarse cloth shall be filled about two-thirds full of concrete, the spare end turned under so that bag is square ended and securely tied. They shall be placed carefully in header and stretcher courses so that the whole mass is interlocked. Bags used for this purpose shall be free from deleterious materials.

e) *Grouting* — A series of round cages made from 50 mm mesh of 6 mm steel and extending over the full height to be concreted shall be prepared and laid vertically over the area to be concreted so that the distance between centres of the cages and also to the faces of the concrete shall not exceed 1 m. Stone aggregate of not less than 50 mm nor more than 200 mm size shall be deposited outside the steel cages over the full area and height to be concreted with due care to prevent displacement of the cages.

A stable 1:2 cement-sand grout with a water-cement ratio of not less than 0.6 and not more than 0.8 shall be prepared in a mechanical mixer and sent down under pressure (about 0.2 N/mm^2) through 38 to 50 mm diameter pipes terminating into steel cages, about 50 mm above the bottom of the concrete. As the grouting proceeds, the pipe shall be raised gradually up to a height of not more than 6 000 mm above its starting level after which it may be withdrawn and placed into the next cage for further grouting by the same procedure.

After grouting the whole area for a height of about 600 mm, the same operation shall be repeated, if necessary, for the next layer of 600 mm and so on.

The amount of grout to be sent down shall be sufficient to fill all the voids which may be either ascertained or assumed as 55 percent of the volume to be concreted.

13.2.5 To minimize the formulation of laitance, great care shall be exercised not to disturb the concrete as far as possible while it is being deposited.

14 SAMPLING AND STRENGTH OF DESIGNED CONCRETE MIX

14.1 General

Samples from fresh concrete shall be taken as per accepted standard [6-5A(16)] and cubes shall be made, cured and tested at 28 days in accordance with accepted standard [6-5A(9)].

14.1.1 In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for modulus of rupture at 72 ± 2 h or at 7 days, or compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test. For this purpose the values should be arrive at based on actual testing. In all cases, the 28 days compressive strength specified in Table 2 shall alone be the criterion for acceptance or rejection of the concrete.

14.2 Frequency of Sampling

14.2.1 *Sampling Procedure*

A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested that is, the sampling should be spread over the entire period of concreting and cover all mixing units.

14.2.2 *Frequency*

The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:

Quantity of Concrete in the Work, m^3	*Number of Samples*
1-5	1
6-15	2
16-30	3
31-50	4
51 and above	4 plus one additional sample for each additional 50 m^3 or part thereof

NOTE — At least one sample shall be taken from each shift. Where concrete is produced at continuous production unit, such as ready-mixed concrete plant, frequency of sampling may be agreed upon mutually by suppliers and purchasers.

14.3 Test Specimen

Three test specimens shall be made for each sample for testing at 28 days. Additional specimens may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the formwork, or to determine the duration of curing, or to check the testing error. Additional specimens may also be required for testing specimens cured by

accelerated methods as described in accepted standard [6-5A(31)]. The specimen shall be tested as described in accepted standard [6-5A(9)].

14.4 Test Results of Sample

The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ± 15 percent of the average. If more, the test results of the sample are invalid.

15 ACCEPTANCE CRITERIA

15.1 Compressive Strength

The concrete shall be deemed to comply with the strength requirements when both the following conditions are met:

a) The mean strength determined from any group of four non-overlapping consecutive test results complies with the appropriate limits in col 2 of Table 11.

b) Any individual test result complies with the appropriate limits in col 3 of Table 11.

15.2 Flexural Strength

When both the following conditions are met, the concrete complies with the specified flexural strength:

a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2.

b) The strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm^2.

15.3 Quantity of Concrete Represented by Strength Test Results

The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches.

For the individual test result requirements given in col 3 of Table 11 or in **15.2** (b), only the particular batch from which the sample was taken shall be at risk.

Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m^3.

15.4 If the concrete is deemed not to comply pursuant to **15.1** or **15.2** as the case may be, the structural adequacy of the parts affected shall be investigated (*see* **16**) and any consequential action as needed shall be taken.

15.5 Concrete of each grade shall be assessed separately.

15.6 Concrete is liable to be rejected if it is porous or honey-combed, its placing has been interrupted without providing a proper construction joint, the reinforcement has been displaced beyond the tolerances specified, or construction tolerances have not been met. However, the hardened concrete may be accepted after carrying out suitable remedial measures to the satisfaction of the engineer-in-charge.

16 INSPECTION AND TESTING OF STRUCTURES

16.1 Inspection

To ensure that the construction complies with the design an inspection procedure should be set up covering materials, records, workmanship and construction.

16.1.1 Tests should be made on reinforcement and the constituent materials of concrete in accordance with the relevant standards. Where applicable, use should be made of suitable quality assurance schemes.

Table 11 Characteristic Compressive Strength Compliance Requirement

(*Clauses* 15.1 *and* 15.3)

Specified Grade	Mean of the Group of 4 Non-Overlapping Consecutive Test Results in N/mm^2	Individual Test Results in N/mm^2
(1)	(2)	(3)
M 15	$\geq f_{ck} + 0.825 \times$ established standard deviation (rounded off to nearest 0.5 N/mm^2) or $f_{ck} + 3$ N/mm^2, whichever is greater	$\geq f_{ck} - 3$ N/mm^2
M 20 or above	$\geq f_{ck} + 0.825 \times$ established standard deviation (rounded off to nearest 0.5 N/mm^2) or $f_{ck} + 4$ N/mm^2, whichever is greater	$\geq f_{ck} - 4$ N/mm^2

NOTE — In the absence of established value of standard deviation, the values given in Table 8 may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.

16.1.2 Care should be taken to see that:

a) design and detail are capable of being executed to a suitable standard, with due allowance for dimensional tolerances;
b) there are clear instructions on inspection standards;
c) there are clear instructions on permissible deviations;
d) elements critical to workmanship, structural performance, durability and appearance are identified; and
e) there is a system to verify that the quality is satisfactory in individual parts of the structure, especially the critical ones.

16.2 Immediately after stripping the formwork, all concrete shall be carefully inspected and any defective work or small defects either removed or made good before concrete has thoroughly hardened.

16.3 Testing

In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete on the basis of **16.4** and/or load test (*see* **16.6**) may be carried out.

16.4 Core Test

16.4.1 The points from which cores are to be taken and the number of cores required shall be at the discretion of the engineer-in-charge and shall be representative of the whole of concrete concerned. In no case, however, shall fewer than three cores be tested.

16.4.2 Cores shall be prepared and tested as described in accepted standard [6-5A(9)].

16.4.3 Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of the grade of concrete specified for the corresponding age and no individual core has a strength less than 75 percent.

16.5 In case the core test results do not satisfy the requirements of **16.4.3** or where such tests have not been done, load test (**16.6**) may be restored to.

16.6 Load Tests for Flexural Member

16.6.1 Load tests should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete.

16.6.2 The structure should be subjected to a load equal to full dead load of the structure plus 1.25 times the imposed load for a period of 24 h and then the imposed load shall be removed.

NOTE — Dead load includes self weight of the structural members plus weight of finishes and walls or partitions, if any, as considered in the design.

16.6.3 The deflection due to imposed load only shall be recorded. If within 24 h of removal of the imposed load, the structure does not recover at least 75 percent of the deflection under superimposed load, the test may be repeated after a lapse of 72 h. If the recovery is less than 80 percent, the structure shall be deemed to be unacceptable.

16.6.3.1 If the maximum deflection in mm, shown during 24 h under load is less than 40 l^2/D, where l is the effective span in m; and D, the overall depth of the section in mm, it is not necessary for the recovery to be measured and the recovery provisions of **16.6.3** shall not apply.

16.7 Members Other than Flexural Members

Members other than flexural members should be preferably investigated by analysis.

16.8 Non-destructive Tests

Non-destructive tests are used to obtain estimation of the properties of concrete in the structure. The methods adopted include ultrasonic pulse velocity (*see* accepted standard [6-5A(32)]), probe penetration, pullout and maturity. Non-destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quality measured by the non-destructive tests.

Any of these methods may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.

SECTION 5A (c) GENERAL DESIGN CONSIDERATION

17 BASES FOR DESIGN

17.1 Aim of Design

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and adequate resistance to the effects of misuse and fire.

17.2 Methods of Design

17.2.1 Structure and structural elements shall normally

be designed by Limit State Method. Account should be taken of accepted theories, experiment and experience and the need to design for durability. Calculations alone do not produce safe, serviceable and durable structures. Suitable materials, quality control, adequate detailing and good supervision are equally important.

17.2.2 Where the Limit State Method can not be conveniently adopted, Working Stress Method may be used (*see* Annex B).

17.2.3 *Design Based on Experimental Basis*

Designs based on experimental investigations on models or full size structure or element may be accepted if they satisfy the primary requirements of **17.1** and subject to experimental details and the analysis connected therewith being approved by the engineer-in-charge.

17.2.3.1 Where the design is based on experimental investigation on full size structure or element, load tests shall be carried out to ensure the following:

a) The structure shall satisfy the requirements for deflection (*see* **22.2**) and cracking (*see* **34.3.2**) when subjected to a load for 24 h equal to the characteristic load multiplied by 1.33 γ_f where γ_f shall be taken from Table 18, for the limit state of serviceability. If within 24 h of the removal of the load, the structure does not show a recovery of at least 75 percent of the maximum deflection shown during the 24 h under the load, the test loading should be repeated after a lapse of 72 h. The recovery after the second test should be at least 75 percent of the maximum deflection shown during the second test.

   NOTE — If the maximum deflection in mm, shown during 24 h under load is less than 40 l^2/D where l is the effective span in m; and D is the overall depth of the section in mm, it is not necessary for the recovery to be measured.

b) The structure shall have adequate strength to sustain for 24 h, a total load equal to the characteristic load multiplied by 1.33 γ_f where γ_f shall be taken from Table 18 for the limit state of collapse.

17.3 Durability, Workmanship and Materials

It is assumed that the quality of concrete, steel and other materials and of the workmanship, as verified by inspections, is adequate for safety, serviceability and durability.

17.4 Design Process

Design, including design for durability, construction and use in service should be considered as a whole. The realization of design objectives requires compliance with clearly defined standards for materials, production, workmanship and also maintenance and use of structure in service.

18 LOADS AND FORCES

18.1 General

In structural design, account shall be taken of the dead, imposed and wind loads and forces such as those caused by earthquake, and effects due to shrinkage, creep, temperature, etc, where applicable.

18.2 Dead Loads

Dead loads shall be calculated on the basis of unit weights which shall be established taking into consideration the materials specified for construction.

18.2.1 Alternatively, the dead loads may be calculated on the basis of unit weights of materials given in good practice [6-5A(33)]. Unless more accurate calculations are warranted, the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m^3 and 25 kN/m^3 respectively.

18.3 Imposed Loads, Wind Loads and Snow Loads

Imposed loads, wind loads and snow loads shall be assumed in accordance with good practice [6-5A(33)].

18.4 Earthquake Forces

The earthquake forces shall be calculated in accordance with accepted standard [6-5A(34)].

18.5 Shrinkage, Creep and Temperature Effects

If the effects of shrinkage, creep and temperature are liable to affect materially the safety and serviceability of the structure, these shall be taken into account in the calculations (*see* **5.2.4**, **5.2.5** and **5.2.6**) and good practice [6-5A(33)].

18.5.1 In ordinary buildings, such as low rise dwellings whose lateral dimension do not exceed 45 m, the effects due to temperature fluctuations and shrinkage and creep can be ignored in design calculations.

18.6 Other Forces and Effects

In addition, account shall be taken of the following forces and effects if they are liable to affect materially the safety and serviceability of the structure:

a) Foundation movement (*see* good practice [6-5A(35)]),
b) Elastic axial shortening,

c) Soil and fluid pressures (*see* good practice [6-5A(33)]),
d) Vibration,
e) Fatigue,
f) Impact (*see* good practice [6-5A(33)]),
g) Erection loads (*see* good practice [6-5A(33)]), and
h) Stress concentration effect due to point load and the like.

18.7 Combination of Loads

The combination of loads shall be as given in good practice [6-5A(33)].

18.8 Dead Load Counteracting Other Loads and Forces

When dead load counteracts the effects due to other loads and forces in structural member or joint, special care shall be exercised by the designer to ensure adequate safety for possible stress reversal.

18.9 Design Load

Design load is the load to be taken for use in the appropriate method of design; it is the characteristic load in case of working stress method and characteristic load with appropriate partial safety factors for limit state design.

19 STABILITY OF THE STRUCTURE

19.1 Overturning

The stability of a structure as a whole against overturning shall be ensured so that the restoring moment shall be not less than the sum of 1.2 times the maximum overturning moment due to the characteristic dead load and 1.4 times the maximum overturning moment due to the characteristic imposed loads. In cases where dead load provides the restoring moment, only 0.9 times the characteristic dead load shall be considered. Restoring moment due to imposed loads shall be ignored.

19.1.1 The anchorages or counterweights provided for overhanging members (during construction and service) should be such that static equilibrium should remain, even when overturning moment is doubled.

19.2 Sliding

The structure shall have a factor against sliding of not less than 1.4 under the most adverse combination of the applied characteristic forces. In this case only 0.9 times the characteristic dead load shall be taken into account.

19.3 Probable Variation in Dead Load

To ensure stability at all times, account shall be taken of probable variations in dead load during construction, repair or other temporary measures. Wind and seismic loading shall be treated as imposed loading.

19.4 Moment Connection

In designing the framework of a building provisions shall be made by adequate moment connections or by a system of bracings to effectively transmit all the horizontal forces to the foundations.

19.5 Lateral Sway

Under transient wind load the lateral sway at the top should not exceed $H/500$, where H is the total height of the building. For seismic loading, reference should be made to good practice [6-5A(34)].

20 FIRE RESISTANCE

20.1 A structure or structural element required to have fire resistance should be designed to possess an appropriate degree of resistance to flame penetration; heat transmission and failure. The fire resistance of a structural element is expressed in terms of time in hours in accordance with good practice [6-5A(36)]. Fire resistance of concrete elements depends upon details of member size, cover to steel reinforcement detailing and type of aggregate (normal weight or light weight) used in concrete. General requirements for fire protection are given in good practice [6-5A(37)]

20.2 Minimum requirements of concrete cover and member dimensions for normal weight aggregate concrete members so as to have the required fire resistance shall be in accordance with **25.4.3** and Fig. 1 respectively.

20.3 The reinforcement detailing should reflect the changing pattern of the structural action and ensure that both individual elements and the structure as a whole contain adequate support, ties, bonds and anchorages for the required fire resistance.

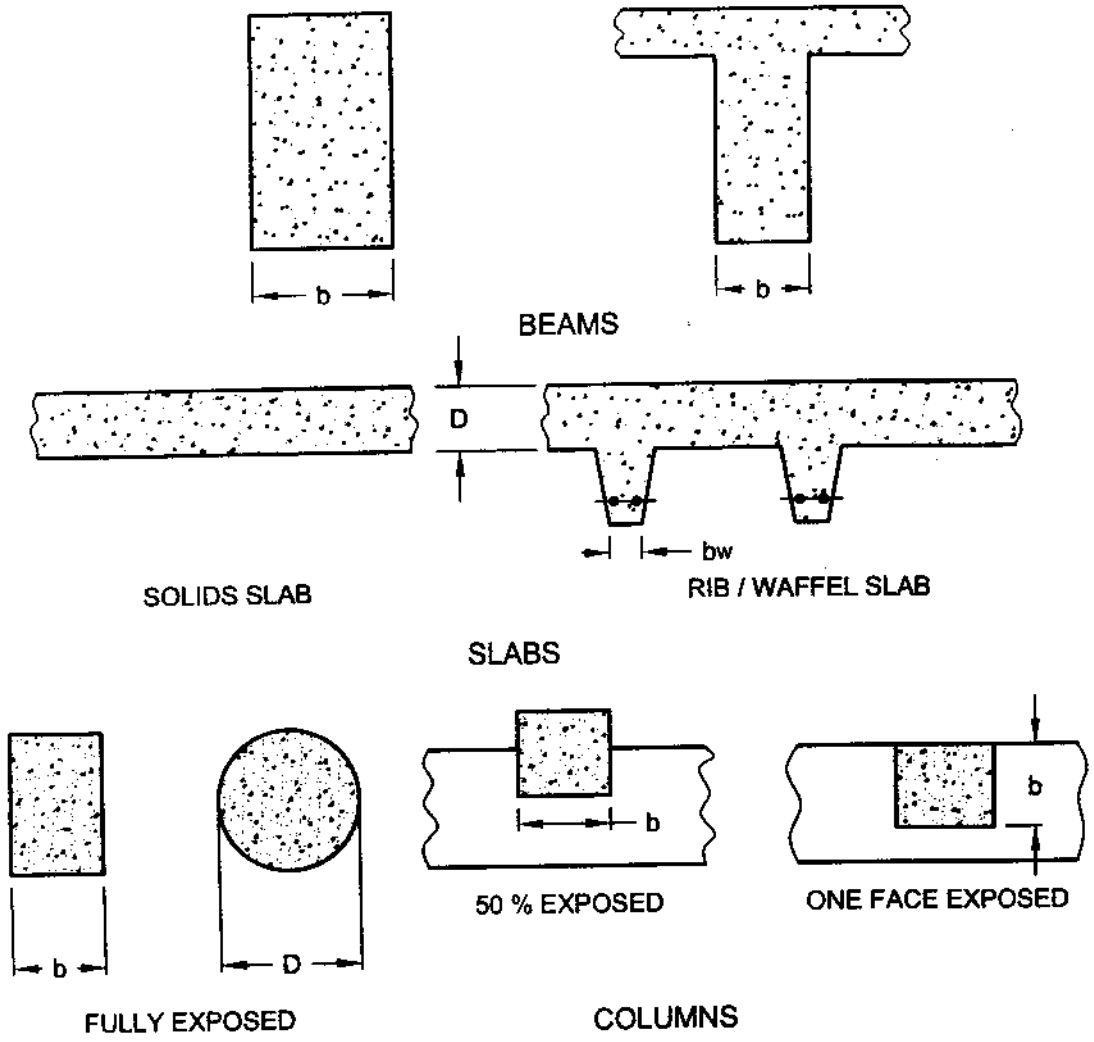
20.3.1 Additional measures such as application of fire resistant finishes, provision of fire resistant false ceilings and sacrificial steel in tensile zone, should be adopted in case the nominal cover required exceeds 40 mm for beams and 35 mm for slabs, to give protection against spalling.

20.4 Specialist literature may be referred to for determining fire resistance of the structures which have not been covered in Fig. 1 or Table 16A.

21 ANALYSIS

21.1 General

All structures may be analyzed by the linear elastic theory to calculate internal actions produced by design



Fire Resistance	*Maximum Beam Width*	*Rib Width of Slabs*	*Minimum Thickness of Floors*	*Column Dimension (b or D)*			*Minimum Wall Thickness*		
				Fully Exposed	50% Exposed	One Face Exposed	$p < 0.4\%$	$0.4\% \le p \le 1\%$	$p > 1\%$
h	*b*	b_w	*D*						
	mm	mm	mm	mm	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0.5	200	125	75	150	125	100	150	100	100
1	200	125	95	200	160	120	150	120	100
1.5	200	125	110	250	200	140	175	140	100
2	200	125	125	300	200	160	—	160	100
3	240	150	150	400	300	200	—	200	150
4	280	175	170	450	350	240	—	240	180

NOTES

1 These minimum dimensions relate specifically to the covers given in Table 16A.

2 p is the percentage of steel reinforcement.

FIG. 1 MINIMUM DIMENSIONS OF REINFORCED CONCRETE MEMBERS FOR FIRE RESISTANCE

loads. In lieu of rigorous elastic analysis, a simplified analysis as given in **21.4** for frames and as given in **21.5** for continuous beams may be adopted.

21.2 Effective Span

Unless otherwise specified, the effective span of a member shall be as follows:

a) *Simply Supported Beam or Slab* — The effective span of a member that is not built integrally with it supports shall be taken as clear span plus the effective depth of slab or beam or centre to centre of supports, whichever is less.

b) *Continuous Beam or Slab* — In the case of continuous beam or slab, if the width of the support is less than 1/12 of the clear span, the effective span shall be as given in **21.2** (a). If the supports are wider than 1/12 of the clear span or 600 mm whichever is less, the effective span shall be taken as under:

   1) For end span with one end fixed and the other continuous or for intermediate spans, the effective span shall be the clear span between supports;

   2) For end span with one end free and the other continuous, the effective span shall be equal to the clear span plus half the effective depth of the beam or slab or the clear span plus half the width of the discontinuous support, whichever is less;

   3) In the case of spans with roller or rocket bearings, the effective span shall always be the distance between the centres of bearings.

c) *Cantilever* — The effective length of a cantilever shall be taken as its length to the face of the support plus half the effective depth except where it forms the end of a continuous beam where the length to the centre of support shall be taken.

d) *Frames* — In the analysis of a continuous frame, centre-to-centre distance shall be used.

21.3 Stiffness

21.3.1 *Relative Stiffness*

The relative stiffness of the members may be based on the moment of inertia of the section determined on the basis of any one of the following definitions:

a) *Gross section* — The cross-section of the member ignoring reinforcement;

b) *Transformed section* — The concrete cross-section plus the area of reinforcement transformed on the basis of modular ratio (*see* **B-1.3**); or

c) *Cracked section* — The area of concrete in compression plus the area of reinforcement transformed on the basis of modular ratio.

The assumptions made shall be consistent for all the members of the structure throughout any analysis.

21.3.2 For deflection calculations, appropriate values of moment of inertia as specified in Annex C should be used.

21.4 Structural Frames

The simplifying assumptions as given in **21.4.1** to **21.4.3** may be used in the analysis of frames.

21.4.1 *Arrangement of Imposed Load*

a) Consideration may be limited to combinations of:

   1) Design dead load on all spans with full design imposed load on two adjacent spans; and

   2) Design dead load on all spans with full design imposed load on alternate spans.

b) When design imposed load does not exceed three-fourths of the design dead load, the load arrangement may be design dead load and design imposed load on all the spans.

NOTE — For beams and slabs continuous over support **21.4.1** (a) may be assumed.

21.4.2 *Substitute Frame*

For determining the moments and shears at any floor or roof level due to gravity loads, the beams at that level together with columns above and below with their far ends fixed may be considered to constitute the frame.

21.4.2.1 Where side sway consideration becomes critical due to unsymmetry in geometry or loading, rigorous analysis may be required.

21.4.3 For lateral loads, simplified methods may be used to obtain the moments and shears for structures that are symmetrical. For unsymmetrical or very tall structures, more rigorous methods should be used.

21.5 Moment and Shear Coefficients for Continuous Beams

21.5.1 Unless more exact estimates are made, for beams of uniform cross-section which support substantially uniformly distributed loads over three or more spans which do not differ by more than 15 percent of the longest, the bending moments and shear forces used in design may be obtained using the coefficients given in Table 12 and Table 13 respectively.

Table 12 Bending Moment Coefficients

(*Clause* 21.5.1)

Type of Load	Span Moments		Support Moments	
	Near Middle of End Span	At Middle of Interior Span	At Support Next to the End Support	At Other Interior Supports
(1)	(2)	(3)	(4)	(5)
Dead load and imposed load (fixed)	$+\frac{1}{12}$	$+\frac{1}{16}$	$-\frac{1}{10}$	$-\frac{1}{12}$
Imposed load (not fixed)	$+\frac{1}{10}$	$+\frac{1}{12}$	$-\frac{1}{9}$	$-\frac{1}{9}$

NOTE — For obtaining the bending moment, the coefficient shall be multiplied by the total design load and effective span.

Table 13 Shear for Coefficients

(*Clauses* 21.5.1 *and* 21.5.2)

Type of Load	At End Support	At Support Next to the End Support		At All Other Interior Supports
		Outer Side	Inner Side	
(1)	(2)	(3)	(4)	(5)
Dead load and imposed load (fixed)	0.4	0.6	0.55	0.5
Imposed load (not fixed)	0.45	0.6	0.6	0.6

NOTE — For obtaining the shear force, the coefficient shall be multiplied by the total design load.

For moments at supports where two unequal spans meet or in case where the spans are not equally loaded, the average of the two values for the negative moment at the support may be taken for design.

Where coefficients given in Table 12 are used for calculation of bending moments, redistribution referred to in **21.7** shall not be permitted.

21.5.2 *Beams and Slabs Over Free End Supports*

Where a member is built into a masonry wall which develops only partial restraint, the member shall be designed to resist a negative moment at the face of the support of $Wl/24$ where W is the total design load and l is the effective span, or such other restraining moment as may be shown to be applicable. For such a condition shear coefficient given in Table 13 at the end support may be increased by 0.05.

21.6 Critical Sections for Moment and Shear

21.6.1 For monolithic construction, the moments computed at the face of the supports shall be used in the design of the members at those section. For non-monolithic construction the design of the member shall be done keeping in view **21.2**.

21.6.2 *Critical Section for Shear*

The shears computed at the face of the support shall be used in the design of the member at that section except as in **21.6.2.1**.

21.6.2.1 When the reaction in the direction of the applied shear introduces compression into the end region of the member, sections located at a distance less than d from the face of the support may be designed for the same shear as that computed at distance d (*see* Fig. 2).

NOTE — The above clauses are applicable for beams generally carrying uniformly distributed load or where the principal load is located farther than $2d$ from the face of the support.

21.7 Redistribution of Moments

Redistribution of moments may be done in accordance with **36.1.1** for Limit State Method and in accordance with **B-1.2** for Working Stress Method. However, where simplified analysis using coefficients is adopted, redistribution of moments shall not be done.

22 BEAMS

22.0 Effective Depth

Effective depth of a beam is the distance between the centroid of the area of tension reinforcement and the maximum compression fibre, excluding the thickness of finishing material not placed monolithically with the member and the thickness of any concrete provided to allow for wear. This will not apply to deep beams.

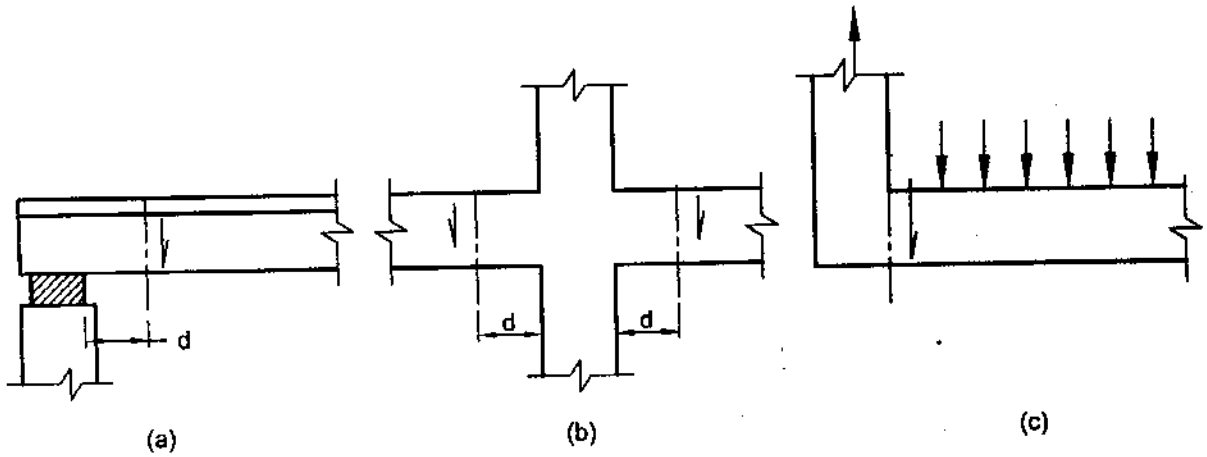


FIG. 2 TYPICAL SPORT CONDITIONS FOR LOCATING FACTORED SHEAR FORCE

22.1 T-Beams and L-Beams

22.1.1 *General*

A slab which is assumed to act as a compression flange of a T-beam or L-beam shall satisfy the following:

a) The slab shall be cast integrally with the web, or the web and the slab shall be effectively bonded together in any other manner; and

b) If the main reinforcement of the slab is parallel to the beam, transverse reinforcement shall be provided as in Fig. 3; such reinforcement shall not be less than 60 percent of the main reinforcement at mid span of the slab.

22.1.2 *Effective Width of Flange*

In the absence of more accurate determination, the effective width of flange may be taken as the following but in no case greater than the breadth of the web plus half the sum of the clear distances to the adjacent beams on either side.

a) For T-beams, $b_f = \frac{l_0}{6} + b_w + 6\,D_f$

b) For L-beams, $b_f = \frac{l_0}{12} + b_w + 3\,D_f$

c) For isolated beams, the effective flange width shall be obtained as below but in no case greater than the actual width:

$$\text{T-beams, } b_f = \frac{l_0}{\left(\frac{l_0}{b}\right)+4} + b_w$$

$$\text{L-beams, } b_f = \frac{0.5\,l_0}{\left(\frac{l_0}{b}\right)+4} + b_w$$

where

b_f = Effective width of flange,
l_0 = Distance between points of zero moments in the beam,
b_w = Breadth of the web,
D_f = Thickness of flange, and
b = Actual width of the flange.

NOTE — For continuous beams and frames, ℓ_0 may be assumed as 0.7 times the effective span.

22.2 Control of Deflection

The deflection of a structure or part thereof shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. The deflection shall generally be limited to the following:

a) The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the supports of floors, roofs and all other horizontal members, should not normally exceed span/250.

b) The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/ 350 or 20 mm whichever is less.

22.2.1 The vertical deflection limits may generally be assumed to be satisfied provided that the span to depth ratios are not greater than the values obtained as below:

a) Basic values of span to effective depth ratios for spans up to 10 m:

Cantilever	7
Simply supported	20
Continuous	26

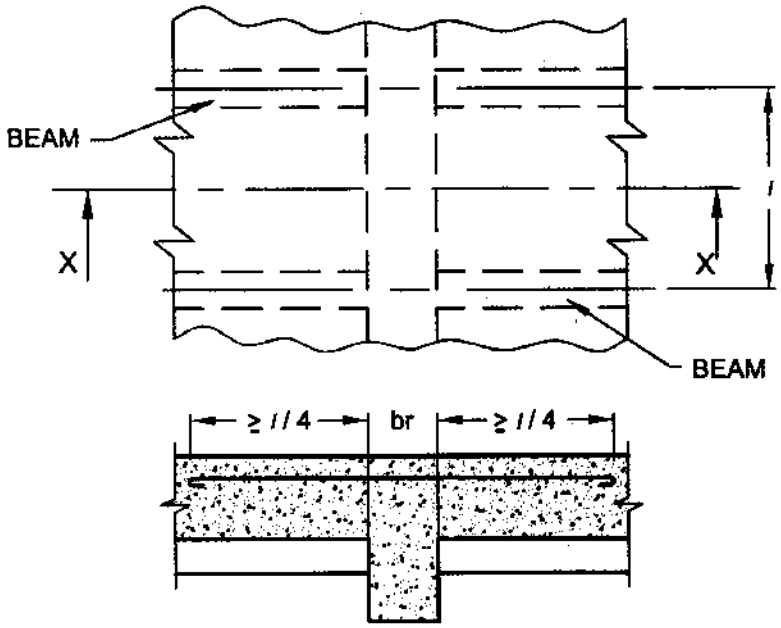


FIG. 3 TRANSVERSE REINFORCEMENT IN FLANGE OF T-BEAM WHEN MAIN REINFORCEMENT OF SLAB IS PARALLEL TO THE BEAM

b) For spans above 10 m, the values in (a) may be multiplied by 10/span in metres, except for cantilever in which case deflection calculations should be made.

c) Depending on the area and the stress of steel for tension reinforcement, the values in (a) or (b) shall be modified by multiplying with the modification factor obtained as per Fig. 4.

d) Depending on the area of compression reinforcement, the value of span to depth ratio be further modified by multiplying with the modification factor obtained as per Fig. 5.

e) For flanged beams, the values of (a) or (b) be modified as per Fig. 6 and the reinforcement percentage for use in Fig. 4 and 5 should be based on area of section equal to $b_f d$.

NOTE — When deflections are required to be calculated, the method given in Annex C may be used.

22.3 Slenderness Limits for Beams to Ensure Lateral Stability

A simply supported or continuous beam shall be so proportioned that the clear distance between the lateral restraints does not exceed 60 b or $\frac{250\,b^2}{d}$ whichever is less, where d is the effective depth of the beam and b the breadth of the compression face midway between the lateral restraints.

For a cantilever, the clear distance from the free end of the cantilever to the lateral restraint shall not exceed 25 b or $\frac{100\,b^2}{d}$ whichever is less.

23 SOLID SLABS

23.1 General

The provisions of **22.2** for beams apply to slabs also.

NOTES

1 For slabs spanning in two directions, the shorter of the two spans should be used for calculating the span to effective depth ratios.

2 For two-way slabs of shorter spans (up to 3.5 m) with mild steel reinforcement, the span to overall depth ratios given below may generally be assumed to satisfy vertical deflection limits for loading class up to 3 kN/m².

Simply supported slabs	35
Continuous slabs	40

For high strength deformed bars of grade Fe 415, the values given above should be multiplied by 0.8.

23.2 Slabs Continuous Over Supports

Slabs spanning in one direction and continuous over supports shall be designed according to the provisions applicable to continuous beams.

23.3 Slabs Monolithic with Supports

Bending moments in slabs (except flat slabs)

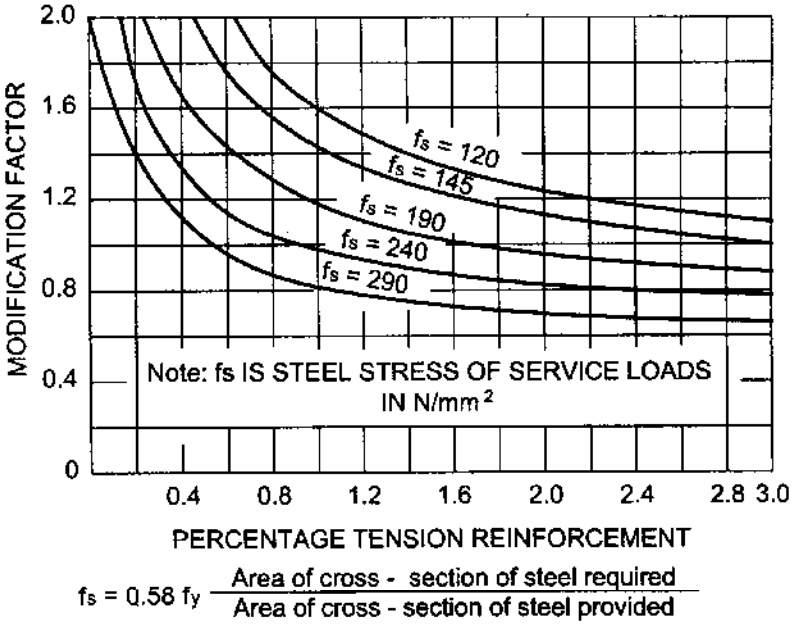


FIG. 4 MODIFICATION FACTOR FOR TENSION REINFORCEMENT

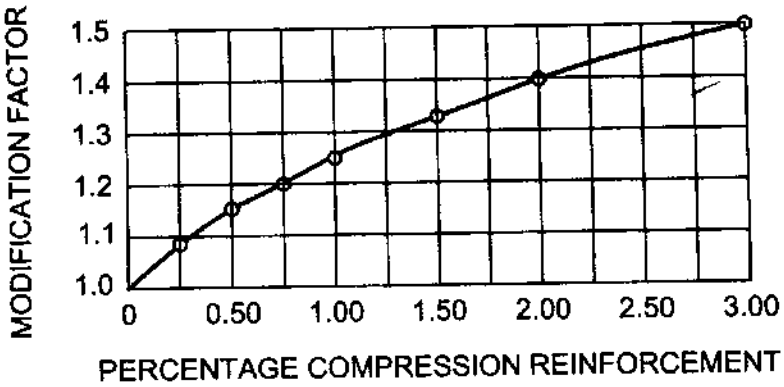


FIG. 5 MODIFICATION FACTOR FOR COMPRESSION REINFORCEMENT

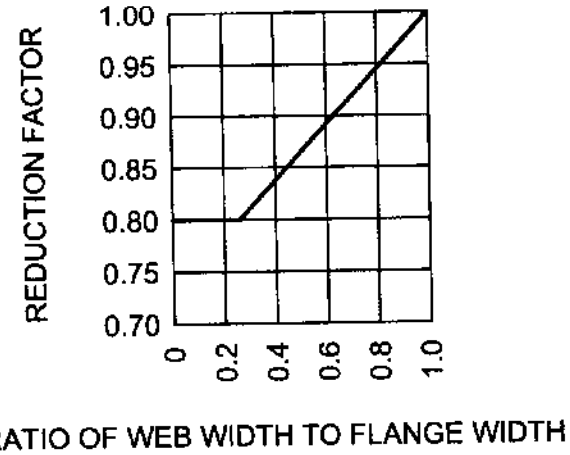


FIG. 6 REDUCTION FACTORS FOR RATIOS OF SPAN TO EFFECTIVE DEPTH FOR FLANGED BEAMS

constructed monolithically with the supports shall be calculated by taking such slabs either as continuous over supports and capable of free rotation, or as members of a continuous framework with the supports, taking into account the stiffness of such supports. If such supports are formed due to beams which justify fixity at the support of slabs, then the effects on the supporting beam, such as, the bending of the web in the transverse direction of the beam and the torsion in the longitudinal direction of the beam, wherever applicable, shall also be considered in the design of the beam.

23.3.1 For the purpose of calculation of moments in slabs in a monolithic structure, it will generally be sufficiently accurate to assume that members connected to the ends of such slabs are fixed in position and direction at the ends remote from their connections with the slabs.

23.3.2 *Slabs Carrying Concentrated Load*

23.3.2.1 If a solid slab supported on two opposite edges, carries concentrated loads the maximum bending moment caused by the concentrated loads shall be assumed to be resisted by an effective width of slab (measured parallel to the supporting edges) as follows:

a) For a single concentrated load, the effective width shall be calculated in accordance with the following equation provided that it shall not exceed the actual width of the slab:

$$b_{ef} = kx\left(1-\frac{x}{l_{ef}}\right)+a$$

where

b_{ef} = Effective width of slab,

k = Constant having the values given in Table 14 depending upon the ratio of the width of the slab (l') to the effective span l_{ef},

x = Distance of the centroid of the concentrated load from nearer support,

l_{ef} = Effective span, and

a = Width of the contact area of the concentrated load from nearer support measured parallel to the supported edge.

And provided further that in case of a load near the unsupported edge of a slab, the effective width shall not exceed the above value nor half the above value plus the distance of the load from the unsupported edge.

Table 14 Values of k for Simply Supported and Continuous Slabs

(*Clause* 24.3.2.1)

l/l_{ef}	k for Simply Supported Slabs	k for Continuous Slabs
(1)	(2)	(3)
0.1	0.4	0.4
0.2	0.8	0.8
0.3	1.16	1.16
0.4	1.48	1.44
0.5	1.72	1.68
0.6	1.96	1.84
0.7	2.12	1.96
0.8	2.24	2.08
0.9	2.36	2.16
1.0 and above	2.48	2.24

b) For two or more concentrated loads placed in a line in the direction of the span, the bending moment per metre width of slab shall be calculated separately for each load according to its appropriate effective width of slab calculated as in (a) above and added together for design calculations.

c) For two or more loads not in a line in the direction of the span, if the effective width of slab for one load does not overlap the effective width of slab for another load, both calculated as in (a) above, then the slab for each load can be designed separately. If the effective width of slab for one load overlaps the effective width of slab for an adjacent load, the overlapping portion of the slab shall be designed for the combined effect of the two loads.

d) For cantilever solid slabs, the effective width shall be calculated in accordance with the following equation:

$$b_{ef} = 1.2a_1 + a$$

where

b_{ef} = Effective width,

a_1 = Distance of the concentrated load from the face of the cantilever support, and

a = Width of contact area of the concentrated load measured parallel to the supporting edge.

Provided that the effective width of the cantilever slab shall not exceed one-third the length of the cantilever slab measured parallel to the fixed edge.

And provided further that when the concentrated load is placed near the extreme ends of the length of cantilever slab in the direction parallel to the fixed edge, the effective width shall not exceed the above value, nor shall it exceed half the above

value plus the distance of the concentrated load from the extreme end measured in the direction parallel to the fixed edge.

23.3.2.2 For slabs other than solid slabs, the effective width shall depend on the ratio of the transverse and longitudinal flexural rigidities of the slab. Where this ratio is one, that is, where the transverse and longitudinal flexural rigidities are approximately equal, the value of effective width as found for solid slabs may be used. But as the ratio decreases, proportionately smaller value shall be taken.

23.3.2.3 Any other recognized method of analysis for cases of slabs covered by **23.3.2.1** and **23.3.2.2** and for all other cases of slabs may be used with the approval of the engineer-in-charge.

23.3.2.4 The critical section for checking shear shall be as given in **33.2.4.1**.

23.4 Slabs Spanning in Two Directions at Right Angles

The slabs spanning in two directions at right angles and carrying uniformly distributed load may be designed by any acceptable theory or by using coefficients given in Annex D. For determining bending moments in slabs spanning in two directions at right angles and carrying concentrated load, any accepted method approved by the engineer-in-charge may be adopted.

NOTE — The most commonly used elastic methods are based on Pigeaud's or Wester guard's theory and the most commonly used limit state of collapse method is based on Johansen's yield-line theory.

23.4.1 *Restrained Slab with Unequal Conditions at Adjacent Panels*

In some cases the support moments calculated from Table 26 for adjacent panels may differ significantly. The following procedure may be adopted to adjust them:

a) Calculate the sum of moments at midspan and supports (neglecting signs).
b) Treat the values from Table 26 as fixed end moments.
c) According to the relative stiffness of adjacent spans, distribute the fixed end moments across the supports, giving new support moments.
d) Adjust midspan moment such that, when added to the support moments from (c) (neglecting signs), the total should be equal to that from (a).

If the resulting support moments are significantly greater than the value from Table 26, the tension steel over the supports will need to be extended further. The procedure should be as follows:

1) Take the span moment as parabolic between supports: its maximum value is as found from (d).
2) Determine the points of contraflexure of the new support moments [from (c)] with the span moment [from (1)].
3) Extend half the support tension steel at each end to at least an effective depth or 12 bar diameters beyond the nearest point of contraflexure.
4) Extend the full area of the support tension steel at each end to half the distance from (3).

23.5 Loads on Supporting Beams

The loads on beams supporting solid slabs spanning in two directions at right angles and supporting uniformly distributed loads, may be assumed to be in accordance with Fig. 7.

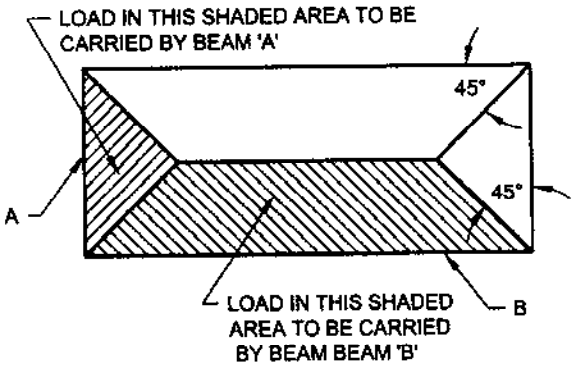


FIG. 7 LOAD CARRIED BY SUPPORTED BEAMS

24 COMPRESSION MEMBERS

24.1 Definitions

24.1.1 Column or strut is a compression member, the effective length of which exceeds three times the least lateral dimension.

24.1.2 *Short and Slender Compression Members*

A compression member may be considered as short when both the slenderness ratios $\frac{l_{ex}}{D}$ and $\frac{l_{ey}}{b}$ are less than 12:

where

l_{ex} = Effective length in respect of the major axis,
D = Depth in respect of the major axis,
l_{ey} = Effective length in respect of the minor axis, and
b = Width of the member.

It shall otherwise be considered as a slender compression member.

24.1.3 *Unsupported Length*

The unsupported length, l, of a compression member shall be taken as the clear distance between end restraints except that:

a) in flat slab construction, it shall be clear distance between the floor and the lower extremity of the capital, the drop panel or slab whichever is the least.

b) in beam and slab construction, it shall be the clear distance between the floor and the underside of the shallower beam framing into the columns in each direction at the next higher floor level.

c) in columns restrained laterally by struts, it shall be the clear distance between consecutive struts in each vertical plane, provided that to be an adequate support, two such struts shall meet the columns at approximately the same level and the angle between vertical planes through the struts shall not vary more than 30° from a right angle. Such struts shall be of adequate dimensions and shall have sufficient anchorage to restrain the member against lateral deflection.

d) in columns restrained laterally by struts or beams, with brackets used at the junction, it shall be the clear distance between the floor and the lower edge of the bracket, provided that the bracket width equals that of the beam strut and is at least half that of the column.

24.2 Effective Length of Compression Members

In the absence of more exact analysis, the effective length l_{ef} of columns may be obtained as described in Annex E.

24.3 Slenderness Limits for Columns

24.3.1 The unsupported length between end restraints shall not exceed 60 times the least lateral dimension of a column.

24.3.2 If, in any given plane, one end of a column is unrestrained, its unsupported length, l, shall not exceed $\frac{100\,b^2}{D}$.

where

b = Width of that cross-section, and

D = Depth of the cross-section measured in the plane under consideration.

24.4 Minimum Eccentricity

All columns shall be designed for minimum eccentricity, equal to the unsupported length of column/ 500 plus lateral dimensions/30, subject to a minimum of 20 mm. Where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

25 REQUIREMENTS GOVERNING REINFORCEMENT AND DETAILING

25.1 General

Reinforcing steel of same type and grade shall be used as main reinforcement in a structural member. However, simultaneous use of two different types or grades of steel for main and secondary reinforcement respectively is permissible.

25.1.1 Bars may be arranged singly, or in pairs in contact, or in groups of three or four bars bundled in contact. Bundled bars shall be enclosed within stirrups or ties. Bundled bars shall be tied together to ensure the bars remaining together. Bars larger than 32 mm diameter shall not be bundled, except in columns.

25.1.2 The recommendations for detailing for earthquake-resistant construction given in good practice [6-5A(38)] should be taken into consideration, where applicable (*see also* good practice [6-5A(38)]).

25.2 Development of Stress in Reinforcement

The calculated tension or compression in any bar at any section shall be developed on each side of the section by an appropriate development length or end anchorage or by a combination thereof.

25.2.1 *Development Length of Bars*

The development length L_d is given by

$$L_d = \frac{\phi\sigma_s}{4\tau_{bd}}$$

where

ϕ = Nominal diameter of the bar,

σ_s = Stress in bar at the section considered at design load, and

τ_{bd} = Design bond stress given in **25.2.1.1**.

NOTES

1 The development length includes anchorage values of hooks in tension reinforcement.

2 For bars of sections other than circular, the development length should be sufficient to develop the stress in the bar by bond.

25.2.1.1 Design bond stress in limit state method for plain bars in tension shall be as below:

Grade of concrete	M 20	M 25	M 30	M 35	M 40 and above
Design bond stress, τ_{bd}, N/mm^2	1.2	1.4	1.5	1.7	1.9

For deformed bars conforming to accepted standard [6-5A(40)] these values shall be increased by 60 percent.

For bars in compression, the values of bond stress for bars in tension shall be increased by 25 percent.

The values of bond stress in working stress design, are given in **B-2.1.**

25.2.1.2 *Bars bundled in contact*

The development length of each bar of bundled bars shall be that for the individual bar, increased by 10 percent for two bars in contact, 20 percent for three bars in contact and 33 percent for four bars in contact.

25.2.2 *Anchoring Reinforcing Bars*

25.2.2.1 *Anchoring bars in tension*

a) Deformed bars may be used without end anchorages provided development length requirement is satisfied. Hooks should normally be provide for plain bars in tension.

b) *Bends and hooks* — Bends and hooks shall conform to good practice [6-5A(26)]:

1) *Bends* — The anchorage value of bend shall be taken as 4 times the diameter of the bar for each 45° bend subject to a maximum of 16 times the diameter of the bar.

2) *Hooks* — The anchorage value of a standard U-type hook shall be equal to 16 times the diameter of the bar.

25.2.2.2 *Anchoring bars in compression*

The anchorage length of straight bar in compression shall be equal to the development length of bars in compression as specified in **25.2.1**. The projected length of hooks, bends and straight lengths beyond bends if provided for a bar in compression, shall only be considered for development length.

25.2.2.3 *Mechanical devices for anchorage*

Any mechanical or other device capable of developing the strength of the bar without damage to concrete may be used as anchorage with the approval of the engineer-in-charge.

25.2.2.4 *Anchoring shear reinforcement*

a) *Inclined bars* — The development length shall be as for bars in tension; this length shall be measured as under:

1) In tension zone, from the end of the sloping or inclined portion of the bar, and

2) In the compression zone, from the mild depth of the beam.

b) *Stirrups* — Notwithstanding any of the provisions of this standard, incase of secondary reinforcement, such as stirrups and transverse ties, complete development lengths and anchorage shall be deemed to have been provided when the bar is bent through an angle of at least 90° round a bar of at least its own diameter and is continued beyond the end of the curve for a length of at least eight diameters, or when the bar is bent through an angle of 135° and is continued beyond the end of the curve for a length of at least six bar diameters or when the bar is bent through an angle of 180° and is continued beyond the end of the curve for a length of at least four bar diameters.

25.2.2.5 *Bearing stresses at bends*

The bearing stress in concrete for bends and hooks described in good practice [6-5A(26)] need not be checked. The bearing stress inside a bend in any other bend shall be calculated as given below:

$$\text{Bearing stress} = \frac{F_{bt}}{r\phi}$$

where

F_{bt} = Tensile force due to design loads in a bar or group of bars,

r = Internal radius of the bend, and

ϕ = Size of the bar or, in bundle, the size of bar of equivalent area.

For limit state method of design, this stress shall not exceed $\frac{1.5\, f_{ck}}{1+2\phi/a}$ where f_{ck} is the characteristic cube strength of concrete and a, for a particular bar or group of bars in contact shall be taken as the centre to centre distance between bars or groups of bars perpendicular to the plane of the bend; for a bar or group of bars adjacent to the face of the member a shall be taken as the cover plus size of bar (ϕ). For working stress method of design, the bearing stress shall not exceed $\frac{f_{ck}}{1+2\phi/a}$.

25.2.2.6 If a change in direction of tension or compression reinforcement induces a resultant force acting outward tending to split the concrete, such force should be taken up by additional links or

stirrups. Bent tension bar at a re-entrant angle should be avoided.

25.2.3 *Curtailment of Tension Reinforcement in Flexural Members*

25.2.3.1 For curtailment, reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of the member or 12 times the bar diameter, whichever is greater except at simple support or end of cantilever. In addition **25.2.3.2** to **25.2.3.5** shall also be satisfied.

NOTE — A point at which reinforcement is no longer required to resist flexure is where the resistance moment of the section, considering only the continuing bars, is equal to the design moment.

25.2.3.2 Flexural reinforcement shall not be terminated in a tension zone unless any one of the following conditions is satisfied:

a) The shear at the cut-off point does not exceed two-thirds that permitted, including the shear strength of web reinforcement provided.

b) Stirrup area in excess of that required for shear and torsion is provided along each terminated bar over a distance from the cut-off point equal to three-fourths the effective depth of the member. The excess stirrup area shall be not less than $0.4\ bs/f_y$, where b is the breadth of beam, s is the spacing and f_y is the characteristic strength of reinforcement in N/mm^2. The resulting spacing shall not exceed $d/8\ \beta_b$ where β_b is the ratio of the area of bars cut-off to the total area of bars at the section, and d is the effective depth.

c) For 36 mm and smaller bars, the continuing bars provide double the area required for flexure at the cut-off point and the shear does not exceed three-fourths that permitted.

25.2.3.3 *Positive moment reinforcement*

a) At least one-third the positive moment reinforcement in simple members and one-fourth the positive moment reinforcement in continuous members shall extend along the same face of the member into the support, to a length equal to $L_d/3$.

b) When a flexural member is part of the primary lateral load resisting system, the positive reinforcement required to be extended into the support as described in (a) shall be anchored to develop its design stress in tension at the face of the support.

c) At simple supports and at points of inflection, positive moment tension reinforcement shall be limited to a diameter such that L_d computed for f_d by **25.2.1** does not exceed

$$\frac{M_1}{V} + L_0$$

where

M_1 = Moment of resistance of the section assuming all reinforcement at the section to be stressed to f_d;

f_d = $0.87 f_y$ in the case of limit state design and the permissible stress σ_{st} in the case of working stress design;

V = Shear force at the section due to design loads;

L_0 = Sum of the anchorage beyond the centre of the support and the equivalent anchorage value of any hook or mechanical anchorage at simple support; and at a point of inflection, L_0 is limited to the effective depth of the members or 12ϕ, whichever is greater; and

ϕ = Diameter of bar.

The value of M_1/V in the above expression may be increased by 30 percent when the ends of the reinforcement are confined by a compressive reaction.

25.2.3.4 *Negative moment reinforcement*

At least one-third of the total reinforcement provided for negative moment at the support shall extend beyond the point of inflection for a distance not less than the effective depth of the member of 12ϕ or one-sixteenth of the clear span whichever is greater.

25.2.3.5 *Curtailment of bundled bars*

Bars in a bundle shall terminate at different points spaced apart by not less than 40 times the bar diameter except for bundles stopping at a support.

25.2.4 *Special Members*

Adequate end anchorage shall be provided for tension reinforcement in flexural members where reinforcement stress is not directly proportional to moment, such as sloped, stepped, or tapered footings; brackets; deep beams; and members in which the tension reinforcement is not parallel to the compression face.

25.2.5 *Reinforcement Splicing*

Where splices are provided in the reinforcing bars, they shall as far as possible be away from the sections of maximum stress and be staggered. It is recommended that splices in flexural members should not be at sections where the bending moment is more than 50 percent of the moment of resistance; and not more than half the bars shall be spliced at a section.

Where more than one-half of the bars are spliced at a

section or where splices are made at points of maximum stress, special precautions shall be taken such as increasing the length of lap and/or using spirals or closely-spaced stirrups around the length of the splice.

25.2.5.1 *Lap splices*

a) Lap splices shall not be used for bars larger than 36 mm; for larger diameters, bars may be welded (*see* **11.4**); in cases where welding is not practicable, lapping of bars larger than 36 mm may be permitted, in which case additional spirals should be provided around the lapped bars.

b) Lap splices shall be considered as staggered if the centre to centre distance of the splices is not less than 1.3 times the lap length calculated as described in (c).

c) Lap length including anchorage value of hooks for bars in flexural tension shall be L_d (*see* **25.2.1**) or 30ϕ whichever is greater. The straight length of the lap shall not be less than 15ϕ or 200 mm. The following provisions shall also apply:

   Where lap occurs for a tension bar located at:

   1) top of a section as cast and the minimum cover is less than twice the diameter of the lapped bar, the lap length shall be increased by a factor of 1.4.

   2) corner of a section and the minimum cover to either face is less than twice the diameter of the lapped bar or where the clear distance between adjacent laps is less than 75 mm or 6 times the diameter of lapped bar, whichever is greater, the lap length should be increased by a factor of 1.4.

      Where both conditions (1) and (2) apply, the lap length should be increased by a factor of 2.0.

      NOTE: Splices in tension members shall be enclosed in spirals made of bars not less than 6 mm diameter with pitch not more than 100 mm.

d) The lap length in compression shall be equal to the development length in compression, calculated as described in **25.2.1**, but not less than 24ϕ.

e) When bars of two different diameters are to be spliced, the lap length shall be calculated on the basis of diameter of the smaller bar.

f) When splicing of welded wire fabric is to be carried out, lap splices of wires shall be made so that overlap measured between the extreme cross wires shall be not less than the spacing of cross wires plus 100 mm.

g) In case of bundled bars, lapped splices of bundled bars shall be made by splicing one bar at a time; such individual splices within a bundle shall be staggered.

25.2.5.2 *Strength of welds*

The following values may be used where the strength of the weld has been proved by tests to be at least as great as that of the parent bar.

a) *Splices in compression* — For welded splices and mechanical connection, 100 percent of the design strength of joined bars.

b) *Splices in tension*

   1) 80 percent of the design strength of welded bars (100 percent if welding is strictly supervised and if at any cross-section of the member not more than 20 percent of the tensile reinforcement is welded).

   2) 100 percent of design strength of mechanical connection.

25.2.5.3 *End-bearing splices*

End-bearing splices shall be used only for bars in compression. The ends of the bars shall be square cut and concentric bearing ensured by suitable devices.

25.3 Spacing of Reinforcement

25.3.1 For the purpose of this clause, the diameter of a round bar shall be its nominal diameter, and in the case of bars which are not round or in the case of deformed bars or crimped bars, the diameter shall be taken as the diameter of a circle giving an equivalent effective area. Where spacing limitations and minimum concrete cover (*see* **25.4**) are based on bar diameter, a group of bars bundled in contact shall be treated as a single bar of diameter derived from the total equivalent area.

25.3.2 *Minimum Distance Between Individual Bars*

The following shall apply for spacing of bars:

a) The horizontal distance between two parallel main reinforcing bars shall usually be not less than the greatest of the following:

   1) The diameter of the bar if the diameters are equal,

   2) The diameter of the larger bar if the diameters are unequal, and

   3) 5 mm more than the nominal maximum size of coarse aggregate.

      NOTE — This does not preclude the use of larger size of aggregates beyond the congested reinforcement in the same member; the size of aggregates may be reduced around congested reinforcement to comply with this provision.

b) Greater horizontal distance than the minimum specified in (a) should be provided wherever possible. However, when needle vibrators are used the horizontal distance between bars of a group may be reduced to two-thirds the nominal maximum size of the coarse aggregate, provided that sufficient space is left between groups of bars to enable the vibrator to be immersed.

c) Where there are two or more rows of bars, the bars shall be vertically in line and the minimum vertical distance between the bars shall be 15 mm, two-thirds the nominal maximum size of aggregate or the maximum size of bars, whichever is greater.

25.3.3 *Maximum Distance Between Bars in Tension*

Unless the calculation of crack widths shows that a greater spacing is acceptable, the following rules shall be applied to flexural members in normal internal or external conditions of exposure.

a) *Beams* — The horizontal distance between parallel reinforcement bars, or groups, near the tension face of a beam shall not be greater than the value given in Table 15 depending on the amount of re-distribution carried out in analysis and the characteristic strength of the reinforcement.

Table 15 Clear Distance Between Bars

(*Clause* 25.3.3)

f_y	Percentage Re-distribution to or from Section Considered				
	−30	−15	0	+15	+30
	Clear Distance Between Bars				
N/mm²	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)
250	215	260	300	300	300
415	125	155	180	210	235
500	105	130	150	175	195

NOTE — The spacings given in table are not applicable to members subjected to particularly aggressive environments unless in the calculation of the moment of resistance f_y has been limited to 300 N/mm² in limit state design and σ_{st} limited to 165 N/mm² in working stress design.

b) *Slabs*

1) The horizontal distance between parallel main reinforcement bars shall not be more than three times the effective depth of solid slab or 300 mm whichever is smaller.

2) The horizontal distance between parallel reinforcement bars provided against shrinkage and temperature shall not be more than five times the effective depth of a solid slab or 450 mm whichever is smaller.

25.4 Nominal Cover to Reinforcement

25.4.1 *Nominal Cover*

Nominal cover is the design depth of concrete cover to all steel reinforcements, including links. It is the dimension used in design and indicated in the drawings. It shall be not less than the diameter of the bar.

25.4.2 *Nominal Cover to Meet Durability Requirement*

Minimum values for the nominal cover of normal-weight aggregate concrete which should be provided to all reinforcement, including links depending on the condition of exposure described in **7.2.2** shall be as given in Table 16.

25.4.2.1 However for a longitudinal reinforcing bar in a column nominal cover shall in any case not be less than 40 mm, or less than the diameter of such bar. In the case of columns of minimum dimension of 200 mm or under, whose reinforcing bars do not exceed 12 mm, a nominal cover of 25 mm may be used.

25.4.2.2 For footings minimum cover shall be 50 mm.

25.4.3 *Nominal Cover to Meet Specified Period of Fire Resistance*

Minimum values of nominal cover of normal-weight aggregate concrete to be provided to all reinforcement including links to meet specified period of fire resistance shall be given in Table 16 A.

Table 16 Nominal Cover to Meet Durability Requirements

(*Clause* 25.4.2)

Exposure	Nominal Concrete Cover in mm not Less Than
(1)	(2)
Mild	20
Moderate	30
Severe	45
Very Severe	50
Extreme	75

NOTES

1 For main reinforcement up to 12 mm diameter bar for mild exposure the nominal cover may be reduced by 5 mm.

2 Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by $^{+10}_{-0}$ mm.

3 For exposure condition 'severe' and 'very severe', reduction of 5 mm may be made, where concrete grade is M 35 and above.

Table 16A Nominal Cover to Meet Specified Period of Fire Resistance

(*Clauses* 20.4 *and* 25.4.3 and *Fig.* 1)

Fire Resistance	Beams		Nominal Cover				
	Simply supported	Continuous	Slabs		Ribs		Columns
			Simply supported	Continuous	Simply supported	Continuous	
h	mm	mm	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
0.5	20	20	20	20	20	20	40
1	20	20	20	20	20	20	40
1.5	20	20	25	20	35	20	40
2	40	30	35	25	45	35	40
3	60	40	45	35	55	45	40
4	70	50	55	45	65	55	40

NOTES

1 The nominal covers given relate specifically to the minimum member dimensions given in Fig. 1.

2 Cases that lie below the bold line require attention to the additional measures necessary to reduce the risks of spalling (*see* **20.3.1**).

25.5 Requirements of Reinforcement for Structural Members

25.5.1 *Beams*

25.5.1.1 *Tension reinforcement*

a) *Minimum reinforcement* — The minimum area of tension reinforcement shall be not less than that given by the following:

$$\frac{A_s}{bd} = \frac{0.85}{f_y}$$

where

A_s = Minimum area of tension reinforcement,

b = Breadth of beam of the breadth of the web of T-beam,

d = Effective depth, and

f_y = Characteristic strength of reinforcement in N/mm².

b) *Maximum reinforcement* — The maximum area of tension reinforcement shall not exceed 0.04 bD.

25.5.1.2 *Compression reinforcement*

The maximum area of compression reinforcement shall not exceed 0.04 bD. Compression reinforcement in beams shall be enclosed by stirrups for effective lateral restraint. The arrangement of stirrups shall be as specified in **25.5.3.2**.

25.5.1.3 *Side face reinforcement*

Where the depth of the web in a beam exceeds 750 mm, side face reinforcement shall be provided along the two faces. The total area of such reinforcement shall be not less than 0.1 percent of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness whichever is less.

25.5.1.4 *Transverse reinforcement in beams for shear and torsion*

The transverse reinforcement in beams shall be taken around the outer-most tension and compression bars. In T-beams and I-beams, such reinforcement shall pass around longitudinal bars located close to the outer face of the flange.

25.5.1.5 *Maximum spacing of shear reinforcement*

The maximum spacing of shear reinforcement measured along the axis of the member shall not exceed 0.75 d for vertical stirrups and d for inclined stirrups at 45°, where d is the effective depth of the section under consideration. In no case shall the spacing exceed 300 mm.

25.5.1.6 *Minimum shear reinforcement*

Minimum shear reinforcement in the form of stirrups shall be provided such that:

$$\frac{A_{sv}}{bs_v} \geq \frac{0.4}{0.87 f_y}$$

where

A_{sv} = Total cross-sectional area of stirrups legs effective in shear,

s_v = Stirrup spacing along the length of the member,

b = Breadth of the beam or breadth of the web of flanged beam, and

f_y = Characteristic strength of the stirrup reinforcement in N/mm^2 which shall not be taken greater than 415 N/mm^2.

Where the maximum shear stress calculated is less than half the permissible value and in members of minor structural importance such as lintels, this provision need not be complied with.

25.5.1.7 *Distribution of torsion reinforcement*

When a member is designed for torsion (*see* **40** or **B-6**) torsion reinforcement shall be provided as below:

a) The transverse reinforcement for torsion shall be rectangular closed stirrups placed perpendicular to the axis of the member. The spacing of the stirrups shall not exceed the least of x_1, $\frac{x_1 + y_1}{4}$ and 300 mm, where x_1 and y_1 are respectively the short and long dimensions of the stirrup.

b) Longitudinal reinforcement shall be placed as close as is practicable to the corners of the cross-section and in all cases, there shall be at least one longitudinal bar in each corner of the ties. When the cross-sectional dimension of the member exceeds 450 mm, additional longitudinal bars shall be provided to satisfy the requirements of minimum reinforcement and spacing given in **25.5.1.3**.

25.5.1.8 Reinforcement in flanges of T-beams and L-beams shall satisfy the requirements in **22.1.1**(b). Where flanges are in tension, a part of the main tension reinforcement shall be distributed over the effective flange width or a width equal to one-tenth of the span, whichever is smaller. If the effective flange width exceeds one-tenth of the span, nominal longitudinal reinforcement shall be provided in the outer portions of the flange.

25.5.2 *Slabs*

The rules given in **25.5.2.1** and **25.5.2.2** shall apply to slabs in addition to those given in the appropriate clauses.

25.5.2.1 *Minimum reinforcement*

The mild steel reinforcement in either direction in slabs shall not be less than 0.15 percent of the total cross-sectional area. However, this value can be reduced to 0.12 percent when high strength deformed bars or welded wire fabric are used.

25.5.2.2 *Maximum diameter*

The diameter of reinforcing bars shall not exceed one-eight of the total thickness of the slab.

25.5.3 *Columns*

25.5.3.1 *Longitudinal reinforcement*

a) The cross-sectional area of longitudinal reinforcement, shall be not less than 0.8 percent nor more than 6 percent of the gross cross-sectional area of the column.

NOTE — The use of 6 percent reinforcement may involve practical difficulties in placing and compacting of concrete; hence lower percentage is recommended. Where bars from the columns below have to be lapped with those in the column under consideration, the percentage of steel shall usually not exceed 4 percent.

b) In any column that has a larger cross-sectional area than that required to support the load, the minimum percentage of steel shall be based upon the area of concrete required to resist the direct stress and not upon the actual area.

c) The minimum number of longitudinal bars provided in a column shall be four in rectangular columns and six in circular columns.

d) The bars shall not be less than 12 mm in diameter.

e) A reinforced concrete column having helical reinforcement shall have at least six bars of longitudinal reinforcement within the helical reinforcement.

f) In a helically reinforced column, the longitudinal bars shall be in contact with the helical reinforcement and equidistant around its inner circumference.

g) Spacing of longitudinal bars measured along the periphery of the column shall not exceed 300 mm.

h) In case of pedestals in which the longitudinal reinforcement is not taken in account in strength calculations, nominal longitudinal reinforcement not less than 0.15 percent of the cross-sectional area shall be provided.

NOTE — Pedestal is a compression member, the effective length of which does not exceed three times the least lateral dimension.

25.5.3.2 *Transverse reinforcement*

a) *General* — A reinforced concrete compression member shall have transverse or helical reinforcement so disposed that every longitudinal bar nearest to the compression

face has effective lateral support against buckling subject to provisions in (b). The effective lateral support is given by transverse reinforcement either in the form of circular rings capable of taking up circumferential tension or by polygonal links (lateral ties) with internal angles not exceeding 135°. The ends of the transverse reinforcement shall be properly anchored [*see* **25.2.2.4** (b)].

b) *Arrangement of transverse reinforcement*

1) If the longitudinal bars are not spaced more than 75 mm on either side, transverse reinforcement need only to go round corner and alternate bars for the purpose of providing effective lateral supports (*see* Fig. 8).

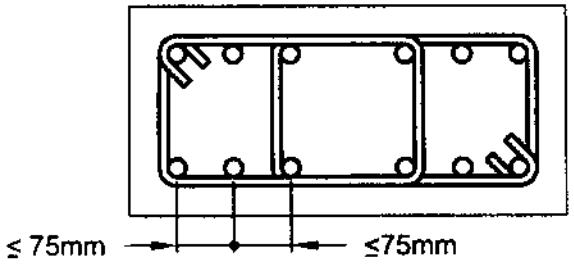


FIG. 8

2) If the longitudinal bars spaced at a distance of not exceeding 48 times the diameter of the tie are effectively tied in two directions, additional longitudinal bars in between these bars need to be tied in one direction by open ties (*see* Fig. 9).

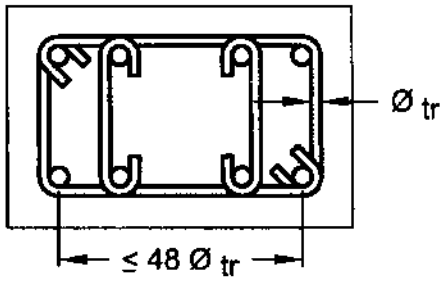


FIG. 9

3) Where the longitudinal reinforcing bars in a compression member are placed in more than one row, effective lateral support to the longitudinal bars in the inner rows may be assumed to have been provided if:

i) transverse reinforcement is provided for the outer-most row in accordance with **25.5.3.2**, and

ii) no bar of the inner row is closer to the nearest compression face than three times the diameter of the largest bar in the inner row (*see* Fig. 10).

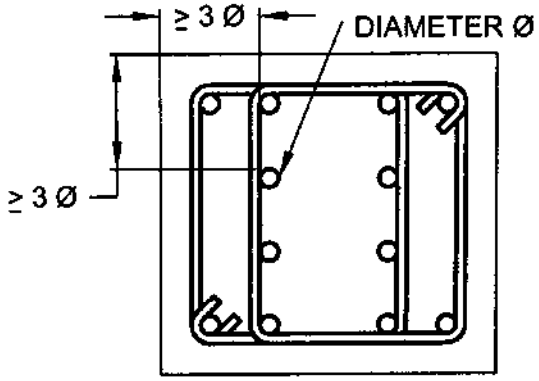


FIG. 10

4) Where the longitudinal bars in a compression member are grouped (not in contact) and each group adequately tied with transverse reinforcement in accordance with **25.5.3.2**, the transverse reinforcement for the compression member as a whole may be provided on the assumption that each group is a single longitudinal bar for purpose of determining the pitch and diameter of the transverse reinforcement in accordance with **25.5.3.2**. The diameter of such transverse reinforcement need not, however, exceed 20 mm (*see* Fig. 11).

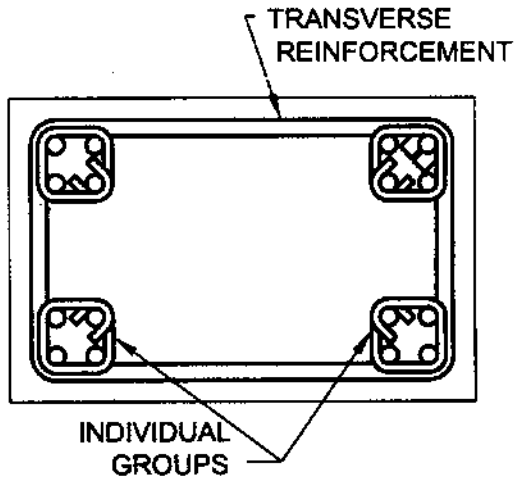


FIG. 11

c) *Pitch and diameter of lateral ties*

1) *Pitch* — The pitch of transverse reinforcement shall be not more than the least of the following distances:

i) The least lateral dimension of the compression members;

ii) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied; and

iii) 300 mm.

2) *Diameter* — The diameter of the polygonal links or lateral ties shall be not less than one-fourth of the diameter of the largest longitudinal bar, and in no case less than 6 mm.

d) *Helical reinforcement*

1) *Pitch* — Helical reinforcement shall be of regular formation with the turns of the helix spaced evenly and its ends shall be anchored properly by providing one and a half extra turns of the spiral bar. Where an increased load on the column on the strength of the helical reinforcement is allowed for, the pitch of helical turns shall be not more than 75 mm, nor more than one-sixth of the core diameter of the column, nor less than 25 mm, nor less than three times the diameter of the steel bar forming the helix. In other cases, the requirements of **25.5.3.2** shall be complied with.

2) The diameter of the helical reinforcement shall be in accordance with **25.5.3.2** (c) (2).

25.5.3.3 In columns where longitudinal bars are offset at a splice, the slope of the inclined portion of the bar with the axis of the column shall not exceed 1 in 6, and the portions of the bar above and below the offset shall be parallel to the axis of the column. Adequate horizontal support at the offset bends shall be treated as a matter of design, and shall be provided by metal ties, spirals, or parts of the floor construction. Metal ties or spirals so designed shall be placed near (not more than eight-bar diameters from) the point of bend. The horizontal thrust to be resisted shall be assumed as one and half times the horizontal components of the nominal stress in the inclined portion of the bar. Offset bars shall be bent before they are placed in the forms. Where column faces are offset 75 mm or more, splices of vertical bars adjacent to the offset face shall be made by separate dowels overlapped as specified in **25.2.5.1**.

26 EXPANSION JOINTS

26.1 Structures in which marked changes in plan dimensions take place abruptly shall be provided with expansion on joints at the section where such changes occur. Expansion joints shall be so provided that the necessary movement occurs with a minimum resistance at the joint. The structures adjacent to the joint should preferably be supported on separate columns or walls but not necessarily on separate foundations. Reinforcement shall not extend across an expansion joint and the break between the sections shall be complete.

26.2 The details as to the length of a structure where expansion joints have to be provided can be determined after taking into consideration various factors, such as temperature, exposure to weather, the time and season of the laying of the concrete, etc. Normally structures exceeding 45 m in length are designed with one or more expansion joints. However in view of the large number of factors involved in deciding the location, spacing and nature of expansion joints, the provision of expansion joint in reinforced cement concrete structures should be left to the discretion of the designer. Good practice [6-5A(41)] gives the design considerations, which need to be examined and provided for.

SECTION 5A (d)
SPECIAL DESIGN REQUIREMENTS FOR STRUCTURAL MEMBERS AND SYSTEMS

27 CONCRETE CORBELS

27.1 General

A corbel is a short cantilever projection which supports a load bearing member and where:

a) the distance a_v between the line of the reaction to the supported load and the root of the corbel is less than d (the effective depth of the root of the corbel); and

b) the depth at the outer edge of the contact area of the supported load is not less than one-half of the depth at the root of the corbel.

The depth of the corbel at the face of the support is determined in accordance with **39.5.1**.

27.2 Design

27.2.1 *Simplifying Assumptions*

The concrete and reinforcement may be assumed to act as elements of a simple strut-and-tie system, with the following guidelines:

half of the design vertical load on the corbel (*see also* **27.2.4**).

b) Compatibility of strains between the strut-and-tie at the corbel root should be ensured.

It should be noted that the horizontal link requirement described in **27.2.3** will ensure satisfactory serviceability performance.

27.2.2 *Reinforcement Anchorage*

At the front face of the corbel, the reinforcement should be anchored either by:

a) *welding to a transverse bar of equal strength* — In this case the bearing area of the load should stop short of the face of the support by a distance equal to the cover of the tie reinforcement, or

b) *bending back the bars to form a loop* — In this case the bearing area of the load should not project beyond the straight portion of the bars forming the main tension reinforcement.

27.2.3 *Shear Reinforcement*

Shear reinforcement should be provided in the form of horizontal links distributed in the upper two-third of the effective depth of root of the corbel; this reinforcement should be not less than one-half of the area of the main tension reinforcement and should be adequately anchored.

27.2.4 *Resistance to Applied Horizontal Force*

Additional reinforcement connected to the supported member should be provided to transmit this force in its entirety.

28 DEEP BEAMS

28.1 General

a) A beam shall be deemed to be a deep beam when the ratio of effective span to overall depth, $\frac{l}{D}$ is less than:

1) 2.0 for a simply supported beam; and

2) 2.5 for a continuous beam.

b) A deep beam complying with the requirements of **28.2** and **28.3** shall be deemed to satisfy the provisions for shear.

28.2 Lever Arm

The lever arm z for a deep beam shall be determined as below:

$z = 0.2\,(l + 2D)$ when $1 \le \frac{l}{D} \le 2$

or

$z = 0.6$ when $\frac{l}{D} < 1$

b) *For continuous beams*:

$z = 0.2\,(l + 1.5D)$ when $1 \le \frac{l}{D} \le 2.5$

or

$z = 0.5\,l$ when $\frac{l}{D} < 1$

where l is the effective span taken as centre to centre distance between supports or 1.15 times the clear span, whichever is smaller, and D is the overall depth.

28.3 Reinforcement

28.3.1 *Positive Reinforcement*

The tensile reinforcement required to resist positive bending moment in any span of a deep beam shall:

a) extend without curtailment between supports;

b) be embedded beyond the face of each support, so that at the face of the support it shall have a development length not less than $0.8\,L_d$; where L_d is the development length (*see* **25.2.1**), for the design stress in the reinforcement; and

c) be placed within a zone of depth equal to $0.25\,D - 0.05\,l$ adjacent to the tension face of the beam where D is the overall depth and l is the effective span.

28.3.2 *Negative Reinforcement*

a) *Termination of reinforcement* — For tensile reinforcement required to resist negative bending moment over a support of a deep beam:

1) It shall be permissible to terminate not more than half of the reinforcement at a distance of $0.5\,D$ from the face of the support where D is as defined in **29.2**; and

2) The remainder shall extend over the full span.

b) *Distribution* — When ratio of clear span to overall depth is in the range 1.0 to 2.5, tensile reinforcement over a support of a deep beam shall be placed in two zones comprising:

1) a zone of depth 0.2 D, adjacent to the tension face, which shall contain a proportion of the tension steel given by

$$0.5\left(\frac{l}{D}-0.5\right)$$

where

l = Clear span, and

D = Overall depth.

2) A zone measuring 0.3 D on either side of the mid-depth of the beam, which shall contain the remainder of the tension steel, evenly distributed.

For span to depth ratios less than unity, the steel shall be evenly distributed over a depth of 0.8 D measured from the tension face.

28.3.3 *Vertical Reinforcement*

If forces are applied to a deep beam in such a way that hanging action is required, bars or suspension stirrups shall be provided to carry all the forces concerned.

28.3.4 *Side Face Reinforcement*

Side face reinforcement shall comply with requirements of minimum reinforcement of wall (*see* **31.4**).

29 RIBBED, HOLLOW BLOCK OR VOIDED SLAB

29.1 General

This covers the slabs constructed in one of the ways described below:

a) As a series of concrete ribs with topping cast on forms which may be removed after the concrete has set;

b) As a series of concrete ribs between precast blocks which remain part of the completed structure; the top of the ribs may be connected by a topping of concrete of the same strength as that used in the ribs; and

c) With a continuous top and bottom face but containing voids of rectangular, oval or other shape.

29.2 Analysis of Structure

The moments and forces due to design loads on continuous slabs may be obtained by the methods given in Section 5A (c) for solid slabs. Alternatively, the slabs may be designed as a series of simply supported spans provided they are not exposed to weather or corrosive conditions; wide cracks may develop at the supports and the engineer shall satisfy himself that these will not impair finishes or lead to corrosion of the reinforcement.

29.3 Shear

Where hollow blocks are used, for the purpose of calculating shear stress, the rib width may be increased to take account of the wall thickness of the block on one side of the rib; with narrow precast units, the width of the jointing mortar or concrete may be included.

29.4 Deflection

The recommendations for deflection in respect of solid slabs may be applied to ribbed, hollow block or voided construction. The span to effective depth ratios given in **22.2** for a flanged beam are applicable but when calculating the final reduction factor for web width, the rib width for hollow block slabs may be assumed to include the walls of the blocks on both sides of the rib. For voided slabs and slabs constructed of box or I-section units, an effective rib width shall be calculated assuming all material below the upper flange of the unit to be concentrated in a rectangular rib having the same cross-sectional area and depth.

29.5 Size and Position of Ribs

In-situ ribs shall be not less than 65 mm wide. They shall be spaced at centres not greater than 1.5 m apart and their depth, excluding any topping, shall be not more than four times their width. Generally ribs shall be formed along each edge parallel to the span of one way slabs. When the edge is built into a wall or rests on a beam, a rib at least as wide as the bearing shall be formed along the edge.

29.6 Hollow Blocks and Formers

Blocks and formers may be of any suitable material. Hollow clay tiles for the filler type shall conform to accepted standard [6-5A(42)]. When required to contribute to the structural strength of a slab they shall:

a) be made of concrete or burnt clay; and

b) have a crushing strength of at least 14 N/mm^2 measured on the net section when axially loaded in the direction of compressive stress in the slab.

29.7 Arrangement of Reinforcement

The recommendations given in **25.3** regarding maximum distance between bars apply to areas of solid concrete in this form of construction. The curtailment, anchorage and cover to reinforcement shall be as described below:

a) At least 50 percent of the total main reinforcement shall be carried through at the bottom on to the bearing and anchored in accordance with **25.2.3.3**.

b) Where a slab, which is continuous over supports, has been designed as simply supported, reinforcement shall be provided over the support to control cracking. This reinforcement shall have a cross-sectional area of not less than one-quarter that required in the middle of the adjoining spans and shall extend at least one-tenth of the clear span into adjoining spans.

c) In slabs with permanent blocks, the side cover to the reinforcement shall not be less than 10 mm. In all other cases, cover shall be provided according to **25.4**.

29.8 Precasts Joists and Hollow Filler Blocks

The construction with precast joists and hollow concrete filler blocks shall conform to good practice [6-5A(43)] and precast joist and hollow clay filler blocks shall conform to good practice [6-5A(44)].

30 FLAT SLABS

30.1 General

The term flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared column heads (*see* Fig. 12). A flat slab may be solid slab or may have recesses formed on the soffit so that the soffit comprises a series of ribs in two directions. The recesses may be formed by removable or permanent filler blocks.

30.1.1 For the purpose of this clause, the following definitions shall apply:

a) *Column strip* — Column strip means a design strip having a width of $0.25\,l_2$, but not greater than $0.25\,l_1$ on each side of the column centre-line, where l_1 is the span in the direction moments are being determined, measured centre-to-centre of supports and l_2 is the span transverse to l_1, measured centre-to-centre of supports.

b) *Middle strip* — Middle strip means a design strip bounded on each of its opposite sides by the column strip.

c) *Panel* — Panel means that part of a slab bounded on each of its four sides by the centre-line of a column or centre-lines of adjacent spans.

30.2 Proportioning

30.2.1 *Thickness of Flat Slab*

The thickness of the flat slab shall be generally controlled by considerations of span to effective depth ratios given in **22.2**.

For slabs with drops conforming to **30.2.2**, span to effective depth ratios given in **22.2** shall be applied directly; otherwise the span to effective depth ratios obtained in accordance with provisions in **22.2** shall be multiplied by 0.9. For this purpose, the longer span shall be considered. The minimum thickness of slab shall be 125 mm.

30.2.2 *Drop*

The drops when provided shall be rectangular in plan, and have a length in each direction not less than one-third of the panel length in that direction. For exterior panels, the width of drops at right angles to the non-continuous edge and measured from the centre-line of the columns shall be equal to one-half the width of drop for interior panels.

30.2.3 *Column Heads*

Where column heads are provided, that portion of a column head which lies within the largest right circular cone or pyramid that has a vertex angle of 90° and can be included entirely within the outlines of the column and the column head, shall be considered for design purposes (*see* Fig. 12).

30.3 Determination of Bending Moment

30.3.1 *Methods of Analysis and Design*

It shall be permissible to design the slab system by one of the following methods:

a) The direct design method as specified in **30.4**, and

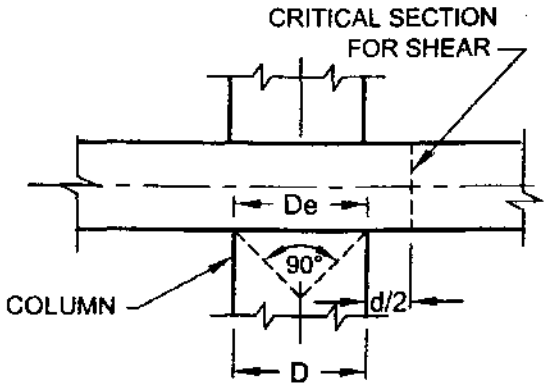
b) The equivalent frame method as specified in **30.5**.

In each case the applicable limitations given in **30.4** and **30.5** shall be met.

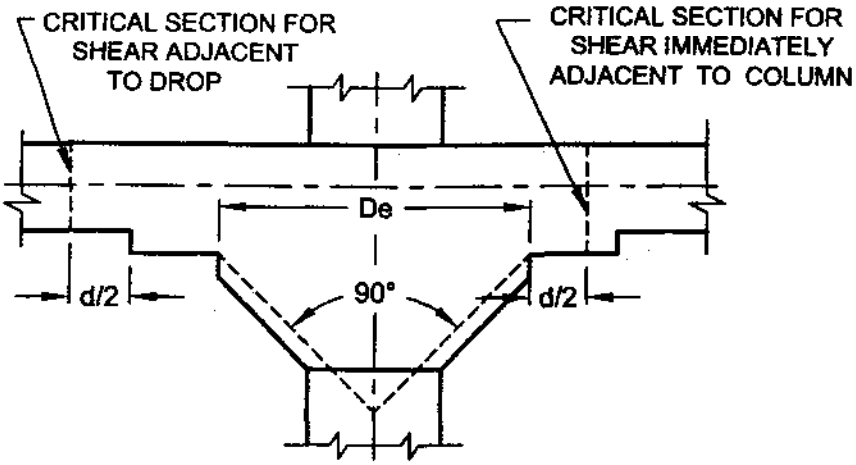
30.3.2 *Bending Moments in Panels with Marginal Beams or Walls*

Where the slab is supported by a marginal beam with a depth greater than 1.5 times the thickness of the slab, or by a wall, then:

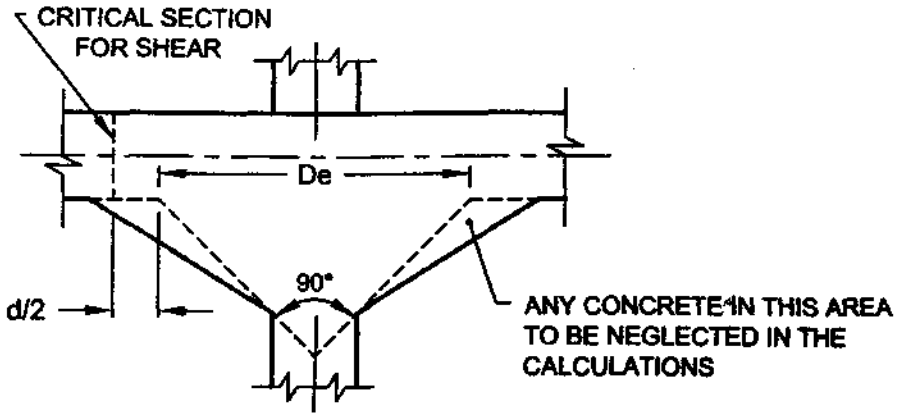
a) the total load to be carried by the beam or wall shall comprise those loads directly on the wall or beam plus a uniformly distributed load equal to one-quarter of the total load on the slab, and



12 A SLAB WITHOUT DROP & COLUMN WITHOUT COLUMN HEAD



12 B SLAB WITH DROP & COLUMN WITH COLUMN HEAD



12 C SLAB WITHOUT DROP & COLUMN WITH COLUMN HEAD

NOTE — D_c is the diameter of column or column head to be considered for design and d is effective depth of slab or drop as appropriate.

FIG. 12 CRITICAL SECTIONS FOR SHEAR IN FLAT SLABS

b) the bending moments on the half-column strip adjacent to the beam or wall shall be one-quarter of the bending moments for the first interior column strip.

30.3.3 *Transfer of Bending Moments to Columns*

When unbalanced gravity load, wind, earthquake, or other lateral loads cause transfer of bending moment between slab and column, the flexural stresses shall be investigated using a fraction, α of the moment given by:

$$\alpha = \frac{1}{1+\frac{2}{3}\sqrt{a_1 / a_2}}$$

where

a_1 = Overall dimension of the critical section for shear in the direction in which moment acts, and

a_2 = Overall dimension of the critical section for shear transverse to the direction in which moment acts.

A slab width between lines that are one and one-half slab or drop panel thickness; 1.5 D, on each side of the column or capital may be considered effective, D being the size of the column.

Concentration of reinforcement over column head by closer spacing or additional reinforcement may be used to resist the moment on this section.

30.4 Direct Design Method

30.4.1 *Limitations*

Slab system designed by the direct design method shall fulfil the following conditions:

a) There shall be minimum of three continuous spans in each direction,

b) The panels shall be rectangular, and the ratio of the longer span to the shorter span within a panel shall not be greater than 2.0,

c) It shall be permissible to offset columns to a maximum of 10 percent of the span in the direction of the offset notwithstanding the provision in (b),

d) The successive span lengths in each direction shall not differ by more than one-third of the longer span. The end spans may be shorter but not longer than the interior spans, and

e) The design live load shall not exceed three times the design dead load.

30.4.2 *Total Design Moment for a Span*

30.4.2.1 In the direct design method, the total design movement for a span shall be determined for a strip bounded laterally by the centre-line of the panel on each side of the centre-line of the supports.

30.4.2.2 The absolute sum of the positive and average negative bending movements in each direction shall be taken as:

$$M_o = \frac{W\, l_n}{8}$$

where

M_o = Total movement;

W = Design load on an area $l_2\, l_n$;

l_n = Clear span extending from face-to-face of columns, capitals, brackets or walls, but not less than 0.65 l_1;

l_1 = Length of span in the direction of M_o; and

l_2 = Length of span transverse to l_1.

30.4.2.3 Circular supports shall be treated as square supports having the same area.

30.4.2.4 When the transverse span of the panels on either side of the centre-line of supports varies l_2 shall be taken as the average of the transverse spans.

30.4.2.5 When the span adjacent and parallel to an edge is being considered, the distance from the edge to the centre-line of the panel shall be substituted for l_2 in **30.4.2.2**.

30.4.3 *Negative and Positive Design Moments*

30.4.3.1 The negative design moment shall be located at the face of rectangular supports, circular supports being treated as square supports having the same area.

30.4.3.2 In an interior span, the total design moment M_o shall be distributed in the following proportions:

Negative design moment	0.65
Positive design moment	0.35

30.4.3.3 In an end span, the total design moment M_o shall be distributed in the following proportions:

Interior negative design moment:

$$0.75 - \frac{0.10}{1+\frac{1}{\alpha_c}}$$

Positive design moment:

$$0.63 - \frac{0.28}{1+\frac{1}{\alpha_c}}$$

Exterior negative design moment:

$$\frac{0.65}{1+\frac{1}{\alpha_c}}$$

α_c is the ratio of flexural stiffness of the exterior columns to the flexural stiffness of the slab at a joint taken in the direction moments are being determined and is given by

$$\alpha_c = \frac{\Sigma K_c}{K_s}$$

where

K_s = Sum of the flexural stiffness of the columns meeting at the joint; and

K_s = Flexural stiffness of the slab, expressed as moment per unit rotation.

30.4.3.4 It shall be permissible to modify these design moments by up to 10 percent, so long as the total design moment, M_o for the panel in the direction considered is not less than that required by **30.4.2.2**.

30.4.3.5 The negative moment section shall be designed to resist the larger of the two interior negative design moments determined for the spans framing into a common support unless an analysis is made to distribute the unbalanced moment in accordance with the stiffness of the adjoining parts.

30.4.4 *Distribution of Bending Moments Across the Panel Width*

Bending moments at critical cross-section shall be distributed to the column strips and middle strips as specified in **30.5.5** as applicable.

30.4.5 *Moments in Columns*

30.4.5.1 Columns built integrally with the slab system shall be designed to resist moments arising from loads on the slab system.

30.4.5.2 At an interior support, the supporting members above and below the slab shall be designed to resist the moment M given by the following equation, in direct proportion to their stiffnesses unless a general analysis is made:

$$M = 0.08 \frac{(w_d + 0.5\, w_l)\, l_2 l_n^2 - w_d' l_2' l_n'^2}{1 + \frac{1}{\alpha_c}}$$

where

w_d, w_l = Design dead and live loads respectively, per unit area;

l_2 = Length of span transverse to the direction of M;

l_n = Length of the clear span in the direction of M, measured face to face of supports;

α_c = $\frac{\Sigma K_c}{\Sigma K_s}$ where K_c and K_s are as defined in **30.4.3.3**; and

w_d', l_2' and l_n', refer to the shorter span.

30.4.6 *Effects of Pattern Loading*

In the direct design method, when the ratio of live load to dead load exceeds 0.5;

a) the sum of the flexural stiffness of the columns above and below the slab, ΣK_c, shall be such that α_c is not less than the appropriate minimum value $\alpha_{c\,min}$ specified in Table 17, or

b) if the sum of the flexural stiffnesses of the columns, ΣK_c, does not satisfy (a), the positive design moments for the panel shall be multiplied by the coefficient β_c given by the following equation:

$$\beta_c = 1 + \left[\frac{2 - \frac{w_d}{w_l}}{4 + \frac{w_d}{w_l}}\right]\left(1 - \frac{\alpha_c}{\alpha_{c\,min}}\right)$$

α_c is the ratio of flexural stiffness of the columns above and below the slab to the flexural stiffness of the slabs at a joint taken in the direction moments are being determined and is given by:

$$\alpha_c = \frac{\Sigma K_c}{\Sigma K_s}$$

where K_c and K_s are flexural stiffnesses of column and slab respectively.

Table 17 Minimum Permissible Values of α_c

(*Clause* 30.4.6)

Imposed Load/ Dead Load	Ratio $\frac{l_2}{l_1}$	Value of $\alpha_{c\,min}$
(1)	(2)	(3)
0.5	0.5 to 2.0	0
1.0	0.5	0.6
1.0	0.8	0.7
1.0	1.0	0.7
1.0	1.25	0.8
1.0	2.0	1.2
2.0	0.5	1.3
2.0	0.8	1.5
2.0	1.0	1.6
2.0	1.25	1.9
2.0	2.0	4.9
3.0	0.5	1.8
3.0	0.8	2.0
3.0	1.0	2.3
3.0	1.25	2.8
3.0	2.0	13.0

30.5 Equivalent Frame Method

30.5.1 *Assumptions*

The bending moments and shear forces may be determined by an analysis of the structure as a continuous frame and the following assumptions may be made:

a) The structure shall be considered to be made up of equivalent frames on column lines taken longitudinally and transversely through the building. Each frame consists of a row of equivalent columns or supports, bounded laterally by the centre-line of the panel on each side of the centre-line of the columns or supports. Frames adjacent and parallel to an edge shall be bounded by the edge and the centre-line of the adjacent panel.

b) Each such frame may be analyzed in its entirety, or, for vertical loading, each floor thereof and the roof may be analyzed separately with its columns being assumed fixed at their remote ends. Where slabs are thus analyzed separately, it may be assumed in determining the bending moment at a given support that the slab is fixed at any support two panels distant therefrom provided the slab continuous beyond the point.

c) For the purpose of determining relative stiffness of members, the moment of inertia of any slab or column may be assumed to be that of the gross cross-section of the concrete alone.

d) Variations of moment of inertia along the axis of the slab on account of provision of drops shall be taken into account. In the case of recessed or coffered slab which is made solid in the region of the columns, the stiffening effect may be ignored provided the solid part of the slab does not extend more than $0.15\ l_{cf}$ into the span measured from the centre-line of the columns. The stiffening effect of flared column heads may be ignored.

30.5.2 *Loading Pattern*

30.5.2.1 When the loading pattern is known, the structure shall be analyzed for the load concerned.

30.5.2.2 When the live load is variable but does not exceed three-quarters of the dead load, or the nature of the live load is such that all panels will be loaded simultaneously, the maximum moments may be assumed to occur at all sections when full design live load is on the entire slab system.

30.5.2.3 For other conditions of live load/dead load ratio and when all panels are not loaded simultaneously:

a) maximum positive moment near midspan of a panel may be assumed to occur when three-quarters of the full design live load is on the panel and on alternate panels; and

b) maximum negative moment in the slab at a support may be assumed to occur when three-quarters of the full design live load is on the adjacent panels only.

30.5.2.4 In no case shall design moments be taken to be less than those occurring with full design live load on all panels.

30.5.3 *Negative Design Moment*

30.5.3.1 At interior supports, the critical section for negative moment, in both the column strip and middle strip, shall be taken at the face of rectilinear supports, but in no case at a distance greater than $0.175\ l_1$ from the centre of the column where l_1 is the length of the span in the direction moments are being determined, measured centre-to-centre of supports.

30.5.3.2 At exterior supports provided with brackets or capitals, the critical section for negative moment in the direction perpendicular to the edge shall be taken at a distance from the face of the supporting element not greater than one-half the projection of the bracket or capital beyond the face of the supporting element.

30.5.3.3 Circular or regular polygon shaped supports shall be treated as square supports having the same area.

30.5.4 *Modification of Maximum Moment*

Moments determined by means of the equivalent frame method, for slabs which fulfil the limitations of **30.4** may be reduced in such proportion that the numerical sum of the positive and average negative moments is not less than the value of total design moment M_o specified in **30.4.2.2**.

30.5.5 *Distribution of Bending Moment Across the Panel Width*

30.5.5.1 *Column strip: Negative moment at an interior support*

At an interior support, the column strip shall be designed to resist 75 percent of the total negative moment in the panel at that support.

30.5.5.2 *Column strip: Negative moment at a exterior support*

a) At an exterior support, the column strip shall be designed to resist the total negative moment in the panel at that support.

b) Where the exterior support consists of a column or a wall extending for a distance equal to or greater than three-quarters of the value of l_2, the length of span transverse to the direction moments are being determined, the exterior negative moment shall be considered to be uniformly distributed across the length l_2.

30.5.5.3 *Column strip: Positive moment for each span*

For each span, the column strip shall be designed to resist 60 percent of the total positive moment in the panel.

30.5.5.4 *Moments in the middle strip*

The middle strip shall be designed on the following bases:

a) That portion of the design moment not resisted by the column strip shall be assigned to the adjacent middle strips.

b) Each middle strip shall be proportioned to resist the sum of the moments assigned to its two half middle strips.

c) The middle strip adjacent and parallel to an edge supported by a wall shall be proportioned to resist twice the moment assigned to half the middle strip corresponding to the first row of interior columns.

30.6 Shear in Flat Slab

30.6.1 The critical section for shear shall be at a distance $d/2$ from the periphery of the column/capital/drop panel, perpendicular to the plane of the slab where d is the effective depth of the section (*see* Fig. 12). The shape in plan is geometrically similar to the support immediately below the slab (*see* Fig. 13A and Fig. 13B).

NOTE — For column sections with re-entrant angles, the critical section shall be taken as indicated in Fig. 13C and 13D.

30.6.1.1 In the case of columns near the free edge of a slab, the critical section shall be taken as shown in Fig. 14.

30.6.1.2 When openings in flat slabs are located at a distance less than ten times the thickness of the slab from a concentrated reaction or when the openings are located within the column strips, the critical sections specified in **30.6.1** shall be modified so that the part of the periphery of the critical section which is enclosed by radial projections of the openings to the centroid of the reaction area shall be considered ineffective (*see* Fig. 15), and openings shall not encroach upon column head.

30.6.2 *Calculation of Shear Stress*

The shear stress τ_v shall be the sum of the values calculated according to **30.6.2.1** and **30.6.2.2.**

30.6.2.1 The nominal shear stress in flat slabs shall be taken as $V/b_o d$ where V is the shear force due to design load, b_o is the periphery of the critical section and d is the effective depth.

30.6.2.2 When unbalanced gravity load, wind, earthquake or other forces cause transfer of bending moment between slab and column, a fraction $(1 - \alpha)$ of the moment shall be considered transferred by eccentricity of the shear about the centroid of the critical section. Shear stresses shall be taken as varying linearly about the centroid of the critical section. The value of α shall be obtained from the equation given in **30.3.3.**

30.6.3 *Permissible Shear Stress*

30.6.3.1 When shear reinforcement is not provided, the calculated shear stress at the critical section shall not exceed $k_s \tau_c$,

where

k_s = $(0.5 + \beta_c)$ but not greater than 1, β_c being the ratio of short side to long side of the column/capital; and

τ_c = $0.25 \sqrt{f_{ck}}$ in limit state method of design, and $0.16 \sqrt{f_{ck}}$ in working stress method of design.

30.6.3.2 When the shear stress at the critical section exceeds the value given in **30.6.3.1**, but less than $1.5 \tau_c$ shear reinforcement shall be provided. If the shear stress $1.5 \tau_c$, the flat slab shall be redesigned. Shear stresses shall be investigated at successive sections more distant from the support and shear reinforcement shall be provided up to a section where the shear stress does not exceed $0.5 \tau_c$. While designing the shear reinforcement, the shear stress carried by the concrete shall be assumed to be $0.5 \tau_c$ and reinforcement shall carry the remaining shear.

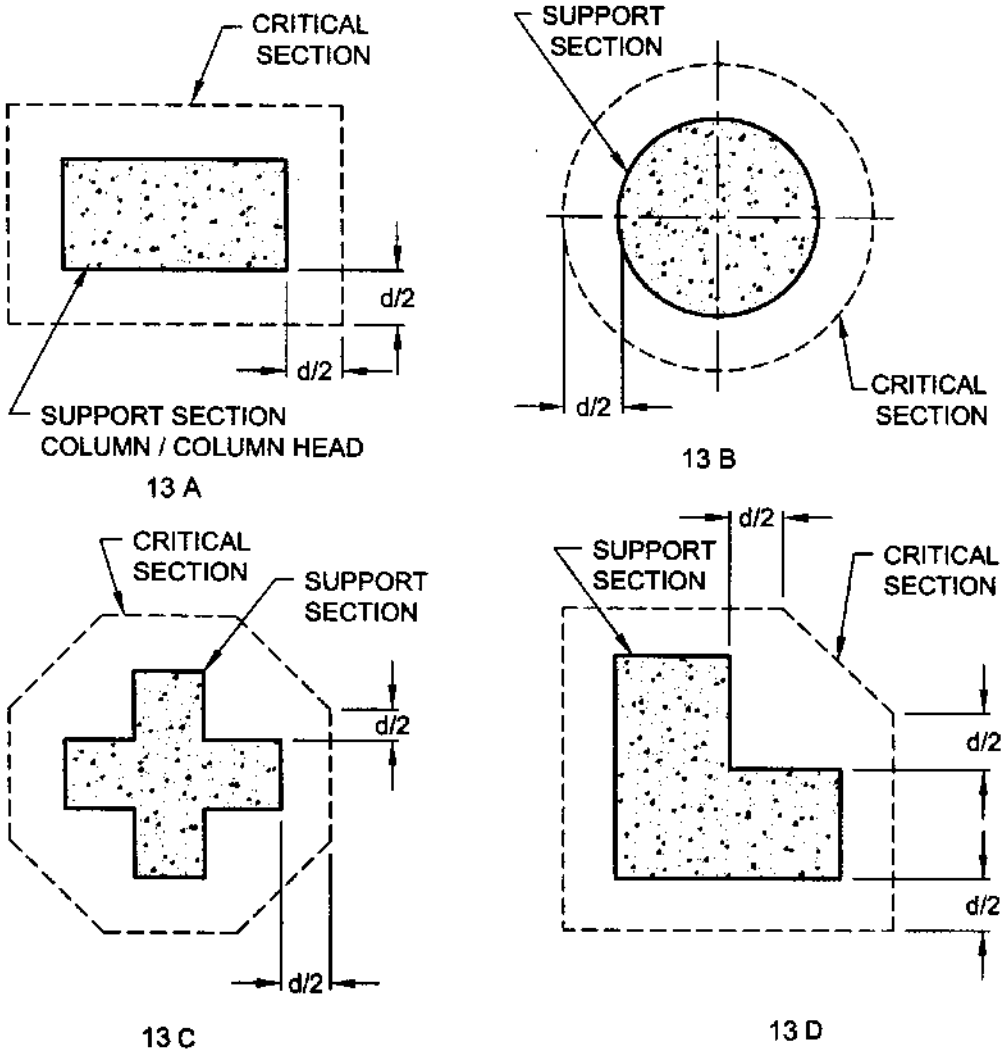
30.7 Slab Reinforcement

30.7.1 *Spacing*

The spacing of bars in a flat slab, shall not exceed 2 times the slab thickness, except where a slab is of cellular or ribbed construction.

30.7.2 *Area of Reinforcement*

When drop panels are used, the thickness of drop panel for determination of area of reinforcement shall be the lesser of the following:



NOTE — d is the effective depth of the flat slab/drop.

FIG. 13 CRITICAL SECTIONS IN PLAN FOR SHEAR IN FLAT SLABS

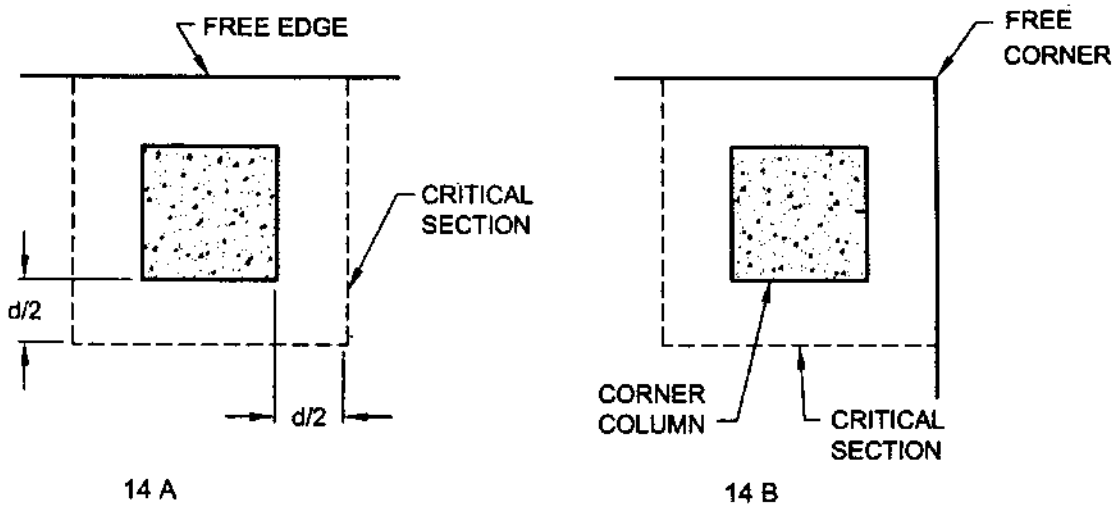


FIG. 14 EFFECT OF FREE EDGES ON CRITICAL SECTION FOR SHEAR

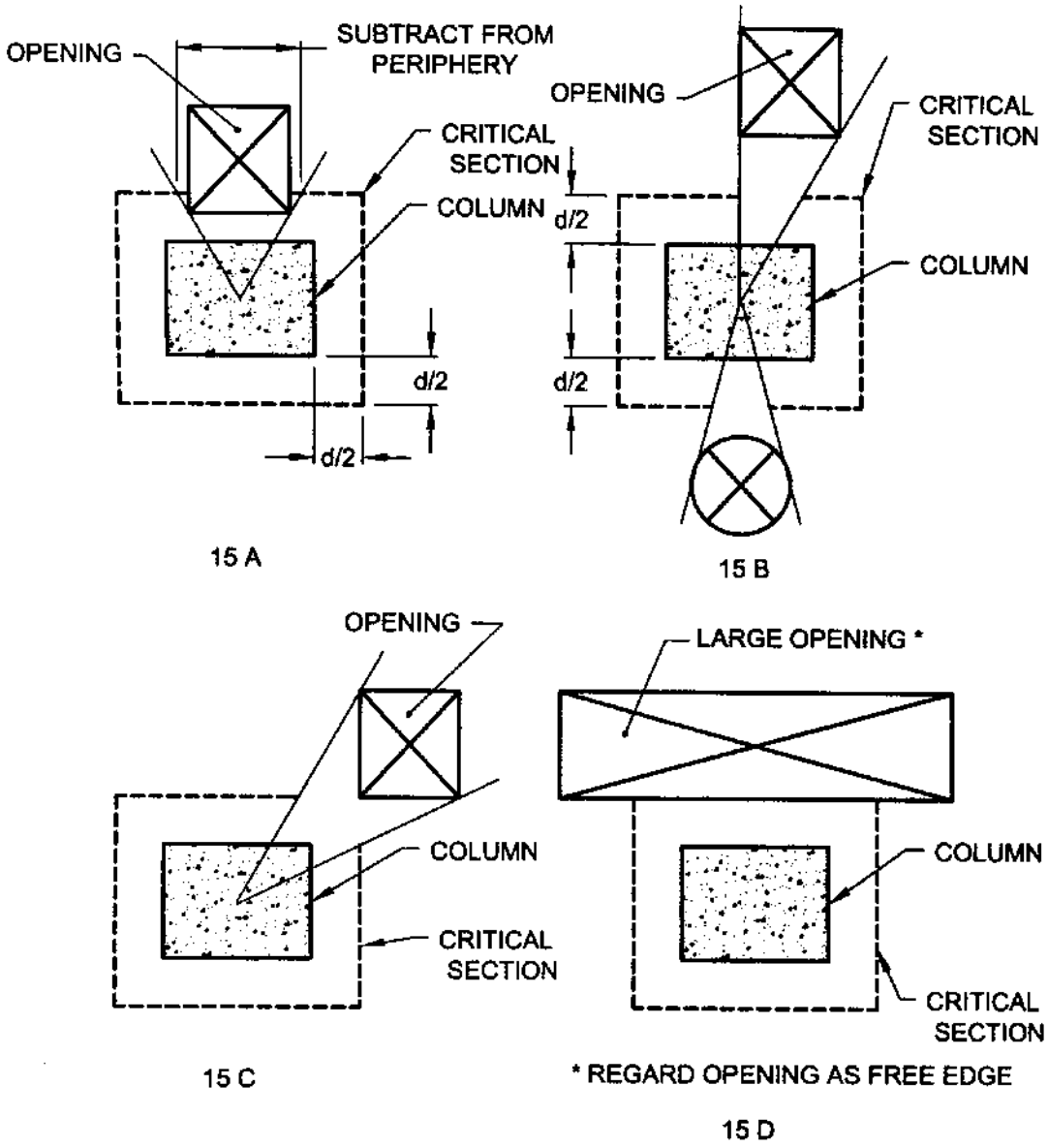


FIG. 15 EFFECT OF OPENINGS ON CRITICAL SECTION FOR SHEAR

a) Thickness of drop, and

b) Thickness of slab plus one quarter the distance between edge of drop and edge of capital.

30.7.3 *Minimum Length of Reinforcement*

a) Reinforcement in flat slabs shall have the minimum lengths specified in Fig. 16. Larger lengths of reinforcement shall be provided when required by analysis.

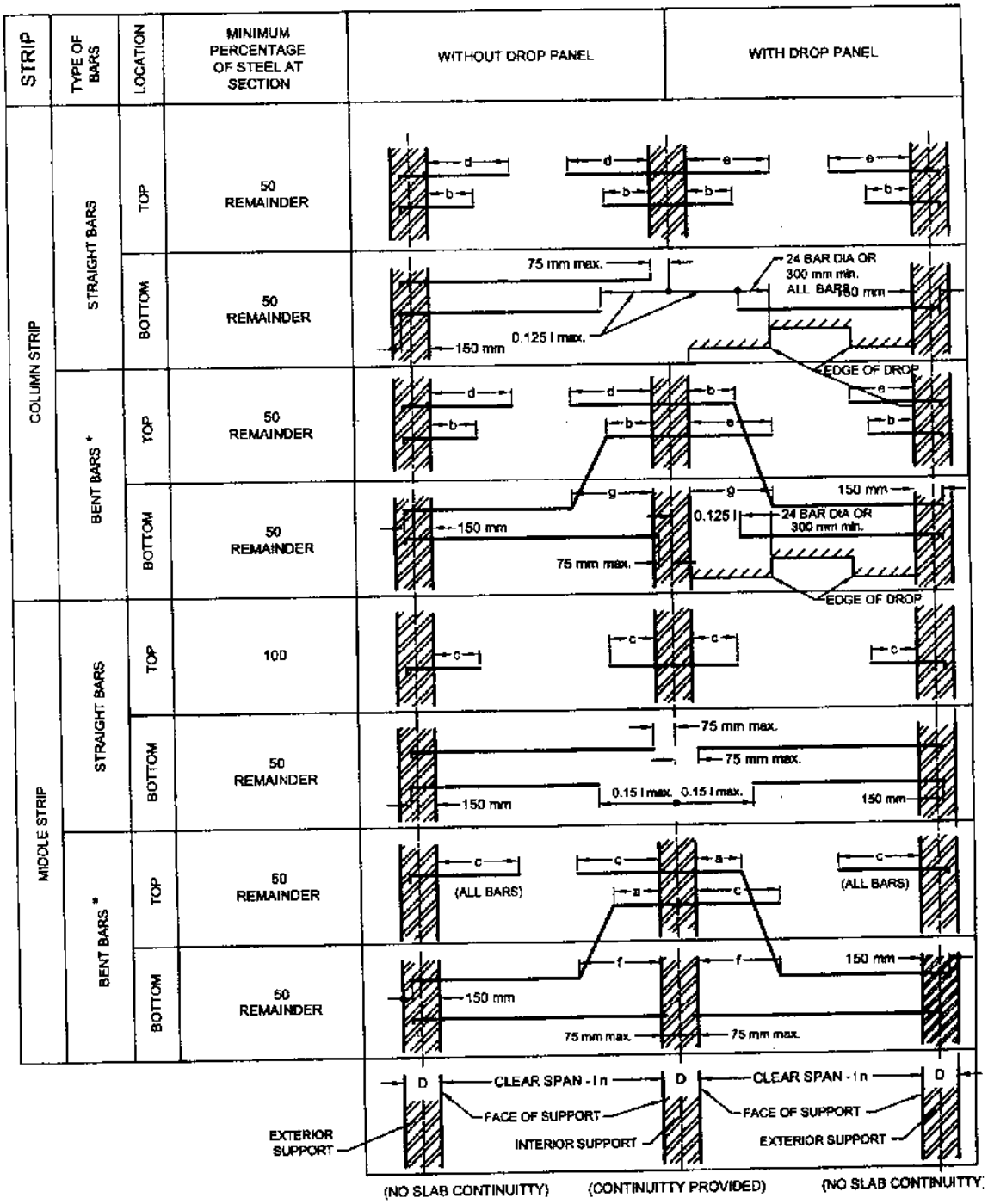
b) Where adjacent spans are unequal, the extension of negative reinforcement beyond each face of the common column shall be based on the longer span.

c) The length of reinforcement for slabs in frames not braced against sideways and for slabs resisting lateral loads shall be determined by analysis but shall not be less than those prescribed in Fig. 16.

30.7.4 *Anchoring Reinforcement*

a) All slab reinforcement perpendicular to a discontinuous edge shall have an anchorage (straight, bent or otherwise anchored) past the internal face of the spandrel beam, wall or column, of an amount:

1) *For positive reinforcement* — not less than 150 mm except that with fabric reinforcement having a fully welded transverse wire directly over the support,



	Bar Length from Face of Support						
	Minimum Length					*Maximum Length*	
Mark	*a*	*b*	*c*	*d*	*e*	*f*	*g*
Length	0.14 l_n	0.20 l_n	0.22 l_n	0.30 l_n	0.33 l_n	0.20 l_n	0.24 l_n

* Bent bars at exterior supports may be used if a general analysis is made.

NOTE — D is the diameter of the column and the dimension of the rectangular column in the direction under consideration.

FIG. 16 MINIMUM BEND JOINT LOCATION AND EXTENSION FOR REINFORCEMENT IN FLAT SLABS

it shall be permissible to reduce this length to one-half of the width of the support or 50 mm, whichever is greater; and

2) *For negative reinforcement* — such that the design stress is developed at the internal face, in accordance with Section 5A (c).

b) Where the slab is not supported by a spandrel beam or wall, or where the slab cantilevers beyond the support, the anchorage shall be obtained within the slab.

30.8 Openings in Flat Slabs

Openings of any size may be provided in the flat slab if it is shown by analysis that the requirements of strength and serviceability are met. However, for openings conforming to the following, no special analysis is required.

a) Openings of any size may be placed within the middle half of the span in each direction, provided the total amount of reinforcement required for the panel without the opening is maintained.

b) In the area common to two column strips, not more than one-eighth of the width of strip in either span shall be interrupted by the openings. The equivalent of reinforcement interrupted shall be added on all sides of the openings.

c) In the area common to one column strip and one middle strip, not more than one-quarter of the reinforcement in either strip shall be interrupted by the openings. The equivalent of reinforcement interrupted shall be added on all sides of the openings.

d) The shear requirements of **30.6** shall be satisfied.

31 WALLS

31.1 General

Reinforced concrete walls subjected to direct compression or combined flexure and direct compression should be designed in accordance with Section 5 or Annex B provided the vertical reinforcement is provided in each face. Braced walls subjected to only vertical compression may be designed as per empirical procedure given in **31.2**. The minimum thickness of walls shall be 100 mm.

31.1.1 Guidelines or design of walls subjected to horizontal and vertical loads are given in **31.3**.

31.2 Empirical Design Method for Walls Subjected to Inplane Vertical Loads

31.2.1 *Braced Walls*

Walls shall be assumed to be braced if they are laterally supported by a structure in which all the following apply:

a) Walls or vertical braced elements are arranged in two directions so as to provide lateral stability to the structure as a whole.

b) Lateral forces are resisted by shear in the planes of these walls or by braced elements.

c) Floor and roof systems are designed to transfer lateral forces.

d) Connections between the wall and the lateral supports are designed to resist a horizontal force not less than

1) the simple static reactions to the total applied horizontal forces at the level of lateral support; and

2) 2.5 percent of the total vertical load that the wall is designed to carry at the level of lateral support.

31.2.2 *Eccentricity of Vertical Load*

The design of a wall shall take account of the actual eccentricity of the vertical force subject to a minimum value of 0.05 t.

The vertical load transmitted to a wall by a discontinuous concrete floor or roof shall be assumed to act at one-third the depth of the bearing area measured from the span face of the wall. Where there is an *in-situ* concrete floor continuous over the wall, the load shall be assumed to act at the centre of the wall.

The resultant eccentricity of the total vertical load on a braced wall at any level between horizontal lateral supports, shall be calculated on the assumption that the resultant eccentricity of all the vertical loads above the upper support is zero.

31.2.3 *Maximum Effective Height to Thickness Ratio*

The ratio of effective height to thickness, H_{we}/t, it shall not exceed 30.

31.2.4 *Effective Height*

The effective height of a braced wall shall be taken as follows:

a) Where restrained against rotation at both ends by

1) floors	0.75 H_w or
2) intersecting walls or similar members whichever is the lesser.	0.75 L_1

b) Where not restrained against rotation at both ends by

1) floors — $1.0\ H_w$ or
2) intersecting walls or similar members whichever is the lesser. — $1.0\ L_1$

where

H_w = Unsupported height of the wall,

L_1 = Horizontal distance between centres of lateral restraint.

31.2.5 *Design Axial Strength of Wall*

The design axial strength P_{uw} per unit length of a braced wall in compression may be calculated from the following equation:

$$P_{uw} = 0.3\ (t \quad 1.2\ e \quad 2\ e_a) f_{ck}$$

where

t = Thickness of the wall,

e = Eccentricity of load measured at right angles to the plane of the wall determined in accordance with **31.2.2**, and

e_a = Additional eccentricity due to slenderness effect taken as $H^2_{we}/2\ 500\ t$.

31.3 Walls Subjected to Combined Horizontal and Vertical Forces

31.3.1 When horizontal forces are in the plane of the wall, it may be designed for vertical forces in accordance with **31.2** and for horizontal shear in accordance with **31.4**. In plane bending may be neglected in case a horizontal cross-section of the wall is always under compression due to combined effect of horizontal and vertical loads.

31.3.2 Walls subjected to horizontal forces perpendicular to the wall and for which the design axial load does not exceed $0.04\ f_{ck} A_g$, shall be designed as slabs in accordance with the appropriate provisions given in **23**, where A_g is gross area of the section.

31.4 Design for Horizontal Shear

31.4.1 *Critical Section for Shear*

The critical section for maximum shear shall be taken at a distance from the base of $0.5\ L_w$ or $0.5\ H_w$ whichever is less.

31.4.2 *Nominal Shear Stress*

The nominal shear stress τ_{vw} in walls shall be obtained as follows:

$$\tau_{vw} = V_u/t.d$$

where

V_u = Shear force due to design loads,

t = Wall thickness,

d = $0.8 \times L_w$ where L_w is the length of the wall.

31.4.2.1 Under no circumstances shall the nominal shear stress τ_{cw} in walls exceed $0.17\ f_{ck}$ in limit state method and $0.12\ f_{ck}$ in working stress method.

31.4.3 *Design Shear Strength of Concrete*

The design shear strength of concrete in walls, τ_{cw}, without shear reinforcement shall be taken as below:

a) For $H_w/L_w \leq 1$

$$\tau_{cw} = (3.0 - H_w/L_w)\ K_1 \sqrt{f_{ck}}$$

where K_1 is 0.2 in limit state method and 0.13 in working stress method.

b) For $H_w/L_w > 1$

Lesser of the values calculated from (a) above and from

$$\tau_{cw} = K_2 \sqrt{f_{ck}}\ \frac{(H_w/L_w + 1)}{(H_w/L_w - 1)}$$

where K_2 is 0.045 in limit state method and 0.03 in working stress method, but τ_{cw} shall be not less than $K_3 \sqrt{f_{ck}}$ in any case where K_3 is 0.15 in limit state method and 0.10 in working stress method.

31.4.4 *Design of Shear Reinforcement*

Shear reinforcement shall be provided to carry a shear equal to $V_u - \tau_{cw}.t(0.8\ L_w)$. In case of working stress method V_u is replaced by V. The strength of shear reinforcement shall be calculated as per **39.4** or **B-5.4** with A_{sv} defined as below:

$$A_{sv} = P_w\ (0.8\ L_w)\ t$$

where P_w is determined as follows:

a) For walls where $H_w/L_w \leq 1$, P_w shall be the lesser of the ratios of either the vertical reinforcement area or the horizontal reinforcement area to the cross-sectional area of wall in the respective direction.

b) For walls where $H_w/L_w > 1$, P_w shall be the ratio of the horizontal reinforcement area to the cross-sectional area of wall per vertical metre.

31.5 Minimum Requirements for Reinforcement in Walls

The reinforcement for walls shall be provided as below:

a) the minimum ratio of vertical reinforcement to gross concrete area shall be:

1) 0.001 2 for deformed bars not larger than 16 mm in diameter and with a

characteristic strength of 415 N/mm^2 or greater.

2) 0.001 5 for other types of bars.

3) 0.001 2 for welded wire fabric not larger than 16 mm in diameter.

b) Vertical reinforcement shall be spaced not farther apart than three times the wall thickness nor 450 mm.

c) The minimum ratio of horizontal reinforcement to gross concrete area shall be:

1) 0.002 0 for deformed bars not larger than 16 mm in diameter and with a characteristic strength of 415 N/mm^2 or greater.

2) 0.002 5 for other types of bars.

3) 0.002 0 for welded wire fabric not larger than 16 mm in diameter.

d) Horizontal reinforcement shall be spaced not farther apart than three times the wall thickness nor 450 mm.

NOTE The minimum reinforcement may not always be sufficient to provide adequate resistance to the effects of shrinkage and temperature.

31.5.1 For walls having thickness more than 200 mm, the vertical and horizontal reinforcement shall be provided in two grids, one near each face of the wall.

31.5.2 Vertical reinforcement need not be enclosed by transverse reinforcement as given in **25.5.3.2** for column, if the vertical reinforcement is not greater than 0.01 times the gross sectional area or where the vertical reinforcement is not required for compression.

32 STAIRS

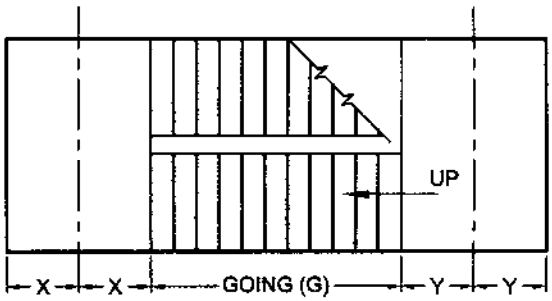
32.1 Effective Span of Stairs

The effective span of stairs without stringer beams shall be taken as the following horizontal distances:

a) Where supported at top and bottom risers by beams spanning parallel with the risers, the distance centre-to-centre of beams;

b) Where spanning on to the edge of a landing slab, which spans parallel, with the risers (*see* Fig. 17), a distance equal to the going of the stairs plus at each end either half the width of the landing or one metre, whichever is smaller; and

c) Where the landing slab spans in the same direction as the stairs, they shall be considered as acting together to form a single slab and the span determined as the distance centre-to-centre of the supporting beams or walls, the going being measured horizontally.



X	Y	SPAN IN METRES
< 1 m	< 1 m	G + X + Y
< 1 m	≥ 1 m	G + X + 1
≥ 1 m	< 1 m	G + Y + 1
≥ 1 m	≥ 1 m	G + 1 + 1

FIG. 17 EFFECTIVE SPAN FOR STAIRS SUPPORTED AT EACH END BY LANDINGS SPANNING PARALLEL WITH THE RISERS

32.2 Distribution of Loading on Stairs

In the case of stairs with open wells, where spans partly crossing at right angles occur, the load on areas common to any two such spans may be taken as one-half in each direction as shown in Fig. 18. Where flights or landings are embedded into walls for a length of not less than 110 mm and are designed to span in the direction of the flight, a 150 mm strip may be deducted from the loaded area and the effective breadth of the section increased by 75 mm for purposes of design (*see* Fig. 19).

32.3 Depth of Section

The depth of section shall be taken as the minimum thickness perpendicular to the soffit of the staircase.

33 FOOTINGS

33.1 General

Footings shall be designed to sustain the applied loads, moments and forces and the induced reactions and to ensure that any settlement which may occur shall be as nearly uniform as possible, and the safe bearing capacity of the soil is not exceeded {*see* good practice [6-5A(35)] }.

33.1.1 In sloped or stepped footings the effective cross-section in compression shall be limited by the area above the neutral plane, and the angle of slope or depth and location of steps shall be such that the design

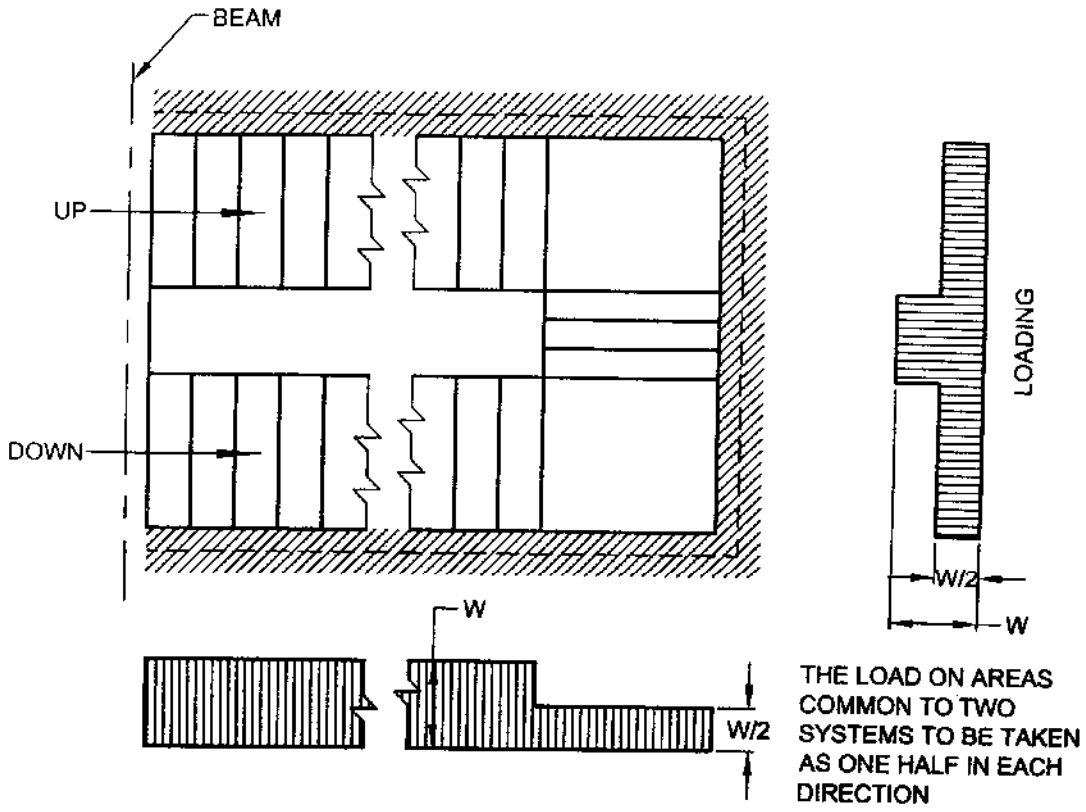


FIG. 18 LOADING ON STAIRS WITH OPEN WELLS

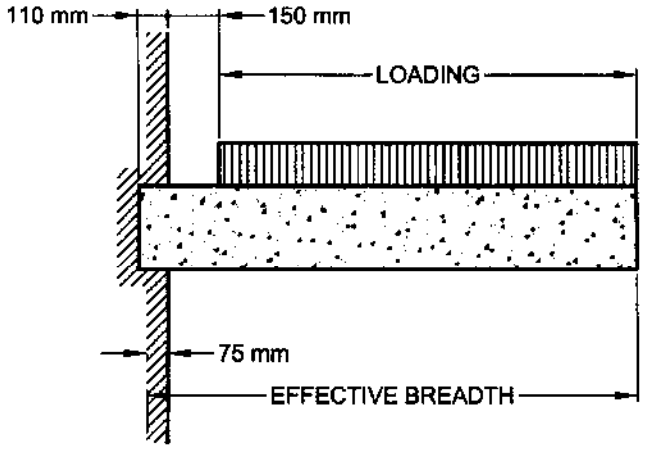


FIG. 19 LOADING ON STAIRS BUILT INTO WALLS

requirements are satisfied at every section. Sloped and stepped footings that are designed as a unit shall be constructed to assure action as a unit.

33.1.2 *Thickness at the Edge of Footing*

In reinforced and plain concrete footings, the thickness at the edge shall be not less than 150 mm for footings on soils, nor less than 300 mm above the tops of piles for footings on piles.

33.1.3 In the case of plain concrete pedestals, the angle between the plane passing through the bottom edge of the pedestal and the corresponding junction edge of the column with pedestal and the horizontal plane (*see* Fig. 20) shall be governed by the expression:

$$\tan \alpha \leq 0.9\sqrt{\frac{100\,q_c}{f_{ck}}+1}$$

q_u = Calculated maximum bearing pressure at the base of the pedestal in N/mm², and

f_{ck} = Characteristic strength of concrete at 28 days in N/mm²

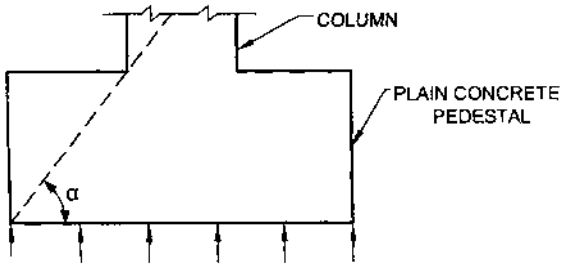


FIG. 20

33.2 Moments and Forces

33.2.1 In the case of footings on piles, computation for moments and shears may be based on the assumption that the reaction from any pile is concentrated at the centre of the pile.

33.2.2 For the purpose of computing stresses in footings which support a round or octagonal concrete column or pedestal, the face of the column or pedestal shall be taken as the side of a square inscribed within the perimeter of the round or octagonal column or pedestal.

33.2.3 *Bending Moment*

33.2.3.1 The bending moment at any section shall be determined by passing through the section a vertical plane which extends completely across the footing, and computing the moment of the forces acting over the entire area of the footing on one side of the said plane.

33.2.3.2 The greatest bending moment to be used in the design of an isolated concrete footing which supports a column, pedestal or wall, shall be the moment computed in the manner prescribed in **33.2.3.1** at sections located as follows:

a) At the face of the column, pedestal or wall, for footings supporting a concrete column, pedestal or wall;

b) Halfway between the centre-line and the edge of the wall, for footings under masonry walls; and

c) Halfway between the face of the column or pedestal and the edge of the gussetted base, for footings under gussetted bases.

33.2.4 *Shear and Bond*

33.2.4.1 The shear strength of footings is governed by the more severe of the following two conditions:

a) the footing acting essentially as a wide beam a plane across the entire width; the critical section for this condition shall be assumed as a vertical section located from the face of the column, pedestal or wall at a distance equal to the effective depth of footing in case of footings on soils, and at a distance equal to half the effective depth of footing for footings on piles.

b) Two-way action of the footing, with potential diagonal cracking along the surface of truncated cone or pyramid around the concentrated load; in this case, the footing shall be designed for shear in accordance with appropriate provisions specified in **30.6**.

33.2.4.2 In computing the external shear on any section through a footing supported on piles, the entire reaction from any pile of diameter D_p whose centre is located $D_p/2$ or more outside the section shall be assumed as producing shear on the section; the reaction from any pile whose centre is located $D_p/2$ or more inside the section shall be assumed as producing no shear on the section. For intermediate positions of the pile centre, the portion of the pile reaction to be assumed as producing shear on the section shall be based on straight line interpolation between full value at $D_p/2$ outside the section and zero value at $D_p/2$ inside the section.

33.2.4.3 The critical section for checking the development length in a footing shall be assumed at the same planes as those described for bending moment in **33.2.3** and also at all other vertical planes where abrupt changes of section occur. If reinforcement is curtailed, the anchorage requirements shall be checked in accordance with **25.2.3**.

33.3 Tensile Reinforcement

The total tensile reinforcement at any section shall provide a moment of resistance at least equal to the bending moment on the section calculated in accordance with **33.2.3**.

33.3.1 Total tensile reinforcement shall be distributed across the corresponding resisting section as given below:

a) In one-way reinforced footing, the reinforcement extending in each direction shall be distributed uniformly across the full width of the footing;

b) In two-way reinforced square footing, the reinforcement extending in each direction shall be distributed uniformly across the full width of the footing; and

c) In two-way reinforced rectangular footing, the reinforcement in the long direction shall be distributed uniformly across the full width of the footing. For reinforcement in the short direction, a central band equal to the width of the footing shall be marked along the length of the footing and portion of the reinforcement determined in accordance with the equation given below shall be uniformly distributed across the central band:

$$\frac{\text{Reinforcement in central band width}}{\text{Total reinforcement in short direction}} = \frac{2}{\beta + 1}$$

where β is the ratio of the long side to the short side of the footing. The remainder of the reinforcement shall be uniformly distributed in the outer portions of the footing.

33.4 Transfer of Load at the Base of Column

The compressive stress in concrete at the base of a column or pedestal shall be considered as being transferred by bearing to the top of the supporting pedestal or footing. The bearing pressure on the loaded area shall not exceed the permissible bearing stress in direct compression multiplied by a value equal to

$$\sqrt{\frac{A_1}{A_2}}$$ but not greater than 2;

where

A_1 = Supporting area for bearing of footing, which in sloped or stepped footing may be taken as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base, the area actually loaded and having side slope of one vertical to two horizontal; and

A_2 = Loaded area at the column base.

For working stress method of design the permissible bearing stress on full area of concrete shall be taken as $0.25 f_{ck}$; for limit state method of design the permissible bearing stress shall be $0.45 f_{ck}$.

33.4.1 Where the permissible bearing stress on the concrete in the supporting or supported member would be exceeded, reinforcement shall be provided for developing the excess force, either by extending the longitudinal bars into the supporting member, or by dowels (*see* **33.4.3**).

33.4.2 Where transfer of force is accomplished by reinforcement, the development length of the reinforcement shall be sufficient to transfer the compression or tension to the supporting member in accordance with **25.2**.

33.4.3 Extended longitudinal reinforcement or dowels of at least 05 percent of the cross-sectional area of the supported column or pedestal and a minimum of four bars shall be provided. Where dowels are used, their diameter shall not exceed the diameter of the column bars by more than 3 mm.

33.4.4 Column bars of diameters larger than 36 mm, in compression only can be dowelled at the footings with bars of smaller size of the necessary area. The dowel shall extend into the column, a distance equal to the development length of the column bar and into the footing, a distance equal to the development length of the dowel.

33.5 Nominal Reinforcement

33.5.1 Minimum reinforcement and spacing shall be as per the requirements of solid slab.

33.5.2 The nominal reinforcement for concrete sections of thickness greater than 1 m shall be 360 mm^2 per metre length in each direction on each face. This provision does not supersede the requirement of minimum tensile reinforcement based on the depth of the section.

SECTION 5A (e) STRUCTURAL DESIGN (LIMIT STATE METHOD)

34 SAFETY AND SERVICEABILITY REQUIREMENTS

34.1 General

In the method of design based on limit state concept, the structure shall be designed to withstand safely all loads liable to act on it throughout its life; it shall also satisfy the serviceability requirements, such as limitations on deflection and cracking. The acceptable limit for the safety and serviceability requirements before failure occurs is called a 'limit state'. The aim of design is to achieve acceptable probabilities that the structure will not become unfit for the use for which it is intended, that is, that it will not reach a limit state.

34.1.1 All relevant limit states shall be considered in design to ensure an adequate degree of safety and serviceability. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

34.1.2 For ensuring the above objective, the design should be based on characteristic values for material strengths and applied loads, which take into account the variations in the material strengths and in the loads to be supported. The characteristic values should be based on statistical data if available; where such data are not available they should be based on experience.

The 'design values' are derived from the characteristic values through the use of partial safety factors, one for material strengths and the other for loads. In the absence of special considerations these factors should have the values given in **35** according to the material, the type of loading and the limit state being considered.

34.2 Limit State of Collapse

The limit state of collapse of the structure or part of the structure could be assessed from rupture of one or more critical sections and from buckling due to elastic or plastic instability (including the effects of sway where appropriate) or overturning. The resistance to bending, shear, torsion and axial loads at every section shall not be less than the appropriate value at that section produced by the probable most unfavourable combination of loads on the structure using the appropriate partial safety factors.

34.3 Limit States of Serviceability

34.3.1 *Deflection*

Limiting values of deflections are given in **22.2**.

34.3.2 *Cracking*

Cracking of concrete should not adversely affect the appearance or durability of the structure; the acceptable limits of cracking would vary with the type of structure and environment. Where specific attention is required to limit the designed crack width to a particular value, crack width calculation may be done using formula given in Annex F.

The practical objective of calculating crack width is merely to give guidance to the designer in making appropriate structural arrangements and in avoiding gross errors in design, which might result in concentration and excessive width of flexural crack.

The surface width of the cracks should not, in general, exceed 0.3 mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel nor upon the durability of the structures. In members where cracking in the tensile zone is harmful either because they are exposed to the effects of the weather or continuously exposed to moisture or in contact soil or ground water, an upper limit of 0.2 mm is suggested for the maximum width of cracks. For particularly aggressive environment, such as the 'sever' category in Table 3, the assessed surface width of cracks should not in general, exceed 0.1 mm.

34.4 Other Limit States

Structures designed for unusual or special functions shall comply with any relevant additional limit state considered appropriate to that structure.

35 CHARACTERISTIC AND DESIGN VALUES AND PARTIAL SAFETY FACTORS

35.1 Characteristic Strength of Materials

The term 'characteristic strength' means that value of the strength of the material below which not more than 5 percent of the test results are expected to fall. The characteristic strength for concrete shall be in accordance with Table 2. Until the relevant Indian Standard Specifications for reinforcing steel are modified to include the concept of characteristic strength, the characteristic value shall be assumed as the minimum yield stress/0.2 percent proof stress specified in the relevant Indian Standard Specifications.

35.2 Characteristic Loads

The term 'characteristic load' means that value of load which has a 95 percent probability of not being exceeded during the life of the structure. Since data are not available to express loads in statistical terms, for the purpose of this Section, dead loads, imposed loads, wind loads, snow load in accordance with the good practice [6-5A(33)] and seismic forces in accordance with the good practice [6-5A(34)] shall be assumed as the characteristic loads.

35.3 Design Values

35.3.1 *Materials*

The design strength of the materials, f_d is given by

$$f_d = \frac{f}{\gamma_m}$$

where

f = Characteristic strength of the material (*see* **35.1**), and

γ_m = Partial safety factor appropriate to the material and the limit state being considered.

35.3.2 *Loads*

The design load, F_d is given by

$$F_d = F\gamma_f$$

where

F = Characteristic load (*see* **35.2**), and

γ_f = Partial safety factor appropriate to the nature of loading and the limit state being considered.

35.3.3 *Consequences of Attaining Limit State*

Where the consequences of a structure attaining a limit state are of a serious nature such as huge loss of life and disruption of the economy, higher values for γ_f and γ_m than those given under **35.4.1** and **35.4.2** may be applied.

35.4 Partial Safety Factors

35.4.1 *Partial Safety Factor γ_f for Loads*

The values γ_f given in Table 18 shall normally be used.

Table 18 Values of Partial Safety Factor γ_f for Loads

(*Clauses* 17.2.3.1, 35.4.1 *and* B-4.3)

Load Combination	Limit State of Collapse			Limit States of Serviceability		
	DL	*IL*	*WL*	*DL*	*IL*	*WL*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
DL+ *IL*	1.5		—	1.0	1.0	—
DL+ *WL*	1.5 or 0.9[1)]	—	1.5	1.0	—	1.0
DL+ *IL*+ *WL*	1.2			1.0	0.8	0.8

NOTES

1 While considering earthquake effects, substitute *EL* for *WL*.

2 For the limit states of serviceability, the values of γ_f given in this table are applicable for short-term effects. While assessing the long-term effects due to creep the dead load and that part of the live load likely to be permanent may only be considered.

[1)] This value is to be considered when stability against overturning or stress reversal is critical.

35.4.2 *Partial Safety Factor γ_m for Material Strength*

35.4.2.1 When assessing the strength of a structure or structural member for the limit state of collapse, the values of partial safety factor, γ_m should be taken as 1.5 for concrete and 1.15 for steel.

NOTE — γ_m values are already incorporated in the equations and tables given in this Section for limit state design.

35.4.2.2 When assessing the deflection, the material properties such as modulus of elasticity should be taken as those associated with the characteristic strength of the material.

36 ANALYSIS

36.1 Analysis of Structure

Method of analysis as in **21** shall be used. The material strength to be assumed shall be characteristic values in the determination of elastic properties of members irrespective of the limit state being considered. Redistribution of the calculated moments may be made as given in **36.1.1**.

36.1.1 *Redistribution of Moments in Continuous Beams and Frames*

The redistribution of moments may be carried out satisfying the following conditions:

a) Equilibrium between the internal forces and the external loads is maintained.

b) The ultimate moment of resistance provided at any section of a member is not less than 70 percent of the moment at the section obtained from an elastic maximum moment diagram covering all appropriate combinations of loads.

c) The elastic moment at any section in a member due to a particular combination of loads shall not be reduced by more than 30 percent of the numerically largest moment given anywhere by the elastic maximum moments diagram for the particular member, covering all appropriate combination of loads.

d) At sections where the moment capacity after redistribution is less than that from the elastic maximum moment diagram, the following relationship shall be satisfied:

$$\frac{x_u}{d} + \frac{\delta M}{100} \leq 0.6$$

where

x_u = Depth of neutral axis,

d = Effective depth, and

δM = Percentage reduction in moment.

e) In structures in which the structural frame provides the lateral stability, the reduction in moment allowed by condition given in **36.1.1** (c) shall be restricted to 10 percent for structures over 4 storeys in height.

36.1.2 *Analysis of Slabs Spanning in Two Directions at Right Angles*

Yield line theory or any other acceptable method may be used. Alternatively the provisions given in Annex D may be followed.

37 LIMIT STATE OF COLLAPSE: FLEXURE

37.1 Assumptions

Design for the limit state of collapse in flexure shall be based on the assumptions given below:

a) Plane sections normal to the axis remain plane after bending.

b) The maximum strain in concrete at the outermost compression fibre is taken as 0.003 5 in bending.

c) The relationship between the compressive stress distribution in concrete and the strain in concrete may be assumed to be rectangle, trapezoid, parabola or any other shape which result in prediction of strength in substantial agreement with the results of test. An

acceptable stress strain curve is given in Fig. 21. For design purposes, the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor $\gamma_m = 1.5$ shall be applied in addition to this.

NOTE — For the stress-strain curve in Fig. 21 the design stress block parameters are as follows (*see* Fig. 22).

Area of stress block $= 0.36 f_{ck}.x_u$

Depth of centre of compressive force from the extreme fibre in compression $= 0.42\, x_u$

where

f_{ck} = Characteristic compressive strength of concrete, and

x_u = Depth of neutral axis.

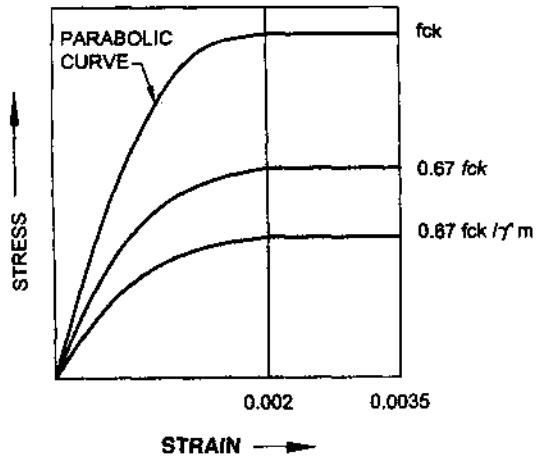


FIG. 21 STRESS-STRAIN CURVE FOR CONCRETE

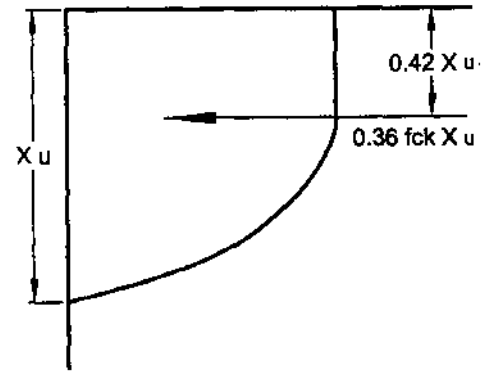


FIG. 22 STRESS BLOCK PARAMETERS

d) The tensile strength of the concrete is ignored.

e) The stresses in the reinforcement are derived from representative stress-strain curve for the type of steel used. Typical curves are given in Fig. 23. For design purposes the partial safety factor γ_m, equal to 1.15 shall be applied.

f) The maximum strain in the tension reinforcement in the section at failure shall not be less than:

$$\frac{f_y}{1.15\, E_s} + 0.002$$

where

f_y = Characteristic strength of steel, and

E_s = Modulus of elasticity of steel.

NOTE — The limiting values of depth of neutral axis for different grades of steel based on the assumptions of **37.1** are as follows:

f_y	$x_{u,max}/d$
250	0.53
415	0.48
500	0.46

The expression for obtaining the moments of resistance for rectangular and T-Sections, based on the assumptions of **37.1**, are given in Annex G.

38 LIMIT STATE OF COLLAPSE: COMPRESSION

38.1 Assumptions

In addition to the assumptions given in **37.1**(a) to **37.1**(e) for flexure, the following shall be assumed:

a) The maximum compressive strain in concrete in axial compression is taken as 0.002.

b) The maximum compressive strain at the highly compressed extreme fibre in concrete subjected to axial compression and bending and when there is no tension on the section shall be 0.003 5 minus 0.75 times the strain at the least compressed extreme fibre.

38.2 Minimum Eccentricity

All members in compression shall be designed for the minimum eccentricity in accordance with **24.4**. Where calculated eccentricity is larger, the minimum eccentricity should be ignored.

38.3 Short Axially Loaded Members in Compression

The member shall be designed by considering the assumptions given in **38.1** and the minimum eccentricity. When the minimum eccentricity as per **24.4** does not exceed 0.05 times the lateral dimension, the members may be designed by the following equation:

$$P_u = 0.4\, f_{ck}.A_c + 0.67 f_y.A_{sc}$$

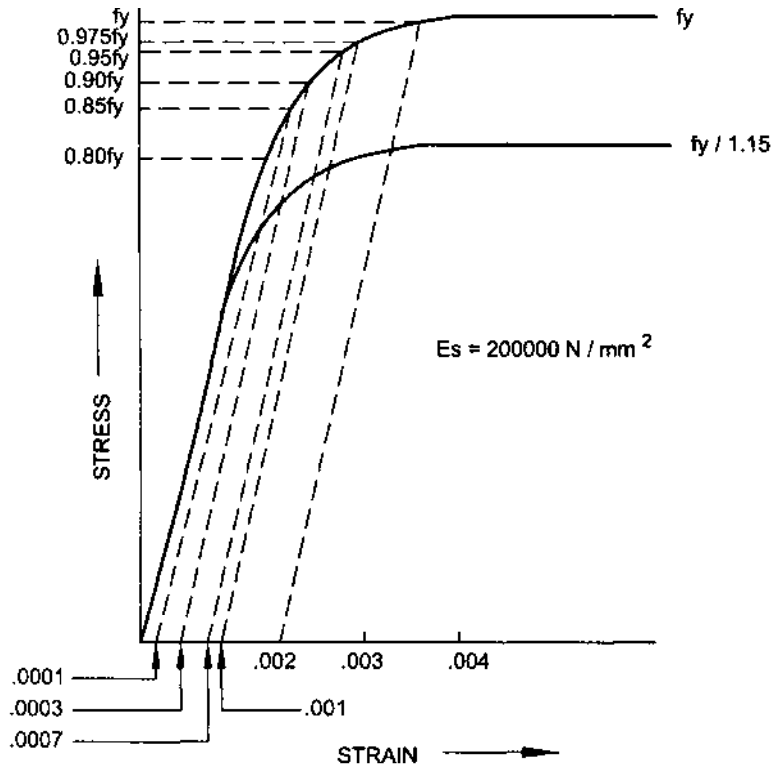
where

P_u = Axial load on the member,

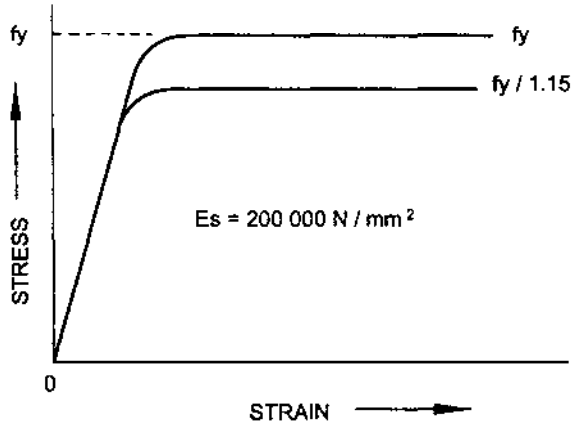
f_{ck} = Characteristic compressive strength of the concrete,

A_c = Area of concrete

f_y = Characteristic strength of the compression reinforcement, and



23A COLD WORKED DEFORMED BAR



23B STEEL BAR WITH DEFINITE YIELD POINT

FIG. 23 REPRESENTATIVE STRESS-STRAIN CURVES FOR REINFORCEMENT

A_{sc} = Area of longitudinal reinforcement for columns.

38.4 Compression Members with Helical Reinforcement

The strength of compression members with helical reinforcement satisfying the requirement of **38.4.1** shall be taken as 1.05 times the strength of similar member with lateral ties.

38.4.1 The ratio of the volume of helical reinforcement to the volume of the core shall not be less than $0.36\,(A_g/A_c - 1)\,f_{ck}/f_y$

where

A_g = Gross area of the section,

A_c = Area of the core of the helically reinforced column measured to the outside diameter of the helix,

f_{ck} = Characteristic compressive strength of the concrete, and

f_y = Characteristic strength of the helical reinforcement but not exceeding 415 N/mm^2.

38.5 Members Subjected to Combined Axial Load and Uniaxial Bending

A member subjected to axial force and uniaxial bending shall be designed on the basis of **38.1** and **38.2**.

NOTE — The design of member subject to combined axial load and uniaxial bending will involve lengthy calculation by trial and error. In order to overcome these difficulties interaction diagrams may be used. These have been prepared and published by BIS in SP 16 'Design aids for reinforced concrete to IS 456'.

38.6 Members Subjected to Combined Axial Load and Biaxial Bending

The resistance of a member subjected to axial force and biaxial bending shall be obtained on the basis of assumptions given in **38.1** and **38.2** with neutral axis so chosen as to satisfy the equilibrium of load and moments about two axes. Alternatively such members may be designed by the following equation:

$$\left[\frac{M_{ux}}{M_{ux1}}\right]^{\alpha_n} + \left[\frac{M_{uy}}{M_{uy1}}\right]^{\alpha_n} \leq 1.0$$

where

M_{ux}, M_{uy} = Moments about x and y axes due to design loads,

M_{ux1}, M_{uy1} = Maximum uniaxial moment capacity for an axial load of P_u, bending about x and y axes respectively, and α_n is related to P_u/P_{uz}

where

$$P_{uz} = 0.45 f_{ck} \cdot A_c + 0.75 f_y \cdot A_{sc}$$

For values of $P_u/P_{uz} = 0.2$ to 0.8, the values of α_n vary linerly from 1.0 to 2.0. For values less than 0.2 α_n is 1.0; for values greater than 0.8, α_n is 2.0.

38.7 Slender Compression Members

The design of slender compression members (*see* **24.1.1**) shall be based on the forces and the moments determined from an analysis of the structure, including the effect of deflections on moments and forces. When the effect of deflections are not taken into account in the analysis, additional moment given in **38.7.1** shall be taken into account in the appropriate direction.

38.7.1 The additional moments M_{ax} and M_{ay} shall be calculated by the following formulae:

$$M_{ax} = \frac{P_u D}{2\,000}\left[\frac{l_{ex}}{D}\right]^2$$

$$M_{ay} = \frac{P_u b}{2\,000}\left[\frac{l_{ey}}{b}\right]^2$$

where

P_u = Axial load on the member,

l_{ex} = Effective length in respect of the major axis,

l_{ey} = Effective length in respect of the minor axis,

D = Depth of the cross-section at right angles to the major axis, and

b = Width of the member.

For design of section, **38.5** or **38.6** as appropriate shall apply.

NOTES

1 A column may be considered braced in a given plane if lateral stability to the structure as a whole is provided by walls or bracing or buttressing designed to resist all lateral forces in that plane. It should otherwise be considered as unbraced.

2 In the case of a braced column without any transverse loads occurring in its height, the additional moment shall be added to an initial moment equal to sum of 0.4 M_{u1} and 0.6 M_{u2} where M_{u2} is the larger end moment and M_{u1} is the smaller end moment (assumed negative if the column is bent in double curvature). In no case shall the initial moment be less than 0.4 M_{u2} nor the total moment including the initial moment be less than M_{u2}. For unbraced columns, the additional moment shall be added to the end moments.

3 Unbraced compression members, at any given level or storey, subject to lateral load are usually constrained to deflect equally. In such cases slenderness ratio for each column may be taken as the average for all columns acting in the same direction.

38.7.1.1 The values given by equation **38.7.1** may be multiplied by the following factor:

$$k = \frac{P_{uz} - P_u}{P_{uz} - P_b} \leq 1$$

where

P_u = Axial load on compression member,

P_{uz} = As defined in **38.6**, and

P_b = Axial load corresponding to the condition of maximum compressive strain of 0.003 5 in concrete and tensile strain of 0.002 in outer most layer of tension steel.

39 LIMIT STATE OF COLLAPSE: SHEAR

39.1 Nominal Shear Stress

The nominal shear stress in beams of uniform depth shall be obtained by the following equation:

$$\tau_v = \frac{V_u}{bd}$$

where

V_u = Shear force due to design loads;

b = Breadth of the member, which for flanged section shall be taken as the breadth of the web, b_w; and

d = Effective depth.

39.1.1 *Beams of Varying Depth*

In the case of beams of varying depth the equation shall be modified as:

$$\tau_v = \frac{V_u \pm \frac{M_u}{d} \tan \beta}{bd}$$

where

τ_v, V_u, b and d are the same as in **39.1**,

M_u = Bending moment at the section, and

β = Angle between the top and the bottom edges of the beam.

The negative sign in the formula applies when the bending moment M_u increases numerically in the same direction as the effective depth d increases, and the positive sign when the moment deceases numerically in this direction.

39.2 Design Shear Strength of Concrete

39.2.1 The design shear strength of concrete in beams without shear reinforcement is given in Table 19.

39.2.1.1 For solid slabs, the design shear strength for concrete shall be $\tau_c k$, where k has the values given below:

Overall Depth of Slab, mm	300 or more	275	250	225	200	175	150 or less
k	1.00	1.05	1.10	1.15	1.20	1.25	1.30

NOTE — This provision shall not apply to flat slabs for which **30.6** shall apply

39.2.2 *Shear Strength of Members under Axial Compression*

For members subjected to axial compression P_u, the design shear strength of concrete, given in Table 19, shall be multiplied by the following factor:

$$\delta = 1 + \frac{3P_u}{A_g f_{ck}} \text{ but not exceeding } 1.5$$

where

P_u = Axial compressive force in Newtons,

A_g = Gross area of the concrete section in mm^2, and

f_{ck} = Characteristic compressive strength of concrete.

39.2.3 *With Shear Reinforcement*

Under no circumstances, even with shear reinforcement,

Table 19 Design Shear Strength of Concrete, τ_c, N/mm^2

(*Clauses* 39.2.1, 39.2.2, 39.3, 39.4, 39.5.3, 40.3.2, 40.3.3 *and* 40.4.3)

$100\frac{A_s}{bd}$	Concrete Code					
	M 15	M 20	M 25	M 30	M 35	M 40 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)
≤ 0.15	0.28	0.28	0.29	0.29	0.29	0.30
0.25	0.35	0.36	0.36	0.37	0.37	0.38
0.50	0.46	0.48	0.49	0.50	0.50	0.51
0.75	0.54	0.56	0.57	0.59	0.59	0.60
1.00	0.60	0.62	0.64	0.66	0.67	0.68
1.25	0.64	0.67	0.70	0.71	0.73	0.74
1.50	0.68	0.72	0.74	0.76	0.78	0.79
1.75	0.71	0.75	0.78	0.80	0.82	0.84
2.00	0.71	0.79	0.82	0.84	0.86	0.88
2.25	0.71	0.81	0.85	0.88	0.90	0.92
2.50	0.71	0.82	0.88	0.91	0.93	0.95
2.75	0.71	0.82	0.90	0.94	0.96	0.98
3.00 and above	0.71	0.82	0.92	0.96	0.99	1.01

NOTE — The term A_s is the area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at support where the full area of tension reinforcement may be used provided the detailing conforms to **25.2.2** and **25.2.3**.

shall be nominal shear stress in beams τ_v exceed $\tau_{c\,max}$ given in Table 20.

39.2.3.1 For solid slabs, the nominal shear stress shall not exceed half the appropriate values given in Table 20.

Table 20 Maximum Shear Stress, $\tau_{c\,max}$, N/mm²

(*Clauses* 39.2.3, 39.2.3.1, 39.5.1 *and* 40.3.1)

Concrete Grade	M 15	M 20	M 25	M 30	M 35	M 40 and above
$\tau_{c\,max}$, N/mm²	2.5	2.8	3.1	3.5	3.7	4.0

39.3 Minimum Shear Reinforcement

When τ_v is less than τ_c given in Table 19, minimum shear reinforcement shall be provided in accordance with **25.5.1.6**.

39.4 Design of Shear Reinforcement

When τ_v exceeds τ_c given in Table 19, shear reinforcement shall be provided in any of the following forms:

a) Vertical stirrups,
b) Bent-up bars along with stirrups, and
c) Inclined stirrups

Where bent-up bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement.

Shear reinforcement shall be provided to carry a shear equal to $V_u - \tau_c bd$. The strength of shear reinforcement V_{us} shall be calculated as below:

a) For vertical stirrups:

$$V_{us} = \frac{0.87\, f_y A_{sv} d}{S_v}$$

b) For inclined stirrups or a series of bars bent-up at different cross-sections:

$$V_{us} = \frac{0.87\, f_y A_{sv} d}{S_v} (\sin\alpha + \cos\alpha)$$

c) For single bar or single group of parallel bars, all bent-up at the same cross-section:

$$V_{us} = 0.87 f_y A_{sv} \sin\alpha$$

where

A_{sv} = Total cross-sectional area of stirrup legs or bent-up bars within a distance s_v,
S_v = Spacing of the stirrups or bent-up bars along with the length of the member,
τ_v = Nominal shear stress,
τ_c = Design shear strength of the concrete,
b = Breadth of the member which for flanged beams, shall be taken as the breadth of the web b_w,
f_y = Characteristic strength of the stirrup or bent-up reinforcement which shall not be taken greater than 415 N/mm²,
α = Angle between the inclined stirrup or bent-up bar and the axis of the member, not less than 45°, and
d = Effective depth.

NOTES

1 Where more than one type of shear reinforcement is used to reinforce the same portion of the beam, the total shear resistance shall be computed as the sum of the resistance for the various types separately.

2 The area of the stirrups shall not be less than the minimum specified in **25.5.1.6**.

39.5 Enhanced Shear Strength of Sections Close to Supports

39.5.1 *General*

Shear failure at sections of beams and cantilevers without shear reinforcement will normally occur on plane inclined at an angle 30° to the horizontal. If the angle of failure plane is forced to be inclined more steeply than this [because the section considered $(X-X)$ in Fig. 24 is close to a support or for other reasons], the shear force required to produce failure is increased.

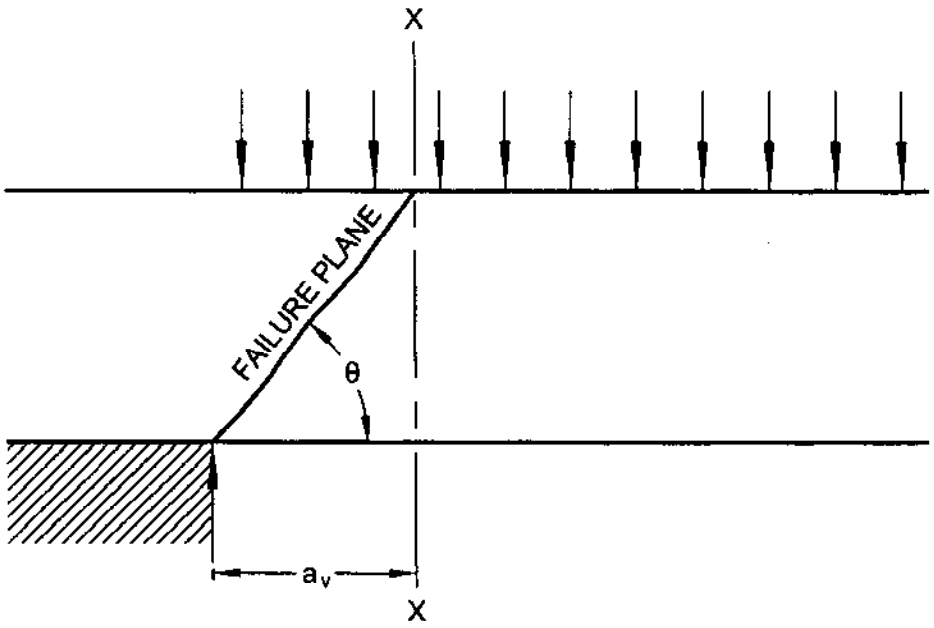
The enhancement of shear strength may be taken into account in the design of sections near a support by increasing design shear strength of concrete to $2d\,\tau_c/a_v$ provided that design shear stress at the face of the support remains less than the values given in Table 20. Account may be taken of the enhancement in any situation here the section considered is closer to the face of a support or concentrated load than twice the effective depth, d. To be effective, tension reinforcement should extend on each side of the point where it is intersected by a possible failure plane for a distance at least equal to the effective depth, or be provided with an equivalent anchorage.

39.5.2 *Shear Reinforcement for Sections Close to Supports*

If shear reinforcement is required, the total area of this is given by

$$A_s = a_v b(\tau_v - 2\,d\tau_c/a_v)/0.87 f_y \geq 0.4\, a_v b/0.87 f_y$$

This reinforcement should be provided within the middle three quarters of a_v, where a_v is less than d, horizontal shear reinforcement will be effective than vertical.



NOTE — The shear causing failure is that acting on Section $X-X$.

FIG. 24 SHEAR FAILURE NEAR SUPPORTS

39.5.3 *Enhanced Shear Strength Near Supports (Simplified Approach)*

The procedure given in **39.5.1** and **39.5.2** may be used for all beams. However for beams carrying generally uniform load or where the principal load is located farther than $2d$ from the face of support, the shear stress may be calculated at a section a distance d from the face of support. The value of τ_c is calculated in accordance with Table 19 and appropriate shear reinforcement is provided at sections closer to the support, no further check for shear at such sections is required.

40 LIMIT STATE OF COLLAPSE: TORSION

40.1 General

In structures, where torsion is required to maintain equilibrium, members shall be designed for torsion in accordance with **40.2** to **40.4**. However, for such indeterminate structures where torsion can be eliminated by releasing redundant restraints, no specific design for torsion is necessary, provided torsional stiffness is neglected in the calculation of internal forces. Adequate control of any torsional cracking is provided by the shear reinforcement as per **39**.

NOTE — The approach to design in this clause is as follows: Torsional reinforcement is not calculated separately from that required for bending and shear. Instead the total longitudinal reinforcement is determined for a fictitious bending moment which is a function of actual bending moment and torsion; similarly web reinforcement is determined for a fictitious shear which is a function of actual shear and torsion.

40.1.1 The design rules laid down in **40.3** and **40.4** shall apply to beams of solid rectangular cross-section. However, these clauses may also be applied to flanged beams, by substituting b_w for b in which case they are generally conservative; therefore specialist literature may be referred to.

40.2 Critical Section

Sections located less than a distance d, from the face of the support may be designed for the same torsion as computed at a distance d, where d is the effective depth.

40.3 Shear and Torsion

40.3.1 *Equivalent Shear*

Equivalent shear V_e, shall be calculated from the formula:

$$V_e = V_u + 1.6\frac{\tau_u}{b}$$

where

V_e = Equivalent shear,
V_u = Shear,
τ_u = Torsional moment, and
b = Breadth of beam.

The equivalent nominal shear stress τ_{ve} in this case shall be calculated as given in **40.1**, except for substituting V_u by V_e. The values of τ_{ve} shall not exceed the values of $\tau_{c\,max}$ given in Table 20.

40.3.2 If the equivalent nominal shear stress τ_{ve} does not exceed τ_c given in Table 19, minimum shear reinforcement shall be provided as per **25.5.1.6**.

40.3.3 If τ_{ve} exceeds τ_c given in Table 19, both longitudinal and transverse reinforcement shall be provided in accordance with **40.4**.

40.4 Reinforcement in Members Subjected to Torsion

40.4.1 Reinforcement for torsion, when required, shall consist of longitudinal and transverse reinforcement.

40.4.2 *Longitudinal Reinforcement*

The longitudinal reinforcement shall be designed to resist an equivalent bending moment, M_{el}, given by

$$M_{el} = M_u + M_t$$

where

M_u = Bending moment at the cross-section, and

$$M_t = T_u \frac{(1 + D/b)}{1.7}$$

where

T_u is the torsional moment, D is the overall depth of the beam and b is the breadth of the beam.

40.4.2.1 If the numerical value of M_t as defined in **40.4.2** exceeds the numerical value of the moment M_u, longitudinal reinforcement shall be provided on the flexural compression face, such that the beam can also withstand an equivalent M_{c2} given by $M_{c2} = M_t - M_u$, the moment M_{c2} being taken as acting in the opposite sense to the moment M_u.

40.4.3 *Transverse Reinforcement*

Two legged closed hoops enclosing the corner longitudinal bars shall have an area of cross-section A_{sv}, given by

$$A_{sv} = \frac{T_u s_v}{b_1 d_1 (0.87 f_y)} + \frac{V_u s_v}{2.5 d_1 (0.87 f_y)}$$

but the total transverse reinforcement shall not be less than

$$\frac{(\tau_{ve} - \tau_c) b . s_v}{0.87 f_y}$$

where

T_u = Torsional moment,

V_u = Shear force,

s_v = Spacing of the stirrup reinforcement,

b_1 = Centre-to-centre distance between corner bars in the direction of the width,

d_1 = Centre-to-centre distance between corner bars,

b = Breadth of the member,

f_y = Characteristic strength of the stirrup reinforcement,

τ_{ve} = Equivalent shear stress as specified in **40.3.1**, and

τ_c = Shear strength of the concrete as per Table 19.

41 LIMIT STATE OF SERVICEABILITY: DEFLECTION

41.1 Flexural Members

In all normal cases, the deflection of a flexural member will not be excessive if the ratio of its span to its effective depth is not greater than appropriate ratios given in **22.2.1**. When deflections are calculated according to Annex C, they shall not exceed the permissible values given in **22.2**.

42 LIMIT STATE OF SERVICEABILITY: CRACKING

42.1 Flexural Members

In general, compliance with the spacing requirements of reinforcement given in **25.3.2** should be sufficient to control flexural cracking. If greater spacing are required, the expected crack width should be checked by formula given in Annex F.

42.2 Compression Members

Cracks due to bending in a compression member subjected to a design axial load greater than $0.2 f_{ck} A_c$, where f_{ck} is the characteristic compressive strength of concrete and A_c is the area of the gross section of the member, need not be checked. A member subjected to lesser load than $0.2 f_{ck} A_c$ may be considered as flexural member for the purpose of crack control (*see* **42.1**).

ANNEX A

(Foreword)

SELF COMPACTING CONCRETE

A-1 Self compacting concrete is concrete that is able to flow under its own weight and completely fill the formwork, even in the presence of dense reinforcement, without segregation, whilst maintaining homogeneity.

A-2 APPLICATION AREA

Self compacting concrete may be used in precast-applications or for concrete placed on site. It can be manufactured in a site batching plant or in a ready mix concrete plant and delivered to site by truck. It can then be placed either by pumping or pouring into horizontal or vertical structures. In designing the mix, the size and the form of the structure, the dimension and density of reinforcement and cover should be taken in consideration.

A-3 CHARACTERISTICS OF FRESH SELF COMPACTING CONCRETE

The level of fluidity of self compacting concrete is governed chiefly by the dosing and type of superplasticizer. Due to the high fluidity of self compacting concrete, the risk of segregation and blocking is very high. Preventing segregation is therefore an important feature of the control regime. The tendency to segregation can be reduced by the use of a sufficient amount of fines (< 0.125 mm), or using a Viscosity Modifying Admixture (VMA).

Features of fresh self compacting concrete

a) Slump about 600 mm
b) Sufficient amount of fines (<0.125 mm)
c) Use of Viscosity Modifying Admixture
d) Segregation resistance

ANNEX B

(Clauses 17.2.2, 21.3.1, 21.7, 25.2.1 *and* 31.1)

STRUCTURAL DESIGN (WORKING STRESS METHOD)

B-1 GENERAL

B-1.1 General Design Requirements

The general design requirements of Section 3 shall apply to this Annex.

B-1.2 Redistribution of Moments

Except where the simplified analysis using coefficients (*see* **21.5**) is used, the moments over the supports for any assumed arrangement of loading, including the dead load moments may each be increased or decreased by not more than 15 percent, provided that these modified moments over the supports are used for the calculation of the corresponding moments in the spans.

B-1.3 Assumptions for Design of Members

In the methods based on elastic theory, the following assumptions shall be made:

a) At any cross-section, plane sections before bending remain plain after bending.
b) All tensile stresses are taken up by reinforcement and none by concrete, except as otherwise specifically permitted.
c) The stress-strain relationship of steel and concrete, under working loads, is a straight line.
d) The modular ratio m has the value $\frac{280}{3\sigma_{cbc}}$

where σ_{cbc} is permissible compressive stress due to bending in concrete in N/mm² as specified in Table 21.

NOTE — The expression given for m partially takes into account long-term effects such as creep. Therefore this m is not the same as the modular ratio derived based on the value of E_c given in **5.2.3.1**.

B-2 PERMISSIBLE STRESSES

B-2.1 Permissible Stresses in Concrete

Permissible stresses for the various grades of concrete shall be taken as those given in Tables 21 and 23.

NOTE — For increase in strength with age **5.2.1** shall be applicable. The values of permissible stress shall be obtained by interpolation between the grades of concrete.

B-2.1.1 *Direct Tension*

For members in direct tension, when full tension is taken by the reinforcement alone, the tensile stress shall be not greater than the values given below:

Grade of Concrete	M 10	M 15	M 20	M 25	M 30	M 35	M 40	M 45	M 50	M 55
Tensile Stress, N/mm^2	1.2	2.0	2.8	3.2	3.6	4.0	4.4	4.8	5.2	5.6

The tensile stress shall be calculated as $\frac{F_t}{A_c + m A_{st}}$

where

F_t = Total tension on the member minus pretension in steel, if any, before concreting;

A_c = Cross-sectional area of concrete excluding any finishing material and reinforcing steel;

m = Modular ratio; and

A_{st} = Cross-sectional area of reinforcing steel in tension.

B-2.1.2 *Bond Stress for Deformed Bars*

In the case of deformed bars conforming to accepted standard [6-5A(40)], the bond stresses given in Table 21 may be increased by 60 percent.

Table 21 Permissible Stresses in Concrete

(*Clauses* B-1.3, B-2.1, B-2.1.2, B-2.3 *and* B-4.2)

Grade of Concrete	Permissible Stress in Compression		Permissible Stress in Bond (Average) for Plain Bars in Tension
	Bending σ_{cbc}	Direct σ_{cc}	τ_{bd}
(1)	(2)	(3)	(4)
M 10	3.0	2.5	—
M 15	5.0	4.0	0.6
M 20	7.0	5.0	0.8
M 25	8.5	6.0	0.9
M 30	10.0	8.0	1.0
M 35	11.5	9.0	1.1
M 40	13.0	10.0	1.2
M 45	14.5	11.0	1.3
M 50	16.0	12.0	1.4
M 55	17.5	13.0	1.5

NOTES

1 The values of permissible shear stress in concrete are given in Table 23.

2 The bond stress given in col 4 shall be increased by 25 percent for bars in compression.

B-2.2 Permissible Stresses in Steel Reinforcement

Permissible stresses in steel reinforcement shall not exceed the values specified in Table 22.

B-2.2.1 In flexural member the value of σ_{st} given in Table 22 is applicable at the centroid of the tensile reinforcement subject to the condition that when more than one layer of tensile reinforcement is provided, the stress at the centroid of the outermost layer shall not exceed by more than 10 percent the value given in Table 22.

B-2.3 Increase in Permissible Stresses

Where stresses due to wind (or earthquake) temperature and shrinkage effects are combined with those due to dead, live and impact load, the stresses specified in Tables 21, 22 and 23 may be exceeded up to a limit of 33⅓ percent. Wind and seismic forces need not be considered as acting simultaneously.

B-3 PERMISSIBLE LOADS IN COMPRESSION MEMBERS

B-3.1 Pedestals and Short Columns with Lateral Ties

The axial load P permissible on a pedestal or short column reinforced with longitudinal bars and lateral ties shall not exceed that given by the following equation:

$$P = \sigma_{cc} A_c + \sigma_{sc} A_{sc}$$

where

σ_{cc} = Permissible stress in concrete in direct compression,

A_c = Cross-sectional area of concrete excluding any finishing material and reinforcing steel,

A_{sc} = Cross-sectional area of the longitudinal steel.

NOTE — The minimum eccentricity mentioned in **24.4** may be deemed to be incorporated in the above equation.

B-3.2 Short Columns with Helical Reinforcement

The permissible load for columns with helical reinforcement satisfying the requirement of **38.4.1** shall be 1.05 times the permissible load for similar member with lateral ties or rings.

B-3.3 Long Columns

The maximum permissible stress in a reinforced concrete column or part thereof having a ratio of effective column length to least lateral dimension above 12 shall not exceed that which results from the multiplication of the appropriate maximum permissible stress as specified under **B-2.1** and **B-2.2** by the coefficient C_r given by the following formula:

$$C_r = 1.25 - \frac{l_{ef}}{48\,b}$$

where

C_r = Reduction coefficient;

l_{ef} = Effective length of column; and

b = Least lateral dimension of column; for

Table 22 Permissible Stresses in Steel Reinforcement

(*Clauses* B-2.2, B-2.2.1, B-2.3 *and* B-4.2)

Sl No.	Type of Stress in Steel Reinforcement	Permissible Stresses in N/mm²		
		Mild Steel Bars Conforming to Grade I of IS 432 (Part 1)	Medium Tensile Steel Conforming to IS 432 (Part 1)	High Yield Strength Deformed Bars Conforming to IS 1786 (Grade Fe 415)
(1)	(2)	(3)	(4)	(5)
i)	Tension (σ_{st} or σ_{sc})			
	a) Up to and including 20 mm	140	Half the guaranteed	230
	b) Over 20 mm	130	yield stress subject to a maximum of 190	230
ii)	Compression in column bars (σ_{sc})	130	130	190
iii)	Compression in bars in a beam or slab when the compressive resistance of the concrete is taken into account	The calculated compressive stress in the surrounding concrete multiplied by 1.5 times the modular ratio or σ_{sc} whichever is lower		
iv)	Compression in bars in a beam or slab where the compressive resistance of the concrete is not taken into account:			
	a) Up to and including 20 mm	140	Half the guaranteed	190
	b) Over 20 mm	130	yield stress subject to a maximum of 190	190

NOTES

1 For high yield strength deformed bars of Grade Fe 500 the permissible stress in direct tension and flexural tension shall be $0.55 f_y$. The permissible stresses for shear and compression reinforcement shall be as for Grade Fe 415.

2 For welded wire fabric conforming to accepted standard [6-5A(46)], the permissible value in tension σ_{st} is 230 N/mm².

3 For the purpose of this Section, the yield stress of steels for which there is no clearly defined yield point should be taken to be 0.2 percent proof stress.

4 When mild steel conforming to Grade II of accepted standard [6-5A(45)] is used, the permissible stresses shall be 90 percent of the permissible stresses in col 3, or if the design details have already been worked out on the basis of mild steel conforming to Grade 1 of accepted standard [6-5A(45)]; the area of reinforcement shall be increased by 10 percent of that required for Grade 1 steel.

column with helical reinforcement, b is the diameter of the core.

For more exact calculations, the maximum permissible stresses in a reinforced concrete column or part thereof having a ratio of effective column length to least lateral radius of gyration above 40 shall not exceed those which result from the multiplication of the appropriate maximum permissible stresses specified under **B-2.1** and **B-2.2** by the coefficient C_r given by the following formula:

$$C_r = 1.25 - \frac{l_{ef}}{160\, i_{min}}$$

where i_{min} is the least radium of gyration.

B-3.4 Composite Columns

a) *Allowable load* — The allowable axial load P on a composite column consisting of structural steel or cast-iron column thoroughly encased in concrete reinforced with both longitudinal and spiral reinforcement, shall not exceed that given by the following formula:

$$P = \sigma_{cc} A_c + \sigma_{sc} A_{sc} + \sigma_{mc} A_m$$

where

σ_{cc} = Permissible stress in concrete in direct compression;

A_c = Net area of concrete section; which is equal to the gross area of the concrete section $-A_{sc} - A_m$;

A_{sc} = Cross-sectional area of longitudinal bar reinforcement;

σ_{mc} = Allowable unit stress in metal core, not to exceed 125 N/mm² for a steel core, or 70 N/mm² for a steel core, or 70 N/mm² for a cast iron core; and

A_m = Cross-sectional area of the steel or cast iron core.

b) *Metal core and reinforcement* — The cross-sectional area of the metal core shall not exceed 20 percent of the gross area of the column. If a hollow metal core is used, it shall be filled with concrete. The amount of longitudinal and spiral reinforcement and the requirements as to spacing of bars, details of splices and thickness of protective shall outside the spiral, shall conform to requirements of **25.5.3**. A clearance of at least

75 mm shall be maintained between the spiral and the metal core at all points, except that when the core consists of a structural steel H-column, the minimum clearance may be reduced to 50 mm.

c) *Splices and connections of metal cores* — Metal cores in composite columns shall be accurately milled at splices and positive provisions shall be made for alignment of one core above another. At the column base, provisions shall be make to transfer the load to the footing at safe unit stresses in accordance with 33. The base of the metal section shall be designed to transfer the load from the entire composite columns to the footing, or it may be designed to transfer the load from the metal section only, provided it is placed in the pier or pedestal as to leave ample section of concrete above the base for the transfer of load from the reinforced concrete section of the column by means of bond on the vertical reinforcement and by direct compression on the concrete. Transfer of loads to the metal core shall be provided for by the use of bearing members, such as billets, brackets or other positive connections, these shall be provided at the top of the metal core and at intermediate floor levels where required. The column as a whole shall satisfy the requirements of formula given under (a) at any point; in addition to this, the reinforced concrete portion shall be designed to carry, according to **B-3.1** or **B-3.2** as the case may be, all floor loads brought into the column at levels between the metal brackets or connections. In applying the formula under **B-3.1** or **B-3.2** the gross area of column shall be taken to be the area of the concrete section outside the metal core, and the allowable load on the reinforced concrete section shall be further limited to $0.28 f_{ck}$ times gross sectional area of the column.

d) *Allowable load on metal core only* — The metal core of composite columns shall be designed to carry safely any construction or other loads to be placed upon them prior to their encasement in concrete.

B-4 MEMBERS SUBJECTED TO COMBINED AXIAL LOAD AND BENDING

B-4.1 Design Based on Uncracked Section

A member subjected to axial load and bending (due to eccentricity of load, monolithic construction, lateral forces, etc) shall be considered safe provided the following conditions are satisfied.

a) $$\frac{\sigma_{cc,\,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,\,cal}}{\sigma_{cbc}} \leq 1$$

where

$\sigma_{cc,\,cal}$ = Calculated direct compressive stress in concrete,

σ_{cc} = Permissible axial compressive stress in concrete,

$\sigma_{cbc,\,cal}$ = Calculated bending compressive stress in concrete, and

σ_{cbc} = Permissible bending compressive stress in concrete.

b) The resultant tension in concrete is not greater than 35 percent and 25 percent of the resultant compression for biaxial and uniaxial bending respectively, or does not exceed three-fourths, the 7 day modulus of rupture of concrete.

NOTES

1 $\sigma_{cbc,\,cal} = \frac{P}{A_c + 1.5m\,A_{sc}}$ for columns with ties where P, A_c and A_{sc} defined in **B-3.1** and m is the modular ratio.

2 $\sigma_{cbc,\,cal} = \frac{M}{Z}$ where M equals the moment and Z equals modulus of section. In the case of sections subject to moments in two directions, the stress shall be calculated separately and added algebraically.

B-4.2 Design Based on Cracked Section

If the requirements specified in **B-4.1** are not satisfied, the stresses in concrete and steel shall be calculated by the theory of cracked section in which the tensile resistance of concrete is ignored. If the calculated stresses are within the permissible stress specified in Tables 21, 22 and 23 the section may be assumed to be safe.

NOTE — The maximum stress in concrete and steel may be found from tables and charts based on the cracked section theory or directly by determining the no-stress line which should satisfy the following requirements:

a) The direct load should be equal to the algebraic sum of the forces on concrete and steel,

b) The moment of the external loads about any reference line should be equal to the algebraic sum of the moment of the forces in concrete (ignoring the tensile force in concrete) and steel about the same line, and

c) The moment of the external loads about any other reference lines should be equal to the algebraic sum of the moment of the forces in concrete (ignoring the tensile force in concrete) and steel about the same line.

B-4.3 Members Subjected to Combined Direct Load and Flexure

Members subjected to combined direct load flexure and shall be designed by limit state method as given

in **38.5** after applying appropriate load factors as given in Table 18.

B-5 SHEAR

B-5.1 Nominal Shear Stress

The nominal shear stress τ_v in beams or slabs of uniform depth shall be calculated by the following equation:

$$\tau_v = \frac{V}{bd}$$

where

V = Shear force due to design loads,

b = Breadth of the member, which for flanged sections shall be taken as the breadth of the web, and

d = Effective depth.

B-5.1.1 *Beams of Varying Depth*

In the case of beams of varying depth, the equation shall be modified as:

$$\tau_v = \frac{V \pm \frac{M \tan \beta}{d}}{bd}$$

where

τ_v, V, b and d are the same as in **B-5.1**.

M = Bending moment at the section, and

β = Angle between the top and the bottom edges of the beam.

The negative sign in the formula applies when the bending moment M increases numerically in the same direction as the effective depth d increases, and the positive sign when the moment decreases numerically in this direction.

B-5.2 Design Shear Strength of Concrete

B-5.2.1 The permissible shear stress in concrete in beams without shear reinforcement is given in Table 23.

B-5.2.1.1 For solid slabs the permissible shear stress in concrete shall be $k\tau_c$ where k has the value given below:

Overall Depth of Slab, mm	300 or more	275	250	225	200	175	150 or less
k	1.00	1.05	1.10	1.15	1.20	1.25	1.30

NOTE — This does not apply to flat slabs for which **30.6** shall apply.

B-5.2.2 *Shear Strength of Members Under Axial Compression*

For members subjected to axial compression P, the permissible shear stress in concrete ζ_c given in Table 23, shall be multiplied by the following factor:

$$\delta = 1 + \frac{5P}{A_g f_{ck}}, \text{ but not exceeding 1.5.}$$

Table 23 Permissible Shear Stress in Concrete

(*Clauses* B-2.1, B-2.3, B-4.2, B-5.2.1, B-5.2.2, B-5.3, B-5.4, B-5.5.3, B-6.3.2, B-6.3.3 *and* B-6.4.3)

$100\frac{A_s}{bd}$	Permissible Shear Stress in Concrete τ_c, N/mm² Grade of Concrete					
	M 15	M 20	M 25	M 30	M 35	M 40 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)
≤ 0.15	0.18	0.18	0.19	0.20	0.20	0.20
0.25	0.22	0.22	0.23	0.23	0.23	0.23
0.50	0.29	0.30	0.31	0.31	0.31	0.32
0.75	0.34	0.35	0.36	0.37	0.37	0.38
1.00	0.37	0.39	0.40	0.41	0.42	0.42
1.25	0.40	0.42	0.44	0.45	0.45	0.46
1.50	0.42	0.45	0.46	0.48	0.49	0.49
1.75	0.44	0.47	0.49	0.50	0.52	0.52
2.00	0.44	0.49	0.51	0.53	0.54	0.55
2.25	0.44	0.51	0.53	0.55	0.56	0.57
2.50	0.44	0.51	0.55	0.57	0.58	0.60
2.75	0.44	0.51	0.56	0.58	0.60	0.62
3.00 and above	0.44	0.51	0.57	0.60	0.62	0.63

NOTE — A_s is that area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at supports where the full area of tension reinforcement may be used provided the detailing conforms to **25.2.2** and **25.2.3.**

P = Axial compressive force in N,

A_g = Gross area of the concrete section in mm^2,

f_{ck} = Characteristic compressive strength of concrete.

B-5.2.3 *With Shear Reinforcement*

When shear reinforcement is provided the nominal shear stress τ_v in beams shall not exceed $\tau_{c\,max}$ given in Table 24.

B-5.2.3.1 For slabs, τ_v shall not exceed half the value of $\tau_{c\,max}$ given in Table 24.

Table 24 Maximum Shear Stress $\tau_{c\,max}$ N/mm^2

(Clauses B-5.2.3, B-5.2.3.1, B-5.5.1 *and* B-6.3.1)

Concrete Grade	M 15	M 20	M 25	M 30	M 35	M 40 and above
$\tau_{c\,max}$ N/mm^2	1.6	1.8	1.9	2.2	2.3	2.5

B-5.3 Minimum Shear Reinforcement

When τ_v is less than τ_c given in Table 23, minimum shear reinforcement shall be provided in accordance with **25.5.1.6**.

B-5.4 Design of Shear Reinfocement

When τ_v exceeds τ_c given in Table 23, shear reinforcement shall be provided in any of the following forms:

a) Vertical stirrups,

b) Bent-up bars along with stirrups, and

c) Inclined stirrups.

Where bent-up bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement.

Shear reinforcement shall be provided to carry a shear equal to $V - \tau_c bd$. The strength of shear reinforcement V_s shall be calculated as below:

a) For vertical stirrups

$$V_s = \frac{\sigma_{sv} A_{sv} d}{S_v}$$

b) For inclined stirrups or a series of bars bent-up at different cross-sections:

$$V_s = \frac{\sigma_{sv} A_{sv} d}{S_v} (\sin\alpha + \cos\alpha)$$

c) For single bar or single group of parallel bars, all bent-up at the same cross-section:

$$V_s = \sigma_{sv} A_{sv} \sin\alpha$$

A_{sv} = Total cross-sectional area of stirrup legs or bent-up bars within a distance,

S_v = Spacing of the stirrups or bent-up bars along the length of the member,

τ_c = Design shear strength of the concrete,

b = Breadth of the member which for flanged beams, shall be taken as the breadth of the web b_w,

σ_{sv} = Permissible tensile stress in shear reinforcement which shall not be taken greater than 230 N/mm^2,

α = Angle between the inclined stirrup or bent-up bar and the axis of the member, not less than 45°, and

d = Effective depth.

NOTE — Where more than one type of shear reinforcement is used to reinforce the same portion of the beam, the total shear resistance shall be computed as the sum of the resistance for the various types separately. The area of the stirrups shall not be less than the minimum specified in **25.5.1.6**.

B-5.5 Enhanced Shear Strength of Sections Close to Supports

B-5.5.1 *General*

Shear failure at sections of beams and centilevers without shear reinforcement will normally occur on plane inclined at an angle 30° to the horizontal. If the angle of failure plane is forced to be inclined more steeply than this [because the section considered (*X* –*X*) in Fig. 24 is close to a support or for other reasons], the shear force required to produce failure is increased.

The enhancement of shear strength may be taken into account in the design of sections near a support by increasing design shear strength of concrete, τ_c to $2d$ τ_c/a_v provided that the design shear stress at the face of support remains less than the values given in Table 24. Account may be taken of the enhancement in any situation where the section considered is closer to the face of a support of concentrated load than twice the effective depth, d. To be effective, tension reinforcement should extend on each side of the point where it is intersected by a possible failure plane for a distance at least equal to the effective depth, or be provided with an equivalent anchorage.

B-5.5.2 *Shear Reinforcement for Sections Close to Supports*

If shear reinforcement is required, the total area of this is given by:

$$A_s = a_v b\,(\tau_v - 2d\,\tau_c/a_v)/\sigma_{sv} \geq 0.4\,a_v b/0.87 f_y$$

This reinforcement should be provided within the

middle three quarters of a_v. Where a_v is less than d, horizontal shear reinforcement will be more effective than vertical.

B-5.5.3 *Enhanced Shear Strength Near Supports (Simplified Approach)*

The procedure given in **B-5.5.1** and **B-5.5.2** may be used for all beams. However for beams carrying generally uniform load or where the principal load is located further than 2 d from the face of support, the shear stress may be calculated at a section a distance d from the face of support. The value of τ_c is calculated in accordance with Table 23 and appropriate shear reinforcement is provided at sections closer to the support, no further check for such section is required.

B-6 TORSION

B-6.1 General

In structures where torsion is required to maintain equilibrium, members shall be designed for torsion in accordance with **B-6.2** to **B-6.4**. However, for such indeterminate structures where torsion can be eliminated by releasing redundant restraints, no specific design for torsion is necessary provided torsional stiffness is neglected in the calculation of internal forces. Adequate control of any torsional, cracking is provided by the shear reinforcement as per **B-5**.

NOTE — The approach to design in this clause for torsion is as follows:

Torsional reinforcement is not calculated separately from that required for bending and shear. Instead the total longitudinal reinforcement is determined for a fictitious bending moment which is a function of actual bending moment and torsion; similarly web reinforcement is determined for a fictitious shear which is a function of actual shear and torsion.

B-6.1.1 The design rules laid down in **B-6.3** and **B-6.4** shall apply to beams of solid rectangular cross-section. However, these clauses may also be applied to flanged beams by substituting b_w for b, in which case they are generally conservative; therefore specialist literature may be referred to.

B-6.2 Critical Section

Sections located less than a distance d, from the face of the support may be designed for the same torsion as computed at a distance d, where d is the effective depth.

B-6.3 Shear and Torison

B-6.3.1 *Equivalent Shear*

Equivalent shear, V_e shall be calculated from the formula:

$$V_e = V + 1.6\frac{T}{b}$$

where

V_e = Equivalent shear,
V = Shear
T = Torsional moment, and
b = Breadth of beam.

The equivalent nominal shear stress, τ_{ve}, in this case shall be calculated as given in **B-5.1**, except for substituting V by V_e. The values of τ_{ve} shall not exceed the values of $\tau_{c\,max}$ given in Table 24.

B-6.3.2 If the equivalent nominal shear stress τ_{ve} does not exceed τ_c, given in Table 23, minimum shear reinforcement shall be provided as specified in **25.5.1.6**.

B-6.3.3 If τ_{ve} exceeds τ_c given in Table 23, both longitudinal and transverse reinforcement shall be provided in accordance with **B-6.4**.

B-6.4 Reinforcement in Members Subjected to Torsion

B-6.4.1 Reinforcement for torsion, when required, shall consist of longitudinal and transverse reinforcement.

B-6.4.2 *Longitudinal Reinforcement*

The longitudinal reinforcement shall be designed to resist an equivalent bending moment, M_{el}, given by

$$M_{el} = M + M_t$$

where

M = Bending moment at the cross-section, and

$M_t = T\frac{(1+D/b)}{1.7}$, where T is the torsional moment, D is the overall depth of the beam and b is the breadth of the beam.

B-6.4.2.1 If the numerical value of M_t as defined in **B-6.4.2** exceeds the numerical value of the moment M, longitudinal reinforcement shall be provided on the flexural compression face, such that the beam can also withstand an equivalent moment M_{e2} given by $M_{e2} = M_t - M$, the moment M_{e2} being taken as acting in the opposite sense to the moment M.

B-6.4.3 *Transverse Reinforcement*

Two legged closed hoops enclosing the corner longitudinal bars shall have an area of cross-section A_{sv}, given by

$$A_{sv} = \frac{T.S_v}{b_1 d_1 \delta_{sv}} + \frac{V.S_v}{2.5 d_1 \sigma_{sv}}$$, but the total transverse reinforcement shall not be less than

$$\frac{(\tau_{ve} \tau_c)\, b.s_v}{\delta_{sv}}$$

where

T = Torsional moment,

V = Shear force,

S_v = Spacing of the stirrup reinforcement,

b_1 = Centre-to-centre distance between corner bars in the direction of the depth,

d_1 = Centre-to centre distance between corner bars in the direction of the depth,

b = Breadth of the member

σ_{sv} = Permissible tensile stress in shear reinforcement

τ_{ve} = Equivalent shear stress as specified in **B-6.3.1**, and

τ_c = Shear strength of the concrete as specified in Table 23.

ANNEX C

(*Clauses* 21.3.2, 22.2.1 *and* 41.1)

CALCULATION OF DEFLECTION

C-1 TOTAL DEFLECTION

C-1.1 The total deflection shall be taken as the sum of the short-term deflection determined in accordance with **C-2** and the long-term deflection, in accordance with **C-3** and **C-4**.

C-2 SHORT-TERM DEFLECTION

C-2.1 The short-term deflection may be calculated by the usual methods for elastic deflections using the short-term modulus of elasticity of concrete, E_c and an effective moment of intertia I_{eff} given by the following equation:

$$I_{eff} = \frac{I_r}{1.2\frac{M_r}{M}\frac{z}{d}\left(1-\frac{x}{d}\right)\frac{b_w}{b}}; \text{ but}$$

$$I_r \le I_{eff} \le I_{gr}$$

where

I_r = Moment of inertia of the cracked section,

M_r = Cracking moment, equal to $\frac{f_{cr}\, I_{gr}}{y_t}$ where

f_{cr} = Modulus of rupture of concrete,

I_{gr} = Moment of inertia of the gross section about the centroidal axis, neglecting the reinforcement, and y_t is the distance from centroidal axis of gross section, neglecting the reinforcement, to extreme fibre in tension,

M = Maximum moment under service loads

z = Lever arm,

x = Depth of neutral axis,

d = Effective depth,

b_w = Breadth of web, and

b = Breadth of compression face.

For continuous beams, deflection shall be calculated using the values of I_{gr}, I_{gr} and M_r modified by the following equation:

$$X_c = k_1\left[\frac{X_1 + X_2}{2}\right] + (1 - k_1)X_o$$

where

X_c = Modified value of X,

X_1, X_2 = Values of X at the supports,

X_o = Value of X at mid span,

k_1 = Coefficient given in Table 25, and

X = Value of I_{gr}, I_{gr} or M_r as appropriate.

C-3 DEFLECTION DUE TO SHRINKAGE

C-3.1 The deflection due to shrinkage a_{cs} may be computed from the following equation:

$$a_{cs} = k_3 \psi_{cs} l^2$$

where

k_3 is a constant depending upon the support conditions,

0.5 for cantilevers,

0.125 for simply supported members,

0.086 for members continuous at one end, and

0.063 for fully continuous members,

ψ_{cs} is shrinkage curvature equal to $k_4 \frac{\varepsilon_{cs}}{D}$

where ε_{cs} is the ultimate shrinkage strain of concrete (*see* **5.2.4**),

$$k_4 = 0.72 \times \frac{P_t - P_c}{\sqrt{P_t}} \le 1.0 \text{ for } 0.25 \le P_t - P_c < 1.0$$

$$= 0.65 \times \frac{P_t - P_c}{\sqrt{P_t}} \leq 1.0 \text{ for } 0.25 \leq P_t - P_c \geq 1.0$$

where

$$P_t = \frac{100\, A_{st}}{bd} \quad \text{and} \quad P_c \frac{100\, A_{sc}}{bd}$$

Table 25 Values of Coefficient, k_1

(*Clause* C-2.1)

k_2	0.5 or less	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
k_1	0	0.03	0.08	0.16	0.30	0.50	0.73	0.91	0.97	1.0

NOTE — k_2 is given by

$$k_2 = \frac{M_1 + M_2}{M_{F1} + M_{F2}}$$

where

M_1, M_2 = Support moments, and

M_{F1}, M_{F2} = Fixed end moments

and D is the total depth of the section, and l is the length of span.

C-4 DEFLECTION DUE TO CREEP

C-4.1 The creep deflection due to permanent loads $a_{cc\,(perm)}$ may be obtained from the following equation:

$$a_{cc\,(perm)} = a_{i,\,cc\,(perm)} - a_{i(perm)}$$

where

$a_{i,cc(perm)}$ = Initial plus creep deflection due to permanent loads obtained using an elastic analysis with an effective modulus of elasticity;

E_{cc} = $\frac{E_c}{1+\theta}$, θ being the creep coefficient; and

$a_{i\,(perm)}$ = Short-term deflection due to permanent load using E_c.

ANNEX D

(*Clauses* 23.4 *and* 36.1.2)

SLABS SPANNING IN TWO DIRECTIONS

D-1 RESTRAINED SLABS

D-1.0 When the corners of a slab are prevented from lifting, the slab may be designed as specified in **D-1.1** to **D-1.11**.

D-1.1 The maximum bending moments per unit width in a slab are given by the following equations:

$$M_x = \alpha_x w l_x^2$$

$$M_y = \alpha_y w l_y^2$$

where

α_x and α_y are coefficients given in Table 26,

w = Total design and load per unit area.

M_x, M_y = Moments on strips of unit width spanning l_x and l_y respectively, and

l_x and l_y = Lengths of the shorter span and longer span respectively.

D-1.2 Slabs are considered as divided in each direction into middle strips and edge strips as shown in Fig. 25 the middle strip being three-quarters of the width and each edge strip one-eight of the width.

D-1.3 The maximum moments calculated as in **D-1.1** apply only to the middle strips and no re-distribution shall be made.

D-1.4 Tension reinforcement provided at mid-span in the middle strip shall extend in the lower part of the slab to within 0.25 l of a continuous edge, or 0.15 l of a discontinuous edge.

D-1.5 Over the continuous edges of a middle strip, the tension reinforcement shall extend in the upper part of the slab a distance of 0.15 l from the support, and at least 50 percent shall extend a distance of 0.3 l.

D-1.6 At a discontinuous edge, negative moments may arise. They depend on the degree of fixity at the edge of the slab but, in general, tension reinforcement equal to 50 percent of that provided at mid-span extending 0.1 l into the span will be sufficient.

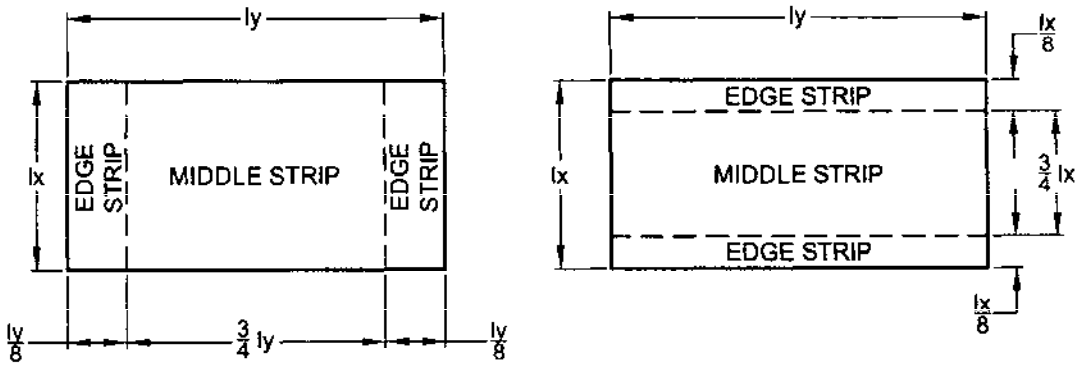
D-1.7 Reinforcement in edge strip, parallel to that edge, shall comply with the minimum given in Section 3 and the requirements for torsion given in **D-1.8** to **D-1.10**.

D-1.8 Torsion reinforcement shall be provided at any corner where the slab is simply supported on both edges meeting at that corner. It shall consist of top and bottom reinforcement, each with layers of bars placed parallel

Four Sides with Provision for Torsion at Corners

(*Clauses* D-1.1 *and* 23.4.1)

Case No.	Type of Panel and Moments Considered	Short Span Coefficients α_x (Values of l_y/l_x)								Long Span Coefficients α_y for All Values of l_y/l_x
		1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	*Interior Panels*:									
	Negative moment at continuous edge	0.032	0.037	0.043	0.047	0.051	0.053	0.060	0.065	0.032
	Positive moment at mid-span	0.024	0.028	0.032	0.036	0.039	0.041	0.045	0.049	0.024
2	*One Short Edge Discontinuous*:									
	Negative moment at continuous edge	0.037	0.043	0.048	0.051	0.055	0.057	0.064	0.068	0.037
	Positive moment at mid-span	0.028	0.032	0.036	0.039	0.041	0.044	0.048	0.052	0.028
3	*One Long Edge Discontinuous*:									
	Negative moment at continuous edge	0.037	0.044	0.052	0.057	0.063	0.067	0.077	0.085	0.037
	Positive moment at mid-span	0.028	0.033	0.039	0.044	0.047	0.051	0.059	0.065	0.028
4	*Two-Adjacent Edges Discontinuous*:									
	Negative moment at continuous edge	0.047	0.053	0.060	0.065	0.071	0.075	0.084	0.091	0.047
	Positive moment at mid-span	0.035	0.040	0.045	0.049	0.053	0.056	0.063	0.069	0.035
5	*Two Short Edges Discontinuous*:									
	Negative moment at continuous edge	0.045	0.049	0.052	0.056	0.059	0.060	0.065	0.069	—
	Positive moment at mid-span	0.035	0.037	0.040	0.043	0.044	0.045	0.049	0.052	0.035
6	*Two Long Edges Discontinuous*:									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
	Positive moment at mid-span	0.035	0.043	0.051	0.057	0.063	0.068	0.080	0.088	0.035
7	*Three Edges Discontinuous*: (One Long Edge Continuous)									
	Negative moment at continuous edge	0.057	0.064	0.071	0.076	0.080	0.084	0.091	0.097	—
	Positive moment at mid-span	0.043	0.048	0.053	0.057	0.060	0.064	0.069	0.073	0.043
8	*Three Edges Discontinuous (One Short Edge Continuous)*:									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.057
	Positive moment at mid-span	0.043	0.051	0.059	0.065	0.071	0.076	0.087	0.096	0.043
9	*Four Edges Discontinuous*:									
	Positive moment at mid-span	0.056	0.064	0.072	0.079	0.085	0.089	0.100	0.107	0.056



25 A - FOR SPAN lx

25 B - FOR SPAN ly

FIG. 25 DIVISION OF SLAB INTO MIDDLE AND EDGE STRIPS

to the sides of the slab and extending from the edges a minimum distance of one-fifth of the shorter span. The area of reinforcement in each of these four layers shall be three-quarters of the area required for the maximum mid-span moment in the slab.

D-1.9 Torsion reinforcement equal to half that described in **D-1.8** shall be provided at a corner contained by edges over only one of which the slab is continuous.

D-1.10 Torsion reinforcements need not be provided at any corner contained by edges over both of which the slab is continuous.

D-1.11 Where l_y/l_x is greater than 2, the slabs shall be designed as spanning one way.

D-2 SIMPLY SUPPORTED SLABS

D-2.1 When simply supported slabs do not have adequate provision to resist torsion at corners and to prevent the corners from lifting, the maximum moments per unit width are given by the following equation:

$$M_x = \alpha_x w l_x^2$$

$$M_y = \alpha_y w l_x^2$$

where

M_x, M_y, l_y, l_x are same as those in **D-1.1**, and α_x and α_y are moment coefficients given in Table 27.

D-2.1.1 At least 50 percent of the tension reinforcement provided at mid-span should extend to the supports. The remaining 50 percent should extend to within 0.1 l_x or 0.1 l_y of the support, as appropriate.

Table 27 Bending Moment Coefficients for Slabs Spanning in Two Directions at Right Angles, Simply Supported on Four Sides

(Clause D-2.1)

l_y/l_x	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	2.5	3.0
α_x	0.062	0.074	0.084	0.093	0.099	0.104	0.113	0.118	0.122	0.124
α_y	0.062	0.061	0.059	0.055	0.051	0.046	0.037	0.029	0.020	0.014

ANNEX E

(*Clause* 25.2)

EFFECTIVE LEGNTH OF COLUMNS

E-1 In the absence of more exact analysis, the effective length of columns in framed structures may be obtained from the ratio of effective length to unsupported length l_e/l give in Fig. 26 when relative displacement of the ends of the column is prevented and in Fig. 26 when relative lateral displacement of the ends is not prevented. In the latter case, it is recommended that the effective length ratio l_{ef}/l may not be taken to be less than 1.2.

NOTES

1 Figures 26 and 27 are reproduced from 'The Stratural Engineer' No. 7, Volume 52, July 1974 by the permission of the Council of the Institution of Structural Engineers, U.K.

2 In Fig. 26 and 27 β_1 and β_2 are equal to

$$\frac{K_c}{K_c + K_b}$$

where the summation is to be done for the members framing into a joint at top and bottom respectively; and K_c and K_b being the flexural stiffness for column and beam respectively.

E-2 To determine whether a column is a no sway or a sway column, stability index Q may be computed as given below:

$$Q = \frac{P_u \Delta_u}{H_u h_s}$$

where

P_u = Sum of axial loads on all column in the storey,

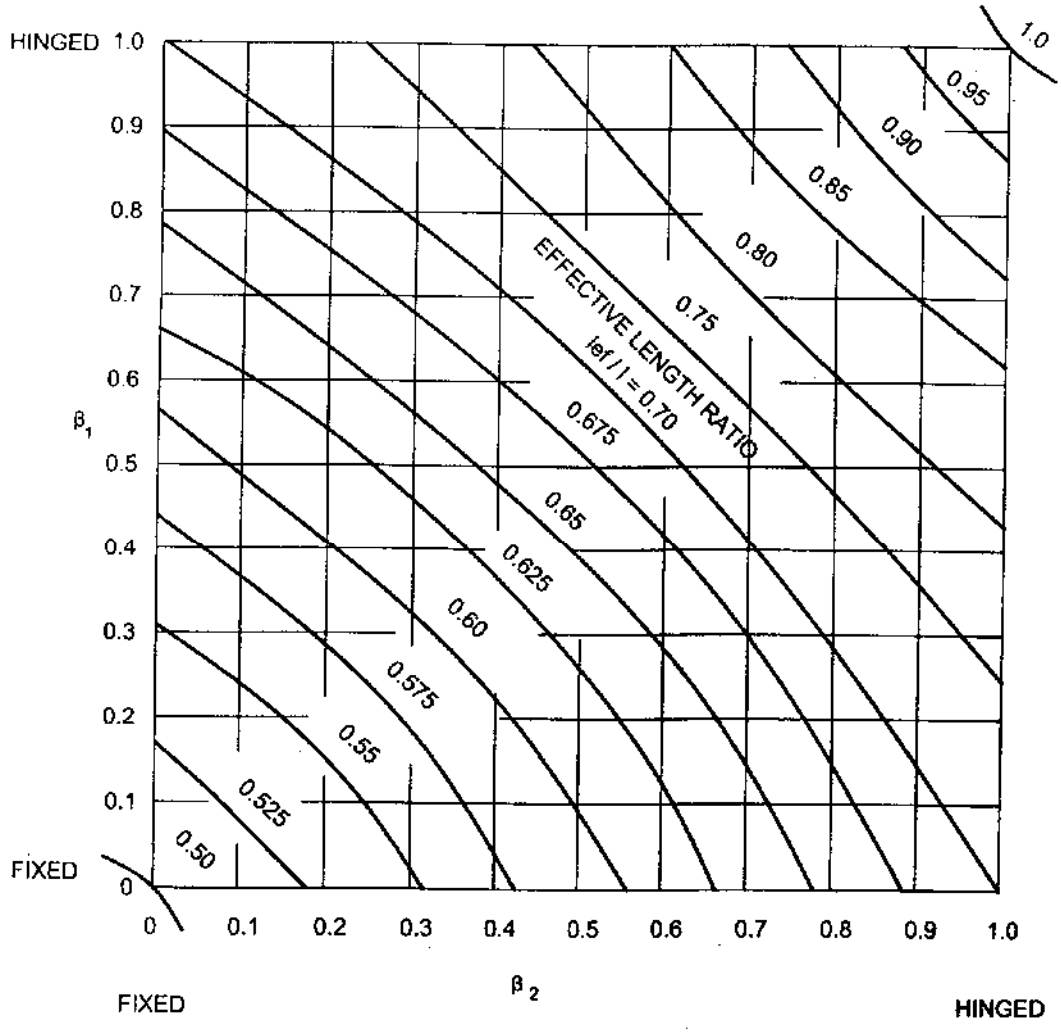


FIG. 26 EFFECTIVE LENGTH RATIOS FOR A COLUMN IN A FRAME WITH NO SWAY

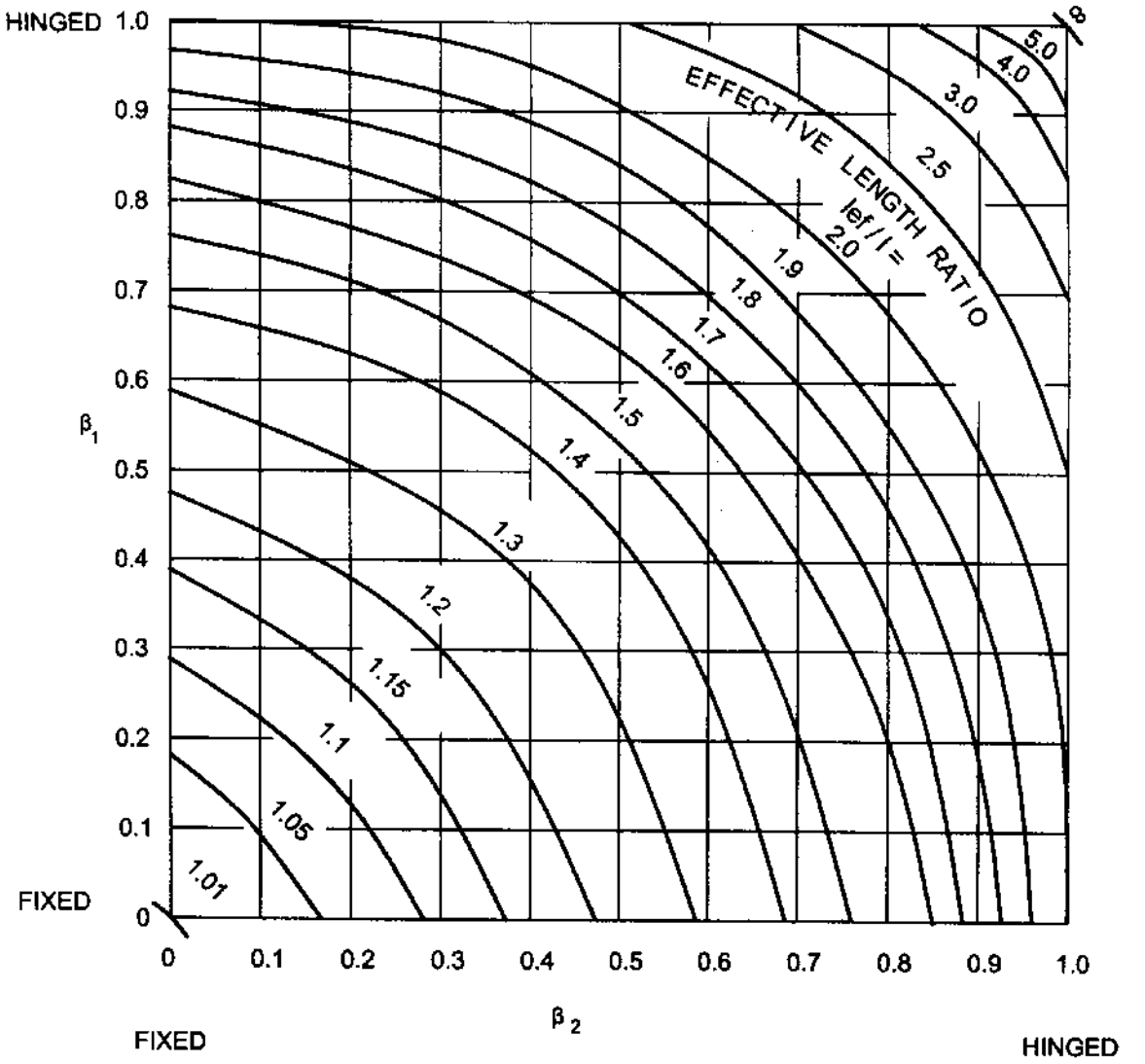


FIG. 27 EFFECTIVE LENGTH RATIOS FOR A COLUMN IN A FRAME WITHOUT RESTRAINT AGAINST SWAY

Δ_u = Elastically computed first order lateral deflection,

H_u = Total lateral force acting within the storey, and

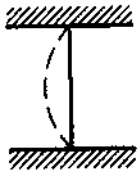
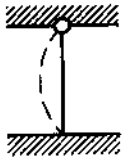
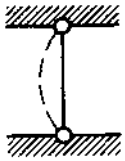
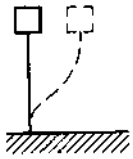
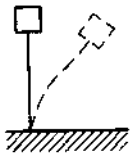
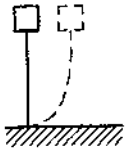
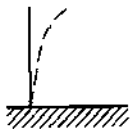
h_s = Height of the storey.

If $Q \leq 0.04$, then the column in the frame may be taken as no sway column, otherwise the column will be considered as sway column.

E-3 For normal usage assuming idealized conditions, the effective length l_{ef} of in a given plane may be assessed on the basis of Table 28.

Table 28 Effective Length of Compression Members

(*Clause* E-3)

Degree of End Restraint of Compression Members	Symbol	Theoretical Value of Effective Length	Recommended Value of Effective Length
(1)	(2)	(3)	(4)
Effectively held in position and restrained against rotation at both ends		0.50 *l*	0.65 *l*
Effectively held in position at both ends, restrained against rotation at one end		0.70 *l*	0.80 *l*
Effectively held in position at both ends, but not restrained against rotation		1.00 *l*	1.00 *l*
Effectively held in position and restrained against rotation at one end, and at the other restrained against rotation but not held in position		1.00 *l*	1.20 *l*
Effectively held in position and restrained against rotation in one end, and at the other partially restrained against rotation but not held in position		—	1.50 *l*
Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position		2.00 *l*	2.00 *l*
Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end		2.00 *l*	2.00 *l*

NOTE — *l* is the unsupported length of compression member.

ANNEX F

(Clauses 34.3.2 *and* 42.1)

CALCULATION OF CRACK WIDTH

Provided that the strain in the tension reinforcement is limited to 0.8 F_y/E_s, the design surface crack width, which should not exceed the appropriate value given in **34.3.2** may be calculated from the following equation:

Design surface crack width

$$W_{cr} = \frac{3a_{cr}\varepsilon_m}{1+\frac{2(a_{cr}-C_{min})}{h-x}}$$

where

a_{cr} = Distance from the point considered to the surface of the nearest longitudinal bar,

C_{min} = Minimum cover to the longitudinal bar,

ε_m = Average steel strain at the level considered,

h = Overall depth of the member, and

x = Depth of the neutral axis.

The average steel strain ε_m may be calculated on the basis of the following assumption:

The concrete and the steel are both considered to be fully elastic in tension and in compression. The elastic modulus of the steel may be taken as 200 kN/mm^2 and the elastic modulus of the concrete is as derived from the equation given in **5.2.3.1** both in compression and in tension.

Alternatively, as an approximation, it will normally be satisfactory to calculate the steel stress on the basis of a cracked section and then reduce this by an amount equal to the tensile force generated by the triangular distributions, having a value of zero at the neutral axis and a value at the centroid of the tension steel of 1 N/mm^2 instantaneously, reducing to 0.55 N/mm^2 in the long-term, acting over the tension zone divided by the steel area.

These assumptions are illustrated in Fig. 28,

where

h = Overall depth of the section,

x = Depth from the compression face to the neutral axis.

f_c = Maximum compressive stress in the concrete,

f_s = Tensile stress in the reinforcement, and

E_s = Modulus of elasticity of the reinforcement.

For a rectangular tension zone, this gives

$$\varepsilon_m = \varepsilon_1 - \frac{b(h-x)(a-x)}{3E_sA_s(d-x)}$$

where

A_s = Area of tension reinforcement,

b = Width of the section at the centroid of the tension steel,

ε_1 = Strain at the level considered, calculated ignoring the stiffening of the concrete in the tension zone,

a = Distance from the compression face to the point at which the crack width is being calculated, and

d = Effective depth.

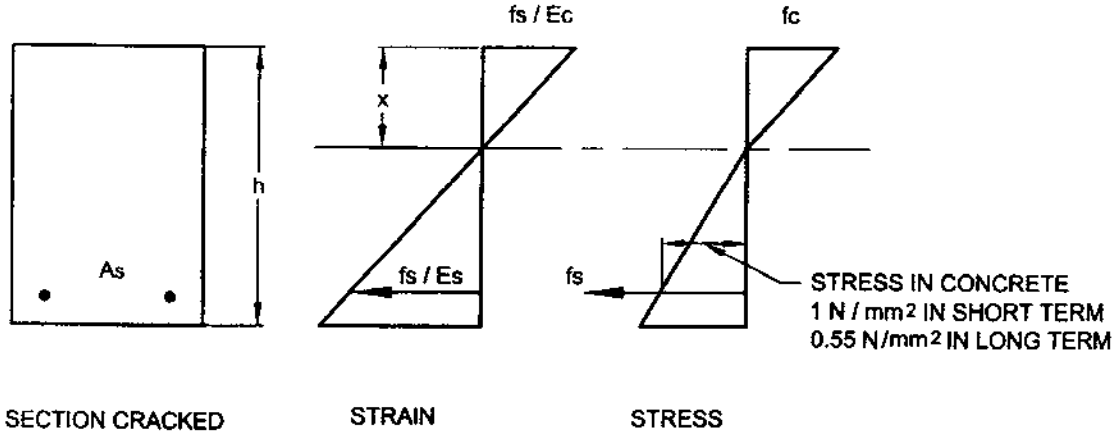


FIG. 28

ANNEX G

(*Clause* 38.1)

MOMENTS OF RESISTANCE FOR RECTANGULAR AND T-SECTIONS

G-0 The moments of resistance of rectangular and T-sections based on the assumption of **37.1** are given in this Annex.

G-1 RECTANGULAR SECTIONS

G-1.1 Sections Without Compression Reinforcement

The moment of resistance of rectangular sections without compression reinforcement should be obtained as follows:

a) Determine the depth of neutral axis from the following equation:

$$\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b.d}$$

b) If the value of x_u/d is less than the limiting value (*see* Note below **37.1**), calculate the moment of resistance by the following expression:

$$M_u = 0.87 f_y A_{st} d\left[1 - \frac{A_{st} f_y}{bd f_{ck}}\right]$$

c) If the value of x_u/d is equal to the limiting value, the moment of resistance of the section is given by the following expression:

$$M_{u,lim} = 0.36 \frac{x_{u,max}}{d}\left[1 - 0.42\frac{x_{u,max}}{d}\right] bd^2 f_{ck}$$

d) If x_u/d is greater than the limiting value, the section should be redesigned.

In the above equations,

x_u = Depth of neutral axis,
d = Effective depth,
f_y = Characteristic strength of reinforcement,
A_{st} = Area of tension reinforcement,
f_{ck} = Characteristic compressive strength of concrete,
b = Width of the compression face,
$M_{u;lim}$ = Limiting moment of resistance of a section without compression reinforcement, and
$x_{u,max}$ = Limiting value of x_u from **37.1**.

G-1.2 Section with Compression Reinforcement

Where the ultimate moment of resistance of section exceeds the limiting value, $M_{u;lim}$ compression reinforcement may be obtained from the following equation:

$$M_u - M_{u,lim'} = f_{sc} A_{sc} (d - d')$$

where

$M_u, M_{u,lim}, d$ are same as in **G-1.1**

f_{sc} = Design stress in compression reinforcement corresponding to a strain of

$$0.003\,5 \frac{(x_{u,max} - d')}{x_{u,max}}$$

$x_{u,max}$ = Limiting value of x_u from **37.1**.
A_{sc} = Area of compression reinforcement, and
d' = Depth of compression reinforcement from compression face.

The total area of tension reinforcement shall be obtained from the following equation:

$$A_{st} = A_{st1} + A_{st2}$$

where

A_{st} = Area of the total tensile reinforcement,
A_{st1} = Area of the tensile reinforcement for a singly reinforced section for $M_{u,lim}$, and
$A_{st2} = A_{sc} f_{sc}/0.87 f_y$.

G-2 FLANGED SECTION

G-2.1 For $x_u < D_f$ the moment of resistance may be calculated from the equation given in **G-1.1**.

G-2.1 The limiting value of the moment of resistance of the section may be obtained by the following equation when the ratio D_f/d does not exceed 0.2:

$$M_u = 0.36 \frac{x_{u,max}}{D}\left[1 - 0.42\frac{x_{u,max}}{d}\right] f_{ck} b_w d^2$$

$$+ 0.45 f_{ck} (b_f - b_w) D_f \left[d - \frac{D_f}{2}\right]$$

where

$M_u, x_{u,max}, d$ and f_{ck} are same as in **G-1.1**,
b_f = Breadth of the compression face/flange,
b_w = Breadth of the web,
D_f = Thickness of the flange.

G-2.2.1 When the ratio D_f/d exceeds 0.2, the moment of resistance of the section may be calculated by the following equation:

$$M_u = 0.36 \frac{x_{u,max}}{D}\left[1-0.42\frac{x_{u,max}}{d}\right] f_{ck} b_w d^2$$

$$+ 0.45\, f_{ck}\, (b_f - b_w)\, y_f \left[d - \frac{y_f}{2}\right]$$

where

y_f = $(0.15\, x_u + 0.65\, D_f)$, but not greater than D_f

and the other symbols are same as in **G-1.1** and **G-2.2.**

G-2.3 For $x_{u,\,max} > x_u > D_f$, the moment of resistance may be calculated by the equations given in **G-2.2** when D_f/x_u does not exceed 0.43 and **G-2.2.1** when D_f/x_u exceeds 0.43; in both cases substituting $x_{u,\,max}$ by x_u.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

	IS No.	*Title*
(1)	3370	Code of practice for concrete structures for the storage of liquid:
	(Part 1) : 1965	General requirements
	(Part 2) : 1965	Reinforced concrete structures
	2210 : 1998	Criteria for design of reinforced concrete shell structures and folded plates (*first revision*)
	3201 : 1988	Criteria for design and construction of precast-trusses and purlins (*first revision*)
	4090 : 1967	Criteria for design of reinforced concrete arches
	4995	Criteria for design of reinforced concrete bins for Storage of granular and powdery materials
	(Part 1) : 1974	General requirements and bin loads
	(Part 2) : 1974	Design criteria
	4998 (Part 1) : 1992	Criteria for design of reinforced concrete chimneys: Part 1 Assessment of loads (*second revision*)
(2)	4845 : 1968	Definitions and terminology relating to hydraulic cement
	6461	Glossary of terms relating to cement:
	(Part 1) : 1972	Concrete aggregates
	(Part 2) : 1972	Materials
	(Part 3) : 1972	Concrete reinforcement
	(Part 4) : 1972	Types of concrete
	(Part 5) : 1972	Formwork for concrete
	(Part 6) : 1972	Equipment, tool and plant
	(Part 7) : 1973	Mixing, laying, compaction, curing and other construction aspect
	(Part 8) : 1973	Properties of concrete
	(Part 9) : 1973	Structural aspects
	(Part 10) : 1973	Tests and testing apparatus
	(Part 11) : 1973	Prestressed concrete
	(Part 12) : 1973	Miscellaneous
(3)	269 : 1989	Specification for ordinary Portland cement, 33 grade (*fourth revision*)
	8112 : 1989	Specification for 43 grade ordinary Portland cement (*fist revision*)
	12269 : 1987	Specification for 53 grade ordinary Portland cement
	8041 : 1990	Specification for rapid hardening Portland cement (*second revision*)
	455 : 1989	Specification for Portland slag cement (*fourth revision*)
	1489	Specification for Portland pozzolana cement:
	(Part 1) : 1991	Fly ash based (*third revision*)
	(Part 2) : 1991	Calcined clay based (*third revision*)
	8043 : 1991	Specification for hydrophobic Portland cement (*second revision*)
	12600 : 1989	Specification for low heat Portland cement
	12330 : 1988	Specification for sulphate resisting Portland cement

IS No.	*Title*
(4) 6452 : 1989	Specification for high alumina cement for structural use
6909 : 1990	Specification for supersulphated cement
(5) 3812	Specification for pulverized fuel ash:
(Part 1) : 2003	For use as pozzolana in cement, cement mortar and concrete (*second revision*)
(Part 2) : 2003	For use as admixture in cement mortar and concrete (*second revision*)
(6) 12089 : 1987	Specification for granulated slag for manufacture of Portland slag cement
(7) 383 : 1970	Specification for coarse and fine aggregates from natural sources for concrete (*second revision*)
(8) 3025	Methods of sampling and test (physical and chemical) for water and waste water:
(Part 17) : 1984	Non-filterable residue (total suspended solids) (*first revision*)
(Part 18) : 1984	Volatile and fixed residue (total filterable and non-filterable) (*first revision*)
(Part 22) : 1986	Acidity (*first revision*)
(Part 23) : 1986	Alkalinity (*first revision*)
(Part 24) : 1986	Sulphates (*first revision*)
(Part 32) : 1988	Chloride (*first revision*)
(9) 516 : 1959	Method of test for strength of concrete
(10) 4031 (Part 5) : 1988	Methods of physical tests for hydraulic cement: Part 5 Determination of initial and final setting times (*first revision*)
(11) 9103 : 1999	Specification for admixtures for concrete (*first revision*)
(12) 432 (Part 1) : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (*third revision*)
1786 : 1985	Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*)
1566 : 1982	Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*)
2062 : 1999	Steel for general structural purposes (*fifth revision*)
(13) 4082 : 1996	Recommendations on stacking and storage of construction materials and components at site (*second revision*)
(14) 516 : 1959	Method of test for strength of concrete
5816 : 1999	Method of test for splitting tensile strength of concrete (*first revision*)
(15) 1343 : 1980	Code of practice for prestressed concrete (*first revision*)
(16) 1199 : 1959	Methods of sampling and analysis of concrete
(17) 9013 : 1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
(18) 383 : 1970	Specification for coarse and fine aggregates from natural sources for concrete (*second revision*)
455 : 1989	Specification for Portland slag cement (*fourth revision*)
(19) 1489 (Part 1) : 1991	Specification for Portland pozzolana cement: Part 1 Fly ash based (*third revision*)
(20) 6909 : 1990	Specification for super-sulphated cement
(21) 4925 : 1968	Specification for concrete batching and mixing plant
(22) 4926 : 2003	Code of practice for ready-mixed concrete (*second revision*)
(23) 2386 (Part 3) : 1963	Methods of test for aggregates for concrete: Part 3 Specific gravity, density, voids, absorption and bulking
(24) 1791 : 1985	Specification for batch type concrete mixers (*second revision*)
12119 : 1987	General requirements for pan mixers for concrete
(25) 14687 : 1999	Guidelines for falsework for concrete structure

IS No.	*Title*
(26) 2502 : 1963	Code of practice for bending and fixing of bars for concrete reinforcement
(27) 2751 : 1979	Recommended practice for welding of mild steel plain and deformed bars for reinforced construction (*first revision*)
9417 : 1989	Recommendations for welding cold worked bars for reinforced concrete construction (*first revision*)
(28) 2505 : 1992	Concrete vibrators — Immersion type — General requirements
2506 : 1985	General requirements for screed board concrete vibrators (*first revision*)
2514 : 1963	Specification for concrete vibrating tables
4656 : 1968	Specification for form vibrators for concrete
(29) 11817 : 1986	Classification of joints in buildings for accommodation of dimensional deviations during construction
(30) 7861	Code of practice for extreme weather concreting:
(Part 1) : 1975	Recommended practice for hot weather concreting
(Part 2) : 1981	Recommended practice for cold weather concreting
(31) 9013 : 1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
(32) 13311	Methods of non-destructive testing of concrete:
(Part 1) : 1992	Ultrasonic pulse velocity
(Part 2) : 1992	Rebound hammer
(33) 875	Code of practice for design loads (other than earthquake) for buildings and structures:
(Part 1) : 1987	Dead loads — Unit weights of building material and stored materials (*second revision*)
(Part 2) : 1987	Imposed loads (*second revision*)
(Part 3) : 1987	Wind loads (*second revision*)
(Part 4) : 1987	Snow loads (*second revision*)
(Part 5) : 1987	Special loads and load combinations (*second revision*)
(34) 1893 (Part 1) : 2002	Criteria for earthquake resistant design of structures: General provisions and buildings (*fifth revision*)
(35) 1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
(36) 1641 : 1988	Code of practice for fire safety of buildings (general): General principles of fire grading and classification (*first revision*)
(37) 1642 : 1989	Code of practice for fire safety of buildings (general): Details of construction (*first revision*)
(38) 13920 : 1993	Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces
(39) 4326 : 1993	Code of practice for earthquake resistant design and construction of buildings (*second revision*)
(40) 1786 : 1985	Specification for high strength deformed steel bars and wires for concrete reinforcement (*third revision*)
(41) 3414 : 1968	Code of practice for design and installation of joints in buildings
(42) 3951 (Part 1) : 1975	Specification for hollow clay tiles for floors and roofs: Part 1 Filler type (*first revision*)
(43) 6061	Code of practice for construction of floor and roof with joists and filler blocks:
(Part 1) : 1971	With hollow concrete filler blocks
(Part 2) : 1981	With hollow clay filler blocks (*first revision*)
(44) 432 (Part 1) : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (*third revision*)
(45) 1566 : 1982	Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*)

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 5 Concrete: 5B Prestressed Concrete

BUREAU OF INDIAN STANDARDS

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FOREWORD ... 3

1 SCOPE ... 5
2 STRUCTURAL DESIGN USING PRESTRESSED CONCRETE ... 5

FOREWORD

This sub-section covers the structural design aspects of prestressed concrete.

This sub-section is largely based on IS 1343 : 1980 'Code of practice for prestressed concrete (*first revision*)', which is under revision at the time of publication of this Code. Major changes have been envisaged in the revision of IS 1343. In the absence of availability of finalized version of revised IS 1343, at the time of revision of this Code, the provision of design as per existing IS 1343 : 1980 have been continued through appropriate reference to the same.

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 5 Concrete: 5B Prestressed Concrete

1 SCOPE

This sub-section deals with the general structural use of prestressed concrete. It covers both work carried out on site and the manufacture of precast prestressed concrete units.

2 STRUCTURAL DESIGN USING PRESTRESSED CONCRETE

The provisions relating to design and general structural use of prestressed concrete including on:

a) materials, workmanship, inspection and testing;
b) general design requirements; and
c) structural design: limit state method,

shall be in accordance with good practices contained in IS 1343 : 1980 'Code of practice for prestressed concrete (*first revision*)'.

NOTE— At the time of publication of this sub-section, IS 1343 was under revision; and once the revised IS 1343 is published, the same shall replace the provisions given in this sub-section.

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 6 Steel

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section covers the structural design aspect of steel structures in buildings.

This Section covers the use of hot-rolled structural steel sections and steel tubes in buildings. It permits the design by working stress method and plastic theory, and now in this revision by limit state method. Further, reference to space frame has now found place in this Section.

This Section is based on IS 800 : 1984 'Code of practice for general construction in steel (*second revision*)' and IS 806 : 1968 'Code of practice for use of steel tubes in general building construction (*first revision*)', and also enables design using limit state method.

More rigorous analytical procedures than envisaged as per this Section are available and can be made use of for finding effective lengths of compression members in determining elastic critical loads.

The Indian Standard IS 800, on which this Section is largely based is under revision at the time of publication of this Code. Major changes have been envisaged in the revision of IS 800 including introduction of limit state method. In the absence of availability of finalized version of revised IS 800 at the time of revision of this Section, in this revision, the provisions of design as per existing IS 800 : 1984 have been continued through appropriate reference to the same; similarly reference has been made to IS 806. At the same time, the limit state method having already gained acceptance has been taken into account in this revision by providing suitable enabling provisions and also covering certain general principles thereof.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 6 Steel

1 SCOPE

1.1 This Section covers the use of structural steel in general building construction including the use of hot rolled steel sections and steel tubes.

1.2 The provisions of this Section are generally applicable to rivetted, bolted and welded construction.

2 TERMINOLOGY

For the purpose of this Section, the definitions as given in accepted standard [6-6(1)] shall apply.

3 PLANS AND DRAWINGS

3.1 Plans, drawings and stress sheets shall be prepared according to good practice [6-6(2)].

3.2 Plans

The plans (design drawings) shall show the complete design with sizes, sections, and the relative locations of the various members. Floor levels, column centres, and offsets shall be dimensioned. Plans shall be drawn to a scale large enough to convey the information adequately. Plans shall indicate the type of construction to be employed; and shall be supplemented by such data on the assumed loads, shears, moments and axial forces to be resisted by all members and their connections, as may be required for the proper preparation of shop drawings. Any special precaution to be taken in the erection of structure from the design considerations, the same shall also be indicated in the drawing.

3.3 Shop Drawings

Shop drawings, giving complete information necessary for the fabrication of the component parts of the structure including the location, type, size, length and detail of all welds, shall be prepared in advance of the actual fabrication. They shall clearly distinguish between shop and field rivets, bolts and welds. For additional information to be included on drawings for designs based on the use of welding, reference shall be made to appropriate Indian Standards. Shop drawings shall be made in accordance with good practice [6-6(2)]. A marking diagram allotting distinct identification marks to each separate part of steel work shall be prepared. The diagram shall be sufficient to ensure convenient assembly and erection at site.

4 MATERIALS

All materials used in structural steel construction shall conform to Part 5 'Building Materials'. Structural steel, rivets, welding consumables, steel castings, bolts and nuts, washers and steel tubes shall be in accordance with accepted standards [6-6(3)] and other relevant Indian Standards.

5 DESIGN AND CONSTRUCTION IN STEEL

The design and construction in steel including general design requirements, design of tension members, design of compression members, design of members subjected to bending, design of members subjected to combined stresses, design of connections, plastic design, design of encased members, fabrication and erection, and the steel work tenders and contracts, shall be done in accordance with good practice [6-6(1)] and the design and construction involving use of steel tubes shall be in accordance with good practice [6-6(4)].

6 DESIGN USING LIMIT STATE METHOD

6.1 General

6.1.1 The design in steel may be done using the limit state method, which is generally based on the following basic aspects/principles:

a) It makes use of the plastic range of material for the design of structural members and incorporates load factors to take into account the variability of loading configurations.

b) It considers the good performance of steel in tension compared to compression and specifies variable factors. It takes into account this variance by defining limit states which address strength and serviceability.

c) According to this method, a structure or part of it, is considered unfit for use when it exceeds the limit state beyond which it infringes any one of the criteria governing its performance or use.

d) The two limit states are classified as the Ultimate Limit State and Serviceability Limit State. The limit states take care of the safe operation and adequacy of the structure from strength point of view. The criteria which are used to define the ultimate limit state are yielding, plastic strength, fatigue, buckling, etc. Serviceability limit state takes care of the performance and behaviour of the structure during its service period. Deflection, vibration, drift, etc are considered as serviceability criteria.

element of a member. This method has provisions to enhance resistance of plate elements against local buckling by suitably reducing the slenderness ratio. Hence, it is possible to develop the full flexural moment capacity of a member subjected to flexure or the Limit State in flexure for a beam. In Limit State Method, based on slenderness ratio of the constituent plate elements, a member can be classified as Slender, Semi-compact, Compact and Plastic. This section classification becomes essential as the moment or load capacities of each of these sections take different values depending upon these classifications.

6.1.2 In this method, the factored loads, in different combinations, are applied to the structure to determine the load effects. The latter are then compared with the design strength of the elements.

This is expressed mathematically as:

The effects of

$$\gamma_L \cdot Q_k \leq \left[\frac{1}{\gamma_m}\right]$$

[Function of σ_y and other geometric variables]

γ_m = $\gamma_f \cdot \gamma_{m1} \cdot \gamma_{m2}$
= Partial safety factor for material.

γ_L = Partial factor for loads.

γ_f Factor that takes into account the inaccuracies in assessment of loads, stress distribution and construction tolerances.

γ_{m1}, γ_{m2} = Factors that take into account, uncertainties in material strength and quality, and manufacturing tolerances respectively.

Q_k = Specified nominal load induced based on design stipulations.

σ_y = Yield strength of the material.

6.2 The detailed design procedure shall be as agreed between the parties concerned.

NOTE — At the time of publication of this Section IS 800 was under revision and once the revised IS 800 is published, the same shall replace the provisions given in this section.

7 SPACE FRAME

For analysis and design of space frame along with its components, specialist literature may be referred to, and the methodology for the same may be as agreed between the parties concerned.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	800 : 1984	Code of practice for general construction in steel (*second revision*)
(2)	962 : 1989	Code of practice for architectural and building drawings (*second revision*)
	8000	Geometrical tolerancing on technical drawings:
	(Part 1) : 1985	Tolerances of form, orientation, location and run-out, and appropriate geometrical definitions (*first revision*)
	(Part 2) : 1992	Maximum material principles (*first revision*)
	(Part 3) : 1992	Dimensioning and tolerancing of profiles (*second revision*)
	(Part 4) : 1976	Practical examples of indications on drawings
	IS 8976 : 1978	Guide for preparation and arrangement of sets of drawings and parts list
(3)	*Structural Steel*	
	1977 : 1996	Specification for low tensile structural steels (*third revision*)
	2062 : 1999	Specification for steel for general structural purpose (*fifth revision*)

IS No.	Title
8500 : 1991	Specification for structural steel-microalloyed (medium and high tensile qualities) (*first revision*)
1161 : 1998	Specification for steel tubes for structural purposes (*third revision*)
Rivets	
1929 : 1982	Specification for hot forged steel rivets for hot closing (12 to 36 mm diameter) (*first revision*)
2155 : 1982	Specification for cold forged solid steel rivets for hot closing (6 to 16 mm diameter) (*first revision*)
1148 : 1982	Specification for hot-rolled rivet bars (up to 40 mm diameter) for structural purposes (*third revision*)
1149 : 1982	Specification for high tensile steel rivet bars for structural purposes (*third revision*)
Welding Consumables	
1278 : 1972	Specification for filler rods and wires for gas welding (*second revision*)
814 : 1991	Specification for covered electrodes for manual metal arc welding of carbon and carbon manganese steels (*fifth revision*)
1395 : 1982	Specification for low and medium alloy steel covered electrodes for manual metal arc welding (*third revision*)
7280 : 1974	Specification for bare wire electrodes for submerged arc welding of structural steels
3613 : 1974	Specification for acceptance tests for wire-flux combinations for submerged arc welding (*first revision*)
6419 : 1996	Specification for welding rods and bare electrodes for gas shielded arc welding of structural steel (*first revision*)
6560 : 1996	Specification for molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding (*first revision*)

IS No.	Title
Steel Castings	
1030 : 1998	Specification for carbon steel castings for general engineering purposes (*fifth revision*)
2708 : 1993	Specification for 1.5 percent manganese steel castings for general engineering purposes (*third revision*)
Bolts and Nuts	
1363	Specification for hexagon head bolts, screws and nuts of product grade C:
(Part 1) : 2002	Hexagon head bolts (size range M5 to M64) (*fourth revision*)
(Part 2) : 2002	Hexagon head screws (size range M5 to M64) (*fourth revision*)
(Part 3) : 2002	Hexagon nuts (size range M5 to M64) (*fourth revision*)
IS 1364	Specification for hexagon head bolts, screws and nuts of product grade A and B:
(Part 1) : 1992	Hexagon head bolts (size range M1.6 to M64) (*fourth revision*)
(Part 2) : 2002	Hexagon head screws (size range M1.6 to M64) (*fourth revision*)
IS 1367	Technical supply conditions for threaded steel fasteners:
(Part 1) : 2002	General requirements for bolts, screws and studs (*third revision*)
(Part 2) : 2002	Tolerances for fastners — Bolts, screws, studs and nuts — Product grades A, B and C (*third revision*)
IS 3640 : 1982	Specification for hexagon fit bolts (*first revision*)
IS 3757 : 1985	Specification for high strength structural bolts (*second revision*)
IS 6623 : 1985	Specification for high strength structural nuts (*first revision*)
IS 6639 : 1972	Specification for hexagon bolts for steel structures
Washers	
IS 5369 : 1975	General requirements for plain washers and lock washers (*first revision*)

	with outside diameter more than three times the diameter
5372 : 1975	Specification for taper washers for channels (ISMC) (*first revision*)
5374 : 1975	Specification for taper washers for I-beams (ISMB) (*first revision*)
	bolts (*first revision*)
6610 : 1972	Specification for heavy washers for steel structures
6649 : 1985	Specification for hardened and tempered washers for high strength structural bolts and nuts (*first revision*)

(4)

806 : 1968	Code of use of steel tubes in general building construction

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction: 7A Prefabricated Concrete

BUREAU OF INDIAN STANDARDS

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FOREWORD

Prefabrication, though desirable for large scale building activities, has yet to take a firm hold in the country. Two aspects of prefabrication specifically to be borne in mind are the system to be adopted for the different categories of buildings and the sizes of their components. Here the principle of modular co-ordination is of value and its use is recommended.

Advantages of recent trends in prefabrication have been taken note of and also the hazards attended to such construction. A few recommendations on the need to avoid 'progressive collapse' of the structure have been included. This has become necessary in view of such collapses in the past. A specific point to be borne in mind, therefore, is the need to make the structure reasonably safe against such a collapse.

Prefabricated constructions being comparatively a new technique, some of the essential requirements for the manufacture of the prefabricated components and elements are also included in this Section.

Since the aim of prefabrication is to effect economy, improvement in quality and speed in construction, the selection of proper materials for prefabrication is also an important factor in the popularization of this technique. The use of locally available materials with required characteristics and those materials which, due to their innate characteristics like lightweight, easy workability, thermal insulation, non-combustibility, etc, effect economy and improved quality, may be tried. However, this Section pertains to prefabricated elements with cementatious materials.

It is possible to achieve or evolve aesthetically satisfying designs using prefabricated construction. A careful and judicious handling of materials and use of finishes on a prefabricated building can help the designer a great deal in ensuring that the appearance of the building as aesthetically appealing. The purpose of finishes and architectural treatment is not only to give prefabricated buildings an individual character but also to effect better performance and greater user satisfaction.

The design of prefabricated buildings shall include provision for all installations of services and their required piping, wiring and accessories to be installed in the building.

This Section was first published in 1970 and was subsequently revised in 1983. In the last revision the following main changes were made:

a) A brief provision regarding importance of architectural treatment and finishes as applicable to prefabricated buildings were included;
b) A brief clause was added on the requirements of materials for use in prefabrication;
c) The clause on prefabricating systems and structural elements was elaborated;
d) The clause on testing of components was revised to include testing of structure or part of structure; and
e) A brief clause on the manufacture of cellular concrete was added.

In this revision, this Section, earlier named as Prefabrication and Systems Building has been named and restructured as follows:

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction
7A Prefabricated Concrete
7B Systems Building and Mixed/Composite Construction

This sub-section covers Prefabricated concrete. In this revision the following main changes have been made:

a) Modular coordination and modular dimension of the components have been revised to have more flexibility for planning.
b) The provisions on tolerance has been revised to include different types of prefabricated components.

has been included.

d) A clause on sampling procedure has been added for testing of components.

e) List of Indian Standards referred as good practice has been updated, specially in view of formulation of a large number of new Indian Standards on partially prefabricated components.

All standards cross-referred to in the main text of the sub-section, are subject to revision. The parties to agreement based on this sub-section are encouraged to investigate the possibility of applying the most recent editions of the standard.

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction: 7A Prefabricated Concrete

1 SCOPE

This sub-section gives recommendations regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transport and erection of prefabricated concrete elements for use in buildings and such related requirements for prefabricated concrete.

2 TERMINOLOGY

2.1 For the purpose of this sub-section, the following definitions shall apply.

2.1.1 *Authority Having Jurisdiction* — The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.1.2 *Basic Module* — The fundamental module used in modular co-ordination, the size of which is selected for general application to building and its components.

NOTE — The value of the basic module has been chosen as 100 mm for the maximum flexibility and convenience. The symbol for the basic module is *M*.

2.1.3 *Cellular Concrete* — The material consisting of an inorganic binder (such as, lime or cement or both) in combination with a finely ground material containing siliceous material (such as sand), gas generating material (for example, aluminium powder), water and harmless additives (optional); and steam cured under high pressure in autoclaves.

2.1.4 *Components* — A building product formed as a distinct unit having specified sizes in three dimensions.

2.1.5 *Composite Members* — Structural members comprising prefabricated structural units of steel, prestressed concrete or reinforced concrete and cast *in-situ* concrete connected together in such a manner that they act monolithically.

2.1.6 *Increments* — Difference between two homologous dimensions of components of successive sizes.

2.1.7 *Light Weight Concrete* — Concrete of substantially lower unit weight than that made from gravel or crushed stone.

2.1.8 *Module* — A unit of size used in dimensional co-ordination.

2.1.9 *Modular Co-ordination* — Dimensional co-ordination employing the basic module or a multi-module.

NOTE — The purposes of modular co-ordination are:

a) to reduce the variety of component sizes produced, and
b) to allow the building designer greater flexibility in the arrangement of components.

2.1.10 *Modular Grid* — A rectangular coordinate reference system in which the distance between consecutive lines is the basic module or a multi-module. This multi-module may differ for each of the two dimensions of the grid.

2.1.11 *Multi-module* — A module whose size is a selected multiple of the basic module.

2.1.12 *Prefabricate* — To fabricate components or assembled units prior to erection or installation in a building.

2.1.13 *Prefabricated Building* — The partly/fully assembled and erected building, of which the structural parts consist of prefabricated individual units or assemblies using ordinary or controlled materials, including service facilities; and in which the service equipment may be either prefabricated or constructed *in-situ*.

2.1.14 *Sandwich Concrete Panels* — Panels made by sandwiching an insulation material between two layers of reinforced concrete to act as insulation for concrete panels.

2.1.15 *Self Compacting Concrete* — Concrete that is able to flow under its own weight and completely fill the voids within the formwork, even in the presence of dense reinforcement without any vibration, whilst maintaining homogeneity without segregation.

2.1.16 *Shear Connectors* — Structural elements, such as anchors, studs, channels and spirals, intended to transmit the horizontal shear between the prefabricated member and the cast *in-situ* concrete and also to prevent vertical separation at the interface.

2.1.17 *System* — It is a particular method of construction of buildings with certain order and discipline using the prefabricated components, tunnel form or large panel shutters which are inter-related in functions and are produced based on a set of instructions.

2.1.18 *Unit* — Building material formed as a simple article with all three dimensions specified, complete

in itself but intended to be part of a compound unit or complete building. Examples are brick, block, tile, etc.

3 MATERIALS, PLANS AND SPECIFICATIONS

3.1 Materials

All materials shall conform to Part 5 'Building Materials'.

3.1.1 While selecting the materials for prefabrication, the following characteristics shall be considered:

a) Easy availability;
b) Light weight for easy handling and transport;
c) Thermal insulation property;
d) Easy workability;
e) Durability;
f) Non-combustibility;
g) Sound insulation;
h) Economy; and
j) Any other special requirement in a particular application.

3.2 Plans and Specifications

The detailed plans and specifications shall cover the following:

a) Such drawings shall describe the elements and the structure and assembly including all required data of physical properties of component materials. Material specification, age of concrete for demoulding, casting/erection tolerance and type of curing to be followed.
b) Details of connecting joints of prefabricates shall be given to an enlarged scale.
c) Site or shop location of services, such as installation of piping, wiring or other accessories integral with the total scheme shall be shown separately.
d) Data sheet indicating the location of the inserts and acceptable tolerances for supporting the prefabricate during erection, location and position of doors/windows/ventilators, etc, if any.
e) The drawings shall also clearly indicate location of handling arrangements for lifting and handling the prefabricated elements. Sequence of erection with critical check points and measures to avoid stability failure during construction stage of the building.

4 MODULAR CO-ORDINATION, ARCHITECTURAL TREATMENT AND FINISHES

4.1 Modular Co-ordination

The basic module is to be adopted. After adopting this, further work is necessary to outline suitable range of multi-modules with greater increments, often referred to as preferred increments. A set of rules as detailed below would be adequate for meeting the requirements of conventional and prefabricated construction.

These rules relate to the following basic elements:

a) The planning grid in both directions of the horizontal plan shall be:
   1) 15 *M* for industrial buildings,
   2) 3 *M* for other buildings.

   The centre lines of load bearing walls should preferably coincide with the gridlines.
b) The planning module in the vertical direction shall be 2 *M* for industrial buildings and 1 *M* for other buildings.
c) Preferred increments for sill heights, doors, windows and other fenestration shall be 1 *M*.
d) In the case of internal columns, the grid lines shall coincide with the centre lines of columns. In case of external columns and columns near the lift and stair wells, the grid lines shall coincide with centre lines of the column in the topmost storey.

4.2 Architectural Treatment and Finishes

Treatment and finishes have to be specified keeping in view the requirements of protection, function and aesthetics of internal and external spaces and surfaces.

While deciding the type of architectural treatment and finishes for prefabricated buildings, the following points should be kept in view:

a) Suitability for mass production techniques;
b) Recognition of the constraints imposed by the level of workmanship available;
c) Possibility of using different types of finishes;
d) Use of finishes and architectural treatment for the creation of a particular architectural character in individual buildings and in groups of buildings by the use of colour, texture, projections and recesses on surfaces, etc;
e) Incorporation of structural elements like joists, columns, beams, etc, as architectural features and the treatment of these for better overall performance and appearance;
f) Satisfactory finishing of surfaces; and
g) Use of light weight materials to effect economy in the structural system.

Some of the acceptable methods of finishes integral with the precasting are:

a) Concrete surface moulded to design; shape;

b) Laid-on finishing tiles fixed during casting;

c) Finishes obtained by washing, tooling, grinding, grooving of hardened concrete;

d) Exposed aggregates; and

e) Other integral finishes.

5 COMPONENTS

5.1 The preferred dimensions of precast elements shall be as follows:

a) *Flooring and Roofing Scheme* — Precast slabs or other precast structural flooring units:

1) *Length* — Nominal length shall be in multiples of 1 *M*;

2) *Width* — Nominal width shall be in multiples of 0.5 *M*; and

3) *Overall Thickness* — Overall thickness shall be in multiples of 0.1 *M*.

b) *Beams*

1) *Length* — Nominal length shall be in multiples of 1 *M*;

2) *Width* — Nominal width shall be in multiples of 0.1 *M*; and

3) *Overall Depth* — Overall depth of the floor zone shall be in multiples of 0.1 *M*.

c) *Columns*

1) *Height* — Height of columns for industrial and other building 1 *M*; and

2) *Lateral Dimensions* — Overall lateral dimension or diameter of columns shall be in multiples of 0.1 *M*.

d) *Walls*

Thickness — The nominal thickness of walls shall be in multiples of 0.1 *M*.

e) *Staircase*

Width — Nominal width shall be in multiples of 1 *M*.

f) *Lintels*

1) *Length* — Nominal length shall be in multiples of 1 *M*;

2) *Width* — Nominal width shall be in multiples of 0.1 *M*; and

3) *Depth* — Nominal depth shall be in multiples of 0.1 *M*.

g) *Sunshades/Chajja Projections*

1) *Length* — Nominal length shall be in multiples of 1 *M*.

2) *Projection* — Nominal length shall be in multiples of 0.5 *M*.

5.2 Casting Tolerances of Precast Components

Sl No.	*Product Tolerances*	*Product (see Note)*
(1)	(2)	(3)
i)	*Length*	
	± 5 mm	1, 7
	± 5 mm or ± 0.1 percent whichever is greater	2, 3, 8
	± 0.1 percent subject to maximum of $^{+5}_{-10}$ mm	4
	± 2 mm for length below and up to 500 mm	5
	± 5 mm for length over 500 mm	5
	± 10 mm	6, 9,10
ii)	*Thickness/Cross-sectional dimensions*	
	± 3 mm	1
	± 3 mm or 0.1 percent whichever is greater	2, 8
	± 2 mm up to 300 mm wide ± 3 mm greater than 300 mm wide	4
	± 2 mm	3, 7
	± 4 mm	6, 9, 10
iii)	*Straightness/Bow*	
	± 5 mm or 1/750 of length whichever is greater	2, 4, 8
	± 3 mm	1, 5
	± 2 mm	7
iv)	*Squareness*	
	When considering the squareness of the corner, the longer of two adjacent sides being checked shall be taken as the base line.	
	The shorter side shall not vary in length from the perpendicular by more than 5 mm	2, 5, 8
	The shorter side shall not vary in length from the perpendicular by more than 3 mm	1, 7
	The shorter side shall not be out of square line for more than $^{+2}_{-5}$ mm	4
v)	*Twist*	
	Any corner shall not be more than the tolerance given below from the plane containing the other three corners:	
	± 5 mm (Up to 600 mm in width and up to 6 m in length)	2, 8
	± 10 mm (Over 600 mm in width and for any length)	
	± 1/1 500 of dimension of ± 5 mm whichever is less	4

(1)	(2)	(3)
	± 3 mm	1
	± 1 mm	7
vi)	*Flatness*	
	The maximum deviation from 1.5 m straight edge placed in any position on a nominal plane surface shall not exceed	
	± 5 mm	2, 8
	± 3 mm	4
	± 2 mm	1, 7
	± 4 or maximum of 0.1 percent length	5

NOTES — Key for product reference

1 Channel unit
2 Ribbed slab unit/hollow slab
3 Waffle unit
4 Large panel prefabrication
5 Cellular concrete floor/roof slabs
6 Prefabricated brick panel
7 Precast planks
8 Ribbed/plain wall panel
9 Column
10 Step unit

6 PREFABRICATION SYSTEMS AND STRUCTURAL SCHEMES

6.1 The word 'system' is referred to a particular method of construction of buildings using the prefabricated components which are inter-related in functions and are produced to a set of instructions. With certain constraints, several plans are possible, using the same set of components. The degree of flexibility varies from system to system. However, in all the systems there is a certain order and discipline.

6.2 The following aspects, among others, are to be considered in devising a system:

a) Effective utilization of spaces;
b) Straight and simple walling scheme;
c) Limited sizes and numbers of components;
d) Limited opening in bearing walls;
e) Regulated locations of partitions;
f) Standardized service and stair units;
g) Limited sizes of doors and windows with regulated positions;
h) Structural clarity and efficiency;
j) Suitability for adoption in low rise and high rise building;
k) Ease of manufacturing, storing and transporting;
m) Speed and ease of erection; and
n) Simple jointing system.

6.3 Prefabrication Systems

The system of prefabricated construction depends on the extent of the use of prefabricated components, their materials, sizes and the technique adopted for their manufacture and use in building.

6.3.1 *Types of Prefabrication Components*

The prefabricated concrete components such as those given below may be used which shall be in accordance with Part 5 'Building Materials' and the accepted standards [6-7A(1)], where available:

a) Reinforced/Prestressed concrete channel unit,
b) Reinforced/Prestressed concrete slab unit,
c) Reinforced/Prestressed concrete beams,
d) Reinforced/Prestressed concrete columns,
e) Reinforced/Prestressed concrete hollow core slab,
f) Reinforced concrete waffle slab/shells,
g) Reinforced/Prestressed concrete wall elements,
h) Hollow/Solid blocks and battens,
j) Precast planks and joists for flooring and roofing,
k) Precast joists and trussed girders,
m) Light weight/cellular concrete slabs,
n) Precast lintel and chajjas,
p) Large panel prefabricates,
q) Reinforced/Prestressed concrete trusses,
r) Reinforced/Prestressed roof purlins,
s) Precast concrete L-panel unit,
t) Prefabricated brick panel unit,
u) Prefabricated sandwich concrete panel, and
v) Precast foundation.

There may be other types of components which may be used with the approval of the Authority.

NOTE — The elements may be cast at the site or off the site.

6.3.2 There are two categories of open prefab system depending on the extent of prefabrication used in the construction as given in **6.3,2.1** and **6.3.2.2**.

6.3.2.1 *Partial prefabrication system*

This system basically uses precast roofing and flooring components and other minor elements like lintels, *CHAJJAS*, kitchen sills in conventional building construction. The structural system could be in the form of *in-situ* framework or load bearing walls.

6.3.2.2 *Full prefabrication system*

In this system almost all the structural components are prefabricated. The filler walls may be of brick/block masonry or of any other locally available material.

6.3.3 *Large Panel Prefabrication System*

This system is based on the use of large prefab components. The components used are precast concrete large panels for walls, floors, roofs, balconies, staircases, etc. The casting of the components could be at the site or off the site.

Depending upon the extent of prefabrication, this system can also lend itself to partial prefab system and full prefab system.

Structural scheme with precast large panel walls can be classified as given in **6.3.3.1** to **6.3.3.3**.

6.3.3.1 *Precast Walls*

6.3.3.1.1 Based on the structural functions of the walls, the precast walls may be classified as:

a) load bearing walls,
b) non-load bearing walls, and
c) shear walls.

6.3.3.1.2 Based on construction, the precast walls may be classified as:

a) *Homogeneous walls* — which could be solid, hollow or ribbed; and
b) *Non-homogeneous walls* — these could be composite or sandwich panels.

6.3.3.1.3 Based on their locations and functional requirements the precast walls may also classified as:

a) external walls, which may be load bearing or non-load bearing depending upon the lay-out; these are usually non-homogeneous walls of sandwiched type to impart better thermal comforts; and
b) internal walls providing resistance against vertical loads, horizontal loads, fire, etc; these are normally homogeneous walls.

6.3.3.2 *Precast floors*

6.3.3.2.1 Depending upon the composition of units, precast flooring units may be homogeneous or non-homogeneous.

a) Homogeneous floors may be solid slabs, cored slabs, ribbed or waffle slabs.
b) Non-homogeneous floors may be multi-layered ones with combinations of light weight concrete or reinforced/prestressed concrete, with filler blocks.

6.3.3.2.2 Depending upon the way the loads are transferred, the precast floors may be classified as one way or two way systems:

a) One way system transfers loads to supporting members in one direction only. The precast elements which come under this category are channel slabs, hollow core slabs, channels and ties system, light weight/cellular concrete slabs, etc.
b) Two way systems transfer loads in both the directions imparting loads on the four edges. The precast elements under this category are room sized panels, two way ribbed or waffle slab systems, etc.

6.3.3.3 *Staircase systems*

Staircase system may consist of single flights with in-built risers and treads in the element. The flights are normally unidirectional transferring the loads to supporting landing slabs or load bearing walls.

6.3.4 *Box Type Construction*

In this system, room size units are prefabricated and erected at site. Toilet and kitchen blocks could also be similarly prefabricated and erected at site.

NOTE — This system derives its stability and stiffness from the box units which are formed by four adjacent walls. Walls are jointed to make rigid connections among themselves. The box unit rests on foundation which may be of conventional type or precast type.

6.4 Design Considerations

The precast structure should be analyzed as a monolithic one and the joints in them designed to take the forces of an equivalent discrete system. Resistance to horizontal loading shall be provided by having appropriate moment and shear resisting joints or placing shear walls (in diaphragm braced frame type of construction) in two directions at right angles or otherwise. No account is to be taken of rotational stiffness, if any, of the floor-wall joint in case of precast bearing wall buildings. The individual components shall be designed, taking into consideration the appropriate end conditions and loads at various stages of construction. The components of the structure shall be designed for loads in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects'. In addition members shall be designed for handling, erection and impact loads that might be expected during handling and erection.

6.4.1 In some conventional forms of construction, experience has shown that the structures are capable of safely sustaining abnormal conditions of loading and remaining stable after the removal of primary structural members. It has been shown that some forms of building structure and particularly some industrialized large panel systems have little reserve strength to resist forces not specifically catered for in the design. In the light of this, therefore, recommendations made in **6.4.2** to **6.4.9** should be kept in mind for ensuring stability of such structure.

6.4.2 Adequate buttressing of external wall panels is important since these elements are not fully restrained on both sides by floor panels. Adequate design precautions may be taken by the designer. Experience shows that the external wall panel connections are the weakest points of a precast panel building.

6.4.3 It is equally important to provide restraint to all load bearing elements at the corners of the building. These elements and the external ends of cross-wall units should be stiffened either by introducing columns as connecting units or by jointing them to non-structural wall units which in emergency may support the load. Jointing of these units should be done bearing in mind the need for load support in an emergency.

6.4.4 In prefabricated construction, the possibility of gas or other explosions which can remove primary structural elements leading to progressive collapse of the structure shall be taken into account. It is, therefore, necessary to consider the possibility of progressive collapse in which the failure or displacement of one element of a structure causes the failure or displacement of another element and results in the partial or total collapse of the building.

6.4.5 Provision in the design to reduce the probability of progressive collapse is essential in buildings of over six storeys and is of relatively higher priority than for buildings of lower height.

6.4.6 It is necessary to ensure that any local damage to a structure does not spread to other parts of the structure remote from the point of mishap and that the overall stability is not impaired, but it may not be necessary to stiffen all parts of the structure against local damage or collapse in the immediate vicinity of a mishap, unless the design briefs specifically requires this to be done.

6.4.7 Additional protection may be required in respect of damage from vehicles; further, it is necessary to consider the effect of damage to or displacement of a load-bearing member by an uncontrolled vehicle. It is strongly recommended that important structural members are adequately protected by concrete kerbs or similar method.

6.4.8 In all aspects of erection that affect structural design, it is essential that the designer should maintain a close liaison with the builder/contractor regarding the erection procedures to be followed.

6.4.9 Failures that have occurred during construction appear to be of two types. The first of these is the pack-of-cards type of collapse in which the absence of restraining elements, such as partitions, cladding or shear walls, means that the structure is not stable during the construction period. The second is the situation in which one element falls during erection and lands on an element below. The connections of the lower element then give way under the loading, both static and dynamic, and a chain reaction of further collapse is set up.

6.4.9.1 A precaution against the first form of failure is that the overall stability of a building shall be considered in all its erection stages as well as in its completed state. All joints that may be required to resist moments and shears during the erection stage only, shall be designed with these in mind. Temporary works required to provide stability during construction shall be designed carefully.

6.4.9.2 To guard against the second form of failure, that is, the dropping of a unit during erection, particular attention shall be given to the details of all pre-formed units and their seatings to ensure that they are sufficiently robust to withstand the maximum stresses that can arise from site conditions. Precast concrete construction generally shall be capable of withstanding the impact forces that can arise from bad workmanship on site.

6.5 Design Requirements for Safety Against Progressive Collapse

6.5.1 Prefabricated buildings shall be designed with proper structural integrity to avoid situations where damage to small areas of a structure or failure of single elements may lead to collapse of major parts of the structure.

The following precaution may generally provide adequate structural integrity:

a) All buildings should be capable of safely resisting the minimum horizontal load of 1.5 percent of characteristic dead load applied at each floor or roof level simultaneously (*see* Fig. 1).

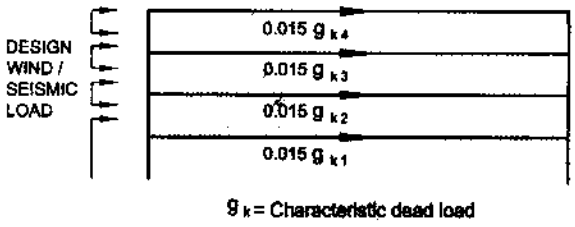


FIG. 1 HORIZONTAL LOADS

b) All buildings are provided with effective horizontal ties
   1) Around the periphery
   2) Internally (in both directions)
   3) To columns and walls

c) Vertical ties for buildings of five or more storeys.

In proportioning the ties, it may be assumed that no other forces are acting and the reinforcement is acting at its characteristic strength.

Normal procedure may be to design the structure for the usual loads and then carry out a check for the tie forces.

6.5.2 *Continuity and Anchorage of Ties*

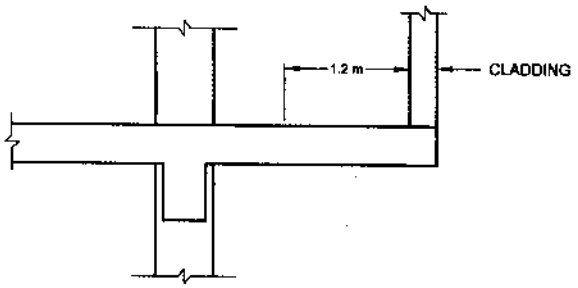
Bars shall be lapped, welded or mechanically joined as in accordance with Part 6 'Structural Design, Section 5 Plain, Reinforced and Prestressed Concrete: 5A Plain and Reinforced Concrete'.

6.5.3 *Design of Ties*

6.5.3.1 *Peripheral ties*

At each floor and roof level an effectively continuous tie should be provided within 1.2 m of the edge of the building or within the perimeter wall (*see* Fig. 2).

The tie should be capable to resisting a tensile force of F_t equal to 60 kN or (20 + 4*N*) kN whichever is less, where *N* is the number of storeys (including basement)



NOTE — If there are cantilever slabs, supporting external cladding, projecting in front of the columns and these are more than 1.2 m, than the peripheral tie shall go in the slab.

FIG. 2 POSITION FOR PERIPHERAL TIE

6.5.3.2 *Internal ties*

These are to be provided at each floor and roof level in two directions approximately at right angles. Ties should be effectively continuous throughout their length and be anchored to the peripheral tie at both ends, unless continuing as horizontal ties to columns or walls (*see* Fig. 3). The tensile strength, in kN/m width shall be the greater of

$$\frac{(g_k + q_k)}{7.5}\frac{l_r}{5}F_t \text{ and } 1.5F_t$$

where $(g_k + q_k)$ is the sum of average characteristic dead and imposed floor loads in kN/m^2 and l_r is the greater of the distance between the centre of columns, frames or walls supporting any two adjacent floor spans in the direction of the tie under consideration.

The bars providing these ties may be distributed evenly in the slabs (*see* Fig. 4) or may be grouped at or in the beams, walls or other appropriate positions but at spacings generally not greater than 1.5 l_r.

6.5.3.3 *Horizontal ties to column and wall*

All external load-bearing members such as columns and walls should be anchored or tied horizontally into the structure at each floor and roof level. The design force for the tie is to be greater of:

a) 2 F_t kN or $l_s \times F_t/2.5$ kN whichever is less for a column or for each metre length if there is a wall l_s is the floor to ceiling height in metres.
b) 3 percent of the total ultimate vertical load in the column or wall at that level.

For corner columns, this tie force should be provided in each of two directions approximately at right angles.

6.5.3.4 *Vertical ties (for buildings of five or more storeys)*

Each column and each wall carrying vertical load should be tied continuously from the foundation to the roof level. The reinforcement provided is required only to resist a tensile force equal to the maximum design ultimate load (dead and imposed) received from any one storey.

In situation where provision of vertical ties cannot be done, the element should be considered to be removed and the surrounding members designed to bridge the gap.

6.5.4 *Key Elements*

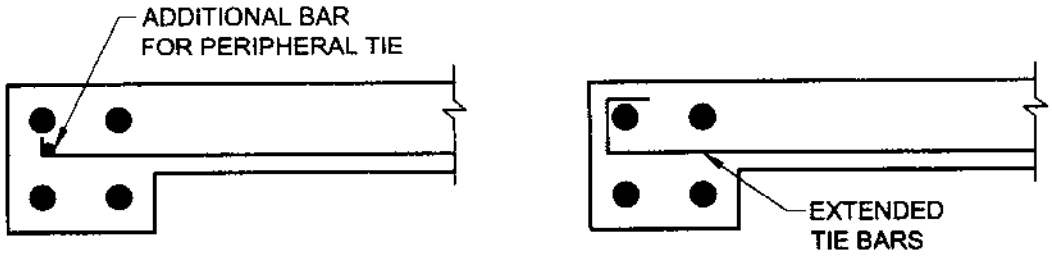
For buildings of five or more storeys, the layout should be checked to identify key elements. A key element is such that its failure would cause the collapse of more than a limited area close to it.

The limited area defined above may be taken equal to 70 m^2 or 15 percent of the area of the storey whichever is lesser.

If key elements exists, it is preferable to modify the layout so that the key element is avoided.

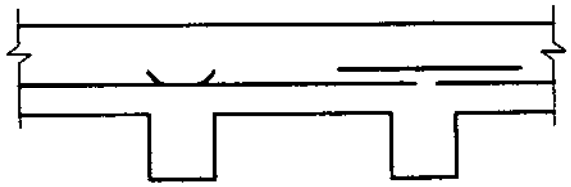
6.6 Bearing for Precast Units

Precast units shall have a bearing at least of 100 mm on masonry supports and of 75 mm at least on steel or concrete. Steel angle shelf bearings shall have a 100 mm horizontal leg to allow for a 50 mm bearing exclusive of fixing clearance. When deciding to what extent, if any, the bearing width may be reduced in special circumstances, factors, such as, loading, span, height of wall and provision of continuity, shall be taken into consideration.



NOTE — If the peripheral tie consists of bars in an edge beam, then the bottom bars in the slabs will not be at the same level as the peripheral tie bars. It is suggested that either an additional bar be used for the peripheral tie or the internal tie bars be extended and anchored around the top bar in the beam.

FIG. 3 ANCHORING OF TIES IN SLABS



NOTE — For continuity in continuous slabs, bars are distributed evenly in a floor slab by means of lapping some bottom steel at supports, either by extending existing bars or by the addition of splice bars.

FIG. 4 CONTINUITY REQUIREMENT FOR SLAB

7 JOINTS

7.1 The design of joints shall be made in the light of their assessment with respect to the following considerations:

a) *Feasibility* — The feasibility of a joint shall be determined by its load-carrying capacity in the particular situation in which the joint is to function.

b) *Practicability* — Practicability of joint shall be determined by the amount and type of material required in construction; cost of material, fabrication and erection and the time for fabrication and erection.

c) *Serviceability* — Serviceability shall be determined by the joints/expected behaviour to repeated or possible overloading and exposure to climatic or chemical conditions.

d) *Fire Rating* — The fire rating for joints of precast components shall be higher or at least equal to connecting members.

e) *Appearance* — The appearance of precast components joint shall merge with architectural aesthetic appearance and shall not be physically prominent compared to other parts of structural components.

7.2 The following are the requirements of a structural joint:

a) It shall be capable of being designed to transfer the imposed load and moments with a known margin of safety;

b) It shall occur at logical locations in the structure and at points which may be most readily analysed and easily reinforced;

c) It shall accept the loads without marked displacement or rotation and avoid high local stresses;

d) It shall accommodate tolerances in elements;

e) It shall require little temporary support, permit adjustment and demand only a few distinct operation to make;

f) It shall permit effective inspection and rectification;

g) It shall be reliable in service with other parts of the building; and

h) It shall enable the structure to absorb sufficient energy during earthquakes so as to avoid sudden failure of the structure.

7.2.1 Precast structures may have continuous or hinged connections subject to providing sufficient rigidity to withstand horizontal loading. When only compressive forces are to be taken, hinged joints may be adopted. In case of prefabricated concrete elements, load is transmitted via the concrete. When both compressive force and bending moment are to be taken,

rigid or welded joints may be adopted; the shearing force is usually small in the column and can be taken up by the friction resistance of the joint. Here load transmission is accomplished by steel inserted parts together with concrete.

7.2.2 When considering thermal shrinkage and heat effects, provision of freedom of movement or introduction of restraint may be considered.

7.3 Joining techniques/materials normally employed are:

a) Welding of cleats or projecting steel,
b) Overlapping reinforcement, loops and linking steel grouted by concrete,
c) Reinforced concrete ties all round a slab,
d) Prestressing,
e) Epoxy grouting,
f) Bolts and nuts connection,
g) A combination of the above, and
h) Any other method proven by test.

8 TESTS FOR COMPONENTS/STRUCTURES

8.1 Sampling Procedure

8.1.1 *Lot*

All the precast units of the same size, manufactured from the same material under similar conditions of production shall be grouped together to constitute a lot.

The number of units to be selected from each lot for dimensional requirements shall depend upon the size of the lot and shall be in accordance with col 1 and 2 of Table 1.

Table 1 Sample Size and Rejection Number

(*Clauses* 8.1.1 *and* 8.1.2)

Lot Size	First Sample Size	Second Sample Size	First Rejection Number	Second Rejection Number
(1)	(2)	(3)	(4)	(5)
Up to 100	5	5	2	2
101 to 300	8	8	2	2
301 to 500	13	13	2	2
500 and above	20	20	3	4

The units shall be selected from the lot at random. In order to ensure the randomness of selection, reference may be made to good practice [6-7A(2)].

8.1.2 *Number of Tests and Criteria for Conformity*

All the units selected at random in accordance with col 1 and 2 of Table 1 shall be subjected to the dimensional requirements. A unit failing to satisfy any of the dimensional requirements shall be termed as defective. The lot shall be considered as conforming to the dimensions requirements if no defective is found in the sample, and shall be rejected if the number of defectives is greater than or equal to the first rejection number. If the number of defectives is less than the first rejection number the second sample of the same size as taken in the first stage shall be selected from the lot at random and subjected to the dimensional requirements. The number of defectives in the first sample and the second sample shall be combined and if the combined number of defectives is less than the second rejection number, the lot shall be considered as conforming to the dimensional requirements; otherwise not.

The lot which has been found as satisfactory with respect to the dimensional requirements shall then be tested for load test. For this purpose one unit shall be selected for every 300 units or part thereof. The lot shall be considered as conforming to the strength requirement if all the units meet the requirement; otherwise not.

8.2 Testing on Individual Components

The component should be loaded for one hour at its full span with a total load (including its own self weight) of 1.25 times the sum of the dead and imposed loads used in design. At the end of this time it should not show any sign of weakness, faulty construction or excessive deflection. Its recovery one hour after the removal of the test load, should not be less than 75 percent of the maximum deflection recorded during the test. If prestressed, it should not show any visible cracks up to working load and should have a recovery of not less than 85 percent in 1 h.

8.3 Load Testing of Structure or Part of Structure

Loading test on a completed structure should be made if required by the specification or if there is a reasonable doubt as to the adequacy of the strength of the structure.

8.3.1 In such tests the structure should be subjected to full dead load of the structures plus an imposed load equal to 1.25 times the specified imposed load used in design, for a period of 24 h and then the imposed load shall be removed. During the tests, vertical struts equal in strength to take the whole load should be placed in position leaving a gap under the member.

NOTE — Dead load includes self weight of the structural members plus weight of finishes and walls or partitions, if any, as considered in the design.

8.3.1.1 If within 24 h of the removal of the load, a reinforced concrete structure does not show a recovery of at least 75 percent of the maximum deflection shown during the 24 h under load, test loading should be repeated after a lapse of 72 h. If the recovery is less

than 80 percent in second test, the structure shall be deemed to be unacceptable.

8.3.1.2 If within 24 h of the removal of the load, prestressed concrete structure does not show a recovery of at least 85 percent of the maximum deflection shown during the 24 h under load, the test loading should be repeated. The structure should be considered to have failed, if the recovery after the second test is not at least 85 percent of the maximum deflection shown during the second test.

8.3.1.3 If the maximum deflection in mm, shown during 24 h under load is less than 40 l^2/D, where l is the effective span in m; and D, the overall depth of the section in mm, it is not necessary for the recovery to be measured and the recovery provisions of **8.3.1.1** and **8.3.1.2** shall not apply.

9 MANUFACTURE, STORAGE, TRANSPORT AND ERECTION OF PRECAST ELEMENTS

9.1 Manufacture of Precast Concrete Elements

9.1.1 A judicious location of precasting yard with concreting, initial curing (required for demoulding), storage facilities, suitable transporting and erection equipments and availability of raw materials are the crucial factors which should be carefully planned and provided for effective and economic use of precast concrete components in constructions.

9.1.2 *Manufacture*

The manufacture of the components can be done in a factory for the commercial production established at the focal point based on the market potential or in a site precasting yard set up at or near the site of work.

9.1.2.1 *Factory prefabrication*

Factory prefabrication is resorted to in a *factory for the commercial production for the* manufacture of standardized components on a long-term basis. It is a capital intensive production where work is done throughout the year preferably under a closed shed to avoid effects of seasonal variations. High level of mechanization can always be introduced in this system where the work can be organized in a factory-like manner with the help of a constant team of workmen.

9.1.2.2 *Site prefabrication*

Prefabricated components produced at site or near the site of work as possible.

This system is normally adopted for a specific job order for a limited period. Under this category there are two types that is semi-mechanized and fully-mechanized.

9.1.2.2.1 *Semi-mechanized*

The work is normally carried out in open space with locally available labour force. The equipment machinery used may be minor in nature and moulds are of mobile or stationary in nature.

9.1.2.2.2 *Fully-mechanized*

The work will be carried out under shed with skilled labour. The equipments used will be similar to one of factory production. This type of precast yards will be set up for the production of precast components of high quality, high rate of production.

Though there is definite economy with respect to cost of transportation, this system suffers from basic drawback of its non-suitability to any high degree of mechanization and no elaborate arrangements for quality control. Normal benefits of continuity of work is not available in this system of construction.

9.1.3 The various processes involved in the manufacture of precast elements may be classified as follows:

9.1.3.1 *Main process*

a) Providing and assembling the moulds, placing reinforcement cage in position for reinforced concrete work, and stressing the wires in the case of prestressed elements;
b) Fixing of inserts and tubes, where necessary (for handling);
c) Pouring the concrete into the moulds;
d) Vibrating the concrete and finishing;
e) Curing (steam curing, if necessary); and
f) Demoulding the forms and stacking the precast products.

9.1.3.2 *Auxiliary process*

Process necessary for the successful completion of the processes covered by the main process:

a) Mixing and manufacture of fresh concrete (done in a mixing station or by a batching plant);
b) Prefabrication of reinforcement cage (done in a steel yard or workshop);
c) Manufacture of inserts and other finishing items to be incorporated in the main precast products;
d) Finishing the precast products; and
e) Testing of products.

9.1.3.3 *Subsidiary process*

All other work involved in keeping the main production work to a cyclic working:

a) Storage of materials;
b) Transport of cement and aggregates;

c) Transport of green concrete and reinforcement cages;

d) Transport and stacking the precast elements;

e) Repairs and maintenance of tools, tackles and machines;

f) Repairs and maintenance of moulds, and

g) Generation of steam, etc.

9.1.4 For the manufacture of precast elements all the above processes shall be planned in a systematic way to achieve the following:

a) A cyclic technological method of working to bring in speed and economy in manufacture;

b) Mechanization of the process to increase productivity and to improve quality;

c) The optimum production satisfying the quality control requirements and to keep up the expected speed of construction aimed;

d) Better working conditions for the people on the job; and

e) To minimize the effect of weather on the manufacturing schedule.

9.1.5 The various stages of precasting can be classified as in Table 2 on the basis of the equipments required for the various stages. This permits mechanization and rationalization of work in the various stages. In the precasting, stages 6 and 7 given in Table 2 form the main process in the manufacture of precast concrete elements. For these precasting stages there are many technological processes to suit the concrete product under consideration which have been proved rational, economical and time saving. The technological line or process is the theoretical solution for the method of planning the work involved by using machine complexes. Figure 5 illustrates diagramatically the various stages involved in a plant process.

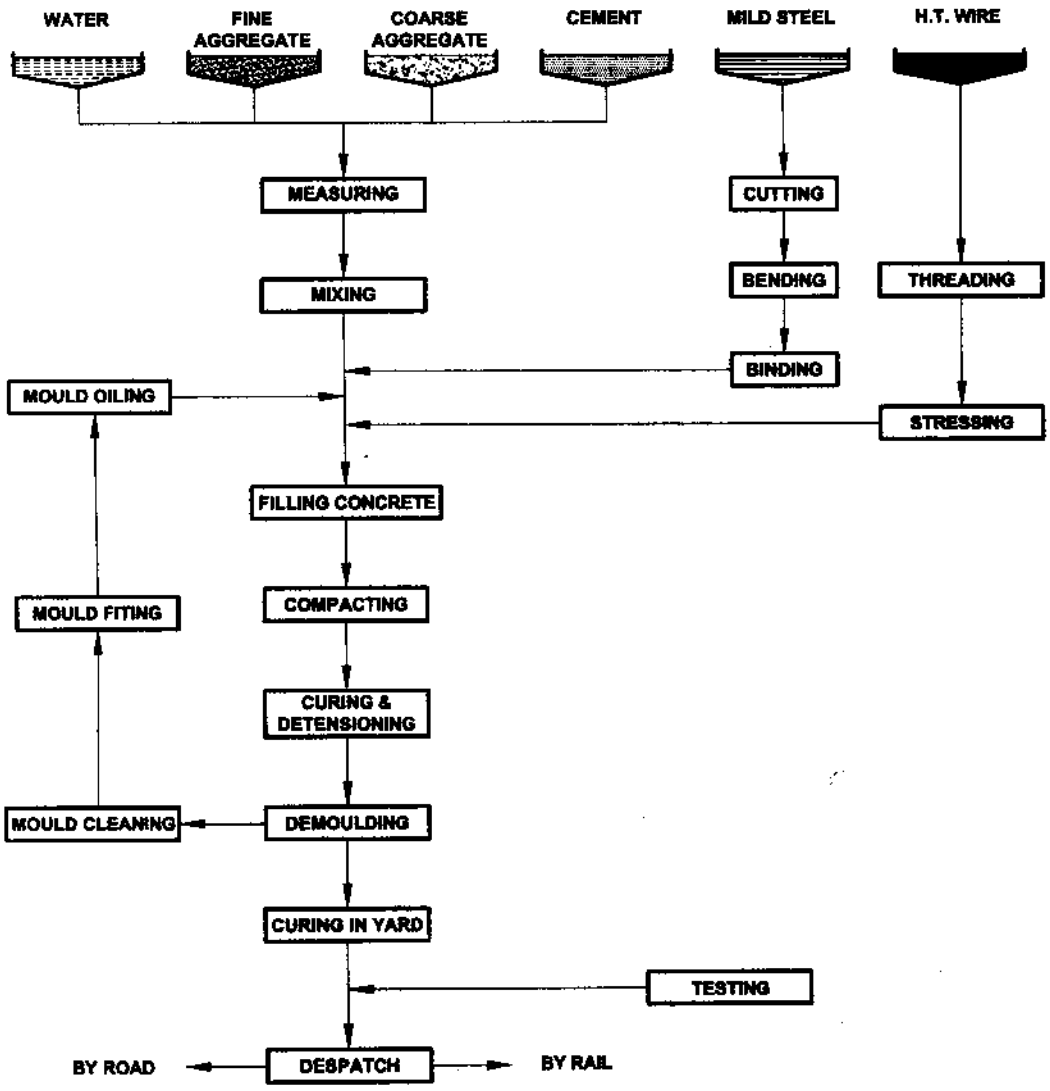


FIG. 5 PLANT PROCESS

Table 2 Stages of Precasting of Concrete Products

[*Clauses* 9.1.5 *and* 9.11(g)]

Sl No.	Precasting Stage No.	Name of Process	Operations Involved
(1)	(2)	(3)	(4)
i)	1	Procurement and storage of construction materials	Unloading and transport of cement, coarse and the aggregates, and steel, and storing them in bins, silos or storage sheds
ii)	2	Testing of raw materials	Testing of all materials including steel
iii)	3	Design of concrete mix	Testing of raw materials, plotting of grading curves and trial of mixes in laboratory
iv)	4	Making of reinforcement cages	Unloading of reinforcement bars from wagons or lorries and stacking them in the steel yard, cutting, bending, tying or welding the reinforcements and making in the form of a cage, which can be directly introduced into the mould.
v)	5	Applying form release agent and laying of moulds in position	Moulds are cleaned, applied with form release agent and assembled and placed at the right place.
vi)	6	Placing of reinforcement cages, inserts and fixtures	The reinforcement cages are placed in the moulds with spacers, etc as per data sheet prepared for the particular prefabricate.
vii)	7	Preparation of green concrete	Taking out aggregates and cement from bins, silos, etc, batching and mixing.
viii)	8	Transport of green concrete	Transport of green concrete from the mixer to the moulds. In the case of precast method involving direct transfer of concrete from mixer to the mould or a concrete hopper attached to the mould this prefabrication stage is not necessary.
ix)	9	Pouring and consolidation of concrete	Concrete is poured and vibrated to a good finish.
x)	10	Curing of concrete and demoulding	Either a natural curing with water or an accelerated curing using steam curing and other techniques. In the case of steam curing using trenches or autoclaves, this stage involves transport of moulds with the green concrete into the trench or autoclave and taking them out after the curing and demoulding elements cutting of protruding wires also falls in this stage. In certain cases the moulds have to be partly removed and inserts, have to be removed after initial set. The total demoulding is done after a certain period and the components are then allowed to be cured. All these fall in this operation.
xi)	11	Stacking of precast elements	Lifting of precast elements from the mould and transporting to the stacking yard for further transport by trailer or rail is part of this stage.
xii)	12	Testing of finished components	Tests are carried out on the components individually and in combination to ensure the adequacy of their strength.
xiii)	13	Miscellaneous	a) Generation of steam involving storing of coal or oil necessary for generation of steam and providing insulated steam pipe connection up to the various technological lines. b) Repair of machines used in the production.

9.1.6 The various accepted methods of manufacture of precast units can be broadly classified into two methods:

a) The 'Stand Method' where the moulds remain stationary at places, when the various processes involved are carried out in a cyclic order at the same place, and

b) The 'Flow Method' where the precast unit under consideration is in movement according to the various processes involved in the work which are carried out in an assembly-line method.

The various accepted precasting methods are listed in Table 3 with details regarding the elements that can be manufactured by these methods.

9.2 Preparation and Storage of Materials

Storage of materials is of considerable importance in the precasting industry, as a mistake in planning in this aspect can greatly influence the economics of production. From experience in construction, it is clear that there will be very high percentages of loss of materials as well as poor quality due to improper storage and transport. So, in a precast factory where everything is produced with special emphasis on quality, proper storage and preservation of building materials, especially cement, coarse and fine aggregates, is of prime importance. Storage of materials shall be done in accordance with Part 7 'Constructional Practices and Safety'.

9.3 Moulds

9.3.1 Moulds for the manufacture of precast elements

Sl No.	Precasting Method	Where Used	Dimensions and Weights	Advantages and Remarks
(1)	(2)	(3)	(4)	(5)
i)	Individual Mould Method (precasting method which may be easily assembled out of bottom and sides, transportable, if necessary. This may be either in timber or in steel using needle or mould vibrators and capable of taking prestressing forces)	a) Ribbed slabs, beams, girders, window panels, box type units and special elements. b) Prestressed railway sleepers, parts of pre-stressed girders, etc.	No limit in size and weight. Depends on the equipment used for demoulding, transporting and placing	a) Strengthening of the cross-section possible b) Openings are possible in two planes
ii)	Battery Form Method (The shuttering panels may be adjusted into the form of a battery at the required distances equal to the thickness of the concrete member)	Interior wall panels, shell elements, reinforced concrete battens, rafters, purlins and, roof and floor slabs	Length : 18 m Breadth : 3 m Mass : 5 t	Specially suitable for mass production of wall panels where shuttering cost is reduced to a large extent and autoclave or trench steam curing may be adopted by taking the steam pipes through the shuttering panels.
iii)	Stack Method	Floor and roof slab panels	Length : Any desired length Breadth : 1 to 4 m Mass : 5 t	For casting identical reinforced or prestressed panels one over the other with separating media interposed in between.
iv)	Tilting Mould Method (This method is capable of being skipped vertically using hydraulic jacks)	Exterior wall panels where special finishes are required on one face or for sandwich panel.	Length : 6 m Breadth : 4 m Mass : 5 t	Suitable for manufacturing the external wall panels
v)	Long Line Prestressing Bed Method	Double tees, ribbed slabs, purlins, piles and beams	Length : Any desired Breadth : 2 m Height : 2 m Mass : Up to 10 t	Ideally suited for pretension members
vi)	Extrusion Method (Long concrete mould with constant cross-section where concreting and vibration are done automatically just as in hollow code slab casting)	Roof slabs, foam concrete wall panels and beams cross-section where concreting and vibration are done automatically just as in hollow cored slab casting.	Length : Any desired Breadth : Less than 2 m Height : Less than 3 m	May be used with advantage in the case of un-reinforced blocks, foam concrete panels

may be of steel, timber, concrete and plastic or a combination thereof. For the design of moulds for the various elements, special importance should be given to easy demoulding and assembly of the various parts. At the same time rigidity, strength and watertightness of the mould, taking into consideration forces due to pouring of green concrete and vibrating, are also important.

9.3.2 *Tolerances*

The moulds have to be designed in such a way to take into consideration the tolerances given in **5**.

9.3.3 *Slopes of the Mould Walls*

For easy demoulding of the elements from the mould with fixed sides, the required slopes have to be maintained. Otherwise there is a possibility of the elements getting stuck up with the mould at the time of demoulding.

9.4 *Accelerated Hardening*

In most of the precasting factories, it is economical to use faster curing methods or artificial curing methods, which in turn will allow the elements to be demoulded much earlier permitting early re-use of the forms. Any of the following methods may be adopted:

a) *By Heating the Aggregates and Water Before Mixing the Concrete* — By heating of the aggregates as well as water to about 70°C to 80°C before making the concrete mix and placing the same in the moulds, sufficiently high earlier strengths are developed to allow the elements to be stripped and transported.

b) *Steam Curing* — Steam curing may be done under high pressure and high temperature in an autoclave. This technique is more suited to smaller elements. Alternatively, this could be done using low pressure steam having

temperature around 80°C. This type of curing shall be done as specified in **9.5.2**. For light weight concrete products when steam cured under high pressure, the drying shrinkage is reduced considerably. Due to this reason, high pressure steam curing in autoclave is specified for light weight low densities ranging from 300 to 1 000 kg/m^3. For normal heavy concretes as well as light weight concretes of higher densities, low pressure steam curing may be desirable as it does not involve using high pressures and temperatures requiring high investment in an autoclave (*see also* **9.5.2**).

c) *Steam Injection During Mixing of Concrete* — In this method low pressure saturated steam is injected into the mixer while the aggregates are being mixed. This enables the heating up of concrete to approximately 60°C. Such a concrete after being placed in the moulds attains high early strength.

d) *Heated Air Method* — In this method, the concrete elements are kept in contact with hot air with a relative humidity not less than 80 percent. This method is specially useful for light weight concrete products using porous coarse aggregates.

e) *Hot Water Method* — In this method, the concrete elements are kept in a bath of hot water around 50°C to 80°C. The general principles of this type of curing are not much different from steam curing.

f) *Electrical Method* — The passage of current through the concrete panels generates heat through its electro-resistivity and accelerates curing. In this method, the concrete is heated up by an alternating current ranging from 50 volts for a plastic concrete and gradually increasing to 230 V for the set concrete. This method is normally used for massive concrete products.

9.4.1 After the accelerated hardening of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

9.4.2 Accelerated hardening may also be achieved by the following techniques:

a) *Construction Chemicals* — Suitable construction chemicals may be used.

b) *Consolidation by Spinning* — Such a method is generally used in the centrifugal moulding of pipes and such units. The spinning motion removes excess water, effects consolidation and permits earlier demoulding.

c) *Pressed Concrete* — This method is suitable for fabrication of small or large products at high speed of production. A 100-200 tonnes press compresses the wet concrete in rigid moulds and expels water. Early handling and a dense wear resistant concrete is obtained.

d) *Vacuum Treatment* — This method removes the surplus air and water from the newly placed concrete as in slabs and similar elements. A suction up to about 70 percent of an atmosphere is applied for 20 to 30 minutes per centimetre thickness of the units.

e) *Consolidation by Shock* — This method is suitable for small concrete units dropped repeatedly from a height in strong moulds. The number of shocks required to remove excess water and air may vary from 6 to 20 and the height of lift may be up to as much as half the depth of the mould.

9.4.3 After the accelerated curing of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

9.5 Curing

9.5.1 The curing of the prefabricated elements can be effected by the normal methods of curing by sprinkling water and keeping the elements moist. This can also be done in the case of smaller elements by immersing them in a specially made water tanks.

9.5.2 *Steam Curing*

9.5.2.1 The steam curing of concrete products shall take place under tarpaulin in tents, under hoods, under chambers, in tunnels or in special autoclaves. The steam shall have a uniform quality throughout the length of the member. The precast elements shall be so stacked, with sufficient clearance between each other and the bounding enclosure, so as to allow proper circulation of steam.

Before the concrete products are subjected to any accelerated method of curing, the cement to be used shall be tested in accordance with accepted standards (*see* Part 5 Building Materials) especially for soundness, setting time and suitability for steam curing.

In the case of elements manufactured by accelerated curing methods, concrete admixtures to reduce the water content can be allowed to be used. The normal aeration agents used to increase the workability of concrete should not be allowed to be used. Use of calcium chloride should be avoided for reinforced concrete elements.

9.5.2.2 The surrounding walls, the top cover and the

floor of steam curing chamber or tunnel or hood shall be so designed as not to allow more than 1 kcal/m^2/h/°C.

9.5.2.3 The inside face of the steam curing chamber, tunnel or hood shall have a damp-proof layer to maintain the humidity of steam. Moreover, proper slope shall be given to the floor and the roof to allow the condensed water to be easily drained away. At first, when steam is let into the curing chambers, the air inside shall be allowed to go out through openings provided in the hoods or side walls which shall be closed soon after moist steam is seen jetting out.

9.5.2.4 It is preferable to let in steam at the top of the chamber through perforated pipelines to allow uniform entry of steam throughout the chamber.

9.5.2.5 The fresh concrete in the moulds should be allowed to get the initial set before allowing the concrete to come into contact with steam. The regular heating up of fresh concrete product from about 20°C to 35°C should start only after a waiting period ranging from 2 to 5 h depending on the setting time of cement used. It may be further noted that steam can be let in earlier than this waiting period provided the temperature of the concrete product does not rise beyond 35°C within this waiting period.

9.5.2.6 The second stage in steam curing process is to heat up the concrete elements, moulds and the surroundings in the chamber:

a) In the low pressure steam curing the airspace around the member is heated up to a temperature of 75°C to 80°C at a gradual rate, usually not faster than 30°C per hour.

   This process takes around 1 h to 1½ h depending upon outside temperature.

b) In the case of curing under high pressure steam in autoclaves, the temperature and pressure are gradually built up during a period of about 4 h.

9.5.2.7 The third stage of steam curing is to maintain the uniform temperature and pressure for a duration depending upon thickness of the section. This may vary from 3 h to 5½ h in the case of low pressure steam curing and 4 h to 7 h in the case of high pressure steam curing.

9.5.2.8 The fourth stage of steam curing is the gradual cooling down of concrete products and surroundings in the chamber and normalization of the pressure to bring it at par with outside air. The maximum cooling rate, which is dependent on the thickness of the member, should normally not exceed 30°C per hour.

9.5.3 In all these cases, the difference between the temperature of the concrete product and the outside temperature should not be more than 60°C for concretes up to M 30 and 75°C for concretes greater than M 45. In the case of light weight concrete, the difference in temperature should not be more than 60°C for concretes less than M 25. For concretes greater than M 50, the temperature differences can go up to 75°C.

9.6 Stacking During Transport and Storage

Every precaution shall be taken against overstress or damage, by the provision of suitable packings at agreed points of support. Particular attention is directed to the inherent dangers of breakage and damage caused by supporting other than at two positions, and also by the careless placing of packings (for example, not vertically one above the other). Ribs, corners and intricate projections from solid section should be adequately protected. Packing pieces shall not discolour, disfigure or otherwise permanently cause mark on units or members. Stacking shall be arranged or the precast units should be protected, so as to prevent the accumulation of trapped water or rubbish, and if necessary to reduce the risk of efflorescence.

9.6.1 The following points shall be kept in view during stacking:

a) Care should be taken to ensure that the flat elements are stacked with right side up. For identification, top surfaces should be clearly marked.

b) Stacking should be done on a hard and suitable ground to avoid any sinking of support when elements are stacked.

c) In case of horizontal stacking, packing materials shall be at specified locations and shall be exactly one over the other to avoid cantilever stress in panels.

d) *Components* — should be packed in a uniform way to avoid any undue projection of elements in the stack which normally is a source of accident.

9.7 Handling Arrangements

9.7.1 Lifting and handling positions shall be clearly defined particularly where these sections are critical. Where necessary special facilities, such as bolt holes or projecting loops, shall be provided in the units and full instructions supplied for handling.

9.7.2 For precast prestressed concrete members, the residual prestress at the age of particular operation of handling and erection shall be considered in conjunction with any stresses caused by the handling or erection of member. The compressive stress thus computed shall not exceed 50 percent of the cube strength of the concrete at the time of handling and

erection. Tensile stresses up to a limit of 50 percent above those specified in Part 6 'Structural Design, Section 5 Concrete' shall be permissible.

9.8 Identification and Marking

All precast units shall bear an indelible identification, location and orientation marks as and where necessary. The date of manufacture shall also be marked on the units.

9.8.1 The identification markings on the drawings shall be the same as that indicated in the manufacturer's literature and shall be shown in a table on the setting schedule together with the length, type, size of the unit and the sizes and arrangement of all reinforcement.

9.9 Transport

Transport of precast elements inside the factory and to the site of erection is of considerable importance not only from the point of view of economy but also from the point of view of design and efficient management. Transport of precast elements must be carried out with extreme care to avoid any jerk and distress in elements and handled as far as possible in the same orientation as it is to be placed in final position.

9.9.1 *Transport Inside the Factory*

Transport of precast elements moulded inside the factory depends on the method of production, selected for the manufacture as given in Table 3.

9.9.2 *Transport from Stacking Yard Inside the Factory to the Site of Erection*

Transport of precast concrete elements from the factory to the site of erection should be planned in such a way so as to be in conformity with the traffic rules and regulations as stipulated by the Authorities. The size of the elements is often restricted by the availability of suitable transport equipment, such as tractor-cum-trailers, to suit the load and dimensions of the member in addition to the opening dimensions under the bridge and load carrying capacity while transporting the elements over the bridge.

9.9.2.1 While transporting elements in various systems, that is, wagons, trucks, bullock carts, care should be taken to avoid excessive cantilever actions and desired supports are maintained. Special care should be taken at location of sharp bends and on uneven or slushy roads to avoid undesirable stresses in elements.

9.9.2.2 Before loading the elements in the transporting media, care should be taken to ensure that the base packing for supporting the elements are located at specified positions only. Subsequent packings must be kept strictly one over the other.

9.10 Erection

In the 'erection of precast elements', all the following items of work are meant to be included:

a) Slinging of the precast element;
b) Tying up of erection ropes connecting to the erection hooks;
c) Cleaning of the elements and the site of erection;
d) Cleaning of the steel inserts before incorporation in the joints, lifting up of the elements, setting them down into the correct envisaged position;
e) Adjustment to get the stipulated level, line and plumb;
f) Welding of cleats;
g) Changing of the erection tackles;
h) Putting up and removing of the necessary scaffolding or supports;
j) Welding of the inserts, laying of reinforcements in joints and grouting the joints; and
k) Finishing the joints to bring the whole work to a workmanlike finished product.

9.10.1 In view of the fact that the erection work in various construction jobs using prefabricated concrete elements differs from place to place depending on the site conditions, safety precautions in the work are of utmost importance. Hence only those skilled foremen, trained workers and fitters who have been properly instructed about the safety precautions to be taken should be employed on the job. For additional information, *see* Part 7 'Constructional Practices and Safety'.

9.10.2 Transport of people, workers or visitors, by using cranes and hoists should be strictly prohibited on an erection site.

9.10.3 In the case of tower rail mounted cranes running on rails, the track shall not have a slope more than 0.2 percent in the longitudinal direction. In the transverse direction the rails shall lie in a horizontal plane.

9.10.4 The track of the crane should be daily checked to see that all fish plates and bolts connecting them to the sleepers are in place and in good condition.

9.10.5 The operation of all equipment used for handling and erection shall follow the operations manual provided by the manufacturer. All safety precautions shall be taken in the operations of handling and erection.

10 EQUIPMENT

10.1 General

The equipment used in the precast concrete industry/

construction may be classified into the following categories:

a) Machinery required for quarrying of coarse and fine aggregates;
b) Conveying equipment, such as, belt conveyors, chain conveyors, screw conveyors, bucket elevators, hoists, etc;
c) Concrete mixing machines;
d) Concrete vibrating machines;
e) Erection equipment, such as, cranes, derricks, hoists, chain pulley blocks, etc;
f) Transport machinery, such as, tractor-cum-trailers, dumpers, lorries, locomotives, motor boats and rarely even helicopters;
g) Workshop machinery for making and repairing steel and timber moulds;
h) Bar straightening, bending and welding machines to make reinforcement cages;
j) Minor tools and tackles, such as, wheel barrows, concrete buckets, etc; and
k) Steam generation plant for accelerated curing.

In addition to the above, pumps and soil compacting machinery are required at the building site for the execution of civil engineering projects involving prefabricated components.

Each of the above groups may further be classified into various categories of machines and further to various other types depending on the source of power and capacity.

10.2 Mechanization of the Construction and Erection Processes

The various processes can be mechanized as in any other industry for attaining the advantages of mass production of identical elements which in turn will increase productivity and reduce the cost of production in the long run, at the same time guaranteeing quality for the end-product. On the basis of the degree of mechanization used, the various precasting factories can be divided into three categories:

a) With simple mechanization,
b) With partial mechanization, and
c) With complex mechanization leading to automation.

10.2.1 In simple mechanization, simple mechanically operated implements are used to reduce the manual labour and increase the speed.

10.2.2 In partial mechanization, the manual work is more or less eliminated in the part of a process. For example, the batching plant for mixing concrete, hoists to lift materials to a great height and bagger and bulldozer to do earthwork come under this category.

10.2.3 In the case of complex mechanization leading to automation, a number of processes leading to the end-product are all mechanized to a large extent (without or with a little manual or human element involved). This type of mechanization reduces manual work to the absolute minimum and guarantee the mass production at a very fast rate and minimum cost.

10.2.4 The equipment shall conform to accepted standards as listed in Part 7 'Constructional Practices and Safety'.

11 PREFABRICATED STRUCTURAL UNITS

11.1 For the design and construction of composite structures made up of prefabricated structural units and cast *in-situ* concrete, reference may be made to good practice [6-7A(3)].

11.2 For design and construction of precast reinforced and prestressed concrete triangulated trusses reference may be made to good practice [6-7A(4)].

11.3 For design and construction of floors and roofs using various precast units, reference may be made to good practice [6-7A(5)].

11.4 For construction with large panel prefabricates, reference may be made to good practice [6-7A(6)].

11.5 For construction of floors and roofs with joists and filler blocks, reference may be made to good practice [6-7A(7)].

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

In the following list the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

IS No.	*Title*
(1) 2185	Specification for concrete masonry units:
(Part 1) : 1979	Hollow and solid concrete blocks (*second revision*)

(Part 3) : 1984	Autoclaved cellular aerated concrete blocks (*first revision*)
3201 : 1988	Criteria for design and construction of precast trusses and purlins (*first revision*)
6072 : 1971	Specification for autoclaved reinforced cellular concrete wall slabs
6073 : 1971	Specification for autoclaved reinforced cellular concrete floor and roof slabs
9893 : 1981	Specification for precast concrete blocks for lintels and sills
10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/ prestressed concrete ribbed or cored slab unit
10505 : 1983	Code of practice for construction of floors and roofs using precast concrete waffle units
11447 : 1985	Code of practice for construction with large panel prefabricates
12440 : 1988	Specification for precast concrete stone masonry blocks
13990 : 1994	Specification for precast reinforced concrete planks and joists for flooring and roofing
14143 : 1994	Specification for prefabricated brick panel and partially precast concrete joist for flooring and roofing
14201 : 1994	Specification for precast reinforced concrete channel unit for construction of floors and roofs
14241 : 1994	Specification for precast L-Panel units for roofing

(5) 3935 : 1966 Code of practice for composite construction

(4) 3201 : 1988	Criteria for design and construction of precast trusses and purlins (*first revision*)
(5) 6332 : 1984	Code of practice for construction of floor and roofs using precast doubly-curved shell units (*first revision*)
10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/ prestressed concrete ribbed or cored slab units
10505 : 1983	Code of practice for construction of floors and roofs using precast reinforced concrete waffle units
13994 : 1994	Code of practice for design and construction of floor and roof with precast reinforced concrete planks and RC joists
14142 : 1994	Code of practice for design and construction of floors and roofs with prefabricated brick panel
14215 : 1994	Code of practice for construction of floor and roof with RC channel units
14242 : 1994	Code of practice for design and construction of roof with L-Panel units
(6) 11447 : 1985	Code of practice for construction with large panel prefabricates
(7) 6061	Code of practice for construction of floor and roof with joists and hollow filler blocks:
(Part 1) : 1971	With hollow concrete filler blocks
(Part 2) : 1981	With hollow clay filler blocks (*first revision*)

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction:
7B Systems Building and Mixed/Composite Construction

BUREAU OF INDIAN STANDARDS

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FOREWORD

Systems building and mixed/composite construction is an upcoming field as far as its development and use in the country is concerned. Two aspects specifically to be borne in mind are the system to be adopted for the different categories of buildings and the sizes of their components. Here the principle of modular co-ordination is of value and its use is recommended.

This section was first published in 1970 and was subsequently revised in 1983.

In this second revision, this section, earlier named as Prefabrication and Systems Building has been renamed and restructured as follows:

Section 7 Prefabrication, Systems Buildings and Mixed/Composite Construction

7A Prefabricated Concrete

7B Systems Buildings and Mixed/Composite Construction

This sub-section covers systems building and mixed/composite construction, while such systems approach using predominantly concrete as material for components is being dealt with in sub-section 7A.

In this sub-section, an attempt has been made to prescribe general requirements applicable to all valid existing systems and mixed/composite constructions as also to accommodate any new system introduced in the country in future.

All standards cross referred to in the main text of this sub-section, are subject to revision. The parties to agreement based on this sub-section are encouraged to investigate the possibility of applying the most recent editions of the standards.

NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction: 7B Systems Building and Mixed/Composite Construction

1 SCOPE

This sub-section covers recommendations regarding modular planning, component sizes, joints, manufacture, storage, transport and erection of prefabricated elements for use in buildings and such related requirements for systems building and mixed/composite construction.

2 TERMINOLOGY

2.1 For the purpose of this sub-section, the following definitions shall apply.

2.1.1 *Authority Having Jurisdiction* — The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.1.2 *Basic Module* — The fundamental module used in modular co-ordination, the size of which is selected for general application to building and its components.

NOTE — The value of the basic module has been chosen as 100 mm for the maximum flexibility and convenience. The symbol for the basic module is *M*.

2.1.3 *Cellular Concrete* — The material consisting of an inorganic binder (such as, lime or cement or both) in combination with a finely ground material containing siliceous acid (such as sand), gas generating material (for example, aluminium powder), water and harmless additives (optional); and steam cured under pressure in autoclaves.

2.1.4 *Components* — A building product formed as a distinct unit having specified sizes in three dimensions.

2.1.5 *Composite/Mixed Construction* — Construction involving two or more components, such as, prefabricated structural units of steel, prestressed concrete or reinforced concrete and cast *in-situ* concrete, timber, masonry in brickwork and blockwork, glass and glazing connected together in such a manner that they act integrally.

2.1.6 *Increments* — Difference between two homologous dimensions of components of successive sizes.

2.1.7 *Module* — A unit of size used in dimensional co-ordination.

2.1.8 *Modular Co-ordination* — Dimensional co-ordination employing the basic module or a multi-module.

NOTE — The purposes of modular co-ordination are:

a) to reduce the variety of component sizes produced, and
b) to allow the building designer greater flexibility in the arrangement of components.

2.1.9 *Modular Grid* — A rectangular coordinate reference system in which the distance between consecutive lines is the basic module or a multi-module. This multi-module may differ for each of the three orthogonal dimensions of the grid, two in plan and one in vertical direction.

2.1.10 *Multi-module* — A module whose size is a selected multiple of the basic module.

2.1.11 *Prefabricate* — To fabricate components or assembled units prior to erection or installation in a building.

2.1.12 *Prefabricated Building* — The partly/fully assembled and erected building, of which the structural parts consist of prefabricated individual units or assemblies using ordinary or controlled materials, including service facilities; and in which the service equipment may be either prefabricated or constructed *in-situ*.

2.1.13 *Sandwich Panels* — Panels made by sandwiching a layer of insulation material between two outer layers of hard durable materials like steel, dense concrete, plastic, cement based sheet, ceramic, etc. The hard coverings on two outer faces may be of same or different materials; the three layers being bonded with each other to behave as a composite panel.

2.1.14 *Self-Compacting Concrete* — Concrete that is able to flow under its own weight and completely fill the voids within the formwork, even in the presence of dense reinforcement without any vibration, whilst maintaining homogeneity without segregation.

2.1.15 *Shear Connectors* — Structural elements, such as anchors, studs, channels and spirals, intended to transmit the shear between the prefabricated member and the cast *in-situ* concrete and also to prevent separation at the interface.

2.1.16 *System* — The method of construction of buildings with certain order and discipline and repetitive operations using the prefabricated components, tunnel form or engineered shuttering, where the work is organized and follows a defined procedure.

2.1.17 *Unit* — Building material formed as a simple article with all three dimensions specified, complete in itself but intended to be part of a compound unit or complete building. Examples are brick, block, tile, etc.

3 MATERIALS, PLANS AND SPECIFICATIONS

3.1 Materials

3.1.1 *See* Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete', regarding materials and the characteristics to be considered in their selection.

3.1.2 The materials used in prefabricated components may be many and the modern trend is to use concrete, steel, treated wood, aluminium, cellular concrete, light weight concrete, ceramic products, etc. However, this section pertains to mixed/composite construction.

3.2 Plans and Specifications

See Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

4 MODULAR CO-ORDINATION, ARCHITECTURAL TREATMENT AND FINISHES

4.1 Modular Co-ordination

See Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

4.2 Architectural Treatment and Finishes

See Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

5 COMPONENTS

5.1 The preferred dimensions of precast elements used and their casting tolerances shall be in accordance with Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

5.2 The permissible tolerances of timber used shall be in accordance with Part 6 'Structural Design, Sub-section 3A Timber'.

5.3 For permissible tolerances of steel and masonry, reference may be made to relevant Indian Standards.

6 FORMWORK SYSTEMS

The formwork systems which are utilized in buildings shall be as given in **6.1** to **6.5**.

6.1 Tunnel Form

This is a system which casts walls and slab together like a portal in a single pour. Façade walls are precast or of block masonry to enable removal of tunnel form. All components are made up of steel. This produces very rapid construction. Accelerated curing if required is possible enabling early stripping of formwork.

6.2 Slipform

Slipform is a continuously moving form at such a speed that the concrete when exposed has already achieved enough strength to support the vertical pressure from concrete still in the form as well as to withstand nominal lateral forces. Slipform may be classified as straight slipform, tapering slipform and slipform for special applications. Construction of lift cores and stairwell using slipform technique comes under special applications because of their complex sizes, shapes and loads to be lifted alongwith the slipform like walkway truss, etc, which is essential for construction. This system uses hydraulic jacks avoiding crane for lifting of assembly during construction operation. This system facilitates rapid construction and continual casting, creating a monolithic structure thereby avoiding construction joints.

6.3 Aluminium Formwork

This system of formwork uses aluminium, which is light and rust free material, in both sheathing and framework. It may be used for a broad range of applications from wall to slab construction panels to more complicated structures involving bay windows, stairs and hoods. Every component is light enough to be handled easily thereby minimizing the need for heavy lifting equipment.

6.4 Large Panel Shuttering System

This is a system, which gives an advantage of combining speed and quality of construction. The vertical load carrying members are made of steel whereas the horizontal members are of plywood inserted into two wooden beams thereby forming a web flange. All the formwork and support systems shall be designed for the loads coming during the actual execution stage.

6.5 Other/New Systems

Any other/new system may be used for systems building after due examination and approval by the Authority.

7 SYSTEM AND STRUCTURAL SCHEMES

7.1 Several schemes are possible, with certain constraints, using the same set of components. The degree of flexibility varies from system to system. However, in all the systems there is a certain order and discipline.

7.2 The following aspects, among others, are to be considered in devising a system:

a) Effective utilization of spaces;
b) Straight and simple walling scheme;
c) Limited sizes and numbers of components;
d) Limited opening in bearing walls;
e) Regulated locations of partitions;
f) Standardized service and stair units;
g) Limited sizes of doors and windows with regulated positions;
h) Structural clarity and efficiency;
j) Suitability for adoption in low and high rise building;
k) Ease of manufacturing, storing and transporting;
m) Speed and ease of erection; and
n) Simple jointing system.

7.3 Systems for Mixed/Composite Construction

The system of mixed/composite construction depends on the extent of the use of prefabricated components, their materials, sizes and the technique adopted for their manufacture and use in building.

7.3.1 *Combinations of System Components for Mixed/ Composite Construction*

The following combinations may be used in mixed/ composite construction:

a) Structural steel work and timber roofs on precast frames.
b) Precast floors onto steel and concrete beams, and masonry walls.
c) Profiled metal decking on precast beams.
d) Precast frames onto cast *in-situ* foundations, retaining walls, etc.
e) Precast frames stabilized by masonry walls, steel bracing, etc.
f) Precast cladding in steel or cast *in-situ* frames and *vice versa*.
g) Glass curtain walling, stone cladding or metal sheeting onto precast concrete frames, etc.
h) Reinforced concrete and structural steel as composite columns and beams.

7.3.1.1 Precast concrete may be combined with cast *in-situ* concrete, often termed hybrid construction. Cast *in-situ* is mostly used to form homogenous connections between precast elements and provide a structural topping for horizontal diaphragm action. In other cases it is used to form the foundations and sub-structure to the building.

7.3.1.2 Structural steelwork is largely used in long span prestressed concrete floors supported on rolled and prefabricated steel beams and also as steel roof trusses supported on concrete columns.

7.3.1.3 Timber may be used as long span glue-laminated beams and rafters, with precast concrete. Precast floors may be used in timber frame construction. Similarly, timber frames with precast elements shall be used as a building system.

7.3.1.4 Brick and block masonry may be combined with precast concrete structures and floors. The most common combinations is to use prestressed floors on load bearing walls.

7.4 Design Considerations

The mixed/composite structures shall be analyzed appropriately and the joints in them designed to take the forces of an equivalent discrete system. Resistance to horizontal loading shall be provided by placing beams, walls and bracings in two directions at right angles or otherwise. The individual components shall be designed, taking into consideration appropriate end conditions and loads at various stages of construction. The components of the structure shall be designed for loads in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects'. In addition, members shall be designed for handling, erection and impact loads that may be expected during handling and erection.

7.4.1 For mixed and composite construction the following points shall be considered:

a) *Positions of stability cores, walls, bracing, etc.* — In high rise buildings the most popular method is a cast *in-situ* core constructed several storeys ahead of the framework. In medium height buildings this may be precast concrete or brick infill, steel cross bracing or precast concrete diagonal bracing.
b) *Maturity of connections* — This may be decisive for or alter planned site progress unless it is properly managed. Cast *in-situ* grouted joints need a few days of temporary propping unless combined mechanical connections are also used.
c) As a consequence of the above, the need to design some of the key components to achieve temporary stability.
d) *The availability and/or positioning of equipments to transport and erect components* — The size and weight of the various components shall be organized to make optimum use of crane capacity, for example, the lightest units farthest from the operating zone.
e) *Erection safety and speed of construction, with attention to cast in-situ concreting sequences* — This is particularly important

f) *Tolerances for economical construction* — This is particularly important where different manufacturers are producing components in different materials.

7.4.2 Other design considerations and safety requirements against progressive collapse shall be in accordance with Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

8 JOINTS

Design of joints shall be in accordance with Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

9 TESTS FOR COMPONENTS/STRUCTURES

Sampling procedure, testing on individual components and load testing of structure shall be in accordance with Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

10 CONSTRUCTIONAL ASPECTS

10.1 Manufacture, Storage, Transport and Erection of Precast Elements

The requirements relating to manufacture, storage, transport and erection of precast concrete elements shall be in accordance with Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

Constructional practices relating to decking shall be as given in Annex A.

10.3 Concreting on Decking

Concreting on decking shall be carried out in accordance with Annex B.

11 EQUIPMENT

The requirements relating to equipment used in the precast concrete construction shall be in accordance with Part 6 'Structural Design, Sub-section 7A Prefabricated Concrete'.

12 PREFABRICATED STRUCTURAL UNITS

12.1 For the design and construction of composite structures made up of prefabricated structural units and cast *in-situ* concrete, reference may be made to good practice [6-7B(1)].

12.2 For design and construction of precast reinforced and prestressed concrete triangulated trusses reference may be made to good practice [6-7B(2)].

12.3 For design and construction of floors and roofs using various precast units, reference may be made to good practice [6-7B(3)].

12.4 For construction with large panel prefabricates, reference may be made to good practice [6-7B(4)].

12.5 For construction of floors and roofs with joists and filler blocks reference may be made to good practice [6-7B(5)].

ANNEX A

(*Clause* 10.2)

CONSTRUCTION PRACTICE FOR DECKING

A-1 RECEIVING, STORING AND LIFTING DECKING

A-1.1 Receiving Decking

Decking is packed by the manufacturer into bundles of up to 24 sheets, and the sheets are normally secured with metal banding. Each bundle may be up to 1 m wide (the width of a single sheet) by 750 mm deep, and may weigh up to 2.5 t, depending on sheet length (average mass of sheet being about 1.5 t). Loads are normally delivered by articulated vehicles approximately 16 m long with a maximum gross mass of up to 40 t, and a turning circle of approximately 19 m. It shall be ensured that there is suitable access and appropriate standing and off-loading areas.

Each bundle will be given an identification tag by the manufacturer. The information on each tag shall be checked immediately upon arrival, to prevent incorrect sheets being used, or unnecessary delays if changes are necessary. In particular, the stated sheet thickness shall be checked against the requirement specified on the drawings, and a visual inspection shall be made to ensure that there is no damage.

The bundles shall be lifted from the vehicle. Bundles shall never be off-loaded by tipping, dragging, dropping or other improvized means.

A-1.2 Storing Decking

The decking shall not be delivered more than one month before its anticipated use, as it may be vulnerable to abuse and damage if stored for longer periods on site. If it is not for immediate use, the decking shall be

stored on the steel frame. If this is not possible, it shall be located in an area where it will not be contaminated by site traffic, and placed on bearers, which provide a gentle slope to the bundle. This will allow any condensation or rain to drain and a free flow of air around the bundle. Bundles shall not be stacked more than 4 m high, and no other materials shall be stored on top of them. Bearers shall be placed between bundles, and positioned to prevent bending of the sheets.

A-1.3 Lifting and Positioning the Decking

The support steelwork shall be prepared to receive the decking before lifting the bundles onto it. The top surface of the underlying beams shall be reasonably clean. When through-deck welding of shear studs is specified, the tops of the flanges shall be free of primer, paint and galvanising.

The identification tags shall be used to ensure that bundles are positioned on the frame at the correct floor level, and in the nominated bay shown on the deck layout drawing. The bundles shall be positioned such that the interlocking side laps are on the same side. This will enable the decking to be laid progressively without the need to turn the sheets. The bundles shall also be positioned in the correct span orientation, and not at 90° to it. Care shall be taken to ensure that the bundles are not upside down, particularly with trapezoidal profiles. For most trapezoidal decking profiles, the embossments shall be oriented so that they project upwards.

Care is needed when lifting the decking bundles; protected chain slings are recommended for the same. Unprotected chain slings can damage the bundle during lifting. When synthetic slings are used there is a risk of the severing them on the edges of the decking sheets.

If timber packers are used, they shall be secured to the bundle before lifting so that when the slings are released they do not fall to the ground (with potentially disastrous results). Bundles shall never be lifted using metal banding.

A-2 DECK INSTALLATION

A-2.1 Placement of Decking

Breaking open the bundles and installing the decking shall be done only when all the sheets can be positioned and secured. The decking layout drawing shall also be checked to ensure that any temporary support that need to be in position prior to deck laying, is in place.

Access for installation may normally be achieved using ladders connected to the steel frame. Once the laying out the sheets is started by erectors, they shall create working platform by securely fixing the decking as they progress.

The laying of sheets shall begin at the locations indicated on the decking layout drawings. These would normally be at the corner of the building at each level, to reduce the number of 'leading edges', that is unprotected edges where the decking is being laid. When the bundles have been properly positioned, as provided above, there shall be no need to turn the sheets manually, and there shall be no doubt which way up the sheet shall be fixed.

Individual sheets shall be slid into place and, where possible, fixed to the steelwork before moving onto the next sheet. This will minimize the risk of an accident occurring as a result of movement of a sheet when it is being used as a platform. However, for setting-out purposes, it may be necessary to lay out an entire bay using a minimum number of temporary fixings before fully securing the sheets later.

Sheets shall be positioned to provide a minimum bearing of 50 mm on the steel support beams. The ends of adjacent sheets shall be butted together. A gap of up to 5 mm is generally considered not to allow excessive seepage, but, if necessary, the ends of the sheets may be taped together. When end gaps are greater than 5 mm, it is normally sufficient to seal them with an expanding foam filler. The longitudinal edges shall be overlapped, to minimize concrete seepage along the seams. Although not normally required, seam fixings may be necessary in some circumstances. Sheets projecting freely more than 600 mm shall be avoided.

If necessary, sheets shall be cut using a grinder or a nibbler. However, field cutting shall be kept to a minimum and shall only be necessary where a column or other obstruction interrupts the decking. Gaps adjacent to the webs of columns shall be filled in with off-cuts or thin strips of steel. Decking sheets shown as continuous on the decking layout drawing shall never be cut into more than one length. Also, sheets shall never be severed at the location of a temporary support, and the decking shall never be fastened to a temporary support.

As the work progresses, scraps and off-cuts shall be disposed of in a skip placed alongside the appropriate level of working. The skip shall be positioned carefully over a support beam to avoid overloading the decking. If a skip is not available, scraps shall be gathered for collection as soon as is possible. Partially used bundles shall be secured, to avoid individual sheets moving in strong winds.

A-2.2 Fixing of Decking

Decking sheets shall be fixed to the top of the

supporting structure. All fixings shall be made through the troughs in the decking. Fixings shall be at approximately 300 mm centres (or in every trough) along the end supports, and at 600 mm centres (or in alternate troughs) along the internal supports. As an absolute minimum, each sheet shall be connected at least twice to each permanent support. The number and placement of fasteners will normally be given on the decking layout drawing. Fixings shall not be made to temporary supports.

The fixings, together with 'through-deck' welded studs (if present) normally provide lateral restraint to the beams during the construction stages.

ANNEX B

(*Clause* 10.3)

CONSTRUCTION PRACTICE FOR CONCRETING ON DECKING

B-1 PLACING CONCRETE

B-1.1 Preparation

Prior to beginning work on the decking, guardrails shall be in position at all perimeters, internal edges and voids. The positions of any props (and back props) shall be checked against the details shown on the decking layout drawings to ensure that adequate support has been provided.

B-1.2 Cleaning the Decking

The surface of the decking shall be reasonably free of dirt, oil, etc prior to concreting.

B-1.3 Construction Joints

Although there is no technical limitation to the area that may be concreted, the usual pour area is up to 1 000 m^2/day. Where the limits of the pour do not coincide with permanent slab edges, construction joints are used to define the extent of the pour.

The locations and details of the construction joints may have an effect on the cracking. The layout and details of the joints shall be determined by the structural designer. For example, when brittle bonded finishes are used, the relationship between the joints in the concrete and the joints in the finishes shall be considered at the outset, to reduce the risk of cracking in undesirable locations.

Where possible, the construction joints shall be located close to butt joints in the decking. Where shear connectors are used, it is preferable to create the joint to one side of the line of the shear connectors, to ensure sound concrete around the studs. If the construction joint cannot be made near a butt joint, it is suggested that no more than one-third of the decking span from a butt joint shall be left unpoured. Concreting shall not be stopped within a sheet length, because excessive deflections may occur when the loads on a continuous decking sheet are not balanced either side of the intermediate support beam.

Stop ends, usually in the form of timber or plastic inserts, are used to create the construction joints. As with all the joints and ends of the decking, they shall be checked for potential grout loss.

B-1.4 Reinforcement

All reinforcement shall be properly supported so that it does not get displaced during concreting. Plastic stools, loops or preformed mesh may be used as 'chairs', but not plastic channels, which can induce cracking. Chairs shall be robust. In particular, the handling and movement of concrete carrying pipes during pumping can cause significant local impacts on the reinforcement.

The reinforcement that has been fixed shall be checked. Particular attention shall be given to checking any additional bar reinforcement, such as may be needed around openings.

B-1.5 Grout Loss

The decking joints shall be closely butted and exposed ends shall be 'stopped' with proprietary filler pieces to avoid grout loss. Gaps greater than 5 mm shall be sealed.

B-2 PLACEMENT

B-2.1 Concrete shall be placed in a way that minimizes the permanent deformation of the decking. This is particularly important for spans greater than 3 m. When concreting is progressed in the same direction as the span of the decking (that is, parallel to the decking ribs), it shall be placed first over supports where the decking is continuous, followed by the mid-span region and finally the areas above the end supports. When concreting is progressed in a direction perpendicular to the decking span (that is, transverse to the decking

ribs), it shall be placed first at the edge where a decking sheet is supported by the underlap of an adjacent sheet. This helps to ensure that longitudinal seams between panels remain closed.

The concrete shall be well compacted, particularly near and around any shear connectors. This may be done using a vibrating beam, which may require adequate supports at either ends, or an immersion poker vibrator. Hand tamping is not recommended as a way of compacting the concrete. For slim floors with deep decking, or for other partially encased beams, a poker is needed to ensure proper concrete flow around the beams, beyond the ends of the decking.

B-2.2 Concrete Pumping

Pumping may be adopted for both normal and lightweight concrete mixes. Flow rates in the order of 0.5 m^3 to 1 m^3 of concrete per minute may be achieved, although, clearly, the longer the pump lines and the higher the concrete is to be pumped, the slower the operation. A pump may normally lift the concrete up to 30 m. Secondary pumps, placed at intermediate levels, may be necessary for higher lifts.

Pumplines are normally 150 mm in diameter and are assembled in segments. As the force exerted at bends may be significant, straight line pumping is preferred. The lines shall be supported on timber blocks at intervals of 2 m to 3 m. Re-setting of pumplines is required at frequent intervals as the pour progresses. This means that the outlet pipe shall be moved frequently and carefully so that concrete heaping is minimized. A minimum of two operatives are necessary for this operation, one to hold and manoeuvre the outlet pipe, the other to shovel away excess concrete. No more than 4 workmen shall be present around the pipe outlet during pumping, because of the potential for overloading the decking. The concrete shall not be dropped from the outlet pipe onto the decking from a height of more than about 1 m.

B-2.3 Skip and Barrow

Placing concrete from a skip hung from a crane may be difficult because of obstructions from beams and decking at higher floor levels. However, despite being time consuming, it is sometimes efficient to use the skip and barrow technique for small infill bays.

Skips shall have a means of controlling the rate of discharge, and shall not be discharged from more than 0.5 m above the decking or barrow. When discharging into a barrow, the barrow shall be supported by thick (about 30 mm) boards covering a 2 m × 2 m area, or by a finished part of the slab. Either provision limits impact loads. Barrows shall be run over thick boards placed on the mesh, which shall be supported locally.

B-3 FINISHING, CURING AND DRYING

If power floating is to be carried out, this shall be done within 2 h to 3 h of casting. This allows time for the concrete to harden sufficiently.

As the concrete is only exposed on one surface of a composite floor, it can take longer than a traditional reinforced concrete slab to dry out.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 3935 : 1966	Code of practice for composite construction
(2) 3201 : 1988	Criteria for the design and construction of precast — trusses and purlins (*first revision*)
(3) 6332 : 1984	Code of practice for construction of floor and roofs using precast doubly-curved shell units (*first revision*)
10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/ prestressed concrete ribbed or cored units
10505 : 1983	Code of practice for construction of floors and roofs using precast reinforced concrete waffle units
13994 : 1994	Code of practice for design and construction of floor and roof with precast reinforced concrete planks and RC joists

IS No.	*Title*
14142 : 1994	Code of practice for design and construction of floors and roofs with prefabricated brick panel
14215 : 1994	Code of practice for construction of floor and roof with RC channel units
14242 : 1994	Code of practice for design and construction of roof with L-Panel units
(4) 11447 : 1985	Code of practice for construction with large panel prefabricates
(5) 6061	Code of practice for construction of floor and roof with joists and filler blocks:
(Part 1) : 1971	With hollow concrete filler blocks
(Part 2) : 1981	With hollow clay filler blocks (*first revision*)

PART 7 CONSTRUCTIONAL PRACTICES AND SAFETY

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Part of the Code emphasizes the importance of carrying out all constructional operations in a safe and efficient manner. Workers in large number, both skilled and unskilled, are engaged in the innumerable construction works. Due to increased tempo of such a building activity and large scale mechanization, hazards of accidents could increase considerably. It is, therefore, imperative that adequate safety rules are laid down for every phase of construction work.

Planning the various constructional operations before hand and making adequate arrangements for procurement and storage of materials, and the machinery to get work done is as important as carrying out these constructional operations in accordance with good practice. Lack of planning or defective planning may result in avoidable delay in the completion of work and consequently increased hazards from the point of view of fire, health and structural soundness.

The first version of this Part was prepared in 1970, which was subsequently revised in 1983. In the first revision, information regarding handling operations, that is unloading, stacking, lifting, loading and conveying of building materials, was also given along with the storage practices. Additional information regarding the use of ladders; safety requirements for floor and wall openings, railings and toe boards; piling and other deep foundations; constructions involving use of hot bituminous materials; and erection of structural steel work and concrete framed structures, etc, were included.

As a result of experience gained in implementation of 1983 version of this part and feedback received as well as in view of formulation of new standards in the field of constructional practices and safety and revision of some existing standards, a need to revise this Part was felt. This revision has, therefore, been prepared to take care of these aspects. The significant changes incorporated in this revision include:

a) The Section 1 Constructional Practices have been revamped and now includes the Planning and Management aspects.
b) The provisions with regard to stacking and storage of building materials and components have been updated and comprehensively covered in line with IS 4082 : 1996. This revision now also covers provisions for materials like stones, blocks, roof tiles, partially prefabricated wall and roof components, cinder, aluminium section, cast iron and aluminium sheets, plastic sheets, doors and windows, etc.
c) Provisions on constructional practices using bamboo have been included.
d) Provisions of safety requirements of hoists/lifts for worker during construction have been added.
e) Provisions with regard to safety at work site have been detailed incorporating aspects like preventive measures, such as, falling material hazards prevention, fall prevention, disposal of debris, fire protection, etc.
f) Provisions regarding safety management at work sites have been added.
g) A new section on 'Maintenance management, repairs, retrofitting and strengthening of buildings' has been added, covering aspects like maintenance management, prevention of cracks, and repairs and seismic strengthening of buildings.
h) Safety provisions with respect to demolition of buildings have been updated.
j) Reference to all the concerned Indian Standards have been updated.

Bamboo is a versatile renewable resource having low gestation period, characterized by high strength, low mass and ease of working with simple tools. Resilience coupled with lightness makes it suitable for housing in earthquake-prone and disaster-prone areas. It has the capacity to absorb more energy and shows larger deflections before collapse and as such is safer under earth tremors. In this revision of this Part, therefore, provisions on construction using bamboo have been incorporated. The structural design aspects are covered in Part 6 'Structural Design, Section 3 Timber and Bamboo, 3B Bamboo'.

The information contained in this Part is largely based on the following Indian Standards and Special Publications:

IS No.	*Title*
3696	Safety code for scaffolds and ladders:
(Part 1) : 1987	Scaffolds
(Part 2) : 1991	Ladders
3764 : 1992	Code of practice for excavation work (*first revision*)
4082 : 1996	Recommendations on stacking and storage of construction materials and components at site (*second revision*)
4130 : 1991	Safety code for demolition of buildings (*second revision*)
4912 : 1978	Safety requirements for floor and wall openings, railing and toe boards (*first revision*)
5121 : 1969	Safety code for piling and other deep foundations
5916 : 1970	Safety code for construction involving use of hot bituminous materials
7205 : 1974	Safety code for erection of structural steel work
7969 : 1975	Safety code for handling and storage of building materials
8989 : 1978	Safety code for erection of concrete framed structures
13415 : 1992	Safety code for protective barrier in and around buildings
13416	Recommendations for preventive measures against hazards at work places:
(Part 1) : 1992	Falling material hazards prevention
(Part 2) : 1992	Fall prevention
(Part 3) : 1994	Disposal of debris
(Part 4) : 1994	Timber structures
(Part 5) : 1994	Fire protection
13430 : 1992	Code of practice for safety during additional construction and alteration to existing buildings

A reference to SP 62 : 1992 'Handbook on building construction practices (excluding electrical works)' and SP 70 : 2001 'Handbook on construction safety practices' may also be made.

All standards, whether given herein above or cross referred to in the main text of this Part, are subject to revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 7 CONSTRUCTIONAL PRACTICES AND SAFETY

1 SCOPE

This Part of the Code covers the constructional planning, management and practices in buildings; storage, stacking and handling of materials and safety of personnel during construction operations for all elements of a building and demolition of buildings. It also covers guidelines relating to maintenance management, repairs, retrofitting and strengthening of buildings.

SECTION 1 CONSTRUCTIONAL PRACTICES

2 PLANNING, MANAGEMENT AND PRACTICES

2.1 Planning Aspects

Construction planning aspects aim to identify and develop various stages of project execution on site which should be consistent with the management considerations. Planning aspects evolve out of the objectives of project and requirements of the final completed constructed facility. These objectives could relate to the final constraints, cost considerations, quality standards, safety standards, environmental considerations and health considerations. Construction practices would, then have to satisfy these objectives during construction phase of the project.

Having established objectives of the construction phase, planning determines processes, resources (including materials, equipments, human and environmental) and monitoring system to ensure that the practices are appropriately aligned. Adequate knowledge about pre-construction phase evolution of project, especially related to customer's requirements, is an essential prerequisite for construction planning.

2.1.1 *Preconstruction Phase*

2.1.1.1 Besides the design aspects, preconstruction phase should also address all the issues related to the implementation of the design at the site through suitable construction strategy. During the design stage, the site conditions should be fully understood with anticipated difficulties and avoid the risk of subsequent delays and changes after the construction has started.

2.1.1.2 The selection of construction methods, building systems and materials, components, manpower and equipments and techniques are best done in the preconstruction phase. Such selection is influenced by the local conditions like terrain, climate, vulnerability for disasters, etc.

2.1.1.3 Construction in busy localities of cities needs special considerations and meticulous planning due to restricted space, adjoining structures, underground utilities, traffic restrictions, noise and other environmental pollution and other specific site constraints.

2.1.1.4 The constructability aspects of the proposed construction methods needs to be carefully evaluated at the planning stage to ensure ease of construction besides optimizing the construction schedule and achieving quality, reliability and maintainability of the constructed facilities.

2.1.1.5 Constructional practices in hilly regions needs to take into considerations the problem of landslides, slope stability, drainage, etc, besides ensuring no adverse impact on the fragile environmental conditions.

2.1.1.6 Durability of constructions in corrosive atmospheric conditions like coastal regions and aggressive ground situations with high chlorides and sulphates should also be taken care of with appropriate constructional practices.

2.1.1.7 Constructional practices in disaster prone areas need specific planning. The type of construction, use of materials, construction techniques require special considerations in such areas.

2.1.1.8 Adverse weather conditions have strong bearing on construction phase. Situations wherein constructions are to be carried out in adverse weather conditions, such as heavy and continuous rain fall, extreme hot or cold weather, dust storms, etc, the practices have to address the relevant aspects. Accordingly, suitable design and field operations should be adapted or redefined in anticipation of these aspects. Some of these aspects are:

a) Site layout which enables accessibility in adverse weather.
b) Adequate protected storage for weather sensitive materials/equipments.
c) Protections to personnel from extreme hot/ control conditions.
d) Scheduling to allow maximization of outdoor activities during fair weather conditions.
e) Special design and construction provisions for activities in extreme temperature conditions like hot or cold weather concreting, staple of false work in extreme wind conditions (gusts).
f) Adequate lighting for shorter days in winter/ night work.
g) Design for early enclosure.

2.1.2 *Resource Planning*

Resource planning aims to identify requirement, availability and regulatory/control processes related to resources. Resource planning is a generic expression but the actual process of planning is specific to the resources considered.

In construction phases, the resources could be categorized as materials, manufactured products, equipments for construction, installation and fabrication, human resources as a part of overall organization, information resources, such as, reference standards and other practice documents, environmental conditions for work on site and infrastructure facilities. Therefore, the resource planning encompasses identification, estimation, scheduling and allocation of resources. Resource planning needs to establish a control system for controlling consumption monitoring, corrective action and resource reappropriation in the event of favourable deviation. Organizational capability, commitment to the project requirements and other constraints such as time and cost, need to be considered as inputs while planning resources. Techniques of management and planning, such as, Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM) (*see* Annex A) may be used.

Non-availability of basic building materials (brick, stone aggregate, etc) within reasonable lead would influence the constructional practice by alternative materials. The constructional practices also get decided by the local skills of the manpower for constructional activities. The equipment selection would also be governed by the site constraints. Therefore, as, the resource planning is critical to the project viability itself, the inputs to the resource planning need to be validated appropriately and established for such management. Resource planning should establish a proper system of data collection so as to facilitate effective resources control mechanism. Resource planning responsibility has to be specifically defined in the overall organizational setup.

2.1.3 *Construction Phase*

2.1.3.1 *Organizational structure*

The site management should be carried out through suitable site organization structure with roles and responsibilities assigned to the construction personnel for various construction related functions. Safety management is one of the important components of site management.

2.1.3.2 *Site layout*

The layout of the construction site should be carefully planned keeping in view the various requirements to construction activities and the specific constraints in terms of its size, shape, topography, traffic and other restrictions, in public interest. A well planned site layout would enable safe smooth and efficient construction operations. The site layout should take into considerations the following factors:

a) Easy access and exit, with proper parking of vehicle and equipments during construction.
b) Properly located material stores for easy handling and storage.
c) Adequate stack areas for bulk construction materials.
d) Optimum location of plants and equipments (batching plants, etc).
e) Layout of temporary services (water, power, power suppression unit, hoists, cranes, elevators, etc).
f) Adequate yard lighting and lighting for night shifts.
g) Temporary buildings; site office and shelter for workforce with use of non-combustible materials as far as possible including emergency medical aids.
h) Roads for vehicular movement with effective drainage plan.
j) Construction safety with emergency access and evacuations and security measures.
k) Fabrication yards for reinforcement assembly, concrete precasting and shuttering materials.
m) Fencing, barricades and signages.

2.1.3.3 *Access for fire fighting equipment vehicles*

Access for fire fighting equipment shall be provided to the construction site at the start of construction and maintained until all construction work is completed.

2.1.3.3.1 Free access from the street to fire hydrants/ static water tanks, where available, shall be provided and maintained at all times.

2.1.3.3.2 No materials for construction shall be placed within 3 m of hydrants/static water tanks.

2.1.3.3.3 During building operations, free access to permanent, temporary or portable first-aid fire fighting equipment shall be maintained at all times.

2.1.3.4 *Access to the upper floors during construction*

In all buildings over two storeys high, at least one stairway shall be provided in usable condition at all times. This stairway shall be extended upward as each floor is completed. There shall be a handrail on the staircase.

2.1.3.5 *Construction strategy and construction sequence*

Construction strategy and construction methods are to be evolved at the planning and design stage specific to the conditions and constraints of the project site and implemented by the site management personnel to ensure ease of construction and smooth flow of construction activities. Sites of high water table conditions with aggressive chemical contents of subsoil needs special design considerations. Buildings with basement in sites of high water table should be planned with dewatering scheme with appropriate construction sequence. Duration of dewatering should continue till sufficient dead loads are achieved to stabilize the buoyancy loads with adequate factor of safety. The construction sequence should be planned taking into consideration the following aspects:

a) Availability of resources (men, material and equipment);
b) Construction methods employed including prefabrication;
c) Planned construction time;
d) Design requirements and load transfer mechanism;
e) Stability of ground like in hilly terrain;
f) Ensuring slope stability with retaining structure before the main construction;
g) Installation and movement of heavy equipments like cranes and piling equipments;
h) Effect of weather; and
j) Minimum time to be spent below ground level working.

2.1.4 *Scope Management*

Construction management efforts should ensure that the project features and functions that characterise the project scope remain as established during the design finalization stage. Accordingly, construction phase practices need to be oriented to manage the project scope. As a part of overall project scope management functions, the processes of scope planning, scope definition and scope verification are associated with the preconstruction phase of the project. The scope monitoring and the change control are critical to the construction phase leading to serious implications on the time and cost aspects. In this respect, consolidated brief of the project established at the end of the design completion is an essential reference for scope baseline.

2.2 Construction Management

Construction phase of the project transfers the project conceived on paper in the form of plans and designs, into reality by use of resources like materials, machines and men through one or more construction agencies. To fulfil the construction scope with quality, in time and under safe conditions within a reasonable cost, it is desired that the project is planned for managing construction for amalgamation of above resources for their optimum use and its continuous monitoring. Agencies managing the supervision and/or construction are desired to plan and document a management system with clear cut responsibilities and for managing various parameters like scope, time, quality, health, safety and environment and cost for implementation, monitoring and control for their effectiveness. This may be preferably inline with proven National/International documentation system covering all aspects of monitoring and controls. Various parameters to be managed during construction are as below.

2.2.1 *Time Management*

Considering the importance of time in a project, it is desirable that project is completed in the defined time schedule to get its fruitful benefits. The system planned should cover total schedule of completion with one or more construction agencies, number of vendors, identification of total resources, timely availability of all inputs, including critical ones, its processing during construction of a project. The system should include a periodic review of a project with all parameters as well as catch up plans in case of delay identified for controls and reporting from time to time. The system planned should preferably be computer friendly and simple to follow for implementation, monitoring and controls and for reporting from time-to-time.

2.2.2 *Quality Management*

Quality of a project should be planned for all activities from inception to completion. It is desirable that the system planned gives adequate assurance and controls that it shall meet project quality objectives. The system shall cover review of existing requirements, sub-contracting, materials, processes and controls during process, auditing, training of personnel, final inspection and acceptance. All activities shall be planned and controlled. Quality systems approach may be referred for planning, suitable to a particular project for implementation.

2.2.3 *Health, Safety and Environement*

Each project affects the safety and health of the workmen and surroundings during construction. Various activities having impact on health, safety and environment need to be identified with their likely effect and proposed preventive corrective actions, together with the concerned statutory obligations. The system planned for health, safety and environment shall address and cover the above including use of personnel protective equipments by all concerned, and reporting

on their monitoring and controls during project implementation.

2.2.4 *Cost Management*

To keep the project under viable proposition, it is desired that cost of the project during construction are monitored and controlled through a documentation system. The various parameters which may affect the basic cost, escalations, cost due to variation in scope and quantities, etc need to be monitored at a defined frequency. The system planned may be in line with a proven cost control method or similar in nature and cost incurred vis-a-vis cost sanctioned and cost anticipated to be reported and controlled from time to time.

2.3 Construction Control and Practices

2.3.1 *Professional Services and Responsibilities*

The responsibility of professionals with regard to planning designing and supervision of building construction work, etc and that of the owner shall be in accordance with Part 2 'Administration'. All applications for permits and issuance of certificates, etc shall be as given in Part 2 'Administration'. Employment of trained workers shall be encouraged for building construction activity.

2.3.2 *Construction of all Elements*

Construction of all elements of a building shall be in accordance with good practice [7(1)]. Constructional aspects using bamboo shall be as given in **2.3.3**. It shall also be ensured that the elements of structure satisfy the appropriate fire resistance requirements as specified in Part 4 'Fire and Life Safety', and quality of building materials/components used shall be in accordance with Part 5 'Building Materials'.

2.3.3 *Construction Using Bamboo*

2.3.3.1 Bamboo being a versatile resource characterized by high strength, low mass and ease of working with simple tools, it is desirable to increasingly make appropriate use of this material. Design of structures using bamboo shall be done in accordance with Part 6 'Structural Design, Section 3 Timber and Bamboo, 3B Bamboo'. For construction using bamboo, some of the important constructional provisions given in **2.3.3.2** to **2.3.3.6** shall be followed.

2.3.3.2 *Working finishing*

2.3.3.2.1 Bamboo can be cut and split easily with very simple hand tools. Immature bamboos are soft, pliable and can be moulded to desired shape. It takes polish and paint well.

2.3.3.2.2 While it is possible to walk with bamboo simply using a machete, a few basic tools, such as, machete, hack saw, axe, hatchet, sharpening tools, adze, chisel (20 mm), drill, wood rasps, steel rod, and pliers, will greatly increase the effectiveness of the construction process.

2.3.3.2.3 For providing safety to the structure against fire, bamboo may be given fire retardant treatment using following chemicals; a few drops of concentrated HCl shall be added to the solution to dissolve the precipitated salts:

Ammonium phosphate	3 parts
Boric acid	3 parts
Copper sulphate	1 part
Zinc chloride	5 parts
Sodium dichromate	3 parts
Water	100 parts

2.3.3.2.4 *Foundations*

Bamboo in direct contact with ground, bamboo on rock or preformed concrete footing, bamboo incorporated into concrete or bamboo piles may form the foundation structure (*see* Fig. 1).

2.3.3.2.5 *Floors*

The floor of bamboo may be at ground level with covering of bamboo matting, etc. In elevated floors, bamboo members become an integral part of structural framework of building. The floor will comprise structural bamboo elements and bamboo decking.

2.3.3.2.6 *Jointing Techniques*

The jointing techniques in construction using bamboo shall be in accordance with Part 6 'Structural Design, Section 3 Timber and Bamboo, 3B Bamboo'.

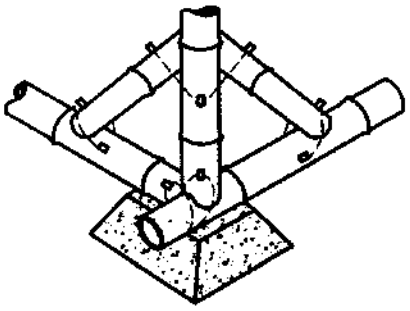
2.3.4 *Low Income Housing*

For low income housing, appropriate planning and selection of building materials and techniques of construction have to be judiciously done and applied in practice. Requirements of low income housing specified in Part 3 'Development Control Rules and General Building Requirements', shall be followed. However, all requirements regarding structural safety, health safety and fire safety shall be in accordance with this Code.

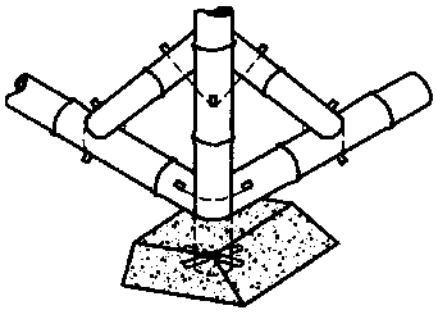
2.3.5 *Site Preparation*

While preparing the site for construction, bush and other wood, debris, etc, shall be removed and promptly disposed of so as to minimize the attendant hazards.

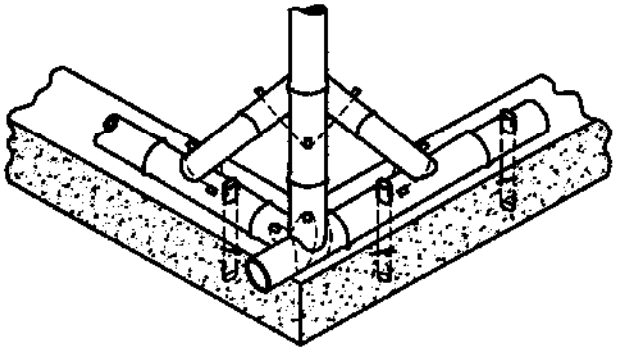
Temporary buildings for construction offices and storage shall be so located as to cause the minimum fire hazards and shall be constructed from non-combustible materials as far as possible.



1A BAMBOO ON PREFORMED CONCRETE FOOTINGS



1B BAMBOO INCORPORATED INTO CONCRETE FOOTINGS (SINGLE POST FOOTING)



1C BAMBOO OUT OF GROUND CONTACT ON STRIP FOOTINGS OF CONCRETE (LARGE DIAMETER THICK WALLED BAMBOO WITH CLOSELY SPACED NODES TO BE USED)

FIG. 1 BAMBOO FOUNDATIONS

2.3.6 *Use of New/Alternative Construction Techniques*

The provisions of this part are not intended to prevent use of any construction techniques including any alternative materials, not specifically prescribed by the Code, provided any such alternative has been approved. The Authority may approve any such alternative such as ferrocement construction, row-lock (rat trap) bond in masonry, stretcher bond in filler slab and filler slab provided it is found that the proposed alternative is satisfactory and conforms to the provisions of relevant parts regarding material, design and construction and that material, method, or work offered is, for the purpose intended, at least equivalent to that prescribed in the Code in quality, strength, compatibility, effectiveness, fire and water resistance, durability and safety.

SECTION 2 STORAGE, STACKING AND HANDLING PRACTICES

3 GENERAL

3.1 Planning and Storage Layout

3.1.1 For any site, there should be proper planning of the layout for stacking and storage of different materials, components and equipments with proper access and proper manoeuvrability of the vehicles carrying the material. While planning the layout, the requirements of various materials, components and equipments at different stages of construction shall be considered.

3.1.2 Materials shall be segregated as to kind, size and length and placed in neat, orderly piles that are safe against falling. If piles are high they shall be stepped back at suitable intervals in height. Piles of materials shall be arranged so as to allow a passageway of not less than 1 m width in between the piles or stacks for inspection or removal. All passageways shall be kept clear of dry vegetation.

3.1.3 Materials shall be stored, stacked and handled in such a manner as to prevent deterioration or intrusion of foreign matter and to ensure the preservation of their quality and fitness for the work.

3.1.4 Materials shall be stacked on well drained, firm and unyielding surface. Materials shall not be stacked so as to impose any undue stresses on walls or other structures.

3.1.5 Materials shall be stacked in such a manner as not to constitute a hazard to passerby. At such places the stacks shall have suitable warning signs in day time and red lights on and around them at night.

3.1.6 Stairways, passageways and gangways shall not become obstructed by storage of building materials, tools or accumulated rubbish.

3.2 Protection Against Atmospheric Agencies

Materials stored at site, depending upon the individual characteristics, shall be protected from atmospheric actions, such as rain, sun, winds and moisture, to avoid deterioration.

3.3 Manual Handling

When heavy materials have to be handled manually each workman shall be instructed by his foreman or supervisor for the proper method of handling such materials. Each workman shall be provided with suitable equipment for his personal safety as necessary. Supervisors shall also take care to assign enough men to each such job depending on the weight and the distance involved.

3.4 Protection Against Fire and Other Hazards

3.4.1 Materials, like timber, bamboo, coal, paints, etc, shall be stored in such a way that there may not be any possibility of fire hazards. Inflammable materials like kerosene and petrol, shall be stored in accordance with the relevant rules and regulations so as to ensure the desired safety during storage. Stacks shall not be piled so high as to make them unstable under fire fighting conditions and in general they shall not be more than 4.5 m in height. The provisions given in good practice [7(2)] shall be followed. Explosives like detonators shall be stored in accordance with the existing regulations of *Indian Explosives Act*.

3.4.2 Materials which are likely to be affected by subsidence of soil like precast beams, slabs and timber of sizes shall be stored by adopting suitable measures to ensure unyielding supports.

3.4.3 Materials liable to be affected by floods, tides, etc shall be suitably stored to prevent their being washed away or damaged due to floods, tides, etc.

4 STORAGE, STACKING AND HANDLING OF MATERIALS

4.1 The storage stacking and handling of materials generally used in construction shall be as given in **4.2** to **4.31**, which have been summarized in the form of a check list in Annex B. Exposure to asbestos fibres/ dust is known to be harmful to health of human beings. Prescribed guidelines in accordance with good practice [7(3)] shall be followed for handling and usage asbestos cement products.

4.2 Cement

a) *Storage and Stacking* — Cement shall be stored at the work site in a building or a shed which is dry, leakproof and as moisture-proof as possible. The building or shed for storage should have minimum number of windows and close fitting doors and these should be kept closed as far as possible.

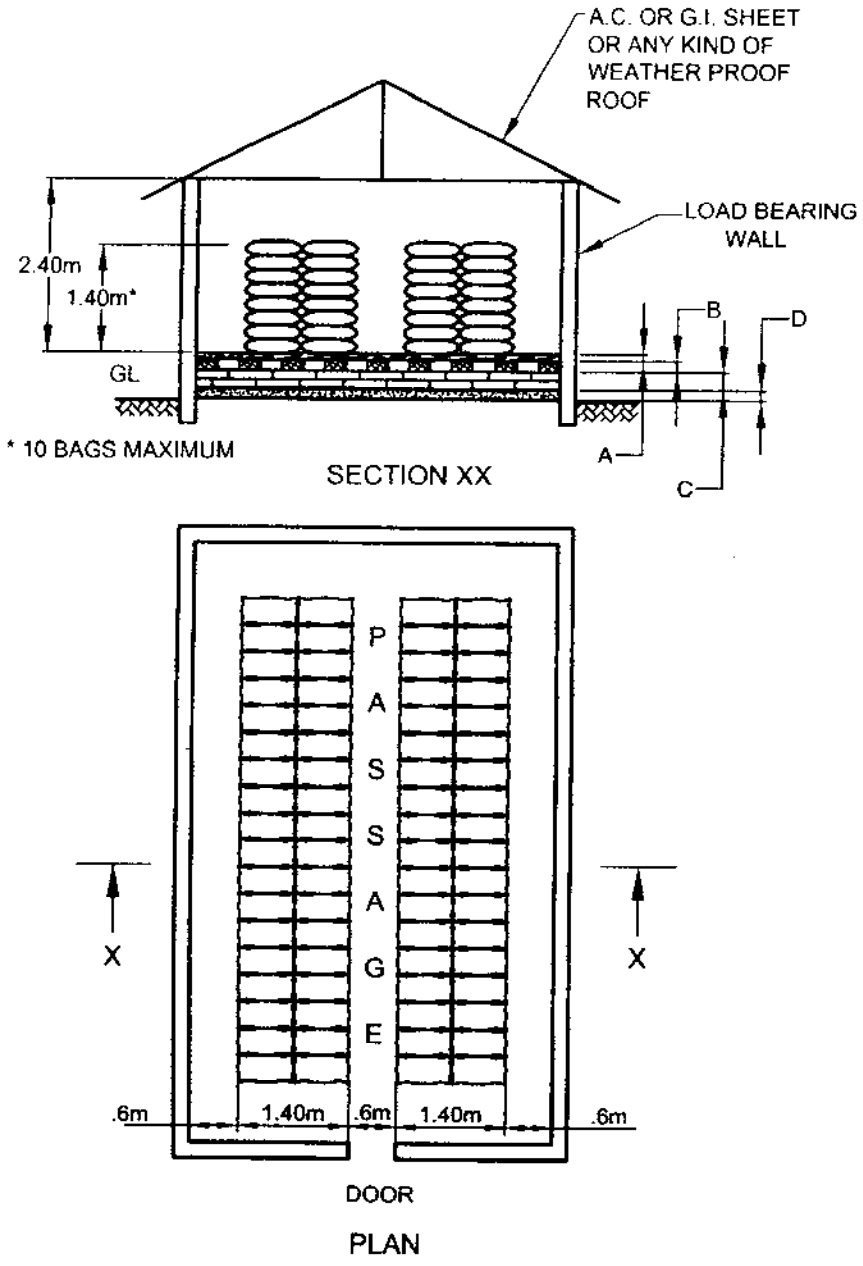
Cement received in bags shall be kept in such a way that the bags are kept free from the possibility of any dampness or moisture coming in contact with them. Cement bags shall be stacked off the floor on wooden planks in such a way as to keep them about 150 mm to 200 mm clear above the floor. The floor may comprise lean cement concrete or two layers of dry bricks laid on a well consolidated earth. A space of 600 mm minimum shall be left alround between the exterior walls and the stacks (*see* Fig. 2). In the stacks the cement bags shall be kept close together to reduce circulation of air as such as possible. Owing to pressure on bottom layer of bags sometimes 'warehouse pack' is developed in these bags. This can be removed easily by rolling the bags when cement is taken out for use. Lumped bags, if any should be removed and disposed off.

The height of stack shall not be more than 10 bags to prevent the possibility of lumping up under pressure. The width of the stack shall be not more than four bags length or 3 metres. In stacks more than 8 bags high, the cement bags shall be arranged alternately length-wise and cross-wise so as to tie the stacks together and minimize the danger of toppling over. Cement bags shall be stacked in a manner to facilitate their removal and use in the order in which they are received; a table showing date of receipt of cement shall be put on each stack to know the age of cement.

For extra safety during monsoon, or when it is expected to store for an unusually long period, the stack shall be completely enclosed by a water proofing membrane such as polyethylene, which shall close on the top of the stack. Care shall be taken to see that the waterproofing membrane is not damaged any time during the use.

Cement in gunny bags, paper bags and polyethylene bags shall be stored separately.

In case cement is received in drums, these



A = Planks
B = Wooden Battens
C = 150 Dry Bricks in Two Layer or Lean Cement Concrete
D = 150 Consolidated Earth

Fig. 2 Typical Arrangement in Cement Godown

shall be stored on plane level ground, as far as possible near the concrete mixing place. After taking out the required quantity of cement, the lid of the drum shall be securely tied to prevent ingress of moisture.

In case cement is received in silos, the silos shall be placed near the concrete batching plan. Proper access shall be provided for the replacement of silos.

Different types of cements shall be stacked and stored separately.

b) *Handling* — Hooks shall not be used for handling cement bags unless specifically permitted by the engineer-in-charge.

For information regarding bulk handling of cement, *see* **4.4**.

4.3 Lime

4.3.1 *Quicklime Before Slaking*

a) *Storage and stacking* — Quicklime should be slaked as soon as possible. If unavoidable it may be stored in compact heaps having only the minimum of exposed area. The heaps shall be stored on a suitable platform and covered to avoid direct contact with rain or being blown away by wind. In case quick lime is stored in a covered shed, a minimum space of 300 mm should be provided alround the heaps to avoid bulging of walls.

Unslaked lime shall be stored in a place inaccessible to water and because of fire hazards, shall be segregated from the combustible materials.

b) *Handling — See* **4.4**.

4.3.2 *Hydrated Lime*

a) *Storage and stacking* — Hydrated lime is generally supplied in containers, such as jute bags lined with polyethylene or craft paper bags. It should be stored in a building to protect the lime from dampness and to minimize warehouse deterioration.

The building should be with a concrete floor and having least ventilation to eliminate draughts through the walls and roof. In general, the recommendations given in **4.2** for storing of cement shall be applicable for hydrated lime. When air movement is reduced to a practical minimum, hydrated lime can be stored for up to three months without appreciable change.

b) *Handling — See* **4.4**.

4.3.3 *Dry Slaked Lime*

a) *Storage and stacking* — The lime shall be stored in a dry and closed godown.

b) *Handling — See* **4.4**.

4.4 Handling of Cement and Lime

Workmen, handling bulk cement or lime shall wear protective clothing, respirators, and goggles; shall be instructed in the need of cleanliness to prevent dermatitis, and shall be provided with hand cream, petroleum jelly, or similar preparation for protection of exposed skin.

Bulk cement stored in silos or bins may fail to feed to the ejection system. When necessary to enter a silo or bin for any purpose, the ejection system employed shall be shut down and locked out electrically as well as mechanically. When necessary for a workman to enter such storage area, he shall wear a life-line, with another workman outside the silo or hopper attending the rope.

4.5 Masonry Units

a) *Stones* — Stones of different sizes, types and classification shall be stored separately. Stones shall be stacked on dry firm ground in a regular heap not more than 1 m in height. Veneering stones shall be stacked against vertical support on a firm dry ground in tiers, up to a height of 1.2 m. A distance of about 0.8 m shall be kept between two adjacent stacks.

b) *Bricks* — Bricks shall be stacked in regular tiers as and when they are unloaded to minimize breakage and defacement. These shall not be dumped at site. In the case of bricks made from clays containing lime *KANKAR*, the bricks in stack should be thoroughly soaked in water (docked) to prevent lime bursting.

Bricks shall be stacked on dry firm ground. For proper inspection of quality and east in counting, the stacks shall be 50 bricks long, 10 bricks high and not more than 4 bricks in width, the bricks being placed on edge, two at a time along the width of the stack. Clear distance between adjacent stacks shall not be less than 0.8 m. Bricks of each truck load shall be put in one stack. Bricks of different types, such as, clay bricks, clay fly ash bricks, fly ash lime bricks, sand lime (calcium silicate) bricks shall be stacked separately. Bricks of different classifications from strength consideration and size consideration (such as, conventional and modular) shall be stacked separately. Also bricks of different types, such as, solid, hollow and perforated shall be stacked separately.

c) *Blocks* — Blocks are available as hollow and solid concrete blocks, hollow and solid light weight concrete blocks, autoclaved aerated concrete blocks, concrete stone masonry blocks and soil based blocks. Blocks shall be unloaded one at a time and stacked in regular tiers to minimize breakage and defacement. These shall not be dumped at site. The height of the stack shall not be more than 1.2 m, the length of the stack shall not be more than 3.0 m, as far as possible and the width shall be of two or three blocks. Normally blocks cured for 28 days only should be received at

site. In case blocks cured for less than 28 days are received, these shall be stacked separately. All blocks should be water cured for 10 to 14 days and air cured for another 15 days; thus no blocks with less than 28 days curing shall be used in building construction. Blocks shall be placed close to the site of work so that least effort is required for their transportation. The date of manufacture of the blocks shall be suitably marked on the stacks of blocks manufactured at factory or site.

d) *Handling* — Brick stacks shall be placed close to the site of work so that least effort is required to unload and transport the bricks again by loading on pallets or in barrows. Unloading of building bricks or handling in any other way likely to damage the corners or edges or other parts of bricks shall not be permitted.

4.6 Floors, Wall and Roof Tiles

a) *Storage and Stacking* — Floor, wall and clay roof tiles of different types, such as, cement concrete tiles (plain, coloured and terrazzo) and ceramic tiles (glazed and unglazed) shall be stacked on regular platform as far as possible under cover in proper layers and in tiers and they shall not be dumped in heaps. In the stack, the tiles shall be so placed that the mould surface of one faces that of another. Height of the stack shall not more than 1 m.

Tiles of different quality, size and thickness shall be stacked separately to facilitate easy removal for use in work. Tiles when supplied by manufacturers packed in wooden crates shall be stored in crates. The crates shall be opened one at a time as and when required for use.

b) *Handling* — Ceramic tiles and roof tiles are generally supplied in cartons which shall be handled with care to avoid breakage. It is preferable to transport these at the site on platform trolleys.

4.7 Aggregate

a) *Storage and Stacking* — Aggregates shall be stored at site on a hard dry and level patch of ground. If such a surface is not available, a platform of planks or old corrugated iron sheets, or a floor of bricks, or a thin layer of lean concrete shall be made so as to prevent the mixing with clay, dust, vegetable and other foreign matter.

Stacks of fine and coarse aggregate shall be kept in separate stock piles sufficiently removed from each other to prevent the material at the edges of the piles from getting intermixed. On a large job it is desirable to construct dividing walls to give each type of aggregates its own compartment. Fine aggregates shall be stacked in a place where loss due to the effect of wind is minimum.

b) *Handling* — When withdrawals are made from stock piles, no over hang shall be permitted.

Employees required to enter hoppers shall be equipped with safety belts and life-lines, attended by another person. Machine driven hoppers, feeders, and loaders shall be locked in the off position prior to entry electrically as well as mechanically.

4.8 Pulverized Fuel Ash/Fly Ash

a) *Storage and Stacking* — Fly ash shall be stored in such a manner as to permit easy access for proper inspection and identification of each consignment. Fly ash in bulk quantities shall be stored in stack similar to fine aggregates, avoiding any intrusion of foreign matter. Fly ash in bags shall be stored in stacks not more than 10 bags high.

b) *Handling* — *See* **4.4**.

4.9 Cinder

Cinder shall be stored in bulk quantities in stacks similar to coarse aggregates avoiding any extrusion of foreign matter.

4.10 Timber

a) *Storage and Stacking* — Timber shall be stored in stacks upon well treated and even surfaced beams, sleepers or brick pillars so as to be above the ground level by at least 150 mm to ensure that the timber will not be affected by accumulation of water under it. Various members shall preferably be stored separately in different lengths, and material of equal lengths shall be piles together in layers with wooden battens, called crossers, separating one layer from another. The crossers shall be of sound wood, straight and uniform in thickness. In case, where separate crossers are not available smaller sections of the available structural timber may be employed in their place. In any layer an air space of about 25 mm shall be provided between adjacent members. The longer pieces shall be placed in the bottom layers and shorter pieces in the top layers but one end of the stack shall be in true vertical alignment.

The crossers in different layers shall be in vertical alignment. The most suitable width and height of a stack are recommended to be about 1.5 m and 2.0 m. Distance between adjacent stacks is recommended to be at least 450 mm. In case the stacking with the help of battens is not possible, the timber may be close piled in heaps on raised foundations with the precautions specified above.

The stacks shall be protected from hot dry winds or direct sun and rain. Heavy weights, such as metal rails or large sections of wood, are recommended to be placed on the top of the stack to prevent distortion or warping of the timber in the stack. In case timber is to be stored for about a year or more, to prevent end-cracking in the material, the ends of all members shall be coated with coal tar, aluminium leaf paints (hardened gloss oil), microcrystalline wax or any other suitable material.

b) Care must be taken that handler or workmen are not injured by rails, straps, etc, attached to the used timber. This applies particularly to planks and formwork for shuttering.

4.11 Bamboo

4.11.1 The site shall be properly inspected and termite colonies or mounds if detected shall be destroyed.

All refuse and useless cellulosic materials shall be removed from the site. The ground may then be disinfected by suitable insecticides. The area should have good drainage.

4.11.2 Bamboo may preferably be stacked on high skids or raised platform atleast 300 mm above ground. Storage under cover reduces the liability to fungal attack. Good ventilation and frequent inspection are important.

4.11.3 Bamboo dries by air-seasoning under cover in the storage yards from 6 to 12 weeks time.

4.11.4 Prophylactic treatment of bamboo during storage prevents losses due to fungi and insects even under open storage. Following chemicals are found suitable at the coverage rate of 24 litres per tonne.

Sodium pentachlorophenate	: 1 percent solution
Boric acid + borax (1:1)	: 2 percent solution
Sodium pentachlorophenate + boric acid + borax (5:1:1)	: 2.5 percent solution

A mixture of these compounds yields the best results.

NOTE — For better protection of structural bamboo (if stored outside), repetition of the treatment after four to six months is desirable.

4.12 Partially Prefabricated Wall and Roof Components

a) *Storage and Stacking* — The wall components comprise blocks, sills, lintels, etc. The blocks shall be stacked in accordance with **4.5**(c). These shall be stacked on plane level ground having a floor of bricks or a thin layer of lean concrete.

The roof components such as precast RC joists, prefabricated brick panels, RC planks, channel units, cored units, waffle units, L-panel, single tee and double tee sections, ferrocement panels, etc shall be unloaded as individual components. These shall be stacked on plane level ground having a floor of bricks or a thin layer of lean concrete. RC planks, prefabricated brick panels and ferrocement panels shall be stacked against a brick masonry wall in slightly inclined position on both sides of the wall. Channel units, cored units and L-panels shall be stacked one over the other up to five tiers. The waffle units shall be stacked upside down as individual units. The RC joists, single tee and double tee sections shall be stacked as individual units one adjacent to the other. The distance between any two adjacent stacks shall not be less than 450 mm.

b) *Handling* — The components shall be handled by holding the individual component by holding a specified points so that the stresses due to handling are minimized.

4.13 Steel

a) *Storage and Stacking* — For each classification of steel, separate areas shall be earmarked. It is desirable that ends of bars and sections of each class be painted in distinct separate colours. Steel reinforcement shall be stored in a way as to prevent distortion and corrosion. It is desirable to coat reinforcement with cement wash before stacking to prevent scaling and rusting.

Bars of different classification, sizes and lengths shall be stored separately to facilitate issues in such sizes and lengths as to minimize wastage in cut from standard lengths.

In case of long storage or in coastal areas, reinforcement bars shall be stacked above ground level by at least 150 mm and a coat of cement wash shall be given to prevent scaling and rusting.

Structural steel of different sections, sizes and lengths shall be stored separately. It shall be

stored above ground level by at least 150 mm upon platforms, skids or any other suitable supports to avoid distortion of sections. In case of coastal areas or in case of long storage, suitable protective coating of cement wash shall be given to prevent scaling and rusting.

b) *Handling* — Tag lines shall be used to control the load in handling reinforcements or structural steel when a crane is employed. Heavy steel sections and bundles shall be lifted and carried with the help of slings and tackles and shall not be carried on the shoulders of the workmen.

4.14 Aluminium Sections

a) *Storage and Stacking* — Aluminium sections of different classification, sizes and lengths shall be stored separately, on a level platform under cover.

b) *Handling* — The aluminium sections shall not be pulled or pushed from the stack nor shall be slided over each other, to protect the anodizing layer.

4.15 Doors, Windows and Ventilators

a) *Storage and Stacking* — Metal and plastic doors, windows and ventilators shall be stacked upright (on their sills) on level ground preferably on wooden battens and shall not come in contact with dirt or ashes. If received in crates they shall be stacked according to manufacturer's instructions and removed from the crates as and when required for the work.

Metal and plastic frames of doors, windows and ventilators shall be stacked upside down with the kick plates at the top. These shall not be allowed to stand for long in this manner before being fixed so as to avoid the door frames getting out of shape and hinges being strained and shutters drooping.

During the period of storage of aluminium doors, windows and ventilators, these shall be protected form loose cement and mortar by suitable covering, such as tarpaulin. The tarpaulin shall be hung loosely on temporary framing to permit circulation of air to prevent moisture condensation.

All timber and other lignocellulosic material based frames and shutters shall be stored in a dry and clean covered space away from any infestation and dampness. The storage shall preferably be in well-ventilated dry rooms. The frames shall be stacked one over the other distances to keep the stack vertical and straight. These cross battens should be of uniform thickness and placed vertically one above the other. The door shutters shall be stacked in the form of clean vertical stacks one over the other and at least 80 mm above ground on pallets or suitable beams or rafters. The top of the stack shall be covered by a protecting cover and weighted down by means of scantlings or other suitable weights. The shutter stack shall rest on hard and level surface.

If any timber or other lignocellulosic material based frame or shutter becomes wet during transit, it shall be kept separate from the undamaged material. The wet material may be dried by stacking in shade with battens in between adjacent boards with free access of dry air. Separate stacks shall be built up for each size, each grade an each type of material. When materials of different sizes, grades and types are to be stacked in one stack due to shortage of space, the bigger size shall be stacked in the lower portion of the stacks. Suitable pallets or separating battens shall be kept in between the two types of material.

Precast concrete door and window frames shall be stored in upright position adopting suitable measures against risk of subsidence of soil/support.

b) *Handling* — While unloading, shifting, handling and stacking timber or other lignocellulosic material based, metal and plastic door and window frames and shutters, care shall be taken that the pieces are not dragged one over the other as it may cause damage to their surface particularly in case of the decorative shutters. The pieces should be lifted and carried preferably flat avoiding damage to corners or sides.

4.16 Roofing Materials

4.16.1 Roofing sheets shall be stored and stacked in such a manner as not to damage them in any way. Damaged sheets shall not be stacked with sound materials. All damaged sheets shall be salvaged as early as possible.

4.16.2 *Asbestos Cement Sheet*

a) *Storage and stackings* — Asbestos cement sheets shall be stacked to a height of not more than one metre on firm and level ground, with timber or other packing beneath them. If stacked in exposed position, they shall be protected from damage by the winds.

b) *Handling* — Not more than two sheets shall

preferably carried by two workmen. Asbestos cement sheets shall be lowered or raised gently and not thrown.

4.16.3 *CGI Sheets*

a) *Storage and stacking* — CGI sheets shall be stacked in not more than 100 bundles per stack built solidly, each bundle consisting of 10 sheets. Bundles shall be so laid that the corrugations run in the same directions in every course. One end of the stack shall be raised by 100 mm to 150 mm to allow water flowing freely. If the sheets are not to be used immediately, these shall be stacked under roof cover.

b) *Handling* — In bulk handling of CGI sheets, workmen shall be provided with suitable hand protection.

4.17 Boards

4.17.1 *Gypsum Boards*

a) *Storage and stacking* — Gypsum boards shall be stored flat in a covered clean and dry place.

b) *Handling* — *See* **4.11.2**(b).

4.17.2 *Plywood, Fibre Board, Particle Board, Block Board, etc*

a) *Storage and Stacking* — Plywood, fibre board, particle board, block board, etc, shall not be stored in the open and exposed to direct sun and rain. The boards shall be stacked on a flat dunnage, on the top of which a wooden frame shall be constructed with battens of 50 mm × 25 mm (*Min*) in such a way that it supports all four edges and corners of the boards with intermediate battens placed at suitable intervals to avoid warping. If required, the stack shall be adequately raised above ground level to ensure that it will not be affected by accumulation of water under it.

The board shall be stacked in a solid block in a clear vertical alignment. The top sheet of each stack shall be suitably weighed down to prevent warping, wherever necessary.

b) *Handling* — The board shall be unloaded and stacked with utmost care avoiding damage to the corners and surface. In case of decorative plywood and decorative boards, the surfaces of which are likely to get damaged by dragging one sheet over another, it is advisable that these are lifted as far as possible in pairs facing each other.

sheets have tendency to break-down during storage. Plastic and rubber sheets shall be stored according to manufacturer's instructions.

The coolest store room available shall be utilized for the storage of the sheets. The store rooms where the sheets are stored shall be well ventilated and direct light should not be allowed to fall on them.

The sheets shall be stored away from electric generators, electric motors, switchgears and other such electrical equipment as they produce harmful gases as they produce harmful order in their vicinity.

Contamination of the sheets with vegetable and mineral oils; greases; organic solvents; acids and their fumes; alkalies; dust and grit shall be prevented. Where greasy contamination occurs this shall be removed immediately with petrol and the sheets and tiles thoroughly wiped dry and dusted with chalk chalk.

Undue stretch and strain, kinks, sharp bends or folds of the sheets and tiles shall be avoided. In case of long storage, the sheets shall be turned over periodically and treated with chalk powder, if necessary.

b) *Handling* — While handling plastic and rubber sheets, workmen shall lift the sheets and carry them flat to avoid sharp bends or folds of the sheets.

4.19 Glass Sheets

a) *Storage and Stacking* — It is important that all glass sheets whether stored in crates or not shall be kept dry. Suitable covered storage space shall be provided for the safe storage of the glass sheets. The glass sheets shall be lifted and stored on their long edges and shall be put into stacks of not more than 25 panes, supported at two points by fillets of wood at about 300 mm from each end. The first pane laid in each stack shall be so placed that its bottom edge is about 25 mm from the base of the wall or other support against which the stack rests. The whole stack shall be as close and as upright as possible. To prevent slipping on smooth floor, the floor shall be covered with gunny bags. The glass sheets of different sizes, thickness and type shall be stacked separately. The distance between any two stacks shall be of the order of 400 mm.

b) *Handling* — Workmen handling glass panes, waste glass pieces and fibre glass shall be provided with suitable hand protection. In removing glass sheets from crates, due care shall be taken to avoid damages. Glass edges shall be covered or otherwise protected to prevent injuries to workmen.

4.20 Cast Iron, Galvanized Iron and Asbestos Cement Pipes and Fittings

a) *Storage and Stacking* — The pipes shall be unloaded where they are required, when the trenches are ready to receive them.

Storage shall be provided at the bottom layer to keep the stack stable. The stack shall be in pyramid shape or the pipes placed length-wise and cross-wise in alternate layers. The pyramid stack is advisable in smaller diameter pipes for conserving space in storing them. The height of the stack shall not exceed 1.5 m. Each stack shall contain only pipes of the same class and size.

Each stack shall contain only pipes of same class and size, with consignment or batch number marked on it with particulars or suppliers wherever possible.

Cast iron detachable joints and fittings shall be stacked under cover and separated from the asbestos cement pipes and fittings.

Rubber rings shall be kept clean, away from grease, oil, heat and light.

b) *Handling* — Pipes in the top layer shall be handled first. At a time only one pipe shall be handled by two labourers while conveying to the actual site and shall be carried on shoulders. Fittings shall be handled individually.

4.21 Polyethylene Pipes

a) *Storage and Stacking* — Black polyethylene pipes may be stored either under cover or in the open. Natural polyethylene pipes, however, should be stored under cover and protected from direct sunlight.

Coils may be stored either on edge or stacked flat one on top of the other, but in either case they should not be allowed to come into contact with hot water or steam pipes and should be kept away from hot surface.

Straight lengths should be stored on horizontal racks giving continuous support to prevent the pipe taking on a permanent set.

Storage of pipes in heated areas exceeding 27°C should be avoided.

b) *Handling* — Removal of pipe from a pile shall be accomplished by working from the ends of the pipe.

4.22 Unplasticized PVC Pipes

a) *Storage and Stacking* — Pipes should be stored on a reasonably flat surface free from stones and sharp projections so that the pipe is supported throughout its length. The pipe should be given adequate support at all times. In storage, pipe racks should be avoided. Pipe should not be stacked in large piles especially under warm temperature conditions as the bottom pipes may distort thus giving rise to difficulty in jointing. Socket and spigot pipes should be stacked in layers with sockets placed at alternate ends or the stacks to avoid lopsided stacks.

It is recommended not to store a pipe inside another pipe. On no account should pipes be stored in a stressed or bend condition or near a source of heat. Pipes should not be stacked more than 1.5 m high. Pipes of different sizes and classes should be stacked separately.

In tropical conditions, pipes should be stored in shade. In very cold weather, the impact strength of PVC is reduced making it brittle.

The ends of pipe should be protected from abrasion particularly those specially prepared for jointing either spigot or socket solvent welded joints or soldered for use with couplings.

If due to unsatisfactory storage or handling a pipe become brittle in very cold weather.

b) *Handling* — Great care shall be exercised in handling these pipes in wintry conditions as these come brittle in very cold weather.

4.23 Pipes of Conducting Materials

a) *Storage and Stacking* — Pipes shall be stacked on solid level sills and contained in a manner to prevent spreading or rolling of the pipe. Where quantity storage is necessary, suitable packing shall be placed between succeeding layers to reduce the pressure and resulting spreading of the pile.

In stacking and handling of pipes and other conducting materials, the following minimum safety distances shall be ensured from the overhead power lines:

11 kV and below	1.40 m
Above 11 and below 33 kV	3.60 m
Above 33 and below 132 kV	4.70 m
Above 132 and below 275 kV	5.70 m
Above 275 and below 400 kV	6.50 m

b) *Handling* — Removal of pipes from a pile shall be accomplished by working from the ends of the pipe. During transportation, the pipes shall be so secured as to insure against displacement.

4.24 Piles and Poles

a) *Storage and Stacking* — Piles and poles shall be carefully stacked on solid, level sills so as to prevent rolling or spreading of the pile.

The storage area shall be maintained free of vegetation and flammable materials.

b) *Handling* — When placing piles or poles on the stack, workmen shall work from the ends of the piles/poles. Similar precautions shall be observed in removal of piles/poles from the stack. Tag lines shall be used to control piles and poles when handling for any purpose.

In stacking and handling of piles and poles, precautions as laid down in **4.18**(a) shall be followed.

4.25 Paints, Varnishes and Thinners

a) *Storage and Stacking* — Paints, varnishes, lacquers, thinners and other flammable materials shall be kept in properly sealed or closed containers. The containers shall be kept in a well ventilated location, free from excessive heat, smoke, sparks or flame. The floor of the paint stores shall be made up of 100 mm thick loose sand.

Paint materials in quantities other than required for daily use shall be kept stocked under regular storage place.

Where the paint is likely to deteriorate with age, the manner of storage shall facilitate removal and use of lots in the same order in which they are received.

Temporary electrical wirings/fittings shall not be installed in the paint store. When electric lights, switches or electrical equipment are necessary, they shall be of explosion proof design.

b) *Handling* — Ventilation adequate to prevent the accumulation of flammable vapours to hazardous levels of concentration shall be provided in all areas where painting is done.

When painting is done is confined spaces where flammable or explosive vapours may develop, any necessary heat shall be provided through duct work remote from the source of flame.

Sources of ignition, such as open flame and exposed heating elements, shall not be permitted in area or rooms where spray painting is done nor shall smoking be allowed there.

Care should be taken not to use any naked flame inside the paint store. Buckets containing sand shall be kept ready for use in case of fire. Fire extinguishers when required shall be of foam type conforming to accepted standards [7(4)].

Each workman handling lead based paints shall be issued ½ litre milk per day for his personal consumption.

4.26 Bitumen, Road Tar, Asphalt, Etc

a) *Storage and Stacking* — Drums or containers containing all types of bitumen, road tar, asphalt, etc, shall be stacked vertically on their bottoms in up to three tiers. Leaky drums shall be segregated. Empty drums shall be stored in pyra midal stacks neatly in rows.

b) *Handling* — *See* **19.3.1.2** and **19.3.4**.

4.27 Bituminous Roofing Felts

a) *Storage and Stacking* — Bituminous roofing felts shall be stored away from other combustible materials and shall be kept under shade.

b) *Handling* — Bituminous roofing felts should be handled in a manner to prevent cracking and other damages.

4.28 Flammable Materials

a) *Storage and Stacking* — In addition to the requirements as laid down in **3.4**, the following provisions shall also apply:

1) Outdoor storage of drums requires some care to avoid contamination because moisture and dirt in hydraulic brake and transmission fluid, gasoline, or lubricants may cause malfunction or failure of equipment, with possible danger to personnel. The storage area should be free of accumulations of spilled products, debris and other hazards.

2) Compressed gases and petroleum products shall not be stored in the same building or close to each other. Storage of petroleum products should be as per Petroleum Rules.

b) *Handling* — Petroleum products delivered to the job site and stored there in drums shall be protected during handling to prevent loss of identification through damage to drum

markings, tags, etc. Unidentifiable petroleum products may result in improper use, with possible fire hazard, damage to equipment or operating failure.

Workmen shall be required to guard carefully against any part of their clothing becoming contaminated with flammable fluids. They shall not be allowed to continue work when their clothing becomes so contaminated.

4.29 Water

Water to be stored for construction purposes shall be stored in proper tanks to prevent any organic impurities. The aggregate capacity of storage tanks shall be determined after taking into account the requirements of fire fighting.

4.30 Sanitary Appliances

a) *Storage and Stacking* — All sanitary appliances shall be carefully stored under cover to prevent damage. When accepting and storing appliances, consideration shall be given to the sequence of removal from the store to the assembly positions. Vitreous fittings shall be stacked separately from the metal ones.

b) *Handling* — Bigger sanitary appliances shall be handled one at a time. Traps, water seals and gullies shall be handled separately. While handling sanitary fittings they shall be free from any oil spillings, etc. The hands of the workers shall also be free from any oily substance. Before lowering the appliances in their position the supporting brackets, pedestals, etc, shall be checked for their soundness and then only the fixtures be attached.

4.31 Other Materials

Polymeric materials such as coatings, sheetings, reflective surfacings/sheetings, etc shall be stored as per the manufacturers' instructions. Special precautions shall be taken in case of storage, handling and usage of toxic materials.

Small articles like screws, bolts, nuts, door and window fittings, polishing stones, protective clothing, spare parts of machinery, linings, packings, water supply and sanitary fittings, and electrical fittings, insulation board, etc, shall be kept in suitable and properly protected containers or store rooms. Valuable small materials shall be kept under lock and key.

4.32 Special Considerations

4.32.1 Materials constantly in use shall be relatively nearer the place of use.

4.32.2 Heavy units like precast concrete members shall be stacked near the hoist or the ramp.

4.32.3 Materials which normally deteriorate during storage shall be kept constantly moving, by replacing old materials with fresh stocks. Freshly arrived materials shall never be placed over materials which had arrived earlier.

4.32.4 Appropriate types of fire extinguishers shall be provided at open sites where combustible materials are stored and for each storage shed/room where flammable/combustible materials are stored. For guidance regarding selection of the appropriate types of fire extinguishers reference may be made to good practice [7(4)]. It is desirable that a minimum of two extinguishers are provided at each such location.

4.32.5 Workers handling excavated earth from foundation, particularly if the site happens to be reclaimed area or marshy area or any other infected area, shall be protected against infection affecting their exposed body portions.

4.32.6 *House Keeping*

Stairways, walkways, scaffolds, and accessways shall be kept free of materials, debris and obstructions. The engineer-in-charge/the foreman shall initiate and carry out a programme requiring routine removal of scrap and debris from scaffolds and walkways.

4.32.7 Where stacking of the materials is to be done on road side berms in the street and other public place, the owner shall seek permission from the Authority for such stacking and also for removing the remnants of the same after the construction is over, so as to avoid any hazard to the public.

5 UNLOADING RAIL/ROAD WAGONS AND MOTOR VEHICLES

5.1 Loading and Unloading Rail/Road Wagons

5.1.1 Appropriate warning signals shall be displayed to indicate that the wagons shall not be coupled or moved.

5.1.2 The wheels of wagons shall always be sprigged or chained while the wagons are being unloaded. The brakes alone shall not be depended upon.

5.1.3 Special level bars shall preferably be used for moving rail wagons rather than ordinary crow bars.

5.1.4 Where gangplanks are used between wagons and platforms of piles (heaps), cleats at lower end of gangplank, or pin through end of gangplanks, shall be used to prevent sliding. If gangplank is on a gradient, cleats or abrasive surface shall be provided for the entire length.

5.1.5 When rail/road wagons are being loaded or unloaded near passageways or walkways, adequate warning signals shall be placed on each end of the wagon to warn pedestrians.

5.2 Loading and Unloading from Motor Vehicles

5.2.1 The motor vehicles shall be properly blocked while being loaded or unloaded; brakes alone shall not be depended upon to hold them.

5.2.2 When motor vehicles are being loaded or unloaded near passageways or walkways, adequate warning signs shall be placed on each end of the vehicle to warn the pedestrians.

5.3 Handling Heavy/Long Items

5.3.1 Loading and unloading of heavy items, shall, as far as possible, be done with cranes or gantries. The workman shall stand clear of the material being moved by mechanical equipment. The slings and the ropes used shall be of adequate load carrying capacity, so as not to give way and result in accidents.

5.3.2 While heavy and long components are being manually loaded into motor vehicle, wagons, trailer, etc, either wooden sleepers or steel rails of sufficient length and properly secured in position shall be put in a gentle slope against the body of the wagon/vehicle at 3 or 4 places for loading. These long items shall be dragged, one by one, gently and uniformly along these supports by means of ropes, being pulled by men with feet properly anchored against firm surface. As soon as the items come on the floor of the vehicle, the same may be shifted by crowbars and other suitable leverage mechanism, but not by hands to avoid causing accident to the workmen.

5.3.3 Similar procedure as outlined in **5.3.2** shall be followed for manual unloading of long or heavy items.

SECTION 3 SAFETY IN CONSTRUCTION OF ELEMENTS OF A BUILDING

6 GENERAL

6.1 The provisions of this Section shall apply to the erection/alterational of the various parts of a building or similar structure. The construction of the different elements shall conform to **2.3.2**.

6.2 Other Laws

Nothing herein stated shall be construed to nullify any rules, regulations, safety standards or statutes of the local state governments or those contained in the various Acts of the Government of India. The specific Rules, Regulations and Acts pertaining to the protection of the public or workmen from health and other hazards wherever specified by the Local/State Authority or in the Acts of the Government take precedence over whatever is herein specified in case of a doubt or dispute.

6.3 Safety Management

6.3.1 The safety of personnel engaged in building construction should be ensured through a well planned and well organized mechanism. For this, depending on the size and complexity of building construction project, safety committee shall be constituted to efficiently manage all safety related affairs. The site in-charge or his nominee of a senior rank shall head the committee and a safety officer shall act as member-secretary. The meetings of the safety committee shall be organized regularly say fortnightly or monthly depending on the nature of the project, however, emergency meetings shall be called as and when required. The safety committees shall deal with all the safety related issues through well structured agenda, in the meetings and all safety related measures installed at the site and implementation thereof shall be periodically reviewed.

6.3.2 Notwithstanding the guidelines given in **6.3.1**, all provisions given in relevant Act/Rules/Regulations as amended from time to time shall be followed; in this regard, reference shall also be made to the *Building and Other Construction Workers Act*, 1996 and the Rules/Regulations framed thereunder.

7 TERMINOLOGY

7.1 For the purpose of this Part the following definitions shall apply.

7.2 Authority Having Jurisdiction — The Authority which has been created by a statute and which for the purpose of administering the Code/Part, may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

7.3 Construction Equipment — All equipment, machinery, tools and temporary retaining structures and working platforms, that is, tools, derricks, staging, scaffolds, runways, ladders and all material, handling equipment including safety devices.

7.4 Floor Hole — An opening measuring less than 300 mm but more than 25mm in its least dimension, in any floor, platform, pavement, or yard, through which materials but not persons may fall; such as, a belt hole, pipe opening or slot opening.

7.5 Floor Opening — An opening measuring 300 mm or more in its least dimension, in any floor, platform, pavement or yard through which person may fall; such as hatch way, stair or ladder opening, pit or large manhole.

7.6 Guard Railing — A barrier erected along exposed edges of an open side floor opening, wall opening, ramp, platform, or catwalk or balcony, etc, to prevent fall of persons.

7.7 Materials Handing Hoists — A platform, bucket or similar enclosure exclusively meant for the lifting or lowering of construction material the hoists being operated from a point outside the conveyance.

7.8 Pile Rig — The complete pile driving equipment comprising piling frame, leader, hammer, extractor winch and power unit. Complete pile driving rig may be mounted on rafts or pontoon or rails. Pile rig may also be a mobile unit mounted on trailers or trucks, or a special full revolving rig for raking piles.

7.9 Platform A working space for persons, elevated above the surrounding floor or ground, such as balcony or platform for the operation of machinery and equipment.

7.10 Scaffold — A temporary erection of timber or metal work used in the construction, alteration or demolition of a building, to support or to allow the hoisting and lowering of workmen, their tools and materials.

7.11 Toe Board — A vertical barrier erected along exposed edge of a floor opening, wall opening, platform, catwalk or ramp to prevent fall of materials or persons.

7.12 Wall Hole — An opening in any wall or partition having height of less than 750 mm but more than 25 mm and width unrestricted.

7.13 Wall Opening — An opening in any wall or partition having both height of at least 750 mm and width of at least 450 mm.

8 TEMPORARY CONSTRUCTION, USE OF SIDE WALLS AND TEMPORARY ENCROACHMENTS

8.1 Temporary Construction

The plans and specifications of temporary constructions, which are likely to interfere with facilities or right of way provided by the Authority, shall be submitted to the Authority for approval showing clearly the layout, design and construction.

8.1.1 Temporary structure referred in **8.1** shall apply to the following types of structures:

a) Structures with roof or walls made of straw, hay, ulugrass, golpatta, hogle, darma, mat, canvas cloth or other like materials not adopted for permanent or continuous occupancy.

b) Site-work sheds, truck-runways, trestles, foot-bridges, etc.

8.2 For detailed information regarding fire safety aspects in respect of construction, location, maintenance and use of temporary structures [mentioned in **8.1.1**(a)] including *PANDALS* used by public for outdoor assembly, reference may be made to good practice [7(5)].

8.3 Special permits shall be obtained for the storage of the materials on side walks and highways. It shall be ensured that the material dump or the storage shed does not create a traffic hazard, nor it shall interfere with the free flow of the pedestrian traffic. Special permits shall also be obtained for the use of water and electricity from the public facilities. Whenever such utilities are made use of, adequate safety precautions regarding drainage and elimination of contamination and hazards from electricity shall be taken.

8.4 In order to ensure safety for the adjoining property, adequate temporary protective guards are to be provided. In case these protective devices project beyond the property, the consent of the Authority and that of the owner of the adjoining property shall be obtained.

9 TESTING

9.1 Tests

No structure, temporary support, scaffolding or any construction equipment during the construction or demolition of any building or structure shall be loaded beyond the allowable loads and working stresses as provided for in Part 6 'Structural Design' {*see also* good practice [7(6)]}.

9.1.1 Whenever any doubt arises about the structural adequacy of a scaffolding, support or any other construction equipment, it shall be tested to two and a half times the superimposed dead and imposed loads to which the material or the equipment is subjected to and the member/material shall sustain the test load without failure if it is to be accepted.

9.2 Notwithstanding the test mentioned above, if any distress in any member is visible, the member shall be rejected.

10 INSPECTION AND RECTIFICATION OF HAZARDOUS DEFECTS

10.1 Inspection

The Authority shall inspect the construction equipment and if during the inspection, it is revealed that unsafe/ illegal conditions exist, the Authority shall intimate

the owner and direct him to take immediate remedial measures to remove the hazard/violation.

10.2 Rectification

The owner shall proceed to rectify the defect, hazardous condition or violation within 24 h of the receipt of the notice from the Authority. The Authority shall have full powers to rectify the unsafe condition and all expenses incurred in this connection is payable by the owner of the property. Illegal encroachments and non-payment of money due, in respect of the rectification of unsafe conditions may vest a lien on the property with the Authority (*see also* Part 2 'Administration').

10.3 When the strength and adequacy of any scaffold or other construction equipment is in doubt or when any complaint is made, the Authority shall get the same inspected before use.

11 FOUNDATIONS

11.1 General

The distribution of the supporting foundation shall be such as to avoid any harmful differential settlement of the structure. The type and design of the foundation adopted shall ensure safety to workmen during construction and residents of the neighbouring property. Sufficient care shall be taken in areas, where withdrawal of ground water from surrounding areas could result in damages to such foundations. During the construction of the foundation, it shall be ensured that the adjoining properties are not affected by any harmful effects.

11.2 Adjoining Properties

The person causing excavation shall, before starting the work, give adequate notices in writing to the owner of the adjoining properties, safety of which is likely to be affected due to excavation. After having given such notices, wherein details regarding the type of protective works that are anticipated to be incorporated in the excavation are shown, written permission shall be obtained for such excavation from the adjoining property owners. Where necessary, the person causing excavation shall make adequate provision to protect the safety of adjacent property. If on giving such notices and the precautionary measures having been approved by the Authority, the adjoining property owner still refuses to give necessary facilities to the person causing excavation for protecting/providing both temporary and permanent supports to such property, the responsibility for any damage to the adjoining property shall be that of the adjoining property owner. The person causing excavation shall be absolved of responsibility for any loss of property or life in the adjoining property.

In driven piles vibration is set up which may cause damage to adjoining structures or service lines depending on the nature of soil condition and the construction standard of such structures and service lines. Possible extent of all such damages shall be ascertained in advance, and operation and mode of driving shall be planned with appropriate measures to ensure safety.

Where in the vicinity of a site where bored or driven piling works are to be carried out there are old structures which are likely to be damaged, tell-tales shall be fixed on such structures to watch their behaviour and timely precautions taken against any undesirable effect.

11.3 During construction, inspection shall be made by the engineer-in-charge to ensure that all protective works carried out to safe-guard the adjoining property are sufficient and in good order to ensure safety (*see* Part 2 'Administration').

11.4 Before carrying out any excavation work/pile driving, the position, depth and size of underground structures, such as water pipes, mains, cables or other services in the vicinity to the proposed work, may be obtained from the Authority to prevent accidents to workmen engaged in excavation work and calamities for the general public.

Prior to commencement of excavation detailed data of the type of soils that are likely to be met with during excavation shall be obtained and the type of protective works by way of shoring timbering, etc, shall be decided upon for the various strata that are likely to be encountered during excavation. For detailed information regarding safety requirements during excavation reference may be made to good practice [7(7)].

12 GENERAL REQUIREMENTS AND COMMON HAZARDS DURING EXCAVATION

12.1 Location of Machinery and Tools

Excavating machinery consisting of both heavy and light types shall be kept back from the excavation site at a distance which would be safe for such type of equipment. Heavy equipment, such as excavating machinery and road traffic shall be kept back from the excavated sites at a distance of not less than the depth of trench or at least 6 m for trench deeper than 6 m. Care shall also be taken to keep excavating tools and materials far away from the edge of trench to prevent such items being inadvertently knocked into the trench.

12.2 Excavated Materials

Excavated materials shall be kept back from the edges of the trench to provide clear berm of safe width. Where this is not feasible, the protective works designed for the trenches shall take into consideration, the additional load due to overburden of materials.

12.2.1 *Other Surcharges*

Proximity of buildings, piles of lumber, crushed rocks, sand and other constructional materials, large trees, etc, may impose surcharges on the side of the trench to cause sliding, etc. Under these conditions additional protective works shall be provided to support the sides of the trench.

12.3 Type of Strata

Adequate precautions, depending upon the type of strata met with during excavation (like quick sand, loose fills and loose boulder) shall be taken to protect the workmen during excavation. Effect of climatic variations and moisture content variations on the materials under excavation shall be constantly watched and precautions taken, where necessary, immediately to prevent accidents at work site.

12.4 Overhang and Slopes

During any excavation, sufficient slopes to excavated sides by way of provision of steps or gradual slopes shall be provided to ensure the safety of men and machine working in the area.

12.5 Blasting for foundation of building is prohibited unless special permission is obtained from the Authority. Where blasting technique has to be resorted to, prior inspection for the stability of slopes shall be carried out. After blasting, overhangs or loose boulders shall be cleared by expert workers carrying out blasting prior to continuation of the excavation by normal working parties.

12.5.1 Burrowing or mining or what is known as 'gophering' shall not be allowed. In any trench where such methods have been followed, the cavities felt shall be eliminated by cutting back the bare slope before removing any further material from the section of the trench.

12.6 Health Hazards

Where gases or fumes are likely to be present in trenches, sufficient mechanical ventilation, to protect the health and safety of persons working there, shall be provided. If necessary, the personnel working there, shall be provided with respiratory protective equipment when work in such unhealthy conditions has to be carried out. The precautionary measures provided shall be inspected by the local health authorities prior to commencement of the work.

12.7 Safety of Materials

Materials required for excavation, like ropes, planks for gangways and walkways, ladders, etc, shall be inspected by the engineer-in-charge who shall ensure that no accident shall occur due to the failure of such materials (*see* Part 5 'Building Materials').

12.8 Fencing and Warning Signals

Where excavation is going on, for the safety of public and the workmen, fencing shall be erected, if there is likelihood of the public including cattle frequenting the area. Sufficient number of notice boards and danger sign lights shall be provided in the area to avoid any member of public from inadvertently falling into the excavation. When excavations are being done on roads, diversion of the roads shall be provided with adequate notice board and lights indicating the diversion well ahead. Where necessary, recourse may be had for additional precautionary measures by way of watchmen to prevent accident to the general public, especially during hours of darkness.

12.9 Effect of Freezing and Thawing

Due to expansion of water when freezing, rock fragments, boulders, etc, are frequently loosened. Therefore, the side walls of the excavation shall be constantly watched for signs of cracks during a thaw. When depending in whole or in part on freezing to support the side walls, great care shall be taken during thaws to provide suitable bracing or remedy the condition by scaling of the loose material from the sides.

12.10 Vibrations from Nearby Sources

Vibration due to adjacent machinery, vehicles, railroads, blasting, piling and other sources require additional precautions to be taken.

12.11 Precautions While Using Petroleum Powered Equipment

At the site of excavation, where petroleum powered equipment is used, petroleum vapours are likely to accumulate at lower levels and may cause fire explosion under favourable circumstances. Care should, therefore, be taken to avoid all sources of ignition in such places.

13 PILING AND OTHER DEEP FOUNDATIONS

13.1 General

13.1.1 *Safety Programme*

All operations shall be carried out under the immediate charge of a properly qualified and competent foreman

13.1.2 For work during night, lighting of at least 100 lux intensity shall be provided at the work site.

13.1.3 Every crane driver or hoisting appliance operator shall be competent to the satisfaction of the engineer-in-charge and no person under the age of 21 years should be in-charge of any hoisting machine including any scaffolding winch, or give signals to operator.

13.1.4 Working in compressed air, in case of deep foundations, requires several precautions to be observed to safeguard the workmen against severe hazards to life, compressed air disease and related ailments. For detailed information regarding safety requirements, reference may be made to good practice [7(8)].

13.2 *Piling Rig*

13.2.1 Pile drivers shall not be erected in dangerous proximity to electric conductors. If two pile drivers are erected at one place these shall be separated by a distance at least equal to the longest leg in either rig.

13.2.2 The frame of any rig shall be structurally safe for all anticipated dead, live or wind loads. Whenever there is any doubt about the structural strength, suitable test shall be carried out by the foreman and the results of the test recorded. No pile driving equipment shall be taken into use until it has been inspected and found to be safe.

13.2.3 Pile drivers shall be firmly supported on heavy timber sills, concrete beds or other secure foundation. If necessary, to prevent danger, pile drivers shall be adequately guyed.

When the rig is not in use, extra precautionary measures for stability, such as securing them with minimum four guys, shall be adopted to prevent any accidents due to wind, storm, gales and earthquake.

13.2.4 Access to working platforms and the top pulley shall be provided by ladders. Working platforms shall be protected against the weather.

13.2.4.1 In tall driven piling rigs or rigs of similar nature where a ladder is necessary for regular use, the ladder shall be securely fastened and extended for the full height of the rig.

13.2.5 Exposed gears, fly wheels, etc, shall be fully enclosed.

13.2.6 Pile driving equipment in use shall be inspected by a competent engineer at regular intervals not exceeding three months. A register shall be maintained at the site of work for recording the results of such any excess wear or any other defect.

13.2.6.1 Defective parts of pile drivers, such as sheaves, mechanism slings and hose shall be repaired by only competent person and duly inspected by foreman-in-charge of the rig and the results recorded in the register. No steam or air equipment shall be repaired while it is in operation or under pressure. Hoisting ropes on pile drivers shall be made of galvanized steel.

13.2.7 Steam and air lines shall be controlled by easily accessible shut-off valves. These lines shall consist of armoured hose or its equivalent. The hose of steam and air hammers shall be securely lashed to the hammer so as to prevent it from whipping if a connection breaks. Couplings of sections of hose shall be additionally secured by ropes or chains.

13.2.8 When not in use the hammer shall be in dropped position and shall be held in place by a cleat, timber or any other suitable means.

13.2.9 For every hoisting machine and for every chain rig hook, shackle, swivel and pulley block used in hoisting or as means of suspension, the safe working loads shall be ascertained. In case of doubt, actual testing shall be carried out and the working load shall be taken as half of the tested load. Every hoisting machine and all gears referred to above shall be plainly marked with the safe working load. In case of a hoisting machine having a variable safe working load, each safe working load together with the conditions under which it is applicable shall be clearly indicated. No part of any machine or any gear shall be loaded beyond the safe working load except for the purpose of testing.

13.2.10 Motor gearing, transmission, electrical wiring and other dangerous parts of hoisting appliances should be provided with efficient safe guards. Hoisting appliances shall be provided with such means as will reduce, to the minimum, the risk of accidental descent of the load and adequate precautions shall be taken to reduce to the minimum, the risk of any part of suspended load becoming accidentally displaced. When workers are employed on electrical installations which are already energized, insulating mats and wearing apparel, such as gloves, etc, as may be necessary, shall be provided. Sheaves on pile drivers shall be guarded so that workers may not be drawn into them.

13.2.10.1 When loads have to be inclined:

a) they shall be adequately counter-balanced, and

b) the tilting device shall be secured against slipping.

13.2.11 Adequate precautions shall be taken to prevent a pile driver from overturning if a wheel breaks.

13.2.12 Adequate precautions shall be taken by providing stirrups or by other effective means, to prevent the rope from coming out of the top pulley or wheel.

13.2.13 Adequate precautions shall be taken to prevent the hammer from missing the pile.

13.2.14 If necessary, to prevent danger, long piles and heavy sheet piling should be secured against falling.

13.2.15 Wherever steam boilers are used, the safety regulations of boilers shall be strictly followed and safety valves shall be adjusted to 7N/cm^2 in excess of working pressure accurately.

13.2.16 Where electricity is used as power for piling rig, only armoured cable conforming to the relevant Indian Standard shall be used.

13.2.17 All checks as given in the Indian Standards and any manuals issued by the manufacturers shall be carried out.

13.3 Operation of Equipment

13.3.1 Workers employed in the vicinity of pile drivers shall wear helmets conforming to accepted standards [7(9)].

13.3.2 Piles shall be prepared at a distance at least equal to twice the length of the longest pile from the pile driver.

13.3.3 Piles being hoisted in the rig should be so slung that they do not have to be swung round, and may not inadvertently, swing or whip round. A hand rope shall be fastened to a pile that is being hoisted to control its movement. While a pile is being guided into position in the leads, workers shall not put their hands or arms between the pile and the inside guide or on top of the pile, but shall use a rope for guiding.

13.3.4 Before a good pile is hoisted into position it shall be provided with an iron ring or cap over the driving end to prevent brooming. When creosoted wood piles are being driven, adequate precautions shall be taken, such as the provision of personal protective equipment and barrier creams, to prevent workers receiving eye or skin injuries from splashes of creosote.

13.3.5 When piles are driven at an inclination to the vertical, if necessary, to prevent danger, these should rest in a guide.

13.3.6 No steam or air shall be blown down until all workers are at a safe distance.

14 WALLS

14.1 General

Depending on the type of wall to be constructed the height of construction per day shall be restricted to ensure that the newly constructed wall does not come down due to lack of strength in the lower layers. Similarly, in long walls adequate expansion/crumple joints shall be provided to ensure safety.

14.2 Scaffold

Properly designed and constructed scaffolding built by competent workmen shall be provided during the construction of the walls to ensure the safety of workers. The scaffolding may be of timber, metal or bamboo sections and the materials in scaffolding shall be inspected for soundness, strength, etc, at site by the engineer-in-charge prior to erection of scaffolds. Steel scaffolds intended for use in normal building construction work shall conform to accepted standards [7(10)]. Bamboo and timber scaffolds shall be properly tied to the junctions with coir ropes of sufficient strength or mechanical joints to ensure that joints do not give way due to the load of workmen and material. Joining the members of scaffolds only with nails shall be prohibited as they are likely to get loose under normal weathering conditions. In the erection or maintenance of tall buildings, scaffoldings shall be of non-combustible material especially when the work is being done on any building in occupation. After initial construction of the scaffolding, frequent inspections of scaffolding. The platforms, gangways and runways provided on the scaffoldings shall be of sufficient strength and width to ensure safe passage for the workmen working on the scaffolding. The joints provided in these gangways, platforms, etc, shall be such as to ensure a firm foot-hold to the workmen. Where necessary, cross bars shall be provided to the full width of gangway or runway to facilitate safe walking. For detailed information regarding safety requirements for erection, use and dismantling of scaffolds, reference may be made to good practice [7(11)].

14.2.1 The engineer-in-charge shall ensure by frequent inspections that gangways of scaffolding have not become slippery due to spillage of material. Loose materials shall not be allowed to remain on the gangways. Where necessary, because of height or restricted width, hand-rails shall be provided on both sides. Workers shall not be allowed to work on the scaffolding during bad weather and high winds.

14.2.2 In the operations involved in the erection or maintenance of outside walls, fittings, etc, of tall buildings, it is desirable to use one or more net(s) for the safety of the workmen when the workmen are required to work on scaffoldings.

All ladders shall be constructed of sound materials and shall be capable of carrying their intended loads safely. The ladders shall have not only adequate strength but rigidity as well. If a ladder shows tendency to spring, a brace shall be attached to its middle and supported from some other non-yielding fixed object. No ladder having a missing or defective rung or one which depends for its support solely on nails, shall be used. Ladders shall not be used as guys, braces or skids or for any other purpose for which they are not intended. They shall not be used in horizontal position as runways. They shall not be overcrowded. Wherever possible, ladders shall not be spliced. Where splicing is unavoidable, it shall be done only under the supervision of engineer-in-charge. Ladders leading to landings or walkways shall extend at least one metre above the landing and shall be secured at the upper end. To prevent slipping, a ladder shall be secured at the bottom end. If this cannot be done, a person shall be stationed at the base whenever it is in use. As a further precautions, the pitch at which a lean-to-ladder is used shall be such that the horizontal distance of its foot from the vertical plane of its top shall be not more than one quarter of its length. If the surface of the floor on which the ladder rests is smooth or sloping, the ladder shall be provided with non-slip bases. If the use of a ladder is essential during strong winds, it shall be securely lashed in position. No ladder shall be placed or leant against window pane, sashes or such other unsafe or yielding objects, nor placed in front of doors opening towards it. If set up in driveways, passageways or public walkways, it shall be protected by suitable barricades. When ascending or descending, the user shall face the ladder, use both his hands and place his feet near the ends of the rungs rather than near the middle. It is dangerous to lean more than 30 cm to side in order to reach a larger area from a single setting of the ladder. Instead, the user shall get down and shift the ladder to the required position.

Metal ladders shall not be used around electrical equipment or circuits of any kind where there is a possibility of coming in contact with the current. Metal ladders shall be marked with signs reading 'CAUTION: DO NOT USE NEAR ELECTRICAL EQUIPMENT'.

Wooden ladders shall be inspected at least once in a month for damage and deterioration. Close visual inspection is recommended in preference to load testing. This condition is particularly applicable to rope and bamboo ladders wherein fraying of ropes and damage to bamboo is likely to occur due to materials falling on them. When a ladder has been accidentally dropped it shall be inspected by the engineer-in-charge prior to re-use. Overhead protection shall be provided reference may be made to good practice [7(12)].

14.4 Opening in Walls

Whenever making of an opening in the existing wall is contemplated, adequate supports against the collapse or cracking of the wall portion above or roof or adjoining walls shall be provided.

14.4.1 *Guarding of Wall Openings and Holes*

Wall opening barriers and screens shall be of such construction and mounting that they are capable of withstanding the intended loads safely. For detailed information reference may be made to good practice [7(13)]. Every wall opening from which there is a drop of more than 1 200 mm shall be guarded by one of the following:

a) *Rail, roller, picket fence, half door or equivalent barrier* — The guard may be removable but should preferably be hinged or otherwise mounted so as to be conveniently replaceable. Where there is danger to persons working or passing below on account of the falling materials, a removable toe board or the equivalent shall also be provided. When the opening is not in use for handling materials, the guards shall be kept in position regardless of a door on the opening. In addition, a grab handle shall be provided on each side of the opening. The opening should have a sill that projects above the floor level at least 25 mm.

b) Extension platform into which materials may be hoisted for handling, shall be of full length of the opening and shall have side rails or equivalent guards.

14.4.2 Every chute wall opening from which there is a drop of more than 1 200 mm shall be guarded by one or more of the barriers specified in **14.4.1** or as required by the conditions.

14.5 Projection from Walls

Whenever projections cantilever out of the walls, temporary formwork shall be provided for such projections and the same shall not be removed till walls over the projecting slabs providing stability load against overturning are completely constructed.

15 COMMON HAZARDS DURING WALLING

15.1 Lifting of Materials for Construction

Implements used for carrying materials to the top of scaffoldings shall be of adequate strength and shall not be overloaded during the work. Where workmen

have to work below scaffoldings or ladder, overhead protection against the falling materials shall be provided. Care shall be taken in carrying large bars, rods, etc, during construction of the walls to prevent any damage to property or injury to workmen.

15.2 Haulage of Materials

15.2.1 In case of precast columns, steel beams, etc, proper precautions shall be taken to correctly handle, use and position them with temporary arrangement of guys till grouting of the base.

15.2.2 Manila or sisal rope shall not be used in rainy season for hoisting of heavy materials as they lose their strength with alternate wetting and drying.

15.3 Electical Hazards

No scaffolding, ladder, working platform, gangway runs, etc, shall exist within 3 m from any uninsulated electric wire.

15.4 Fire Hazards

Gangways and the ground below the scaffolding shall be kept free from readily combustible materials including waste and dry vegetation at all times.

15.4.1 Where extensive use of blow torch or other flame is anticipated scaffoldings, gangways, etc, shall be constructed with fire resistant materials. A portable dry powder extinguisher of 3 kg capacity shall be kept handy.

15.5 Mechanical Hazards

Care shall be taken to see that no part of scaffolding or walls is struck by truck or heavy moving equipment and no materials shall be dumped against them to prevent any damage. When such scaffoldings are in or near a public thoroughfare, sufficient warning lights and boards shall be provided on the scaffoldings to make them clearly visible to the public.

15.6 Fragile Materials

During glazing operations, adequate precautions shall be taken to ensure that the fragments of fragile materials do not cause any injury to workmen or general public in that area by way of providing covering to such material, side protection at work site, etc.

16 ROOFING

16.1 Prevention of accidental falling of workmen during the construction of roofs shall be ensured by providing platforms, catch ropes, etc. If the materials are to be hoisted from the ground level to the roof level, adequate precautions shall be taken by way of correct technique of handling, hoists of sufficient strength to cater for the quantity of stores to be hoisted and prevention of overloading such hoists or buckets, prevention of overturning of hoists or buckets. Where in a multi-storeyed building, the floor of one storey is to be used for storage of materials for the construction of roofs, it shall be ensured that the quantum of stores kept on the floor along with the load due to personnel engaged in the construction work shall not exceed the rated capacity of the floors.

16.2 While roofing work is being done with corrugated galvanized iron or asbestos cement sheets, it shall be ensured that joints are kept secured in position and do not slip, thus causing injury to workmen. Workers should not be allowed to walk on asbestos cement sheets but should be provided with walking boards. While working with tiles, it shall be ensured that they are not kept loose on the roof site resulting in falling of tiles on workmen in lower area. In slopes of more than 30° to the horizontal, the workmen shall use ladders or other safety devices to work on the roof.

16.3 If any glass work is to be carried out in the roof, it shall be ensured that injury to passerby due to breaking of glass is prevented. During wet conditions, the workmen shall be allowed to proceed to work on a sloping roof, only if the engineer-in-charge has satisfied himself that the workmen are not likely to slip due to wet conditions.

16.4 Flat Roof

In any type of flat roof construction, any formwork provided shall be properly designed and executed to ensure that it does not collapse during construction. During actual construction of roof, frequent inspection of the formwork shall be carried out to ensure that no damage has occurred to it.

16.5 While using reinforcement in roofs, it shall be ensured that enough walking platforms are provided in the reinforcement area to ensure safe walking to the concreting area. Loose wires and unprotected rod ends shall be avoided.

16.6 Guarding of Floor Openings and Floor Holes

16.6.1 Every temporary floor opening shall have railings, or shall be constantly attended by someone. Every floor hole into which persons can accidentally fall shall be guarded by either:

a) a railing with toe board on all exposed sides, or

b) a floor hole cover the adequate strength and it should be hinged in place. When the cover is not in place, the floor hole shall be constantly attended by some one or shall be protected by a removable railing.

16.6.2 Every stairway floor opening shall be guarded by a railing on all exposed sides, except at entrance to stairway. Every ladder way floor opening or platform shall be guarded by a guard railing with toe board on all exposed sides (except at entrance to opening), with the passage through the railing either provided with a swinging gate or so offset that a person can not walk directly into the opening.

16.6.3 *Guarding of Open-Side Floors and Platform*

Every open-sided floor or platform 1 200 mm or more above adjacent floor or ground level shall be guarded by a railing (or the equivalent) or all open sides, except where there is entrance to ramp, stair-way, or fixed ladder. The railing shall be provided with a toe board beneath the open sides wherever:

a) persons may pass;
b) there is moving machinery; or
c) there is equipment with which falling materials could create a hazard.

For detailed information, reference may be made to good practice [7(13)].

17 ADDITIONAL SAFETY REQUIREMENTS FOR ERECTION OF CONCRETE FRAMED STRUCTURES (HIGH-RISE BUILDINGS)

17.1 Handling of Plant

17.1.1 *Mixers*

17.1.1.1 All gears, chains and rollers of mixers shall be properly guarded. If the mixer has a charging skip the operator shall ensure that the workmen are out of danger before the skip is lowered. Railings shall be provided on the ground to prevent anyone walking under the skip while it is being lowered.

17.1.1.2 All cables, clamps, hooks, wire ropes, gears and clutches, etc, of the mixer, shall be checked and cleaned, oiled and greased, and serviced once a week. A trial run of the mixer shall be made and defects shall be removed before operating a mixer.

17.1.1.3 When workmen are cleaning the inside of the drums, and operating power of the mixer shall be locked in the off position and all fuses shall be removed and a suitable notice hung at the place.

17.1.2 *Cranes*

17.1.2.1 Crane rails where used shall be installed on firm ground and shall be properly secured. In case of tower cranes, it shall be ensured that the level difference between the two rails remains within the limits prescribed by the manufacturer to safeguard against toppling of the crane.

17.1.2.2 Electrical wiring which can possibly touch the crane or any member being lifted shall be removed, or made dead by removing the controlling fuses and in their absence controlling switches.

17.1.2.3 All practical steps shall be taken to prevent the cranes being operated in dangerous proximity to a live overhead power line. In particular, no member of the crane shall be permitted to approach within the minimum safety distances as laid down in **4.23**(a).

If it becomes necessary to operate the cranes with clearances less than those specified above, it shall be ensured that the overhead power lines shall invariably be shut off during the period of operation of cranes. Location of any underground power cables in the area of operation shall also be ascertained and necessary safety precautions shall be taken.

17.1.2.4 Cranes shall not be used at a speed which causes the boom to swing.

17.1.2.5 A crane shall be thoroughly examined at least once in a period of 6 months by a competent person who shall record a certificate of the check.

17.1.2.6 The operator of the crane shall follow the safe reach of the crane as shown by the manufacturer.

17.1.2.7 No person shall be lifted or transported by the crane on its hook or boom.

17.1.2.8 Toe boards and limit stops should be provided for wheel barrows on the loading/unloading platforms. Material should be loaded securely with no projections.

17.1.2.9 Concrete buckets handled by crane or overhead cableway shall be suspended from deep throated hooks, preferably equipped with swivel and safety latch. In the concrete buckets, both bottom drop type and side drop type, closing and locking of the exit door of the bucket shall always be checked by the man-in-charge of loading concrete in the bucket to avoid accidental opening of the exit door and consequent falling of concrete.

17.1.2.10 Interlocking or other safety devices should be installed at all stopping points of the hoists. The hoists shaft way should be fenced properly.

17.1.2.11 When the bucket or other members being lifted are out of sight of the crane operator, a signalman shall be posted in clear view of the receiving area and the crane operator.

17.1.2.12 A standard code of hand signals shall be adopted in controlling the movements of the crane, and both the driver and the signaler shall be thoroughly familiar with the signals.

The driver of the crane shall respond to signals only from the appointed signaler but shall obey stop signal at any time no matter who gives it.

17.1.2.13 If a traveling gantry crane is operating over casting beds, a warning signal which sounds automatically during travel should be provided to avoid accidents to workmen crossing or standing in the path of the moving loads.

17.1.3 *Trucks*

When trucks are being used on the site, traffic problems shall be taken care of. A reasonably smooth traffic surface shall be provided. If practicable, a loop road shall be provided to permit continuous operation of vehicles and to eliminate their backing. If a continuous loop is not possible, a turnout shall be provided. Backing operations shall be controlled by a signalman positioned so as to have a clear view of the area behind the truck and to be clearly visible to the truck driver. Movement of workmen and plant shall be routed to avoid crossing, as much as possible, the truck lanes.

17.1.4 *Concrete Pumps (Air Compressor Operated)*

Safety requirements in accordance with good practice [7(14)] shall be followed.

17.2 Formwork

17.2.1 Formwork shall be designed after taking into consideration spans, setting temperature of concrete, dead load and working load to be supported and safety factor for the materials used for formwork {*see also* good practice [7(6)]}.

17.2.2 All timber formwork shall be carefully inspected before use and members having cracks and excessive knots shall be discarded.

17.2.3 As timber centering usually takes an initial set when vertical load is applied, the design of this centering shall make allowance for this factor.

17.2.4 The vertical supports shall be adequately braced or otherwise secured in position that these do not fall when the load gets released or the supports are accidently hit.

17.2.5 Tubular steel centering shall be used in accordance with the manufacturer's instructions. When tubular steel and timber centering is to be used in combination necessary precautions shall be taken to avoid any unequal settlement under load.

17.2.6 A thorough inspection of tubular steel centering is necessary before its erection and members showing evidence of excessive resting, kinks, dents or damaged welds shall be discarded. Buckled or broken members shall be replaced. Care shall also be taken that locking devices are in good working order and that coupling pins are effectively aligned to frames.

17.2.7 After assembling the basic unit, adjustment screws shall be set to their approximate final adjustment and the unit shall be level and plumb so that when additional frames are installed the tower shall be in level and plumb. The centering frames shall be tied together with sufficient braces to make a rigid and solid unit. It shall be ensured that struts and diagonals braces are in proper position and are secured so that frames develop full load carrying capacity. As erection progresses, all connecting devices shall be in place and shall be fastened for full stability of joints and units.

17.2.8 In case of timber posts, vertical joints shall be properly designed. The connections shall normally be with bolts and nuts. Use of rusted or spoiled threaded bolts and nuts shall be avoided.

17.2.9 Unless the timber centering is supported by a manufacturer's certificate about the loads it can stand, centering shall be designed by a competent engineer.

17.2.10 Centering layout shall be made by a qualified engineer and shall be strictly followed. The bearing capacity of the soil shall be kept in view for every centering job. The effect of weather conditions as dry clay may become very plastic after a rainfall and show marked decrease in its bearing capacity.

17.2.11 Sills under the supports shall be set on firm soil or other suitable material in a pattern which assures adequate stability for all props. Care shall be taken not to disturb the soil under the supports. Adequate drainage shall be provided to drain away water coming due to rains, washing of forms or during the curing of the concrete to avoid softening of the supporting soil starta.

17.2.12 All centering shall be finally, inspected to ensure that:

a) footings or sills under every post of the centering are sound.
b) all lower adjustment screws or wedges are sung against the legs of the panels.
c) all upper adjustment screws or heads of jacks are in full contact with the formwork.
d) panels are plumb in both directions.
e) all cross braces are in place and locking devices are in closed and secure position.
f) In case of *CHHAJAS* and balconies, the props shall be adequate to transfer the load to the supporting point.

17.2.13 During pouring of the concrete, the centering shall be constantly inspected and strengthened, if required, wedges below the vertical supports tightened and adjustment screws properly adjusted as necessary. Adequate protection of centering shall be secured from moving vehicles or swinging loads.

17.2.14 Forms shall not be removed earlier than as

laid down in the specifications and until it is certain that the concrete has developed sufficient strength to support itself and all loads that will be imposed on it. Only workmen actually engaged in removing the formwork shall be allowed in the area during these operations. Those engaged in removing the formwork shall wear helmets, gloves and heavy soled shoes and approved safety belts if adequate footing is not provided above 2 m level. While cutting any tying wires in tension, care shall be taken to prevent backlash which might hit a workman.

17.2.14.1 The particular order in which the supports are to be dismantled should be followed according to the instructions of the site engineer.

17.3 Ramps and Gangways

17.3.1 Ramps and gangways shall be of adequate strength and evenly supported. They shall either have a sufficiently flat slope or shall have cleats fixed to the surface to prevent slipping of workmen. Ramps and gangways shall be kept free from grease, mud, snow or other slipping hazards or other obstructions leading to tripping and accidental fall of a workman.

17.3.1.1 Ramps and gangways meant for transporting materials shall have even surface and be of sufficient width and provided with skirt boards on open sides.

17.4 Materials Hoists

17.4.1 The hoist should be erected on a firm base, adequately supported and secured. All materials supporting the hoist shall be appropriately designed and strong enough for the work intended and free from defects.

17.4.2 The size of the drum shall match the size of the rope. Not less than two full turns of rope shall remain on the drum at all times. Ropes shall be securely attached to the drum.

17.4.3 All ropes, chains and other lifting gear shall be properly made of sound materials, free from defects and strong enough for the work intended. They shall be examined by a competent person who shall clearly certify the safe working load on each item and the system.

17.4.4 Hoistways shall be protected by a substantial enclosure at ground level, at all access points and wherever persons may be struck by any moving part.

17.4.5 Gates at access points should be at least 2 m high wherever possible. Gates shall be kept closed at all times except when required open for immediate movement of materials at that landing place.

17.4.6 All gates shall be fitted with electronic or mechanical interlocks to prevent movement of the hoist in the event of a gate being opened.

17.4.7 Winches used for hoists shall be so constructed that a brake is applied when the control lever or switch is not held in the operating position (dead-man's handle).

17.4.8 The hoist tower shall be tied to a building or structure at every floor level or at least every 3 m. The height of the tower shall not exceed 6 m after the last tie or a lesser height as recommended by the manufacturer. All ties on a hoist tower shall be secured using right angled couples.

17.4.9 The hoist shall be capable of being operated only from one position at a time. It shall not be operated from the cage. The operator shall have a clear view of all levels or, if he has not, a clear and distinct system of signalling shall be employed.

17.4.10 All hoist platform shall be fitted with guards and gates to a height of at least 1 m, to prevent materials rolling/falling from the platform.

17.4.11 Where materials extend over the height of the platform guards, a frame shall be fitted and the materials secured to it during hoisting/lowering. (Care should be taken to ensure that neither the frame nor materials interfere or touch any part of the hoisting mechanism.)

17.4.12 The platform of a goods hoist shall carry a notice stating:

a) the safe working load; and
b) that passengers shall not ride on the hoist.

17.4.13 All hoist operators shall be adequately trained and competent, and shall be responsible for ensuring that the hoist is not overloaded or otherwise misued.

17.4.14 All hoists shall be tested and thoroughly examined by a competent person before use on a site, after substantial alteration, modification or repair of hoists, and at least every 6 months.

17.4.15 Every hoist shall be inspected at least once each week by a competent person and a record of these inspections kept.

17.5 Prestressed Concrete

17.5.1 In pre-stressing operations, operating, maintenance and replacement instructions of the supplier of the equipment shall be strictly adhered to.

17.5.2 Extreme caution shall be exercised in all operations involving the use of stressing equipment as wires/strands under high tensile stresses become a lethal weapon.

17.5.3 During the jacking operation of any tensioning

element(s) the anchor shall be kept turned up close to anchor plate, wherever possible, to avoid serious damage if a hydraulic line fails.

17.5.4 Pulling-headers, bolts and hydraulic jacks/rams shall be inspected for signs of deformation and failure. Threads on bolts and nuts should be frequently inspected for diminishing cross section. Choked units shall be carefully cleaned.

17.5.5 Care shall be taken that no one stands in line with the tensioning elements and jacking equipment during the tensioning operations and that no one is directly over the jacking equipment when deflection is being done. Signs and barriers shall be provided to prevent workmen from working behind the jacks when the stressing operation is in progress.

17.5.6 Necessary shields should be put up immediately behind the prestressing jacks during stressing operations.

17.5.7 Wedges and other temporary anchoring devices shall be inspected before use.

17.5.8 The prestressing jacks shall be periodically examined for wear and tear.

17.6 Erection of Prefabricated Members

17.6.1 A spreader beam shall be used wherever possible so that the cable can be as perpendicular to the members being lifted as practical. The angle between the cable and the members to be lifted shall not be less than 60°.

17.6.2 The lifting wires shall be tested for double the load to be handled at least once in six months. The guy line shall be of adequate strength to perform its function of controlling the movement of members being lifted.

17.6.3 Temporary scaffolding of adequate strength shall be used to support precast members at predetermined supporting points while lifting and placing them in position and connecting them to other members.

17.6.4 After erection of the member, it shall be guyed and braced to prevent it from being tipped or dislodged by accidental impact when setting the next member.

17.6.5 Precast concrete units shall be handled at specific picking points and with specific devices. Girders and beams shall be braced during transportation and handled. In such a way as to keep the members upright.

17.6.6 Methods of assembly and erection specified by the designer, shall be strictly adhered to at site. Immediately on erecting any unit in position, temporary connections or supports as specified shall be provided before releasing the lifting equipment. The permanent structural connections shall be established at the earliest opportunity.

17.7 Heated Concrete

When heaters are being used to heat aggregates and other materials and to maintain proper curing temperatures, the heaters shall be frequently checked for functioning and precautions shall be taken to avoid hazards in using coal, liquid, gas or any other fuel.

17.8 Structural Connections

17.8.1 When reliance is placed on bond between precast and *in-situ* concrete the contact surface of the precast units shall be suitably prepared in accordance with the specifications.

17.8.2 The packing of joints shall be carried out in accordance with the assembly instructions.

17.8.3 Levelling devices, such as wedges and nuts which have no load bearing function in the completed structure shall be released or removed as necessary prior to integrating the joints.

17.8.4 If it becomes necessary to use electric power for *in-situ* work, the same should be stepped down to a safe level as far as possible.

17.9 General

Workmen working in any position where there is a falling hazard shall wear safety belts or other adequate protection shall be provided.

18 ADDITIONAL SAFETY REQUIREMENTS FOR ERECTION OF STRUCTURAL STEEL WORK

18.1 Safety Organization

The agency responsible for erecting the steel work should analyze the proposed erection scheme for safety; the erection scheme should cover safety aspects right from the planning stage up to the actual execution of the work.

18.2 Safety of Workpersons

18.2.1 *General*

While engaging persons for the job the supervisor should check up and make sure that they are skilled in the particular job they have to perform.

18.2.1.1 The helmets shall be worn properly and at all times during the work and shall conform to the accepted standards [7(9)].

18.2.1.2 The safety goggles shall be used while performing duties which are hazardous to eye like

drilling, cutting and welding. The goggles used shall conform to the accepted standards [7(15)] and should suit individual workers.

18.2.1.3 The welders and gas cutters shall be equipped with proper protective equipment like gloves, safety boots, aprons and hand shields [*see* accepted standard 7(15)]. The filter glass of the hand shield shall conform to the accepted standards [7(16)] and should be suitable to the eyes of the particular worker.

18.2.1.4 When the work is in progress, the area shall be cordoned off by barricades to prevent persons from hitting against structural components, or falling into excavated trenches or getting injured by falling objects.

18.2.1.5 Warning signs shall be displayed where necessary to indicate hazards, for example (a) '440 VOLTS', (b) 'DO NOT SMOKE', (c) 'MEN WORKING AHEAD', etc. Hand lamps shall be of low voltage preferably 24 V to prevent electrical hazards.

18.2.1.6 All electrically operated hand tools shall be provided with double earthing.

18.2.2 Anchors for guys or ties shall be checked for proper placement. The weight of concrete in which the anchors are embedded shall be checked for uplift and sliding.

18.2.2.1 Split-end eye anchors shall only be used in good, solid rock.

18.2.2.2 The first load lifted by a guy derrick shall be kept at a small height for about 10 min and the anchors immediately inspected for any signs or indications of failure.

18.2.3 When a number of trusses or deep girders is loaded in one car or on one truck, all but one being lifted shall be tied back unless they have been tied or braced to prevent their falling over and endangering men unloading.

18.2.4 The erection gang shall have adequate supply of bolts, washers, rivets, pins, etc, of the correct size. Enough number of bolts shall be used in connecting each piece using a minimum of two bolts in a pattern to ensure that the joint will not fail due to dead load and erection loads. All splice connections in columns, crane girders, etc, shall be completely bolted or riveted or welded as specified in the drawing before erection.

18.2.5 Girders and other heavy complicated structural members may require special erection devices like cleats and hooks, which can be shop assembled and bolted or riveted or welded to the piece and may be left permanently in the place after the work.

18.2.6 If a piece is laterally unstable when picked at its centre, use of a balance beam is advisable, unless a pair of bridles slings can be placed far enough apart for them to be safe lifting points. The top flange of a truss, girder or long beam may be temporarily reinforced with a structural member laid flat on top of the member and secured temporarily.

18.2.7 On deep girders, and even on some trusses, a safety 'bar' running their full length will aid the riggers, fitters and others employed on the bottom flange or bottom chord to work with greater safety. This can be a single 16 mm diameter wire rope through vertical stiffeners of such members about one metre above the bottom flange and clamped at the ends with wire rope clamps. If the holes cannot be provided, short eye bolts can be welded to the webs of the girder at intervals to be removed and the surface chipped or ground to leave it smooth after all work on the piece has been completed.

18.2.8 Safety belts shall always be available at work spot to be used whenever necessary. The rope shall be chemically treated to resist dew and rotting. These shall not be tied on sharp edges of steel structures. They shall be tied generally not more than 2 m to 3 m away from the belt.

18.2.9 On a guy derrick or climbing crane job, the tool boxes used by the erection staff shall be moved to the new working floor each time the rig is changed. On a mobile crane job, the boxes shall be moved as soon as the crane starts operating in a new area too far away for the men to reach the boxes conveniently. While working a tall and heavy guy derrick, it is advisable to control tension in guys by hand winches to avoid jerks, which may cause an accident.

18.2.10 The proper size, number and spacing of wire rope clamps shall be used, depending on the diameter of the wire rope. They shall be properly fixed in accordance with good practice [7(17)]. They shall be checked as soon as the rope has been stretched, as the rope, especially if new, tends to stretch under the applied load, which in turn may cause it to shrink slightly in diameter. The clamps shall then be promptly tightened to take care of this new condition. In addition, the clamps shall be inspected frequently to be sure that they have not slipped and are tight enough.

18.2.11 When the men can work safely from the steel structure itself, this is preferable to hanging platforms or scaffolds, as it eliminates additional operations, which in turn, reduces the hazard of an accident.

18.2.11.1 To aid men working on floats or scaffolds, as well as men in erection gangs, or other gangs using small material, such as bolts and drift pins, adequate bolt baskets or similar containers with handles of sufficient strength and attachment to carry the loaded containers, shall be provided.

18.2.11.2 The men should be trained to use such containers, and to keep small tools gathered up and put away in tool boxes when not in use. Material shall not be dumped overboard when a scaffold is to be moved. Rivet heaters shall have safe containers or buckets for hot rivets left over at the end of the day.

18.2.12 During the erection of tall buildings, it is desirable to use nylon nets at a height of 3 m to 4 m to provide safety to men. The safety net should be made from man or machine-made fibre ropes which are UV stablized and conforming to the acceptable standard [7(18)].

18.2.13 *Safety Against Fire*

A fire protection procedure is to be set up if there is to be any flame cutting, burning, heating, rivetting or any operation that could start a fire. For precautions to be observed during welding and cutting operations, reference may be made to good practice [7(19)].

18.2.13.1 The workers should be instructed not to throw objects like hot rivets, cigarette stubs, etc, around.

18.2.13.2 Sufficient fire extinguishers shall be placed at strategic points. Extinguishers shall always be placed in cranes, hoists, compressors and similar places. Where electrical equipments are involved, CO_2 or dry powder extinguishers shall be provided {*see also* good practice [7(4)]}.

18.2.14 Riding on a load, tackle or runner shall be prohibited.

18.2.15 The load shall never be allowed to rest on wire ropes. Ropes in operation should not be touched. Wire rope with broken strand shall not be used for erection work. Wire ropes/manila ropes conforming to acceptable standards [7(20)] shall be used for guying.

18.2.16 *Lifting Appliances*

Precautions as laid down in **17.1.2** shall be followed.

18.2.17 *Slinging*

18.2.17.1 Chains shall not be joined by bolting or wiring links together. They shall not be shortened by tying knots. A chain in which the links are locked, stretched or do not move freely shall not be used. The chain shall be free of kinks and twists. Proper eye splices shall be used to attach the chain hooks.

18.2.17.2 Pulley blocks of the proper size shall be used to allow the rope free play in the sheave grooves and to protect the wire rope from sharp bends under load. Idle sling should not be carried on the crane hook alongwith a loaded sling. When idle slings are carried they shall be hooked.

18.2.17.3 While using multilegged slings, each sling or leg shall be loaded evenly and the slings shall be of sufficient length to avoid a wide angle between the legs.

18.2.18 *Rivetting Operations*

18.2.18.1 *Handling rivets*

Care shall be taken while handling rivets so that they do not fall, strike or cause injury to men and material below. Rivet catchers shall have false wooden bottoms to prevent rivets from rebounding.

18.2.18.2 *Rivetting dollies*

Canvas, leather or rope slings shall be used for riveting dollies. Chain shall not be used for the purpose.

18.2.18.3 *Rivetting hammers*

Snaps and plungers of pneumatic riveting hammers shall be secured to prevent the snap from dropping out of place. The nozzle of the hammer shall be inspected periodically and the wire attachment renewed when born.

18.2.18.4 *Fire protection*

The rivet heating equipment should be as near as possible to the place of work. A pail of water shall always be kept already for quenching the fire during rivetting operations and to prevent fires when working near inflammable materials.

18.2.19 *Welding and Gas Cutting*

18.2.19.1 For safety and health requirements in electric gas welding and cutting operations, reference may be made to good practice [7(21)]. The recommendations given in **18.2.19.2** to **18.2.19.4** are also applicable.

18.2.19.2 All gas cylinders shall be used and stored in the upright position only and shall be conveyed in trolleys. While handling by cranes they shall be carried in cages. The cylinders shall be marked 'full' or 'empty' as the case may be. Gas cylinders shall be stored away from open flames and other sources of heat. Oxygen cylinders shall not be stored near combustible gas, oil, grease and similar combustible materials. When the cylinders are in use, cylinder valve key or wrench shall be placed in position. Before a cylinder is moved, cylinder valve shall be closed. All cylinder valves shall be closed when the torches are being replaced or welding is stopped for some reason. The cylinder valve and connections shall not be lubricated.

18.2.19.3 Gas cutting and welding torches shall be lighted by means of special lighters and not with matches. The cables from welding equipment should be placed in such a way that they are not run over by

traffic. Double earthing shall be provided. Before undertaking welding operations near combustible materials, suitable blanketing shall be provided and fire extinguishers kept nearby. Welding shall not be undertaken in areas where inflammable liquids and gases are stored.

18.2.19.4 Gas lines and compressed air lines shall be identified by suitable colour codes for easy identification, to avoid confusion and to prevent fire and explosion hazards.

18.3 Safety of Structure

18.3.1 *General*

The structure itself should be safeguarded during its erection. The first truss of the roof system shall be guyed on each side before the hoisting rope is detached from it. After the subsequent trusses and roof purlins are erected, protective guides shall be firmly established and the required wind bracings shall be erected to prevent the whole structure being blown over by a sudden gale at night. Bracing and guying precautions shall be taken on every structure until it is complete. Guying shall be specifically done for trusses and structural components which after their erection form an erection device. On structures used for temporary material storage overloading shall be avoided.

18.3.1.1 Erection of columns shall be immediately followed by vertical bracing between columns before the roof structure is erected.

19 MISCELLANEOUS ITEMS

19.1 Staircase Construction

While staircase is under construction, depending on the type of construction, namely, concrete or brickwork, etc, suitable precautions shall be taken by way of support, formworks, etc, to prevent any collapse. Workmen or any other person shall not be allowed to use such staircases till they are tested and found fit for usage by the Authority/engineer-in-charge. Till the permanent handrails are provided, temporary provisions like ropes, etc, shall be provided on staircases prior to commencement of use of such staircases.

19.2 Lift Wells

Till the installation of the lift is completed, lift wells shall be protected with check boards or railings together with notice boards, danger lights, etc, to precent persons accidentally falling into the wells. The handrails provided shall be capable of withstanding pressure exerted due to normal bumping of an individual against the same.

19.3 Construction Involving the Use of Hot Bituminous Tar Materials

19.3.1 *Safety Programme*

19.3.1.1 *General*

On all major works, an experienced and competent foreman or supervisor shall be placed in-charge of the work, and shall be made responsible for the strict observance of the safety rules. He shall stock the necessary protective equipment, fire extinguishing equipment, first-aid kit, etc. He shall also keep a record of the accidents taking place on any particular job, with reasons thereof, and shall suggest suitable remedial measures to the management for prevention thereof.

19.3.1.2 *Protective covering*

Workers engaged on jobs involving handling of hot bitumen, tar, and bituminous mixtures shall use protective wears, such as boots and gloves, preferably of asbestos or otherwise of rubber; goggles and helmet. No workers shall be permitted to handle such materials without wearing the needed protective covering.

19.3.1.3 *Fire fighting arrangements*

When heating and handling of hot bituminous materials is to be done in the open, sufficient stocks of clean dry sand or loose earth shall be made available at the work site to cope with any resultant fires. When such materials are not available, nor are any suitable type of fire extinguishers provided at the work site in the open, and reliance has to be on using water for fighting any fire, the water supply available should be in abundance and the water shall be applied to the fire in the form of spray. When heating of bituminous materials is carried out in enclosed spaces, sufficient number of properly maintained dry powder fire extinguisher or form extinguisher conforming to accepted standards [7(21)] shall be kept in readiness on the work site.

19.3.2 *Sprayer, Spreader/Paver*

19.3.2.1 *Sprayer*

The sprayer shall be provided with a fire resisting screen. The screen shall have an observation window. Piping for hot tar and bitumen shall be adequately insulated to protect workers from injury by burns. Flexible piping work under positive pressure shall be of metal which shall be adequately insulated. Workers shall not stand facing the wind directions while spraying hot binder, lest it may fall on them causing burns.

19.3.2.2 *Spreader/Paver*

Spreaders in operation shall be protected by signals, signs or other effective means. People should be

warned against walking over hot mixture laid. Gravel spreaders shall always keep a safe distance from sprayer. Elevated platforms on spreaders shall be protected by suitable railing and be provided with an access ladder.

19.3.3 *Equipment for Heating of Bitumen and Tars*

19.3.3.1 Tanks, vats, kettles, pots, drums and other vessels for heating tar, bitumen and other bituminous materials shall be:

a) adequately resistant to damage by heat, transportation, etc;
b) capable of holding a full load without danger of collapse, bursting or distortion;
c) provided with a close fitting cover suitable for smothering a fire in the vessel or protection from rain; and
d) leak proof, and provided with suitable outlets which can be controlled for taking out the hot material.

19.3.3.2 Suitable indicator gauges shall be used to ascertain level and temperature of the material in the boiler. On no account shall workers be allowed to peep into the boiler for this purpose. For ascertaining levels, in small plants, dipstick may also be used.

19.3.3.3 Gas and oil-fired bitumen and tar kettles or pots shall be equipped with burners, regulators and safety devices of types approved by the Authority. Heating appliances for vessels shall distribute the heat uniformly over the heating surface so as to avoid overheating. In case of bituminous mixtures using mineral aggregates filler together with bitumen, it is preferable to have some means for stirring as well. Only vessels heated by electricity shall be used inside buildings. Tar boilers shall never be used on combustible roof.

19.3.3.4 Buckets for hot bitumen, bituminous materials of tar shall have:

a) the bail or handle firmly secured, and
b) a second handle near the bottom for tipping.

19.3.3.5 Bitumen or tar boilers mounted on wheels for easy transport or towing shall preferably be provided with hand pumps for spraying purposes.

19.3.3.6 Vessels in operation shall be kept at a safe distance from combustible materials. When vessels are used in confined spaces, the gases, fumes and smoke generated shall be removed by exhaust ventilation or by forced ventilations. Vessels that are being heated shall not be left unattended. Pieces of bituminous material shall not be thrown into the hot vessels so as to cause splashing. Covers shall be kept closed when vessels are not in use. Containers shall not be filled with hot bitumen or tar to a level that might cause danger when they are carried or hoisted. Enough space shall be left in vessels for expansion of binder when heated.

19.3.3.7 Bitumen/Tar shall be kept dry and to avoid fire due to foaming, boiler shall have a device that prevents foam from reaching the burners or anti-foaming agents shall be used to control the same. Alternatively to avoid fire due to foaming, the heating shall be at low temperature till the water entrapped, if any, is completely evaporated. Any water present in the boiler shall also be drained before using it for heating binders. No open light shall be used for ascertaining the level of binder in boilers. If a burner goes out, the fuel supply shall be cut off and the heating tube shall be thoroughly blown out by the fan so as to prevent a back fire.

19.3.3.8 Cutbacks shall not be heated over an open flame unless a water jacket is used. While they are being heated the vessel shall be kept open.

19.3.3.9 Piping shall not be warmed with burning rags and instead blow-lamps or similar devices shall be used.

19.3.3.10 Spilled bitumen or tar shall be promptly cleaned up around boilers.

19.3.3.11 Inspection openings shall not be opened while there is any pressure in the boiler.

19.3.3.12 When tanks are cleaned by steam, adequate precautions shall be taken to prevent any built up of pressure.

19.3.4 *Handling Bitumen/Tar*

Bitumen/tar shall not be heated beyond the temperature recommended by the manufacturer of the product. While discharging heated binder from the boiler, workers shall not stand opposite to the jet so as to avoid the possibility of hot binder falling on them. The container shall be handled only after closing the control valve. While handling hot bitumen/tar, workers shall exercise scrupulous care to prevent accidental spillage thereof. The buckets and cans in which the hot material is carried from boiler shall be checked before use to ensure that they are intact and safe. Mops and other applicators contaminated with bituminous materials shall not be stored inside buildings.

19.3.5 *Bitumen Plants*

Safety requirements shall be in accordance with good practice [7(22)].

19.4 Timber Structure

Preventive measures against hazards in work places involving construction of timber structures shall be taken in accordance with good practice [7(23)].

20 FINISHES

20.1 Painting, Polishing and Other Finishes

Only the quantity of paint, thinner and polish required for the day's work should be kept at the work spot.

20.1.1 All containers of paint, thinner and polish which are not in actual use should be closed with tight fitting lids and kept at a safe place away from the actual work site.

20.1.2 A 5 kg dry powder fire extinguisher conforming to acceptable standards [7(23)] shall be kept handy.

20.1.3 Metal receptacles with pedal operated metal lids shall be kept handy at the work site for depositing used cotton rags/waste. The contents of such receptacles shall be disposed off before the end of each day's work at a safe place, preferably by burning under proper supervision.

20.1.4 All containers of paint shall be removed from the work site and deposited in the paint store before the close of day's work. Used paint brushes shall be cleaned and deposited in the store alongwith the containers.

20.1.5 Some paints/polishing and finishing materials are injurious to the health of workmen. Adequate protective clothing, respiratory equipment, etc, shall be provided for the use of workmen during such operations where necessary.

21 FRAGILE FIXTURES

21.1 It shall be ensured that sufficient number of workmen and equipment are provided to carry the fragile fixtures like sanitary fittings, glass panes, etc, to prevent injury to workmen due to accidental dropping of such fixtures.

22 SAFETY IN SPECIAL OPERATIONS

22.1 Safety in compressed airwork, drilling, blasting and welding operations shall be in accordance with good practice [7(25)].

23 ELECTRICAL INSTALLATIONS AND LIFTS

23.1 Temporary Electrical Wiring

23.1.1 Frayed and/or bare wires shall not be used for temporary electrical connections during construction. All temporary wiring shall be installed and supervised by a competent electrician. Adequate protection shall be provided for all electrical wiring laid on floor which may have to be crossed over by construction machinery or by the workmen. All flexible wiring connecting the electrical appliances shall have adequate mechanical strength and shall preferably be enclosed in a flexible metal sheath. Overhead wires/cables shall be so laid that they leave adequate head room.

23.1.2 All electrical circuits, other than those required for illumination of the site at night, shall be switched off at the close of day's work. The main switch board from which connections are taken for lighting, power operated machinery, etc, shall be located in an easily accessible and prominent place. No articles of clothing nor stores shall be kept at the back of or over the board or anywhere near it. One 3 kg/4.5 kg CO_2 extinguisher or one 5 kg dry powder extinguisher shall be provided near the switch board.

23.2 Permanent Electrical Installations

Besides the fire safety measures for electrical installations covered under **23.1**, safety in electric installations in buildings and installations of lifts shall be in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations and Section 5 Installation of Lifts and Escalators'.

24 GENERAL REQUIREMENTS

24.1 Sanitation

a) Adequate toilet facilities shall be provided for the workmen within easy access of their place of work. The total number to be provided shall be not less than one per 30 employees in any one shift.

b) Toilet facilities shall be provided from the start of building operations, and connection to a sewer shall be made as soon as practicable.

c) Every toilet shall be so constructed that the occupant is sheltered from view and protected from the weather and falling objects.

d) Toilet facilities shall be maintained in a sanitary condition. A sufficient quantity of disinfectant shall be provided.

e) An adequate supply of drinking water shall be provided, and unless connected to a municipal water supply, samples of the water shall be tested at frequent intervals by the Authority.

f) Washing facilities shall be installed, and when practicable shall be installed, and when practicable shall be connected to municipal water supply and shall discharge to a sewer.

g) Natural or artificial illumination shall be provided.

24.2 Fire Protection

24.2.1 In addition to the provision of fire extinguishers, as specified in this Part of the Code, other fire extinguishing equipment shall also be provided and conveniently located within the building under construction or on the building site, as required by the Authority.

good practice [7(4)] and all necessary guidelines regarding fire protection at workplaces followed in accordance with good practice [7(2)].

24.2.1.2 It shall be ensured that all workmen and supervisory staff are fully conversant with the correct operation and use of fire extinguishers provided at the construction site.

24.2.1.3 Telephone number of local fire brigade should be prominently displayed near each telephone provided at construction site.

24.2.1.4 Watch and ward services should be provided at construction sites during holidays and nights.

24.2.2 Access shall be provided and maintained at all times to all fire fighting equipment, including fire hose, extinguishers, sprinkler valves and hydrants.

24.2.2.1 Approach roads for fire fighting should be planned, properly maintained and kept free from blockage. Width of approach road should be not less than 5 m to facilitate fire fighting operations.

24.2.2.2 Emergency plan and fire order specifying the individual responsibility in the event of fire should be formulated and mock drills should be practised periodically in case of large and important construction sites to ensure upkeep and efficiency of fire fighting appliances.

24.2.2.3 Periodical inspection should be carried out to identify any hazard and proper records maintained and follow up action taken.

24.2.2.4 Evaluation facilities and fire exits should be provided at all locations susceptible to fire hazards.

24.2.3 Where the building plans require the installation of fixed fire fighting equipment, such as hydrants, stand pipes, sprinklers and underground water mains or other suitable arrangements for provision of water shall be installed, completed and made available for permanent use as soon as possible, but in any case not later than the stage at which the hydrants, etc, are required for use as specified in **24.2.3.1** to **24.2.3.4**.

24.2.3.1 A stand pipe system (landing valves), permanent in nature shall be installed and made available before the building has reached the height of 15 m above the grade, and carried up with each floor.

24.2.3.2 The standpipe (landing valve/internal fire hydrant) and its installation shall conform to the accepted standards [7(26)].

24.2.3.3 The standpipe shall be carried up with each floor and securely capped at the top. Top hose outlets,

24.2.3.4 A substantial box, preferably of metal, should be provided and maintained near each hose outlet. The box should contain adequate lengths of hose to reach all parts of the floor as well as a short branch fitted with 12 mm or 20 mm nozzle.

24.2.4 Close liaison shall be maintained with the local fire brigade, during construction of all buildings above 15 m in height and special occupancies, like educational, assembly, institutional, industrial, storage, hazardous and mixed occupancies with any of the aforesaid occupancies having area more than 500 m^2 on each floor.

24.2.5 It is desirable that telephone system or other means of inter-communication system be provided during the construction of all buildings over 15 m in height or buildings having a plinth area in excess of 1 000 m^2.

24.2.6 All work waste, such as scrap timber, wood shavings, sawdust, paper, packing materials and oily waste shall be collected and disposed of safely at the end of each day's work. Particular care shall be taken to remove all waste accumulation in or near vertical shaft openings like stairways, lift-shaft, etc.

24.2.7 An independent water storage facility shall be provided before the commencement of construction operations for fire-fighting purposes. It shall be maintained and be available for use at all times.

24.2.8 *Fire Cut-offs*

Fire walls and exit stairways required for a building should be given construction priority. Where fire doors, with or without automatic closing devices, are stipulated in the building plans they should be hung as soon as practicable and before any significant quantity of combustible material is introduced in the building.

24.2.8.1 As the work progresses, the provision of permanent stairways, stairway enclosures, fire walls and other features of the completed structure which will prevent the horizontal and vertical spread of fire should be ensured.

24.3 Clothing

24.3.1 It shall be ensured that the clothes worn by the workmen be not of such nature as to increase the chances of their getting involved in accident to themselves or to others. As a rule, wearing of *CHADDARS* or loose garments shall be prohibited.

24.3.2 Workmen engaged in processes which splash liquid or other materials which will injure the skin shall have enough protective clothing to cover the body.

24.3.3 Individuals engaged in work involving use of naked flames (such as welding) shall not wear synthetic fibre or similar clothing which increases the risk of fire hazards.

24.4 Safety Measures Against Fall Prevention

Persons working at heights may use safety belts and harnesses. Provision of cat-walks, wire mesh, railings reduces chances of fall-ladder and scaffoldings, stagings etc, should be anchored on firm footing and should be secured and railing should be provided as far as possible. All accesses should be barricaded to prevent accidental fall. For details as fall prevention reference may be made to good practice [7(27)].

24.5 Falling Materials Hazard Prevention

Preventive measures against falling materials hazards in work places shall be taken in accordance with good practice [7(28)].

24.6 Disposal of Debris

Preventive measures against hazards relating to disposal of debris shall be taken in accordance with [7(29)].

25 CONSTRUCTION MACHINERY

25.1 Specification and requirements of construction machinery used in construction or demolition work shall conform to accepted standards [7(30)].

25.2 For safety requirements for working with construction machinery, reference may be made to good practice [7(31)].

25.3 Petroleum powered air compressors, hoists, derricks, pumps, etc, shall be so located that the exhausts are well away from combustible materials. Where the exhausts are pipes to outside the building under construction, a clearance of at least 150 mm shall be maintained between such piping and combustible material.

SECTION 4 MAINTENANCE MANAGEMENT, REPAIRS, RETROFITTING AND STRENGTHENING OF BUILDINGS

26 MAINTENANCE MANAGEMENT

26.1 Maintenance management of building is the art of preserving over a long period what has been constructed. Whereas construction stage lasts for a short period, maintenance continues for comparatively very large period during the useful life of building. Inadequate or improper maintenance adversely affects the environment in which people work, thus affecting the overall output. In the post construction stage the day to day maintenance or upkeep of the building shall certainly delay the decay of the building structure. Though the building may be designed to be very durable it needs maintenance to keep it in good condition.

26.2 Terminology

For the purpose of this Section, the following definitions shall apply.

26.2.1 *Maintenance* — The combination of all technical and associated administrative actions intended to retain an item in or restore it to a state in which it can perform its required function.

26.2.2 *Maintenance Management* — The organization of maintenance within an agreed policy. Maintenance can be seen as a form of 'steady state' activity.

26.2.3 *Building Fabric* — Elements and components of a building other than furniture and services.

26.2.4 *Building Maintenance* — Work undertaken to maintain or restore the performance of the building fabric and its services to provide an efficient and acceptable operating environment to its users.

26.2.5 *House Keeping* — The routine recurring work which is required to keep a structure in good condition so that it can be utilized at its original capacity and efficiency along with proper protection of capital investment, throughout its economic life.

26.2.6 *Owner* — Person or body having a legal interest in a building. This includes freeholders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

26.2.7 *Confined Space* — Space which may be inadequately ventilated for any reason and may result in a deficiency of oxygen, or a build-up of toxic gases, e.g. closed tanks, sewers, ducts, closed and unventilated rooms, and open topped tanks particularly where heavier than air gases or vapours may be present.

26.3 Building Maintenance

26.3.1 *General*

Any building (including its services) when built has certain objectives and during its total economic life, it has to be maintained. Maintenance is a continuous process requiring a close watch and taking immediate remedial action. It is interwoven with good quality of house keeping. It is largely governed by the quality of original construction. The owners, engineers,

constructors, occupants and the maintenance agency are all deeply involved in this process and share a responsibility. Situation in which all these agencies merge into one is ideal and most satisfactory.

There are two processes envisaged, that is, the work carried out in anticipation of failure and the work carried out after failure. The former is usually referred to as preventive maintenance and the latter as corrective maintenance. The prime objective of maintenance is to maintain the performance of the building fabric and its services to provide an efficient and acceptable operating environment to its users.

26.3.1.1 Maintenance in general term can be identified in the following broad categories.

a) *Cleaning and servicing* — This is largely of preventive type, such as checking the efficacy of rain water gutters and servicing the mechanical and electrical installations. This covers the house keeping also.

b) *Rectification and repairs* — This is also called periodical maintenance work undertaken by, say, annual contracts and including external replastering, internal finishing etc.

c) *Replacements* — This covers major repair or restoration such as re-roofing or re-building defective building parts.

26.3.2 *Factors Affecting Maintenance*

26.3.2.1 Maintenance of the buildings is influenced by the following factors:

a) *Technical factors* — These include age of building, nature of design, material specifications, past standard of maintenance and cost of postponing maintenance.

b) *Policy* — A maintenance policy ensures that value for money expended is obtained in addition to protecting both the asset value and the resource value of the buildings concerned and owners.

c) *Financial and economics factors* — (*see* **26.9**).

d) *Environmental* — All buildings are subject to the effects of a variety of external factors such as air, wind precipitation, temperature etc. which influence the frequency and scope of maintenance.

The fabric of building can be adversely affected as much by the internal environment as by the elements externally. Similar factors of humidity, temperature and pollution should be considered. Industrial buildings can be subject to many different factors subject to processes carried out within. Swimming pool structures are vulnerable to the effects of chlorine used in water.

e) *User* — The maintenance requirements of buildings and their various parts are directly related to the type and intensity of use they receive.

26.3.2.2 *Influence of design*

The physical characteristics, the life span and the aesthetic qualities of any building depend on the considerations given at the design stage. All buildings, however well designed and conscientiously built, will require repair and renewal as they get older.

However, for better performance of the building envelop, the following are the ways to minimize troubles at the later stage.

a) Minimize defects during construction and design.

b) Detail and choose materials during construction so that the job of maintenance is less onerous.

26.3.2.2.1 In addition to designing a building for structural adequacy, consideration should also be given to environmental factors such as moisture, natural weathering, corrosion and chemical action, user wear and tear, pollution, flooding, subsidence, earthquake, cyclones etc.

26.3.2.2.2 A list of common causes for maintenance problems is given in Annex C for guidance. However, no such list is likely to be entirely comprehensive.

26.3.3 *Maintenance Policy*

The policy should cover such items as the owner's anticipated future requirement for the building taking account of the building's physical performance and its functional suitability. This may lead to decisions regarding:

a) the present use of the building anticipating any likely upgradings and their effect on the life cycles of existing components or engineering services; and

b) a change of use for the building and the effect of any conversion work on the life cycles of existing components or engineering services.

26.3.4 *Maintenance Work Programmes*

The programming of maintenance work can affect an owner or his activities in the following ways:

a) maintenance work should be carried out at such times as are likely to minimize any adverse effect on output or function.

b) programme should be planned to obviate as far as possible any abortive work.

has been completed or if work such as rewiring is carried out after redecorations.

c) any delay in rectifying a defect should be kept to a minimum only if such delay is likely to affect output or function. The cost of maintenance increases with shortening response times.

d) maintenance work, completed or being carried out should comply with all statutory and other legal requirements.

26.3.5 *Maintenance Guides*

An owner responsible for a large number of buildings may have established procedures for maintenance. When an owner is responsible for the maintenance of only one building or a small number of buildings, the preparation of a guide tailored to suit each particular building, can offer significant advantages. Such a guide should take into account the following:

a) type of construction and residual life of the building, and

b) environment and intensity of use (*see* **26.3.2**).

The guide may form part of a wider manual covering operational matters.

26.3.6 *Planning of Maintenance Work*

Work should take account of the likely maintenance cycle of each building element and be planned logically, with inspections being made at regular intervals. Annual plans should take into account subsequent years' programmes to incorporate items and to prevent additional costs. It should be stressed that the design of some buildings can lead to high indirect costs in maintenance contracts and therefore, careful planning can bring financial benefits. Decisions to repair or replace should be taken after due consideration.

26.3.7 *Feed Back*

26.3.7.1 Feed back is normally regarded as an important procedure of providing information about the behaviour of materials and detailing for the benefit of the architect/engineer designing new buildings, which will result in lessening maintenance costs. It is an equally valuable source of information for the persons responsible for maintenance. Every maintenance organization should develop a sample way of communicating its know how, firstly for benefit of others in the organization and secondly for the benefit of the building industry as a whole. There should be frank and recorded dialogue on an on-going basis between those who occupy and care for buildings and those who design and construct them.

a) User satisfaction,

b) Continuous improvement, and

c) Participation by all.

26.3.7.3 *Source of information*

The information on feed back can be obtained from the following:

a) Occupants,

b) Inspections,

c) Records, and

d) Discussions.

26.3.8 *Means of Effecting Maintenance*

26.3.8.1 *Responsibility*

Some maintenance work will be carried out by the occupier of a building or by the occupier's representative. In the case of leasehold or similar occupation not all maintenance may be the responsibility of occupier. Responsibility of common areas may be clearly defined.

26.3.8.2 Maintenance work sub-divided into major repair, restoration, periodical and routine or day-to-day operations will be undertaken by one of the following:

a) Directly employed labour,

b) Contractors, and

c) Specialist contractors under service agreement or otherwise.

26.3.8.3 The merits of each category for typical maintenance work must be considered because optimum use of resources appropriate to tasks in a given situation is an important element of policy.

26.3.8.4 The success of contracting out depends on the nature of the services, conditions in which contracting is undertaken (the tendering process), how the contract is formulated and subsequent monitoring of service quality. The important consideration in the decision to contract out is whether a contractor can ensure a socially desirable quantity and quality of service provision at a reasonable cost to the consumers.

26.4 Access

26.4.1 *General*

All maintenance activities including any preliminary survey and inspection work require safe access and in some situations this will have to be specially designed. Maintenance policy, and maintenance costs, will be much influenced by ready or difficult access to the fabric and to building services. Special precautions and access provisions may also need to be taken for roof

work or for entry into confined spaces such as ducts or voids.

26.4.2 *Access Facilities*

26.4.2.1 Permanent accessibility measures should be provided at the design stage only for all the areas for safe and proper maintenance. It is a matter on which those experienced in the case of the building can make an important contribution at design stage in the interest of acceptable maintenance costs.

26.4.2.2 A wide variety of temporary access equipment may appropriately be provided for maintenance work, ranging from ladders to scaffoldings or powered lift platforms.

26.4.2.3 Wherever possible it is better to provide permanent access facilities such as fixed barriers, ladders, and stairways. When such permanent access facilities are provided necessary arrangement may be included in maintenance plans for their regular inspection, maintenance and testing.

26.4.2.4 All personnel employed for carrying out maintenance should be provided with the necessary protective clothing and equipment and instructed in its use.

26.4.2.5 When physical access is not possible in situations such as wall cavities, drains etc, inspections may be made with the aid of closed circuit television or optical devices such as endoscopes.

26.4.3 *Access to Confined Spaces*

26.4.3.1 *Ventilation*

Special precautions need to be taken when entering a confined space. Such confined spaces should be adequately ventilated, particularly before being entered, to ensure that they are free from harmful concentrations of gases, vapours other airborne substances and that the air is not deficient in oxygen.

26.4.3.2 *Lighting*

Good lighting is necessary in order that maintenance work can be carried out satisfactorily. This is particularly important in confined spaces. When the normal lighting is inadequate it should be supplemented by temporary installations. These should provide general and spot illumination as appropriate.

26.5 Records

26.5.1 *General*

Good records can save owners and users/occupiers much unnecessary expense and reduce potential hazards in exploration work when faults arise.

26.5.2 *Use of Building Records*

26.5.2.1 All personnel involved in the maintenance of the building should be made aware of the existence of the building records.

26.5.2.2 Known hazardous areas should be explicitly marked on the records as well as being marked on site and should be pointed out to such personnel together with any system of work adopted for use in such areas.

26.5.2.3 Records are of value only if they are kept up to date and arrangements for this should be included in any provision that may be made for records.

26.5.2.4 Records should be readily accessible for use and the place of storage should take into account the form of the records and the conditions needed to keep them from damage of any kind. It is recommended that a duplicate set of records is kept in a secure place other than building itself and is kept up to date.

26.5.3 Following should be typical contents of the maintenance records:

a) A brief history of property, names and addresses of consultants and contractors.
b) Short specifications, constructional processes, components, material finishes, hidden features, special features etc.
c) "As built" plans and as subsequently altered with sections, elevations and other detailed drawings.
d) Foundation and structural plans/sections such as concrete reinforcement drawings.
e) Detail specification of all materials incorporated, for example, concrete mix, species and grades of timber etc. Potentially hazardous materials and types or methods of construction that under some circumstances may become hazardous may be identified.
f) Information on house keeping and routine maintenance with details of internal and external surfaces and decorations, schedule of cleaning, inspection and maintenance.
g) Means of operating mechanical, electrical and plumbing installations.
h) Description of renovations, extensions, adaptations and repair to each elements.
j) All plant, machinery and propriety articles including manufacturers trade literature and instructions for installation, use and maintenance.
k) Methods of work used in construction such as assembly of prefabricated units.
m) All information related to fire such as:

1) Location and service arrangements of all fire alarm and call points;
2) Location and service arrangements of all extinguishers, hose reels and other fire fighting installations;
3) Location of all fire compartment walls, doors, floors and screens;
4) Location of all areas of exceptional fire hazard;
5) Fire escape routes;
6) Details of application of any fire protection treatment; and
7) Location details and description of any installation for smoke control or protection of escape routes.

n) There should be a wall chart showing at a glance the various operations which have to be undertaken. Line drawings of buildings are always useful.

p) Records of security measures should be known to authorized personnel only.

q) Where no records exist, information should be slowly built up as it becomes available during the course of maintenance work.

r) Use of computers for storing information may be preferred.

26.5.4 *Mechanical Records*

26.5.4.1 *Documentation*

Documentation should record the following as installed:

a) the location, including level if buried, of all public service connections (for example, fuel gas and cold water supplies) together with the points of origin and termination, size and materials of pipes, line pressure and other relevant information;

b) the layout, location and extent of all piped services showing pipe sizes, together with all valves for regulation, isolation and other purposes as well as the results of all balancing, testing and commissioning data;

c) the location, identity, size and details of all apparatus and all control equipment served by, or associated with, each of the various services together with copies of any test certificates for such apparatus where appropriate. The information with respect to size and details may be presented in schedule form;

d) the layout, location and extent of all air ducts showing dampers and other equipment, acoustic silencers, grilles, diffusers or other terminal components. Each duct and each terminal component should be marked with its size, the air quantity flowing and other relevant balancing data; and

e) the location and identity of each room or space housing plant, machinery or apparatus.

26.5.4.2 *Drawings*

Drawings should record the following as installed:

a) detailed general arrangements of boiler houses, machinery spaces, air handling plants, tank rooms and other plant or apparatus, including the location, identity, size and rating of each apparatus. The information with respect to the size and rating can be presented in schedule form;

b) isometric or diagrammatic views of boiler houses, plant rooms, tank rooms and similar machinery, including valve identification charts. It is useful to frame and mount a copy of such drawings on the wall of the appropriate room; and

c) comprehensive diagrams that show power wiring and control wiring and/or pneumatic or other control piping including size, type or conductor or piping used and identifying the terminal points of each.

26.5.5 *Electrical Records*

Documentation should record the following including locations, as installed:

a) main and submain cables, showing origin, route, termination, size and type of each cable; cables providing supplies to specialist equipment, for example, computers, should be identified separately; and

b) lighting conduits and final subcircuit cables, showing origin, route, termination and size of each, together with the number and size of cables within each conduit. The drawings should indicate for each conduit or cable, whether it is run on the surface or concealed, for example, in a wall chase, in a floor screed, cast *in-situ*, above a false ceiling etc.

These drawings should also indicate the locations of lighting fittings, distribution boards, switches, draw-in-boxes and point boxes, and should indicate circuitry:

a) location and purpose of each emergency lighting fitting including an indication of the circuit to which it is connected;

b) single and three phase power conduits and final subcircuit cables showing locations of power distribution boards, motors, isolators,

starters, remote control units, socket outlets and other associated equipment;

c) other miscellaneous equipment, conduits and cables;

d) lightening conductor, air terminals, conductors, earth electrodes and test clamps;

e) location of earth tapes, earth electrodes and test points other than those in (f); and

f) cables providing earth circuits for specialist equipment, for example computers, should be identified separately.

Documentation should also include, when applicable.

a) distribution diagrams or schedules to show size, type and length (to within 1 m) of each main and submain cable, together with the measured earth continuity resistance of each;

b) schedule of lighting fittings installed stating location, manufacturer and type or catalogue number together with the type or manufacturer's reference, voltage and wattage of the lamp installed;

c) schedule of escape and emergency lighting fittings installed stating location, manufacturer, type or catalogue number together with the type or manufacturer's reference, voltage and wattage of the lamp installed. For battery systems the position of the battery, its ampere hour rating and battery system rated endurance in hours should be stated;

d) records of smoke detectors, sprinklers, fire precautions;

e) incoming supply details; the type of system, voltage, phases, frequency, rated current and short circuit level, with the details of the supply protection and time of operation as appropriate;

g) main switchgear details; for purpose made equipment this should include a set of manufacturers' drawings and the site layout;

h) transformer, capacitor and power plant details; the leading details should be given, for example, for transformers the V.A rating, voltages and type of cooling; and

j) Completion certificate, according to the *Indian Electricity Act.*

26.6 Inspections

26.6.1 *General*

Regular inspections are actual part of the procedures for the maintenance of buildings. They are needed for a variety of purposes and each purpose requires a different approach if it is to be handled with maximum economy and efficiency. A more detailed inspection covering all parts of a building is needed to determine what work should be included in cyclic and planned maintenance programme.

26.6.2 *Frequency of Inspection*

Inspection should be carried out at the following frequencies:

a) *Routine* — Continuous regular observations should be undertaken by the building user as part of the occupancy of building. Feed back resulting from this type of observation should be encouraged.

b) *General* — Visual inspections of main elements should be made annually under the supervision of suitably qualified personnel at appropriate times.

c) *Detailed* — The frequency of full inspection of the building fabric by suitably qualified personnel should not normally exceed a 5 year period.

26.6.2.1 *Inspection schedule*

The preparation of a specific schedule should be encouraged. Once prepared, it can be used for subsequent inspections.

26.6.3 *Inspection of Engineering Services*

Engineering services generally have a shorter life expectancy than building fabric and because of their dynamic function should be subjected to more frequent inspections and maintenance.

26.6.3.1 Inspection of services should be carried out for three purposes as follows:

a) to check if maintenance work is required,

b) to check if maintenance work is being adequately carried out, and

c) for safety reasons to comply with statutory requirements and if required, with recommendations of other relevant organizations.

26.6.3.2 The frequency of inspections for purpose (a) will depend upon types of plant and system manufacturer's recommendations and subjective judgement. Frequencies for purpose (b) should be carried out on an annual basis.

26.6.3.3 *Method of inspection*

The limited life of building services means it is important to record their residual life so that their replacement can be budgeted for, and inspection methods should be arranged accordingly.

A check list of items of plant to be inspected should be considered. Detailed specifications of how inspections should be carried out are necessary because a simple visual inspection is unlikely to show whether plant is operating correctly and efficiently.

Inspections frequently necessitate the use of appropriate instruments by competent persons. An example of this is the inspections carried out to check compliance with statutory requirements.

When instruments are used it is important that adequate training is provided in the use of the instruments and the interpretation of the results.

26.6.4 Records of all inspections should be kept.

26.6.5 *Inspection Report*

Inspection report may be prepared in the format as given in Annex D.

26.7 Maintenance of Electrical Appliances

26.7.1 *Planning of Maintenance Work*

26.7.1.1 If the authorized person has complete knowledge of the electrical appliances to be worked upon, then safety will be more assured. If the person attending to the job is not technically competent to handle the job then more careful planning is required before hand.

26.7.1.2 Repetitive nature of jobs involve little or no pre-planning whereas infrequent nature of jobs may need careful planning even if the person attending the job is technically competent.

26.7.1.3 Planned routine maintenance will facilitate continued safe and acceptable operation of an electrical system with a minimum risk of breakdown and consequent interruption of supply.

26.7.1.4 As far as the electrical equipments/ installations are concerned, it is not possible to laydown precise recommendations for the interval between the maintenance required. The recommendation for frequency of maintenance in this regard from the manufacturer is more relevant. The manufacturer should be requested to specify minimum maintenance frequency under specified conditions. These intervals depend greatly upon the design of the equipment, the duty that it is called on to perform and the environment in which it is situated.

26.7.2 Following two types of maintenance are envisaged.

26.7.2.1 *Routine maintenance*

Routine maintenance of the electrical equipments goes alongwith the regular inspections of the equipments. Inspections shall reveal the undue damage and excessive wear to the various components. Examination of the equipment shall reveal any need for conditioning of the contact system, lubrication and adjustment of the mechanisms.

26.7.2.2 *Post fault maintenance*

When there is a breakdown in the system and certain parts are identified for the replacement and then the maintenance/repair of the defective part away from the operating environment is covered under post fault maintenance.

26.7.3 *Guidelines for the Maintenance of Electrical Appliances*

26.7.3.1 Uninterrupted and hazard free functioning of the electrical installations are the basic parameters of maintenance. The equipment should be restored to correct working conditions. Special attention should be paid to the items and settings that might have been disturbed during the operational phase. Loose and extraneous equipment or wiring give rise to potential safety hazards. All covers and locking arrangements should be properly checked and secured to achieve original degree of protection.

26.7.3.2 Guidelines to be followed for the maintenance of electrical equipments to ensure their smooth functioning are given in Annex E.

26.8 Operating and Maintenance Manuals

The engineering services within buildings frequently are dynamic, involving complex systems of integrated plant items. Operation of such plant can require detailed knowledge and direction. Maintenance can also require extensive information to be available. It is, therefore, important to have suitable operating and maintenance manuals to provide the necessary guidance. These should be included as part of the contractual requirements for new installations and should ideally be prepared as reference documents for existing installations where no such information exists.

26.9 For details on labour management concerning building maintenance, reference shall be made to good practice [7(32)].

26.10 For details on financial management concerning building maintenance, reference shall be made to good practice [7(33)].

27 PREVENTION OF CRACKS

27.1 Cracks in buildings are of common occurrence. A building component develops cracks whenever stress in the component exceeds its strength. Stress in a building component could be caused by externally applied forces, such as dead, imposed, wind or seismic loads, or foundation settlement or it could be induced

internally due to thermal movements, moisture changes, chemical action, etc.

27.2 Cracks could be broadly classified as structural or non-structural. Structural cracks are those which are due to incorrect design, faulty construction or overloading and these may endanger the safety of a building. Extensive cracking of an RCC beam is an instance of structural cracking. Non-structural cracks are mostly due to internally induced stresses in building materials and these generally do not directly result in structural weakening. In course of time, however, sometime non-structural cracks may, because of penetration of moisture through cracks or weathering action, result in corrosion of reinforcement and thus may render the structure unsafe. Vertical cracks in a long compound wall due to shrinkage or thermal movement is an instance of non-structural cracking. Non-structural cracks, normally do not endanger the safety of a building, but may look unsightly, or may create an impression of faulty work or may give a feeling of instability. In some situations, cracks may, because of penetration of moisture through them, spoil the internal finish, thus adding to cost of maintenance. It is, therefore, necessary to adopt measures of prevention or minimization of these cracks.

27.3 For complete details on causes and prevention of non-structural cracks, reference shall be made to good practice SP 25 : 1984 'Handbook on causes and prevention of cracks in buildings'.

28 REPAIRS AND SEISMIC STRENGTHENING OF BUILDINGS

28.1 General Principles and Concepts

28.1.1 *Non-structural/Architectural Repairs*

28.1.1.1 The buildings affected by earthquake may suffer both non-structural and structural damages. Non-structural repairs may cover the damages to civil and electrical items including the services in the building. Repairs to non-structural components need to be taken up after the structural repairs are carried out. Care should be taken about the connection details of architectural components to the main structural components to ensure their stability.

28.1.1.2 Non-structural and architectural components get easily affected/dislocated during the earthquake. These repairs involve one or more of the following:

a) Patching up of defects such as cracks and fall of plaster;
b) Repairing doors, windows, replacement of glass panes;
c) Checking and repairing electric conduits/ wiring;
d) Checking and repairing gas pipes, water pipes and plumbing services;
e) Re-building non-structural walls, smoke chimneys, parapet walls, etc;
f) Re-plastering of walls as required;
g) Rearranging disturbed roofing tiles;
h) Relaying cracked flooring at ground level; and
j) Redecoration — white washing, painting, etc.

The architectural repairs as stated above do not restore the original structural strength of structural components in the building and any attempt to carry out only repairs to architectural/non-structural elements neglecting the required structural repairs may have serious implications on the safety of the building. The damage would be more severe in the event of the building being shaken by the similar shock because original energy absorption capacity of the building would have been reduced.

28.1.2 *Structural Repairs*

28.1.2.1 Prior to taking up of the structural repairs and strengthening measures, it is necessary to conduct detailed damage assessment to determine:

a) the structural condition of the building to decide whether a structure is amendable for repair; whether continued occupation is permitted; to decide the structure as a whole or a part require demolition, if considered dangerous;
b) if the structure is considered amendable for repair then detailed damage assessment of the individual structural components (mapping of the crack pattern, distress location; crushed concrete, reinforcement bending/yielding, etc). Non-destructive testing techniques could be employed to determine the residual strength of the members; and
c) to work out the details of temporary supporting arrangement of the distressed members so that they do not undergo further distress due to gravity loads.

28.1.2.2 After the assessment of the damage of individual structural elements, appropriate repair methods are to be carried out componentwise depending upon the extent of damage. The repair may consist of the following:

a) Removal of portions of cracked masonry walls and piers and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.
b) Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall

through spikes or bolts and then covering it, suitably, with cement mortar or micro-concrete.

c) Injecting cement or epoxy like material which is strong in tension, into he cracks in walls.

d) The cracked reinforced cement elements may be repaired by epoxy grouting and could be strengthened by epoxy or polymer mortar application like shotcreting, jecketting, etc.

28.1.3 *Seismic Strengthening*

The main purpose of the seismic strengthening is to upgrade the seismic resistance of a damaged building while repairing so that it becomes safer under future earthquake occurrences. This work may involve some of the following actions:

a) Increasing the lateral strength in one or both directions by increasing column and wall areas or the number of walls and columns.

b) Giving unity to the structure, by providing a proper connection between its resisting elements, in such a way that inertia forces generated by the vibration of the building can be transmitted to the members that have the ability to resist them. Typical important aspects are the connections between roofs or floors and walls, between intersecting walls and between walls and foundations.

c) Eliminating features that are sources of weakness or that produce concentration of stresses in some members. Asymmetrical plan distribution of resisting members, abrupt changes of stiffness from one floor to the other, concentration of large masses and large openings in walls without a proper peripheral reinforcement are examples of defects of this kind.

d) Avoiding the possibility of brittle modes of failure by proper reinforcement and connection of resisting members.

28.1.4 *Seismic Retrofitting*

Many existing buildings do not meet the seismic strength requirements of present earthquake codes due to original structural inadequacies and material degradation due to time or alterations carried out during use over the years. Their earthquake resistance can be upgraded to the level of the present day codes by appropriate seismic retrofitting techniques, such as mentioned in **28.1.3**.

28.1.5 *Strengthening or Retrofitting Versus Reconstruction*

28.1.5.1 Replacement of damaged buildings or existing unsafe buildings by reconstruction is, generally, avoided due to a number of reasons, the main ones among them being;

a) higher cost than that of strengthening or retrofitting,

b) preservation of historical architecture, and

c) maintaining functional social and cultural environment.

In most instances, however, the relative cost of retrofitting to reconstruction cost determines the decision. As a thumb rule, if the cost of repair and seismic strengthening is less than about 50 percent of the reconstruction cost, the retrofitting is adopted. This may also require less working time and much less dislocation in the living style of the population. On the other hand reconstruction may offer the possibility of modernization of the habitat and may be preferred by well-to-do communities.

28.1.5.2 Cost-wise the building construction including the seismic code provisions in the first instance, works out the cheaper in terms of its own safety and that of the occupants. Retrofitting an existing inadequate building may involve as much as 4 to 5 times the initial extra expenditure required on seismic resisting features. Repair and seismic strengthening of a damaged building may even be 5 to 10 times as expensive. It is, therefore, very much safe as well as cost-effective to construct earthquake resistant buildings at the initial stage itself according to the relevant seismic IS codes.

28.2 For detailed guidelines for repairs and seismic strengthening of buildings, reference shall be made to good practice [7(34)].

28.3 For detailed guidelines for improving earthquake resistance of low strength masonry buildings, reference shall be made to good practice [7(35)].

28.4 For detailed guidelines for improving earthquake resistance of earthen buildings, reference shall be made to good practice [7(36)].

SECTION 5 SAFETY IN DEMOLITION OF BUILDINGS

29 GENERAL

29.1 This Section lays down the safety requirements for carrying out demolition/dismantling work.

29.2 Planning

Before beginning the actual work of demolition a careful study shall be made of the structure which is to be pulled down and also of all its surroundings. This shall, in particular, include study of the manner in which the various parts of the building to be demolished are supported and how far the stage by stage demolition

will affect the safety of the adjoining structure. A definite plan of procedure for the demolition work, depending upon the manner in which the loads of the various structural parts are supported, shall be prepared and approved by the engineer-in-charge and this shall be followed as closely as possible, in actual execution of the demolition work. Before the commencement of each stage of demolition, the foreman shall brief the workmen in detail regarding the safety aspects to be kept in view.

It should be ensured that the demolition operations do not, act any stage, endanger the safety of the adjoining buildings. Moreover, the nuisance effect of the demolishing work on the use of the adjacent buildings should be kept to the minimum.

No structure or part of the structure or any floor or temporary support or scaffold, side wall or any device for equipment shall be loaded in excess of the safe carrying capacity, in its then existing condition.

30 PRECAUTIONS PRIOR TO DEMOLITION

30.1 On every demolition job, danger signs shall be conspicuously posted all around the structure and all doors and openings giving access to the structure shall be kept barricaded or manned except during the actual passage of workmen or equipment. However, provisions shall be made for at least two independent exits for escape of workmen during any emergency.

30.2 During nights, red lights shall be placed on or about all the barricades.

30.3 Where in any work of demolition it is imperative, because of danger existing, to ensure that no unauthorized person shall enter the site of demolition outside hours; a watchman should be employed. In addition to watching the site he shall also be responsible for maintaining all notices, lights and barricades.

30.4 All the necessary safety appliances shall be issued to the workers and their use explained. It shall be ensured that the workers are using all the safety appliances while at work.

30.5 The power on all electrical service lines shall be shut off and all such lines cut or disconnected at or outside the property line, before the demolition work is started. Prior to cutting of such lines, the necessary approval shall be obtained from the electrical authorities concerned. The only exception will be any power lines required for demolition work itself.

30.6 All gas, water steam and other service lines shall be shut off and capped or otherwise controlled at or outside the building line, before demolition work is started.

30.7 All the mains and meters of the building shall be removed or protected from damage.

30.8 If a structure to be demolished has been partially wrecked by fire, explosion or other catastrophe, the walls and damaged roofs shall be shored or braced suitably.

30.9 Protection of the Public

30.9.1 Safety distances to ensure safety of the public shall be clearly marked and prominently sign posted. Every sidewalk or road adjacent to the work shall be closed or protected. All main roads, which are open to the shall be kept open to the public clear and unobstructed at all times. Diversions for pedestrians shall be constructed, where necessary for safety.

30.9.2 If the structure to be demolished is more than two storeyed or 7.5 m high, measured from the side walk or street which can not be closed or safely diverted, and the horizontal distance from the inside of the sidewalk to the structure is 4.5 m or less, a substantial sidewalk shed shall be constructed over the entire length of the sidewalk adjacent to the structure, of sufficient width with a view to accommodating the pedestrian traffic without causing congestion. The side walk shed shall be lighted sufficiently to ensure safety at all times. For detailed information reference may be made to good practice [7(37)].

A toe board of at least 1 m high above the roof of the shed shall be provided on the outside edge and ends of the sidewalk shed. Such boards may be vertical or inclined outward at not more than 45°.

Except where the roof of a sidewalk shed solidly abuts the structure, the face of the sidewalk shed towards the building shall be completely closed by providing sheating/planking to prevent falling material from penetrating into the shed.

The roof of sidewalk sheds shall be capable of sustaining a load of 73 N/mm^2. Only in exceptional cases, say due to lack of other space, the storing of material on a sidewalk shed may be permitted in which case the shed shall be designed for a load of 146 N/mm^2. Roof of sidewalk shed shall be designed taking into account the impact of the falling debris. By frequent removal of loads it shall be ensured that the maximum load, at any time, on the roof of work shed is not more than 6 000 N/mm^2. The height of sidewalk shed shall be such as to give a minimum clearance of 2.4 m.

Sidewalk shed opening, for loading purposes, shall be kept closed at all time except during actual loading operations.

The deck flooring of the sidewalk shed shall consist of plank of not less than 50 mm in thickness closely laid and deck made watertight. All members of the shed shall be adequately bracked and connected to resist displacement of members or distortion of framework.

30.9.3 When the horizontal distance from the inside of the sidewalk to the structure is more than 4.5 m and less than 7.5 m, a sidewalk shed or fence a substantial railing shall be constructed on the inside of the sidewalk or roadway along the entire length of the demolition side of the property with movable bars as may be necessary for the proper prosecution of the work.

31 PRECAUTIONS DURING DEMOLITION

31.1 Prior to commencement of work, all material of fragile nature like glass shall be removed.

31.2 All openings shall be boarded up.

31.3 Dust shall be controlled by suitable means to prevent harm to workmen.

31.4 Stacking of materials or debris shall be within safe limits of the structural member. Additional supports, where necessary, shall be given.

31.5 Adequate natural or artificial lighting and ventilation shall be provided for the workmen.

32 SEQUENCE OF DEMOLITION OPERATIONS

32.1 The demolition work shall be proceeded with in such a way that:

a) it causes the least damage and nuisance to the adjoining building and the members of the public, and
b) it satisfies all safety requirements to avoid any accidents.

32.2 All existing fixtures required during demolition operations shall be well protected with substantial covering to the entire satisfaction of the rules and regulations of the undertakings or they shall be temporarily relocated.

32.3 Before demolition work is started, glazed sash, glazed doors and windows, etc, shall be removed. All fragile and loose fixtures shall be removed. The lath and all loose plaster shall be stripped off throughout the entire building. This is advantageous because it reduces glass breakage and also eliminates a large amount of dust producing material before more substantial parts of the buildings are removed.

32.4 All well openings which extend down to floor level shall be barricaded to a height of not less than 1 m above the floor level. This provision shall not apply to the ground level floor.

32.5 All floor openings and shafts not used for material chutes shall be floored over and be enclosed with guard rails and toe boards.

32.6 The demolition shall always proceed systematically storey by storey. In the descending order. All work in the upper floor shall be completed and approved by the engineer-in-charge prior to disturbance to any supporting member on the lower floor. Demolition of the structure in sections may be permitted in exceptional cases if proper precautions are ensured to prevent injuries to persons and damage to property.

33 WALLS

33.1 While walls of sections of masonry are being demolished, it shall be ensured that they are not allowed to fall as single mass upon the floors of the building that are being demolished so as to exceed the safe carrying capacity of the floors. Overloading of floors shall be prevented by removing the accumulating debris through chutes or by other means immediately. The floor shall be inspected by the engineer-in-charge before undertaking demolition work and if the same is found to be incapable to carry the load of the debris, necessary additional precautions shall be taken so as to prevent any possible unexpected collapse of the floor.

33.2 Walls shall be removed part by part. Stages shall be provided for the men to work on if the walls are less than one and a half brick thick and dangerous to work by standing over them.

33.3 Adequate lateral bracing shall be provided for walls which are unsound. For detailed information reference may be made to good practice [7(37)].

34 FLOORING

34.1 Prior to removal of masonry or concrete floor adequate support centering shall be provided.

34.2 When floors are being removed, no workmen shall be allowed to work in the area, directly underneath and such area shall be barricaded to prevent access to it.

34.3 Planks of sufficient strength shall be provided to give workmen firm support to guard against any unexpected floor collapse.

34.4 When floors are being removed no person shall be allowed to work in an area directly underneath and access to such area shall be barricaded.

35 DEMOLITION OF STEEL STRUCTURES

35.1 When a derrick is used, care shall be taken to see that the floor on which it is supported is amply strong for the loading so imposed. If necessary heavy planking shall be used to distribute the load to floor beam and girders.

35.2 Overloading of equipment shall not be allowed.

35.3 Tag lines shall be used on all materials being lowered or hoisted up and a standard signal system shall be used and the workmen instructed on the signals.

35.4 No person shall be permitted to ride the load line.

35.5 No beams shall be cut until precautions have been taken to prevent it from swinging freely and possibly striking any worker or equipment to any part of the structure being demolished.

35.6 All structural steel members shall be lowered from the building and shall not be allowed to drop.

36 CATCH PLATFORM

36.1 In demolition of exterior walls of multistorey structures, catch platform of sufficient strength to prevent injuries to workers below and public shall be provided, when the external walls are more than 20 m in height.

36.2 Such catch platform shall be constructed and maintained not more than 3 storeys below the storey from which exterior wall is being demolished. When demolition has progressed to within 3 storeys of ground level, catch platform will not be considered necessary.

36.3 Catch platform shall be capable of sustaining a live load of not less than 6 100 N/m^2.

36.4 Materials shall not be dumped on the catch platform nor shall they be used for storage of materials.

37 STAIRS, PASSAGEWAYS AND LADDERS

37.1 Stairs with railings, passageways and ladders shall be left in place as long as possible and maintained in a safe condition.

37.2 All ladders shall be secured against, slipping out at the bottom and against movement in any direction at the top.

38 MECHANICAL DEMOLITION

When demolition is to be performed by mechanical devices, such as weight ball and power shovels, the following additional precautions may be observed:

a) The area shall be barricaded for a minimum distance of 1½ times the height of the wall,

b) While the mechanical device is in operation, no workmen shall be allowed to enter the building being demolished,

c) The device shall be so located as to avoid falling debris, and

d) The mechanical device when being used shall not cause any damage to adjacent structure, power line, etc.

39 DEMOLITION OF CERTAIN SPECIAL TYPES AND ELEMENTS OF STRUCTURES

39.1 Roof Trusses

If a building has a pitched roof, the structure should be removed to wall plate level by hand methods. Sufficient purlins and bracing should be retained to ensure stability of the remaining roof trusses while each individual truss is removed progressively.

39.1.1 Temporary bracking should be added, where necessary, to maintain stability. The end frame opposite to the end where dismantling is commenced, or a convenient intermediate frame should be independently and securely guyed in both directions before work starts.

39.1.2 On no account should the bottom tie of roof trusses be cut until the principal rafters are prevented from making out ward movement.

39.1.3 Adequate hoisting gears suitable for the loads shall be provided. If during demolition any thing is to be put on the floor below the level of the truss, it shall be ensured that the floor is capable of taking the load.

39.2 Heavy Floor Beams

Heavy baulks of timber and steel beams should be supported before cutting at the extremities and should then be lowered gently to a safe working place.

39.3 Jack Arches

Where tie rods are present between main supporting beams, these should not be cut until after the arch or series of arches in the floor have been removed. The floor should be demolished in strips parallel to the span of the arch rings (at right angles to the main floor beams).

39.4 Brick Arches

Expert advice should be obtained and, at all stages of the demolition, the closet supervision should be given by persons fully experienced and conversant in the type of work to ensure that the structure is stable at all times.

However, the following points may be kept in view.

39.4.1 On no account should the restraining influence of the abutments be removed before the dead load of the spandrel fill and the arch rings are removed.

39.4.2 A single span arch can be demolished by hand by cutting narrow segments progressively from each springing parallel to the span of the arch, until the width of the arch has been reduced to a minimum which can then be collapsed.

39.4.3 Where deliberate collapse is feasible, the crown may be broken by the demolition ball method working progressively from edges to the centre.

39.4.4 Collapse of the structure can be effected in one action by the use of explosives. Charges should be inserted into bore holes drilled in both arch and abutments.

39.4.5 In multi-span arches, before individual arches are removed, lateral restraint should be provided at the springing level. Demolition may then proceed as for single span; where explosives are used it is preferable to ensure the collapse of the whole structure in one operation to obviate the chance of leaving unstable portion standing.

39.5 Cantilever (Not Part of a Framed Structure)

Canopies, cornices, staircases and balconies should be demolished or supported before tailing down load is removed.

39.6 *In-situ* Reinforced Concrete

Before commencing demolition, the nature and condition of the concrete, the condition and position of reinforcement, and the possibility of lack of continuity of reinforcement should be ascertained.

Demolition should be commenced by removing partitions and external non-load bearing cladding.

39.6.1 *Reinforced Concrete Beams*

A supporting rope should be attached to the beam. Then the concrete should be removed from both ends by pneumatic drill and the reinforcement exposed. The reinforcement should then be cut in such a way as to allow the beam to be lowered under control to the floor.

39.6.2 *Reinforced Concrete Columns*

The reinforcement should be exposed at the base after restraining wire guy ropes have been placed round the member at the top. The reinforcement should then be out in such a way as to allow it to be pulled down to the floor under control.

39.6.3 *Reinforced Concrete Walls*

These should be cut into strips and demolished as for columns.

39.6.4 *Suspended Floors and Roofs*

The slab should be cut into strips parallel to the main reinforcement and demolished strip by strip. Where ribbed construction has been used, the principle of design and method of construction should be determined before demolition is commenced. Care should be taken not to cut the ribs inadvertently.

39.7 Precast Reinforced Concrete

Due precautions shall be taken to avoid toppling over of prefabricated units or any other part of the structure and whenever necessary temporary supports shall be provided.

39.8 Prestressed Reinforced Concrete

Before commencing of the demolition work, advice of an engineering expert in such demolition shall be obtained and followed.

40 LOWERING, REMOVAL AND DISPOSAL OF MATERIALS

40.1 Dismantled materials may be thrown to the ground only after taking adequate precautions. The material shall preferably be dumped inside the building. Normally such materials shall be lowered to the ground or to the top of the sidewalk shed where provided by means of ropes or suitable tackles.

40.2 Through Chutes

40.2.1 Wooden or metal chutes may be provided from removal of materials. The chutes shall preferably be provided at the centre of the building for efficient disposal of debris.

40.2.2 Chutes, if provided at an angle of more than 45° from the horizontal, shall be entirely enclosed on all the four sides, except for opening at or about the floor level for receiving the materials.

40.2.3 To prevent the descending material attaining a dangerous speed, chute shall not extend in an unbroken line for more than two storeys. A gate or stop shall be provided with suitable means for closing at the bottom of each chute to stop the flow of materials.

40.2.4 Any opening into which workmen dump debris at the top of chute shall be guarded by a substantial guard rail extending at least 1 m above the level of the floor or other surface on which men stand to dump the materials into the chute.

40.2.5 A toe board or bumper, not less than 50 mm thick and 150 mm high shall be provided at each chute openings, if the material is dumped from the wheel barrows. Any space between the chute and the edge of the opening in the floor through which it passes shall be solidly planked over.

40.3 Through Holes in the Floors

40.3.1 Debris may also be dropped through holes in the floor without the use of chutes. In such a case the total area of the hole cut in any intermediate floor, one which lies between floor that is being demolished and the storage floor shall not exceed 25 percent of such floor area. It shall be ensured that the storage floor is of adequate strength to withstand the impact of the falling material.

40.3.2 All intermediate floor openings for passage of

materials shall be completely enclosed with barricades or guard rails not less than 1 m high and at a distance of not less than 1 m from the edge of general opening. No barricades or guard rails shall be removed until the storey immediately above has been demolished down to the floor line and all debris cleared from the floor.

40.3.3 When the cutting of a hole in an intermediate floor between the storage floor and the floor which is being demolished makes the intermediate floor or any portion of it unsafe, then such intermediate floor shall be properly shored. It shall also be ensured that the supporting walls are not kept without adequate lateral restraints.

40.4 Removal of Materials

40.4.1 As demolition work proceeds, the released serviceable materials of different types shall be separated from the unserviceable lot (hereinafter called '*MALBA*') at suitable time intervals and properly stocked clear of the spots where demolition work is being done.

40.4.2 The *MALBA* obtained during demolition shall be collected in well-formed heaps at properly selected places, keeping in view safe conditions for workmen in the area. The height of each *MALBA* heap shall be limited to ensure its toppling over or otherwise endangering the safety of workmen or passersby.

40.4.3 The *MALBA* shall be removed from the demolition site to a location as required by the local civil authority. Depending on the space available at the demolition site, this operation of conveying *MALBA* to its final disposal location may have to be carried out a number of times during the demolition work. In any case, the demolition work shall not be considered as completed and the area declared fit for further occupation till all the *MALBA* has been carried to its final disposal location and the demolition areas tidied up.

40.4.4 Materials which are likely to cause dust nuisance or undue environmental pollution in any other way, shall be removed from the site at the earliest and till then they shall be suitable covered. Such materials shall be covered during transportation also.

40.4.5

a) Glass and steel should be dumped or buried separately to prevent injury.

b) Workman should be provided with suitable protective gears for personal safety during works, lie safety helmets, boots, hand gloves, goggles, special attire, etc.

c) The work of removal of debris should be carried out during day. In case of poor visibility artificial light may be provided.

d) The debris should first be removed from top. Early removal from bottom or sides of dump may cause collapse of debris, causing injuries.

41 MISCELLANEOUS

41.1 No demolition work should be carried out during night as far as possible, especially when the structure to be demolished is in an inhabited area. If such night work has to be done, additional precautions by way of additional red warning signals, working lights and watchmen, shall be provided to avoid any injury to workmen and public. Demolition work shall not be carried out during storm and heavy rain.

41.2 Warning devices shall be installed in the area to warn the workers in case of any danger.

41.3 Safety devices like industrial safety helmets conforming to the accepted standards [7(9)] and goggles made of celluloid lens, shall be issued to the workmen. Foreman-in-charge of the work areas shall ensure that all the workmen are wearing the safety devices before commencing any work.

41.4 Construction sheds and tool boxes shall be so located as to protect workers from injuries from the falling debris.

41.5 Where there is a likelihood of injuries to hands of workmen when demolishing RCC, steel structures, etc, gloves of suitable materials shall be worn by workmen.

41.6 Sufficient protection by way of both overhead cover and screens shall be provided to prevent injuries to the workmen and the public.

41.7 Safety belts or ropes shall be used by workmen when working at higher levels.

41.8 Grading of Plot

When a building has been demolished and no building operation has been projected or approved, the vacant plot shall be filled, graded and maintained in conformity to the established street grades at curb level. The plot shall be maintained free from the accumulation of rubbish and all other unsafe and hazardous conditions which endangers the life or health of the public; and provisions shall be made to prevent the accumulation of water or damage to any foundations on the premises or the adjoining property.

42 FIRST-AID

42.1 A copy of all pertinent regulations and notices concerning accidents, injury and first-aid shall be prominently exhibited at the work site.

42.2 Depending on the scope and nature of the work,

a person, qualified in first-aid shall be available at work site to render and direct first-aid to casualties. He shall maintain a list of individuals qualified to serve in first-aid work. Enough first-aid kit, including a stretcher and cot with accessories shall be provided at site. A telephone may be provided to first-aid assistant with telephone numbers of the hospitals prominently displayed.

Complete reports of all accidents and action taken thereon shall be forwarded to the competent authorities.

ANNEX A

(*Clause* 2.1.2)

PROGRAMME EVALUATION AND REVIEW TECHNIQUE, AND CRITICAL PATH METHOD

A-0 INTRODUCTION

A-0.1 Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM) are modern management tools or devices, which have made it possible to achieve considerable savings in cost and time of construction. They can be used with advantage for demolition, constructional safety and fire protection measures, by including them in the list of activities (also called events) along-side with other 'events' of the project.

A-0.2 Advance Planning

A-0.2.1 PERT and CPM enable us to achieve judicious employment and utilization of resources, such as labour, materials, and equipment by pre-determining the various stages, listing out the various activities and drawing out 'Arrow Network Diagram'.

A-0.3 Synchronization of Sub-Projects

A-0.3.1 Another extremely important advantage of CPM is that various factors influencing completion of a project can be scientifically planned to be coordinated such that the completion of various sub-projects and services, such as furniture, sewage, electricity and water supply synchronises.

A-1 PREPARATION OF CPM CHART (LISTING OUT THE ACTIVITIES)

A-1.1 The most important step in preparation of CPM network is to list out the activities involved to the minutest details. For example, a few activities in case of a building project are given below:

a) Planning and designing of building by architect, engineer and approval of plans by the Authority.
b) Making the land available.
c) Outlining detailed specifications.
d) Procurement of materials, such as sand, cement, stone and timber; and plants, such as concrete mixer, vibrators, water pump for curing.
e) Soil explorations and trial pits.
f) Excavation in foundations, including demolition, if needed.
g)[1] Construction safety aspects specially in case of pile foundations.
h)[1] Blasting if required (for deep foundations).
j)[1] Fire protection measures.

A-1.2 Time Needed for Each Activity

An assessment is to be made to find out the time needed for each activity and then to list out those activities, which can be executed concurrently (or simultaneously) with each other. For example, while designing of the building is in hand, correspondence for land purchase can also go on side by side; or while work in foundations is in progress, order for 'joinery' can be placed.

A-1.3 Critical Activity

It should then be seen as to which of the activities are critical, that is which items are such that a single day's delay will mean overall delay on the project. Contrary to this, it will be seen from CPM Network that certain activities can be delayed to a certain extent without delaying the completion of the project. This is a very useful and valuable information for the 'Project Manager'. That is where resources scheduling becomes easier and economical and a time saver. It eliminates chances of idle labour and higher expenses which are results of haphazard planning.

A-2 UPDATING

A-2.1 In implementing the CPM, there could be gaps between the planned CPM and actual progress

[1] These can be further sub-divided and number of activities increased.

or position on ground. This should be checked periodically-weekly, fortnightly or monthly depending on nature and size of project.

A-3 GENERAL

A-3.1 In case of projects being executed by contractors for the owners, or departments, it is recommended that it should be an essential condition of the contract to submit a CPM Chart along with the quoted tenders. This will ensure that the construction work will be according to a systematic, engineer-like and well-knit plan of execution.

ANNEX B

(*Clause* 4.1)

CHECK LIST FOR STACKING AND STORAGE OF MATERIALS

Sl No.	*Material/Component*	*Base*			*Stack*				*Type of Cover*		
		Firm Level Ground	Hard Floor	Off-Floor	Heaps	Tiers	Flat	Vertical	Open	Open but covered	Under shed
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1.	Cement			✓		✓					✓
2.	Lime										
	a) Quick lime		✓		✓					✓	
	b) Hydrated lime			✓		✓					✓
3.	Stones and Aggregates										
	a) Stones, aggregates, fly ash and cinder	✓			✓				✓		
	b) Veneering stones	✓				✓		✓	✓		
4.	Bricks and Blocks	✓				✓			✓		
5.	Tiles										
	a) Clay and concrete floor, wall and roof tiles	✓				✓	✓		✓		
	b) Ceramic tiles		✓			✓	✓				✓
6.	Partially Pre-fabricated Wall and Roof Components										
	a) RC planks, prefabricated brick panels and ferro-cement panels	✓						✓	✓		
	b) Channel units, cored units and L-Panels	✓				✓			✓		
	c) Waffle units, RC joists, single tee and double tee	✓					✓		✓		
7.	Timber			✓		✓					✓
8.	Steel	✓					✓		✓		
9.	Aluminium Sections		✓				✓				✓
10.	Doors, Windows and Ventilators		✓					✓			✓
11.	Roofing Sheets										
	a) AC	✓				✓	✓		✓		
	b) GI and Aluminium sheets	✓				✓	✓			✓	
	c) Plastic sheets			✓		✓	✓				✓

ANNEX B — *Continued*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
12.	Boards like Plywood, Particle Boards, Fibre Boards, Blockboards and Gypsum Board			✓		✓	✓				✓
13.	Plastic and Rubber Flooring										
	a) Sheets in rolls	✓						✓			✓
	b) Tiles	✓				✓	✓				✓
14.	Glass Sheets		✓					✓			✓
15.	Glass Bricks/Blocks		✓			✓					✓
16.	CI, GI and AC Pipes and Fittings										
	a) Pipes	✓				✓	✓		✓		
	b) CI and GI Fittings		✓				✓				✓
	c) AC Fittings		✓				✓		✓		
17.	Polyethylene Pipes			✓		✓	✓				✓
18.	Unplasticized PVC Pipes	✓				✓	✓		✓		
19.	Bitumen, Road Tar, Asphalt, etc in Drums	✓				✓			✓		
20.	Oil Paints		✓			✓					✓
21.	Sanitary Appliances			✓			✓				✓

ANNEX C

(*Clause* 26.3.2.2.2)

COMMON CAUSES FOR MAINTENANCE PROBLEMS

C-0 MAJOR CAUSES FOR MAINTENANCE PROBLEMS

C-1 FLOORS

a) Poor quality of construction which includes quality of construction material and workmanship.

b) Improper slopes, mainly in kitchen, bathrooms/ toilets etc.

c) Lack of rounding at junctions of walls with floors.

d) Lack of dampproof course treatment in walls and particularly in sunken floors.

e) Poor design of building.

C-2 ROOFS

a) Inadequate roof slopes.

b) Inferior quality of construction.

c) Cracks on roof surfaces.

d) Inadequate provision of rain water spouts.

e) Blockages in gratings/rain water pipes.

f) Worn out felts.

g) Bubbling up of tarfelt and separation of joints.

h) Leakage from the openings provided on the roof.

C-3 PLUMBING

a) Inadequate slopes in soil/waste pipes.

b) Improper lead joints.

c) Joints in walls.

d) Improper junctions of stacks.

e) Inadequate cleaning eyes at junctions.

f) Inadequate slopes in sewage pipes.

g) Throwing of solid wastes in WC's.

h) Lack of periodical checking and cleaning.

j) Lack of motivation/education to users for proper use.

k) Overflow from service tanks.

m) Inferior quality of fittings and fixtures.

n) Inadequate design.

C-4 DRAINAGE

a) Improper surface dressing around buildings and improper upkeep of surroundings.
b) Growth of wild grass and vegetation.
c) Inadequate drainage system around the building.
d) Inadequate slope of the drains or drainage pipes.
e) Inadequate number of inspection chambers.
f) Theft of manhole covers etc.
g) Throwing of solid waste in the open surface drains.

C-5 ELECTRICAL

a) Loose connections.
b) Improper earthing and earth connections.
c) Damages to wires, cables and other installations.
d) Under rated cables/wires and other installations.

ANNEX D

(*Clause* 26.6.5)

FORMAT FOR INSPECTION REPORT

Date : .....
Building/Block : .....
.....

	Condition		
	Sound	Suspect	Defective
FLOORS & STAIRCASES			
Ground Floor			
Finish			
Skirting			
Structure			
Damp-proofing			
Ceiling			
Under floors, spaces, (Suspended floors)			
Termites/insects			
Upper Floors			
Finish			
Structure			
Ceiling			
Suspended ceiling			
Stair cases			
Structure			
Treads			
Finishes			
Balustrade			
Soffits			
Finish			
ROOFING			
Flat/Pitched			
Finish			
Insulation			
Structure			

ANNEX D — *Continued*

		Condition		
		Sound	Suspect	Defective
Roof lights/glazing				
Parapets				
Cutters				
Rain Water Pipes				
Mud *Phuska*				
Roof interiors (Pitched)				
Growth of vegetation				
SANITARY INSTALLATIONS				
Plumbing				
Fittings/Pipings, WC's				
Taps				
Sinks				
Basins				
Urinals				
Cisterns				
Geysers				
Sewage Disposal				
Soil pipes				
Manholes				
Sewerlines				
Drainage				
Gully chambers				
Sewers				
Surface drains				
Inspection chambers				
Structural movement				
Failure of material				
Design or construction defects				
Overhead Tanks/Underground				
Sumps/Terrace Tanks				
Septic Tanks				
Remarks				

ANNEX E

(*Clause* 26.7.3.2)

GUIDELINES FOR MAINTENANCE OF ELECTRICAL EQUIPMENTS

E-1 In case of electrical appliances, manufacturer's instructions for the usage and maintenance of the equipment should be strictly followed.

E-2 The detailed/working drawings of all the components of electrical installations should always be available with the maintenance unit. Following records should be available.

a) Manufacturer's name

b) Nameplate of the equipment and its sailent features such as capacity, rating etc.

c) Manufacturer's recommendations regarding availability/usage of spare parts.

d) Manufacturer's recommendations for periodical maintenance and post fault maintenance.

e) Details of the maintenance operations performed in the past.

E-3 Care should be taken while selecting replacement parts. The spare parts should be correct and suitable, preferably as recommended by the manufacturer of the installation. During the placement of order for the supply of spare parts, nameplate particulars and serial number should be quoted.

E-4 The space where the equipment is kept should be clean and properly ventilated. Equipment should not be disturbed needlessly. Before cleaning, the equipment should be made dead. For internal cleaning a section cleaner should be used.

E-5 Covers and doors should not be left open unnecessarily during maintenance. Afterwards they should be promptly and correctly closed and locked.

E-6 Before removing the covers and connections, all covers and cable terminations should be marked to ensure correct replacements. Disturbed connections and temporary connections should be marked to facilitate re-connection. Temporary connections and markings should be removed before the installation is put to use.

E-7 Those connections which have not been disturbed should also be checked for soundness and overheating.

E-8 All insulations should be regularly checked. Solid insulations should be checked for cracks and other defects. Fibrous and organic insulations should be checked for sign of blistering, delamination and mechanical damage. For insulating oils the interval between tests should be carried out as per the recommendations of the manufacturer and keeping the adverse environmental conditions in mind.

E-9 It should be ensured that the earthing connections are sound and all contact screws are tight.

E-10 During the examination of interlocks it is necessary to take precautions to prevent danger to plant or persons in the event of malfunction or inadvertent operation. A person responsible for checking and maintaining any interlock system should have thorough knowledge of the extent, nature and function of the interlock.

E-11 If the equipment is ventilated then it should be ensured that the airflow is smooth and not restricted. If filters are provided, they should be cleaned or replaced as necessary.

E-12 The standby system for tripping and closing supplies should always be kept in good order. Indicators and alarms should be maintained in time with the manufacturer's instructions.

E-13 Tools, spares and instruments should be stored near to the installation. These should be regularly checked against an inventory.

E-14 Before the start of maintenance of the circuit switches it should be ensured that all incoming and outgoing main auxiliary circuits are dead and remain so during the maintenance. Over heating of the circuit switches is the root cause for faults. Overheating may be caused by inadequate ventilation, overloading, loose connection, insufficient contact force and malalignment.

E-15 Some circuit breakers are not intended to be maintained, such as miniature circuit breakers (MCBs). Such items should not be dismantled for maintenance. These should be renewed periodically.

E-16 For the maintenance of fuses periodical inspection should be done for correct rating, security, overheating and correct location/orientation. Element of renewable fuses should be renewed when the deterioration is apparent. The availability and correct replacement of fuse links should be ensured.

E-17 If a fuse link of certain rating has failed and is replaced, then all fuse-links of same rating apparently subjected to the fault should be destroyed and replaced by new fuse links.

E-18 In order to be reasonably sure that circuit breaker is capable of operation when required, these should be tripped and reclosed at regular intervals. Tripping should be proved manually and where possible electrically via the protective relay contacts. The leakage of oil, sign of corrosion, and any unusual smell which may indicate over-heating should be detected through inspections.

E-19 Timing devices are mostly designed for specialist maintenance. These should not be dismantled for maintenance or overhaul purposes unless specifically recommended by the manufacturers'. Actual timing periods should be verified with set values and application requirements.

E-20 In case of cable boxes and terminations, security of mounting and earthing should be examined. Exposed tails should be inspected for good conditions of insulation and freedom from moisture.

E-21 Battery cells should be inspected for shedding of active material, sedimentation and buckling of plates. Level of electrolyte should be regularly checked and the level should be corrected with distilled water.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

	IS No.	*Title*
(1)	a) *Foundations*	
	1080 : 1985	Code of practice for design and construction of shallow foundations on soils (other than raft, ring and shell) (*second revision*)
	1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
	2911	Code of practice for design and construction of pile foundations
	(Part 1/Sec 1) : 1979	Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*first revision*)
	(Part 1/Sec 2) : 1979	Concrete piles, Section 2 Board cast *in-situ* piles (*first revision*)
	(Part 1/Sec 3) : 1979	Concrete piles, Section 3 Driven precast concrete piles (*first revision*)
	(Part 1/Sec 4) : 1984	Concrete piles, Section 4 Bored precast concrete piles (*first revision*)
	(Part 2) : 1980	Timber piles (*first revision*)
	(Part 3) : 1980	Under-reamed piles (*first revision*)
	(Part 4) : 1985	Load test on piles (*first revision*)
	2974	Code of practice for design and construction of machine foundations
	(Part 1) : 1982	Foundations for reciprocating type machines (*second revision*)
	(Part 2) : 1980	Foundations for impact type machines (hammer foundations) (*first revision*)
	(Part 3) : 1992	Foundations for rotary type machines (medium and high frequency) (*second revision*)
	(Part 4) : 1979	Foundations for rotary type machines of low frequency (*first revision*)
	(Part 5) : 1987	Foundations for impact machines other than hammers forging and stamping press pig breakers (drop crusher and jolter) (*first revision*)
	9456 : 1980	Code of practice for design and construction of conical and hyperbolic paraboidal types of shell foundations
	9556 : 1980	Code of practice for design and construction of diaphragm walls
	13094 : 1992	Guidelines for selection of ground improvement techniques for foundation in weak soils
	15284 (Part 1) : 2003	Design and construction for ground improvement: Part 1 Stone columns
	b) *Masonry*	
	1597	Code of practice for construction of stone masonry
	(Part 1) : 1992	Rubble stone masonry (*first revision*)
	(Part 2) : 1992	Ashlar masonry (*first revision*)
	2110 : 1980	Code of practice for *in-situ* construction of walls in buildings with soil-cement (*first revision*)
	2212 : 1991	Code of practice for brickwork (*first revision*)
	2250 : 1981	Code of practice for preparation and use of masonry mortars (*first revision*)
	2572 : 1963	Code of practice for construction of hollow concrete block masonry

IS No.	*Title*
3630 : 1992	Code of practice for construction of non-load bearing gypsum block partitions (*first revision*)
4407 : 1967	Code of practice for reed walling
4441 : 1980	Code of practice for use of silicate type chemical resistant mortars (*first revision*)
4442 : 1980	Code of practice for use of sulphur type chemical resistant mortars (*first revision*)
4443 : 1980	Code of practice for use of resin type chemical resistant mortars (*first revision*)
6041 : 1985	Code of practice for construction of autoclaved cellular concrete block masonry (*first revision*)
6042 : 1969	Code of practice for construction of light weight concrete block masonry (*first revision*)
c) *Timber and Bamboo*	
1634 : 1992	Code of practice for design and constructions of wood stair for houses (*second revision*)
2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
3670 : 1989	Code of practice for construction of timber floors (*first revision*)
4913 : 1968	Code of practice for selection, installation and maintenance of timber doors and windows
4983 : 1984	Code of practice for design and construction of nail laminated timber beams
5390 : 1984	Code of practice for construction of timber ceilings (*first revision*)
11096 : 1984	Code of practice for design and construction of bolt-jointed timber construction
12506 : 1988	Code of practice for improved thatching of roof with wrought and fire retardant treatment
d) *Concrete*	
456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
457 : 1957	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
2502 : 1963	Code of practice for bending and fixing of bars for concrete reinforcement
2541 : 1991	Code of practice for preparation and use of lime concrete (*second revision*)
3370	Code of practice for concrete structures for the storage of liquids
(Part 1) : 1965	General requirements
(Part 2) : 1965	Reinforced concrete structures
(Part 3) : 1967	Prestressed concrete structures
3558 : 1983	Code of practice for use of immersion vibrators for consolidating concrete (*first revision*)
5817 : 1992	Code of practice for preparation and use of lime pozzolana mixture concrete in buildings and roads (*first revision*)
7246 : 1974	Recommendations for use of table vibrators for consolidating concrete
7861	Code of practice for extreme whether concreting
(Part 1) : 1975	Recommended practice for hot weather concreting
(Part 2) : 1981	Recommended practice for cold weather concreting
10262 : 1982	Recommended guidelines for concrete mix design
10359 : 1982	Code of practice for manufacture and use of lime pozzolana concrete blocks for paving

IS No.	*Title*
14687 : 1999	Guidelines for falsework for concrete structures
e) *Steel*	
800 : 1984	Code of practice for general steel construction (*second revision*)
801 : 1975	Code of practice for use of cold formed light gauge steel structural members in general building construction (*first revision*)
805 : 1968	Code of practice for use of steel in gravity water tanks
806 : 1968	Code of practice for use of steel tubes in general building construction (*first revision*)
4000 : 1992	Code of practice for high strength bolts in steel structures (*first revision*)
4180 : 1967	Code of practice for corrosion protection of light gauge steel sections used in building
6533	Code of practice for design and construction of steel chimneys
(Part 1) : 1989	Mechanical aspects (*first revision*)
(Part 2) : 1989	Structural aspects (*first revision*)
8629 (Parts 1 to 3) : 1977	Code of practice for protection of iron and steel structures from atmospheric corrosion
9077 : 1979	Code of practice of corrosion protection of steel reinforcement in RB and RCC construction
9172 : 1979	Recommended design practice for corrosion prevention of steel structures
f) *Flooring and Roofing*	
658 : 1982	Code of practice for magnesium oxychloride composition floors (*second revision*)
1196 : 1978	Code of practice for laying bitumen mastic flooring (*second revision*)
1197 : 1970	Code of practice for laying of rubber floors (*first revision*)
1198 : 1982	Code of practice for laying, fixing and maintenance of linoleum floor (*first revision*)
1443 : 1972	Code of practice for laying and finishing of cement concrete flooring tiles (*first revision*)
2118 : 1980	Code of practice for construction of jack-arch type of building floor or roof (*first revision*)
2119 : 1980	Code of practice for construction of brick-*cum*-concrete composite (Madras terrace) floor or roof (*first revision*)
2204 : 1962	Code of practice for construction of reinforced concrete shell roof
2571 : 1970	Code of practice for laying *in-situ* cement concrete flooring (*first revision*)
2700 : 1987	Code of practice for roofing with wooden shingles (*first revision*)
2792 : 1964	Code of practice for design and construction of stone slab over joist floor
2858 : 1984	Code of practice for roofing with Mangalore tiles (*first revision*)
3007	Code of practice for laying of asbestos cement sheets:
(Part 1) : 1999	Corrugated sheets (*first revision*)
(Part 2) : 1999	Semi-corrugated sheets (*first revision*)
3670 : 1989	Code of practice for construction of timber floors (*first revision*)
5119 (Part 1) : 1968	Code of practice for laying and fixing of sloped roof coverings: Part 1 Slating
5318 : 1969	Code of practice for laying of flexible PVC sheet and tile flooring

IS No.	*Title*
5389 : 1969	Code of practice for laying of hard wood parquet and wood block floors
5390 : 1984	Code of practice for construction of timber ceilings (*first revision*)
5766 : 1970	Code of practice for laying burnt clay brick flooring
6061	Code of practice for construction of floor and roof with joists and filler blocks
(Part 1) : 1971	With hollow concrete filler blocks
(Part 2) : 1981	With hollow clay filler blocks (*first revision*)
(Part 3) : 1981	Precast hollow clay blocks joists and hollow clay filler blocks
(Part 4) : 1981	With precast hollow clay block slab panels
6332 : 1984	Code of practice for construction of floors and roofs using precast doubly-curved shell units (*first revision*)
9472 : 1980	Code of practice for laying mosaic parquet flooring
10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/prestressed concrete ribbed or cored slab units
10440 : 1983	Code of practice for construction of reinforced brick and RBC floors and roofs
10505 : 1983	Code of practice for construction of floors and roofs using precast concrete waffle units
g) *Finishes*	
1346 : 1991	Code of practice for waterproofing of roofs with bitumen felts (*third revision*)
1414 : 1989	Code of practice for fixing wall coverings
1477	Code of practice for painting of ferrous metals in buildings
(Part 1) : 1971	Pretreatment (*first revision*)
(Part 2) : 1971	Painting (*first revision*)
IS 1609 : 1991	Code of practice for laying damp-proofing treatment using bitumen felts (*second revision*)
1661 : 1972	Code of practice for application of cement and cement lime plaster finishes (*first revision*)
2114 : 1984	Code of practice for laying *in-situ* terrazzo floor finish (*first revision*)
2115 : 1980	Code of practice for flat-roof finish: Mud PHUSKA (*second revision*)
2338	Code of practice for finishing of wood and wood based materials
(Part 1) : 1967	Operations and workmanship
(Part 2) : 1967	Schedules
2394 : 1984	Code of practice for application of lime plaster finish (*first revision*)
2395	Code of practice for painting concrete, masonry and plaster surfaces
(Part 1) : 1994	Operations and workmanship (*first revision*)
(Part 2) : 1994	Schedule (*first revision*)
2402 : 1963	Code of practice for external rendered finishes
2441 : 1984	Code of practice for fixing ceiling covering (*first revision*)
2524	Code of practice for painting of non-ferrous metals in buildings:
(Part 1) : 1968	Pre-treatment
(Part 2) : 1968	Painting
3036 : 1992	Code of practice for laying lime concrete for a water-proofed roof finish (*second revision*)
3067 : 1988	Code of practice for general design details and preparatory work for damp-proofing and waterproofing of buildings (*first revision*)

IS No.	*Title*
3140 : 1965	Code of practice for painting asbestos cement building products
3548 : 1988	Code of practice for glazing in building (*first revision*)
4101	Code of practice for external facing and veneers:
(Part 1) : 1967	Stone facing
(Part 2) : 1967	Cement concrete facing
(Part 3) : 1985	wall tiling and mosaics (*first revision*)
4365 : 1967	Code of practice for application of bitumen mastic for waterproofing of roofs
4597 : 1968	Code of practice for finishing of wood and wood based products with nitrocellulose and cold catalysed materials
4631 : 1986	Code of practice for laying of epoxy resin floor toppings (*first revision*)
5491 : 1969	Code of practice for laying *in-situ* granolithic concrete floor topping
6278 : 1971	Code of practice for white-washing and colour washing
6494 : 1988	Code of practice for water proofing of underground water reservoirs and swimming pools (*first revision*)
7198 : 1974	Code of practice for damp-proofing using bitumen mastic
7290 : 1979	Recommendations for use of polyethylene film for waterproofing of roofs (*first revision*)
9918 : 1981	Code of practice for *in-situ* waterproofing and damp-proofing treatments with glass fibre tissue reinforced bitumen
h) *Piping*	
783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
4127 : 1983	Code of practice for laying of glazed stoneware pipes (*first revision*)
5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)
5822 : 1994	Code of practice for laying of welded steel pipes for water supply (*second revision*)
6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
7634	Code of practice for plastics pipe work for portable water supplies:
(Part 1) : 1975	Choice of materials and general recommendations
(Part 2) : 1975	Laying and jointing polyethylene (PE) pipes
(Part 3) : 2003	Laying and jointing of unplasticized PVC pipes
j) *Measurements*	
1200	Method of measurement of building and civil engineering works:
(Part 1) : 1992	Earthwork (*fourth revision*)
(Part 2) : 1974	Concrete work (*third revision*)
(Part 3) : 1976	Brickwork (*third revision*)
(Part 4)1976	Stone masonry (*third revision*)
(Part 5) : 1982	Formwork (*third revision*)
(Part 6) : 1974	Refactory work (*second revision*)
(Part 7) : 1972	Hardware (*second revision*)
(Part 8) : 1993	Steel work and iron work (*fourth revision*)
(Part 9) : 1973	Roof covering (including cladding) (*second revision*)
(Part 10) : 1973	Ceiling and linings (*second revision*)
(Part 11) : 1977	Paving, floor finishes dado and skirting (*third revision*)
(Part 12) : 1976	Plastering and pointing (*third revision*)

IS No.	*Title*
(Part 13) : 1994	White washing, colour washing, distempering and painting of building surfaces (*fifth revision*)
(Part 14) : 1984	Glazing (*third revision*)
(Part 15) : 1987	Paining, polishing, varnishing, etc (*fourth revision*)
(Part 16) : 1979	Laying of water and sewer lines including appurtenant items (*third revision*)
(Part 17) : 1985	Roadwork including air field pavements (*third revision*)
(Part 18) : 1974	Demolition and dismantling (*third revision*)
(Part 19) : 1981	Water supply, plumbing and drains (*third revision*)
(Part 20) : 1981	Laying of gas and oil pipe lines (*third revision*)
(Part 21) : 1973	Woodwork and joinery (*second revision*)
(Part 23) : 1988	Piling (*fourth revision*)
(Part 24) : 1983	Well foundations (*third revision*)
3861 : 2002	Method of measurement of plinth, carpet and rentable areas of buildings (*second revision*)
k) *Others*	
1081 : 1960	Code of practice for fixing and glazing of metal (steel and aluminium) doors, windows and ventilators
1649 : 1962	Code of practice for design and construction of flues and chimneys for domestic heating appliances
1946 : 1961	Code of practice for use of fixing devices in walls, ceilings and floors of solid construction
2470	Code of practice for installation of septic tanks:
(Part 1) : 1985	Design criteria and construction (*second revision*)
(Part 2) : 1985	Secondary treatment and disposal of septic tank effluent (*second revision*)
2527 : 1984	Code of practice for fixing rain-water gutters and down pipes for roof drainage (*first revision*)
3414 : 1968	Code of practice for design and installation of joints in buildings
3548 : 1988	Code of practice for glazing in buildings (*first revision*)
3558 : 1983	Code of practice for use of immersion vibrators for consolidating concrete (*first revision*)
3935 : 1966	Code of practice for composite construction
4326 : 1993	Code of practice for earthquake resistant design and construction of buildings (*second revision*)
4913 : 1968	Code of practice for selection, installation and maintenance of timber doors and windows
6313	Code of practice for anti-termite measures in buildings:
(Part 1) : 1981	Constructional measures (*first revision*)
(Part 2) : 2001	Pre-constructional chemical treatment measures (*second revision*)
(Part 3) : 2001	Treatment for existing buildings (*second revision*)
6924 : 1973	Code of practice for the construction of refuse chutes in multistoreyed buildings
7246 : 1974	Recommendation for use of table vibrators for consolidating concrete
8147 : 1976	Code of practice for use of aluminium alloys in structures
(2) 13416 (Part 5) : 1994	Recommendations for preventive measure against hazards at workplaces: Part 5 Fire protection
(3) 11769 (Part 1) : 1987	Guidelines for safe use of products containing asbestos: Part 1 Asbestos cement products

	IS No.	Title
(4)	2190 : 1992	Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (*third revision*)
(5)	8758 : 1993	Recommendations for fire precautionary measures in construction of temporary structures and pandals (*first revision*)
(6)	10439 : 1983	Code of practice patent glazing
	14687 : 1999	Guidelines for falsework for concrete structures
(7)	3764 : 1992	Safety code for excavation work (*first revision*)
(8)	4138 : 1977	Safety code for working in compressed air (*first revision*)
(9)	2925 : 1984	Specification for industrial safety helmets (*second revision*)
(10)	2750 : 1964	Specification for steel scaffoldings
(11)	3696 (Part 1) : 1987	Safety code for scaffolds and ladders: Part 1 Scaffolds
(12)	3696 (Part 2) : 1991	Safety code for scaffolds and ladders: Part 2 Ladders
(13)	4912 : 1978	Safety requirements for floors and wall openings, railing and toe boards (*first revision*)
(14)	11461 : 1985	Code of practice for compressor safety
(15)	1179 : 1967	Specification for equipment for eye and face protection during welding (*first revision*)
(16)	5983 : 1980	Specification for eye-protectors (*first revision*)
(17)	2361 : 2002	Specification for bull-dog grips (*third revision*)
(18)	11057 : 1984	Specification for industrial safety nets
(19)	3016 : 1982	Code of practice for fire precautions in welding and cutting operations (*first revision*)
(20)	1084 : 1994	Specification for manila ropes (*fourth revision*)
	2266 : 2002	Specification for steel wire ropes for general engineering purposes (*forth revision*)
(21)	818 : 1968	Code of practice for safety and health requirements in electric and gas welding and cutting operations (*first revision*)
(22)	5916 : 1970	Safety code for constructions involving use of hot bituminous materials
(23)	13416 (Part 4) : 1994	Recommendations for preventive measure against hazards at workplaces: Part 4 Timber structure
(24)	2171 : 1999	Specification for portable fire extinguishers, dry powder (Cartridge type) (*third revision*)
(25)	819 : 1957	Code of practice for resistance spot welding for light assemblies in mild steel
	1261 : 1959	Code of practice for seam welding in mild steel
	3016 : 1982	Code of practice for fire precautions in welding and cutting operations (*first revision*)
	4081 : 1986	Safety code for blasting and related drilling operations (*first revision*)
	4138 : 1977	Safety code for working in compressed gas (*first revision*)
	9595 : 1996	Recommendations for metal arc welding of carbon and carbon manganese steels (*first revision*)
	10178 : 1995	Recommended procedure for CO_2 gas shielded metal-arc welding of structural steels (*first* revision)
(26)	3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision*)
	5290 : 1993	Specification for landing valves (*third revision*)

IS No.	*Title*
(27) 13416 (Part 2) : 1992	Recommendation for preventive measures against hazards at work places: Part 2 Fall prevention
(28) 13416 (Part 1) : 1992	Recommendation for preventive measures against hazards at work places: Part 1 Falling material hazard prevention
(29) 13416 (Part 3) : 1994	Recommendation for preventive measures against hazards at work places: Part 3 Disposal of debris
(30) 274	Specification for shovels:
(Part 1) : 1981	General purpose shovels (*third revision*)
(Part 2) : 1981	Heat-treated shovels (*third revision*)
663 : 1980	Specification for adzes (*second revision*)
704 : 1984	Specification for crow bars and claw bars (*second revision*)
841 : 1983	Specification for steel hammers (*second revision*)
844	Specification for screw drivers:
(Part 2) : 1979	Dimensions (*second revision*)
(Part 3) : 1979	Dimensions for screw drivers for recessed head screws (*second revision*)
1630 : 1984	Specification for mason's tools for plaster work and pointing work (*first revision*)
1759 : 1986	Specification for *POWRAHS* (*second revision*)
1791 : 1985	Specification for batch type concrete mixers (*second revision*)
1930 : 1995	Specification for chisels and gauges (*second revision*)
1931 : 2000	Specification for engineer's files (*third revision*)
2028 : 2004	Specification for open jaw wrenches (spanners) (*fourth revision*)
2029 : 1998	Specification for ring wrenches (spanners) (*fourth revision*)
2030 : 1989	Specification for box spanners (*second revision*)
2094	Specification for heater for bitumen (tar) and emulsion (*second revision*):
(Part 1) : 1996	Specification (*second revision*)
(Part 2) : 1999	Bitumen sprayer (*third revision*)
(Part 3) : 1999	Emulsion (*third revision*)
2431 : 1963	Specification for steel wheel barrows (single wheel-type)
2438 : 1963	Specification for roller pan mixer
2439 : 1963	Specification for metal hand rollers (fixed-weight type)
2505 : 1992	Specification for concrete vibrators, immersion type (general requirements)
2506 : 1985	General requirements for screed board concrete vibrators (*first revision*)
2514 : 1963	Specification for concrete vibrating tables
2587 : 1975	Specification for pipes vices (open side type and fixed sides type) (*first revision*)
2588 : 1975	Specification for blacksmith's vices (*first revision*)
2722 : 1964	Specification for portable swing weigh batchers for concrete (single and double bucket type)
2852 : 1998	Specification for carpenters augers (*first revision*)
3066 : 1965	Specification for hot asphalt mixing plants
3251 : 1965	Specification for asphalt paver finisher
3365 : 1965	Specification for floor polishing machines
3559 : 1966	Specification for pneumatic concrete breakers

IS No.	*Title*
3587 : 1986	Specification for rasps (*second revision*)
3650 : 1981	Specification for combination side cutting pliers (*second revision*)
3938 : 1983	Specification for electric wire rope hoists (*second revision*)
4003	Specification for pipe wrenches
(Part 1) : 1978	General purposes (*first revision*)
(Part 2) : 1986	Heavy duty (*first revision*)
4017 : 1992	Specification for carpenters squares (*first revision*)
4057 : 1986	Specification for carpenters adjustable metal bodied bench planes (*first revision*)
4095 : 1991	Specification for pincers (*second revision*)
4183 : 1967	Specification for metal hand rammers
4184 : 1967	Specification for steel wheel barrows (with two wheels)
4508 : 1992	Specification for open ended slugging wrenches (spanners) (*first revision*)
4656 : 1968	Specification for form vibrators for concrete
4915 : 1968	Specification for welders chipping hammer
5066 : 1969	Specification for glass pliers
5067 : 1969	Specification for fencing pliers
5087 : 1969	Specification for wire stripping pliers
5098 : 1969	Specification for cross cut and rip saws
5123 : 1969	Specification for tenon and dovetail saws
5169 : 1986	Specification for hack-saw frames (*first revision*)
5200 : 1998	Specification for bolt clippers (*first revision*)
5658 : 1990	Specification for snipenose pliers (*first revision*)
5663 : 1970	Specification for brick and mason's chisels
5684 : 1970	Specification for pipe vices (chain type)
5697 : 1970	Specification for ripping chisels
5889 : 1994	Specification for vibratory plate compactor (*first revision*)
5890 : 1970	Specification for mobile hot mix asphalt plants, light duty
5891 : 1970	Specification for hand-operated concrete mixer
5995 : 1971	Specification for pipe grip pliers
6007 : 1971	Specification for pipe vices (hinged type)
6078 : 1986	Specification for line man's pliers (*second revision*)
6087 : 1971	Specification for metal cutting shears
6118 : 1991	Specification for multiple slip joint pliers (*first revision*)
6149 : 1984	Specification for single ended open jaw adjustable wrenches (*first revision*)
6375 : 1991	Specification for wood splitting wedges (*first revision*)
6389 : 1998	Specification for combination wrenches with equal openings (*second revision*)
6428 : 1972	Specification for pile frame
6430 : 1985	Specification for mobile air compressor for construction purposes (*first revision*)
6433 : 1972	Specification for guniting equipment
6546 : 1989	Specification for claw hammers (*first revision*)
6836 : 1973	Specification for hand snaps and set-ups for solid rivets
6837 : 1973	Specification for three wheel type pipe cutter
6841 : 1973	Specification for wrecking bars
6861 : 1973	Specification for engineers' scrapers

IS No.	*Title*
6881 : 1973	Specification for link type pipe cutters
6891 : 1973	Specification for carpenter's auger bits
6892 : 1973	Specification for blacksmith's brick-iron
7041 : 1973	Specification for carpenter's plain brace
7042 : 1973	Specification for carpenter's ratchet brace
7077 : 1973	Specification for bending bars
7958 : 1976	Specification for hand vices
8202 : 1994	Specification for carpenter's wooden bodied planes (*first revision*)
8671 : 1977	Specification for nail puller
(31) 7293 : 1974	Safety code for working with construction machinery
(32) 15183 (Part 3) : 2002	Maintenance management for buildings — Guidelines: Part 3 Labour
(33) 15183 (Part 2) : 2002	Maintenance management for buildings — Guidelines: Part 2 Finance
(34) 13935 : 1993	Guidelines for repair and seismic strengthening of buildings
(35) 13828 : 1993	Improving earthquake resistance of low strength masonry buildings — Guidelines
(36) 13827 : 1993	Improving earthquake resistance of earthen buildings — Guidelines
(37) 4130 : 1991	Safety code for demolition of buildings (*second revision*)

NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 1 Lighting and Ventilation

BUREAU OF INDIAN STANDARDS

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FOREWORD

Illumination levels for different tasks are recommended to be achieved either by daylighting or artificial lighting or a combination of both. This Section, read together with Part 8 'Building Services, Section 2 Electrical and Allied Installations', adequately covers the illumination levels required and methods of achieving the same.

Ventilation requirements to maintain air quality and control body odours in terms of air changes per hour and to ensure thermal comfort and heat balance of body are laid for different occupancies and the methods of achieving the same by natural means are covered in this Section. The provisions on mechanical ventilation are covered in Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation'.

Climatic factors which normally help in deciding the orientation of the buildings to get desirable benefits of lighting and ventilation inside the buildings are also covered in this Section.

This Section was first published in 1970. The first revision of the Section was brought out in 1983. In this revision, some provisions have been updated based on the information given in the SP 41 : 1987 'Handbook on functional requirements of buildings (other than industrial buildings)'; other major changes in this revision are:

a) Rationalization of definitions and inclusion of definitions for some more terms.
b) A climatic classification map of India based on a new criteria has been included.
c) Data on total solar radiations incident on various surfaces of buildings for summer and winter seasons have been updated.
d) Design guidelines for natural ventilation have been included.
e) For guidelines on mechanical ventilation, reference to Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' has been made, where these provisions have now been covered exhaustively.
f) Rationalized method for estimation of desired capacity of ceiling fans and their optimum height above the floor for rooms of different sizes have been included.
g) Design sky illuminance values for different climatic zones of India have been incorporated.

Energy efficiency is an important aspect being taken care of in this revision of the Code. Accordingly, the relevant requirements for energy efficient system for lighting and ventilation have been duly included in the concerned provisions under this Section.

The provisions of this Section are without prejudice to the various Acts, Rules and Regulations including the *Factories Act*, 1948 and Rules and Regulations framed thereunder.

The information contained in this Section in largely based on the following Indian Standards/Special Publications:

IS 2440 : 1975	Guide for daylighting of buildings (*second revision*)
IS 3103 : 1975	Code of practice for industrial ventilation (*first revision*)
IS 3362 : 1977	Code of practice for natural ventilation of residential buildings (*first revision*)
IS 3646 (Part 1) : 1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for building interiors (*first revision*)
IS 7662 (Part 1) : 1974	Recommendations for orientation of buildings: Part 1 Non-industrial buildings
IS 11907 : 1986	Recommendations for calculation of solar radiation on buildings
SP 32 : 1986	Handbook on functional requirements of industrial buildings (lighting and ventilation)
SP 41 : 1987	Handbook on functional requirements of buildings other than industrial buildings

Provisions given in National Lighting Code (*under preparation*) may also be referred.

The following publication has also been referred to in the preparation of this Section:

Report on energy conservation in buildings, submitted to Department of Power, Ministry of Energy by Central Building Research Institute, Roorkee.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 8 BUILDING SERVICES

Section 1 Lighting and Ventilation

1 SCOPE

This Section covers requirements and methods for lighting and ventilation of buildings.

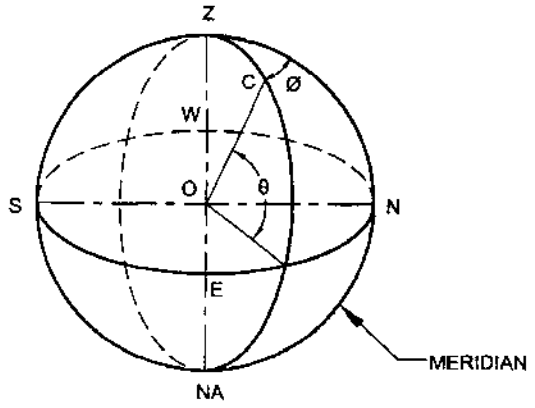
2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions shall apply.

2.1 Lighting

2.1.1 *Altitude* (θ) — The angular distance of any point of celestial sphere, measured from the horizon, on the great circle passing through the body and the zenith (*see* Fig. 1).

2.1.2 *Azimuth* (ϕ) — The angle measured between meridians passing through the north point and the point in question (point *C* in Fig. 1).



REFERENCES

O	Observer's station	*S*	Geographical south
C	Celestial body	*E*	Geographical east
Z	Zenith	*W*	Geographical west
NA	Nadir	*N*	Geographical north

FIG. 1 ALTITUDE AND AZIMUTH OF A CELESTIAL BODY

2.1.3 *Brightness Ratio or Contrast* — The variations or contrast in brightness of the details of a visual task, such as white print on blackboard.

2.1.4 *Candela* (*cd*) — The SI unit of luminous intensity.

Candela = 1 lumen per steradian

2.1.5 *Central Field* — The area of circle round the point of fixation and its diameter, subtending an angle of about 2° at the eye. Objects within this area are most critically seen in both their details and colour.

2.1.6 *Clear Design Sky* — The distribution of luminance of such a sky is non-uniform; the horizon is brighter than the zenith, and when L_z is the brightness at zenith, the brightness at an altitude (θ) in the region away from the sun, is given by the expression:

$$L_\theta = L_z \text{ cosec } \theta$$

when θ lies between 15° and 90°, and L_θ is constant when θ lies between 0° and 15°.

2.1.7 *Colour Rendering Index (CRI)* — Measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

2.1.8 *Correlated Colour Temperature (CCT) (Unit: K)* — The temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions.

2.1.9 *Daylight Area* — The superficial area on the working plane illuminated to not less than a specified daylight factor, that is, the area within the relevant contour.

2.1.10 *Daylight Factor* — The measure of total daylight illuminance at a point on a given plane expressed as the ratio (or percentage) which the illuminance at the point on the given plane bears to the simultaneous illuminance on a horizontal plane due to clear design sky at an exterior point open to the whole sky vault, direct sunlight being excluded.

2.1.11 *Daylight Penetration* — The maximum distance to which a given daylight factor contour penetrates into a room.

2.1.12 *Direct Solar Illuminance* — The illuminance from the sun without taking into account the light from the sky.

2.1.13 *External Reflected Component (ERC)* — The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received by direct reflection from external surfaces as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

2.1.14 *Glare* — A condition of vision in which there is discomfort or a reduction in the ability to see

significant objects or both due to an unsuitable distribution or range of luminance or due to extreme contrasts in space and time.

2.1.15 *Illuminance* — At a point on a surface, the ratio of the luminous flux incident on an infinitesimal element of the surface containing the point under consideration to the area of the element.

NOTE — The unit of illuminance (the measurement of illumination) is lux which is 1 lumen per square metre.

2.1.16 *Internal Reflected Component (IRC)* — The ratio (or percentage) of that part of the daylight illuminance at a point in a given plane which is received by direct reflection or inter-reflection from the internal surfaces as compared to the simultaneous exterior illuminance on a horizontal plane due to the entire hemisphere of an unobstructed clear design sky.

2.1.17 *Light Output Ratio (LOR) or Efficiency (η)* — The ratio of the luminous flux emitted from the luminaire to that emitted from the lamp(s) (nominal luminous flux). It is expressed in percent.

2.1.18 *Lumen (lm)* — SI unit of luminous flux. The luminous flux emitted within unit solid angle (one steradian) by a point source having a uniform intensity of one candela.

2.1.19 *Luminance (At a point of a Surface in a Given Direction) (Brightness)* — The quotient of the luminous intensity in the given direction of an infinitesimal element of the surface containing the point under consideration by the orthogonally projected area of the element on a plane perpendicular to the given direction. The unit is candela per square metre (cd/m^2).

2.1.20 *Luminous Flux (ϕ)* — The quantity characteristic of radiant flux which expresses its capacity to produce visual sensation evaluated according to the values of relative luminous efficiency for the light adapted eye:

a) *Effective luminous flux (ϕ_n)* — Total luminous flux which reaches the working plane.

b) *Nominal luminous flux (ϕ_o)* — Total luminous flux of the light sources in the interior.

2.1.21 *Maintenance Factor (d)* — The ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the average illuminance obtained under the same conditions for a new installation.

2.1.22 *Meridian* — It is the great circle passing through the zenith and nadir for a given point of observation.

2.1.23 *North and South Points* — The point in the respective directions where the meridian cuts the horizon.

2.1.24 *Orientation of Buildings* — In the case of non-square buildings, orientation refers to the direction of the normal to the long axis. For example, if the length of the building is east-west, its orientation is north-south.

2.1.25 *Peripheral Field* — It is the rest of the visual field which enables the observer to be aware of the spatial framework surrounding the object seen.

NOTE — A central part of the peripheral field, subtending an angle of about 30° on either side of the point of fixation, is chiefly involved in the perception of glare.

2.1.26 *Reflected Glare* — The variety of ill effects on visual efficiency and comfort produced by unwanted reflections in and around the task area.

2.1.27 *Reflection Factor (Reflectance)* — The ratio of the luminous flux reflected by a body (with or without diffusion) to the flux it receives. Some symbols used for reflection factor are:

r_c = Reflection factor of ceiling.

r_w = Reflection factor of parts of the wall between the working surface and the luminaires.

r_f = Reflection factor of floor.

2.1.28 *Reveal* — The side of an opening for a window.

2.1.29 *Room Index (k_r)* — An index relating to the shape of a rectangular interior, according to the formula:

$$k_r = \frac{L.W}{(L+W)\,H_m}$$

where L and W are the length and width respectively of the interior, and H_m is the mounting height, that is, height of the fittings above the working plane.

NOTES

1 For rooms where the length exceeds 5 times the width, L shall be taken as $L = 5W$.

2 If the reflection factor of the upper stretch of the walls is less than half the reflection factor of the ceiling, for indirect or for the greater part of indirect lighting, the value H_m is measured between the ceiling and the working plane.

2.1.30 *Sky Component (SC)* — The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received directly from the sky as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

2.1.31 *Solar Load* — The amount of heat received into a building due to solar radiation which is affected by orientation, materials of construction and reflection of external finishes and colour.

2.1.32 *Utilization Factor (Coefficient of Utilizaiton) (μ)* — The ratio of the total luminous flux which reaches the working plane (effective luminous

flux, ϕ_u) to the total luminous flux of the light sources in the interior (nominal luminous flux, ϕ_o).

2.1.33 *Visual Field* — The visual field in the binocular which includes an area approximately 120° vertically and 160° horizontally centering on the point to which the eyes are directed. The line joining the point of fixation and the centre of the pupil of each eye is called its primary line of sight.

2.1.34 *Working Plane* — A horizontal plane at a level at which work will normally be done (*see* **4.1.3.3** and **4.1.3.4**).

2.2 Ventilation

2.2.1 *Air Change per Hour* — The amount of air leakage into or out of a building or room in terms of the number of building volume or room volume exchanged.

2.2.2 *Axial Flow Fan* — A fan having a casing in which the air enters and leaves the impeller in a direction substantially parallel to its axis.

2.2.3 *Centrifugal Fan* — A fan in which the air leaves the impeller in a direction substantially at right angles to its axis.

2.2.4 *Contaminants* — Dusts, fumes, gases, mists, vapours and such other substances present in air as are likely to be injurious or offensive to the occupants.

2.2.5 *Dilution Ventilation* — Supply of outside air to reduce the air-borne concentration of contaminants in the building.

2.2.6 *Dry Bulb Temperature* — The temperature of the air, read on a thermometer, taken in such a way as to avoid errors due to radiation.

2.2.7 *Effective Temperature (ET)* — An arbitrary index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body and its numerical value is that of the temperature of still saturated air which would induce an identical sensation.

2.2.8 *Exhaust of Air* — Removal of air from a building or a room and its disposal outside by means of a mechanical device, such as a fan.

2.2.9 *Fresh Air or Outside Air* — Air of that quality, which meets the criteria of Table 1 and in addition shall be such that the concentration of any contaminant in the air is limited to within one-tenth the threshold limit value (TLV) of that contaminant.

NOTES

1 Where it is reasonably believed that the air of quality is unexpectable as indicated above, sampling and analysis shall be carried out by a competent authority having jurisdiction and if the outside air of the quality specified is not available, filtration and other treatment devices shall be used to bring its quality to or above the levels mentioned in Table 1.

2 The list of contaminants given in Table 1 is not exhaustive and available special literature may be referred for data on other contaminants.

Table 1 Maximum Allowable Contaminant Concentrations for Ventilation Air Contaminants Annual Average (Arithmetic Mean)

(*Clause* 2.2.9)

Contaminants	Annual Average (Arithmetic Mean)	Short-Term Level (Not to exceed More than Once a Year)	Averaging Period
	µg/m³	µg/m³	h
(1)	(2)	(3)	(4)
Suspended particulates	60	150	24
Sulphur oxides	80	400	24
Carbon monoxide	20 000	30 000	8
Photochemical oxidant	100	500	1
Hydrocarbons (not including methanes)	1 800	4 000	3
Nitrogen oxide	200	500	24
Odour: Essentially unobjectionable			

2.2.10 *General Ventilation* — Ventilation, either natural or mechanical or both, so as to improve the general environment of the building, as opposed to local exhaust ventilation for contamination control.

2.2.11 *Globe Temperature* — The temperature measured by a thermometer whose bulb is enclosed in a matt black painted thin copper globe of 150 mm diameter. It combines the influence of air temperature and thermal radiations received or emitted by the bounding surfaces.

2.2.12 *Humidification* — The process whereby the absolute humidity of the air in a building is maintained at a higher level than that of outside air or at a level higher than that which would prevail naturally.

2.2.13 *Humidity, Absolute* — The mass of water vapour per unit volume.

2.2.14 *Humidity, Relative* — The ratio of the partial pressure or density of the water vapour in the air to the saturated pressure or density respectively of water vapour at the same temperature.

2.2.15 *Local Exhaust Ventilation* — Ventilation effected by exhaust of air through an exhaust appliance, such as a hood with or without fan located as closely as possible to the point at which contaminants are

released, so as to capture effectively the contaminants and convey them through ducts to a safe point of discharge.

2.2.16 *Make-up Air* — Outside air supplied into a building to replace the indoor air.

2.2.17 *Mechanical Ventilation* — Supply of outside air either by positive ventilation or by infiltration by reduction of pressure inside due to exhaust of air, or by a combination of positive ventilation and exhaust of air.

2.2.18 *Natural Ventilation* — Supply of outside air into a building through window or other openings due to wind outside and convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building.

2.2.19 *Positive Ventilation* — The supply of outside air by means of a mechanical device, such as a fan.

2.2.20 *Propeller Fan* — A fan in which the air leaves the impeller in a direction substantially parallel to its axis. Designed to operate normally under free inlet and outlet conditions.

2.2.21 *Spray-Head System* — A system of atomizing water so as to introduce free moisture directly into a building.

2.2.22 *Stack Effect* — Convection effect arising from temperature or vapour pressure difference (or both) between outside and inside of the room and the difference of height between the outlet and inlet openings.

2.2.23 *Tropical Summer Index (TSI)* — The temperature of calm air at 50 percent relative humidity which imparts the same thermal sensation as the given environment. TSI (in °C) is express as

$$0.745\ t_g + 0.308\ t_w - 2.06\ \sqrt{v} + 0.841$$

where

t_g = Globe temperature, °C;
t_w = Wet bulb temperature, °C; and
v = Wind speed, m/s.

2.2.24 *Threshold Limit Value (TLV)* — Refers to airborne concentration of contaminants currently accepted by the American Conference of Governmental Industrial Hygienists and represents conditions under which it is believed that nearly all occupants may be repeatedly exposed, day after day, without adverse effect.

2.2.25 *Velocity, Capture* — Air velocity at any point in front of the exhaust hood necessary to overcome opposing air currents and to capture the contaminants in air at that point by causing the air to flow into the exhaust hood.

2.2.26 *Ventilation* — Supply of outside air into, or the removal of inside air from an enclosed space.

2.2.27 *Wet Bulb Temperature* — The steady temperature finally given by a thermometer having its bulb covered with gauze or muslin moistened with distilled water and placed in an air stream of not less than 4.5 m/s.

3 ORIENTATION OF BUILDING

3.1 The chief aim of orientation of buildings is to provide physically and psychologically comfortable living inside the building by creating conditions which suitably and successfully ward off the undesirable effects of severe weather to a considerable extent by judicious use of the recommendations and knowledge of climatic factors.

3.2 Basic Zones

3.2.1 For the purpose of design of buildings, the country may be divided into the major climatic zones as given in Table 2, which also gives the basis of this classification.

Table 2 Classification of Climate

(*Clause* 3.2.1)

Sl No.	Climatic Zone	Mean Monthly Maximum Temperature (°C)	Mean Monthly Relative Humidity Percentage
(1)	(2)	(3)	(4)
i)	Hot-Dry	above 30	below 55
ii)	Warm-Humid	above 30	above 55
		above 25	above 75
iii)	Temperate	between 25-30	below 75
iv)	Cold	below 25	All values
v)	Composite	*see* 3.2.2	

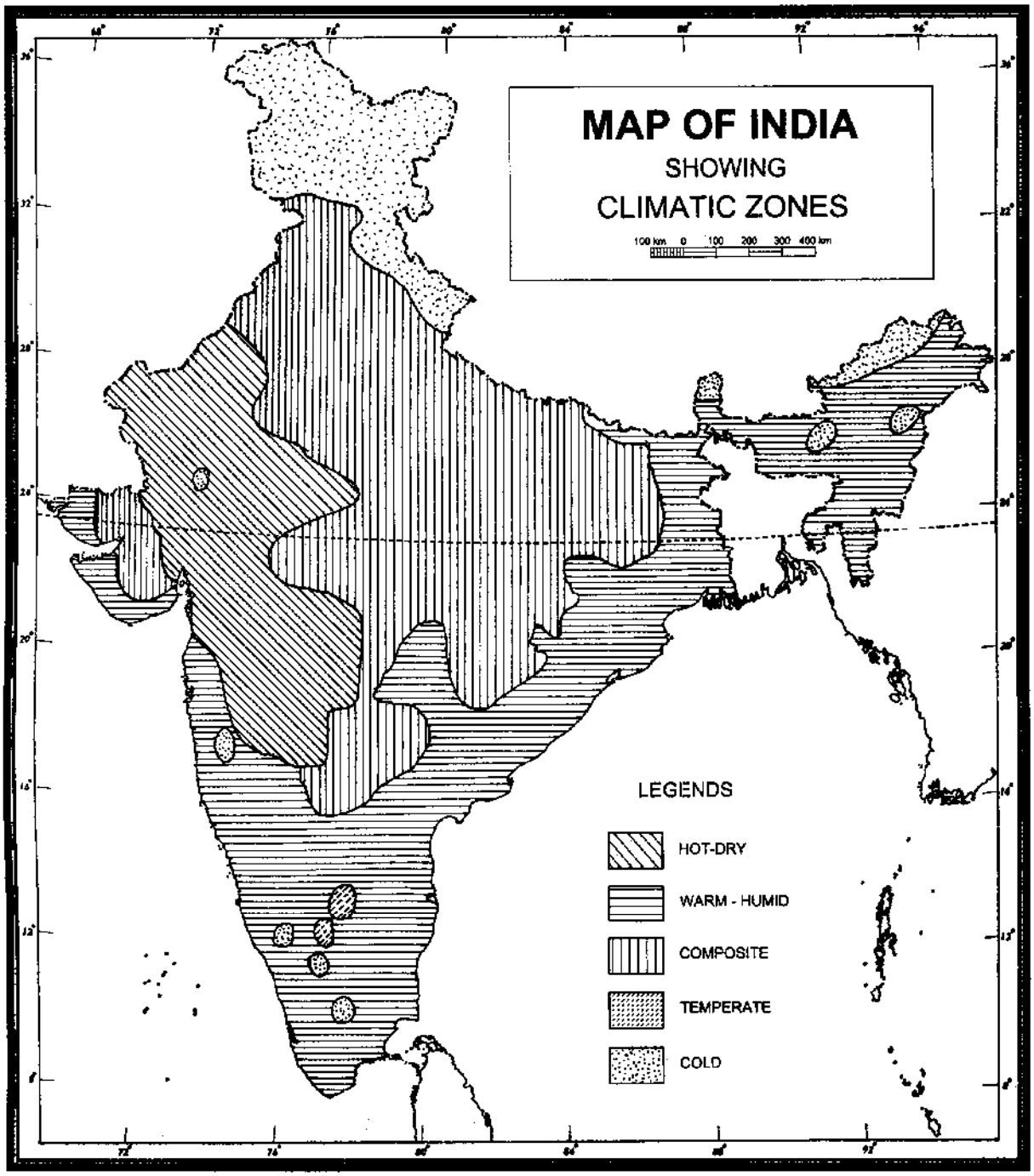
The climatic classification map of India is shown in Fig. 2.

3.2.2 Each climatic zone does not have same climate for the whole year; it has a particular season for more than six months and may experience other seasons for the remaining period. A climatic zone that does not have any season for more than six months may be called as composite zone.

3.3 Climatic Factors

From the point of view of lighting and ventilation, the following climatic factors influence the optimum orientation of the building:

a) solar radiation and temperature
b) relative humidity, and
c) prevailing winds.



Based upon Survey of India Outline Map printed in 1993.

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhattisgarh & Madhya Pradesh have not been verified by Governments concerned.

FIG. 2 MAP OF INDIA SHOWING CLIMATIC ZONES

3.4 Solar Radiation

3.4.1 The best orientation from solar point of view requires that the building as a whole should receive the maximum solar radiation in winter and the minimum in summer. For practical evaluation, it is necessary to know the duration of sunshine, and hourly solar intensity on the various external surfaces on representative days of the seasons. The total direct plus diffused diurnal solar loads per unit area on vertical surface facing different directions are given in Table 3 for two days in the year, that is, 22 June and 22 December, representative of summer and winter, for latitudes corresponding to some important cities all over India. From Table 3, the total heat intake can be calculated for all possible orientations of the building for these extreme days of summer and winter.

3.4.1.1 Except in cold climatic zone, suitable sun-breakers have to be provided to cut off the incursion of direct sunlight to prevent heat radiation and to avoid glare.

3.5 Relative Humidity and Prevailing Winds

3.5.1 The discomfort due to high relative humidity in air when temperatures are also high can be counteracted, to a great extent, by circulation of air with electric fans or by ventilation. In the past, simultaneously with heavy construction and surrounding *VERANDAHS* to counter the effect of sun's radiation, there was also an over emphasis on prevailing winds to minimize the adverse effects of high humidity with high temperatures. With the introduction of electric fan to effectively circulate air and owing to taking into account the rise in cost of construction of buildings, it would perhaps be better to shift the emphasis on protection from solar radiation where temperatures are very high. When, however, there is less diurnal variation between morning and mean maximum temperatures along with high humidity, as in coastal areas, the emphasis should be on prevailing winds.

3.5.1.1 For the purpose of orientation, it is necessary to study the velocity and direction of the wind at each hour and in each month instead of relying on generalizations of a month or a period or for the year as a whole. This helps to spot the right winds for a particular period of day or night.

3.5.1.2 It is generally found that variation up to 30° with respect to the prevalent wind direction does not materially affect indoor ventilation (average indoor air speed) inside the building.

3.5.2 In hot-dry climate, advantage can be taken of evaporative cooling in summer to cool the air before introducing it into the building. But in warm humid climate, it is desirable either to regulate the rate of air movement with the aid of electric fans or to take advantage of prevailing winds.

3.6 Aspects of Daylighting

Since the clear design sky concept for daylighting takes care of the worst possible situation, orientation is not

Table 3 Total Solar Radiation (Direct plus Diffused) Incident on Various Surfaces of Buildings in W/m²/day for Summer and Winter Seasons

(*Clause* 3.4.1)

Orientation		Latitude					
		9°N	13°N	17°N	21°N	25°N	29°N
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
North	Summer	1 494	1 251	2 102	1 775	2 173	1 927
	Winter	873	859	840	825	802	765
North-East	Summer	2 836	2 717	3 144	3 092	3 294	3 189
	Winter	1 240	1 158	1 068	1 001	912	835
East	Summer	3 344	3 361	3 475	3 598	3 703	3 794
	Winter	2 800	2 673	2 525	2 409	2 211	2 055
South-East	Summer	2 492	2 660	2 393	2 629	2 586	2 735
	Winter	3 936	3 980	3 980	3 995	3 892	3 818
South	Summer	1 009	1 185	1 035	1 117	1 112	1 350
	Winter	4 674	4 847	4 958	5 059	4 942	4 981
South-West	Summer	2 492	2 660	2 393	2 629	2 586	2 735
	Winter	3 936	3 980	3 980	3 995	3 892	3 818
West	Summer	3 341	3 361	3 475	3 598	3 703	3 794
	Winter	2 800	2 673	2 525	2 409	2 211	2 055
North-West	Summer	2 836	2 717	3 144	3 092	3 294	3 189
	Winter	1 240	1 158	1 068	1 001	912	835
Horizontal	Summer	8 107	8 139	8 379	8 553	8 817	8 863
	Winter	6 409	6 040	5 615	5 231	4 748	4 281

a major problem for daylighting in buildings, except that direct sunshine and glare should be avoided. However, due allowance should be given to the mutual shading effects of opposite facades.

3.7 Planting of Trees

Planting of trees in streets and in open spaces should be done carefully to take advantage of both shades and sunshine without handicapping the flow of natural winds. Their advantage in abating glare and in providing cool and/or warm pockets in developed areas should also be taken. Some trees shed leaves in winter while retaining thick foliage in summer. Such trees will be very advantageous, particularly where southern and western exposures are concerned, by allowing maximum sun during winter and effectively blocking it in summer.

3.8 For detailed information regarding orientation of buildings and recommendations for various climatic zones of country, reference may be made to good practice [8-1(1)].

4 LIGHTING

4.1 Principles of Lighting

4.1.1 *Aims of Good Lighting*

Good lighting is necessary for all buildings and has three primary aims. The first aim is to promote work and other activities carried out within the building; the second aim is to promote the safety of the people using the building; and the third aim is to create, in conjunction with the structure and decoration, a pleasing environment conducive to interest of the occupants and a sense of their well-being.

4.1.1.1 Realization of these aims involves:

a) careful planning of the brightness and colour pattern within both the working areas and the surroundings so that attention is drawn naturally to the important areas, detail is seen quickly and accurately and the room is free from any sense of gloom or monotony (*see* **4.1.3**);

b) using directional lighting where appropriate to assist perception of task detail and to give good modeling;

c) controlling direct and reflected glare from light sources to eliminate visual discomfort;

d) in artificial lighting installations, minimizing flicker from certain types of lamps and paying attention to the colour rendering properties of the light;

e) correlating lighting throughout the building to prevent excessive differences between adjacent areas so as to reduce the risk of accidents; and

f) installation of emergency lighting systems, where necessary.

4.1.2 *Planning the Brightness Pattern*

The brightness pattern seen within an interior may be considered as composed of three main parts — the task itself, immediate background of the task and the general surroundings of walls, ceiling, floor, equipment and furnishings.

4.1.2.1 In occupations where the visual demands are small, the levels of illumination derived from a criterion of visual performance alone may be too low to satisfy the other requirements. For such situations, therefore, illuminance recommendations are based on standards of welfare, safety and amenity judged appropriate to the occupations; they are also sufficient to give these tasks brightness which ensured that the visual performance exceeds the specified minimum. Unless there are special circumstances associated with the occupation, it is recommended that the illuminance of all working areas within a building should generally be 150 lux, even though the visual demands of the occupation might be satisfied by lower values.

4.1.2.2 Where work takes place over the whole utilizable area of room, the illumination over that area should be reasonably uniform and it is recommended that the uniformity ratio (minimum illuminance divided by average illuminance levels) should be not less than 0.7 for the working area.

4.1.2.3 When the task brightness appropriate to an occupation has been determined, the brightness of the other parts of the room should be planned to give a proper emphasis to visual comfort and interest.

A general guide for the brightness relationship within the normal field of vision should be as follows:

		Maximum
a)	For high task brightness (above 100 cd/m^2)	
	1) Between the visual task and the adjacent areas like table tops	3 to 1
	2) Between the visual task and the remote areas of the room	10 to 1
b)	For low and medium task brightness (below 100 cd/m^2): The task should be brighter than both the background and the surroundings; the lower the task brightness, the less critical is the relationship.	

4.1.3 *Recommended Values of Illuminance*

Table 4 gives recommended values of illuminance commensurate with the general standards of lighting

described in this section and related to many occupations and buildings; These are valid under most of the conditions whether the illumination is by daylighting, artificial lighting or a combination of the two. The great variety of visual tasks makes it impossible to list them all and those given should be regarded as representing types of task.

4.1.3.1 The different locations and tasks are grouped within the following four sections:

a) Industrial buildings and process;
b) Offices, schools and public buildings;
c) Surgeries and hospitals; and
d) Hotels, restaurants, shops and homes.

4.1.3.2 The illumination levels recommended in Table 4 are those to be maintained at all time on the task. As circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity instead of a single value of illuminance. Each range consists of three sucessive steps of the recommended scale of illuminances. For working interiors the middle value of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

4.1.3.2.1 The higher value of the range should be used when:

a) unusually low reflectances or contrasts are present in the task;
b) errors are costly to rectify;
c) visual work is critical;
d) accuracy or higher productivity is of great importance; and
e) the visual capacity of the worker makes it necessary.

4.1.3.2.2 The lower value of the range may be used when:

a) reflectances or contrast are unusually high;
b) speed and accuracy is not important; and
c) the task is executed only occasionally.

4.1.3.3 Where a visual task is required to be carried out throughout an interior, general illumination level to the recommended value on the working plane is necessary; where the precise height and location of the task are not known or cannot be easily specified, the recommended value is that on horizontal plane 850 mm above floor level.

NOTE — For an industrial task, working plane for the purpose of general illumination levels is that on a work place which is generally 750 mm above the floor level. For certain purposes, such as viewing the objects of arts, the illumination levels recommended are for the vertical plane at which the art pieces are placed.

4.1.3.4 Where the task is localized, the recommended value is that for the task only; it need not, and sometimes should not, be the general level of illumination used throughout the interior. Some processes, such as industrial inspection process, call for lighting of specialized design, in which case the level of illumination is only one of the several factors to be taken into account.

4.1.4 *Glare*

Excessive contrast or abrupt and large changes in brightness produce the effect of glare. When glare is present, the efficiency of vision is reduced and small details or subtle changes in scene cannot be perceived. It may be

a) direct glare due to light sources within the field of vision,
b) reflected glare due to reflections from light sources or surfaces of excessive brightness, and
c) veiling glare where the peripheral field is comparatively very bright.

4.1.4.1 An example of glare sources in daylighting is the view of the bright sky through a window or skylight, especially when the surrounding wall or ceiling is comparatively dark or weakly illuminated. Glare can be minimized in this case either by shielding the open sky from direct sight by louvers, external hoods or deep reveals, curtains or other shading devices or by cross lighting the surroundings to a comparable level. A gradual transition of brightness from one portion to the other within the field of vision always avoids or minimizes the glare discomfort.

4.1.5 *Lighting for Movement about a Building*

Most buildings are complexes of working areas and other areas, such as passages, corridors, stairways, lobbies and entrances. The lighting of all these areas should be properly correlated to give safe movement within the building at all times.

4.1.5.1 *Corridors, passages and stairways*

Accidents may result if people leave a well-lighted working area and pass immediately into corridors or on to stairways where the lighting is inadequate, as the time needed for adaptation to the lower level may be too long to permit obstacles or the treads of stairs to be seen sufficiently quickly. For the same reason, it is desirable that the illumination level of rooms which open off a working area should be fairly high even though the rooms may be used only occasionally.

Table 4 Recommended Values of Illuminance

(*Clauses* 4.1.3, 4.1.3.2, 4.3.2 *and* 4.3.2.1)

Sl No.	Type of Interior or Activity	Range of Service Illuminance in Lux	Quality Class of Direct Glare Limitation	Remarks
(1)	(2)	(3)	(4)	(5)
1	**AGRICULTURE AND HORTICULTURE**			
1.1	Inspection of Farm Produce where Colour is Important	300-500-750	1	Local lighting may be appropriate
	Other Important Tasks	200-300-500	2	Local lighting may be appropriate
1.2	Farm Workshops			
1.2.1	General	50-100-150	3	
1.2.2	Workbench or machine	200-300-500	2	Local or portable lighting may be appropriate
1.3	Milk Premises	50-100-150	3	
1.4	Sick Animal Pets, Calf Nurseries	30-50-100	3	
1.5	Other Firm and Horticultural Buildings	20-30-50	3	
2	**COAL MINING (SURFACE BUILDINGS)**			
2.1	Coal Preparation Plant			
2.1.1	Walkways, floors under conveyors	30-50-100	3	
2.1.2	Wagon loading, bunkers	30-50-100	3	
2.1.3	Elevators, chute transfer pits, washbox area	50-100-150	3	
2.1.4	Drum filters, screen, rotating shafts	100-150-200	3	
2.1.5	Picking belts	150-200-300	3	Directional and colour properties of lighting may be important for easy recognition of coal and rock
2.2	Lamp Rooms			
2.2.1	Repair section	200-300-500	2	
2.2.2	Other areas	100-150-200	3	
2.3	Weight Cabins, Fan Houses	100-150-200	3	
2.4	Winding Houses	100-150-200	3	
3	**ELECTRICITY GENERATION, TRANSMISSION AND DISTRIBUTION**			
3.1	General Plant			
3.1.1	Turbine houses (operating floor)	150-200-300	2	
3.1.2	Boiler and turbine house basements	50-100-150	3	
3.1.3	Boiler houses, platforms, areas around burners	50-100-150	3	
3.1.4	Switch rooms, meter rooms, oil plant rooms, HV substations (indoor)	100-150-200	2	
3.1.5	Control rooms	200-300-500	1	Localized lighting of control display and the control desks may be appropriate
3.1.6	Relay and telecommunication rooms	200-300-500	2	
3.1.7	Diesel generator rooms, compressor rooms	100-150-200	3	
3.1.8	Pump houses, water treatment plant houses	100-150-200	3	
3.1.9	Battery rooms, chargers, rectifiers	50-100-150	3	
3.1.10	Precipitator chambers, platforms, etc	50-100-150	3	
3.1.11	Cable tunnels and basements, circulating water culverts and screen chambers, storage tanks (indoor), operating areas and filling points at outdoor tanks	30-50-100	3	
3.2	Coal Plant			
3.2.1	Conveyors, gantries, junction towers, unloading hoppers, ash handling plants, settling pits, dust hoppers outlets	50-100-150	3	
3.2.2	Other areas where operators may be in attendance	100-150-200	3	
3.3	Nuclear Plants			
	Gas circulation bays, reactor area, boiler platform, reactor charges and discharge face	100-150-200	2	
4	**METAL MANUFACTURE**			
4.1	Iron Making			
4.1.1	Sinter plant:			
	Plant floor	150-200-300	3	

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
	Mixer drum, fan house, screen houses, coolers, transfer stations	100-150-200	3	
4.1.2	Furnaces, cupola:			
	General	100-150-200	3	
	Control platforms	200-300-500	2	Local lighting may be appropriate
	Conveyor galleries, walkways	30-50-100	3	
4.2	Steel Making			
4.2.1	Electric melting shops	150-200-300	3	
4.2.2	Basic oxygen steel making plants			
4.2.2.1	General	100-150-200	3	
4.2.2.2	Convertor floor, teeming bay	150-200-300	3	
4.2.2.3	Control platforms	200-300-500	2	Local lighting may be appropriate
4.2.2.4	Scrap bays	100-150-200	3	
4.3	Metal Forming and Treatment			
4.3.1	Ingot stripping, soaking pits, annealing and heat treatment bays, acid recovery plant Picking and cleaning bays, roughing mills, cold mills, finishing mills, tinning and galvanizing lines, cut up and rewind lines	150-200-300	3	
4.3.2	General	100-150-200	3	
4.3.3	Control platforms	200-300-500	2	Local lighting may be appropriate
4.3.4	Wire mills, product finishing, steel inspection and treatment	200-300-500	3	
4.3.5	Plate/strip inspection	300-500-700	2	
4.3.6	Inspection of tin plate, stainless steel, etc	—	—	Special lighting to reveal faults in the specular surface of the material will be required
4.4	Foundries			
4.4.1	Automatic Plant			
4.4.1.1	Without manual operation	30-50-100	3	
4.4.1.2	With occasional manual operation	100-150-200	3	
4.4.1.3	With continuous manual operation	150-200-300	3	
4.4.1.4	Control room	200-300-500	1	Localized lighting of the control display and the control desks may be appropriate
4.4.1.5	Control platforms	200-300-500	2	
4.4.2	Non-automatic plants			
4.4.2.1	Charging floor, pouring, shaking out, cleaning, grinding fettling	200-300-500	3	
4.4.2.2	Rough moulding, rough core making	200-300-500	3	
4.4.2.3	Fine moulding, fine core making	300-500-750	2	
4.4.2.4	Inspection	300-500-750	2	
4.5	Forges (Severe vibration is likely to occur)			
4.5.1	General	200-300-500	2	
4.5.2	Inspection	300-500-750	2	
5	**CERAMICS**			
5.1	Concrete products			
	Mixing, casting, cleaning	150-200-300	3	
5.2	Potteries			
5.2.1	Grinding, moulding, pressing, cleaning, trimming, glazing, firing	200-300-500	3	
5.2.2	Enamelling, colouring	500-750-1000	1	
5.3	Glass Works			
5.3.1	Furnace rooms, bending, annealing	100-150-200	3	
5.3.2	Mixing rooms, forming, cutting, grinding, polishing, toughening	200-300-500	3	
5.3.3	Beveling, decorative cutting, etching, silvering	300-500-750	2	
5.3.4	Inspection	300-500-750	2	

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
6	**CHEMICALS**			
6.1	Petroleum, Chemical and Petrochemical Works			
6.1.1	Exterior walkways, platforms, stairs and ladders	30-50-100	3	
6.1.2	Exterior pump and valve areas	50-100-150	3	
6.1.3	Pump and compressor houses	100-150-200	3	
6.1.4	Process plant with remote control	30-50-100	3	
6.1.5	Process plant requiring occasional manual intervention	50-100-150	3	
6.1.6	Permanently occupied work stations in process plant	150-200-300	3	
6.1.7	Control rooms for process plant	200-300-500	1	
6.2	Pharmaceutial Manufacturer and Fine Chemicals Manufacturer			
6.2.1	Pharmaceutical manufacturer Grinding, granulating, mixing, drying, tableting, sterilizing, washing, preparation of solutions, filling, capping, wrapping, hardening	300-500-750	2	
6.2.2	Fine chemical manufacture			
6.2.2.1	Exterior walkways, platforms, stairs and ladders	30-50-100	3	
6.2.2.2	Process plant	50-100-150	3	
6.2.2.3	Fine chemical finishing	300-500-750	2	
6.2.2.4	Inspection	300-500-750	1	Local lighting may be appropriate
6.3	Soap Manufacture			
6.3.1	General area	200-300-500	2	
6.3.2	Automatic processes	100-200-300	2	
6.3.3	Control panels	200-300-500	1	Local lighting may be appropriate
6.3.4	Machines	200-300-500	2	
6.4	Paint Works			
6.4.1	General	200-300-500	2	
6.4.2	Automatic processes	150-200-300	2	
6.4.3	Control panels	200-300-500	2	
6.4.4	Special batch mixing	500-750-1000	2	
6.4.5	Colour matching	750-1000-1500	1	
7	**MECHANICAL ENGINEERING**			
7.1	Structural Steel Fabrication			
7.1.1	General	200-300-500	3	
7.1.2	Marking off	300-500-750	3	Local lighting may be appropriate
7.2	Sheet Metal Works			
7.2.1	Pressing, punching, shearing, stamping, spinning, folding	300-500-750	2	
7.2.2	Benchwork, scribing, inspection	500-750-1000	2	
7.3	Machine and Tool Shops			
7.3.1	Rough bench and machine work	200-300-500	3	
7.3.2	Medium bench and machine work	300-500-750	2	
7.3.3	Fine bench and machine work	500-750-1000	2	
7.3.4	Gauge rooms	750-1000-1500	1	Optical aids may be required
7.4	Die Sinking Shops			
7.4.1	General	300-500-750	2	
7.4.2	Fine work	1000-1500-2000	1	Flexible local lighting is desirable
7.5	Welding and Soldering Shops			
7.5.1	Gas and arc welding, rough spot welding	200-300-500	3	
7.5.2	Medium soldering, brazing, spot welding	300-500-750	3	
7.5.3	Fine soldering, fine spot welding	750-1000-1500	2	Local lighting is desirable
7.6	Assembly Shops			
7.6.1	Rough work for example, frame and heavy machine assembly	200-300-500	3	The lighting of vertical surface may be important
7.6.2	Medium work, for example, engine assembly, vehicle body assembly	300-500-750	2	
7.6.3	Fine work, for example, office machinery assembly	500-750-1000	1	Localized lighting may be useful

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
7.6.4	Very fine work, for example, instrument assembly	750-1000-1500	1	Local lighting and optical aids are desirable
7.6.5	Minute work, for example, watch making	1000-1500-2000	1	Local lighting and optical aids are desirable
7.7	Inspection and Testing Shops			
7.7.1	Coarse work, for example, using go/no-go gauges, inspection of large sub-assemblies	300-500-750	2	Local or localized lighting may be appropriate
7.7.2	Medium work, for example, inspection of painted surfaces	500-750-1000	1	Local or localized lighting may be appropriate
7.7.3	Fine work, for example, using calibrated scales, inspection of precision mechanisms	750-1000-1500	1	Local or localized lighting may be appropriate
7.7.4	Very fine work, for example, inspection of small intricate parts	1000-1500-2000	1	Local lighting and optical aids are desirable
7.7.5	Minute work, for example, inspection of very small instruments	2000	1	Local lighting and optical aids are desirable
7.8	Points Shops and Spray Booths			
7.8.1	Dipping, rough spraying	200-300-500	3	
7.8.2	Preparation, ordinary painting, spraying and finishing	200-500-750	2	
7.8.3	Fine painting, spraying and finishing	500-750-1000	2	
7.8.4	Inspection, re-touching and matching	750-1000-1500	2	
7.9	Plating Shops			
7.9.1	Vats and baths	200-300-500	3	
7.9.2	Buffing, polishing burnishing	300-500-750	2	
7.9.3	Final buffing and polishing	500-750-1000	2	
7.9.4	Inspection	—	—	Special light to reveal fault in the surface of the material will be required
8	**ELECTRICAL AND ELECTRONIC ENGINEERING**			
8.1	Electrical Equipment Manufacture			
8.1.1	Manufacture of cables and insulated wires, winding, varnishing and immersion of coils, assembly of large machines, simple assembly work	200-300-500	3	
8.1.2	Medium assembly, for example, telephones, small motors	300-500-750	3	Local lighting may be appropriate
8.1.3	Assembly of precision components, for example, telecommunication equipment, adjustment, inspection and calibration	750-1000-1500	1	Local lighting is desirable. Optical aids may be useful
8.1.4	Assembly of high precision parts	1000-1500-2000	1	Local lighting is desirable. Optical aids may be useful
8.2	Electronic Equipment Manufacture			
8.2.1	Printed circuit board			
8.2.1.1	Silk screening	300-500-750	1	Local lighting may be appropriate
8.2.1.2	Hand insertion of components, soldering	500-750-1000	1	Local lighting may be appropriate
8.2.1.3	Inspection	750-1000-1500	1	A large, low luminance luminaire overhead ensures specular reflection conditions which are helpful for inspection of printed circuits
8.2.1.4	Assembly of wiring harness, cleating harness, testing and calibration	500-750-1000	1	Local lighting may be appropriated
8.2.1.5	Chassis assembly	750-1000-1500	1	Local lighting may be appropriated
8.2.2	Inspection and testing			
8.2.2.1	Soak test	150-200-300	2	
8.2.2.2	Safety and functional tests	200-300-500	2	
9	**FOOD, DRINK AND TOBACCO**			
9.1	Slaughter Houses			
9.1.1	General	200-300-500	3	
9.1.2	Inspection	300-500-750	2	
9.2	Canning, Preserving and Freezing			
9.2.1	Grading and sorting of raw materials	500-750-1000	2	Lamp of colour rendering group 1A or 1B will be required, if colour judgement is required

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
9.2.2	Preparation	300-500-750	3	
9.2.3	Canned and bottled goods			
9.2.3.1	Retorts	200-300-500	3	
9.2.3.2	Automatic processes	150-200-300	3	
9.2.3.3	Labelling and packaging	200-300-500	3	
9.2.4	Frozen foods			
9.2.4.1	Process area	200-300-500	3	
9.2.4.2	Packaging and storage	200-300-500	3	
9.3	Bottling, Brewing and Distilling			
9.3.1	Keg washing and handling, bottle washing	150-200-300	3	
9.3.2	Keg inspection	200-300-500	3	
9.3.3	Bottle inspection	—	—	Special lighting will be required
9.3.4	Process areas	200-300-500	3	
9.3.5	Bottle filling	500-750-1000	3	
9.4	Edible Oils and Fats Processing			
9.4.1	Refining and blending	200-300-500	3	
9.4.2	Production	300-500-750	2	
9.5	Mills-Milling, Filtering and Packing	200-300-500	3	
9.6	Bakeries			
9.6.1	General	200-300-500	2	
9.6.2	Hand decorating, icing	300-500-750	2	
9.7	Chocolate and Confectionery Manufacture			
9.7.1	General	200-300-500	3	
9.7.2	Automatic processes	150-200-300	3	
9.7.3	Hand decoration, inspection, wrapping and packing	300-500-750	2	If accurate colour judgements are required, lamps of colour rendering group 1A or 1B are used
9.8	Tobacco Processing			
9.8.1	Material preparation, making and packing	300-500-750	2	
9.8.2	Hand processes	500-750-1000	2	
10	**TEXTILES**			
10.1	Fibre Preparation			
10.1.1	Bale breaking, washing	200-300-500	3	
10.1.2	Stock dyeing, tinting	200-300-500	3	
10.2	Yarn Manufacture			
10.2.1	Spinning, roving, winding, etc	300-500-750	2	
10.2.2	Healding (drawing in)	750-1000-750	2	
10.3	Fabric Production			
10.3.1	Knitting	300-500-750	2	
10.3.2	Weaving			
10.3.2.1	Jute and hemp	200-300-500	2	
10.3.2.2	Heavy woolens	300-500-750	1	
10.3.2.3	Medium worsteds, fine woolens, cottons	500-750-1000	1	
10.3.2.4	Fine worsteds, fine linens, synthetics	750-1000-1500	1	
10.3.2.5	Mending	1000-1500-2000	1	
10.3.2.6	Inspection	1000-1500-2000	1	
10.4	Fabric Finishing			
10.4.1	Dyeing	200-300-500	3	
10.4.2	Calendaring, chemical treatment, etc	300-500-750	2	
10.4.3	Inspection			
10.4.3.1	'Grey' cloth	750-1000-1500	1	
10.4.3.2	Final	1000-1500-2000	1	
10.5	Carpet Manufacture			
10.5.1	Winding, beaming	200-300-500	3	
10.5.2	Setting pattern, tufting cropping, trimming, fringing, latexing and latex drying	300-500-750	2	
10.5.3	Designing, weaving, mending	500-750-1000	2	
10.5.4	Inspection			
10.5.4.1	General	750-1000-1500	1	Local lighting may be appropriate
10.5.4.2	Piece dyeing	500-750-1000	1	Local lighting may be appropriate

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
11	**LEATHER INDUSTRY**			
11.1	Leather Manufacture			
11.1.1	Cleaning, tanning and stretching, vats, cutting, fleshing, stuffing	200-300-500	3	
11.1.2	Finishing, scarfing	300-500-750	2	
11.2	Leather Working			
11.2.1	General	200-300-500	3	
11.2.2	Pressing, glazing	300-500-750	2	
11.2.3	Cutting, splitting, scarfing, sewing	500-750-1000	2	Directional lighting may be useful.
11.2.4	Grading, matching		2	Local lighting may be appropriate
12	**CLOTHING AND FOOTWEAR**			
12.1	Clothing Manufacture			
12.1.1	Preparation of cloth	200-300-500	2	
12.1.2	Cutting	500-750-1000	1	
12.1.3	Matching	500-750-1000	1	
12.1.4	Sewing	750-1000-1500	1	
12.1.5	Pressing	300-500-750	2	
12.1.6	Inspection	1000-1500-2000	1	Local lighting may be appropriate
12.1.7	Hand tailoring	1000-1500-2000	1	Local lighting may be appropriate
12.2	Hosiery and Knitwear Manufacture			
12.2.1	Flat bed knitting machines	300-500-750	2	
12.2.2	Circular knitting machines	500-750-1000	2	
12.2.3	Lockstitch and overlocking machine	750-1000-1500	1	
12.2.4	Linking or running on	750-1000-1500	1	
12.2.5	Mending, hand finishing	1000-1500-3000	—	Local lighting may be appropriate
12.2.6	Inspection	1000-1500-2000	2	Local lighting may be appropriate
12.3	Glove Manufacture			
12.3.1	Sorting and grading	500-750-1000	1	
12.3.2	Pressing, knitting, cutting	300-500-750	2	
12.3.3	Sewing	500-750-1000	2	
12.3.4	Inspection	1000-1500-2000	—	Local lighting may be appropriate
12.4	Hat Manufacture			
12.4.1	Stiffening, braiding, refining, forming, sizing, pounding, ironing	200-300-500	2	
12.4.2	Cleaning, flanging, finishing	300-500-750	2	
12.4.3	Sewing	500-750-1000	2	
12.4.4	Inspection	1000-1500-2000	—	Local lighting may be appropriate
12.5	Boot and Shoe Manufacture			
12.5.1	Leather and synthetics			
12.5.2	Sorting and grading	750-1000-1500	1	
12.5.3	Clicking, closing	750-1000-1500	2	Local or localized lighting may be appropriate
12.5.4	Preparatory operations	750-1000-1500	2	Local or localized lighting may be appropriate
12.5.5	Cutting tables and pressure	1000-1500-2000	1	Local or localized lighting may be appropriate
12.5.6	Bottom stock preparation, lasting, bottoming finishing, shoe rooms	750-1000-1500	1	Local or localized lighting may be appropriate
12.5.7	Rubber			
12.5.7.1	Washing, compounding, coating, drying, varnishing, vulcanizing, calendaring, cutting	200-300-500	3	
12.5.7.2	Lining, making and finishing	300-500-750	2	
13	**TIMBER AND FURNITURE**			
13.1	Sawmills			
13.1.1	General	150-200-300	3	
13.1.2	Head saw	300-500-750	2	Localized lighting may be appropriate
13.1.3	Grading	500-750-1000	2	Directional lighting may be useful
13.2	Woodwork Shops			
13.2.1	Rough sawing, bench work	200-300-500	2	

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
13.2.2	Sizing, planning, sanding, medium machining and bench work	300-500-750	2	
13.2.3	Fine bench and machine work, fine sanding, finishing	500-750-1000	2	Localized lighting may be appropriate
13.3	Furniture Manufacture			
13.3.1	Raw material stores	50-100-150	3	
13.3.2	Finished goods stores	100-150-200	3	
13.3.3	Wood matching and assembly, rough sawing, cutting	200-300-500	2	
13.3.4	Machining, sanding and assembly, polishing	300-500-750	2	Localized lighting may be appropriate
13.3.5	Tool room	300-500-750	2	
13.3.6	Spray booths			
13.3.6.1	Colour finishing	300-500-750	2	
13.3.6.2	Clear finishing	200-300-500	2	
13.3.7	Cabinet making			
13.3.7.1	Veneer sorting and grading	750-1000-1500	1	
13.3.7.2	Marquetry, pressing, patching and fitting	300-500-750	1	
13.3.7.3	Final inspection	500-750-1000	1	Special lighting will be required
13.4	Upholstery Manufacture			
13.4.1	Cloth inspection	1000-1500-2000	1	Special lighting will be required
13.4.2	Filling, covering	300-500-750	2	
13.4.3	Slipping, cutting, sewing	500-750-1000	2	
13.4.4	Mattress making			
13.4.5	Assembly	300-500-750	2	
13.4.6	Tape edging	750-1000-1500	2	Local lighting may be appropriate
14	**PAPER AND PRINTING**			
14.1	Paper Mills			
14.1.1	Pulp mills, preparation plants	200-300-500	3	
14.1.2	Paper and board making			
14.1.2.1	General	200-300-500	3	
14.1.2.2	Automatic process	150-200-300	3	Supplementary lighting may be necessary for maintenance work
14.1.2.3	Inspection, sorting	300-500-750	1	
14.1.3	Paper converting processes			
14.1.3.1	General	200-300-500	3	
14.1.3.2	Associated printing	300-500-750	2	
14.2	Printing Works			
14.2.1	Type foundries			
14.2.1.1	Matrix making, dressing type, hand and machine coating	200-300-500	3	
14.2.1.2	Front assembly, sorting	500-750-1000	2	
14.2.2	Composing rooms			
14.2.2.1	Hand composing, imposition and distribution	500-750-1000	1	
14.2.2.2	Hot metal keyboard	500-750-1000	1	
14.2.2.3	Hot metal casting	200-300-500	2	
14.2.2.4	Photo composing keyboard or setters	300-500-750	1	
14.2.2.5	Paste up	500-750-1000	1	
14.2.2.6	Illuminated tables — general lighting	200-300-500	—	Dimming may be required
14.2.2.7	Proof presses	300-500-750	2	
14.2.2.8	Proof reading	500-750-1000	1	
14.2.3	Graphic reproduction			
14.2.3.1	General	300-500-750	2	
14.2.3.2	Precision proofing, retouching, etching	750-1000-1500	1	Local lighting may be appropriate
14.2.3.3	Colour reproduction and inspection	750-1000-1500	1	
14.2.4	Printing machine room			
14.2.4.1	Presses	300-500-750	2	
14.2.4.2	Premake ready	300-500-750	2	
14.2.4.3	Printed sheet inspection	750-1000-1500	1	
14.2.5	Binding			
14.2.5.1	Folding, pasting, punching and stitching	300-500-750	2	
14.2.5.2	Cutting, assembling, embossing	500-750-1000	2	
15	**PLASTIC AND RUBBER**			
15.1	Plastic Products			
15.1.1	Automatic plant			

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
15.1.1.1	Without manual control	30-50-100	3	
15.1.1.2	With occasional manual control	50-100-150	3	
15.1.1.3	With continuous manual control	200-300-500	3	
15.1.1.4	Control rooms	200-300-500	1	
15.1.1.5	Control platforms	200-300-500	2	Local lighting may be appropriate
15.1.2	Non-automatic plant			
15.1.2.1	Mixing, calendaring, extrusion, injection, compression and blow moulding, sheet fabrication	200-300-500	3	
15.1.2.2	Trimming, cutting, polishing, cementing	300-500-750	2	
15.1.2.3	Printing, inspection	750-1000-1500	1	
15.2	Rubber Products			
15.2.1	Stock preparation — plasticizing, milling	150-200-300	3	
15.2.2	Calendaring, fabric preparation, stock-cutting	300-500-750	3	
15.2.3	Extruding, moulding	300-500-750	2	
15.2.4	Inspection	750-1000-1500	—	
16	**DISTRIBUTION AND STORAGE**			
16.1	Work Stores	100-150-200	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.1	Unpacking, sorting	150-200-300	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.2	Large item storage	50-100-150	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.3	Small item rack storage	200-300-500	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.4	Issue counter, records, storeman's desk	300-500-750	2	Local or localized lighting may be appropriate
16.2	Warehouses and Bulk Stores			
16.2.1	Storage of goods where indentification requires only limited preparation of detail	50-100-150	3	
16.2.2	Storage of goods where identification requires perception of detail	100-150-200	3	
16.2.3	Automatic high bay rack stores			
16.2.3.1	Gangway	20	—	
16.2.3.2	Control station	150-200-300	3	
16.2.3.3	Packing and dispatch	200-300-500	3	
16.2.3.4	Loading bays	100-150-200	3	Avoid glare to drivers of vehicles approaching the loading bay
16.3	Cold Stores			
16.3.1	General	200-300-500	3	
16.3.2	Breakdown, make-up and dispatch	200-300-500	3	
16.3.3	Loading bays	100-150-200	3	Avoid glare to drivers of vehicles approaching the loading bay
17	**COMMERCE**			
17.1	Offices			
17.1.1	General offices	300-500-750	1	
17.1.2	Deep plan general offices	500-750-1000	1	
17.1.3	Computer work stations	300-500-750	1	
17.1.4	Conference rooms, executive offices	300-500-750	1	
17.1.5	Computer and data preparation rooms	300-500-750	1	
171.6	Filing rooms	200-300-500	1	
17.2	Drawing Offices			
17.2.1	General	300-500-750	1	
17.2.2	Drawing boards	500-750-1000	1	
17.2.3	Computer aided design and drafting	—	—	Special lighting is required
17.2.4	Print rooms	200-300-500	1	
17.3	Banks and Building Societies			
17.3.1	Counter, office area	300-500-750	1	
17.3.2	Public area	200-300-500	1	
18	**SERVICES**			
18.1	Garages			
18.1.1	Interior parking areas	20-30-50	3	

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
18.1.2	General repairs, servicing, washing, polishing	200-300-500	2	
18.1.3	Workbench	300-500-750	1	Local or localized lighting may be appropriate
18.1.4	Spray booths	300-500-750	1	
18.1.5	External apron			
18.1.5.1	General	30-50-100	—	Care should be taken to avoid glare to drivers and neightbouring residents
18.1.5.2	Pump area (retail sales)	200-300-500	—	*See* 'Retailing'
18.2	Appliance servicing			
18.2.1	Workshop			
18.2.1.1	General	200-300-500	2	
18.2.1.2	Workbench	300-500-750	2	Localized lighting may be appropriate
18.2.1.3	Counter	200-300-500	2	Localized lighting may be appropriate
18.2.1.4	Stores	200-300-500	3	
18.3	Laundries			
18.3.1	Commercial laundries			
18.3.2	Receiving, sorting, washing, drying, ironing, despatch, dry-cleaning, bulk machine work	200-300-500	3	
18.3.3	Head ironing, pressing, mending, spotting, inspection	300-500-750	3	
18.3.4	Launderettes	200-300-500	3	
18.4	Sewage Treatment Works			
18.4.1	Walkways	30-50-100	3	
18.4.2	Process areas	50-100-150	3	
19	**RETAILING**			
19.1	Small Shops with Counters	300-500-750	1	The service illuminance should be provided on the horizontal plane of the counter. Where wall displays are used, a similar illuminance on the walls is desirable
19.2	Small Self-Service Shops with Island Displays	300-500-750	1	
19.3	Supper Markets, Hyper-Markets			
19.3.1	General	300-500-750	2	
19.3.2	Checkout	300-500-750	2	
19.3.3	Showroom for large objects, for example, cars, furnitures	300-500-750	1	
19.3.4	Shopping precincts and arcades	100-150-200	2	
20	**PLACES OF PUBLIC ASSEMBLY**			
20.1	Public Rooms, Village Halls, Worship Halls	200-300-500	1	
20.2	Concert Halls, Cinemas and Theatres			
20.2.1	Foyer	150-200-300	—	
20.2.2	Booking office	200-300-500	—	Local or localized lighting may be appropriate
20.2.3	Auditorium	50-100-150	—	Dimming facilities will be necessary. Special lighting of the aisles is desirable
20.2.4	Dressing rooms	200-300-500		Special mirror lighting for make-up may be required
20.2.5	Projection room	100-150-200	—	
20.3	Churches			
20.3.1	Body of church	100-150-200	2	
20.3.2	Pulpit, lectern	200-300-500	2	Use local lighting
20.3.3	Choir stalls	200-300-500	2	Local lighting may be appropriate
20.3.4	Alter, communion table, chancel	100-150-200	2	Additional lighting to provide emphasis is desirable
20.3.5	Vestries	100-150-200	2	
20.3.6	Organ	200-300-500	—	
20.4	Hospitals			
20.4.1	Anaesthatic rooms			

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
20.4.1.1	General	200-300-500	—	
20.4.1.2	Local	750-1000-1500	—	
20.4.2	Consulting areas			
20.4.2.1	General	200-300-500	—	
20.4.2.2	Examination	750-1000-1500	—	
20.4.3	Corridors			
20.4.3.1	General	100-150-200	—	
20.4.4	Ward corridors			
20.4.4.1	Day, screened from bays	150-200-300	—	
20.4.4.2	Day, open to natural light	150-200-300 (total)	—	
20.4.4.3	Morning/Evening	100-150-200	—	
20.4.4.4	Night	5-10	—	
20.4.5	Cubicles			
20.4.5.1	General	200-300-500	—	
20.4.5.2	Treatment	750-1000-1500	—	
20.4.6	Examination			
20.4.6.1	General	200-300-500	—	
20.4.6.2	Local inspection	750-1000-1500	—	
20.4.7	Intensive therapy			
20.4.7.1	Bad head	30-50	—	
20.4.7.2	Circulation between bed ends	50-100-150	—	
20.4.7.3	Observation	200-300-500	—	
20.4.7.4	Local observation	750-1000-1500	—	
20.4.7.5	Staff base (day)	200-300-500	—	
20.4.7.6	Staff base (night)	30	—	
20.4.8	Laboratories			
20.4.8.1	General	200-300-500	—	
20.4.8.2	Examination	300-500-750	—	
20.4.9	Nurses' stations			
20.4.9.1	Morning/day/evening	200-300-500	—	
20.4.9.2	Night desks	30	—	
20.4.9.3	Night, medical trolleys	50-100-150	—	
20.4.10	Operating theatres			
20.4.10.1	General	300-500-750	—	
20.4.10.2	Local	10 000 to 50 000	—	Special operating lights are used
20.4.11	Pathology departments			
20.4.11.1	General	200-300-500	—	
20.4.11.2	Examination	300-500-750	—	
20.4.11.3	Pharmacies	200-300-500	—	
20.4.11.4	Reception/enquiry	200-300-500	—	
20.4.11.5	Recovery rooms	200-300-500	—	
20.4.12	Ward-circulation			
20.4.12.1	Day	50-100-150	—	
20.4.12.2	Morning/Evening	50-100-150	—	
20.4.12.3	Night	3-5	—	
20.4.13	Ward-bed head			
20.4.13.1	Morning/Evening	30-50		
20.4.13.2	Reading	100-150-200		
20.4.14	Night			
20.4.14.1	Adult	0.1-1		
20.4.14.2	Pediatric	1		
20.4.14.3	Psychiatric	1-5		
20.4.14.4	Watch	5		
20.4.15	X-Ray areas			
20.4.15.1	General	150-200-300		
20.4.15.2	Diagnostic	150-200-300		
20.4.15.3	Operative	200-300-500		
20.4.15.4	Process dark room	50		
20.4.16	Surgeries			
20.4.16.1	General	200-300-500	—	
20.4.16.2	Waiting rooms	100-150-200	—	
20.4.17	Dental surgeries			
20.4.17.1	Chair	Special lighting		

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
20.4.17.2	Laboratories	300-500-750	—	
20.4.18	Consulting rooms			
20.4.18.1	General	200-300-500	—	
20.4.18.2	Desk	300-500-750	—	
20.4.18.3	Examination couch	300-500-750	—	
20.4.18.4	Ophthalmic wall and near-vision charts	300-500-750	—	
20.5	Hotels			
20.5.1	Entrance halls	50-100-150		
20.5.2	Reception, cashier's and porters' desks	200-300-500		Localized lighting may be appropriate
20.5.3	Bars, coffee base, dining rooms, grill rooms, restaurants, lounges	50-200		The lighting should be designed to create an appropriate atmosphere
20.5.4	Cloak rooms, baggage rooms	50-100-150	3	
20.5.5	Bed rooms	30-50-100	—	Supplementary local lighting at the bed head, writing table should be provided
20.5.6	Bathroom	50-100-150		Supplementary local lighting near the mirror is desirable
20.5.7	Food preparation and stores, cellars, lifts and corridors	—	—	*See* 'General Building Areas'
20.6	Libraries			
20.6.1	Lending library			
20.6.1.1	General	200-300-500	1	
20.6.1.2	Counters	300-500-750	1	Localized lighting may be appropriate
20.6.1.3	Bookshelves	100-150-200	2	The service illuminance should be provided on the vertical face at the bottom of the bookstack
20.6.1.4	Reading rooms	200-300-500	1	
20.6.1.5	Reading tables	200-300-500	1	Localized lighting may be appropriate
20.6.2	Catalogues			
20.6.2.1	Card	100-150-200	2	
20.6.2.2	Microfiche/Visual display units	100-150-200	2	
20.6.3	Reference libraries			
20.6.3.1	General	200-300-500	1	
20.6.3.2	Counters	300-500-750	1	Localized lighting may be appropriate
20.6.3.3	Bookshelves	100-150-200	2	The service illuminance should be provided on a vertical surface at the foot of the bookshelves
20.6.3.4	Study tables, carrels	300-500-750	1	
20.6.3.5	Map room	200-300-500	1	
20.6.4	Display and exhibition areas			
20.6.4.1	Exhibits insensitive to light	200-300-500	—	
20.6.4.2	Exhibit sensitive to light, for example, pictures, prints, rare books in archives	50 to 150	—	
20.6.5	Library workrooms			
20.6.5.1	Book repair and binding	300-500-750	2	
20.6.5.2	Catalogue and sorting	300-500-750	2	
20.6.5.3	Remote book stores	100-150-200	3	
20.7	Museums and Art Galleries			
20.7.1	Exhibits insensitive to light	200-300-500	—	
20.7.2	Light sensitive exhibits, for example, oil and temper paints, undyed leather, bone, ivory, wood, etc	150	—	This is a maximum illuminance to be provided on the principal plane of the exhibit
20.7.3	Extremely light sensitive exhibits, for example, textiles, water colours, prints and drawings, skins, botanical specimens, etc	50	—	This is the maximum illuminance to be provided on the principal plane of the object
20.7.4	Conservation studies and workshops	300-500-750	1	
20.8	Sports Facilities			

Table 4 — *Continued*

(1)	(2)	(3)	(4)	(5)
	Multi-purpose sports halls	300-750	—	This lighting system should be sufficiently flexible to provide lighting suitable for the variety of sports and activities that take place in sports halls. Higher illuminance of 1000-2000 lux would be required for television coverage
21	**EDUCATION**			
21.1	Assembly Halls			
21.1.1	General	200-300-500	3	
21.1.2	Platform and stage	—	—	Special lighting to provide emphasis and to facilitate the use of the platform/ stage is desirable
21.2	Teaching Spaces			
	General	200-300-500	1	
21.3	Lecture Theatres			
21.3.1	General	200-300-500	1	
21.3.2	Demonstration benches	300-500-750	1	Localized lighting may be appropriate
21.4	Seminar Rooms	300-500-750	1	
21.5	Art Rooms	300-500-750	1	
21.6	Needlework Rooms	300-500-750	1	
21.7	Laboratories	300-500-750	1	
21.8	Libraries	200-300-500	1	
21.9	Music Rooms	200-300-500	1	
21.10	Sports Halls	200-300-500	1	
21.11	Workshops	200-300-500	1	
22	**TRANSPORT**			
22.1	Airports			
22.1.1	Ticket counters, checking desks, and information desks	300-500-750	2	Localized lighting may be appropriate
22.1.2	Departure lounges, other waiting areas	150-200-300	2	
22.1.3	Baggage reclaim	150-200-300	2	
22.1.4	Baggage handling	50-100-150	2	
22.1.5	Customs and immigration halls	300-500-750	2	
22.1.6	Concourse	150-200-300	2	
22.2	Railway Stations			
22.2.1	Ticket office	300-500-750	2	Localized lighting may be appropriate
22.2.2	Information office	300-500-750	2	Localized lighting over the counter may be appropriate
22.2.3	Parcels office, left			
22.2.4	Luggage office			
22.2.4.1	General	50-100-150	2	
22.2.4.2	Counter	150-200-300	2	
22.2.5	Waiting rooms	150-200-300	2	
22.2.6	Concourse	150-200-300	2	
22.2.7	Time table	150-200-300	2	Localized lighting may be appropriate
22.2.8	Ticket barriers	150-200-300	2	Localized lighting may be appropriate
22.2.9	Platforms (covered)	30-50-100	2	Care should be taken to light and mark the edge of the platform clearly
22.2.10	Platforms (open)	20	—	Care should be taken to light and mark the edge of the platform clearly
22.3	Coach Stations			

Table 4 — *Concluded*

(1)	(2)	(3)	(4)	(5)
22.3.1	Ticket offices	300-500-750	2	Localized lighting over the counter may be appropriate
22.3.2	Information offices	300-500-750	2	Localized lighting over the counter may be appropriate
22.3.3	Left luggage office			
22.3.3.1	General	50-100-150	3	
22.3.3.2	Counter	150-200-300	3	Localized lighting is appropriate
22.3.4	Waiting rooms	150-200-300	2	
22.3.5	Concourse	150-200-300	2	
22.3.6	Time tables	150-200-300	2	Local lighting is appropriate
22.3.7	Loading areas	100-150-200	3	
23	**GENERAL BUILDING AREAS**			
23.1	Entrance			
23.1.1	Entrance halls, lobbies, waiting rooms	150-200-300	2	
23.1.2	Enquiry desks	300-500-750	2	Localized lighting may be appropriate
23.1.3	Gatehouses	150-200-300	2	
23.2	Circulation Areas			
23.2.1	Lifts	50-100-150	—	
23.2.2	Corridors, passageways, stairs	50-100-150	2	
23.2.3	Escalators, travellators	100-150-200	—	
23.3	Medical and First Aid Centres			
23.3.1	Consulting rooms, treatment rooms	300-500-750	1	
23.3.2	Rest rooms	100-150-200	1	
23.3.3	Medical stores	100-150-200	2	
23.4	Staff Rooms			
23.4.1	Changing, locker and cleaners rooms, cloakrooms, lavatories	50-100-150	—	
23.4.2	Rest rooms	100-150-200	1	
23.5	Staff Restaurants			
23.5.1	Canteens, cafeterias, dining rooms, mess rooms	150-200-300	2	
23.5.2	Servery, vegetable preparation, washing-up area	200-300-500	2	
23.5.3	Food preparation and cooking	300-500-750	2	
23.5.4	Food stores, cellars	100-150-200	2	
23.6	Communications			
23.6.1	Switchboard rooms	200-300-500	2	
23.6.2	Telephone apparatus rooms	100-150-200	2	
23.6.3	Telex room, post room	300-500-750	2	
23.6.4	Reprographic room	200-300-500	2	
23.7	Building Services			
23.7.1	Boiler houses			
23.7.1.1	General	50-100-150	3	
23.7.1.2	Boiler front	100-150-200	3	
23.7.1.3	Boiler control room	200-300-500	2	Localized lighting of the control display and the control desk may be appropriate
23.7.1.4	Control rooms	200-300-500	2	Localized lighting of the control display and the control desk may be appropriate
23.7.1.5	Mechanical plant room	100-150-200	2	
23.7.1.6	Electrical power supply and distribution rooms	100-150-200	2	
23.7.1.7	Store rooms	50-100-150	3	
23.8	Car Parks			
23.8.1	Covered car parks			
23.8.1.1	Floors	5-20	—	
23.8.1.2	Ramps and corners	30	—	
23.8.1.3	Entrances and exits	50-100-150	—	
23.8.1.4	Control booths	150-200-300	—	
23.8.1.5	Outdoor car parks	5-20	—	

It is important, when lighting stairways, to prevent disability from glare caused by direct sight of bright sources to emphasize the edges of the treads and to avoid confusing shadows. The same precautions should be taken in the lighting of cat-walks and stairways on outdoor industrial plants.

4.1.5.2 *Entrances*

The problems of correctly grading the lighting within a building to allow adequate time for adaptation when passing from one area to another area are particularly acute at building entrances. These are given below:

a) By day, people entering a building will be adapted to the very high levels of brightness usually present outdoors and there is risk of accident if entrance areas, particularly any steps, are poorly lighted. This problem may often be overcome by arranging windows to give adequate natural lighting at the immediate entrance, grading to lower levels further inside the entrance area. Where this cannot be done, supplementary artificial lighting should be installed to raise the level of illumination to an appropriate value.

b) At night it is desirable to light entrance halls and lobbies so that the illumination level reduces towards the exit and so that no bright fittings are in the line of sight of people leaving the building. Any entrance steps to the building should be well-lighted by correctly screened fittings.

4.1.6 For detailed information regarding principles of good lighting, reference may be made to good practice [8-1(2)].

4.2 Daylighting

The primary source of lighting for daylighting is the sun. The light received by the earth from the sun consists of two parts, namely, direct solar illuminance and sky illuminance. For the purposes of daylighting design, direct solar illuminance shall not be considered and only sky illuminance shall be taken as contributing to illumination of the building interiors during the day.

4.2.1 The relative amount of sky illuminance depends on the position of the sun defined by its altitude, which in turn, varies with the latitude of the locality, the day of the year and the time of the day, as indicated in Table 5.

4.2.2 The external available horizontal sky illuminance (diffuse illuminance) values which are exceeded for about 90 percent of the daytime working hours may be taken as outdoor design illuminance values for ensuring adequacy of daylighting design. The outdoor design sky illuminance varies for different climatic regions of the country. The recommended design sky illuminance values are 6 800 lux for cold climate, 8 000 lux for composite climate, 9 000 lux for warm humid climate, 9 000 lux for temperate climate and 10 500 for hot-dry climate. For integration with the artificial lighting during daytime working hours an increase of 500 lux in the recommended sky design illuminance for daylighting is suggested.

4.2.3 The daylight factor is dependent on the sky luminance distribution, which varies with atmospheric conditions. A clear design sky with its non-uniform distribution of luminance is adopted for the purposes of design in this section.

Table 5 Solar-Altitudes (to the Nearest Degree) for Indian Latitudes

(*Clause* 4.2.1)

Period of Year	22 June						21 March and 23 September						22 December					
Hours of Day (Sun or Solar)	07 00	08 00	09 00	10 00	11 00	12 00	07 00	08 00	09 00	10 00	11 00	12 00	07 00	08 00	09 00	10 00	11 00	12 00
Latitude	17 00	16 00	15 00	14 00	13 00	—	17 00	16 00	15 00	14 00	13 00	—	17 00	16 00	15 00	14 00	13 00	—
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(118)	(19)
10°N	18	31	45	58	70	77	15	30	44	59	72	80	9	23	35	46	53	57
13°N	19	32	46	60	72	80	15	29	44	58	70	77	8	21	33	43	51	54
16°N	20	33	47	61	74	83	14	29	43	56	68	74	7	19	31	41	48	51
19°N	21	34	48	62	75	86	14	28	42	55	66	71	5	18	29	48	45	48
22°N	22	35	49	62	75	89	14	28	41	53	64	68	4	16	27	36	42	45
25°N	23	36	49	63	76	88	13	27	40	52	61	65	3	14	25	34	39	42
28°N	23	36	49	63	76	86	13	26	39	50	59	62	1	13	23	31	37	39
31°N	24	37	50	62	75	82	13	25	37	48	56	56	—	11	21	28	34	36
34°N	25	37	49	62	73	79	12	25	36	46	53	56	—	9	18	26	31	33

4.2.4 *Components of Daylight Factor*

Daylight factor is the sum of all the daylight reaching on an indoor reference point from the following sources:

a) The direct sky visible from the point,
b) External surfaces reflecting light directly (*see* Note 1) to the point, and
c) Internal surfaces reflecting and inter-reflecting light to the point.

NOTES

1 External surface reflection may be computed approximately only for points at the centre of the room, and for detailed analysis procedures are complicated and these may be ignored for actual calculations.

2 Each of the three components, when expressed as a ratio or percent of the simultaneous external illuminance on the horizontal plane, defines respectively the sky component (SC), the external reflected component (ERC) and the internal reflected component (IRC) of the daylight factor.

4.2.4.1 The daylight factors on the horizontal plane only are usually taken, as the working plane in a room is generally horizontal; however, the factors in vertical planes should also be considered when specifying daylighting values for special cases, such as daylighting on class-rooms, blackboards, pictures and paintings hung on walls.

4.2.5 *Sky Component (SC)*

Sky component for a window of any size is computed by the use of the appropriate table of Annex A.

a) The recommended sky component level should be ensured generally on the working plane at the following positions:
   1) at a distance of 3 m to 3.75 m from the window along the central line perpendicular to the window,
   2) at the centre of the room if more appropriate, and
   3) at fixed locations, such as school desks, black-boards and office tables.
b) The daylight area of the prescribed sky component should not normally be less than half the total area of the room.

4.2.5.1 The values obtainable from the tables are for rectangular, open unglazed windows, with no external obstructions. The values shall be corrected for the presence of window bars, glazing and external obstructions, if any. This assumes the maintenance of a regular cleaning schedule.

4.2.5.2 *Corrections for window bars*

The corrections for window bars shall be made by multiplying the values read from tables in Annex A by a factor equal to the ratio of the clear opening to the overall opening.

4.2.5.3 *Correction for glazing*

Where windows are glazed, the sky components obtained from Annex A shall be reduced by 10 to 20 percent, provided the panes are of clear and clean glass. Where glass is of the frosted (ground) type, the sky components read from Annex A may be reduced by 15 to 30 percent. In case of tinted or reflective glass the reduction is about 50 percent. Higher indicated correction corresponds to larger windows and/or near reference points. In the case of openings and glazings which are not vertical, suitable correction shall be taken into account.

4.2.5.4 *Correction for external obstructions*

There is no separate correction, except that the values from tables in Annex A shall be read only for the unobstructed portions of the window.

4.2.6 *External Reflected Component (ERC)*

The value of the sky component corresponding to the portion of the window obstructed by the external obstructions may be found by the use of methods described in Annex B of good practice [8-1(3)].

These values when multiplied by the correction factors, corresponding to the mean elevation of obstruction from the point in question as given in Table 6, can be taken as the external reflected components for that point.

Table 6 Correction Factor for ERC

(*Clause* 4.2.6)

Mean Angle of Elevation	Correction Factor
(1)	(2)
5°	0.086
15°	0.086
25°	0.142
35°	0.192
45°	0.226
55°	0.274
65°	0.304
75°	0.324
85°	0.334

4.2.6.1 For method of calculating ERC, reference may be made to accepted standard (*see* Examples 10 and 11 given in Annex B of good practice [8-1(3)].

4.2.7 *Internal Reflected Component (IRC)*

The component of daylight factor contributed by reflection from the inside surfaces varies directly as the window area and inversely as the total area of internal surfaces, and depends on the reflection factor of the floor, wall and roof surfaces inside and of the

ground outside. For rooms white-washed on walls and ceiling and windows of normal sizes, the IRC will have sizeable value even at points far away from the window. External obstructions, when present, will proportionately reduce IRC. Where accurate values of IRC are desired, the same may be done in accordance with the good practice [8-1(3)].

4.2.8 *General Principles of Openings to Afford Good Lighting*

4.2.8.1 Generally, while taller openings give greater penetrations, broader openings give better distribution of light. It is preferable that some area of the sky at an altitude of 20° to 25° should light up the working plane.

4.2.8.2 Broader openings may also be equally or more efficient, provided their sills are raised by 300 mm to 600 mm above the working plane.

NOTE – It is to be noted that while placing window with a high sill level might help natural lighting, this is likely to reduce ventilation at work levels. While designing the opening for ventilation also, a compromise may be made by providing the sill level about 150 mm below the head level of workers.

4.2.8.3 For a given penetration, a number of small openings properly positioned along the same, adjacent or opposite walls will give better distribution of illumination than a single large opening. The sky component at any point, due to a number of openings may be easily determined from the corresponding sky component contour charts appropriately superposed. The sum of the individual sky component for each opening at the point gives the overall component due to all the openings. The same charts may also facilitate easy drawing of sky component contours due to multiple openings.

4.2.8.4 Unilateral lighting from side openings will, in general, be unsatisfactory if the effective width of the room is more than 2 to 2.5 times the distance from the floor to the top of the opening. In such cases provision of light shelves is always advantageous.

4.2.8.5 Openings on two opposite sides will give greater uniformity of internal daylight illumination, especially when the room is 7 m or more across. They also minimize glare by illuminating the wall surrounding each of the opposing openings. Side openings on one side and clerestory openings on the opposite side may be provided where the situation so requires.

4.2.8.6 Cross-lighting with openings on adjacent walls tends to increase the diffused lighting within a room.

4.2.8.7 Openings in deep reveals tend to minimize glare effects.

4.2.8.8 Openings shall be provided with *CHAJJAHS*, louvers, baffles or other shading devices to exclude, as far as possible, direct sunlight entering the room. *CHAJJAHS*, louvers, etc, reduce the effective height of the opening for which due allowance shall be made. Broad and low openings are, in general, much easier to shade against sunlight entry. Direct sunlight, when it enters, increases the inside illuminance very considerably. Glare will result if it falls on walls at low angles, more so than when it falls on floors, especially when the floors are dark coloured or less reflective.

4.2.8.9 Light control media, such as translucent glass panes (opal or matt) surfaced by grinding, etching or sandblasting, configurated or corrugated glass, certain types of prismatic glass, tinted glass and glass blasts are often used. They should be provided, either fixed or movable outside or inside, especially in the upper portions of the openings. The lower portions are usually left clear to afford desirable view. The chief purpose of such fixtures is to reflect part of the light on to the roof and thereby increase the diffuse lighting within, light up the farther areas in the room and thereby produce a more uniform illumination throughout. They will also prevent the opening causing serious glare discomfort to the occupants but will provide some glare when illuminated by direct sunlight.

4.2.9 *Availability of Daylight in Multi-storeyed Block*

Proper planning and layout of building can add appreciably to daylighting illumination inside. Certain dispositions of building masses offer much less mutual obstruction to daylight than others and have a significant relevance, especially when intensive site planning is undertaken. The relative availability of daylight in multi-storeyed blocks of different relative orientations are given in Table 7.

Table 7 Relative Availability of Daylight on the Window Plane at Ground Level in a Four-Storeyed Building Blocks (Clear Design-Sky as Basis, Daylight Availability Taken as Unity on an Unobstructed Façade, Values are for the Centre of the Blocks)

(*Clause* 4.2.9)

Distance of Separation Between Blocks	Infinitely Long Parallel Blocks	Parallel Blocks Facing Each Other (Length = 2 × Height)	Parallel Blocks Facing Gaps Between Opposite Blocks (Length = 2 × Height)
(1)	(2)	(3)	(4)
0.5 *Ht*	0.15	0.15	0.25
1.0 *Ht*	0.30	0.32	0.38
1.5 *Ht*	0.40	0.50	0.55
2.0 *Ht*	0.50	0.60	0.68

4.2.10 For specified requirements for daylighting of special occupancies and areas, reference may be made to good practice [8-1(4)].

4.3 Artificial Lighting

4.3.1 Artificial lighting may have to be provided

a) where the recommended illumination levels have to be obtained by artificial lighting only,

b) to supplement daylighting when the level of illumination falls below the recommended value, and

c) where visual task may demand a higher level of illumination.

4.3.2 *Artificial Lighting Design for Interiors*

For general lighting purposes, the recommended practice is to design for a level of illumination on the working plane on the basis of the recommended levels for visual tasks given in Table 4 by a method called 'Lumen method'. In order to make the necessary detailed calculations concerning the type and quantity of lighting equipment necessary, advance information on the surface reflectances of walls, ceilings and floors is required. Similarly, calculations concerning the brightness ratio in the interior call for details of the interior décor and furnishing. Stepwise guidance regarding designing the interior lighting systems for a building using the 'Lumen method' is given in **4.3.2.1** to **4.3.2.4.**

4.3.2.1 *Determination of the illumination level*

Recommended value of illumination shall be taken from Table 4, depending upon the type of work to be carried out in the location in question and the visual tasks involved.

4.3.2.2 *Selection of the light sources and luminaires*

The selection of light sources and luminaires depends on the choice of lighting system, namely, general lighting, directional lighting and localized or local lighting.

4.3.2.3 *Determination of the luminous flux*

a) The luminous flux (ϕ) reaching the working plane depends upon the following:

1) lumen output of the lamps,
2) type of luminaire,
3) proportion of the room (room index) (k_r),
4) reflectance of internal surfaces of the room,
5) depreciation in the lumen output of the lamps after burning their rated life, and
6) depreciation due to dirt collection on luminaires and room suface.

b) *Coefficient of Utilization or Utilization Factor*

1) The compilation of tables for the utilization factor requires a considerable amount of calculations, especially if these tables have to cover a wide range of lighting practices. For every luminaire, the exact light distribution has to be measured in the laboratory and their efficiencies have to be calculated and measured exactly. These measurements comprise:

i) the luminous flux radiated by the luminaires directly to the measuring surface,

ii) the luminous flux reflected and re-reflected by the ceiling and the walls to the measuring surface, and

iii) the inter-reflections between the ceiling and wall which result in the measuring surface receiving additional luminous flux.

All these measurements have to be made for different reflection factors of the ceiling and the walls for all necessary room indices. These tables have also to indicate the maintenance factor to be taken for the luminous flux depreciation throughout the life of an installation due to ageing of the lamp and owing to the deposition of dirt on the lamps and luminaires and room surfaces.

2) The values of the reflection factor of the ceiling and of the wall are as follows:

White and very light colours	0.7
Light colours	0.5
Middle tints	0.3
Dark colours	0.1

For the walls, taking into account the influence of the windows without curtains, shelves, almirahs and doors with different colours, etc, should be estimated.

c) *Calculation for determining the luminous flux*

$$E_{av} = \frac{\mu \phi}{A}$$

or, $\phi = \frac{E_{av} A}{\mu}$ for new condition

and $\phi = \frac{E_{av} A}{\mu d}$ for working condition

where

ϕ = Total luminous flux of the light sources installed in the room inlumens;

E_{av} = Average illumination level required on the working plane inlux;

A = Area of the working plane in m^2;

μ = the utilization factor in new conditions; and

d = maintenance factor.

In practice, it is easier to calculate straightaway the number of lamps or luminaires from:

$$N_{\text{lamp}} = \frac{E_{\text{av}} A}{\mu\, d\, \phi_{\text{lamp}}}$$

$$N_{\text{luminaires}} = \frac{E_{\text{av}} A}{\mu\, d\, \phi_{\text{luminaires}}}$$

where

ϕ_{lamp} = Luminous flux of each lamp in lumens,

$\phi_{\text{luminaires}}$ = Luminous flux of each luminaire in lumens,

N_{lamp} = Total number of lamps, and

$N_{\text{luminaires}}$ = Total number of luminaires.

4.3.2.4 *Arrangement of the luminaires*

This is done to achieve better uniformly distributed illumination. The location of the luminaires has an important effect on the utilization factor.

a) In general, luminaires are spaced 'a' metre apart in either direction, while the distance of the end luminaire from the wall is '½a' metre. The distance 'a' is more or less equal to the mounting height 'H_m' between the luminaire and the working plane. The utilization factor tables are calculated for this arrangement of luminaires.

b) For small rooms where the room index (k_r) is less than 1, the distance 'a' should always be less than H_m, since otherwise luminaires cannot be properly located. In most cases of such rooms, four or two luminaires are placed for good general lighting. If, however, in such rooms only one luminaire is installed in the middle, higher utilization factors are obtained, but the uniformity of distribution is poor. For such cases, references should be made to the additional tables for k_r = 0.6 to 1.25 for luminaires located centrally.

4.3.3 *Artificial Lighting to Supplement Daylighting*

4.3.3.1 The need for general supplementary artificial lighting arises due to diminution of daylighting beyond design hours, that is, for solar altitude below 15° or when dark cloudy conditions occur.

4.3.3.2 The need may also arise for providing artificial lighting during the day in the innermost parts of the building which cannot be adequately provided with daylighting, or when the outside windows are not of adequate size or when there are unavoidable external obstructions to the incoming daylighting.

4.3.3.3 The need for supplementary lighting during the day arises, particularly when the daylighting on the working plane falls below 100 lux and the surrounding luminance drops below 19 cd/m^2.

4.3.3.4 The requirement of supplementary artificial lighting increases with the *decrease* in daylighting availability. Therefore, conditions near sunset or sunrise or equivalent conditions due to clouds or obstructions, etc, represent the worst conditions when the supplementary lighting is most needed.

4.3.3.5 The requirement of supplementary artificial lighting when daylighting availability becomes poor may be determined from Fig. 3 for an assumed ceiling height of 3.0 m, depending upon floor area, fenestration percentage and room surface reflectance. Cool daylight fluorescent tubes are recommended with semi-direct luminaires. To ensure a good distribution of illumination, the mounting height should be between 1.5 m and 2.0 m above the work plane for a separation of 2.0 m to 3.0 m between the luminaires. Also the number of lamps should preferably be more in the rear half of the room than in the vicinity of windows. The following steps may be followed for using Fig. 3 for determining the number of fluorescent tubes required for supplementary daylighting.

a) Determine fenestration percentage of the floor area, that is,

$$\frac{\text{Window Area}}{\text{Floor Area}} \times 100$$

b) In Fig. 3, refer to the curve corresponding to the percent fenestration determined above and the set of reflectances of ceiling, walls and floor actually provided.

c) For the referred curve of Fig. 3 read, along the ordinate, the number of 40 W fluorescent tubes required, corresponding to the given floor area on the abscissa.

4.3.4 For detailed information on the design aspects and principles of artificial lighting, reference may be made to good practice [8-1(2)].

4.3.5 For specific requirements for lighting of special occupancies and areas, reference may be made to good practice [8-1(5)].

4.3.6 Electrical installation aspect for artificial lighting shall be in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

4.4 Energy Conservation in Lighting

4.4.1 A substantial portion of the energy consumed on lighting may be saved by utilization of daylight and rational design of supplementary artificial lights.

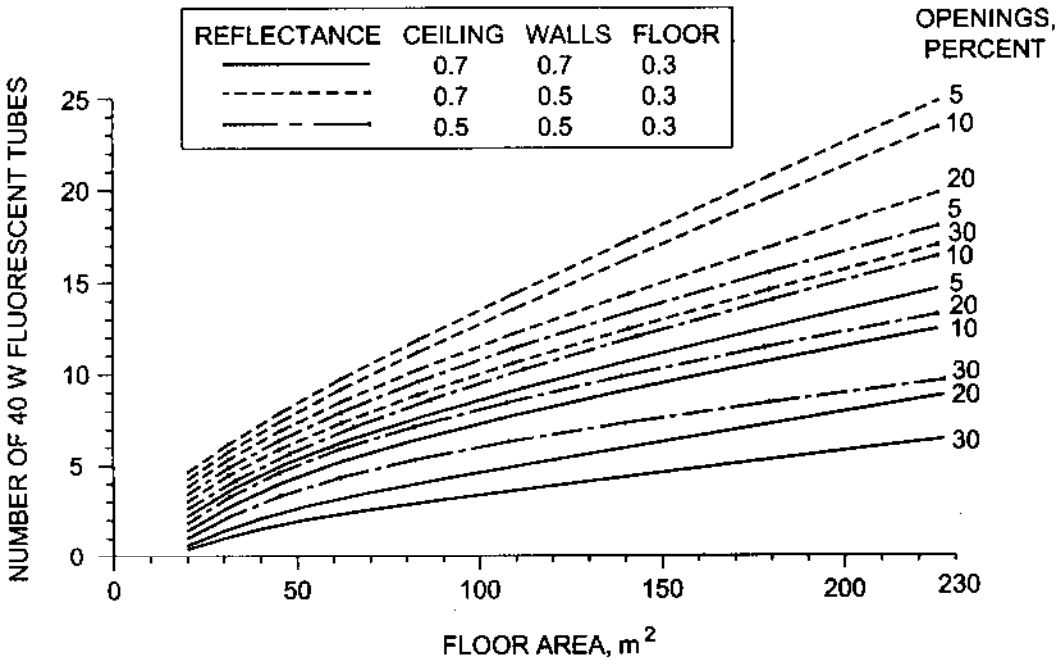

FIG. 3 SUPPLEMENTARY ARTIFICIAL LIGHTING FOR 40W FLUORESCENT TUBES

4.4.2 Daytime use of artificial lights may be minimized by proper design of windows for adequate daylight indoors. Daylighting design should be according to **4.2**.

4.4.3 Fenestration expressed as percentage of floor area required for satisfactory visual performance of a few tasks for different separation to height (*S/H*) ratio of external obstructions such as opposite buildings may be obtained from the design nomograph (Fig. 4). The obstructions at a distance of three times their height or more ($S/H > 3$) from a window façade are not significant and a window facing such an obstruction may be regarded as a case of unobstructed window.

4.4.3.1 The nomograph consists of horizontal lines indicating fenestration percentage of floor area and vertical lines indicating the separation to height ratio of external obstructions such as opposite buildings. Any vertical line for separation to height ratio other than already shown in the nomograph (1.0, 2.0 and 3.0) may be drawn by designer, if required. For cases where there is no obstruction, the ordinate corresponding to the value 3.0 may be used. The value of percentage fenestration and separation to height ratio are marked on left hand ordinate and abscissa respectively. The illumination levels are marked on the right hand ordinate. The values given within brackets are the illumination levels on the work plane at centre and rear of the room. The wattage of fluorescent tubes required per square metre of the floor area for different illumination levels is shown on each curve.

4.4.3.2 Following assumptions have been made in the construction of the nomograph:

a) An average interior finish with ceiling white, walls off white and floor grey has been assumed.

b) Ceiling height of 3 m and room depths up to 10 m and floor area between 30 m^2 and 50 m^2 have been assumed. For floor area beyond 50 m^2 and less than 30 m^2, the values of percent fenestration as well as wattage per m^2 should be multiplied by a factor of 0.85 and 1.15 respectively.

c) It is assumed that windows are of metallic sashes with louvers of width up to 600 mm or a *CHHAJJA* (balcony projection) at ceiling level of width up to 2.0 m. For wooden sashes, the window area should be increased by a factor of about 1.1.

d) Luminaires emanating more light in the downward direction than upward direction (such as reflectors with or without diffusing plastics) and mounted at a height of 1.5 m to 2.0 m above the workplane have been considered.

4.4.3.3 *Method of use*

The following steps shall be followed for the use of nomograph:

a) *Step 1* — Decide the desired illumination level depending upon the task illumination requirement in the proposed room and read the value of watts per square metre on the curve corresponding to the required illumination level.

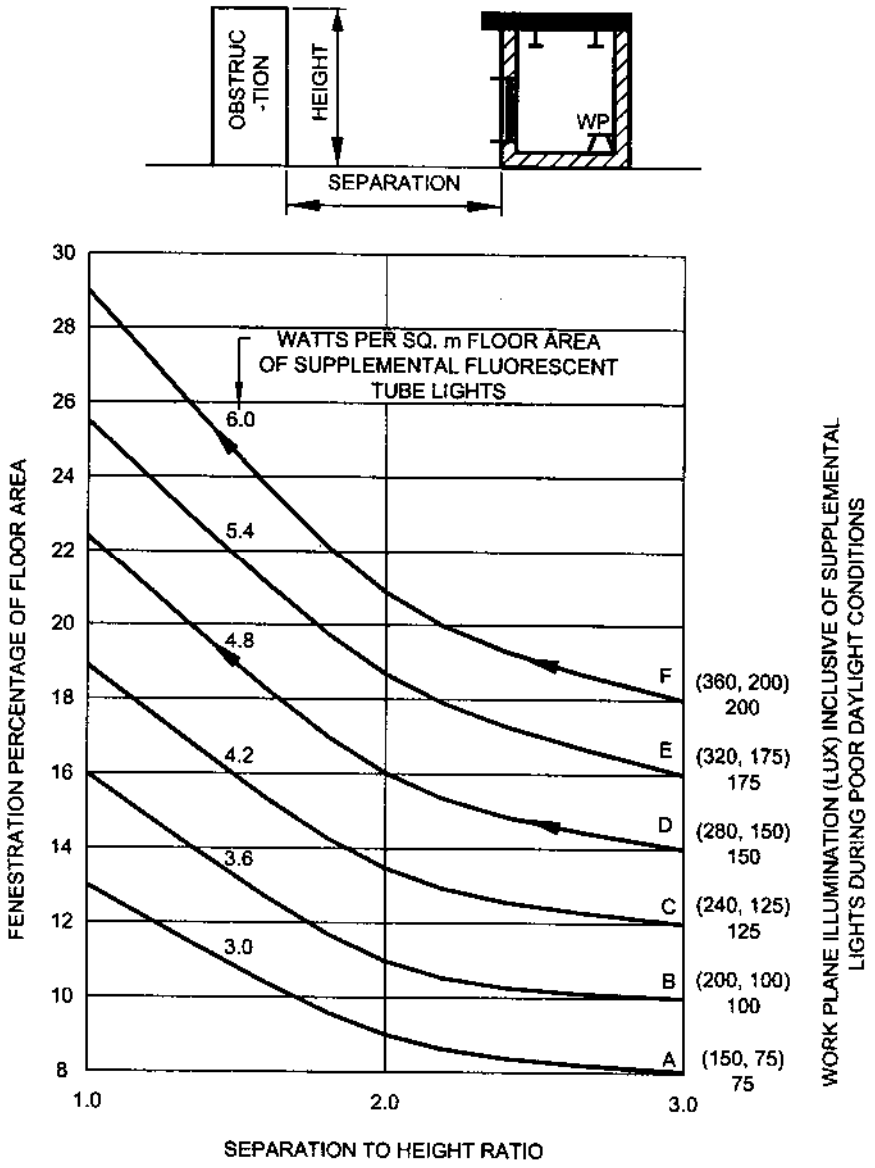

FIG. 4 NOMOGRAPH FOR DAYLIGHTING AND SUPPLEMENTAL LIGHTING DESIGN OF BUILDING

b) *Step 2* — Fix the vertical line corresponding to the given separation to height ratio of opposite buildings on the abscissa. From the point of intersection of this vertical line and the above curve move along horizontal, and read the value of fenestration percent on the left hand ordinate.

c) *Step 3* — If the floor area is greater than 50 m^2 and less than 30 m^2, the value of watts per square metre as well as fenestration percent may be easily determined for adequate daylighting and supplemental artificial lighting for design purposes. However, if the fenestration provided is less than the required value, the wattage of supplementary artificial lights should be increased proportionately to make up for the deficiency of natural illumination.

4.4.4 For good distribution of day light on the working plane in a room, window height, window width and height of sill should be chosen in accordance with the following recommendations:

a) In office buildings windows of height 1.2 m or more in the center of a bay with sill level at 1.0 to 1.2 m above floor and in residential buildings windows of height 1.0 m to 1.1 m with sill height as 0.9 m to 0.7 m above floor are recommended for good distribution of daylight indoors. Window width can

accordingly be adjusted depending upon the required fenestration percentage of the floor area.

b) If the room depth is more than 10 m, windows should be provided on opposite sides for bilateral lighting.

c) It is desirable to have a white finish for ceiling and off white (light colour) to white for walls. There is about 7 percent improvement in lighting levels in changing the finish of walls from moderate to white.

4.4.5 For good distribution and integration of daylight with artificial lights the following guidelines are recommended:

a) Employ cool daylight fluorescent tubes for supplementary artificial lighting.

b) Distribute luminaries with a separation of 2 m to 3 m in each bay of 3 m to 4 m width.

c) Provide more supplementary lights such as twin tube luminaries in work areas where daylight is expected to be poor for example in the rear region of a room having single window and in the central region of a room having windows on opposite walls. In the vicinity of windows only single tube luminaries should be provided.

4.4.6 *Artificial Lighting*

Energy conservation in lighting is effected by reducing wastage and using energy effective lamps and luminaires without sacrificing lighting quality. Measures to be followed comprise utilization of daylight, energy effective artificial lighting design by providing required illumination where needed, turning off artificial lights when not needed, maintaining lighter finishes of ceiling, walls and furnishings, and implementing periodic schedule for cleaning of luminaires and group replacement of lamps at suitable intervals. Choice of light sources with higher luminous efficacy and luminaires with appropriate light distribution is the most effective means of energy saving in lighting. However, choice of light sources also depends on the other lighting quality parameters like colour rendering index and colour temperature or appearance. For example, high pressure sodium vapour lamps, which have very high luminous efficacy, are not suitable for commercial interiors because of poor colour rendering index and colour appearance, but are highly desirable in heavy industries. Also the choice of light sources depends on the mounting height in the interiors. For example, fluorescent lamps are not preferred for mounting beyond 7 m height, when high pressure gas discharge lamps are preferred because of better optical control due to their compact size.

4.4.6.1 *Efficient artificial light sources and luminaires*

Luminous efficacy of some of the lamps used in lighting of buildings are given in Table 8 along with average life in burning hours, Colour Rendering Index and Colour Temperature.

Following recommendations may be followed in the choice of light sources for different locations:

a) For supplementary artificial lighting of work area in office building care should be taken to use fluorescent lamps, which match with colour temperature of the daylight.

b) For residential buildings fluorescent lamps and/or CFLs of proper CRI and CCT are recommended to match with the colours and interior design of the room.

c) For commercial interiors, depending on the mounting heights and interior design, fluorescent lamps, CFLs and low wattage metal halilde lamps are recommended. For highlighting the displays in show windows, hotels, etc, low wattage tubular or dichroic reflector type halogen lamps can be used.

d) For industrial lighting, depending on the mounting height and colour consideration fluorescent lamps, high pressure mercury vappour lamps or high pressure sodium vapour lamps are recommended.

4.4.6.2 For the same lumen output, it is possible to save 75 to 80 percent energy if GLS lamps are replaced with CFL and 65 to 70 percent if replaced with fluorescent lamps. Similar energy effective solutions are to be chosen for every application area.

Similarly with white fluorescent tubes recommended for corridors and staircases, the electrical consumption reduces to 1/4.5 of the energy consumption with incandescent lamps.

4.4.6.3 Efficient luminaire also plays an important role for energy conservation in lighting. The choice of a luminaire should be such that it is efficient not only initially but also throughout its life. Following luminaries are recommended for different locations:

a) For offices semi-direct type of luminaries are recommended so that both the work plane illumination and surround luminance can be effectively enhanced.

b) For corridors and staircases direct type of luminaries with wide spread of light distributions are recommended.

c) In residential buildings, bare fluorescent tubes are recommended. Wherever the incandescent lamps are employed, they should be provided

Table 8 Luminous Efficacy, Life, CRI and CCT of Light Sources

(*Clause* 4.4.6.1)

Sl No.	Light Source	Efficacy lm/W	Average Life h	CRI	CCT K
(1)	(2)	(3)	(4)	(5)	(6)
i)	Incandescent lamps GLS 25 W-1 000 W	8-18	1 000	100	2 800
ii)	Tungsten halogen incandescent lamps Mains-voltage types: 60 W-2 000 W Low-voltage types with reflector have lower wattages	10% higher than comparable GLS lamp	2 000	100	2 800-3 200
iii)	Fluorescent lamps (FTL)				
	a) Standard lamps 38 mm (T12) 20 W-65 W 26 mm (T 8) 18 W-58 W				
	Cool daylight	61	5 000	72	6 500
	Warm white	67	5 000	57	3 500
	b) Tri-Phosper lamps 38 mm (T12) 20 W-65 W 26 mm (T 8) 18 W-58 W	88-104	12 000-18 000	85-95	2 700-6 500
iv)	Compact Fluorescent Lamps (CFL) 5 W-25 W	40-80	8 000	Similar to FTL	
v)	High pressure mercury vapour lamps 80 W-400 W	36-60	5 000	45	4 000
vi)	Blended — Light lamps MLL 100 W-500 W	11-26	5 000	61	3 600
vii)	High Pressure Sodium Vapour Lamps 50 W-1 000 W	69-130	10 000-15 000	23	2 000
viii)	Metal halide lamps 35 W-2 000 W	69-83	10 000	68-92	3 000-5 600

NOTES

1 The table includes lamps and wattages currently in use in buildings in India.

2 Luminous efficacy varies with the wattage of the lamp.

3 Average life values are from available Indian Standards. Where Indian Standard is not available, values given are only indicative.

4 CRI and CCT values are only indicative.

5 For exact values, it is advisable to contact manufacturers.

with white enamelled conical reflectors at an inclination of about 45° from vertical.

4.4.7 *Cleaning Schedule for Window Panes and Luminaires*

Adequate schedule for cleaning of window panes and luminaries will result in significant advantage of enhanced daylight and lumen output from luminaries. This will tend to reduce the duration over which artificial lights will be used and minimize the wastage of energy. Depending upon the location of the building a minimum of three to six months interval for periodic cleaning of luminaries and window panes is recommended for maximum utilization of daylight and artificial lights.

4.4.8 *Photocontrols for Artificial Lights*

There is a considerable wastage of electrical energy in lighting of buildings due to carelessness in switching off lights even when sufficient daylight is available indoors. In offices and commercial buildings, occupants may switch on lights in the morning and keep them on throughout the day. When sufficient daylight is available inside, suitable photo controls can be employed to switch off the artificial lights and thus prevent the wastage of energy.

4.4.9 *Solar Photovoltaic Systems (SPV)*

Solar photovoltaic system enables direct conversion of sunlight into electricity and is viable option for lighting purpose in remote nongrid areas. The common SPV lighting systems are:

a) Solar lantern,

b) Fixed type solar home lighting system, and

c) Street lighting system.

4.4.9.1 SPV lighting system should preferably be provided with CFL for energy efficiency.

4.4.9.2 Invertors used in buildings for supplying electricity during the power cut period should be charged through SPV system.

4.4.9.3 Regular maintenance of SPV system is necessary for its satisfactory functioning.

5 VENTILATION

5.1 General

Ventilation of buildings is required to supply fresh air for respiration of occupants, to dilute inside air to prevent vitiation by body odours and to remove any products of combustion or other contaminants in air and to provide such thermal environments as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health of the occupants.

5.2 Design Considerations

5.2.1 *Respiration*

Supply of fresh air to provide oxygen for the human body for elimination of waste products and to maintain carbon dioxide concentration in the air within safe limits rarely calls for special attention as enough outside air for this purpose normally enters the areas of occupancy through crevices and other openings.

5.2.1.1 In normal habitable rooms devoid of smoke generating source, the content of carbon dioxide in air rarely exceeds 0.5 percent to 1 percent and is, therefore, incapable of producing any ill effect. The amount of air required to keep the concentration down to 1 percent is very small. The change in oxygen content is also too small under normal conditions to have any ill effects; the oxygen content may vary quite appreciably without noticeable effect, if the carbon dioxide concentration is unchanged.

5.2.2 *Vitiation by Body Odours*

Where no products of combustion or other contaminants are to be removed from air, the amount of fresh air required for dilution of inside air to prevent vitiation of air by body odours, depends on the air space available per person and the degree of physical activity; the amount of air decreases as the air space available per person increases, and it may vary from 20 m^3 to 30 m^3 per person per hour. In rooms occupied by only a small number of persons such an air change will automatically be attained in cool weather by normal leakage around windows and other openings and this may easily be secured in warm weather by keeping the openings open.

No standards have been laid down under the *Factories Act*, 1948 as regards the amount of fresh air required per worker or the number of air changes per hour. Section 16 relating to over-crowding requires that at least 14 m^3 to 16 m^3 of space shall be provided for every worker and for the purpose of that section no account shall be taken of any space in a work room which is more than 4.25 m above the floor level.

NOTE — Vitiation of the atmosphere can also occur in factories by odours given off due to contaminants of the product itself, say for example, from tobacco processing in a 'Bidi' factory. Here the ventilation will have to be augmented to keep odours within unobjectionable levels.

5.2.2.1 *Recommended values for air changes*

The standards of general ventilation are recommended/ based on maintenance of required oxygen, carbon dioxide and other air quality levels and for the control of body odours when no products of combustion or other contaminants are present in the air; the values of air changes should be as follows:

Sl No.	*Application*	*Air Change per Hour*
(1)	(2)	(3)
1.	Assembly rooms	4-8
2.	Bakeries	20-30
3.	Banks/building societies	4-8
4.	Bathrooms	6-10
5.	Bedrooms	2-4
6.	Billiard rooms	6-8
7.	Boiler rooms	15-30
8.	Cafes and coffee bars	10-12
9.	Canteens	8-12
10.	Cellars	3-10
11.	Churches	1-3
12.	Cinemas and theatres	10-15
13.	Club rooms	12, *Min*
14.	Compressor rooms	10-12
15.	Conference rooms	8-12
16.	Dairies	8-12
17.	Dance halls	12, *Min*
18.	Dye works	20-30
19.	Electroplating shops	10-12
20.	Engine rooms	15-30
21.	Entrance halls	3-5
22.	Factories and work shops	8-10
23.	Foundries	15-30
24.	Garages	6-8
25.	Glass houses	25-60
26.	Gymnasium	6, *Min*
27.	Hair dressing saloon	10-15
28.	Hospitals-sterlizing	15-25
29.	Hospital-wards	6-8
30.	Hospital domestic	15-20
31.	Laboratories	6-15
32.	Launderettes	10-15
33.	Laundries	10-30
34.	Lavatories	6-15
35.	Lecture theatres	5-8
36.	Libraries	3-5
37.	Living rooms	3-6
38.	Mushroom houses	6-10

39.	Offices	6-10
40.	Paint shops (not cellulose)	10-20
41.	Photo and X-ray dark room	10-15
42.	Public house bars	12, *Min*
43.	Recording control rooms	15-25
44.	Recording studios	10-12
45.	Restaurants	8-12
46.	Schoolrooms	5-7
47.	Shops and supermarkets	8-15
48.	Shower baths	15-20
49.	Stores and warehouses	3-6
50.	Squash courts	4, *Min*
51.	Swimming baths	10-15
52.	Toilets	6-10
53.	Utility rooms	15-20
54.	Welding shops	15-30

NOTE — The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below ground.

5.2.3 *Heat Balance of Body*

Specially in hot weather, when thermal environment inside the room is worsened by heat given off by machinery, occupants and other sources, the prime need for ventilation is to provide such thermal environment as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health. Excess of heat either from increased metabolism due to physical activity of persons or gains from a hot environment has to be offset to maintain normal body temperature (37°C). Heat exchange of the human body with respect to the surroundings is determined by the temperature and humidity gradient between the skin and the surroundings and other factors, such as age of persons, clothing, etc, and the latter depends on air temperature (dry bulb temperature), relative humidity, radiation from the solid surroundings and rate of air movement. The volume of outside air to be circulated through the room is, therefore, governed by the physical considerations of controlling the temperature, air distribution or air movement. Air movement and air distribution may, however, be achieved by recirculation of the inside air rather than bringing in all outside air. However, fresh air supply or the circulated air will reduce heat stress by dissipating heat from body by evaporation of the sweat, particularly when the relative humidity is high and the air temperature is near body temperature.

5.2.3.1 *Limits of comfort and heat tolerance*

Thermal comfort is that condition of thermal environment under which a person can maintain a body heat balance at normal body temperature and without perceptible comfort of a person lies between 15I values of 25°C and 30°C with optimum condition at 27.5°C. Air movement is necessary in hot and humid weather for body cooling. A certain minimum desirable wind speed is needed for achieving thermal comfort at different temperatures and relative humidities. Such wind speeds are given in Table 9. These are applicable to sedentary work in offices and other places having no noticeable sources of heat gain. Where somewhat warmer conditions are prevalent, such as in godowns and machine shops and work is of lighter intensity, and higher temperatures can be tolerated without much discomfort, minimum wind speeds for just acceptable warm conditions are given in Table 10. For obtaining values of indoor wind speed above 2.0 m/s, mechanical means of ventilation may have to be adopted (*see also* Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation').

Table 9 Desirable Wind Speeds (m/s) for Thermal Comfort Conditions

(*Clause* 5.2.3.1)

Dry Bulb Temperature, °C	Relative Humidity (Percentage)						
	30	40	50	60	70	80	90
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
28	*	*	*	*	*	*	*
29	*	*	*	*	*	0.06	0.19
30	*	*	*	0.06	0.24	0.53	0.85
31	*	0.06	0.24	0.53	1.04	1.47	2.10
32	0.20	0.46	0.94	1.59	2.26	3.04	**
33	0.77	1.36	2.12	3.00	**	**	**
34	1.85	2.72	**	**	**	**	**
35	3.20	**	**	**	**	**	**

* None

** Higher than those acceptable in practice.

Table 10 Minimum Wind Speeds (m/s) for Just Acceptable Warm Conditions

(*Clause* 5.2.3.1)

Dry Bulb Temperature, °C	Relative Humidity (Percentage)						
	30	40	50	60	70	80	90
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
28	*	*	*	*	*	*	*
29	*	*	*	*	*	*	*
30	*	*	*	*	*	*	*
31	*	*	*	*	*	0.06	0.23
32	*	*	*	0.09	0.29	0.60	0.94
33	*	0.04	0.24	0.60	1.04	1.85	2.10
34	0.15	0.46	0.94	1.60	2.26	3.05	**
35	0.68	1.36	2.10	3.05	**	**	**
36	1.72	2.70	**	**	**	**	**

* None

** Higher than those acceptable in practice.

5.2.3.2 There will be a limit of heat tolerance when air temperatures are excessive and the degree of physical activity is high. This limit is determined when the bodily heat balance is upset, that is, when the bodily heat gain due to conduction, convection and the radiation from the surroundings exceeds the bodily heat loss, which is mostly by evaporation of sweat from the surface of the body. The limits of heat tolerance for Indian workers are based on the study conducted by the Chief Adviser Factories, Government of India, Ministry of Labour and are given in his report on Thermal Stress in Textile Industry (Report No. 17) issued in 1956. According to this Report, where workers in industrial buildings wearing light clothing are expected to do work of moderate severity with the energy expenditure in the range 273 to 284 W, the maximum wet bulb temperature shall not exceed 29°C and adequate air movement subject to a minimum air velocity of 30 m/min shall be provided, and in relation to the dry bulb temperature, the wet bulb temperature of air in the work room, as far as practicable, shall not exceed that given in Table 11.

Table 11 Maximum Permissible Wet Bulb Temperatures for Given Dry Bulb Temperatures

(*Clause* 5.2.3.2)

Dry Bulb Temperature °C	Maximum Wet-Bulb Temperature, °C
(1)	(2)
30	29.0
35	28.5
40	28.0
45	27.5
50	27.0

NOTES

1 These are limits beyond which the industry should not allow the thermal conditions to go for more than 1 h continuously. The limits are based on a series of studies conducted on Indian subjects in psychrometric chamber and on other data on heat casualties in earlier studies conducted in Kolar Gold Fields and elsewhere.

2 Figures given in this table are not intended to convey that human efficiency at 50°C will remain the same as at 30°C, provided appropriate wet bulb temperatures are maintained. Efficiency decreases with rise in the dry bulb temperature as well, as much as possible. Long exposures to temperature of 50°C dry bulb/27°C wet bulb may prove dangerous.

3 Refrigeration or some other method of cooling is recommended in all cases where conditions would be worse than those shown in this table.

5.3 Methods of Ventilation

General ventilation involves providing a building with relatively large quantities of outside air in order to improve general environment of the building. This may be achieved in one of the following ways:

a) Natural supply and natural exhaust of air;

b) Natural supply and mechanical exhaust of air;

c) Mechanical supply and natural exhaust of air; and

d) Mechanical supply and mechanical exhaust of air.

5.3.1 *Control of Heat*

Although it is recognized that general ventilation is one of the most effective methods of improving thermal environmental conditions in factories, in many situations, the application of ventilation should be preceded by and considered along with some of the following other methods of control. This would facilitate better design of buildings for general ventilation, either natural or mechanical or both, and also reduce their cost.

5.3.1.1 *Isolation*

Sometimes it is possible to locate heat producing equipment, such as furnaces in such a position as would expose only a small number of workers to hot environment. As far as practicable, such sources of heat in factories should be isolated.

In situations where relatively few people are exposed to severe heat stress and their activities are confined to limited areas as in the case of rolling mill operators and crane operators, it may be possible to enclose the work areas and provide spot cooling or supply conditioned air to such enclosures.

5.3.1.2 *Insulation*

A considerable portion of heat in many factories is due to the solar radiation falling on the roof surfaces, which, in turn, radiate heat inside the building. In such situations, insulations of the roof or providing a false ceiling or double roofing would be very effective in controlling heat. Some reduction can also be achieved by painting the roof in heat reflective shades.

Hot surfaces of equipment, such as pipes, vessels, etc, in the building should also be insulated to reduce their surface temperature.

5.3.1.3 *Substitution*

Sometimes, it is possible to substitute a hot process by a method that involves application of localized or more efficiently controlled method of heating. Examples include induction hardening instead of conventional heat treatment, cold riveting or spot welding instead of hot riveting, etc.

5.3.1.4 *Radiant shielding*

Hot surfaces, such as layers of molten metal emanate radiant heat, which can best be controlled by placing a shield having a highly reflecting surface between the source of heat and the worker, so that a major portion of the heat falling on the shield is reflected back to the

source. Surfaces such as of tin and aluminium have been used as materials for shields. The efficiency of the shield does not depend on its thickness, but on the reflectivity and emissivity of its surface. Care should be taken to see that the shield is not heated up by conduction and for this purpose adequate provision should be made for the free flow upwards of the heated air between the hot surface and the shield by leaving the necessary air space and providing opening at the top and the bottom of the sides.

5.3.2 *Volume of Air Required*

The volume of air required shall be calculated by using both the sensible heat or latent heat gain as the basis. The larger of the two figures obtained should be used in actual practice.

5.3.2.1 *Volume of air required for removing sensible heat*

When the amount of sensible heat given off by different sources, namely, the sun, the manufacturing processes, machinery, occupants and other sources, is known and a suitable value for the allowable temperature rise is assumed, the volume of outside air to be provided for removing the sensible heat may be calculated from:

$$Q_1 = \frac{2.976\,8\,K_s}{t}$$

where

Q_1 = Quantity of air in m^3/h,
K_s = Sensible heat gained in W, and
t = Allowable temperature rise in °C.

5.3.2.2 Temperature rise refers mainly to the difference between the air temperatures at the outlet (roof exit) and at the inlet openings for outside air. As very little data exist on allowable temperature rise values for supply of outside air in summer months, the values given in Table 12 related to industrial buildings may be used for general guidance.

Table 12 Allowable Temperature Rise Values

(*Clause* 5.3.2.2)

Height of Outlet Opening (1)	Temperature Rise (2)
6	3 to 4.5
9	4.5 to 6.5
12	6.5 to 11

NOTES

1 The conditions are limited to light or medium heavy manufacturing processes, freedom from radiant heat and inlet openings not more than 3 to 4.5 m above floor level.

2 At the working zone between floor level and 1.5 m above floor level, the recommended maximum allowable temperature rise for air is 2°C to 3°C above the air temperature at the inlet openings.

5.3.2.3 *Volume of air required for removing latent heat*

If the latent heat gained from the manufacturing processes and occupants is also known and a suitable value for the allowable rise in the vapour pressure is assumed:

$$Q_2 = \frac{4\,127.26 \times K_1}{h}$$

where

Q_2 = Quantity of air in m^3/h,
K_1 = Latent heat gained in W, and
h = Allowable vapour pressure difference in mm of mercury.

NOTE — In majority of the cases, the sensible heat gain will far exceed the latent heat gain, so that the amount of outside air to be drawn by ventilating equipment can be calculated in most cases on the basis of the equation given in **5.3.2.1**.

5.3.2.4 Ventilation is also expressed as m^3/h per m^2 of floor area. This relationship fails to evaluate the actual heat relief provided by a ventilation system, but it does give a relationship which is independent of building height. This is a more rational approach, because, with the same internal load, the same amount of ventilation air, properly applied to the work zone with adequate velocity, will provide the desired heat relief quite independently of the ceiling height of the space, with few exceptions. Ventilation rates of 30 to 60 m^3/h per m^2 have been found to give good results in many plants.

5.4 Natural Ventilation

The rate of ventilation by natural means through windows or other openings depends on:

a) direction and velocity of wind outside and sizes and disposition of openings (wind action), and
b) convection effects arising from temperature of vapour pressure difference (or both) between inside and outside the room and the difference of height between the outlet and inlet openings (stack effect).

5.4.1 *Ventilation of Non-industrial Buildings*

Ventilation in non-industrial buildings due to stack effect, unless there is a significant internal load, could be neglected, except in cold regions, and wind action may be assumed to be predominant.

5.4.1.1 In hot dry regions, the main problem in summer is to provide protection from sun's heat so as to keep the indoor temperature lower than those outside under the sun. For this purpose windows and other openings

are generally kept closed *during day time* and only minimum ventilation is provided for the control of odours or for removal of products of combustion.

5.4.1.2 In warm humid regions, the problem in the design of non-industrial buildings is to provide free passage of air to keep the indoor temperature as near to those outside in the shade as possible, and for this purpose the buildings are oriented to face the direction of prevailing winds and windows and other openings are kept open on both windward and leeward sides.

5.4.1.3 In winter months in cold regions, the windows and other openings are generally kept shut, particularly during night; and ventilation necessary for the control of odours and for the removal of products of combustion can be achieved either by stack action or by some infilteration of outside air due to wind action.

5.4.2 *Ventilation of Industrial Buildings*

In providing natural ventilation of all industrial buildings having significant internal heat loads due to manufacturing process, proper consideration should be given to the size and distribution of windows and other inlet openings in relation to outlet openings so as to give, with due regard to orientation, prevailing winds, size and configuration of the building and manufacturing processes carried on, maximum possible control of thermal environment.

5.4.2.1 In the case of industrial buildings wider than 30 m, the ventilation through windows may be augmented by roof ventilation.

5.4.3 *Design Guidelines for Natural Ventilation*

5.4.3.1 *By wind action*

i) A building need not necessarily be oriented perpendicular to the prevailing outdoor wind; it may be oriented at any convenient angle between 0° and 30° without loosing any beneficial aspect of the breeze. If the prevailing wind is from East or West, building may be oriented at 45° to the incident wind so as to diminish the solar heat without much reduction in air motion indoors.

ii) Inlet openings in the buildings should be well distributed and should be located on the windward side at a low level, and outlet openings should be located on the leeward side. Inlet and outlet openings at high levels may only clear the top air at that level without producing air movement at the level of occupancy.

iii) Maximum air movement at a particular plane is achieved by keeping the sill height of the opening at 85 percent of the critical height (such as head level) for the following recommended levels of occupancy:

1) For sitting on chair 0.75 m,
2) For sitting on bed 0.60 m, and
3) For sitting on floor 0.40 m.

iv) Inlet openings should not as far as possible be obstructed by adjoining buildings, trees, sign boards or other obstructions or by partitions inside in the path of air flow.

v) In rooms of normal size having identical windows on opposite walls the average indoor air speed increases rapidly by increasing the width of window up to two-third of the wall width; beyond that the increase is in much smaller proportion than the increase of the window width. The air motion in the working zone is maximum when window height is 1.1 m. Further increase in window height promotes air motion at higher level of window, but does not contribute additional benefits as regards air motion in the occupancy zones in buildings.

vi) Greatest flow per unit area of openings is obtained by using inlet and outlet openings of nearby equal areas at the same level.

vii) For a total area of openings (inlet and outlet) of 20 percent to 30 percent of floor area, the average indoor wind velocity is around 30 percent of outdoor velocity. Further increase in window size increases the available velocity but not in the same proportion. In fact, even under most favourable conditions the maximum average indoor wind speed does not exceed 40 percent of outdoor velocity.

viii) Where the direction of wind is quite constant and dependable, the size of the inlet should be kept within 30 to 50 percent of the total area of openings and the building should be oriented perpendicular to the incident wind. Where direction of the wind is quite variable the openings may be arranged so that as far as possible there is approximately equal area on all sides. Thus no matter what the wind direction be, there would be some openings directly exposed to wind pressure and others to air suction and effective air movement through the building would be assured.

ix) Windows of living rooms should open directly to an open space. In places where building sites are restricted, open space may have to be created in the buildings by providing adequate courtyards.

x) In the case of rooms with only one wall exposed to outside, provision of two windows

on that wall is preferred to that of a single window.

xi) Windows located diagonally opposite to each other with the windward window near the upstream corner give better performance than other window arrangements for most of the building orientations.

xii) Horizontal louvers, that is a sunshade, atop a window deflects the incident wind upward and reduces air motion in the zone of occupancy. A horizontal slot between the wall and horizontal louver prevents upward deflection of air in the interior of rooms. Provision of inverted L type (Γ) louver increases the room air motion provided that the vertical projection does not obstruct the incident wind.

xiii) Provision of horizontal sashes inclined at an angle of 45° in appropriate direction helps to promote the indoor air motion. Sashes projecting outward are more effective than projecting inward.

xiv) Air motion at working plane 0.4 m above the floor can be enhanced by 30 percent using a pelmet type wind deflector.

xv) Roof overhangs help promoting air motion in the working zone inside buildings.

xvi) *VERANDAH* open on three sides is to be preferred since it causes an increase in the room air motion for most of the orientations of the building with respect to the outdoor wind.

xvii) A partition placed parallel to the incident wind has little influence on the pattern of the air flow, but when located perpendicular to the main flow, the same partition creates a wind shadow. Provision of a partition with spacing of 0.3 m underneath, helps augmenting air motion near floor level in the leeward compartment of wide span buildings.

xviii) Air motion in a building unit having windows tangential to the incident wind is accelerated when another unit is located at end-on position on down stream side.

xix) Air motion in two wings oriented parallel to the prevailing breeze is promoted by connecting them with a block on downstream side.

xx) Air motion in a building is not affected by constructing another building of equal or smaller height on the leeward side; but it is slightly reduced if the leeward building is taller than the windward block.

xxi) Air motion in a shielded building is less than that in an unobstructed building. To minimize shielding effect, the distances between two rows should be 8 H for semi-detached houses and 10 H for long rows houses. However, for smaller spacing the shielding effect is also diminished by raising the height of the shielded building.

xxii) Hedges and shrubs defect the air away from the inlet openings and cause a reduction in indoor air motion. These elements should not be planted at a distance of about 8 m from the building because the induced air motion is reduced to minimum in that case. However, air motion in the leeward part of the building can be enhanced by planting a low hedge at a distance of 2 m from the building.

xxiii) Trees with large foliage mass having trunk bare of branches up to the top level of window, deflect the outdoor wind downwards and promotes air motion in the leeward portion of buildings.

xxiv) Ventilation conditions indoors can be ameliorated by constructing buildings on earth mound having a slant surface with a slope of 10° on upstream side.

xxv) In case of industrial buildings the window height should be about 1.6 m and width about two-third of wall width. These should be located at a height of 1.1 m above the floor. In addition to this, openings around 0.9 m high should be provided over two-third length of the glazed area in the roof lights.

xxvi) Height of industrial buildings, although determined by the requirements of industrial processes involved, generally kept large enough to protect the workers against hot stagnant air below the ceiling as also to dilute the concentration of contaminant inside. However, if high level openings in roof or walls are provided, building height can be reduced to 4 m without in any way impairing the ventilation performance.

NOTE — For data on outdoor wind speeds at a place, reference may be made to 'The Climatic Data Handbook prepared by Central Building Research Institute, Roorkee, 1999'.

5.4.3.2 *By stack effect*

Natural ventilation by stack effect occurs when air inside a building is at a different temperature than air outside. Thus in heated buildings or in buildings wherein hot processes are carried on and in ordinary buildings during summer nights and during premonsoon periods, the inside temperature is higher than that of outside, cool outside air will tend to enter

through openings at low level and warm air will tend to leave through openings at high level. It would, therefore, be advantageous to provide ventilators as close to ceilings as possible. Ventilators can also be provided in roofs as, for example, cowl, ventpipe, covered roof and ridge vent.

5.5 Mechanical Ventilation

The requirements of mechanical ventilation shall be in accordance with Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation'.

5.6 Determining Rate of Ventilation

5.6.1 *Natural Ventilation*

This is difficult to measure as it varies from time-to-time. The amount of outside air through windows and other openings depends on the direction and velocity of wind outside (wind action) and/or convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building (stack effect).

5.6.1.1 *Wind action*

For determining the rate of ventilation based on wind action the wind may be assumed to come from any direction within 45° of the direction of prevailing wind. Ventilation due to external wind is given by the following formula:

$$Q = KAV$$

where

Q = Rate of air flow in m^3/h;

K = Coefficient of effectiveness, which may be taken as 0.6 for wind perpendicular to openings and 0.3 for wind at an angle less than 45° to the openings;

A = Free area of inlet openings in m^2; and

V = Wind speed in m/h.

NOTE — For wind data at a place, the local Meteorological Department may be consulted.

5.6.1.2 *Stack effect*

Ventilation due to convection effects arising from temperature difference between inside and outside is given by:

$$Q = 7.0\,A\sqrt{h\,(t_r - t_o)}$$

where

Q = Rate of air flow in m^3/h;

A = Free area of inlet openings in m^2;

h = Vertical distance between inlets and outlets in m;

t_r = Average temperature of indoor air at height h in °C; and

t_o = Temperature of outdoor air in °C.

NOTE — The equation is based on 0.65 effectiveness of openings. This should be reduced to 0.50 if conditions are not favourable.

5.6.1.3 When areas of inlet and outlet openings are unequal, the value of A may be calculated using the equation

$$\frac{2}{A^2} = \frac{1}{A_{inlet}^2} + \frac{1}{A_{outlet}^2}$$

5.6.1.4 When both forces (wind and thermal) act together in the same direction, even without interference, the resulting air flow is not equal to the two flows estimated separately. Flow through any opening is proportional to the square root of the sum of the two heads acting on that opening.

Wind velocity and direction, outdoor temperature, and indoor distribution can not be predicted with certainty, and refinement in calculation is not justified. A simple method is calculate the sum of the flows produced by each force separately. Then using the ratio of the flow produced by thermal forces to the aforementioned sum, the actual flow due to the combined forces can be approximated from Fig. 5. When the two flows are equal, the actual flow is about 30 percent greater than the flow caused by either force acting independently (*see* Fig. 5).

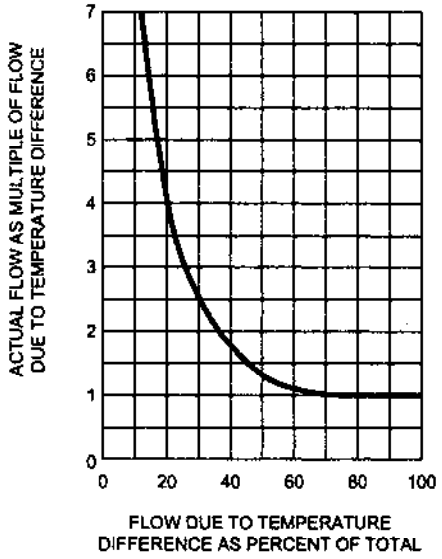

FIG. 5 DETERMINATION OF FLOW CAUSED BY COMBINED FORCES OF WIND AND TEMPERATURE DIFFERENCE

Judgement is necessary for proper location of openings in a building specially in the roof, where heat, smoke and fumes are to be removed. Usually, windward monitor openings should be closed, but if wind is so

slight that temperature head can overcome it, all openings may be opened.

5.6.1.5 For method for determining the rate of ventilation based on probable indoor wind speed with typical illustrative example for residential building, reference may be made to good practice [8-1(6)].

5.6.2 *Mechanical Ventilation*

The determination of rate of ventilation in case of mechanical ventilation shall be done in accordance with Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation'.

5.6.3 *Combined Effect of Different Methods of Ventilation*

When combination of two or more methods of general ventilation is used, the total rate of ventilation shall be reckoned as the highest of the following three, and this rule shall be followed until an exact formula is established by research:

a) 1.25 times the rate of natural ventilation,
b) Rate of positive ventilation, and
c) Rate of exhaust of air.

5.6.4 *Air Movement*

The rate of air movement of turbulent type at the working zone shall be measured either with a Kata thermometer (dry silvered type) or heated thermometer or properly calibrated thermocouple anemometer. Whereas anemometer gives the air velocity directly, the Kata thermometer and heated thermometer give cooling power of air and the rate of air movement is found by reference to a suitable nomogram using the ambient temperature.

5.7 Energy Conservation in Ventilation System

5.7.1 Maximum possible use should be made of wind induced natural ventilation. This may be accomplished by following the design guidelines given in **5.7.1.1**.

5.7.1.1 Adequate number of circulating fans should be installed to serve all interior working areas during summer months in the hot dry and warm humid regions to provide necessary air movement at times when ventilation due to wind action alone does not afford sufficient relief.

5.7.1.1.1 The capacity of a ceiling fan to meet the requirement of a room with the longer dimension D metres should be about 55 D m^3/min.

5.7.1.1.2 The height of fan blades above the floor should be $(3H + W)/4$, where H is the height of the room, and W is the height of work plane.

5.7.1.1.3 The minimum distance between fan blades and the ceiling should be about 0.3 metre.

5.7.2 Electronic regulators should be used instead of resistance type regulators for controlling the speed of fans.

5.7.3 When actual ventilated zone does not cover the entire room area, then optimum size of ceiling fan should be chosen based on the actual usable area of room, rather than the total floor area of the room. Thus smaller size of fan can be employed and energy saving could be achieved.

5.7.4 Power consumption by larger fans is obviously higher, but their power consumption per square metre of floor area is less and service value higher. Evidently, improper use of fans irrespective of the rooms dimensions is likely to result in higher power consumption. From the point of view of energy consumption, the number of fans and the optimum sizes for rooms of different dimensions are given in Table 13.

Table 13 Optimum Size/Number of Fans for Rooms of Different Sizes

(*Clause* 5.7.4)

Room Width	Room Length										
m	4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m	12 m	14 m	16 m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
3	1 200/1	1 400/1	1 500/1	1 050/2	1 200/2	1 400/2	1 400/2	1 400/2	1 200/3	1 400/3	1 400/3
4	1 200/1	1 400/1	1 200/2	1 200/2	1 200/2	1 400/2	1 400/2	1 500/2	1 200/3	1 400/3	1 500/3
5	1 400/1	1 400/1	1 400/2	1 400/2	1 400/2	1 400/2	1 400/2	1 500/2	1 400/3	1 400/3	1 500/3
6	1 200/2	1 400/2	900/4	1 050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
7	1 200/2	1 400/2	1 050/4	1 050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
8	1 200/2	1 400/2	1 200/4	1 200/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
9	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
10	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
11	1 500/2	1 500/2	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/6	1 500/6	1 500/6
12	1 200/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 200/7	1 400/9	1 400/9
13	1 400/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9
14	1 400/3	1 400/3	1 400/6	1 400/6	1 400/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9

ANNEX A

(*Clauses* 4.2.5, 4.2.5.2, 4.2.5.3 *and* 4.2.5.4)

SKY COMPONENT TABLES

A-1 DESCRIPTION OF TABLES

A-1.1 The three sky component tables are as given below:

Table 14	Percentage sky components on the horizontal plane due to a vertical rectangular opening for the clear design sky
Table 15	Percentage sky components on the vertical plane perpendicular to a vertical rectangular opening for the clear design sky
Table 16	Percentage sky components on the vertical plane parallel to a vertical rectangular opening for the clear design sky

A-1.2 All the tables are for an unglazed opening illuminated by the clear design sky.

A-1.3 The values tabulated are the components at a point *P* distant from the opening on a line perpendicular to the plane of the opening through one of its lower corners, and *l* and *h* are the width and height respectively of the rectangular opening (*see* Fig. 6).

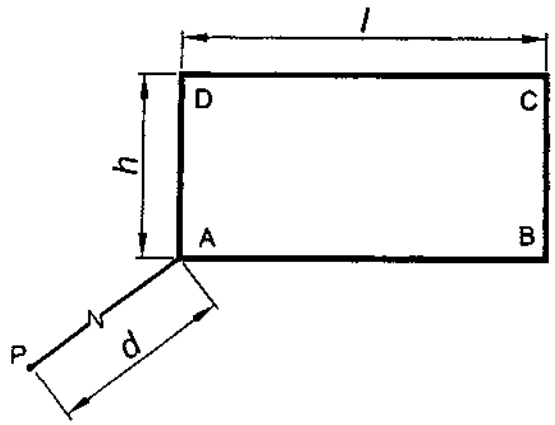

FIG. 6

A-1.4 Sky component for different *h/d* and *l/d* values are tabulated, that is, for windows of different size and for different distances of the point *P* from the window.

A-1.5 By suitable combination of the values obtained from the three tables, for a given point for a given window, the sky component in any plane passing through the point may be obtained.

A-1.6 Method of Using the Tables

A-1.6.1 Method of using the Tables to get the sky component at given point is explained with help of the following example.

A-1.6.2 *Example*

It is desired to calculate the sky component due to a vertical window *ABCD* with width 1.8 m and height 1.5 m at a point *P* on a horizontal plane 3.0 m from the window wall located as shown in Fig. 7. Foot of the perpendicular *N* is 0.6 m below the sill and 0.9 m to the left of *AD*.

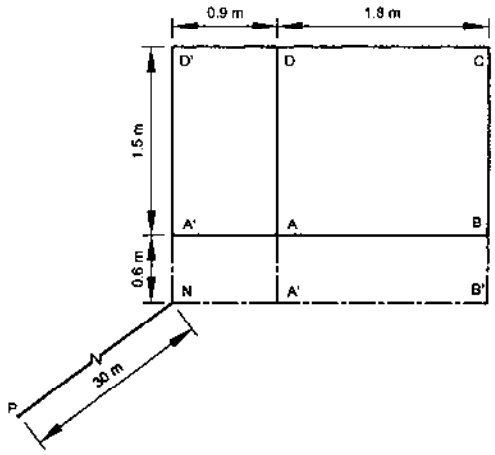

FIG. 7

Consider *ABCD* extended to *NB′CD′*

1) For *NB′CD′*
   l/d = (1.8 + 0.9)/3 = 0.9
   h/d = (1.5 + 0.6)/3 = 0.7
   F_1 = 5.708 percent (from Table 15)
2) For *NA′DD′*
   l/d = 0.9/3 = 0.3
   h/d = (1.5 + 0.6)/3 = 0.7
   F_2 = 2.441 percent (from Table 15)
3) For *NB′BA′*
   l/d = (1.8 + 0.9)/3 = 0.9
   h/d = 0.6/3 = 0.2
   F_3 = 0.878 percent (from Table 15)
4) For *NA′AA′*
   l/d = 0.9/3 = 0.3
   h/d = 0.6/3 = 0.2
   F_4 = 0.403 percent (from Table 15)

Since *ABCD* = *NB′CD′*–*NA′DD′*–*NB′BA′*+*NA′AA′*

Sky Component *F* = F_1–F_2–F_3+F_4
= 5.708–2.441–0.878+0.403
= 2.792

Table 14 Percentage Sky Components on the Horizontal Plane Due to a Verticle Rectandular Opeining for the Clear Design Sky

(*Clause* A-1.5)

l/d → 0.1 / *h/d* ↓	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
0.1	0.036	0.071	0.104	0.133	0.158	0.179	0.198	0.213	0.225	0.235	0.243	0.250	0.256	0.261	0.264	0.268	0.270	0.272	0.274	0.276	0.284	0.286	0.287	0.288	0.288
0.2	0.141	0.277	0.403	0.516	0.614	0.699	0.770	0.829	0.878	0.918	0.950	0.977	0.999	1.018	1.033	1.046	1.056	1.065	1.072	1.079	1.110	1.118	1.122	1.125	1.125
0.3	0.300	0.589	0.859	1.102	1.315	1.499	1.653	1.782	1.888	1.976	2.048	2.108	2.157	2.197	2.231	2.259	2.282	2.302	2.318	2.333	2.401	2.421	2.429	2.436	2.437
0.4	0.460	0.905	1.322	1.702	2.041	2.337	2.590	2.804	2.984	3.134	3.258	3.361	3.446	3.516	3.574	3.623	3.664	3.699	3.728	3.753	3.873	3.909	3.922	3.935	3.937
0.5	0.604	1.189	1.741	2.247	2.700	3.099	3.444	3.740	3.992	4.204	3.383	4.553	4.659	4.765	4.853	4.928	4.990	5.043	5.088	5.126	5.312	5.366	5.387	5.408	5.410
0.6	0.732	1.443	2.114	2.732	3.289	3.781	4.211	4.582	4.900	5.171	5.401	5.596	5.761	5.901	6.020	6.121	6.208	6.281	6.344	6.397	6.661	6.739	6.769	6.798	6.802
0.7	0.844	1.665	2.441	3.159	3.808	4.385	4.891	5.330	5.708	6.034	6.311	6.548	6.751	6.924	7.071	7.198	7.307	7.400	7.481	7.551	7.902	8.006	8.047	8.087	8.092
0.8	0.942	1.858	2.727	3.532	4.262	4.914	5.488	5.989	6.423	6.798	7.119	7.395	7.632	7.836	8.011	8.162	8.292	8.405	8.502	8.587	9.029	9.164	9.217	9.268	9.276
0.9	1.026	2.025	2.974	3.855	4.657	5.375	6.011	6.567	7.051	7.470	7.832	8.144	8.413	8.645	8.846	9.019	9.170	9.301	9.415	9.515	10.045	10.214	10.280	10.345	10.355
1.0	1.099	2.169	3.188	4.135	5.000	5.776	6.465	7.071	7.600	8.060	8.458	8.803	9.102	9.361	9.585	9.780	9.950	10.098	10.228	10.343	10.957	11.162	11.243	11.323	11.335
1.1	1.161	2.294	3.372	4.377	5.296	6.124	6.861	7.510	8.079	8.576	9.008	9.383	9.709	9.992	10.239	10.454	10.642	10.806	10.951	11.078	11.776	12.017	12.114	12.209	12.224
1.2	1.215	2.401	3.531	4.586	5.553	6.425	7.204	7.893	8.498	9.027	9.489	9.892	10.243	10.549	10.816	11.050	11.254	11.434	11.593	11.732	12.509	12.786	12.900	13.013	13.030
1.3	1.262	2.493	3.668	4.767	5.775	6.687	7.503	8.226	8.863	9.422	9.912	10.339	10.713	11.040	11.326	11.577	11.797	11.992	12.163	12.314	13.167	13.478	13.609	13.742	13.762
1.4	1.302	2.573	3.787	4.924	5.968	6.915	7.764	8.517	9.183	9.769	10.283	10.733	11.127	11.473	11.777	12.044	12.279	12.487	12.670	12.833	13.758	14.102	14.251	14.404	14.427
1.5	1.337	2.643	3.891	5.060	6.136	7.114	7.991	8.772	9.664	10.073	10.609	11.080	11.493	11.857	12.176	12.458	12.707	12.927	13.122	13.295	14.289	14.666	14.832	15.006	15.033
1.6	1.367	2.703	3.981	5.179	6.283	7.287	8.190	8.996	9.710	10.341	10.897	11.386	11.817	12.196	12.531	12.826	13.088	13.319	13.525	13.708	14.768	15.176	15.359	15.555	15.585
1.7	1.394	2.756	4.060	5.283	6.412	7.440	8.366	9.192	9.927	10.577	11.151	11.657	12.104	12.498	12.846	13.154	13.427	13.669	13.885	14.078	15.199	15.638	15.838	16.056	16.091
1.8	1.417	2.803	4.129	5.375	6.526	7.574	8.520	9.366	10.119	10.786	11.376	11.898	12.359	12.766	13.127	13.446	13.730	13.983	14.208	14.409	15.590	16.058	16.274	16.516	16.554
1.9	1.438	2.844	4.190	5.456	6.626	7.693	8.656	9.520	10.289	10.972	11.577	12.112	12.587	13.006	13.378	13.708	14.002	14.264	14.498	14.707	15.944	16.441	16.673	16.937	16.980
2.0	1.456	2.880	4.244	5.527	6.714	7.798	8.778	9.656	10.440	11.137	11.755	12.303	12.789	13.220	13.603	13.943	14.246	14.516	14.758	14.975	16.265	16.790	17.037	17.325	17.372
3.0	1.559	3.087	4.553	5.937	7.223	8.403	9.478	10.448	11.321	12.103	12.804	13.431	13.993	14.496	14.947	15.353	15.718	16.048	16.346	16.676	18.301	19.051	19.432	19.943	20.046
4.0	1.600	3.168	4.676	6.100	7.426	8.646	9.759	10.768	11.678	12.498	13.235	13.897	14.493	15.030	15.514	15.951	16.347	16.706	17.033	17.330	19.241	20.142	20.623	21.322	21.495
5.0	1.620	3.208	4.735	6.179	7.525	8.765	9.897	10.925	11.854	12.693	13.448	14.128	14.742	15.296	15.798	16.252	16.664	17.040	17.382	17.695	19.740	20.740	21.293	22.148	22.393
10.0	1.648	3.263	4.818	6.289	7.662	8.930	10.089	11.144	12.100	12.965	13.747	14.454	15.094	15.674	16.201	16.681	17.118	17.518	17.885	18.222	20.491	21.681	22.390	23.676	24.238
INF	1.657	3.282	4.846	6.327	7.710	8.986	10.155	11.220	12.186	13.060	13.851	14.567	15.217	15.806	16.342	16.831	17.278	17.688	18.064	18.410	20.770	22.046	22.838	24.463	26.111

Table 15 Percentage Sky Components on the Vertical Plane Perpendicular to a Vertical Rectandular Opening for the Clear Design Sky

(*Clauses* A-1.5 *and* A-1.6.2)

l/d → 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
h/d ↓																								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
0.1	0.036	0.141	0.303	0.506	0.734	0.971	1.207	1.432	1.643	2.836	1.011	2.168	2.308	2.433	2.544	2.642	2.730	2.808	2.878	2.940	3.309	3.461	3.536	3.641	3.678
0.2	0.071	0.277	0.594	0.993	1.442	1.910	2.374	2.820	3.236	3.618	3.964	4.276	4.554	4.802	5.022	5.219	5.393	5.549	5.688	5.812	6.547	6.850	7.000	7.211	7.284
0.3	0.103	0.401	0.863	1.445	2.100	2.793	3.475	4.180	4.743	5.306	5.818	6.278	6.690	7.058	7.385	7.677	7.936	8.168	8.375	8.560	9.657	10.110	10.335	10.651	10.760
0.4	0.126	0.491	1.059	1.779	2.597	3.460	4.326	5.166	5.958	6.691	7.359	7.967	8.507	8.900	9.420	9.804	10.146	10.451	10.724	10.968	12.421	13.024	13.323	13.743	13.889
0.5	0.142	0.554	1.197	2.015	2.947	3.937	4.938	5.914	6.842	7.707	8.503	9.228	9.883	10.472	10.999	11.476	11.897	12.273	12.610	12.912	14.712	15.462	15.835	16.360	16.542
0.6	0.154	0.600	1.298	2.187	3.204	4.288	5.389	6.468	7.498	8.464	9.358	10.177	10.922	11.596	12.204	12.752	13.244	13.686	14.084	14.441	16.583	17.478	17.924	18.552	18.771
0.7	0.162	0.634	1.372	2.316	3.397	4.552	5.729	6.887	7.997	9.042	10.013	10.907	11.723	12.465	13.138	13.746	14.296	14.793	15.241	15.646	18.111	19.148	19.665	20.397	20.653
0.8	0.169	0.660	1.429	2.413	3.543	4.754	5.990	7.209	8.382	9.490	10.523	11.476	12.350	13.147	13.873	14.531	15.129	15.670	16.161	16.606	19.361	20.538	21.127	21.961	22.253
0.9	0.174	0.680	1.472	2.487	3.655	4.909	6.192	7.460	8.683	9.841	10.924	11.926	12.847	13.690	14.459	15.159	15.796	16.375	16.902	17.381	20.387	21.701	22.360	23.397	23.625
1.0	0.178	0.695	1.505	2.545	3.743	5.030	6.350	7.657	8.921	10.120	11.243	12.284	13.245	14.126	14.931	15.666	16.337	16.948	17.504	18.012	21.237	22.680	23.408	24.446	24.810
1.1	0.181	0.707	1.532	2.591	3.812	5.126	6.475	7.814	9.110	10.342	11.498	12.573	13.356	14.478	15.314	16.079	16.778	17.416	17.999	18.531	21.946	23.508	24.303	25.441	25.841
1.2	0.183	0.716	1.552	2.626	3.866	5.202	6.575	7.939	9.261	10.521	11.705	12.807	13.827	14.766	15.628	16.418	17.141	17.802	18.407	18.961	22.543	24.208	25.072	26.309	26.745
1.3	0.185	0.723	1.568	2.655	3.910	5.263	6.655	8.040	9.384	10.666	11.873	12.998	14.041	15.003	15.887	16.698	17.442	18.123	18.747	19.320	23.049	24.809	25.735	27.070	27.542
1.4	0.186	0.729	1.582	2.678	3.945	5.312	6.720	8.122	9.484	10.785	12.011	13.155	14.217	15.198	16.101	16.931	17.692	18.391	19.032	19.621	23.480	25.326	26.308	27.441	28.249
1.5	0.188	0.734	1.592	2.697	3.973	5.352	6.773	8.189	9.566	10.883	12.124	13.285	14.364	15.361	16.280	17.125	17.902	18.616	19.272	19.875	23.850	25.772	26.808	28.336	28.880
1.6	0.189	0.738	1.601	2.712	3.996	5.385	6.816	8.244	9.634	10.963	12.219	13.394	14.486	15.497	16.430	17.289	18.079	18.806	19.475	20.090	24.169	26.161	27.245	28.866	29.445
1.7	0.189	0.741	1.608	2.724	4.016	5.412	6.852	8.290	9.690	11.031	12.298	13.484	14.589	15.511	16.556	17.427	18.229	18.968	19.648	20.274	24.444	26.501	27.629	29.340	29.955
1.8	0.190	0.744	1.614	2.735	4.032	5.434	6.882	8.328	9.737	11.087	12.364	13.561	14.675	15.708	16.663	17.545	18.357	19.105	19.795	20.431	24.684	26.799	27.969	29.765	30.416
1.9	0.191	0.746	1.619	2.743	4.045	5.453	6.908	8.360	9.777	11.135	12.420	13.625	14.749	15.791	16.755	17.645	18.466	19.224	19.922	20.567	24.893	27.062	28.270	30.149	30.835
2.0	0.191	0.748	1.623	2.751	4.056	5.469	6.929	8.387	9.811	11.175	12.468	13.680	14.811	15.861	16.833	17.731	18.560	19.325	20.031	20.684	25.077	27.294	28.537	30.496	31.217
3.0	0.193	0.756	1.642	2.785	4.109	5.544	7.030	8.517	9.972	11.371	12.699	13.950	15.120	16.211	17.224	18.164	19.036	19.844	20.594	21.289	26.082	28.619	30.108	32.676	32.742
4.0	0.194	0.759	1.648	2.794	4.124	5.566	7.058	8.540	10.018	11.427	12.767	14.029	15.212	16.316	17.343	18.298	19.185	20.008	20.772	21.483	26.439	29.128	30.745	33.687	35.064
5.0	0.194	0.760	1.650	2.798	4.129	5.574	7.069	8.568	10.036	11.449	12.793	14.060	15.248	16.357	17.390	18.351	19.243	20.073	20.844	21.562	26.592	29.359	31.049	34.232	35.872
10.0	0.194	0.761	1.652	2.801	4.135	5.581	7.080	8.582	10.053	11.470	12.818	14.095	15.283	16.398	17.436	18.403	19.302	20.138	20.917	21.641	26.758	29.624	31.419	35.049	37.513
INF	0.194	0.761	1.652	2.802	4.136	5.582	7.081	8.584	10.056	11.473	12.822	14.095	15.288	16.404	17.443	18.411	19.311	20.148	20.928	21.654	26.785	29.672	31.490	35.274	39.172

Table 16 Percentage Sky Components on the Vertical Plane Parallel to a Vertical Rectangular Opening for the Clear Design Sky

(*Clause* A-1.5)

l/d → *h/d* ↓	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
0.1	0.728	1.429	2.078	2.600	3.167	3.660	3.964	4.265	4.513	4.717	4.883	5.020	5.132	5.225	5.301	5.365	5.418	5.463	5.501	5.533	5.687	5.733	5.749	5.765	5.766
0.2	1.429	2.803	4.007	5.221	6.220	7.073	7.790	8.385	8.876	9.278	9.609	9.880	10.103	10.286	10.439	10.565	10.671	10.760	10.835	10.899	11.207	11.296	11.330	11.362	11.365
0.3	2.068	4.061	5.913	7.580	9.040	10.285	11.337	12.212	12.934	13.528	14.016	14.417	14.747	15.020	15.246	15.434	15.591	15.724	15.836	15.931	16.390	16.523	16.574	16.623	16.627
0.4	2.529	4.970	7.249	9.312	11.133	12.707	14.042	15.164	16.097	16.870	17.507	18.025	18.458	18.816	19.113	19.360	19.568	19.742	19.890	20.015	20.624	20.801	20.868	20.933	20.939
0.5	2.852	5.608	8.186	10.529	12.606	14.401	15.952	17.256	18.350	19.262	20.021	20.652	21.177	21.613	21.978	22.275	22.530	22.746	22.923	23.082	23.836	24.056	24.140	24.222	24.229
0.6	3.086	6.070	8.867	11.415	13.681	15.656	17.353	18.793	20.008	21.027	21.879	22.592	23.189	23.689	24.109	24.462	24.761	25.014	25.229	25.412	26.229	26.561	26.662	26.759	26.768
0.7	3.259	6.413	9.373	12.074	14.482	16.588	18.402	19.949	21.257	22.359	23.285	24.063	24.716	25.267	25.731	26.124	26.458	26.742	26.984	27.192	28.214	28.517	28.634	28.748	28.758
0.8	3.389	6.672	9.755	12.573	15.090	17.296	19.201	20.830	22.212	23.380	24.365	25.195	25.895	26.486	26.987	27.412	27.775	28.084	28.350	28.578	29.720	30.065	30.198	30.327	30.339
0.9	3.489	6.869	10.046	12.955	15.556	17.840	19.817	21.511	22.952	24.173	25.206	26.078	26.816	27.441	27.972	28.424	28.810	29.141	29.426	29.672	30.927	31.303	31.451	31.596	31.610
1.0	3.565	7.024	10.272	13.250	15.917	18.263	20.297	22.043	23.531	24.795	25.866	26.773	27.542	28.196	28.572	29.226	29.633	29.982	30.283	30.544	31.889	32.302	32.467	32.627	32.643
1.1	3.625	7.139	10.447	13.481	16.200	18.594	20.674	22.462	23.989	25.288	26.391	27.326	28.121	28.798	29.375	29.869	30.293	30.658	30.973	31.246	32.670	33.117	33.297	33.473	33.491
1.2	3.672	7.233	10.586	13.663	16.423	18.857	20.973	22.795	24.353	25.681	26.810	27.770	28.587	29.283	29.878	30.388	30.826	31.204	31.532	31.816	33.309	33.796	33.981	34.173	34.193
1.3	3.709	7.307	10.696	13.807	16.602	19.067	21.213	23.062	24.646	25.998	27.148	28.128	28.963	29.676	30.286	30.810	31.261	31.651	31.989	32.283	33.836	34.350	34.550	34.756	34.779
1.4	3.739	7.366	10.784	13.924	16.745	19.236	21.406	23.278	24.884	26.255	27.424	28.420	29.271	29.998	30.621	31.157	31.618	32.018	32.365	32.667	34.374	34.813	35.035	35.247	35.271
1.5	3.763	7.414	10.856	14.018	16.861	19.373	21.563	23.454	25.077	26.465	27.649	28.660	29.523	30.262	30.897	31.443	31.914	32.322	32.677	32.986	34.641	35.202	35.436	35.663	35.689
1.6	3.783	7.453	10.914	14.095	16.956	19.485	21.692	23.599	25.236	26.638	27.835	28.857	29.732	30.482	31.226	31.680	32.160	32.575	32.937	33.253	34.950	35.532	35.776	36.017	36.046
1.7	3.799	7.485	10.962	14.158	17.034	19.578	21.798	23.718	25.368	26.781	27.989	29.022	29.906	30.665	31.317	31.879	32.366	32.888	33.156	33.477	35.211	35.812	36.067	36.321	36.352
1.8	3.812	7.512	11.002	14.211	17.099	19.655	21.886	23.817	25.478	26.900	28.118	29.160	30.052	30.818	31.477	32.046	32.539	32.967	33.340	33.666	35.435	36.052	36.316	36.584	36.617
1.9	3.824	7.534	11.035	14.254	17.153	19.719	21.960	23.900	25.570	27.001	28.226	26.276	30.175	30.948	31.613	32.188	32.686	33.119	33.497	33.828	35.626	35.259	36.532	36.812	36.847
2.0	3.833	7.553	11.062	14.291	17.199	19.773	22.022	23.970	25.647	27.086	28.318	29.374	31.279	31.058	31.728	32.308	32.811	33.249	33.631	33.965	35.791	36.438	36.719	37.011	37.048
3.0	3.876	7.639	11.192	14.463	17.412	20.027	22.316	24.302	26.016	27.491	28.757	29.846	30.783	31.592	32.291	32.898	33.427	33.889	34.294	34.551	36.640	37.380	37.715	38.107	38.157
4.0	3.888	7.663	11.228	14.511	17.471	20.098	22.398	24.398	26.121	27.606	28.884	29.983	30.930	31.748	32.457	33.074	33.611	34.082	34.496	34.860	36.915	37.699	38.063	38.510	38.579
5.0	3.893	7.672	11.241	14.529	17.494	20.125	22.430	24.432	26.161	27.650	28.932	30.035	30.986	31.808	32.521	33.142	33.683	34.157	34.574	34.943	37.028	37.834	38.214	38.696	38.781
10.0	3.897	7681	11.254	14.546	17.515	20.150	22.459	24.466	26.199	27.693	28.978	30.085	31.041	31.867	32.584	33.208	33.753	34.231	34.652	35.024	37.144	37.978.	38.382	38.927	39.057
INF	3.898	7.682	11.256	44.548	17.518	20.154	22.464	24.471	26.205	27.699	28.985	30.093	31.049	31.876	32.593	33.218	33.764	34.243	34.664	35.037	37.162	38.003	38.411	38.978	39.172

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

	IS No.	*Title*
(1)	7662 (Part 1) : 1974	Recommendations for orientation of buildings: Part 1 Non-industrial buildings
(2)	3646 (Part 1) : 1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for building interiors (*first revision*)
(3)	2440 : 1975	Guide for daylighting of buildings (*second revision*)
(4)	6060 : 1971	Code of practice for daylighting of factory buildings
	7942 : 1976	Code of practice for daylighting of educational buildings
(5)	1944 (Parts 1 & 2) : 1970	Code of practice for lighting of public thoroughfares: Parts 1 and 2 For main and secondary roads (Group A and B) (*first revision*)
	2672 : 1966	Code of practice for library lighting
	4347 : 1967	Code of practice for hospital lighting
	6665 : 1972	Code of practice for industrial lighting
	10894 : 1984	Code of practice for lighting of educational institutions
	10947 : 1984	Code of practice for lighting for ports and harbours
(6)	3362 : 1977	Code of practice for natural ventilation of residential buildings (*first revision*)

NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 2 Electrical and Allied Installations

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section covers essential requirements for electrical and allied installations in buildings.

This Section was first published in 1970 and was subsequently revised in 1983. In the first revision, general guidance for electrical wiring installation in industrial location where voltage supply normally exceeds 650 V was included. This Section was also updated based on the existing version of the Indian Standards. The importance of pre-planning and exchange of information among all concerned agencies from the earlier stages of building work was emphasized.

As a result of experience gained in implementation of 1983 version of the Code and feedback received as well as revision of some of the relevant standards based on which this Section was prepared, a need to revise this part was felt. This revision has, therefore, been prepared to take care of these developments. The title of this Section has been modified from the erstwhile 'electrical installations' to 'electrical and allied installations' to reflect the provisions now being included on certain allied installations. The significant changes incorporated in this revision include:

a) The risk assessment procedure for lightening has been thoroughly changed apart from some other changes in the provision of lightning protection of building.
b) Some of the provisions of wiring have now been aligned with the latest practices.
c) Many existing definitions have been modified in line with current terminologies used at national and international level. Some new definitions have been added.
d) Provisions on installation of distribution transformer inside the multi-storeyed building have been incorporated.
e) Concept of energy conservation in lighting has been introduced.
f) Concept of various types of earthing in building installation has been incorporated.

This Section has to be read together with Part 8 'Building Services, Section 1 Lighting and Ventilation' for making provision for the desired levels of illumination as well as ventilation for different locations in different occupancies. Utmost importance should be given in the installation of electrical wiring to prevent short circuiting and the hazards associated therewith.

Notwithstanding the provisions given in this Section and the National Electrical Code, the provisions of the *Indian Electricity Act*, 2003 and the Rules and Regulations framed thereunder have to be necessarily complied with.

The information contained in this Section is largely based on the following Indian Standards/Special Publication:

IS 732 : 1989	Code of practice for electrical wiring installations (*third revision*)
IS 12032 (Part 11) : 1987	Specification for graphical symbols for diagrams in the field of electrotechnology: Part 11 Architectural and topographical installation plan and diagrams
IS 4648 : 1968	Guide for electrical layout in residential buildings
IS 2309 : 1989	Protection of building and allied structures against lightning — Code of practice (*second revision*)
SP 30 : 1984	National Electrical Code, 1985

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 8 BUILDING SERVICES

Section 2 Electrical and Allied Installations

1 SCOPE

This Section covers the essential requirements for electrical installations in buildings to ensure efficient use of electricity including safety from fire and shock. This Section also includes general requirements relating to lightning protection of buildings.

2 TERMINOLOGY AND CONVENTIONAL SYMBOLS

2.1 For the purpose of this Section, the following definitions shall apply.

2.1.1 *Accessory* — A device, other than current using equipment, associated with such equipment or with the wiring on an installation.

2.1.2 *Apparatus* — Electrical apparatus including all machines, appliances and fittings in which conductors are used or of which they form a part.

2.1.3 *Appliance* — An item of current using equipment other than a luminaire or an independent motor.

2.1.4 *Bunched* — Cables are said to be 'bunched' when two or more are contained within a single conduit, duct, ducting, or trunking or, if not enclosed, are not separated from each other.

2.1.5 *Cable* — A length of single-insulated conductor (solid or stranded), or two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

2.1.6 *Cable, Armoured* — A cable provided with a wrapping of metal (usually in the form of tape or wire) serving as a mechanical protection.

2.1.7 *Cable, Flexible* — A cable containing one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

2.1.8 *Cable, Metal-Sheathed* — An insulated cable with a metal sheath.

2.1.9 *Cable, PVC Sheathed-Insulated* — A cable in which the insulation of the conductor is a polyvinylchloride (PVC) compound; with PVC sheath also providing mechanical protection to the conductor core or cores in the cable.

2.1.10 *Cable, Weatherproof* — A cable so constructed that when installed in uncovered locations, it will withstand all kinds of weather variations (*see* **2.1.80**, for definition of Weatherproofing).

2.1.11 *Cable, XLPE* — A cable in which the insulation of the conductor is cross-linked polythene and the mechanical protection is provided for the core or cores by a sheath of a poly vinyl chloride compound.

2.1.12 *Ceiling Rose* — A fitting (usually used to attach to the ceiling) designed for the connection between the electrical installation wiring and a flexible cord (which is in turn connected to a lampholder).

2.1.13 *Circuit* — An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective device(s). Certain types of circuit are categorized as follows:

a) *Category 1 Circuit* — A circuit (other than a fire alarm or emergency lighting circuit) operating at low voltage and supplied directly from a mains supply system.

b) *Category 2 Circuit* — With the exception of fire alarm and emergency lighting circuits, any circuit for telecommunication (for example, radio, telephone, sound distribution, intruder alarm, bell and call and data transmission circuits) which is supplied from a safety source.

c) *Category 3 Circuit* — A fire alarm circuit or an emergency lighting circuit.

2.1.14 *Circuit Breaker* — A mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also of making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A circuit breaker is usually intended to operate in frequently, although some types are suitable for frequent operation.

2.1.15 *Circuit, Final Sub* — An outgoing circuit connected to one-way distribution board and intended to supply electrical energy at one or more points to current, using appliances without the intervention of a further distribution board other than a one-way board. It includes all branches and extensions derived from that particular way in the board.

2.1.16 *Cleat* — An insulated incombustible support normally used for insulated cable.

2.1.17 *Conductor, Aerial* — Any conductor which is

supported by insulators above the ground and is directly exposed to the weather.

NOTE — Four classes of aerial conductors are recognized:

a) Bare aerial conductors,
b) Covered aerial conductors,
c) Insulated aerial conductors, and
d) Weatherproof neutral-screened cable.

2.1.18 *Conductor, Bare* — A conductor not covered with insulating material.

2.1.19 *Conductor, Earthed* — A conductor with no provision for its insulation from earth.

2.1.20 *Conductor, Insulated* — A conductor adequately covered with insulating material of such quality and thickness as to prevent danger.

2.1.21 *Conductor of a Cable or Core* — The conducting portion consisting of a single wire or group of wires, assembled together and in contact with each other or connected in parallel.

2.1.22 *Connector* — The part of a cable coupler or of an appliance coupler which is provided with female contact and is intended to be attached to the flexible cable connected to the supply.

2.1.23 *Connector Box or Joint Box* — A box forming a part of wiring installation, provided to contain joints in the conductors of cables of the installations.

2.1.24 *Connector for Portable Appliances* — A combination of a plug and socket arranged for attachment to a portable electrical appliance or to a flexible cord.

2.1.25 *Consumer's Terminals* — The ends of the electrical conductors situated upon any consumer's premises and belonging to him at which the supply of energy is delivered from the service line.

2.1.26 *Cord, Flexible* — A flexible cable having conductor of small cross-sectional area. Two flexible cords twisted together are known as twin 'flexible cord'.

2.1.27 *Core of a Cable* — A single conductor of a cable with its insulation but not including any mechanical protective covering.

2.1.28 *Cut-out* — Any appliance for automatically interrupting the transmission of energy through any conductor when the current rises above a predetermined amount.

2.1.29 *Damp Situation* — A situation in which moisture is either permanently present or intermittently present to such an extent as to be likely to impair the effectiveness of an installation conforming to the requirements for ordinary situations.

2.1.30 *Dead* — A portion of the circuit (normally expected to carry a voltage) at or near about earth potential or apparently disconnected from any live system.

2.1.31 *Direct Earthing System* — A system of earthing in which the parts of an installation are so earthed as specified but are not connected within the installation to the neutral conductor of the supply system or to earth through the trip coil of an earth leakage circuit-breaker.

2.1.32 *Distance Area or Resistance Area (for Earth Electrode only)* — The area of ground (around an earth electrode) within which a voltage gradient measurable with ordinary commercial instruments exists when the electrode is being tested.

2.1.33 *Discrimination (Over Current Discrimination)* — Co-ordination of the operating characteristics of two or more over-current protective devices such that, on the incidence of over-currents within stated limits, the device intended to operate within these limits does so, while the others do not.

NOTES

1 Protective devices should have discrimination so that only the affected part (minimum section) of the circuit is isolated, even though a number of protective devices may be in the path of the over current.

2 Distinction is made between series discrimination involving different over-current protective devices passing substancially the same over-current and network discrimination involving identical protective devices passing different proportions of the over-current.

2.1.34 *Earth* — The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.

2.1.35 *Earth Continuity Conductor* — The conductor, including any clamp, connecting to the earthing lead or to each other those parts of an installation which are required to be earthed. It may be in whole or in part the metal conduit or the metal sheath or armour of the cables, or the special continuity conductor of a cable or flexible cord incorporating such a conductor.

2.1.36 *Earth Electrode* — A conductor or group of conductors in intimate contact with and providing an electrical connection to earth.

2.1.37 *Earth Fault* — Accidental connections of a conductor to earth when the impedance is negligible, the connection is called a dead earth.

2.1.38 *Earthing Lead* — The final conductor by which the connection to the earth electrode is made.

2.1.39 *Earth Leakage Circuit Breaker System* — A system of earthing in which the parts of an installation, specified, to be earthed are so earthed through one or more earth leakage circuit-breakers or relays.

2.1.40 *Enclosed Distribution Board* — An enclosure containing bus bars with one or more control and protected devices for the purpose of protecting, controlling or connecting more than one outgoing circuits fed from one or more incoming circuits.

2.1.41 *Exposed Metal* — All metal parts of an installation which are easily accessible other than:

a) parts separated from live parts by double insulation;

b) metal name-plates, screw heads, covers, or plates, which are supported on or attached or connected to substantial non-conducting material only in such a manner that they do not become alive in the event of failure of insulation of live parts and whose means of fixing do not come in contact with any internal metal; and

c) parts which are separated from live parts by other metal parts which are themselves earthed or have double insulation.

2.1.42 *Fire Survival Cable* — A cable which continues in service after exposure to a temperature of 900°C for 20 min or 700°C for 90 min.

2.1.43 *Fitting, Lighting* — A device for supporting or containing a lamp or lamps (for example, fluorescent or incandescent) together with any holder, shade, or reflector, for example, a bracket, a pendant with ceiling rose, an electrolier, or a portable unit.

2.1.44 *Flameproof Enclosure* — An enclosure which will withstand without injury any explosion of inflammable gas that may occur within it under practical conditions of operation within the rating of the apparatus (and recognized overloads, if any, associated therewith) and will prevent the transmission of flame which may ignite any inflammable gas that may be present in the surrounding atmosphere.

NOTES

1 Hazardous areas are classified into different zones, depending upon the extent to which an explosive atmosphere could exist at that place. In such areas flame proof switchgear, fittings, accessories, have to be used/installed in flameproof enclosure.

2 An electrical apparatus is not considered as flameproof unless it complies with the appropriate statutory regulations.

3 Other types of fittings are also in vogue in wiring installations, for example, 'increased safety'.

2.1.45 *Flame Retardant Cable* — Flame retardant cable with reduced halogen evaluation and smoke.

2.1.46 *Fuse* — A device that, by the fusion of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted when the current through it exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.

2.1.47 *Fuse-Element* — A part of the fuse-link designed to melt under the action of current exceeding some definite value for a definite period of time.

2.1.48 *Harmonics (Current and Voltage)* — All alternating current which is not absolutely sinusoidal is made up of a fundamental and a certain number of current harmonics which are the cause of its deformation (distortion) when compared to the theoretical sine-wave.

2.1.49 *Inflammable* — A material capable of being easily ignited.

2.1.50 *Installation (Electrical), of Buildings* — An assembly of associated electrical equipment to fulfil a specific purpose or purposes and having coordinated characteristics.

2.1.51 *Insulated* — Insulated shall mean separated from adjacent conducting material or protected from personal contact by a non-conducting substance or an air space, in either case offering permanently sufficient resistance to the passage of current or to disruptive discharges through or over the surface of the substance or space, to obviate danger or shock or injurious leakage of current.

2.1.52 *Insulation, Basic* — Insulation applied to live parts to provide basic protection against electric shock.

NOTE — Basic insulation does not necessarily include insulation used exclusively for functional purposes.

2.1.53 *Insulation, Double* — Insulation comprising both basic and supplementary insulation.

2.1.54 *Insulation (Electrical)* — Suitable non-conducting material, enclosing, surrounding or supporting a conductor.

2.1.55 *Insulation, Reinforced* — Single insulation applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant standard.

NOTE — The term 'single insulation' does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

2.1.56 *Insulation, Supplementary* — Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

2.1.57 *Linked Switch* — Switches linked together mechanically so as to operate simultaneously or in definite sequence.

2.1.58 *Live or Alive* — Electrically charged so as to have a potential different from that of earth.

2.1.59 *Locations, Industrial* — Locations where tools and machinery requiring electrical wiring are installed for manufacture or repair.

2.1.60 *Locations, Non-Industrial* — Locations other than industrial locations, and shall include residences, offices, shops, showrooms, stores and similar premises requiring electrical wiring for lighting, or similar purposes.

2.1.61 *Miniature Circuit Breaker* — Mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also making carrying currents for specified times and automatically breaking currents under specified abnormal circuit conditions such as those of overload and short circuits.

2.1.62 *Multiple Earthed Neutral System* — A system of earthing in which the parts of an installation specified to be earthed are connected to the general mass of earth and, in addition, are connected within the installation to the neutral conductor of the supply system.

2.1.63 *Neutral Conductor* — Includes the neutral conductor of a three-phase four-wire system, the conductor of a single-phase or dc installation which is earthed by the supply undertaking (or otherwise at the source of the supply), and the middle wire or common return conductor of a three-wire dc or single-phase ac system.

2.1.64 *Plug* — A device, provided with contact pins, which is intended to be attached to a flexible cable, and which can be engaged with a socket outlet or with a connector.

2.1.65 *Point (in Wiring)* — A termination of the fixed wiring intended for the connection of current using equipment.

2.1.66 *Residual Current Circuit Breaker* — A mechanical switching device design to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual currents attains a giving value under specified conditions.

2.1.67 *Service* — The conductors and equipment required for delivering energy from the electric supply system to the wiring system of the premises served.

2.1.68 *Socket-Outlet* — Accessory having socket contacts designed to engage with the pins of a plug and having terminals for the connection of cable(s).

NOTE — A luminaire track system is not regarded as a socket-outlet system.

2.1.69 *Switch* — A mechanical switching device capable of making, carrying and breaking current under normal circuit conditions, which may include specified operating overload conditions, and also of carrying for a specified time currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A switch may also be capable of making, but not breaking, short-circuit currents.

2.1.70 *Switchboard* — An assembly of switchgear with or without instruments, but the term does not apply to a group of local switches in a final circuit.

NOTE — The term 'switchboard' includes a distribution board.

2.1.71 *Switch Disconnectors* — A device used to open (or close) a circuit when either negligible current is interrupted (or established) or when the significant change in the voltage across the terminals of each of the pole of the disconnectors occurs; in the open position it provides an isolating distance between the terminals of each pole.

2.1.72 *Switch Disconnector Fuse* — A composite unit, comprising a switch with the fuse contained in or mounted on the moving member of the switch.

2.1.73 *Switchgear* — A general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric energy.

2.1.74 *Usable Wall Space* — All portions of a wall, except that occupied by a door in its normal open position, or occupied by a fire place opening, but excluding wall spaces which are less than 1 m in extent measured along the wall at the floor line.

2.1.75 *Voltage, Extra Low (ELV)* — The voltage which does not normally exceed 50 V.

2.1.76 *Voltage, Low (LV)* — The voltage which normally exceed 50 V but does not normally exceed 250 V.

2.1.77 *Voltage, Medium (MV)* — The voltage which normally exceeds 250 V but does not exceed 650 V.

2.1.78 *Voltage, High (HT, HV)* — The voltage which normally exceeds 650 V but less than or equal to 33 kV.

2.1.79 *Voltage, Extra High (EHT)* — The voltage, which normally exceeds 33 kV.

2.1.80 *Weatherproof* — Accessories, lighting fittings, current-using appliances and cables are said to be of the weatherproof type, if they are so constructed that when installed in open situation they will withstand the effects of rain, snow, dust and temperature variations.

For definition of other terms reference may be made to accepted standards [8-2(1)].

2.2 Conventional Symbols

The architectural symbols that are to be used in all drawings, wiring plans, etc, for electrical installations in buildings shall be as given in Annex A.

For other graphical symbols used in electrotechnology, reference may be made to good practice [8-2(1)].

3 GENERAL REQUIREMENTS

3.1 Conformity with Electricity Act, 2003 and Rules Amended Up-to-date

The installation shall generally be carried out in conformity with the requirements of *The Electricity Act*, 2003 as amended up-to-date and the *Indian Electricity Rules*, 1956 framed thereunder and also the relevant regulations of the Electric Supply Authority concerned as amended from time to time. Extracts from the *Indian Electricity Rules*, 1956, referred to in this section, are given in Annex B.

NOTE — *Indian Electricity Rules* which are being revised would become applicable on their notification.

3.2 Materials

All materials, fittings, appliances, etc, used in electrical and allied installations, shall conform to Part 5 'Building Materials' and other related Indian Standards.

3.3 Coordination with Local Supply Authority

a) In all cases, that is, whether the proposed electrical work is a new installation or extension of an existing one, or a modification involving major changes, the electricity supply undertaking shall be consulted about the feasibility, etc, at an early date.

b) *Addition to an Installation* — An addition, temporary or permanent, shall not be made to the authorized load of an existing installation, until it has been definitely ascertained that the current carrying capacity and the condition of existing accessories, conductors, switches, etc, affected, including those of the supply authority are adequate for the increased load. The size of the cable/ conductor shall be suitably selected on the basis of the ratings of the protective devices. Ratings of protective devices and their types shall be based on the installed load, switching characteristics and power factor.

Load assessment and application of suitable diversity factor to estimate the full load current shall be made as a first step. This should be done for every circuit, submain and feeder. Power factor and efficiency of loads shall also be considered. Diversity factor assumed shall be based on one's own experience. Allowance should be made for about 15 percent to 20 percent for extension in near future and the design circuit is calculated for each circuit and submain. The wiring system to be adopted should also be decided in accordance with the environmental requirements. The sizes of wiring cables are decided not merely to carry the load currents, but also to withstand thermal effects of likely over currents and also ensure acceptance level of voltage drop.

3.4 Power Factor Improvement in Consumers' Installation

3.4.1 Conditions of supply of electricity boards or licensees stipulate the lower-limit of power factor which is generally 0.85.

3.4.2 Principal causes of low power factor are many. For guidance to the consumers of electric energy who take supply at low and medium voltages for improvement of power factor, reference shall be made in accordance with good practice [8-2(2)].

3.5 Execution of Work

Unless otherwise exempted under the appropriate rule of the *Indian Electricity Rules*, the work of electrical installations shall be carried out by a licensed electrical contractor and under the direct supervision of a person holding a certificate of competency and by persons holding a valid permit issued and recognized by any State government.

3.6 Safety procedures and practices shall be kept in view during execution of the work in accordance with good practice [8-2(4)].

3.7 Safety provisions given in Part 4 'Fire and Life Safety' shall be followed.

4 PLANNING OF ELECTRICAL INSTALLATIONS

4.1 General

The design and planning of an electrical wiring installation involve consideration of all prevailing conditions, and is usually influenced by the type and requirement of the consumer. A competent electrical design engineer should be involved at the planning stage with a view to providing for an installation that will prove adequate for its intended purpose, and safe and efficient in its use. The information given in 3 shall also be kept in view.

4.1.1 The design and planning of an electrical wiring installation shall take into consideration, some or all of the following:

a) the type of supply, occupancy, envisaged load and the earthing arrangement available;

b) the atmospheric condition, such as cooling air temperature, moisture or such other conditions which are likely to affect the installation adversely;

c) the possible presence of inflammable or explosive dust, vapour or gas;

d) the degree of electrical and mechanical protection necessary;

e) the importance of continuity of service including the possible need for standby supply;

f) the probability of need for modification or future extension;

g) the probable operation and maintenance cost taking into account the electricity supply tariffs available;

h) the relative cost of various alternative methods;

j) the need for radio and telecommunication interference suppression;

k) case of maintenance;

m) safety aspects;

n) energy conservation; and

p) the importance of proper discrimination between protective devices for continuity of supply and limited isolation of only the affected portion.

4.1.2 All electrical apparatus shall be suitable for the services these are intended for.

4.1.3 *Co-ordination*

Proper co-ordination and collaboration between the architect, civil engineer and the electrical and mechanical engineer shall be effected from the planning stage of the installation. The provisions that will be needed for the accommodation of substation, transformer, switchrooms, service cable ducts, rising mains and distribution cables, sub-distribution boards, openings and chases in floors and walls for all required electrical installations, etc, shall be specified in advance.

4.1.4 Before starting wiring and installation of fittings and accessories, information should be exchanged between the owner of the building/architect/electrical contractor and the local supply authority in respect of tariffs applicable, types of apparatus that may be connected under each tariff, requirement of space for installing meters, switches, etc, and for total load requirements of lights, fans and power.

4.1.5 While planning an installation, consideration should be taken of the anticipated increase in the use of electricity for lighting, general purpose socket-outlet, kitchen heating, etc.

It is essential that adequate provision should be made for all the services which may be required immediately and during the intended useful life of the building, for the householder may otherwise be tempted to carry out extension of the installation himself or to rely upon use of multiplug adopters and long flexible cords, both of which are not recommended.

4.2 Location and Requirement of Substation

Information on location and requirements of a substation should cover the following:

4.2.1 *Location*

a) The substation should preferably be located in separate building and could be adjacent to the generator room, if any. Location of substation in the basement floors should be avoided, as far as possible.

b) The ideal location for an electrical substation for a group of buildings would be at the electrical load centre on the ground floor.

c) The floor level of the substation or switch room shall be above the highest flood level of the locality.

d) Generally the load centre would be somewhere between the geometrical centre and the air conditioning plant room, as air conditioning plant room would normally be the largest chunk of load, if the building is air conditioned.

e) Substations with oil filled equipment will require great consideration for the fire detection, protection and suppression. Oil cooled transformers require a suitable soak pit with gravity flow to contain the oil in the event of the possibility of oil spillage from the transformer on its failure. Substations with oil filled equipment shall not be located in any floor other than the ground floor or a semi-basement. Such substations with high oil content may be housed in a separate service building or a substation building, which is not the part of a multi-storeyed building.

f) In case electric substation has to be located within the main multi-storeyed building itself for unavoidable reasons, then it should be located on the floor close to ground level, but shall have direct access from the street for operation of the equipments. The provision for installation and removal of substation equipments may be provided from inside the building.

g) Substations located within a multi-storeyed building shall not have oil filled transformers, even if it is at the ground level (*see* Part 4 'Fire and Life Safety'). Substations with very little combustible material, such as a Dry type transformer, with Vaccum (or SF_6) HT switchgear and ACB or MCCB for MV can be located in the basement as well as upper floors in a building with high load density in the upper floors. (Some functional buildings such as hospitals, air traffic control towers, computer centres are likely to have high loading in a few upper floors and in such cases, it may be preferable to provide oil-free substations at upper levels. This measure will decrease the current flow at various points, thereby contributing to reduction of vulnerability to fire).

h) The power supply control to any such substation or transformer (located at basement levels or upper floors) shall be from a location on ground floor/first basement level having direct access from outside so that in case of fire, the electrical supply can be easily disconnected.

j) Oil filled transformers may be used only in substations located in separate single or two storeyed service buildings outside the main building structure and there shall atleast 6 meter clear distance between the adjoining buildings and substation such that fire tender is able to pass between the two structures.

k) If dry type transformer is used, it may be located adjacent to medium voltage switchgear in the form of unit type substation. No separate room or fire barrier for the transformer is required, in a substation with oil free equipment. In such a case the room size will decrease. Layout of equipment has to keep the requirement that any one piece of equipment or sub-assembly can be taken out of service and out of the installed location, while keeping the remaining system in service.

m) The emergency power supply (such as Generating Sets) should not be allowed to be installed above ground floor or below first basement level of building. There shall be provision of separate direct escape and entry into these areas from outside so that in case of fire, electrical supplies can be disconnected to avoid additional losses which may be caused due to electrical supply, present at the time of fire.

n) For transformers having large oil content (more than 2 000 litres), Rule 64 of *Indian Electricity Rules*, 1956 as amended time to time shall apply.

p) Facility for connection from substation to adjoining building to feed essential emergency load in that building, such as escape route lighting, fire or sprinkler pumps, emergency communication systems shall be provided. Similarly, the essential emergency load switchboard of this building or building complex should be so as to be capable of receiving power for such loads from the adjoining building or building complex, with its own substation/DG sets shut off due to crisis conditions such as fire.

q) The availability of power lines nearby may also be kept in view while deciding the location of the substation.

r) For detailed information regarding location of transformers reference may be made to good practice [8-2(3)].

s) All door openings from substation, electrical rooms, etc should open towards outside.

t) For acoustical enclosures/treatment reference may be made to Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control'.

4.2.2 *Type of Building for Substations*

The substations enclosure, that is, walls, floor, ceiling, openings, doors, etc shall have 2 hour fire rating (*see* Part 4 'Fire and Life Safety').

4.2.3 *Layout of Substation*

In allocating the area of substation, it is to be noted that the flow of electric power is from supply company's room to HV room, then to transformer and finally to the medium voltage switchgear room. The layout of the room shall be in accordance with this flow, so as to optimise the cables, bus-trunking etc, Visibility of equipment controlled from the operating point of the controlling switchgear is also a desirable feature, though it may not be achievable in case of large substations.

4.2.4 *Room/Spaces Required*

Generally the following rooms/spaces are required in a substation:

a) Supply company's switchgear room and/or space for meters.

b) *Capacity and Size* — The capacity of a substation depends upon the area of the building and its type. The capacity of substation may be determined based on the following load requirements:

Table of Typical Allowances for Diversity

Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies (1)	*Individual Household Installations, including Individual Dwelling of a Block* (2)	*Type of Premises Small, Shops, Stores Offices and Business Premises* (3)	*Type of Premises Small Hotels, Boarding Houses etc.* (4)
Lighting	66% of total demand	90% of total current demand	75% of total current demand
Heating and power	80% of total current demand upto 10 A +40% of any current demand in excess of 10 A	80% full load of largest appliance +60% of remaining appliances	80% full load of largest appliance +60% of second largest appliances +40% of remaining appliances
Cooking appliances	10 A +30% full load of connected cooking appliances in excess of 10 A + 5 A if socket-outlet incorporated in unit.	80% full load of largest appliance +60% full load of second largest appliance +50% full load of remaining appliances	80% of largest appliance +60% of full load of second largest appliance +50% full load of remaining appliances
Motors (other than lift motors which are subject to special consideration)		80% full load of largest motor +60% full load of second largest motor +50% full load of remaining motors	80% full load of largest motor +50% full load of remaining motors
Water heater	80% full load of largest appliance +50% of second largest appliance +25% full load of remaining appliances	80% full load of largest appliance +60% of second largest appliance +25% full load of remaining appliances	80% full load of largest appliance +60% of second largest appliance +25% full load of remaining appliances
Floor warming installations	50%		
Water heaters thermal storage space heating installations	50%		
Standard arrangements of final circuits in accordance with IS 732	80% of current demand of largest circuit +40% of current demand of every other circuit	80% of current demand of largest circuit +50% of current demand of every other circuit	
Socket outlets other than those included above and stationary equipment other than those listed above	80% of current demand of largest point of +40% of current demand of every other point of.	80% of current demand of largest point of +60% of current demand of every other point of	80% of current demand of largest point of +60% of current demand of every point in main rooms (dinning rooms, etc) +40% of current demand of every other point of.

NOTES

1 For the purpose of the table an instantaneous water heater is deemed to be a water heater of any loading which heats water only while the tap is turned on and therefore uses electricity intermittently.

2 It is important to ensure that the distribution boards are of sufficient rating to take the total load connected to them without the application of any diversity.

After calculating the electrical load on the above basis, a load factor of 70-90 percent is to be applied to arrive at the minimum capacity of substation. The area required for substation and transformer room for different capacities is given in Annex C for general guidance. For reliability, it would be necessary to split the load into more than one transformer and also provide for standby transformer as well as multiple sources, bus-section, etc.

c) *High Voltage Switch Room* — In case of substation having one transformer and one source of supply, the owner is required to provide one high voltage switch. In case of single point supply with two or more transformers the number of switch required will be one for incoming supply and one for each transformer. In case of duplicate supply two switches shall be provided with mechanical/electrical in locking arrangement where necessary in cables with switches. In case the number of incoming and outgoing switches exceed five, bus coupler of suitable capacity should invariably be provided. The floor area required in case of a single switch is roughly 4 m × 4 m and for every additional switch the length would be increased by 1 m.

d) Facility for connection from substation of adjoining building to feed emergency loads shall be permitted for feeding escape route and signage lighting as well as selected section of the fire protection system. Similarly on a reciprocal basis facility to feed the adjoining building for such emergency loads may be provided by necessary switchgear.

e) *Medium Voltage Switch Room* — The floor area required in respect of medium voltage switchgear room may be determined keeping in view the number and type of incoming/ outgoing bus coupler switches including likely expansion in future.

f) *Room for Standby Generator* — It is preferable to install the standby generator in service building. If installed in main building it shall be at the ground floor or at the semi basement, alternatively, in the first basement with facilities for forced ventilation. Adequate space shall be provided for storing of fuel. Compartmentation for fire protection with detection and first-aid protection measures is essential. Different type of requirements exist for the diesel engine and generator for the oil storage area and for the switchgear.

g) Facilities including space at appropriate positions, relative to the location of the installed equipment has to be kept in the layout design for removal of equipment or sub-assemblies for repair or maintenance. When it is located, other than the ground level with direct equipment access, a hatch or ramp shall be required.

h) Other environmental requirements under the provisions of *Environment Protection Rules*, 1986 as amended time-to-time shall be taken into account from the aspect of engine emissions including regarding the height of exhaust pipe and permitted noise levels/noise control.

j) The capacity of standby generating set shall be chosen on the basis of essential light load, essential air conditioning load, essential equipment load and essential services load, such as one lift out of the bank of lifts, one or all water pumps, etc. Having chosen the capacity and number of generating sets, required space may be provided for their installation (*see* Annex D for general guidance).

k) The generating set should preferably be housed adjacent to MV switchgear in the substation building to enable transfer of electrical load quickly as well as to avoid transfer of vibration and noise to the main building. Acoustics lining of the room shall be in line with the requirements of Central Pollution Control Board (CPCB). If DG Set is located outdoor, it shall be housed in acoustics enclosure. The generator house should have proper ventilation, fire fighting equipment, etc (*see also* **4.2.2**).

m) *Requirements of Room*

1) The areas given above in respect of the different categories of rooms holds good if they are provided with windows and independent access doors in accordance with local regulations.

2) All the rooms shall be provided with partitions up to the ceiling and shall have proper ventilation. Special care should be taken to ventilate the transformer rooms and where necessary louvers at lower level and exhaust fans at higher level shall be provided at suitable locations.

3) In order to prevent storm water entering the transformer and switch rooms through the soak-pits, the floor level, the substation shall be at least 15 cm above

the highest flood water level that may be anticipated in the locality. Also, facility shall be provided for automatic removal of water.

4) The minimum height of high voltage switchgear room shall be 3.6 m below the soffit of the beam.

n) *Fire Compartmentation* — It is advisable to provide fire compartmentation of buildings and segregation of associated wiring. Busbar trunking of horizontal and vertical distribution type in place of cable based distribution system shall be used.

4.3 Location of Switch Room

In large installations other than where a substation is provided, a separate switch room shall be provided; this shall be located as closely as possible to the electrical load centre preferably near the entrance of the building on the ground floor or on the first basement level, and suitable ducts shall be laid with minimum number of bends from the points of entry of the main supply cable to the position of the main switchgear. The switch room shall also be placed in such a position that rising ducts may readily be provided therefrom to the upper floors of the building in one straight vertical run. In larger buildings, more than one rising duct may be required and then horizontal ducts may also be required for running cables from the switch room to the foot of each rising main. Such cable ducts shall be either be reserved for the electrical services only or provided with a means of segregation for medium and low voltage installations, such as call-bell systems; telephone installations, fire detection and alarm system, announcement or public address system. Cables for essential emergency services such as those related to fire detection, alarm, announcement should use either metal conduit in addition to physical segregation from power cables or use fire survival cables, so that the service is maintained even in the event of a fire at least for a period of about 20 min.

4.4 Location and Requirements of Distribution Panels

The electrical control gear distribution panels and other apparatus, which are required on each floor may conveniently be mounted adjacent to the rising mains, and adequate space should be provided at each floor for this purpose.

4.5 Substation Safety

The owner or the operator of any substation shall be collectively and severally be responsible for any lapse or neglect leading to an accident or an incidence of an avoidable abnormality and shall take care of the safety requirements as follows:

a) enclose the substation where necessary to prevent, so far as is reasonably practicable, danger or unauthorised access;

b) enclose any part of the substation, which is open to the air and contains live equipment which is not encased, with a fence or wall not less than 2.4 m in height to prevent, so far as is reasonably practicable, danger or unauthorised access;

c) ensure that, so far as is reasonably practicable, there are at all times displayed:

1) sufficient safety signs of such size and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances;

2) a notice which is placed in a conspicuous position and which gives the location or identification of the substation, the name of each generator or distributor who owns or operates the substation equipment making up the substation and the telephone number where a suitably qualified person appointed for this purpose by the generator or distributor will be in constant attendance; and

3) such other signs, which are of such size and placed in such positions, as are necessary to give due warning of danger having regard to the siting of, the nature of, and the measures taken to ensure the physical security of, the substation equipment; and

d) take all reasonable precautions to minimize the risk of fire associated with the equipment.

4.6 Overhead Lines, Wires and Cables

4.6.1 *Height Requirement*

While overhead lines may not be relevant within buildings, regulations related to overhead lines are of concern from two different angles.

a) Overhead lines may be required in building complexes, though use of underground cables is the preferred alternative.

b) Overhead lines may be passing through the site of a building. In such a case the safety aspects are important for the construction activity in the vicinity of the overhead line as well as portions of low height buildings that may have to be constructed below the overhead lines.

For minimum distance (vertical and horizontal) of electric lines/wires/cables from buildings, reference may be made to Part 3 'Development Control Rules and General Building Requirements'.

c) Any person responsible for erecting an overhead line will keep informed the authority(s) responsible for services in that area for telecommunication, gas distribution, water and sewage network, roads so as to have proper co-ordination to ensure safety. He shall also publish the testing, energising programme for the line in the interests of safety.

4.6.2 *Position, Insulation and Protection of Overhead Lines*

Any part of an overhead line which is not connected with earth and which is not ordinarily accessible shall be supported on insulators or surrounded by insulation.

Any part of an overhead line which is not connected with earth and which is ordinarily accessible shall be:

a) made dead; or
b) so insulated that it is protected, so far it is reasonably practicable, against mechanical damage or interference; or
c) adequately protected to prevent danger.

Any person responsible for erecting a building or structure which will cause any part of an overhead line which is not connected with earth to become ordinarily accessible shall give reasonable notice to the generator or distributor who owns or operates the overhead line of his intention to erect that building or structure.

Any bare conductor not connected with earth, which is part of a low voltage overhead line, shall be situated throughout its length directly above a bare conductor which is connected with earth.

No overhead line shall, so far as is reasonably practicable, come so close to any building, tree or structure as to cause danger.

In this regulation the expression "ordinarily accessible" means the overhead line could be reached by hand if any scaffolding, ladder or other construction was erected or placed on/in, against or near to a building or structure.

4.6.3 *Precautions Against Access and Warnings of Dangers*

Every support carrying a high voltage overhead line shall, if the circumstances reasonably require, be fitted with devices to prevent, so far it is reasonably practicable, any unauthorised person from reaching a position at which any such line would be a source of danger.

Every support carrying a high voltage overhead line, and every support carrying a low voltage overhead line incorporating bare phase conductors, shall have attached to it sufficient safety signs and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances.

Poles supporting overhead lines near the road junctions and turnings shall be protected by a masonry or earth fill structure or metal barricade, to prevent a vehicle from directly hitting the pole, so that the vehicle, if out of control, is restrained from causing total damage to the live conductor system, likely to lead to a hazardous condition on the road or foot path or building.

4.6.4 *Fitting of Insulators to Stay Wires*

Every stay wire which forms part of, or is attached to, any support carrying an overhead line incorporating bare phase conductors (except where the support is a lattice steel structure or other structure entirely of metal and connected to earth) shall be fitted with an insulator no part of which shall be less than 3 m above ground or above the normal height of any such line attached to that support.

4.7 Maps of Underground Networks

4.7.1 Any person or organization or authority laying cables shall contact the local authority in charge of that area and find out the layout of

a) water distribution pipe lines in the area;
b) sewage distribution network;
c) telecommunication network; and
d) gas pipeline network and plan the cable network in such a manner that the system is compatible, safe and non interfering either during its installation or during its operation and maintenance. Plan of the proposed cable installation shall be brought to the notice of the other authorities referred above.

4.7.2 Suitable cable markers and danger sign as would be appropriate for the safety of the workmen of any of the systems shall be installed along with the cable installation. Notification of testing and energisation of the system shall also be suitably published for ensuring safety.

4.7.3 Any person or organization or authority laying cables shall have and, so far it is reasonably practicable, keep up to date, a map or series of maps indicating the position and depth below surface level of all networks or parts thereof which he owns or operates.

Any map prepared or kept shall be available for inspection by any of the municipal authority, other service providers, general public provided they have a reasonable cause for requiring to inspect any part of the map.

5 DISTRIBUTION OF SUPPLY AND CABLING

5.0 General

In the planning and design of an electrical wiring installation, due consideration shall be made of all the prevailing conditions. It is recommended that advice of a competent electrical engineer be sought at the initial stage itself with a view to providing an installation, that will prove adequate for its intended purpose be reliable and safe and efficient.

A certain redundancy in the electrical system is necessary and has to be built in from the initial design stage itself. The extent of redundancy will depend on the type of load, its criticality, normal hours of use, quality of power supply in that area, coordination with the standby power supply, capacity to meet the starting current requirements of large motors etc.

5.1 System of Supply

5.1.1 All electrical apparatus shall be suitable for the voltage and frequency of supply.

5.1.2 In case of connected load of 100 kVA and above, the relative advantage of high voltage three-phase supply should be considered. Though the use of high voltage supply entails the provisions of space for the capital cost of providing suitable transformer substation at the consumer's premises, the following advantages are gained:

a) advantage in tariff;
b) more effective earth fault protection for heavy current circuits;
c) elimination of interference with supplies to other consumers permitting the use of large size motors, welding plant, etc; and
d) better control of voltage regulation and more constant supply voltage.

NOTE — Additional safety precautions required to be observed in HV installations shall also be kept in view.

In many cases there may be no choice available to the consumer, as most of the licensees have formulated their policy of correlating the supply voltage with the connected load or the contract demand. Generally the supply is at 400/230 volts, 11 kV (or 22 kV) for loads up to 5 MVA and 33 kV or 66 kV for consumers of more than 5 MVA.

5.1.3 In very large industrial buildings where heavy electric demands occur at scattered locations, the economics of electrical distribution at high voltage from the main substation to other subsidiary transformer substations or to certain items of plant, such as large motors and furnaces, should be considered. The relative economy attainable by use of medium or high voltage distribution and high voltage plant is a matter for expert judgement and individual assessment in the light of experience by a professionally qualified electrical engineer.

5.2 Substation Equipment and Accessories

Substations require an approval by the Electrical Inspectorate. Such approval is mandatory before energizing the substation. It is desirable to get the approval for the general layout, schematic layout, protection plan etc, before the start of the work from the Inspectorate. All substation equipment and accessories and materials, etc, shall conform to relevant Indian Standards wherever they exist, otherwise the consumer (or his consultant) has to specify the standards to which the equipment to be supplied confirms and that shall be approved by the authority. Manufacturers of equipment have to furnish certificate of conformity as well as type test certificates for record, in addition to specified test certificates for acceptance tests and installation related tests for earthing, earth continuity, load tests and tests for performance of protective gear.

5.2.1 *High Voltage Switchgear*

5.2.1.1 The selection of the type of high voltage switchgear for any installation *inter alia* depends upon the following:

a) voltage of the supply system;
b) the prospective short-circuit current at the point of supply;
c) the size and layout of electrical installation;
d) the accommodation available; and
e) the nature of industry.

Making and breaking capacity of switchgear shall be commensurated with short-circuit potentialities of the supply system and the supply authority shall be consulted on this subject.

5.2.1.2 Guidelines on various types of switchgear equipment and their choice for a particular application shall be in accordance with good practice [8-2(4)].

5.2.1.3 In extensive installations of switchgear (having more than four incoming supply cables or having more than 12 circuit breakers), banks of switchgears shall be segregated from each other by means of fire-resisting barriers having 2 h fire resistance rating in

order to prevent spreading of the risk of damage by fire or explosion arising from switch failure. Where a bus-bar section switch is installed, it shall also be segregated from adjoining banks in the same way [*see* 8-2(5)]. Except main LT panel, it would be preferable to locate the sub panels/distribution boards near load centre. Further, it should be ensured that these panels are easily approachable. The preferable location of panels shall be near the exitways.

5.2.1.4 It should be possible to isolate any section from the rest of the switchboards such that work might be undertaken on this section without the necessity of making the switchboard dead. Isolating switches used for the interconnection of sections or for the purpose of isolating circuit-breakers of other apparatus, shall also be segregated within its compartment so that no live part is accessible when work in a neighbouring section is in progress.

5.2.1.5 In the case of duplicate or ring main supply, switchgears with interlocking arrangement shall be provided to prevent simultaneous switching of two different supply sources. Electrical and/or mechanical interlocks may preferably be provided.

5.2.2 *Cables*

5.2.2.1 The smallest size of the cable that shall be used, will depend upon the method of laying cable, permissible maximum temperature it shall withstand, voltage drop over the length of the cable, the prospective short-circuit current to which the cable may be subjected, the characteristics of the overload protection gear installed, load cycle and thermal resistivity of the soil [*see also* 8-2(6)].

NOTE — Guidelines for correlation of the ratings of cables and characteristics of protective device are under consideration. Continuous current carrying capacity (thermal limit leading to permanent change in properties of the insulation) under the installed conditions, voltage drop under required load and the fault current withstand ability of the cable for the duration that the protective device controlling the cable installation will let go the fault current, operating voltage are the prime considerations.

5.2.2.2 The advice of the cable manufacturer with regard to installation, jointing and sealing shall be followed.

5.2.2.3 The HV cables shall either be laid on the cable rack/built-up concrete trenches/tunnel/basement or directly buried in the ground depending upon the specific requirement. It is preferable to use four core cable in place of three and half core to minimize heating of neutral core due to harmonic content in the supply system and also avoidance of overload failures. All cables shall be installed in accordance with good practice [8-2(6)].

5.2.2.4 *Colour identification of cores of non-flexible cables*

Function	*Colour Identification of Core of Rubber of PVC Insulated Non-flexible Cable, or of Sleeve or Disc to be Applied to Conductor or Cable Code*
Protective or earthing	Green and yellow or Green with yellow stripes [1)]
Neutral of a.c. single or three-phase circuit	Black
Phase R of 3-phase a.c. circuit	Red
Phase Y of 3-phase a.c. circuit	Yellow
Phase B of 3-phase a.c. circuit	Blue
Positive of d.c. 2-wire circuit	Red
Negative of d.c. 2-wire circuit	Black
Outer (positive or negative) of d.c. 2-wire circuit derived from 3-wire system	Red
Positive of 3-wire system positive of 3-wire d.c. circuit)	Red
Middle wire of 3-wire d.c. circuit	Black
Negative of 3-wire d.c. circuit	Blue
Functional Earth-Telecommunication	Cream

[1)] Bare conductors are also used for earthing and earth continuity conductors. But it is preferable to use insulated conductors with green insulation with yellow stripes.

5.2.2.5 *Colour, identification of cores of flexible cables and flexible cords*

Number of Cores	*Function of Core*	*Colour(s) of Core*
1	Phase	Brown[1)]
	Neutral	(Light) Blue
	Protective or Earthing	Green & yellow
2	Phase	Brown
	Neutral	(Light) Blue[1)]
3	Phase	Brown
	Neutral	(Light) Blue[1)]
	Protective or Earthing	Green & yellow
4 or 5	Phase	Brown or Black[1)]
	Neutral	(Light) Blue[1)]
	Protective or Earthing	Green & yellow

[1)] Certain alternatives are allowed in Wiring Regulations.

5.2.3 *High Voltage Busbar Trunking/Ducting*

High voltage busbar trunking system is a type-tested switchgear and control gear assembly in the form of an enclosed system. HV bus bar system is used for transporting power between HV Generators, transformers and the infeed main switchgear of the main HV switchgear.

Generally three types of bus ducts namely non-segregated, segregated and isolated phase bus duct shall be used. The non-segregated bus ducts consists of three phase busbars running in a common enclosure made of steel or aluminium. The enclosure shall provide safety for the operational personnel and reduces chances of faults. The enclosures shall be effectively grounded.

Segregated phase bus duct are similar to non-segregated phased duct except that metal or insolation barriers are provided between phase conductors to reduce chances of phase to phase faults. However, it is preferable to use metal barriers.

In the case of isolated bus ducts, each phase conductor shall be housed in a separate non-magnetic enclosures. The bus duct shall be made of sections which are assembled together at site to make complete assembly. The enclosure shall be of either round or square shape and welded construction. The enclosures of all phases in general to be supported on a common steel structure. Provision of fire protection shall be provided in all openings in accordance with Part 4 'Fire and Life Safety'. Fire separation in openings shall be provided using materials having 2h fire resistance rating.

5.2.4 *MV/LV Busbar Trunking/Rising Mains*

Where heavy loads are to be carried, busbar systems are preferred. The busbars are available for continuous run from point to point or with tap offs at standard intervals and have to be chosen as per specific requirement. MV/LV busbar trunking shall be a type-tested switchgear and control gear assembly in the form of an enclosed system. There are two types of MV/LV bus duct system for power distribution system:

a) Conventional type.
b) Compact and sandwich type.

Conventional type bus duct is used for large power handling between transformer and switchgear or between switchgear and large power loads, such as compressor drive motor etc. This type is generally used in plant rooms, riser shafts, substations etc.

Compact type is available either air insulated or sandwich type for use within areas of the building which are put to other higher (aesthetic) level of use. They could be used in false ceiling spaces or even in corridors and shafts for distribution without any false ceiling as they provide an aesthetically acceptable finish to merge with other building elements such as beams, ducts or pipes in functional buildings.

The class of protection shall be specific depending on the requirement at the place of installation. Protection class (IP xx) will automatically identify the ventilation, protection from weather, water, dust etc.

In modern building technology, high demands are made of the power distribution system and its individual components:

a) Long life and good service quality,
b) Safe protection in the event of fire,
c) Low fire load,
d) Low space requirement, and
e) Minimum effort involved in carrying out retrofits.

The high load density in modern large buildings and high rise buildings demands compact and safe solution for the supply of power. The use of busbar trunking system is ideal for such applications.

Bus bar trunking can be installed in vertical risers ducts or horizontally in passages for transmission and distribution of power. Busbar trunking systems allow electrical installations to be planned in a simple and clear fashion. In the building complexes, additional safety demands with respect to fire barriers and fire load and use of bus bar trunking meets this requirement.

Busbar trunking system reduces the combustible material near the area with high energy in comparison with other distribution systems such as cables and makes the building safe from the aspect of vulnerability to fire of electrical origin. In addition, unlike cable systems the reliability of a bus trunking system is vvery high. These systems also require very little periodic maintenance.

Choice of busbar trunking for distribution in buildings can be made on the basis of

a) reduced fire load (drastically reduced in comparison to the cable system),
b) reduced maintenance over its entire lifetime,
c) longer service lifetime in comparison with a cable distribution
d) enhanced reliability due to rigid bolted joints and terminations and extremely low possibility of insulation failure.

5.2.5 *Transformers*

5.2.5.1 General design objective while selecting the transformer(s) for a substation would be to provide at least two or more transformers, so that a certain amount

of redundancy is built in, even if a standby system is provided. The total installed transformation capacity would be marginally higher than the anticipated maximum demand. With growing emphasis on energy conservation, the system design is made for both extremes of loading. During the periods of lowest load in the system, it would be desirable to operate only one transformer and switch in additional transformers as the load variation takes place in a day. The minimum size of a transformer would quite often depend on the minimum load that is anticipated over a period of about 4 h in a day. Total transformer capacity is generally selected on the basis of present load, possible future load, operation and maintenance cost and other system conditions and selection of the maximum size (capacity) of the transformer is guided by short-circuit making and breaking capacity of the switchgear used in the medium voltage distribution system. Maximum size limitation is important from the aspect of feed to a down stream fault.

For feeding final single phase domestic type of loads or general office loads it is advisable to even use transformers of capacity much lower than what the switchgear can handle, so that lower fault MVA is available in such areas and use of hand held equipment fed through flexible cords is safe.

For reasons of reliability and redundancy it is normal practice to provide at least two transformers for any important installation. Interlinking by tie lines is an alternative to enhance reliability/redundancy is areas where there are a number of substations in close vicinity, such as a campus with three or four multi-storeyed blocks each with a substation.

Ring main type of distribution is preferred for complexes having a number of substations.

5.2.5.2 Where two or more transformers are to be installed in a substation to supply a medium voltage distribution system, the distribution system shall be divided into separate sections each of which shall be normally fed from one transformer only unless the medium voltage switchgear has the requisite short-circuit capacity. Provision may, however, be made to interconnect separate sections, through a bus coupler in the event of failure or disconnection of one transformer. *See* **4.2** for details of location and requirements of substation.

The transformers, that may at any time operate in parallel, shall be so selected as to share the load in proportion to their respective load ratings. While the general practice is to avoid operation of transformers in parallel for feeding final distribution in buildings, it is possible to use transformers with slightly different impedance or voltage taps to operate in parallel, but with appropriate protection. Installations designed for parallel operation of transformers shall have protection for avoiding circulating current between transformers, avoid overload of any one transformer due to reactance mismatch and the system shall be so arranged as to trip the secondary breaker in case the primary breaker of that transformer trips.

5.2.6 *Switchgear*

5.2.6.1 Switchgear (and its protective device) shall have breaking capacity not less than the anticipated fault level in the system at that point. System fault level at a point in distribution system is predominantly dependent on the transformer size and its reactance. Parallel operation of transformers naturally increases the fault level

5.2.6.2 Isolation and controlling circuit breaker shall be interlocked so that the isolator cannot be operated unless the corresponding breaker is in open condition. The choice between alternative types of equipment may be influenced by the following considerations:

a) In certain installations supplied with electric power from remote transformer substations, it may be necessary to protect main circuits with circuit-breakers operated by earth fault, in order to ensure effective earth fault protection.

b) Where large electric motors, furnaces or other heavy electrical equipment is installed, the main circuits shall be protected from short-circuits by switch disconnector fuse or circuit breakers. For motor protection, the combination of contactor overload device and fuse or circuit breakers shall be Type-2 co-ordinated in accordance with accepted standards [8-2(7)]. Wherever necessary, back up protection and earth fault protection shall be provided to the main circuit.

c) Where mean of isolating main circuits is separately required, switch disconnector fuse or switch disconnector may form part of main switchboards.

5.2.6.3 It shall be mandatory to provide power factor improvement capacitor at the substation bus. Suitable capacitor may be selected in consultation with the capacitor as well as switchgear manufacture depending upon the nature of electrical load anticipated on the system. Necessary switchgear/feeder circuit breaker shall be provided for controlling of capacitor bank.

Power factor of individual motor may be improved by connecting individual capacitor banks in parallel. For higher range of motors, which are running continuously without much variation in load, individual power factor correction at load end is advisable.

capacitor bank. The motor still rotating after disconnection from the supply, may act as generator by self-excitation and produce a voltage higher than supply voltage. If the motor is again switched on before the speed has fallen to about 80 percent of the normal running speed, the high voltage will be superimposed on the supply circuits and will damage both the motor and capacitor.

As a general rule, the kVAr rating of the capacitor should not exceed the no-load magnetising kVA of the motor.

Generally it would be necessary to provide an automatic control for switching in capacitors matching the load power factor and the bus voltage. Such a scheme would be necessary as capacitors permanently switched in the circuit may cause over voltage at times of light load.

5.2.6.4 Sufficient additional space shall be allowed in substations and switchrooms to allow operation and maintenance and proper means shall be provided for isolating the equipment to allow access for servicing, testing and maintenance. Sufficient additional space shall be allowed for temporary location and installation of standard servicing and testing equipment. Space should also be allowed to provide for anticipated future extensions.

5.2.6.5 Electrical installations in a room or cubicle or in an area surrounded by wall fence, access to which is controlled by lock and key shall be considered accessible to authorized persons only.

A wall or fence less than 1.8 m in height shall not be considered as preventing access unless it has other features that provide a degree of isolation equivalent to a 1.8 m fence.

5.2.6.6 Harmonics on the supply systems are becoming a greater problem due to the increasing use of electronic equipments, computer, fluorescent, mercury vapour and sodium vapour lighting, controlled rectifier and inverters for variable speed drives, power electronics and other non-linear loads. Harmonics may lead to almost as much current in the neutral as in the phases. This current is almost entirely third harmonic. Phase rectification devices may be considered for the limits of harmonic voltage distortion may be considered at the planning stage in such cases.

With the wide spread use of thyristor and rectifier based loads there is necessity of providing a full size neutral; but this requirement is limited to the 3-phase 4-wire distribution generally in the 400/230 V system. As a result it is not desirable to use half-size neutral conductor, as possibility of neutral conductor overload due to harmonics is likely.

5.3.1.1 There shall be a circuit-breaker or miniature circuit-breakers or a load break switch fuse on each live conductor of the supply mains at the point of entry. The wiring throughout the installation shall be such that there is no switch or fuse unit in the earthed neutral of conductor. The neutral shall also be distinctly marked. In this connection, Rule 32(2) and Rule 50(1) of the *Indian Electricity Rules*, 1956 (*see* Annex B) as amended up to date shall also be referred.

5.3.1.2 The main switch shall be easily accessible and situated as near as practicable to the termination of service line.

5.3.1.3 On the main switch, where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor or a multi-wire system or a conductor which is to be connected thereto, an indication of a permanent nature shall be provided to identify the earthed neutral conductor. In this connection, Rule 32(1) of *Indian Electricity Rules*, 1956 (*see* Annex B) shall be referred as amended up-to-date.

5.3.1.4 *Energy meters*

Energy meters shall be installed in residential buildings at such a place which is readily accessible to the owner of the building and the Authority. These should be installed at a height where it is convenient to note the meter reading, it should preferably not be installed below one metre from the ground. The energy meters should either be provided with a protecting covering, enclosing it completely except the glass window through which the readings are noted or should be mounted inside a completely enclosed panel provided with hinged or sliding doors with arrangement for locking.

In multi-storeyed buildings meters shall be installed with tapping point for meters of the rising main (bus trunking) on individual floors.

5.3.2 *Main Switches and Switchboard*

5.3.2.1 All main switches shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply. Every switch shall have an environmental protection level rating (IP), so that its operation is satisfactory in the environment of the installation.

NOTE — Woodwork shall not be used for the construction or mounting of switches and switch boards installed in a building.

5.3.2.2 *Location*

a) The location of the main board should be such

that it is easily accessible for fireman and other personnel to quickly disconnect the supply in case of emergencies. If the room is locked for security, means of emergency access, by schemes such as break glass cupboard, shall be incorporated.

b) Main switch board shall be installed in rooms or cupboards so as to safeguard against operation by unauthorized personnel.

c) Switchboards shall be placed only in dry situations and in ventilated rooms and they shall not be placed in the vicinity of storage batteries or exposed to chemical fumes.

d) In damp situation or where inflammable or explosive dust, vapour or gas is likely to be present, the switchboard shall be totally enclosed and shall have adequate degree of protection. In some cases flameproof enclosure may be necessitated by particular circumstances [*see* 8-2(8)].

e) Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m or any washing unit in the washing rooms or laundries, or in bathrooms, lavatories or toilets, or kitchens.

f) In case of switchboards unavoidably fixed in places likely to be exposed to weather, to drip, or to abnormal moist temperature, the outer casing shall be weatherproof and shall be provided with glands or bushings or adopted to receive screwed conduit, according to the manner in which the cables are run.

g) Adequate illumination shall be provided for all working spaces about the switchboards when installed indoors.

5.3.2.3 Metal-clad switchgear shall preferably be mounted on any of the following types of boards:

a) *Hinged-type metal boards* — These shall consist of a box made of sheet metal not less than 2 mm thick and shall be provided with a hinged cover to enable the board to swing open for examination of the wiring at the back. The joints shall be welded. There shall be a clear distance of not less than 2.5 cm between the teak wood board and the cover, the distance being increased for larger boards in order that on closing of the cover, the insulation of the cables is not subjected to damage and no excessive twisting or bending in any case. The board shall be securely fixed to the wall by means of rag bolts, plugs, or wooden plugs and shall be provided with a locking arrangement and an earthing stud. All wires passing through the metal board shall be protected by a rubber or wooden bush at the entry hole. The earth stud should commensurate with the size of earth lead/ leads. Alternatively, metal boards may be made of suitable size angle iron of minimum size 35 mm × 35 mm × 6 mm or channel iron of minimum size 35 mm × 25 mm × 6 mm frames work suitably mounted on front with a 3 mm thick mild steel plate and on back with 1.5 mm thick mild steel sheet. No apparatus shall project beyond any edge of panel. No fuse body shall be mounted within 2.5 cm of any edge of the panel.

NOTE — Such type of boards are particularly suitable for small switchboard for mounting metal-clad switchgear connected to supply at low voltages.

b) *Fixed-type metal boards* — These shall consist of an angle or channel iron frame fixed on the wall or on floor and supported on the wall at the top, if necessary. There shall be a clear distance of 1 m in front of the switchboards. If there are any attachments of bare connections at the back of the switchboard Rule 51(1)(c) of *Indian Electricity Rules*, 1956 shall apply. The connections between the switchgear mounting and the outgoing cable up to the wall shall be enclosed in a protection pipe.

NOTE — Such type of boards are particularly suitable for large switchboards for mounting large number of switchgears or high capacity metal-clad switchgear or both.

c) *Protected-type switchboard* — A protected switchboard is one where all of the conductors are protected by metal or other enclosures. They may consist of a metal cubicle panel, or an iron frame upon which is mounted metal-clad switchgear. They usually consist of a main switch, busbars and circuit breakers or fuses controlling outgoing circuits.

d) *Open-type switchboard* — An open type switchboard is one, which has exposed current carrying parts on the front of the switchboard. This type of switchboard is rarely used now-a-days but where this exists, a hand rail or barrier has to be provided to prevent unintentional or accidental contact with exposed live parts. They must be located in a special switch room or enclosure and only a competent person may have access to these switchboards.

NOTE — These boards may be existing in old installations. It is recommended that they be phased out. With the continuously increasing fault power feed due to increases in generation and strengthening of distribution systems, these open boards are a source of accidents.

5.3.2.4 *Recessing of boards*

Where so specified, the switchboards shall be recessed in the wall. Ample room shall be provided at the back for connection and at the front between the switchgear mountings.

5.3.2.5 *Marking of apparatus* [*see also* 8-2(9)]

a) Where a board is connected to voltage higher than 250 V, all the apparatus mounted on it shall be marked on the following colours to indicate the different poles or phases to which the apparatus or its different terminals may have been connected:

Alternating Current	*Direct Current*
Three-phases — red, yellow, blue	Three-wire system — 2 outer wire, positive red and negative blue
1 Neutral — black	1 Neutral — black

Where four-wire three-phase wiring is done, the neutral shall be in one colour and the other three wires in another colour as mentioned above or shall be suitably tagged or sleeved for fool proof identification.

b) Where a board has more than one switch, each such switch shall be marked to indicate which section of the installation it controls. The main switch shall be marked as such and where there is more than one main switch in the building, each such switch shall be marked to indicate which section of the installation it controls.

All markings shall be clear and permanent.

5.3.2.6 *Drawings*

Before proceeding with the actual construction, a proper drawing showing the detailed dimensions and design including the disposition of the mountings of the boards, which shall be symmetrically and neatly arranged for arriving at the overall dimensions, shall be prepared along the building drawing. Such drawings will show the mandatory clearance spaces if any, and clear height below the soffit of the beam required to satisfy regulations and safety considerations, so that other designers or installers do not get into such areas or spaces for their equipment.

5.3.2.7 Where a board has more than one switch, each such switch shall be marked to indicate which section of the installation it controls. The main switch shall be marked as such and where there is more than one main switch in the building, each such switch shall be marked to indicate which section of the installation it controls.

All markings shall be clear and permanent.

5.3.2.8 *MV/LV Busbar chambers (400 V/230 V)*

Busbar chambers, which feed two or more circuits, must be controlled by a main disconnector (TP & N), or Isolating links or TPN MCB to enable them to be disconnected from the supply.

5.3.3 *Distribution Boards*

A distribution board comprises of one or more protective devices against over current and ensuring the distribution of electrical energy to the circuits. Distribution board shall provide plenty of wiring space, to allow working as well as to allow keeping the extra length of connecting cables, likely to be required for maintenance.

5.5.3.1 Main distribution board shall be provided with a circuit breaker on each pole of each circuit, or a switch with a fuse on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

All incomers should be provided with surge protection devices.

5.3.4 *Branch Distribution Boards*

5.3.4.1 Branch distribution boards shall be provided, along with earth leakage protective device (ELCB) (incoming), with a fuse or a miniature circuit breaker or both of adequate rating/setting chosen on the live conductor of each sub-circuit and the earthed neutral conductor shall be connected to a common link and be capable of being disconnected individually for testing purposes. At least one spare circuit of the same capacity shall be provided on each branch distribution board. Further, the individual branching circuits (outgoing) shall be protected against over-current with miniature circuit breaker of adequate rating. In residential/ industrial lighting installations, the various circuits shall be separated and each circuit shall be individually protected so that in the event of fault, only the particular circuit gets disconnected.

5.3.4.2 Circuits shall be separate for installations at higher level such as those in the ceiling and at higher levels, above 1 m, on the walls and for installations at lower level such as sockets for portable or stationery plug in equipments. For devices consuming high power and which are to be supplied through supply cord and plug, separate wiring shall be done. For plug-in equipment provisions shall be made for providing ELCB protection in the distribution board.

5.3.4.3 It is preferable to have additional circuit for kitchen and bathrooms. Such sub-circuit shall not have more than a total of ten points of light, fans and 6A socket outlets. The load of such circuit shall be restricted to 800 W. If a separate fan circuit is provided, the number of fans in the circuit shall not exceed ten. Power sub-circuit shall be designed according to the

load but in no case shall there be more than two 16A outlets on each sub-circuit.

5.3.4.4 The circuits for lighting of common area shall be separate. For large halls 3-wire control with individual control and master control installed near the entrance shall be provided for effective conservation of energy.

5.3.4.5 Where daylight would be available, particularly in large halls, lighting in the area near the windows, likely to receive daylight shall have separate controls for lights, so that they can be switched off selectively when daylight is adequate, while keeping the lights in the areas remote from the windows on.

5.3.4.6 Circuits for socket outlets may be kept separate circuits feeding fans and lights. Normally, fans and lights may be wired on a common circuit. In large spaces circuits for fans and lights may also be segregated. Lights may have group control in large halls and industrial areas. While providing group control consideration may be given for the nature of use of the area lit by a group. Consideration has to be given for the daylight utilization, while grouping, so that a group feeding areas receiving daylight can be selectively switched off during daylight period.

5.3.4.7 The load on any low voltage sub-circuit shall not exceed 3 000 W. In case of a new installation, all circuits and sub-circuits shall be designed with an initial load of about 2 500 W, so as to allow a provision of 20 percent increase in load due to any future modification. Power sub-circuits shall be designed according to the load, where the circuit is meant for a specific equipment. Good practice is to limit a circuit to a maximum of four sockets, where it is expected that there will be diversity due to use of very few sockets in large spaces (example sockets for use of vacuum cleaner). General practice is to limit it to two sockets in a circuit, in both residential and non-residential buildings and to provide a single socket on a circuit for a known heavy load appliance such as air conditioner, cooking range etc.

5.3.4.8 In wiring installations at special places like construction sites, stadium, shipyards, open yards in industrial plants, etc, where a large number of high wattage lamp may be required, there shall be no restriction of load on any circuit but conductors used in such circuits shall be of adequate size for the load and proper circuit protection shall be provided.

5.3.5 *Location of Distribution Boards*

a) The distribution boards shall be located as near as possible to the centre of the load they are intended to control.

b) These shall be fixed on suitable stranchion or wall and shall be accessible for replacement/ reset of protective devices, and shall not be more than 1.8 m from floor level.

c) These shall be of either metal-clad type, or air insulated type. But, if exposed to weather or damp situations, these shall be of the weatherproof type and, if installed where exposed to explosive dust, vapour or gas, these shall be of flameproof type in accordance with accepted standards [8-2(10)]. In corrosive atmospheres, these shall be treated with anti-corrosive preservative or covered with suitable plastic compound.

d) Where two and/or more distribution boards feeding low voltage circuits are fed from a supply of medium voltage, the metal case shall be marked 'Danger 415 V' and identified with proper phase marking and danger marks.

e) Each shall be provided with a circuit list giving diagram of each circuit which it controls and the current rating of the circuit and size of fuse element.

f) In wiring branch distribution board, total load of consuming devices shall be divided as far as possible evenly between the number of ways in the board leaving spare circuits for future extension.

5.3.6 *Protection of Circuits*

a) Appropriate protection shall be provided at switchboards, distribution boards and at all levels of panels for all circuits and sub-circuits against short circuit, over-current and other parameters as required. The protective device shall be capable of interrupting maximum prospective short circuit current that may occur, without danger. The ratings and settings of fuses and the protective devices shall be co-ordinated so as to afford selectivity in operation and in accordance with accepted standards [8-2(1)].

b) Where circuit-breakers are used for protection of a main circuit and of the sub-circuits derived therefrom, discrimination in operation may be achieved by adjusting the protective devices of the sub-main circuit-breakers to operate at lower current settings and shorter time-lag than the main circuit-breaker.

c) Where HRC type fuses are used for back-up protection of circuit-breakers, or where HRC fuses are used for protection of main circuits, and circuit-breakers for the protection of sub-circuits derived there from, in the event of short-circuits protection exceeding the short-circuits capacity of the circuit-breakers, the HRC fuses shall operate earlier than the

circuit-breakers; but for smaller overloads within the short-circuit capacity of the circuit-breakers, the circuit-breakers shall operate earlier than the HRC fuse blows.

d) If rewireable type fuses are used to protect sub-circuits derived from a main circuit protected by HRC type fuses, the main circuit fuse shall normally blow in the event of a short-circuit or earth fault occurring on sub-circuit, although discrimination may be achieved in respect of overload currents. The use of rewireable fuses is restricted to the circuits with short-circuit level of 4 kA; for higher level either cartridge or HRC fuses shall be used. However, use of rewireable fuse is not desirable, even for lower fault level areas. MCB's provide a better and dependable protection, as their current setting is not temperable.

e) A fuse carrier shall not be fitted with a fuse element larger than that for which the carrier is designed.

f) The current rating of a fuse shall not exceed the current rating of the smallest cable in the circuit protected by the fuse.

g) Every fuse shall have its own case or cover for the protection of the circuit and an indelible indication of its appropriate current rating in an adjacent conspicuous position.

5.4 Voltage and Frequency of Supply

It should be ensured that all equipment connected to the system including any appliances to be used on it are suitable for the voltage and frequency of supply of the system. The nominal values of low and medium voltage systems in India are 240 V and 415 V ac, respectively, and the frequency 50 Hz.

NOTES

1 The design of the wiring system and the sizes of the cables should be decided taking into account two factors:

a) *Voltage Drop* — This should be kept as low as economy permits to ensure proper functioning of all electrical appliances and equipment including motors; and

b) First cost against operating losses.

2 In view of the latest development at the international level, nominal system voltages have been aligned with IEC recommendation and accordingly the nominal ac system voltage shall be changed from 240/415 V to 230/400 V with a tolerance of ± 10 percent.

5.5 Rating of Cables and Equipments

5.5.1 The current-carrying capacity of different types of cables shall be chosen in accordance with good practice [8-2(12)].

5.5.2 The current ratings of switches for domestic and similar purposes are 6A and 16A.

5.5.3 The current ratings of isolators and normal duty switches and composite units of switches and fuses shall be selected from one of the following values:

16, 25, 32, 63, 100, 160, 200, 320, 400, 500, 630, 800, 1 000 and 1 250 A.

5.5.4 The ratings of rewirable and HRC fuses shall be in accordance with good practice [8-2(13)].

5.5.5 The current ratings of miniature circuit-breakers shall be chosen from the values given below:

6, 8, 10, 13, 16, 20, 25, 32, 40, 50, 63, 80, 100 and 125 A.

5.5.6 The current ratings of moulded case circuit-breakers shall be chosen from the values given below:

100, 125, 160, 200, 250, 315, 400, 630, 800, 1 000, 1 250 and 1 600 A.

5.5.7 The current ratings of air circuit-breakers shall be chosen from the values given below:

630, 800, 1 000, 1 250, 1 600, 2 000, 2 500, 3 200 and 4 000 A.

5.5.8 The current ratings of the distribution fuse board shall be selected from one of the following values:

6, 16, 25, 32, 63 and 100 A.

5.6 Installation Circuits

Type of Circuit	*Wire Size*	*Number of Circuits*
Lighting	1.0 mm^2	2 or more
Socket-outlets 10 A	2.5 mm^2	Any number
		Areas such as kitchens and laundries 3 × double socket-outlets per circuit. Other areas up to 12 double socket-outlets
Socket-outlets 15 or 20 A	2.5 mm^2	1
Water heater 3 kW	1.5 mm^2	1
Water heater 3-6 kW	2.5 mm^2	1
Free standing electric range	6.0 mm^2	1
Separate oven and/ or cook top	4.0 mm^2	1
Permanently connected appliances including dish-washers, heaters, etc	2.5 mm^2	1 above 10 A. Up to 10 A can be wired as part of a socket-outlet circuit
Submains to garage or out-building	2.5 mm^2	1 for each
Mains cable	16 mm^2	1

5.6.1 *Selecting and Installing Cables*

5.6.1.1 *Cable insulation types*

For the mains cable	Tough plastic sheathed (TPS) cable
For installation wiring	Tough plastic sheathed (TPS) cables
For main earth or main equipotential wire	Polyvinyl chloride (PVC) insulated conduit wire
Underground installation and installation in cable trench, feeders between buildings etc.,	PVC insulated, PVC sheathed armoured cables or XLPE insulated, PVC sheathed cables armoured cables
Installation in plant rooms, switch rooms etc, on cable tray or ladder or protected trench, where risk of mechanical damage to cable does not exist.	PVC insulated, PVC sheathed or XLPE insulated, PVC sheathed unarmoured cables

For the purposes of this Code cables above 1 mm^2 must have stranded conductors. All cables when installed, must be adequately protected against mechanical damage. This can be carried out by either having additional protection, such as being enclosed in PVC conduit or metal pipes, or placing the cables in a suitable location that requires no additional protection. The cables for wiring circuits in electrical installation must have the appropriate wire size matching the requirement of the loads and the following table gives the recommendations for different types of loads.

5.6.1.2 *Circuit wire sizes*

Circuits	*Minimum Wire Size*	*Wire Colour*
1-way lighting	2 + E cable wires 1.5 mm^2	Red-Black-Green or Green/Yellow
2-way lighting control (straps between the 2 switches)	3-wire cable 1.5 mm^2	Red-White-Blue
Storage water heaters up to 3 kW	2 + E cable 1.5 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
Storage water heaters between 3 kW and 6 kW	2 + E cable 2.5 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
Socket-outlets and permanent connection units	2 + E cable 2.5 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
Submains to garages or out buildings	2 + E cable 2.5 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
Cooking hobs	2 + E cable 4 mm^2	Red-Black-Green or Green/Yellow
Separate ovens	2 + E cable 4 mm^2 (stranded conductors)	
Electric range	2 + E cable 6 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
Mains	2 wire cable 16 mm^2 (stranded conductors)	Red-Black
Main equipotential bonding wire	Conduit wire 4 mm^2 (stranded conductors)	Green or Green/Yellow
Main earth wire	Conduit wire 6 mm^2 (stranded conductors)	Green or Green/Yellow

2 + E is also known as twin and earth

Switch or isolator controlling a water heater or geyser should not be located within 1 m from the location of a shower or bath tub, to avoid a person in wet condition reaching the switch or isolator. It is preferable to provide the control switch outside the bathroom near the entrance and provide an indication at the water heater. A socket or a connector block with suitable protection against water spray should be provided to connect the water heater. The above considerations apply to switches for outdoor lights and other

bathroom, toilet, garage etc, should not be provided within a height of 1 m from the ground level. Similar care has to be taken for installations involving fountains, swimming pools etc. Light fittings in such areas should be fed at low voltage, preferably through an isolating transformer with a proper earth leakage protection.

5.6.2 *Requirements for Physical Protection of Underground Cables*

Protective Element	*Specifications*
Bricks	a) 100 mm minimum width b) 25 mm thick c) sand cushioning 100 mm and sand cover 100 mm.
Concrete slabs	at least 50 mm thick.
Plastic slabs (polymeric cover strips) Fibre reinforced plastic	at least 10 mm thick, depending on properties and has to be matched with the protective cushioning and cover
PVC conduit or PVC pipe or stoneware pipe or hume pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe.
Galvanized pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe.

The trench shall be backfilled to cover the cable initially by 200 mm of fill; and then a plastic marker strip over the full length of cable in the trench. Fill the trench shall be laid before filling the full trench. The marker signs where any cable enters or leaves a building shall be put. This will identify that there is a cable located underground near the building. If the cables rise above ground to enter a building or other structure, a mechanical protection such as a GI pipe or PVC pipe for the cable from the trench depth to a height of 2.0 m above ground shall be provided.

5.7 Lighting and Levels of Illumination

5.7.1 *General*

Lighting installation shall take into consideration the many factors on which the quality and quantity of artificial lighting depends. The modern concept is to provide illumination with the help of a large number of light sources not of higher illumination level. Also much higher levels of illumination are called for, than in the past, often necessitating the use of fluorescent lighting suitably supplemented with incandescent fittings, where required.

provide a lighting installation to give the recommended illumination levels, the wiring installation at least should be so designed that at a later date, it will permit the provision for additional lighting fittings or conversion from incandescent to fluorescent lighting fittings to bring the installation to the required standard. It is essential that adequate provisions should be made for all the electrical services which may be required immediately and during the intended useful life of the building.

5.7.3 *Principles of Lighting*

When considering the function of artificial lighting, attention shall be given to the following principle characteristics before designing an installation:

a) illumination and its uniformity;
b) special distribution of light. This includes a reference to the composition of diffused and directional light, direction of incidence, the distribution of luminances and the degree of glare; and
c) colour of the light and colour rendition.

5.7.4 The variety of purposes which have to be kept in mind while planning the lighting installation could be broadly grouped as:

a) industrial buildings and processes;
b) offices, schools and public buildings;
c) surgeries and hospitals; and
d) hostels, restaurants, shops and residential buildings.

5.7.4.1 It is important that appropriate levels of illumination for these and the types and positions of fittings determined to suit the task and the disposition of the working planes.

5.7.5 For specific requirements for lighting of special occupancies, reference shall be made to good practice [8-2(14)].

5.7.6 *Energy Conservation*

Energy conservation may be achieved by using the following:

a) Energy efficient lamps, chokes, ballast, etc for lighting equipment.
b) Efficient switching systems such as remote sensors, infrared switches, master switches, remote switches, etc for switching ON and OFF of lighting circuits.
c) Properly made/connected joints/contacts to avoid loose joints leading to loss of power.

5.8 In locations where the system voltage exceeds 650 V, as in the case of industrial locations, for details of design and construction of wiring installation, reference may be made to good practice [8-2(15)].

5.9 Guideline for Electrical Layout in Residential Buildings

For guidelines for electrical installation in residential buildings, reference may be made to good practice [8-2(16)].

A typical distribution scheme in a residential building with separate circuits for lights and fans and for power appliances is given in Fig. 1.

5.10 For detailed information regarding the installation of different electrical equipments, reference may be made to good practice [8-2(17)].

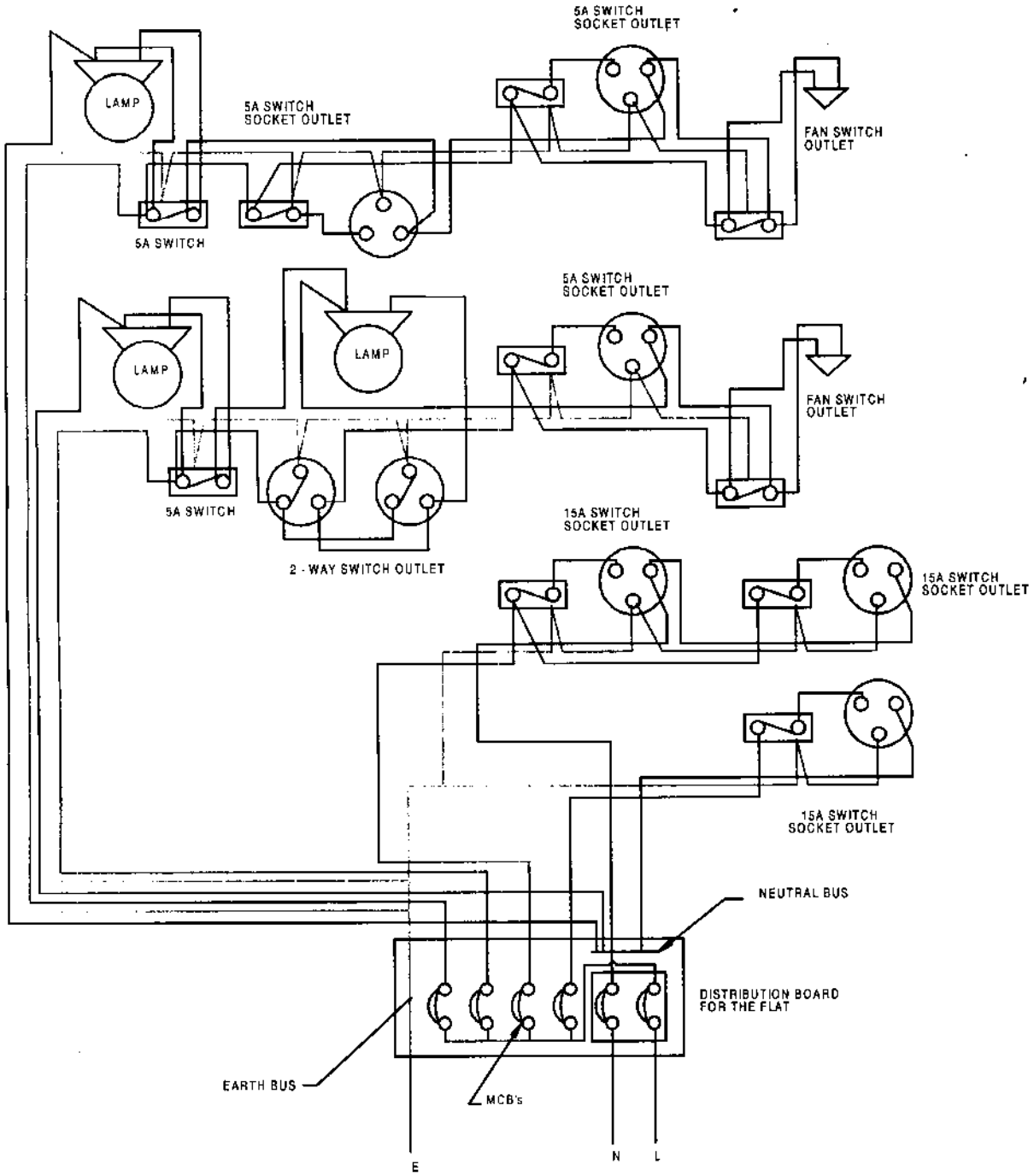


FIG. 1 WIRING DIAGRAM FOR A TYPICAL DISTRIBUTION BOARD SCHEME IN A RESIDENTIAL BUILDING FLAT

6 WIRING

6.1 Provision for Maximum Load

All conductors, switches and accessories shall be of such size as to be capable of carrying, without their respective ratings being exceeded, the maximum current which will normally flow through them.

6.1.1 *Estimation of Load Requirements*

In estimating the current to be carried by any conductor the following ratings shall be taken, unless the actual values are known or specified for these elements:

Element		*Rating* (in W)
Incandescent lamps		60
Ceiling fans Table fans	}	100
Ordinary socket outlet points		100
Fluorescent tubes:		
Length:	600 mm	25
	1 200 mm	50
	1 500 mm	90
Power socket-outlet		1 000
Air-conditioner		2 500

6.1.2 Electrical installation in a new building shall normally begin immediately on the completion of the main structural building work and before finishing work such as plastering has begun except in the case of surface wiring which can be carried out after the plaster work. Usually, no installation work should start until the building is reasonably weatherproof, but where electric wiring is to be concealed within the structures as may be the case with a reinforced concrete building, the necessary conduits and ducts shall be positioned firmly by tying the conduit to the reinforcement before concreting. When shutters are removed after concreting, the conduits ends shall be given suitable anti-corrosive treatment and holes blocked off by putties or caps to protect conduits from getting blocked. All conduit openings and junction box openings, etc shall be properly protected against entry of mortar, concrete, etc during construction.

6.2 Selection of Size of Conductors

The size of conductors of circuits shall be so selected that the drop in voltage from consumer's terminals in a public supply (or from the busbars of the main switchboard controlling the various circuits in a private generation plant) to any point on the installation does not exceed three percent of the voltage at the consumer's terminals (or at two busbars as these may be) when the conductors are carrying the maximum current under the normal conditions of service.

6.2.1 If the cable size is increased to avoid voltage drop in the circuit, the rating of the cable shall be the current which the circuit is designed to carry. In each circuit or sub-circuit the fuse shall be selected to match the cable rating to ensure the desired protection.

6.3 Branch Switches

Where the supply is derived from a three-wire or four-wire source, and distribution is done on the two-wire system, all branch switches shall be placed in the outer or live conductor of the circuit and no single phase switch or protective device shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit. Single-pole switches (other than for multiple control) carrying not more than 16 A may be of tumbler type or flush type which shall be on when the handle or knob is down.

6.4 Layout and Installation Drawing

6.4.1 The electrical layout should be drawn indicating properly the locations of all outlets for lamps, fans, appliances both fixed and transportable, motors, etc, and best suit for wiring.

6.4.2 All runs of wiring and the exact positions of all points of switch-boxes and other outlets shall be first marked on the plans of the building and approved by the engineer-in-charge or the owner before actual commencement of the work.

6.4.3 Industrial layout drawings should indicate the relative civil and mechanical details.

6.4.4 *Layout of Wiring*

The layout of wiring should be designed keeping in view disposition of the lighting system to meet the illumination levels. All wirings shall be done on the distribution system with main and branch distribution boards at convenient physical and electrical load centres. All types of wiring, whether concealed or unconcealed should be as near the ceiling as possible. In all types of wirings due consideration shall be given for neatness and good appearance.

6.4.5 Balancing of circuits in three-wire or poly-phase installation shall be arranged before hand. Proper Balancing can be done only under actual load conditions. Conductors shall be so enclosed in earthed metal or incombustible insulating material that it is not possible to have ready access to them. Means of access shall be marked to indicate the voltage present.

Where terminals or other fixed live parts between which a voltage exceeding 250 V exists are housed in separate enclosures or items of apparatus which, although separated are within reach of each other, a notice shall be placed in such a position that anyone gaining access to live parts is warned of the magnitude of the voltage that exists between them.

the peak load condition based on equipment usage. Facility for change should be built into the distribution design.

NOTE — The above requirements apply equally to three-phase circuits in which the voltage between lines or to earth exceeds 250 V and to groups of two or more single-phase circuits, between which medium voltage may be present, derived therefrom. They apply also to 3-wire dc or 3-wire single-phase ac circuits in which the voltage between lines or to earth exceeds 250 V and to groups of 2-wire circuits, between which medium voltage may be present, derived therefrom.

6.4.6 Medium voltage wiring and associated apparatus shall comply, in all respects, with the requirements of Rules 50, 51 and 61 of the *Indian Electricity Rules*, 1956 as amended up-to-date.

6.5 Conductors and Accessories

6.5.1 *Conductors*

Conductors for all the internal wiring shall be of copper. Conductors for power and lighting circuits shall be of adequate size to carry the designed circuit load without exceeding the permissible thermal limits for the insulation. The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area not less than 1.50 mm^2 copper. The cross-sectional area of conductor for power wiring shall be not less than 4.0 mm^2 copper. The minimum cross-sectional area of conductor of flexible cord shall be 1.50 mm^2 copper.

In existing buildings where aluminium wiring has been used for internal electrification, changeover from aluminium conductor to copper conductor may be made once the former goes beyond economical repairs.

NOTE — It is advisable to replace wiring, which is more than 30 years old as the insulation also would have deteriorated, and will be in a state to cause failure on the slightest of mechanical or electrical disturbance.

6.5.2 *Flexible Cables and Flexible Cords*

Flexible cables and cords shall be of copper and stranded and protected by flexible conduits or tough rubber or PVC sheath to prevent mechanical damage.

6.5.3 *Cable Ends*

When a stranded conductor having a nominal sectional area less than 6 mm^2 is not provided with cable sockets, all strands at the exposed ends of the cable shall be soldered together or crimped using suitable sleeve or ferrules.

6.5.4 *Special Risk*

Special forms of construction, such as flameproof enclosures, shall be adopted where there is risk of the fire or explosion.

Unless otherwise specified, electric connections to ancillary buildings, such as out-houses, garages, etc, adjacent to the main building and when no roadway intervenes shall be taken in an earthed GI pipe or heavy duty PVC or HDPE pipe of suitable size in the exposed portion at a height of not less than 5.8 m or by buried underground cables. This applies to both runs of mains or sub-mains or final sub-circuit wiring between the buildings.

6.5.6 *Expansion Joints*

Distribution boards shall be so located that the conduits shall not normally be required to cross expansion joints in a building. Where such crossing is found to be unavoidable, special care shall be taken to ensure that the conduit runs and wiring are not in any way put to strain or damaged due to expansion of building structure. Anyone of the standard methods of connection at a structural expansion joint shall be followed:

a) Flexible conduit shall be inserted at place of expansion joint.
b) Oversized conduit overlapping the conduit.
c) Expansion box.

6.5.7 *Low Voltage (Types of Wires/Cables)*

Low voltage services utilizes various categories of cables/wires, such as Fibre optic cable, co-axial, CAT 5, etc. These shall be laid at atleast minimum specified distance of 300 mm from any power wire or cable. Special care shall be taken to ensure that the conduit runs and wiring are laid properly for low voltage signal to flow through it.

6.6 Joints and Looping Back

6.6.1 Where looping back system of wiring is specified, the wiring shall be done without any junction or connector boxes on the line. Where joint box system is specified, all joints in conductors shall be made by means of suitable mechanical connectors in suitable joint boxes. Wherever practicable, looping back system should be preferred. Whenever practicable, only one system shall be adopted for a building, preferably a looping back system.

6.6.2 In any system of wiring, no bare or twist joints shall be made at intermediate points in the through run of cables unless the length of a final sub-circuit, sub-main or main or more than the length of the standard coil as given by the manufacturer of the cable. If any jointing becomes unavoidable such joint shall be made through proper cutouts or through proper junction boxes open to easy inspection, but in looping back system no such junction boxes shall be allowed.

6.6.3 Joints are a source of problems in reliability and are also vulnerable to fire. They should be avoided or at least minimized. Where joints in cable conductors or bare conductors are necessary, they shall be mechanically and electrically sound. Joints in non-flexible cables shall be accessible for inspection; provided that this requirement shall not apply to joints in cables buried underground, or joints buried or enclosed in non-combustible building materials. Joints in non-flexible cables shall be made by soldering, brazing, welding or mechanical clamps, or be of the compression type; provided that mechanical clamps shall not be used for inaccessible joints buried or enclosed in the building structure. All mechanical clamps and compression type sockets shall securely retain all the wires of the conductors. Any joint in a flexible cable of flexible cord shall be effected by means of a cable coupler.

For flexible cables for small loads less than 1 kW, while it would be desirable to avoid joints, if unavoidable, joints can be made either by splicing by a recognised method or by using a connector and protecting the joint by suitable insulating tape or sleeve or straight joint. For application of flexible cable for loads of 1 kW or more, if joint is unavoidable, crimped joint would be preferred. Spliced joint should not be used for large loads.

There are different standard joints such as epoxy resin based joint, heat shrinkable plastic sleeve joint etc, and each one has its advantage and disadvantage. Selection has to be made on the basis of application, site conditions and availability of skilled licensed workmen.

6.6.4 Every joint in a cable shall be provided with insulation not less effective than that of the cable cores and shall be protected against moisture and mechanical damage. Soldering fluxes which remain acidic or corrosive at the completion of the soldering operation shall not be used.

For joints in paper-insulated metal-sheathed cables, a wiped metal sleeve or joint box, filled with insulating compound, shall be provided.

Where an aluminium conductor and a copper conductor are joined together, precautions shall be taken against corrosion and mechanical damage to the conductors.

6.6.5 *Pull at Joints and Terminals*

Every connection at a cable termination shall be made by means of a terminal, soldering socket, or compression type socket and shall securely contain and anchor all the wires of the conductor, and shall not impose any appreciable mechanical strain on the terminal or socket.

Flexible cords shall be so connected to devices and to fittings that tension will not be transmitted to joints or terminal screws. This shall be accomplished by a knot in the cord, by winding with tape, by a special fitting designed for that purpose, or by other approved means which will prevent a pull on the cord from being directly transmitted to joints or terminal screws.

6.7 Passing Through Walls and Floors

6.7.1 Where conductors pass through walls, one of the following methods shall be employed. Care shall be taken to see that wires pass freely through protective pipe or box and that the wires pass through in a straight line without any twist or cross in wires on either ends of such holes:

a) The conductor shall be carried either in a rigid steel conduit or a rigid non-metallic conduit conforming to accepted standards [8-2(18)].

b) *Conduit colour coding*

The conduits shall be colour coded as per the purpose of wire carried in the same. The colour coding may be in form of bands of colour (4 inch thick, with centre-to-centre distance of 12 inches) or coloured throughout in the colour. The colour scheme shall be as follows:

Conduit Type	*Colour scheme*
Power conduit	Black
Security conduit	Blue
Fire alarm conduit	Red
Low voltage conduit	Brown
UPS conduit	Green

c) *Cable trunking/cable ways*

For the smaller cables, enclosures such as conduit and trunking, may be employed and PVC-insulated, with or without sheath, single-core cables installed following completion of the conduit/trunking system. As these cables are usually installed in relatively large groups, care must be taken to avoid overheating and to provide identification of the different circuits.

d) *Tray and ladder rack*

As tray provides continuous support, unless mounted on edge or in vertical runs (when adequate strapping or clipping is essential), the mechanical strength of supported cable is not as important as with ladder-racking or structural support methods. Consequently, tray is eminently suitable for the smaller unarmoured cabling while racks and structural support, except for short lengths, call for armoured cables as they provide the necessary strength to avoid sagging between

supports. Both tray and ladder racks can be provided with accessories to facilitate changes of route, and as PVC and similar insulating materials are non-migratory (unlike the older types of impregnated cables) they provide no difficulty in this respect on vertical runs.

e) Insulated conductors while passing through floors shall be protected from mechanical injury by means of rigid steel conduit, non-metal conduit or mechanical protection to a height not less than 1.5 m above the floors and flush with the ceiling below. This steel conduit shall be earthed and securely bushed.

Power outlets and wiring in the floor shall be generally avoided. If not avoidable, use false floor or floor trunking. False floor shall be provided where density of equipment and interconnection between different pieces of equipment is high. Examples are: Mainframe Computer station, Telecommunication switch rooms, etc.

Floor trunking shall be used in large halls, convention centres, open plan offices, laboratory, etc.

In case of floor trunking drain points shall be provided, as there could be possibility of water seepage in the case of wiring passing through the floors. Proper care should be taken for suitable means of draining of water. Possibility of water entry exists from: (1) floor washing, (2) condensation in some particular weather and indoor temperature conditions. At the design stage, these aspects have to be assessed and an appropriate means of avoiding, or reducing, and draining method will have to be built in.

Floor outlet boxes are generally provided for the use of appliances, which require a signal, or communication connection. The floor box and trunking system should cater to serve both power distribution and the signal distribution, with appropriate safety and non-interference.

6.7.2 Where a wall tube passes outside a building so as to be exposed to weather, the outer end shall be bell-mouthed and turned downwards and properly bushed on the open end.

6.8 Wiring of Distribution Boards

6.8.1 All connections between pieces of apparatus or between apparatus and terminals on a board shall be neatly arranged in a definite sequence, following the arrangements of the apparatus mounted thereon, avoiding unnecessary crossings.

6.8.2 Cables shall be connected to a terminal only by soldered or welded or crimped lugs using suitable sleeve, lugs or ferrules unless the terminal is of such a form that it is possible to securely clamp them without the cutting away of cables stands. Cables in each circuit shall be bunched together.

6.8.3 All bare conductors shall be rigidly fixed in such a manner that a clearance of at least 25 mm is maintained between conductors or opposite polarity or phase and between the conductors and any material other than insulation material.

6.8.4 If required, a pilot lamp shall be fixed and connected through an independent single pole switch and fuse to the bus-bars of the board.

6.8.5 In a hinged type board, the incoming and outgoing cables shall be fixed at one or more points according to the number of cables on the back of the board leaving suitable space in between cables, and shall also, if possible, be fixed at the corresponding points on the switchboard panel. The cables between these points shall be of such length as to allow the switchboard panel to swing through on angle of not less than 90°. The circuit breakers in such cases shall be accessible without opening the door of distribution board. Also, circuit breakers or any other equipment (having cable size more than 1.5 sq. mm multistrand wire) shall not be mounted on the door.

NOTE — Use of hinged type boards is discouraged, as these boards lead to deterioration of the cables in the hinged portion, leading to failures or even fire.

6.8.6 Wires terminating and originating from the protective devices shall be properly lugged and taped.

6.9 PVC-Sheathed Wiring System

6.9.1 *General*

Wiring with Tough Rubber-Sheathed (TRS) cables had been the common system for low voltage installations. Now TRS wiring is phased out as better and durable insulating materials are available.

Wiring with PVC-sheathed cables is suitable for medium voltage installation and may be installed directly under exposed conditions of sun and rain or damp places.

6.9.2 *PVC Clamps/PVC Channel*

Link clips had been the common system for wiring on wooden batten, which is now phased out. PVC clamps/ PVC channel shall conform accepted standards. The clamps shall be used for temporary installations of 1-3 sheathed wires only. The clamps shall be fixed on wall at intervals of 100 mm in the case of horizontal runs and 150 mm in the case of vertical runs.

PVC channel shall be used for temporary installations

in case more than 3 wires or wires or unsheathed wires. The channel shall be clamped on wall at intervals not exceeding 300 mm.

6.9.3 *Protection of PVC-Sheathed Wiring from Mechanical Damage*

a) In cases where there are chances of any damage to the wirings, such wirings shall be covered with sheet metal protective covering, the base of which is made flush with the plaster or brickwork, as the case may be, or the wiring shall be drawn through a conduit complying with all requirements of conduit wiring system (*see* **6.10**).

b) Such protective coverings shall in all cases be fitted on all down-drops within 1.5 m from the floor.

6.9.4 *Bends in Wiring*

The wiring shall not in any circumstances be bent so as to form a right angle but shall be rounded off at the corners to a radius not less than six times the overall diameter of the cable.

6.9.5 *Passing Through Floors*

All cables taken through floors shall be enclosed in an insulated heavy gauge steel conduit extending 1.5 m above the floor and flush with the ceiling below, or by means of any other approved type of metallic covering. The ends of all conduits or pipes shall be neatly bushed with porcelain, wood or other approved material.

6.9.6 *Passing Through Walls*

The method to be adopted shall be according to good practice. There shall be one or more conduits of adequate size to carry the conductors [*see* **6.10.1**(a)]. The conduits shall be neatly arranged so that the cables enter them straight without bending.

6.9.7 *Stripping of Outer Covering*

While cutting and stripping of the outer covering of the cables, care shall be taken that the sharp edge of the cutting instrument does not touch the rubber or PVC-sheathed insulation of conductors. The protective outer covering of the cables shall be stripped off near connecting terminals, and this protective covering shall be maintained up to the close proximity of connecting terminals as far as practicable. Care shall be taken to avoid hammering on link clips with any metal instruments, after the cables are laid. Where junction boxes are provided, they shall be made moisture-proof with an approved plastic compound.

6.9.8 *Painting*

If so required, the tough rubber-sheathed wiring shall, after erection, be painted with one coat of oil-less paint or distemper of suitable colour over a coat of oil-less primer, and the PVC-sheathed wiring shall be painted with a synthetic enamel paint of quick drying type.

6.10 Conduit Wiring System

6.10.1 *Surface Conduit Wiring System with Rigid Steel Conduits*

a) *Type and size of conduit* — All conduit pipes shall conform to accepted standards [8-2(19)], finished with galvanized or stove enamelled surface. All conduit accessories shall be of threaded type and under no circumstance pin grip type or clamp type accessories be used. No steel conduit less than 16 mm in diameter shall be used. The number of insulated conductors that can be drawn into rigid conduit are given in Tables 1 and 2.

b) *Bunching of cables* — Unless otherwise specified, insulated conductors of ac supply and dc supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase egregation in separate conduits is recommended.

c) *Conduit joints* — Conduit pipes shall be joined by means of screwed couplers and screwed accessories only [*see* 8-2(19)]. In long distance straight runs of conduit, inspection type couplers at reasonable intervals shall be provided or running threads with couplers and jam-nuts (in the latter case the bare threaded portion shall be treated with anti-corrosive preservative) shall be provided. Threaded on conduit pipes in all cases shall be between 11 mm to 27 mm long sufficient to accommodate pipes to full threaded portion of couplers or accessories. Cut ends of conduit pipes shall have no sharp edges nor any burrs left to avoid damage to the insulation of conductors while pulling them through such pipes.

d) *Protection against dampness* — In order to minimize condensation or sweating inside the tube, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects as far as possible.

e) *Protection of conduit against rust* — The outer surface of the conduit pipes, including all bends, unions, tees, conduit system shall be adequately protected against rust particularly when such system is exposed to weather. In all cases, no bare threaded portion of conduit pipe shall be allowed unless such bare threaded portion is treated with anti-corrosive

Table 1 Maximum Permissible Number of Single-Core Cables up to and Including 1 100 V that can be Drawn into Rigid Steel and Rigid Non-Metallic Conduits

(*Clauses* 6.10.1 *and* 6.10.3.2)

Size of Cable		Size of Conduit (mm)													
Nominal Cross Sectional Area mm^2	Number and Diameter (in mm) of Wires	16		20		25		32		40		50		60	
		(Number of Cables, *Max*)													
		S	B	S	B	S	B	S	B	S	B	S	B	S	B
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1.0	1/1.12[1)]	5	4	7	5	13	10	20	14	—	—	—	—	—	—
1.5	1/1.40	4	3	7	5	12	10	20	14	—	—	—	—	—	—
2.5	1/1.80 3/1.06[1)]	3	2	0	5	10	8	18	12	—	—	—	—	—	—
4	1/2.24 7/0.85[1)]	3	2	4	3	7	8	12	10	—	—	—	—	—	—
6	1/2.80 7/1.06[1]	2	—	3	2	6	5	10	8	—	—	—	—	—	—
10	7/1.40[1)]	—	—	2	—	4	3	6	5	8	6	—	—	—	—
16	7/1.70	—	—	—	—	2	—	4	3	7	6	—	—	—	—
25	7/2.24	—	—	—	—	—	—	3	2	5	4	8	6	9	7
35	7/2.50	—	—	—	—	—	—	2	—	4	3	7	5	8	6
50	19/1.80														

NOTES

1 The table shows the maximum capacity of conduits for the simultaneously drawing of cables. The columns headed S apply to runs of conduit which have distance not exceeding 4.25 m between draw-in boxes, and which do not deflect from the straight by an angle of more than 15°. The columns headed B apply to runs of conduit which deflect from the straight by an angle of more than 15°.

2 In case an inspection type draw-in box has been provided and if the cable if first drawn through one straight conduit, then through the draw-in box, and then through the second straight conduit, such systems may be considered as that of a straight conduit even if the conduit deflects through the straight by more than 15°.

[1)] For copper conductors only.

Table 2 Maximum Permissible Number of Single-Core Cables that can be Drawn into Cable Tunelling and Ducting System (Casing and Capping)

(*Clauses* 6.10.1 *and* 6.10.3.2)

Nominal Cross-Sectional Area of Conductor in mm^2	10/15 mm × 10 mm	20 mm × 10 mm	25 mm × 10 mm	30 mm × 10 mm	40 mm × 20 mm	50 mm × 20 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1.5	3	5	6	8	12	18
2.5	2	4	5	6	9	15
4	2	3	4	5	8	12
6	—	2	3	4	6	9
10	—	1	2	3	5	8
16	—	—	1	2	4	6
25	—	—	—	1	3	5
35	—	—	—	—	2	4
50	—	—	—	—	1	3
70	—	—	—	—	1	2

preservative or covered with suitable plastic compound.

f) *Fixing of conduit* — Conduit pipes shall be fixed by heavy gauge saddles, secured to suitable wood plugs or other plugs with screws in an approved manner at an interval of not more than 1 m, but on either side of couplers or bends or similar fittings, saddles shall be fixed at a distance of 300 cm from the centre of such fittings.

g) *Bends in conduit* — All necessary bends in the system including diversion shall be done

by bending pipes; or by inserting suitable solid or inspection type normal bends, elbows or similar fittings; or fixing cast iron, *thermoplastic* or *thermosetting plastic material* inspection boxes whichever is more suitable. Conduit fittings shall be avoided as far as possible on conduit system exposed to weather; where necessary, solid type fittings shall be used. Radius of such bends in conduit pipes shall be not less than 7.5 cm. No length of conduit shall have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

h) *Outlets* — All outlets for fittings, switches, etc, shall be boxes of suitable metal or any other approved outlet boxes for either surface mounting system.

j) *Conductors* — All conductors used in conduit wiring shall preferably be stranded. No single-core cable of nominal cross-sectional area greater than 130 mm^2 enclosed along in a conduit and used for alternating current.

k) *Erection and earthing of conduit* — The conduit of each circuit or section shall be completed before conductors are drawn in. The entire system of conduit after erection shall be tested for mechanical and electrical continuity throughout and permanently connected to earth conforming to the requirements as already specified by means of suitable earthing clamp efficiently fastened to conduit pipe in a workman like manner for a perfect continuity between each wire and conduit. Gas or water pipes shall not be used as earth medium. If conduit pipes are liable to mechanical damage they shall be adequately protected.

m) Inspection type conduit fittings, such as inspection boxes, draw boxes, bends, elbows and tees shall be so installed that they can remain accessible for such purposes as to withdrawal of existing cables or the installing of traditional cables.

6.10.2 *Recessed Conduit Wiring System with Rigid Steel Conduit*

Recessed conduit wiring system shall comply with all the requirements for surface conduit wiring system specified in **6.10.1** (a) to (k) and in addition, conform to the requirements specified below:

a) *Making of chase* — The chase in the wall shall be nearly made and be of ample dimensions to permit the conduit to be fixed in the manner desired. In the case of buildings under construction, chases shall be provided in the wall, ceiling, etc, at the time of their construction and shall be filled up neatly after erection of conduit and brought to the original finish of the wall. In case of exposed brick/ rubble masonry work, special care shall be taken to fix the conduit and accessories in position along with the building work.

b) *Fixing of conduit in chase* — The conduit pipe shall be fixed by means of staples or by means of saddles not more than 600 mm apart. Fixing of standard bends or elbows shall be avoided as far as practicable and all curves maintained by bending the conduit pipe itself with a long radius which will permit easy drawing-in of conductors. All threaded joints of rigid steel conduit shall be treated with preservative compound to secure protection against rust.

c) *Inspection boxes* — Suitable inspection boxes shall be provided to permit periodical inspection and to facilitate removal of wires, if necessary. These shall be mounted flush with the wall. Suitable ventilating holes shall be provided in the inspection box covers. The minimum sizes of inspection boxes shall be 75 mm × 75 mm.

d) *Types of accessories to be used* — All outlet, such as switches and wall sockets, may be either of flush mounting type or of surface mounting type.

1) *Flush mounting type* — All flush mounting outlets shall be of cast-iron or mild steel boxes with a cover of insulating material or shall be a box made of a suitable insulating material. The switches and other outlets shall be mounted on such boxes. The metal box shall be efficiently earthed with conduit by a suitable means of earth attachment.

2) The switches/socket outlets shall be adequately rated IP for various utilizations.

3) *Surface mounting type* — If surface mounting type otulet box is specified, it shall be of any suitable insulating material and outlets mounted in an approved manner.

6.10.3 *Conduit Wiring System with Rigid Non-Metallic Conduits*

Rigid non-metallic conduits are used for surface, recessed and concealed conduit wiring. Cable trunking and ducting system of insulating material are used for surface wiring.

6.10.3.1 *Type and size*

All non-metallic conduits used shall conform to accepted standards [8-2(19)]. The conduit may be either threaded type or plain type in accordance with accepted standards [8-2(19)] and shall be used with the corresponding accessories [*see* accepted standards [8-2(19)]]. The conduits shall be circular or rectangular cross-sections.

6.10.3.2 *Bunching of cables*

Conductors of ac supply and dc supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase segregation in separate circuits is recommended. The number of insulated cables that may be drawn into the conduits are given in Table 1 and Table 2. In these tables the space factor does not exceed 40 percent.

6.10.3.3 *Conduit joints*

Conduits shall be joined by means of screwed or plain couplers depending on whether the conduits are screwed or plain. Where there are long runs of straight conduit, inspection type couplers shall be provided at intervals. For conduit fittings and accessories reference may be made to the good practice [8-2(19)].

6.10.3.4 *Fixing of conduits*

The provisions of **6.10.1**(f) shall apply except that the spacing between saddles or supports is recommended to be 600 cm for rigid non-metallic conduits.

6.10.3.5 *Bends in conduits*

Wherever necessary, bends or diversions may be achieved by bending the conduits (*see* **6.10.3.8**) or by employing normal bends, inspection bends, inspection boxes, elbows or similar fittings.

6.10.3.6 Conduit fittings shall be avoided, as far as possible, on outdoor systems.

6.10.3.7 *Outlets*

In order to minimize condensation or sweating inside the conduit, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects.

6.10.3.8 Heat may be used to soften the conduit for bending and forming joints in case of plain conduits. As the material softens when heated, sitting of conduit in close proximity to hot surfaces should be avoided. Caution should be exercised in the use of this conduit in locations where the ambient temperature is 50°C or above. Use of such conduits in places where ambient temperature is 60°C or above is prohibited.

6.10.3.9 Non-metallic conduit systems shall be used only where it is ensured that they are:

a) suitable for the extremes of ambient temperature to which they are likely to be subjected in service,
b) resistant to moisture and chemical atmospheres, and
c) resistant to low temperature and sunlight effects.

For use underground, the material shall be resistant to moisture and corrosive agents.

NOTE — Rigid PVC conduits are not suitable for use where the normal working temperature of the conduits and fittings may exceed 55°C. Certain types of rigid PVC conduits and their associated fittings are unsuitable for use where the ambient temperature is likely to fall below –5°C.

6.10.4 *Non-Metallic Recessed Conduit Wiring System*

6.10.4.1 Recessed non-metallic conduit wiring system shall comply with all the requirements of surface non-metallic conduit wiring system specified in **6.10.3.1** to **6.10.3.9** except **6.10.3.4**. In addition, the following requirements **6.10.4.2** to **6.10.4.5** also shall be complied with.

6.10.4.2 *Fixing of conduit in chase*

The conduit pipe shall be fixed by means of stapples or by means of non-metallic saddles placed at not more than 80 cm apart or by any other approved means of fixing. Fixing of standard bends or elbows shall be avoided as far as practicable and all curves shall be maintained by sending the conduit pipe itself with a long radius which will permit easy drawing in of conductors. At either side of bends, saddles/stapples shall be fixed at a distance of 15 cm from the centre of bends.

6.10.4.3 *Inspection boxes*

Suitable inspection boxes to the nearest minimum requirements shall be provided to permit periodical inspection and to facilitate replacement of wires, if necessary. The inspection/junction boxes shall be mounted flush with the wall or ceiling concrete. Where necessary deeper boxes of suitable dimensions shall be used. Suitable ventilating holes shall be provided in the inspection box covers, where required.

6.10.4.4 The outlet boxes such as switch boxes, regulator boxes and their phenolic laminated sheet covers shall be as per requirements of **6.10.1**(h).

They shall be mounted flush with the wall.

6.10.4.5 *Types of accessories to be used*

All outlets such as switches, wall sockets, etc, may be either flush mounting type or of surface mounting type.

7 FITTINGS AND ACCESSORIES

7.1 Ceiling Roses and Similar Attachments

7.1.1 A ceiling rose or any other similar attachment shall not be used on a circuit the voltage of which normally exceeds 250 V.

7.1.2 Normally, only one flexible cord shall be attached to a ceiling rose. Specially designed ceiling roses shall be used for multiple pendants.

7.1.3 A ceiling rose shall not embody fuse terminal as an integral part of it.

7.2 Socket-Outlets and Plugs

Each 16 A socket-outlet provided in buildings for the use of domestic appliances such as air conditioner, water cooler, etc, shall be provided with its own individual fuse, with suitable discrimination with back-up fuse or miniature circuit-breaker provided in the distribution/sub-distribution board. The socket-outlet shall not necessarily embody the fuse as an integral part of it.

7.2.1 Each socket-outlet shall also be controlled by a switch which shall preferably be located immediately adjacent thereto or combined therewith.

7.2.2 The switch controlling the socket-outlet shall be on the live side of the line.

7.2.3 Ordinary socket-outlet may be fixed at any convenient place at a height above 20 cm from the floor level and shall be away from danger of mechanical injury.

NOTE — In situations where a socket-outlet is accessible to children, it is necessary to install an interlocked plug and socket or alternatively a socket-outlet which automatically gets screened by the withdrawal of plug. In industrial premises socket-outlet of rating 20 A and above shall preferably be provided with interlocked type switch.

7.2.4 In an earthed system of supply, a socket-outlet with plug shall be of three-pin type with the third terminal connected to the earth. When such socket-outlets with plugs are connected to any current consuming device of metal or any non-insulating material or both, conductors connecting such current-consuming devices shall be of flexible cord with an earthing core and the earthing core shall be secured by connecting between the earth terminal of plug and the body of current-consuming devices.

In industrial premises three-phase and neutral socket-outlets shall be provided with a earth terminal either of pin type or scrapping type in addition to the main pins required for the purpose.

7.2.5 In wiring installations, metal clad switch, socket-outlet and plugs shall be used for power wiring.

NOTE — A recommended schedule of socket-outlets in a residential building is given below:

Location	*Number of 5A Socket-Outlets*	*Number of 15A Socket-Outlets*
Bed room	2 to 3	1
Living room	2 to 3	2
Kitchen	1	2
Dining room	2	1
Garage	1	1
For refrigerator	—	1
For air conditioner	—	(one for each)
VERANDAH	1 per 10 m^2	1
Bathroom	1	1

7.3 Lighting Fittings

7.3.1 A switch shall be provided for control of every lighting fitting or a group of lighting fittings. Where control at more than one point is necessary as many two way or intermediate switches may be provided as there are control points.

7.3.2 In industrial premises lighting fittings shall be supported by suitable pipe/conduits, brackets fabricated from structural steel, steel chains or similar materials depending upon the type and weight of the fittings. Where a lighting fitting is supported by one or more flexible cords, the maximum weight to which the twin flexible cords may be subjected shall be as follows:

Nominal Cross-Sectional Area of Twin Cord mm^2	*Maximum Permissible Weight* kg
0.5	2
0.75	3
1.0	5
1.5	5.3
2.5	8.8
4	14.0

7.3.3 No flammable shade shall form a part of lighting fittings unless such shade is well protected against all risks of fire. Celluloid shade or lighting fittings shall not be used under any circumstances.

7.3.4 General and safety requirements for electrical lighting fittings shall be in accordance with good practice [8-2(20)].

7.3.5 The lighting fittings shall conform to accepted standards [8-2(10)].

7.4 Fitting-Wire

The use of fittings-wire shall be restricted to the internal wiring of the lighting fittings. Where fittings-wire is used for wiring fittings, the sub-circuit loads shall terminate in a ceiling rose or box with connectors from which they shall be carried into the fittings.

7.5 Lampholders

Lampholders for use on brackets and the like shall be in accordance with accepted standards [8-2(21)] and all those for use with flexible pendants shall be provided with cord grips. All lampholders shall be provided with shade carriers. Where centre-contact Edison screw lampholders are used, the outer or screw contacts shall be connected to the 'middle wire', the neutral, the earthed conductor of the circuit.

7.6 Outdoor Lamps

External and road lamps shall have weatherproof fittings of approved design so as to effectively prevent the ingress of moisture and dust. Flexible cord and cord grip lampholders shall not be used where exposed to weather. In *VERANDAHS* and similar exposed situations where pendants are used, these shall be of fixed rod type.

7.7 Lamps

All lamps unless otherwise required and suitably protected, shall be hung at a height of not less than 2.5 m above the floor level. All electric lamps and accessories shall conform to accepted standards [8-2(22)].

a) Portable lamps shall be wired with flexible cord. Hand lamps shall be equipped with a handle of moulded composition or other material approved for the purpose. Hand lamps shall be equipped with a substantial guard attached to the lampholder or handle. Metallic guards shall be earthed suitably.

b) A bushing or the equivalent shall be provided where flexible cord enters the base or stem of portable lamp. The bushing shall be of insulating material unless a jacketted type of cord is used.

c) All wiring shall be free from short-circuits and shall be tested for these defects prior to being connected to the circuit.

d) Exposed live parts within porcelain fixtures shall be suitably recessed and so located as to make it improbable that wires will come in contact with them. There shall be a spacing of at least 125 mm between live parts and the mounting plane of the fixture.

7.8 Fans, Regulators and Clamps

7.8.1 *Ceiling Fans*

Ceiling fans including their suspension shall conform to accepted standards [8-2(23)] and to the following requirements:

a) Control of a ceiling fan shall be through its own regulator as well as a switch in series.

b) All ceiling fans shall be wired with normal wiring to ceiling roses or to special connector boxes to which fan rod wires shall be connected and suspended from hooks or shackels with insulators between hooks and suspension rods. There shall be no joint in the suspension rod, but if joints are unavoidable then such joints shall be screwed to special couplers of 5 cm minimum length and both ends of the pipes shall touch together within the couplers, and shall in addition be secured by means of split pins; alternatively, the two pipes may be welded. The suspension rod shall be of adequate strength to withstand the dead and impact forces imposed on it. Suspension rods should preferably be procured along with the fan.

c) Fan clamps shall be of suitable design according to the nature of construction of ceiling on which these clamps are to be fitted. In all cases fan clamps shall be fabricated from new metal of suitable sizes and they shall be as close fitting as possible. Fan clamps for reinforced concrete roofs shall be buried with the casting and due care shall be taken that they shall serve the purpose. Fan clamps for wooden beams, shall be of suitable flat iron fixed on two sides of the beam and according to the size and section of the beam one or two mild steel bolts passing through the beam shall hold both flat irons together. Fan clamps for steel joist shall be fabricated from flat iron to fit rigidly to the bottom flange of the beam. Care shall be taken during fabrication that the metal does not crack while hammer to shape. Other fan clamps shall be made to suit the position, but in all cases care shall be taken to see that they are rigid and safe.

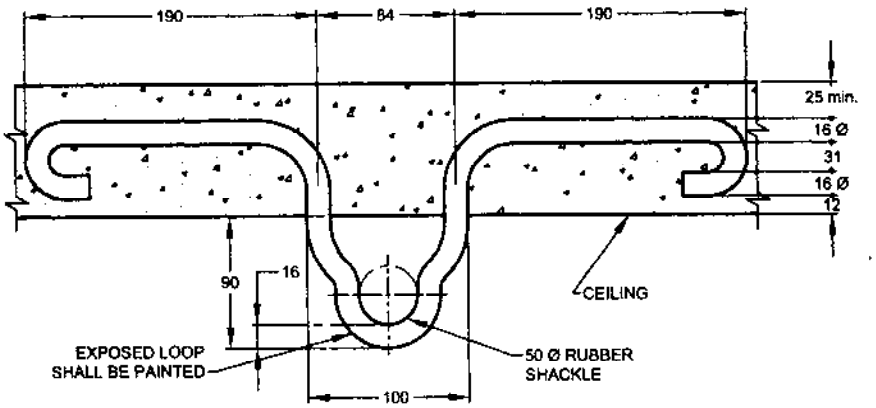
d) Canopies on top and bottom of suspension rods shall effectively conceal suspensions and connections to fan motors, respectively.

e) The lead-in-wire shall be of nominal cross-sectional area not less than 1.5 mm^2 copper and shall be protected from abrasion.

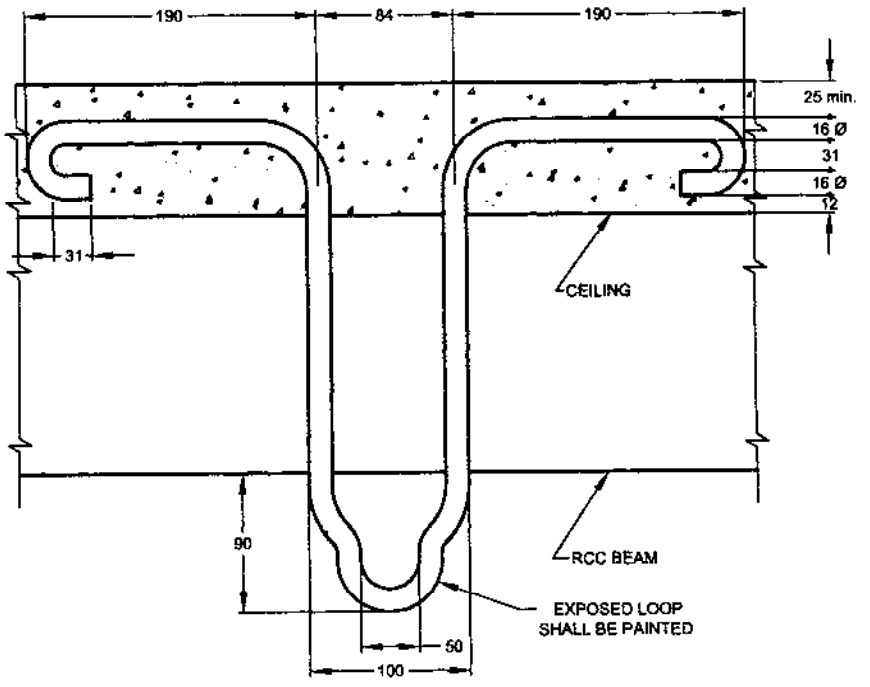
f) Unless otherwise specified, the clearance between the bottom most point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades shall be not less than 300 mm.

A Typical arrangement of a fan clamp is given in Fig. 2.

NOTE — All fan clamps shall be so fabricated that fans revolve steadily.



2A SLAB



2B SLAB WITH BEAM

All dimensions in millimetres.

NOTES

1 RCC slab steel reinforcement not shown.

2 Fan clamp shall be placed in position such that its projecting arms in the line of length of beam.

FIG. 2 TYPICAL DESIGN OF FAN CLAMPS

7.8.2 *Exhaust Fans*

For fixing of an exhaust fan, a circular hole shall be provided in the wall to suit the size of the frame which shall be fixed by means of rag-bolts embedded in the wall. The hole shall be neartly plastered with cement and brought to the original finish of the wall. The exhaust fan shall be connected to exhaust fan point which shall be wired as near to the hole as possible by means of a flexible cord, care being taken that the blades rotate in the proper direction.

7.9 Attachment of Fittings and Accessories

7.9.1 In wiring other than conduit wiring, all ceiling roses, brackets, pendants and accessories attached to walls or ceilings shall be mounted on substantial teak wood blocks twice varnished after all fixing holes are made in them. Blocks shall not be less than 4 cm deep. Brass screws shall only be used for attaching fittings and accessories to their base blocks.

7.9.2 Where teak or hardwood boards are used for mounting switches, regulators, etc, these boards shall

be well varnished with pure shellac on all four sides (both inside and outside), irrespective of being painted to match the surroundings. The size of such boards shall depend on the number of accessories that could conveniently and neatly be arranged. Where there is danger of attack by white ants, the boards shall be treated with suitable anti-termite compound and painted on both sides.

7.10 Interchangeability

Similar part of all switches, lampholders, distribution fuse-boards, ceiling roses, brackets, pendants, fans and all other fittings shall be so chosen that they are of the same type and interchangeable in each installation.

7.11 Equipment

Electrical equipment which form integral part of wiring intended for switching or control or protection of wiring installations shall conform to the relevant Indian Standards wherever they exist.

7.12 Fannage

7.12.1 Where ceiling fans are provided, the bay sizes of a building, which control fan point locations, play an important part.

7.12.2 Fans normally cover an area of 9 m^2 to 10 m^2 and therefore in general purpose office buildings, for every part of a bay to be served by the ceiling fans, it is necessary that the bays shall be so designed that full number of fans could be suitably located for the bay, otherwise it will result in ill-ventilated pockets. In general, fans in long halls may be spaced at 3 m in both the directions. If building modules do not lend themselves for proper positioning of the required number of ceiling fans, such as air circulators or bracket fans would have to be employed for the areas uncovered by the ceiling fans. For this, suitable electrical outlets shall be provided although result will be disproportionate to cost on account of fans.

7.12.3 Proper air circulation could be achieved either by larger number of smaller fans or smaller number of larger fans. The economics of the system as a whole should be a guiding factor in choosing the number and type of fans and their locations.

7.12.4 Exhaust fans are necessary for spaces, such as community toilets, kitchens and canteens, and godowns to provide the required number of air changes (*see* Part 8 'Building Services, Section 1 Lighting and Ventilation'). Since the exhaust fans are located generally on the outer walls of a room appropriate openings in such walls shall be provided for in the planning stage.

NOTE — Exhaust fan requirement is based on the recommended air changes. Reference may also be made to Part 4 'Fire and Life Safety'. Exhaust fan requirement comes for catering to smoke extraction also. Basement areas depend on the system of fresh air fans and exhaust fans.

7.12.5 Positioning of fans and light fittings shall be chosen to make these effective without causing shadows and stroboscopic effect on the working planes.

8 EARTHING

8.1 General

Earthing shall generally be carried out in accordance with the requirements of *Indian Electricity Rules*, 1956 as amended time to time and the relevant regulations of the Electricity Supply Authority concerned.

The main earthing system of an electrical installation must consist of:

a) An earth electrode;
b) A main earthing wire;
c) An earth bar (located on the main switchboard) for the connection of the main earthing wire, protective earthing wires and/or bonding wires within the installation; and
d) A removable link, which effectively disconnects the neutral bar from the earth bar.

NOTE — The requirements of (c) and (d) above must be carried out by the licensed electrician as part of the switchboard installation.

The main earthing wire termination must be readily accessible at the earth electrode.

The main earthing wire connection must:

a) be mechanically and electrically sound;
b) be protected against damage, corrosion, and vibration;
c) not place any strain on the various parts of the connection;
d) not damage the wire or fittings; and
e) be secured at the earth electrode

Use a permanent fitting (like a screwed-down plastic label or copper label, or one that can be threaded onto the cable) at the connection point that is clearly marked with the words: "EARTHING LEAD — DO NOT DISCONNECT" or "EARTHING CONDUCTOR — DO NOT DISCONNECT".

8.1.1 All medium voltage equipment shall be earthed by two separate and distinct connections with earth. The contact area of earth conductor/plate shall be determined using guidelines specified in IS 3043.

Medium voltage systems of 400/230 V, 4-wire, 3-phase, systems are normally operated with the neutral solidly earthed at source. At medium voltage, Indian Electricity Regulations require that the neutral be

400 V) would be the neutral(s) of the transformer(s). Neutral conductor of half the size of the phase conductor was permitted in earlier installations. But with the proliferation of equipment using non-linear devices and consequent increase in harmonics, the neutral will carry a current more than the notional out-of-balance current and as such neutral conductor shall be of the same size as the phase conductor.

In the case of high and extra high voltages, the neutral points shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station or substation and may be earthed at any other point provided no interference is caused by such earthing. The neutral may be earthed through suitable impedance. Neutral earthing conductor shall be sized at to have a current carrying capacity not less than the phase current.

8.1.2 As far as possible, all earth connections shall be visible for inspection.

8.1.3 Earth earth system shall be so devised that the testing of individual earth electrode is possible. It is recommended that the value of any earth system resistance shall be such as to conform with the degree of shock protection desired.

8.1.4 It is recommended that a drawing showing the main earth connection and earth electrodes be prepared for each installation.

8.1.5 No addition to the current-carrying system, either temporary or permanent, shall be made which will increase the maximum available earth fault current or its duration until it has been ascertained that the existing arrangement of earth electrodes, earth busbar, etc, are capable of carrying the new value of earth fault current which may be obtained by this addition.

8.1.6 No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and the live conductors, shall be inserted on any supply system. This, however, does not include the case of a switch for use in controlling a generator or a transformer or a link for test purposes.

8.1.7 All materials, fittings, etc, used in earthing shall conform to Indian Standard specifications, wherever these exist.

8.1.8 Earthing associated with current-carrying conductor is normally essential for the security of the system and is generally known as system earthing, while earthing of non-current carrying metal work and conductor is essential for the safety of human life, of

8.2 Earth Electrodes

Earth electrode either in the form of pipe electrode or plate electrode should be provided at all premises for providing an earth system. Details of typical pipe and plate earth electrodes are given in Fig. 3 and Fig. 4.

Although electrode material does not affect initial earth resistance, care should be taken to select a material which is resistant to corrosion in the type of soil in which it is used. Under ordinary conditions of soil, use of copper, iron or mild steel electrodes is recommended. In case where soil condition leads to excessive corrosion of the electrode, and the connections, it is recommended to use either copper electrode or copper clad electrode or zinc coastal galvanized iron electrode. The electrode shall be kept free from paint, enamel and grease. It is recommended to use similar material for earth electrodes and earth conductors or otherwise precautions should be taken to avoid corrosion.

8.3 As far as possible, all earth connections shall be visible for inspection and shall be carefully made; if they are poorly made or inadequate for the purpose for which they are intended, loss of life and property or serious personal injury may result.

To obtain low overall resistance the current density should be as low as possible in the medium adjacent to the electrodes; which should be so designed as to cause the current density to decrease rapidly with distance from the electrode. This requirement is met by making the dimensions in one direction large compared with those in the other two, thus a pipe, rod or strip has a much lower resistance than a plate of equal surface area. The resistance is not, however, inversely proportional to the surface area of the electrode.

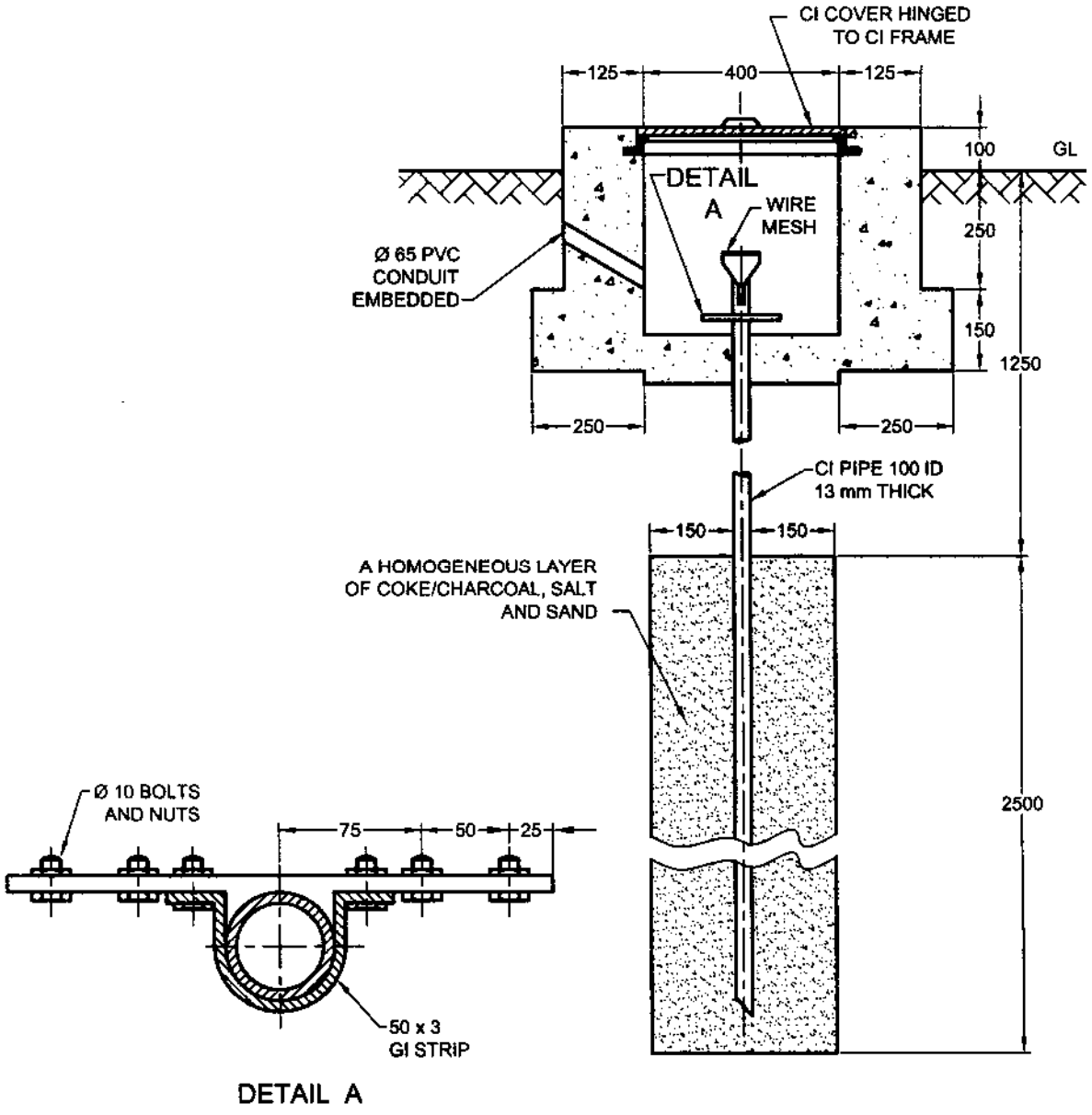
8.4 Equipment and Portions of Installations which shall be Earthed

8.4.1 *Equipment to be Earthed*

Except for equipment provided with double insulation, all the non-current carrying metal parts of electrical installations are to be earthed properly. All metal conduits, trunking, cable sheaths, switchgear, distribution fuseboards, lighting fittings and all other parts made of metal shall be bended together and connected by means of two separate and distinct conductors to an efficient earth electrode.

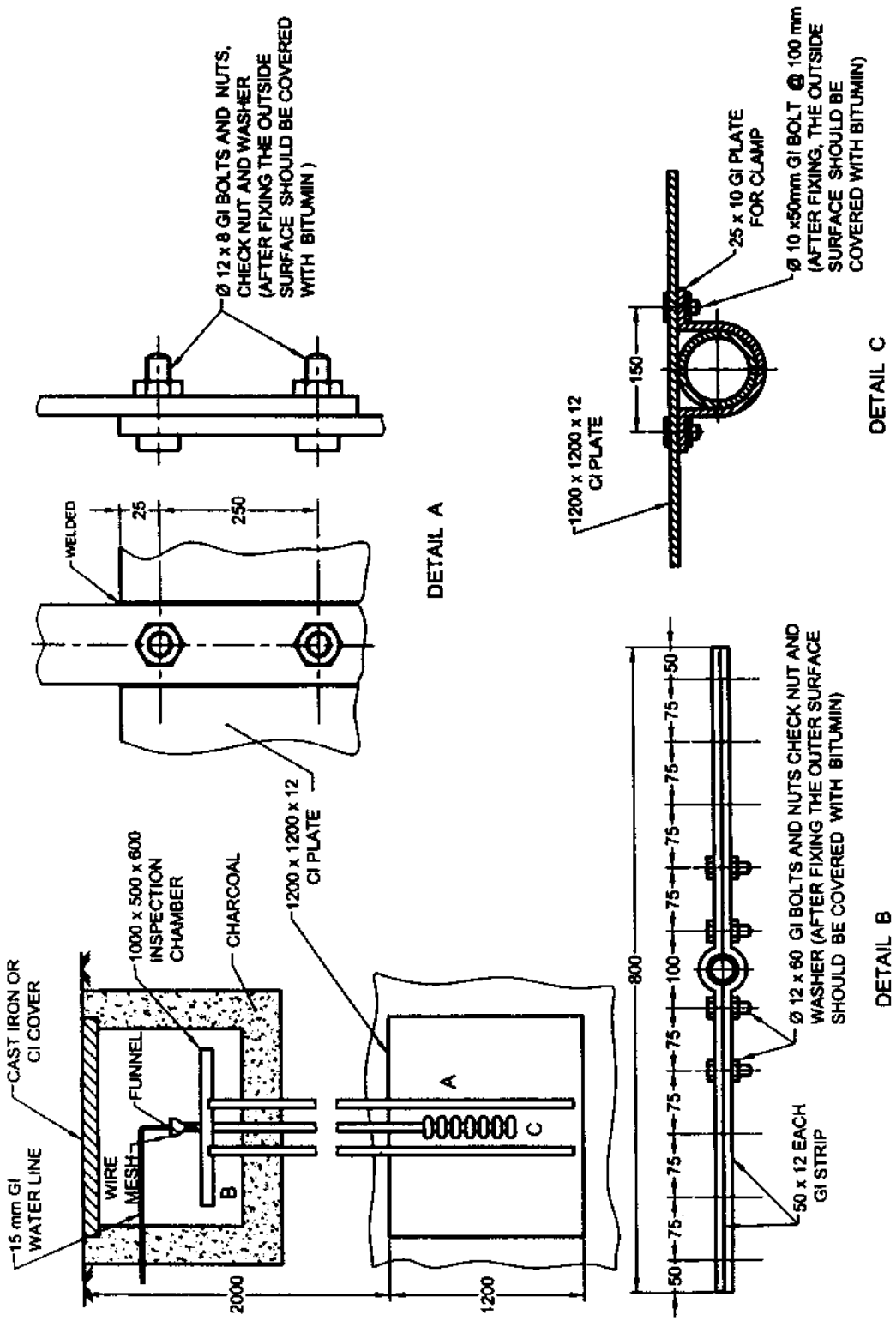
8.4.2 *Structural Metal Work*

Earthing of the metallic parts shall not be effected through any structural metal work which houses the



All dimensions in millimetres.

FIG. 3 TYPICAL ARRANGEMENT OF PIPE EARTHING



All dimensions in millimetres.

FIG. 4 TYPICAL ARRANGEMENT OF PLATE EARTHING

installation. Where metallic parts of the installation are not required to be earthed and are liable to become alive should the insulations of conductors become defective, such metallic parts shall be separated by durable non-conducting material from any structural work.

8.5 Neutral Earthing

To comply with Rule 32(1) of *Indian Electricity Rules* 1956, no fuses or circuit breakers other than a linked circuit breaker shall inserted in an earthed neutral conductor, a linked switch or linked circuit breaker shall be arranged to break or the neutral either with or after breaking all the related phase conductors and. shall positively make (or close) the neutral before making (or closing) the phases.

If this neutral point of the supply system is connected permanently to earth, then the above rule applies throughout the installation including 2-wire final circuits. This means that no fuses may be inserted in the neutral or common return wire. And the neutral should consist of a bolted solid link, or part of a linked switch, which completely disconnects the whole system from the supply. This linked switch must be arranged so that the neutral makes before, and break after the phases.

8.6 System of Earthing

Equipment and portions of installations shall be deemed to be earthed only if earthed in accordance with either the direct earthing system, the multiple earthed neutral system or the earth leakage circuit-breaker system. In all cases, the relevant provisions of Rules 33 and 61 of the *Indian Electricity Rules,* 1956 (*see* Annex B) shall be complied with.

The earthing of electrical installations for non-industrial and industrial buildings shall be done in accordance with good practice [8-2(24)].

8.7 Classification of Earthing System

The earthing systems are classified as follows:

a) *TN System* — A system which has one or more points of the source of energy directly earth, and the exposed and extraneous conductive parts of the installation are connected by means of protective conductors to the earth points of the source, that is, currents to flow from the installation to the earth points of the source.

b) *TT System* — A system which has one or more points of the source of energy directly earth, and the exposed and extraneous conductive parts of the installation are connected to a local earth electrodes or electrodes electrically independent of the source earth.

c) *IT System* — A system which has source either unearthed or earthed through a high impedance and the exposed conductive parts of the installations are connected to electrically independent earth electrodes.

9 INSPECTION AND TESTING OF INSTALLATION

9.1 General Requirements

9.1.1 Before the completed installation, or an addition to the existing installation, is put into service, inspection and testing shall be carried out in accordance with the *Indian Electricity Rules,* 1956. In the event of defects being found, these shall be rectified, as soon as practicable and the installation retested.

9.1.2 Periodic inspection and testing shall be carried out in order to maintain the installation in a sound condition after putting into service.

9.1.3 Where an addition is to be made to the fixed wiring of an existing installation, the latter shall be examined for compliance with the recommendations of the Code.

9.1.4 The individual equipment and materials which form part of the installation shall generally conform to the relevant Indian Standard Specification wherever applicable. If there is no relevant Indian Standard Specification for any item, these shall be approved by the appropriate authority.

9.1.5 *Completion Drawings*

On completion of the electric work, a wiring diagram shall be prepared and submitted to the engineer-in-charge or the owner. All wiring diagrams shall indicate clearly, the main switch board, the runs of various mains and submains and the position of all points and their controls. All circuits shall be clearly indicated and numbered in the wiring diagram and all points shall be given the same number as the circuit in which they are electrically connected. Also the location and number of earth points and the run of each loads should be clearly shown in the completion drawings.

9.2 Inspection of the Installation

9.2.1 *General*

On completion of wiring a general inspection shall be carried out by competent personnel in order to verify that the provisions of this Code and that of *Indian Electricity Rules,* 1956, have been complied with. This, among other things, shall include checking whether all equipments, fittings, accessories, wires/cables, used in the installation are of adequate rating and quality to meet the requirement of the load. General workmanship of the electrical wiring with regard to the layout and

finish shall be examined for neatness that would facilitate easy identification of circuits of the system, adequacy of clearances, soundness, contact pressure and contact area. A complete check shall also be made of all the protective devices, with respect to their ratings, range of settings and co-ordination between the various protective devices.

9.2.2 *Item to be Inspected*

9.2.2.1 *Substation installations*

In substation installation, it shall be checked whether:

1) The installation has been carried out in accordance with the approved drawings;
2) Phase-to-phase and phase to earth clearances are provided as required;
3) All equipments are efficiently earthed and properly connected to the required number of earth electrodes;
4) The required ground clearance to live-terminals is provided;
5) Suitable fencing is provided with gate with lockable arrangements;
6) The required number of caution boards fire-fighting equipments, operating rods, rubber mats, etc, are kept in the substation;
7) In case of indoor substation sufficient ventilation and draining arrangements are made;
8) All cable trenches are provided with non-inflammable covers;
9) Free accessibility is provided for all equipments for normal operation;
10) All name plates are fixed and the equipments are fully painted;
11) All construction materials and temporary connections are removed;
12) Oil-level, busbar tightness, transformer tap position, etc, are in order;
13) Earth pipe troughs and cover slabs are provided for earth electrodes/earth pits and the neutral and LA earth pits are marked for easy identification;
14) Earth electrodes are of GI pipes or CI pipes or copper plates. For earth connections, brass bolts and nuts with lead washers are provided in the pipes/plates;
15) Earth pipe troughs and oil sumps/pits are free from rubbish and dirt and stone jelly and the earth connections are visible and easily accessible;
16) HT and LT panels are switchgears are all vermin and damp-proof and all unused openings or holes are blocked properly;
17) The earth bus bars have tight connections and corrosion-free joint surfaces;
18) Operating handle of protective device are provided at an accessible height from ground;
19) Adequate headroom is available in the transformer room for easy topping-up of oil, maintenance, etc;
20) Safety devices, horizontal and vertical barriers, bus bar covers/shrouds, automatic safety shutters/doors interlock, handle interlock are safe and in reliable operation in all panels and cubicles;
21) Clearances in the front, rear and sides of the main HV and MV and sub-switch boards are adequate;
22) The switches operate freely; the 3 blades make contact at the same time, the arcing horns contact in advance; and the handles are provided with locking arrangements;
23) Insulators are free from cracks, and are clean;
24) In transformers, there is any oil leak;
25) Connections to bushing in transformers for tightness and good contact;
26) Bushings are free from cracks and are clean;
27) Accessories of transformers like breathers, vent pipe, Buchholz relay, etc, are in order;
28) Connections to gas relay in transformers are in order;
29) Oil and winding temperature are set for specific requirements in transformers;
30) In case of cable cellars, adequate arrangements to pump out water that has entered due to seepage or other reasons;
31) All incoming and outgoing circuits of HV and MV panels are clearly and indelibly labelled for identifications;
32) No cable is damaged;
33) There is adequate clearance around the equipments installed; and
34) Cable terminations are proper.

9.2.2.2 *Medium voltage installation*

In medium voltage installations, it shall be checked whether:

1) All blocking materials that are used for safe transportation in switchgears, contactors, relays, etc, are removed;
2) All connections to be earthing system are feasible for periodical inspection;
3) Sharp cable bends are avoided and cables are taken in a smooth manner in the trenches or alongside the walls and ceilings using suitable support clamps at regular intervals;

4) Suitable linked switch or circuit breaker or lockable push button is provided near the motors/apparatus for controlling supply to the motor/apparatus in an easily accessible location;
5) Two separate and distinct earth connections are provided for the motor/apparatus;
6) Control switch-fuse is provided at an accessible height from ground for controlling supply to overhead travelling crane, hoists, overhead bus bar trunking;
7) The metal rails on which the crane travels are electrically continuous and earthed and bonding of rails and earthing at both ends are done;
8) Four core cables are used for overhead travelling crane and portable equipments, the fourth core being used for earthing, and separate supply for lighting circuit is taken;
9) If flexible metallic hose is used for wiring to motors and other equipment, the wiring is enclosed to the full lengths, and the hose secured properly by approved means;
10) The cables are not taken through areas where they are likely to be damaged or chemically affected;
11) The screens and armours of the cables are earthed properly;
12) The belts of the belt driven equipments are properly guarded;
13) Adequate precautions are taken to ensure that no live parts are so exposed as to cause danger;
14) Ammeters and voltmeters are tested;
15) The relays are inspected visually by moving covers for deposits of dusts or other foreign matter;
16) Wherever bus ducts/rising mains/overhead bus trucking are used, special care should be taken for earthing the system. All tap off points shall be provided with adequately rated protective device like MCB, MCCB, fuses, ELCB, RCCB, etc;
17) All equipments shall be weather, dust and vermin proof; and
18) Any and all equipments having air insulation as media shall maintain proper distances between phases; phase to neutral; phase to earth and earth to neutral.

9.2.2.3 *Overhead lines*

For overhead lines it shall be checked whether:

1) All conductors and apparatus including live parts thereof are inaccessible;
2) The types and size of supports are suitable for the overhead lines/conductors used and are in accordance with approved drawing and standards;
3) Clearances from ground level to the lowest conductor of overhead lines, sag conditions, etc, are in accordance with the relevant standard;
4) Where overhead lines cross the roads or cross each other or are in proximity with one another, suitable guarding is provided at road crossings and also to protect against possibility of the lines coming in contact with one another;
5) Every guard wire is properly earthed;
6) The type, size and suitability of the guarding arrangement provided is adequate;
7) Stays are provided suitably on the over-head lines as required and are efficiently earthed or provided with suitably stay insulators of suitable voltages;
8) Anti-climbing devices and Danger Board/ Caution Board Notices are provided on all HT supports;
9) Clearances along the route are checked and all obstructions such as trees/branches and shrubs are cleared on the route to the required distance on either side;
10) Clearance between the live conductor and the earthed metal parts are adequate;
11) For the service connections tapped-off from the overhead lines, cut-outs of adequate capacity are provided;
12) All insulators are properly and securely mounted; also they are not damaged.
13) All poles are properly grouted/insulated so as to avoid bending of pole towards tension; and
14) Steel poles, if used shall be properly earthed.

9.2.2.4 *Lighting circuits*

The lighting circuits shall be checked whether:

1) Wooden boxes and panels are avoided in factories for mounting the lighting boards and switch controls, etc;
2) Neutral links are provided in double pole switch-fuses which are used for lighting control, and no protective devices (such as MCB, MCCB, fuses, ELCB, etc) is provided in the neutral;
3) The plug points in the lighting circuit are all of 3-pin type, the third pin being suitably earthed;

4) Tamper-proof interlocked switch socket and plug are used for locations easily accessible;
5) Lighting wiring in factory area is taken enclosed in conduit and conduit properly earthed, or alternatively, armoured cable wiring is used;
6) A separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipments;
7) Proper connectors and junction boxes are used wherever joints are to be made in conductors or cross over of conductors takes place;
8) Cartridge fuse units are fitted with cartridge fuses only;
9) Clear and permanent identification marks are painted in all distribution boards, switchboards, sub-main boards and switches as necessary;
10) The polarity having been checked and all protective devices (such as MCB, MCCB, fuses, ELCB, etc) and single pole switches are connected on the phase conductor only and wiring is correctly connected to socket-outlets;
11) Spare knockouts provided in distribution boards and switch fuses are blocked;
12) The ends of conduits enclosing the wiring leads are provided with ebonite or other suitable bushes;
13) The fittings and fixtures used for outdoor use are all of weather-proof construction, and similarly, fixtures, fittings and switchgears used in the hazardous area, are of flame-proof application;
14) Proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals;
15) Flat ended screws are used for fixing conductor to the accessories;
16) Use of flat washers backed up by spring washers for making end connections is desirable; and
17) All metallic parts of installation such as conduits, distribution boards, metal boxes, etc have been properly earthed.

9.3 Testing of Installation

9.3.1 *General*

After inspection, the following tests shall be carried out, before an installation or an addition to the existing installation is put into service. Any testing of the electrical installation in an already existing installation shall commence after obtaining permit to work from the engineer-in-charge and after ensuring the safety provisions.

9.3.2 *Testing*

9.3.2.1 *Switchboards*

HV and MV switchboards shall be tested in the manner indicated below:

a) All high voltage switchboards shall be tested for dielectric test as per good practice [8-2(25)].
b) All earth connections shall be checked for continuity.
c) The operation of the protective devices shall be tested by means of secondary or primary injection tests.
d) The operation of the breakers shall be tested from all control stations.
e) Indication/signalling lamps shall be checked for proper working.
f) The operation of the breakers shall be tested for all interlocks.
g) The closing and opening timings of the breakers shall be tested wherever required for auto-transfer schemes.
h) Contact resistance of main and isolator contacts shall be measured.
j) The specific gravity and the voltage of the control battery shall be measured.

9.3.2.2 *Transformers*

Transformers are tested in the manner indicated below:

a) All commissioning tests shall be in accordance with good practice [8-2(26)].
b) Insulation resistance on HV and MV windings shall be measured at the end of 1 min as also at the end of 10 min of measuring the polarization index. The absolute value of insulation resistance should not be the sole criterion for determining the state of dryness of the insulation. Polarization index values should form the basis for determining the state of dryness of insulation. For any class of insulation, the polarization index should be greater than 1.5.

9.3.2.3 *Cables*

Cable installations shall be checked as below:

a) It shall be ensured that the cables conform to the relevant Indian Standards. Tests shall also be done in accordance with good practice [8-2(6)]. The insulation resistance before and after the tests shall be checked.

b) The insulation resistance between each conductor and against earth shall be measured. The insulation resistance varies with the type of insulation used and with the length of cable. The following empirical rule gives reasonable guidance:

$$\text{Insulation resistance in megaohms} = \frac{10 \times \text{Voltage in kV}}{\text{Length in km}}$$

c) Physical examination of cables shall be carried out.

d) Cable terminations shall be checked.

e) Continuity test shall be performed before charging the cable with current.

9.3.2.4 *Motors and other equipments*

The following test is made on motor and other equipment:

The insulation resistance of each phase winding against the frame and between the windings shall be measured. Megger of 500 V or 1 000 V rating shall be used. Star points should be disconnected. Minimum acceptable value of the insulation resistance varies with the rated power and the rated voltage of the motor.

The following relation may serve as a reasonable guide:

$$R = \frac{20 \times E_n}{1\,000 + 2P}$$

where

R_i = Insulation resistance in megohms at 25°C.

E_n = Rated phase to phase voltage.

P = Rated power in kW.

If the resistance is measured at a temperature different from 25°C, the value shall be corrected to 25°C.

The insulation resistance as measured at ambient temperature does not always give a reliable value, since moisture might have been absorbed during shipment and storage. When the temperature of such a motor is raised, the insulation resistance will initially drop considerably, even below the acceptable minimum. If any suspicion exists on this score, motor winding must be dried out.

9.3.2.5 *Wiring installation*

The following tests shall be done:

a) The insulation resistance shall be measured by applying between earth and the whole system of conductor or any section thereof with all fuses in place and all switches closed, and except in earthed concentric wiring, all lamps in position or both poles of installation otherwise electrically connected together, a dc voltage of not less than twice the working voltage, provided that it does not exceed 500 V for medium voltage circuits. Where the supply is derived from three-wire (ac or dc) or a poly-phase system, the neutral pole of which is connected to earth either direct or through added resistance the working voltage shall be deemed to be that which is maintained between the outer or phase conductor and the neutral.

b) The insulation resistance in megaohms of an installation measured as in (a) shall be not less than 50 divided by the number of points on the circuit, provided that the whole installation need not be required to have an insulation resistance greater than one megaohm.

c) Control rheostats, heating and power appliances and electric signs, may, if desired, be disconnected from the circuit during the test, but in that event the insulation resistance between the case of framework, and all live parts of each rheostat, appliance and sign shall be not less than that specified in the relevant Indian Standard specification or where there is no such specification, shall be not less than half a megaohm.

d) The insulation resistance shall also be measured between all conductors connected to one pole or phase conductor of the supply and all the conductors connected to the middle wire or to the neutral on to the other pole of phase conductors of the supply. Such a test shall be made after removing all metallic connections between the two poles of the installation and in these circumstances the insulation resistance between conductors of the installation shall be not less than that specified in (b).

9.3.2.6 *Completion certificate*

On completion of an electrical installation (or an extension to an installation) a certificate shall be furnished by the contractor, counter-signed by the certified supervisor under whose direct supervision the installation was carried out. This certificate shall be in a prescribed form as required by the local electric supply authority. One such recommended form is given in Annex E.

9.3.2.7 *Earthing*

For checking the efficiency of earthing, the following tests are done:

a) The earth resistance of each electrode shall be measured.

b) Earth resistance of earthing grid shall be measured.

c) All electrodes shall be connected to the grid and the earth resistance of the entire earthing system shall be measured.

These tests shall preferably be done during the summer months.

10 TELECOMMUNICATION AND OTHER MISCELLANEOUS SERVICES

10.1 Telecommunication Service

10.1.1 House wiring of telephone subscribers offices in small buildings is normally undertaken by the Telephone Department on the surface of walls. But in large multi-storeyed buildings intended for commercial, business and office use as well as for residential purposes, wiring for telephone connections is generally done in a concealed manner through conduits.

10.1.2 The requirements of telecommunication facilities like Telephone connections, Private Branch Exchange, Intercommunication facilities, Telex and Telegraph lines are to be planned well in advance so that suitable provisions are made in the building plan in such a way that the demand for telecommunication services in any part of the building at any floor are met at any time during the life of the building.

10.1.3 Layout arrangements, methods for internal block wiring and other requirements regarding provisions of space, etc, may be decided defending as the number of phone outlets and other details in consultation with Engineer/Architect and user.

10.2 Public Address System — *See* Part 4 'Fire and Life Safety'.

10.3 Common Antenna System for TV Receivers

10.3.1 In multistoreyed apartments, houses and hotels where many TV receivers are located, a common master antenna system may preferably be used to avoid mushrooming of individual antennas.

10.3.2 Master antenna is generally provided at the top most convenient point in any building and a suitable room on the top most floor or terrace for housing the amplifier unit, etc, may also be provided in consultation with the architect/engineer.

10.3.3 From the amplifier rooms, conduits are laid in recess to facilitate drawing co-axial cable to individual flats. Suitable 'Tap Off' boxes may be provided in every room/flat as required.

10.4 UPS System

An electrical device providing an interface between the mains power supply and sensitive loads (computer systems, instrumentation, etc). The UPS supplies sinusoidal a.c. power free of disturbances and within strict amplitude and frequency tolerances. It is generally made up of a rectifier/charger and an inverter together with a battery for backup power in the event of a mains failure with virtually no time lag.

In general UPS system shall be provided for sensitive electronic equipments like computers, printers, fire alarm panel, public address system equipment, access control panel, EPABX, etc with the following provisions:

a) Provisions of isolation transformers shall be provided where the capacity exceeds 5 kVA.

b) UPS shall have dedicated neutral earthing system.

c) Adequate rating of protective devices such as MCB, MCCB, fuses, ELCB, etc, shall be provided at both incoming and outgoing sides.

d) UPS room shall be provided with adequate ventilation and/or air conditioning as per requirement.

10.5 Inverter

In general inverter system shall be provided for house lighting, shop lighting, etc, with the following provisions:

a) Adequate rating of protective devices such as MCB, MCCB, fuses, ELCB, etc, shall be provided at both incoming and outgoing sides.

b) Earthing shall be done properly.

c) Adequate ventilation space shall be provided around the battery section of the inverter.

d) Care in circuit design to keep the connected load in such a manner that the demand at the time of mains failure is within the capability of the inverter. (If the inverter fails to take over the load at the time of the mains failure, the purpose of providing the inverter and battery back up is defeated.)

e) Circuits which are fed by the UPS or Inverter systems should have suitable marking to ensure that a workman does not assume that the power is off, once he has switched off the mains from the DB for maintenance.

f) UPS systems and Inverter systems have a very limited fault feeding capacity in comparison to the mains supply from the licensee's network. The low fault current feed may cause loss of discrimination in the operation of

MCB's, if the Inverter or UPS system feeds a number of circuits with more than one over current protective device in series (such as incoming MCB at the DB and a few outgoing MCB's). The choice of MCB's in such cases has to be done keeping the circuit operating and fault condition parameters under both (mains operation and UPS operation) conditions.

10.6 Diesel Generating Set (less than 5 kVA)

In general small diesel generating sets shall be provided for small installations such as offices, shops, small scale industry, hostels, etc, with the following provisions:

a) These shall be located near the exit or outside in open areas.

b) They shall be in reach of authorized persons only.

c) Adequate fire fighting equipment shall be provided near such installations.

d) Exhaust from these shall be disposed in such a way so as not to cause health hazard.

e) These shall have acoustic enclosure, or shall be placed at a location so as not to cause noise pollution.

f) Adequate ventilation shall be provided around the installation.

g) Adequate rating of protective devices such as MCB, MCCB, fuses, ELCB, etc, shall be provided.

h) Separate and adequate body and neutral earthings shall be done.

10.7 Building Management System

A building management/automation system may be considered to be provided for controlling and monitoring of all parameters of HVAC, electrical, plumbing, fire fighting, low voltage system such as telephone, TV, etc. This not only lead to reduction of energy consumption, it shall also generate data leading to better operation practice and systematic maintenance scheduling. The total overview provided by a Building Automation System, with a capability to oversee a large number of operating and environmental parameters on real time basis leads to introduction of measures which lead to further reduction in energy consumption.

It shall also help in reduction of skilled manpower required for operation and maintenance of large complexes. This system can further linked to other systems such as Fire alarm system, public address system, etc for more effective running of services.

This system can be used for analysis and controlling of all services in a particular complex, leading efficient and optimum utilization of available services.

10.8 Security System

Security System may be defined as an integrated Closed Circuit Television System, Access Control System, Perimeter Protection Systems, movement sensors, etc. These have a central control panel, which has a defined history storage capacity. This main control panel may be located near to the fire detection and alarm system.

These may be considered for high security areas or large crowded areas or complexes. High security areas may consider uncorded, high-resolution, black and white cameras inplace of coloured cameras. These may be accompanied with movement sensors.

Access control may be provided for entry to high security areas. The systems may have proximity card readers, magnetic readers, etc.

10.9 Computer Networking

Networking is the practice of linking computing devices together with hardware and software that supports data communications across these devices.

10.10 Car Park Management System

The Car Management System may be provided in multi-level parking or other parking lots where number of vehicles to be parked exceeds 1 000 vehicles. The Car Park Management System may have features of Pay and Display Machines and Parking Guidance System. The Pay and Display Machines may be manned and unmanned type. Parking guidance system needs to display number of car spaces vacant on various floors, direction of entry and exit, etc. This system can be of great benefit in evaluating statistical data's such as number of cars in a day or month or hour, stay time of various vehicles, etc.

11 LIGHTNING PROTECTION OF BUILDINGS

11.1 Basic Considerations for Protection

Before proceeding with the detailed design of a lightning protecting system, the following essential steps should be taken:

a) Decide whether or not the structure needs protection and, if so, what are the special requirements (*see* **11.1.1**) {*see* good practice for details [8-2(27)] }.

b) Ensure a close liaison between the architect, the builder, the lightning protective system engineer, and the appropriate authorities throughout the design stages.

c) Agree the procedures for testing, commissioning and future maintenance.

11.1.1 *Need for Protection*

Structures with inherent explosive risks; for example, explosives factories, stores and dumps and fuel tanks; usually need the highest possible class of lightning protective system.

For all other structures, the standard of protection recommended in the remainder of the Code is applicable and the only question remaining is whether to protect or not.

In many cases, the need for protection may be self-evident, for example:

— where large numbers of people congregate;
— where essential public services are concerned;
— where the area is one in which lightning strokes are prevalent;
— where there are very tall or isolated structures; and
— where there are structures of historic or cultural importance.

However, there are many cases for which a decision is not so easy to make. Various factors effecting the risk of being struck and the consequential effects of a stroke in these cases are discussed in **11.1.2** to **11.1.8**.

It must be understood, however, that some factors cannot be assessed, and these may override all other considerations. For example, a desire that there should be no avoidable risk to life or that the occupants of a building should always feel safe, may decide the question in favour of protection, even though it would normally be accepted that there was no need. No guidance can be given in such matters, but an assessment can be made taking account of the exposure risk (that is the risk of the structure being struck) and the following factors:

a) Use to which the structure is put,
b) Nature of its construction,
c) Value of its contents or consequential effects,
d) The location of the structure, and
e) The height of the structure (in the case of composite structures the overall height).

11.1.2 *Estimation of Exposure Risk*

The probability of a structure or building being struck by lightning in any one year is the product of the 'lightning flash density' and the 'effective collection area' of the structure. The lightning flash density, N_g, is the number of (flashes to ground) per km^2 per year.

NOTE — For the purposes of this Code, the information given in Fig. 5 on thunderstorm days per year would be necessary to be translated in terms of estimated average annual density N_g.

The table below which indicates the relationship between thunderstorm days per year and lightning flashes per square kilometre per year:

Thunderstorm days/year	*Lightning Flashes per km^2 per Year*	
	Mean	Limits
5	0.2	0.1 – 0.5
10	0.5	0.15 – 1
20	1.1	0.3 – 3
30	1.9	0.6 – 5
40	2.8	0.8 – 8
50	3.7	1.2 – 10
60	4.7	1.8 – 12
80	6.9	3 – 17
100	9.2	4 – 20

The effective collection area of a structure is the area on the plan of the structure extended in all directions to take account of its height. The edge of the effective collection area is displaced from the edge of the structure by an amount equal to the height of the structure at that point. Hence, for a simple rectangular building of length L, width W and height H metres, the collection area has length $(L + 2H)$ metres and width $(W + 2H)$ metres with four rounded corners formed by quarter circles of radius H metres. This gives a collection area, A_c (in m^2):

$$A_c = (L \times W) + 2(L \times H) + 2(W \times H) + \pi H^2 \quad \ldots (1)$$

The probable number of strikes (risk) to the structure per year is:

$$P = A_c \times N_g \times 10^{-6} \quad \ldots (2)$$

It must first be decided whether this risk P is acceptable or whether some measure of protection is thought necessary.

11.1.3 *Suggested Acceptable Risk*

For the purposes of this Code, the acceptable risk figure has been taken as 10^{-5}, that is, 1 in 100 000 per year.

11.1.4 *Overall Assessment of Risk*

Having established the value of P, the probable number of strikes to the structure per year [*see* equation (2) in **11.1.2**] the next step is to apply the 'weighting factors' in Tables 3 and 4.

This is done by multiplying P by the appropriate factors to see whether the result, the overall weighting factors, exceeds the acceptable risk of $P = 10^{-5}$ per year.

11.1.5 *Weighting Factors*

In Tables 3A to 3E, the weighting factor values are given under headings 'A' to 'E', denoting a relative degree of importance or risk in each case. The tables are mostly self-explanatory but it may be helpful to say something about the intention of Table 3C.

Table 3 Overall Assessment of Risk
(Clauses 11.1.4 *and* 11.1.5)

Table 3A Weighting Factor 'A' (Use of Structure)

Use to Which Structure is Put	Value of 'A'
Houses and other buildings of comparable size	0.3
Houses and other buildings of comparable size with outside aerial	0.7
Factories, workshops and laboratories	1.0
Office blocks, hotels, blocks of flats and other residential buildings other than those included below	1.2
Places of assembly, for example, churches, halls, theatres, museums, exhibitions, departmental stores, post offices, stations, airports, and stadium structures	1.3
Schools, hospitals, children's and other homes	1.7

Table 3B Weighting Factor 'B' (Type of Construction)

Type of Construction	Value of 'B'
Steel framed encased with any roof other than metal[1)]	0.2
Reinforced concrete with any roof other than metal	0.4
Steel framed encased or reinforced concrete with metal roof	0.8
Brick, plain concrete or masonry with any roof other than metal or thatch	1.0
Timber framed or clad with any roof ohte rthan metal or thatch	1.4
Brick, plain concrete, masonry, timber framed but with metal roofing	1.7
Any building with a thatched roof	2.0

[1)] A structure of exposed metal which is continuous down to ground level is excluded from these tables as it requires no lighting protection beyond adequate earthing arrangements.

Table 3C Weighting Factor 'C' (Contents or Consequential Effects)

Contents or Consequential Effects	Value of 'C'
Ordinary domestic or office buildings, factories and workshops not containing valuable or specially susceptible contents	0.3
Industrial and agricultural buildings with specially susceptible [1)] contents	0.8
Power stations, gas works, telepone exchanges, radio stations	1.0
Industrial key plants, ancient monuments and historic buildings, museums, art galleries or other buildings with specially valuable contents	1.3
Schools, hospitals, children's and other homes, places of assembly	1.7

[1)] This means specially valuable plant or materials vulnerable to fire or the results of fire.

Table 3D Weighting Factor 'D' (Degree of Isolation)

Degree of Isolation	Value of 'D'
Structure located in a large area of structures or trees of the same or greater height, for example, in a large town or forest	0.4
Structure located in an area with few other structures or trees of similar height	1.0
Structure completely isolated or exceeding at least twice the height of surrounding structures or trees	2.0

Table 3E Weighting Factor 'E' (Type of Country)

Type of Country	Value of 'E'
Flat country at any level	0.3
Hill country	1.0
Mountain country between 300 m and 900 m	1.3
Mountain country between 900 m	1.7

The effect of the value of the contents of a structure is clears the term 'consequential effect' is intended to cover not only material risks to goods and property but also such aspects as the disruption of essential services of all kinds, particularly in hospitals.

The risk to life is generally very small, but if a building is struck, fire or panic can naturally result. All possible steps should, therefore, be taken to reduce these effects, especially among children, the old, and the sick.

11.1.6 *Interpretation of Overall Risk Factor*

The risk factor method put forward here is to be taken as giving guidance on what might, in some cases, be a difficult problem. If the result obtained is considerably less than 10^{-5} (1 in 100 000) then, in the absence of other overriding considerations, protection does not appear necessary; if the result is greater than 10^{-5}, say for example 10^{-4} (1 in 10 000) then sound reasons would be needed to support a decision not to give protection.

When it is thought that the consequential effects will be small and that the effect of a lighting stroke will most probably be merely slight damage to the fabric of the structure, it may be economic not to incur the cost of protection but to accept the risk. Even though, this decision is made, it is suggested that the calculation is still worthwhile as giving some idea of the magnitude of the calculated risk being taken.

11.1.7 *Anomalies*

Structures are so varied that any method of assessment may lead to anomalies and those who have to decide on protection must exercise judgement. For example, a steel-framed building may be found to have a low risk

factor but, as the addition of an air termination and earthing system will give greatly improved protection, the cost of providing this may be considered worthwhile.

A low risk factor may result for chimneys made of brick or concrete. However, where chimneys are free standing or where they project for more than 4.5 m above the adjoining structure, they will require protection regardless of the factor. Such chimneys are, therefore, not covered by the method of assessment. Similarly, structures containing explosives or flammable substances are also not covered.

Results of calculations for different structures are given in Table 4 and a specific case is worked through in **11.1.8**.

11.1.8 *Sample Calculation of Need for Protection*

A hospital building is 10 m high and covers an area of 70 m × 12 m. The hospital is located in flat country and isolated from other structures. The construction is of brick and concrete with a non-metallic roof.

Is lighting protection needed?

a) *Flashes/km²/year* — Let us say, for the protection of the hospital a value for N_g is 0.7.

b) *Collection area* — Using equation (1) in **11.1.2**:

$$A_c = (70 \times 12) + 2(70 \times 10) + 2(12 \times 10) + (\pi \times 100)$$
$$= 840 + 1\,400 + 240 + 314$$
$$= 2\,794 \text{ m}^2$$

c) *Probability of being struck* — Using equation (2) in **11.1.2**:

$$P = A_c \times N_g \times 10^{-6} \text{ times per year}$$
$$= 2\,794 \times 0.7 \times 10^{-6}$$
$$= 2.0 \times 10^{-3} \text{ approximately}$$

Table 4 Examples of Calculations for Evaluating the Need for Protection

(*Clauses* 11.1.4 *and* 11.1.7)

Sl No.	Description of Structure	Risk of Being Struck (P)			Weighting Factors					Overall Multiplying Factor (Product of cols 6–10)	Overall Risk Factor (Product of cols 5 and 11)	Recommendation
		Collection Area A_c	Flash Density N_g	P $A_c \times N_g \times 10^{-6}$	'A' Use of Structure (Table 3A)	'B' Type of Construction (Table 3B)	'C' Contents or Consequential Effects (Table 3C)	'D' Degree of Isolation (Table 3D)	'E' Type of Country (Table 3E)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	Malsonette, reinforced concrete and brick built, non-metallic roof	3 327	0.6	2×10^{-3}	1.2	0.4	0.3	0.4	0.3	0.02	4×10^{-5}	Protection required
ii)	Office building, reinforced concrete construction, non-metallic roof	4 296	0.6	2.6×10^{-3}	1.2	0.4	0.3	0.4	0.3	0.02	5.2×10^{-5}	Protection required
iii)	School, brick built	1 456	0.7	1×10^{-3}	1.7	1.0	1.7	0.4	0.3	0.3	3×10^{-4}	Protection required
iv)	3 bedroom detached dwelling house, brick built	405	0.4	1.6×10^{-4}	0.3	1.0	0.3	0.4	0.3	0.01	1.6×10^{-4}	No protection required
v)	Village church	5 027	0.6	3×10^{-3}	1.3	1.0	1.7	2.0	0.3	1.3	3.9×10^{-3}	Protection required

NOTE — The risk of being struck, 'P' (col 5), is multiplied by the product of the weighting factors (col 6 to 10) to yield an overall risk factor (col 12). This should be compared with the acceptable risk (1×10^{-5}) for guidance on whether or not to protect.

d) *Applying the weighting factors*

A = 1.7
B = 1
C = 1.7
D = 2.0
E = 0.3

The overall multiplying factor

$= A \times B \times C \times D \times E$
$= 1.7$

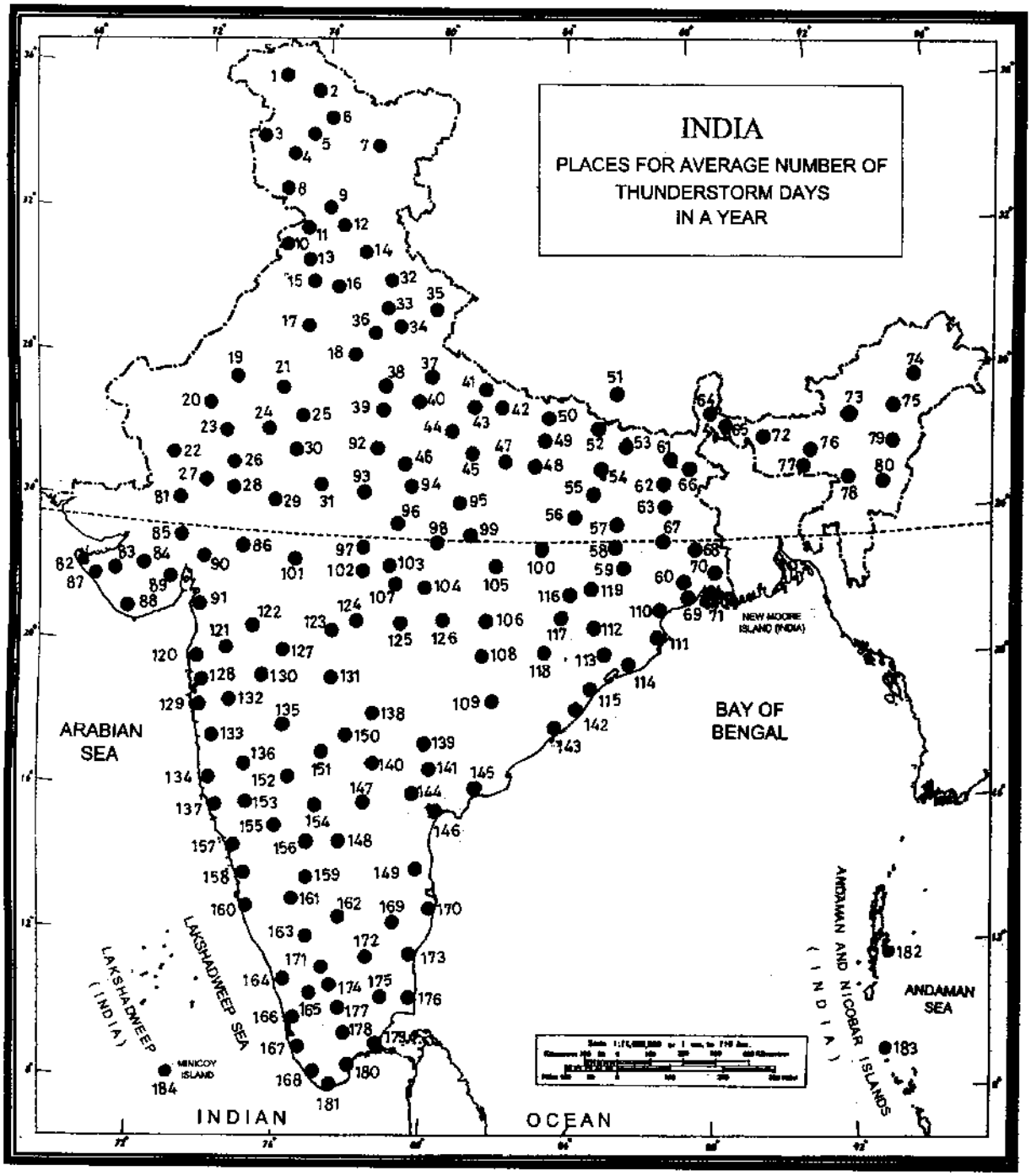
Therefore, the overall risk factor

$= 2.0 \times 1.7 \times 10^{-3}$
$= 3.4 \times 10^{-3}$

Conclusion: Protection is necessary.

11.2 For detailed requirements of lightning protection of various structures, reference may be made to good practice [8-2(27)].

Sl No.	Name of Place	Annual Thunder-storm Days	Sl No.	Name of Place	Annual Thunder-storm Days	Sl No.	Name of Place	Annual Thunder-storm Days
1.	Gilgit	7	63.	Dumka	63	125.	Nagpur	45
2.	Skardu	5	64.	Darjeeling	28	126.	Gondia	10
3.	Gulmarg	53	65.	Jalpaiguri	68	127.	Aurangabad	34
4.	Srinagar	54	66.	Malda	59	128.	Bombay	16
5.	Dras	3	67.	Asansol	71	129.	Alibag	12
6.	Kargil	2	68.	Burdwan	39	130.	Ahmadnagar	10
7.	Leh	3	69.	Kharagpur	76	131.	Parbhani	32
8.	Jammu	26	70.	Calcutta	70	132.	Pune	22
9.	Dharmsala	13	71.	Sagar Island	41	133.	Mahabaleshwar	14
10.	Amritsar	49	72.	Dhubri	8	134.	Ratnagiri	6
11.	Pathankot	4	73.	Tezpur	27	135.	Sholapur	23
12.	Mandi	46	74.	Dibrugarh	98	136.	Miraj	25
13.	Ludhiana	12	75.	Sibsagar	103	137.	Vengurla	39
14.	Simla	40	76.	Shillong	75	138.	Nizambad	36
15.	Patiala	26	77.	Cherrapunji	49	139.	Hnamkonda	43
16.	Ambala	9	78.	Silchar	33	140.	Hyderabad	28
17.	Hissar	27	79.	Kohima	34	141.	Khammam	26
18.	Delhi	30	80.	Imphal	49	142.	Kalingapatam	20
19.	Bikaner	10	81.	Deesa	7	143.	Vishakapatnam	46
20.	Phalodi	14	82.	Dwarka	5	144.	Rentichintala	42
21.	Sikar	17	83.	Jamnagar	8	145.	Masulipatam	20
22.	Barmer	12	84.	Rajkot	12	146.	Ongole	25
23.	Jodhpur	23	85.	Ahmedabad	11	147.	Kurnool	29
24.	Ajmer	26	86.	Dohad	17	148.	Anantpur	22
25.	Jaipur	39	87.	Porbandar	3	149.	Nellore	18
26.	Kankroli	36	88.	Veraval	3	150.	Bidar	15
27.	Mount Abu	5	89.	Bhavnagar	11	151.	Gulbarga	34
28.	Udaipur	38	90.	Baroda	8	152.	Bijapur	9
29.	Neemuch	28	91.	Surat	4	153.	Belgaum	31
30.	Kota	27	92.	Gwalior	53	154.	Raichur	17
31.	Jhalawar	40	93.	Guna	33	155.	Gadag	21
32.	Mussorie	61	94.	Nowgong	59	156.	Bellary	22
33.	Roorkee	74	95.	Satna	41	157.	Karwar	27
34.	Najibabad	36	96.	Sagar	36	158.	Honavar	5
35.	Mukteswar	53	97.	Bhopal	44	159.	Chikalthana	24
36.	Meerut	—	98.	Jabalpur	50	160.	Mangalore	36
37.	Bareilly	34	99.	Umaria	37	161.	Hassan	26
38.	Aligarh	30	100.	Ambikapur	29	162.	Bangalore	46
39.	Agra	24	101.	Indore	34	163.	Mysore	44
40.	Mainpuri	23	102.	Hoshangabad	37	164.	Kozhikode	39
41.	Bahraich	31	103.	Panchmarhi	30	165.	Palghat	35
42.	Gonda	22	104.	Seoni	51	166.	Cochin	69
43.	Lucknow	18	105.	Pendadah	56	167.	Alleppey	51
44.	Kanpur	26	106.	Raipur	34	168.	Trivandrum	68
45.	Fatehpur	24	107.	Chhindwara	27	169.	Vellore	25
46.	Jhansi	20	108.	Kanker	37	170.	Madras	47
47.	Allahabad	51	109.	Jagdalpur	35	171.	Ootacamund	24
48.	Varanasi	51	110.	Balasore	81	172.	Salem	69
49.	Azamgarh	1	111.	Chandbali	75	173.	Cuddalore	37
50.	Gorakhpur	11	112.	Angul	81	174.	Coimbatore	40
51.	Kathmandu	74	113.	Bhubaneswar	46	175.	Trichchirapalli	41
52.	Motihari	38	114.	Puri	33	176.	Nagappattinam	15
53.	Darbhanga	10	115.	Gopalpur	34	177.	Kodaikanal	82
54.	Patna	33	116.	Jharsuguda	85	178.	Madurai	39
55.	Gaya	38	117.	Sambalpur	67	179.	Pamban	5
56.	Daltonganj	73	118.	Titlagarh	24	180.	Tuticorin	14
57.	Hazaribagh	73	119.	Rajgangpur	1	181.	Cape Comorin	68
58.	Ranchi	34	120.	Dahanu	1	182.	Port Blair	62
59.	Chaibasa	70	121.	Nasik	17	183.	Car Nicobar 1	18
60.	Jamshedpur	66	122.	Malegaon	13	184.	Minicoy 1	20
61.	Purnea	52	123.	Akola	20			
62.	Sabour	76	124.	Amraoti	32			



Based upon Survey of India Outline Map printed in 1993.

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate base line.
The boundary of Meghalaya shown on this map is as interpreted from the North-Eastern Areas (Reorganisation) Act, 1971, but has yet to be verified.
Responsibility for correctness of internal details shown on the map rests with the publisher.
The state boundaries between Uttaranchal & Uttar Pradesh, Bihar & Jharkhand and Chhatisgarh & Madhya Pradesh have not been verified by Governments concerned.

FIG. 5 MAP OF INDIA SHOWING PLACES FOR AVERAGE NUMBER OF THUNDERSTORM DAYS IN A YEAR

ANNEX A

(*Clause* 2.2)

DRAWING SYMBOLS FOR ELECTRICAL INSTALLATION IN BUILDING

A-1 WIRING

A-1.0 Remarks 'upwards' and 'downwards' apply only when the drawing is read the right way up.

A-1.0.1 An arrow on the slant line indicates the direction of the power flow.

A-1.0.2 The wiring terminates at the circle or the black dot.

A-1.1 General Wiring

A-1.2 Wiring on the Surface

A-1.3 Wiring under the Surface

A-.1.4 Wiring in Conduit

A-1.4.1 *Conduit on Surface*

A-1.4.2 *Concealed Conduit*

NOTE — The type of conduit may be indicated, if necessary.

A-1.5 *Wiring Going Upwards*

A-1.6 *Wiring Going Downwards*

A-1.7 *Wiring Passing Vertically through a Room*

A-2 FUSE BOARDS

A-2.1 Lighting Circuit Fuse Boards

A-2.1.1 *Main Fuse Board Without Switches*

A-2.1.2 *Main Fuse Board with Switching*

A-2.1.3 *Distribution Fuse Board Without Switches*

A-2.1.4 *Distribution Fuse Board with Switches*

A-2.2 Power Circuit Fuse Boards

A-2.2.1 *Main Fuse Board Without Switches*

A-2.2.2 *Main Fuse Board with Switches*

A-2.2.3 *Distribution Fuse Board Without Switches*

A-2.2.4 *Distribution Fuse Board with Switches*

A-3 SWITCHES AND SWITCH-OUTLETS

A-3.1 One-Way Switch

A-3.1.1 *Single-Pole*

A-3.1.2 *Two-Pole*

A-3.1.3 *Three-Pole*

A-3.2 Single-Pole Pull Switch

A-3.3 Multiposition Switch for Different Degrees of Lighting

A-3.4 Two-Way Switch

A-3.5 Intermediate Switch

A-3.6 Period Limiting Switch

A-3.7 Time Switch

A-3.8 Pendant Switch

A-3.9 Push Button

NOTE — The use of the push button may be indicated, if desired.

A-3.10 Luminous Push Button

A-3.11 Restricted Access Push Button

A-4 SOCKET-OUTLETS

A-4.1 Socket-Outlet, 6A

A-4.2 Socket-Outlet, 16A

A-4.3 Combined Switch and Socket-Outlet, 6 A

A-4.4 Combined Switch and Socket-Outlet, 16 A

A-4.5 Interlocking Switch and Socket-Outlet, 6 A

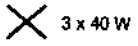
A-4.6 Interlocking Switch and Socket-Outlet, 16 A

A-5 LAMPS AND LIGHTING APPARATUS

A-5.0 Symbols **A-5.1** to **A-5.17.1** represent either the lamp or a group of lamps or the outlet for lamps. If it is desired to specify that the lamp is fixed to the wall or ceiling, a vertical or horizontal line respectively may be added to the symbol.

A-5.1 Lamp or Outlet for Lamp

A-5.1.1 *Group of Three 40-W Lamps*

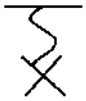


A-5.2 Lamp, Mounted on a Wall

A-5.3 Lamp, Mounted on a Ceiling

A-5.4 Counter Weight Lamp Fixture

A-5.5 Chain Lamp Fixture



A-5.6 Rod Lamp Fixture

A-5.7 Lamp Fixtures with Built-in Switch

A-5.8 Lamp Fed from Variable Voltage Supply

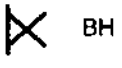
A-5.9 Emergency Lamp

A-5.10 Panic Lamp

A-5.11 Bulk-Head Lamp

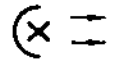
A-5.12 Water-Tight Lighting Fitting

A-5.13 Battern Lamp Holder



A-5.14 Projector

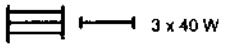
A-5.15 Spot Light



A-5.16 Flood Light

A-5.17 Flourescent Lamp

A-5.17.1 *Group of Three 40-W Fluorescent Lamps*



A-6 ELECTRICAL APPLIANCES

A-6.1 General

NOTE — If necessary, use designation is specify.

A-6.2 Heater

A-6.3 Storage Type Electric Water Heaters

A-7 BELLS, BUZZERS AND SIRENS

A-7.1 Bell

A-7.2 Buzzer

A-7.3 Siren

A-7.4 Horn on Hooter

A-7.5 Indicator (at 'N' insert number of ways)

A-8 FANS

A-8.1 Ceiling Fan

A-8.2 Bracket Fan

A-8.3 Exhaust Fan

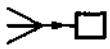
A-8.4 Fan Regulator

A-9 TELECOMMUNICATION APPARATUS

A-9.1 Socket-Outlet for Telecommunications

A-9.2 Aerial

A-9.3 Loudspeaker

A-9.4 Radio Receiving Set 

A-9.5 Amplifying Equipment

A-9.6 Television Receiving Set

A-9.7 Control Board (for Public Address System)

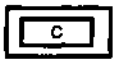
A-10 CLOCKS

A-10.1 Synchronous Clock

A-10.2 Impulse Clock Outlet

A-10.3 Master Clock Outlet

A-11 FIRE ALARMS

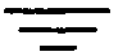
A-11.1 Manual Operated Fire Alarm 

A-11.2 Automatic Fire Detector Switch

A-11.3 Bell Connected to Fire Alarm Switch

A-11.4 Fire Alarm Indicator

A-12 EARTHING

A-12.1 Earth Point 

ANNEX B

[*Clauses* 3.1, 5.3.1.1, 5.3.1.3, 5.3.2.3(b) *and* 8.6]

EXTRACTS FROM INDIAN ELECTRICITY RULES, 1956

B-1 The following are the extracts of some of the rules:

Rule 32, Identification of Earthed and Earthed Neutral Conductors and Position of Switches and Cut-Outs Therein

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be complied with:

1) An indication of permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such conductor to be distinguished from any live conductor. Such indication shall be provided:
   a) Where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply;
   b) Where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor at the point where such connection is to be made;
   c) In all other cases, at a point corresponding to the point of commencement of supply or at such other point as may be approved by an Inspector or any officer appointed to assist the Inspector and hold authorized under sub-rule (2) of Rule 4-A.
2) No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two-wire system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:
   a) A link for testing purposes, or
   b) A switch for use in controlling a generator or transformer.

   NOTE — For the purpose of this rule, the relevant Indian Standards relating to marking and arrangement for switch gear, busbar, main connections, and auxiliary wiring may be referred to.

Rule 33 Earthed Terminal on Consumer's Premises

1) The supplier shall provide and maintain on the consumer's premises for the consumer's use a suitable earthed terminal in an accessible

position at or near the point of commencement of supply as defined under Rule 58;

Provided that in the case of medium, high or extra-high voltage installation, the consumer shall, in addition to aforementioned earthing arrangement, provide his own earthing system with an independent electrode, and maintain the same.

Provided further that the supplier may not provide any earthed terminal in the case of installations already connected to his system on or before the 30th June, 1966 if he is satisfied that the consumer's earthing arrangement is efficient.

2) The consumer shall take all reasonable precautions to prevent mechanical damage to the earthed terminal and its lead belonging to the supplier; and

3) The supplier may recover from the consumer the cost of installation of such earthed terminal on the basis laid down in sub-rule (2) of Rule 82.

Rule 50 Supply and Use of Energy

1) The energy shall not be supplied, transformed, converted or used or continued to be supplied, transformed, converted or used unless the following provisions are observed:

a) A suitable linked switch or a circuit breaker of requisite capacity to carry and break the current is placed as near as possible to, but after the point of commencement of supply, as defined under Rule 58, so as to be readily accessible and capable of being easily operated to completely isolate the supply to the installation, such equipment being in addition to any equipment installed for controlling individual circuits or apparatus.

Provided that where the point of commencement of supply and the consumer's apparatus are near to each other, one linked switch or circuit breaker near the point of commencement of supply shall considered sufficient for the purpose of this rule;

b) A suitable linked switch or circuit-breaker of requisite capacity to carry and break the full load current is inserted on the secondary side of a transformer, in the case of high or extra high voltage installation.

Provided however, that the linked switch on the primary side of the transformer may be of such capacity as to carry the full load current and to break only the magnetising current of the transformer.

Provided further that the provision of the clause shall not apply to transformers installed in sub-station upto and including 100 kVA belonging to the supplier.

Provided also that the provision of a linked switch on the primary side of the transformer shall not apply to the unit auxiliary transformer of the generator.

c) Except in the case of composite control gear designed as a unit; every distinct circuit is protected against excess energy by means of a suitable cut-out or a circuit-breaker of adequate breaking capacity suitably located and so constructed as to prevent danger from overheating, arcing or scattering of hot metal when it comes into operation and to permit of ready renewal of the fusible metal of the cut-out without danger.

d) The supply of energy to each motor or a group of motors or other apparatus, meant for operating one particular machine, is controlled by a suitable linked switch or a circuit-breaker or an emergency tripping device with manual reset of requisite capacity placed in such a position as to be adjacent to the motor or a group of motors or other apparatus, readily accessible to and easily operated by the person in charge and so connected in the circuit of that by its means all supply of energy can be cut-off from the motor or a group of motors or apparatus and from any regulating switch, resistance or other device associated therewith.

e) All insulating material is chosen with special regard to the circumstances of its proposed use, the mechanical strength being sufficient for the purpose, and so far as is practicable, is of such a character or so protected as to maintain adequately the insulating properties under all working conditions in respect of temperature and moisture; and

f) Adequate precautions are taken to ensure that no live parts are so exposed as to cause danger.

2) a) When energy is being supplied, transformed, converted or used, the

consumer or the owner of the concerned installation shall be responsible for the continuous observance of the provisions of sub-rule(1) in respect of his installation.

b) Every consumer shall use all reasonable means to ensure that where energy is supplied by a supplier no person other than the supplier shall interfere with the service lines and apparatus placed by the supplier on the premises of the consumer.

Rule 51 Provisions Applicable to Medium, High or Extra-High Voltage Installations

The following provisions shall be observed where energy at medium, high or extra high voltage is supplied, converted, transformed or used:

1) a) All conductors (other than those of overhead lines) shall be completely enclosed in mechanically strong metal casing or metallic covering which is electrically and mechanical continuous and adequately protected against mechanical damage unless the said conductors are accessible only to an authorised person or are installed and protected to the satisfaction of the Inspector so as to prevent danger.

Provided that rigid non-metallic conduits conforming to IS 2509 : 1963 'Rigid non-metallic conduits for electrical installation', may be used for medium voltage installation subject to any conditions as the Inspector or officer appointed to assist an Inspector may think fit to impose.

b) All metal works enclosing, supporting or associated with the installation, other than that designed to serve as a conductor shall, if considered necessary by the Inspector, be connected with earth.

c) Every switchboard shall comply with the following provisions, namely:

i) a clear space of not less than one metre in width shall be provided in front of the switchboard;

ii) if there are any attachments or bare connections at the back of the switchboard, the space (if any) behind the switchboard shall be either less than 10 cm, or more than 75 cm in width, measured from the farthest outstanding part of any attachment or conductor; and

iii) if the space behind the switchboard exceeds 75 cm in width, there shall be passage way from either end of the switchboard clear to a height of 1.8 metres.

2) Where an application has been made to a supplier for supply of energy to any installation, the shall not commence, or where the supply has been discontinued, recommence the supply unless he is satisfied that the consumer has complied in all respects with the conditions of supply, set out in sub-rule (1) of this rule and Rules 50 and 64.

3) Where a supplier proposes to supply or use energy at medium voltage or to recommence supply after it has been discontinued for a period of six months, he shall, before connecting or re-connecting the supply, give notice in writing of such intention to the Inspector.

4) If at any time after connecting the supply the supplier is satisfiedthat any provision of sub-rule (1) of this rule, or of Rules 50 and 64 is not being observed, he shall give notice of the same in writing to the consumer and the Inspector specifying how the provision has not been observed, and may discontinue the supply if the Inspector so direct.

Rule 58 Point of Commencement of Supply

The point of commencement of supply of energy to a consumer shall be deemed to be the point at the outgoing terminals of the cut-outs inserted by the supplier in each conductor of every service line other than an earthed or earthed neutral conductor or the earthed external conductor of a concentric cable at the consumer's premises.

Rule 61 Connection with Earth

1) The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage between phases or outers normally exceeds 125 volts and of systems at medium voltage:

a) The neutral conductor of a three-phase four-wire system, and the middle conductor of a two-phase three-wire system shall be earthed by not less than two separate and distinct connections with earth both at the generating station and at the substation. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.

c) The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

d) i) In a direct current three-wire system the middle conductor shall be earthed at the generating station only, and the current from the middle conductor to earth shall be continuously recorded by means of recording ammeter, and if at any time the current exceeds one thousandth part of the maximum supply current, immediate steps shall be taken to improve the insulation of the system.

ii) Where the middle conductor is earthed by means of a circuit-breaker with a resistance connected in parallel, the resistance shall not exceed 10 ohms and on the opening of the circuit-breaker, immediate steps shall be taken to improve the insulation of the system, and the circuit-breaker shall be re-closed as soon as possible.

iii) The resistance shall be used only as a protection for the ammeter in case of earths on the system and until such earths are removed, immediate steps shall be taken to locate and remove the earth.

e) In the case of an alternating current system, there shall not be inserted in the connection with earth and impedance (other than that required solely for the operation of switch gear or instrument), cut-out or circuit-breaker, and the result of any test made to ascertain whether the current (if any) passing through the connection with earth is normal, shall be duly recorded by the supplier.

f) No person shall make connection with earth by the aid of, nor shall be keep it in contact with any water main not belonging to him except with the consent of the owner thereof and of the Inspector.

g) Alternating current systems which are connected with earth as aforesaid may be electrically interconnected, provided that each connection with earth is bonded to lines concerned.

2) The frame of every generator, stationary motor, portable motor, and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulating or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.

3) All metal casings or metallic covering containing or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connections throughout their whole length.

Provided that where the supply is at low voltage, this sub-rule shall not apply to isolated wall tubes or to brackets, electrollers, switches, ceiling fans or other fittings (other than portable hand lamps and portable and transportable apparatus) unless provided with earth terminal.

Provided further that where the supply is at low voltage and where the installations are either new or renovated all plug sockets shall be of the three-pin type, having permanently and efficiently earthed.

The sub-rule shall come into force immediately in the case of new installations and in the case of existing installations the provisions of this sub-rule shall be complied with before the expiry of a period of two years from the commencement of those rules.

4) All earthing systems shall before electric supply lines or apparatus are energized, be tested for electrical resistance to ensure efficient earthing.

5) All earthing systems belonging to the supplier shall, in addition, be tested for resistance on dry day during the dry season not less than once every two years.

6) A record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Inspector or any officer appointed to assist the Inspector and authorised under sub-rule (2) of Rule 4A when required.

Rule 64 Use of Energy at High and Extra-High Voltage

1) The Inspector shall not authorise the supplier to commence supply, or where the supply has

been discontinued for a period of one year and above, to re-commence the supply at high or extra-high voltage to any consumer unless:

a) all conductors and apparatus intended for use at high or extra-high voltage and situated on the premises of the consumer are inaccessible except to an authorised person and all operations in connection with the said conductors and apparatus are carried out only by an authorised person;

b) the consumer has provided and agrees to maintain a separate building or a locked weather-proof and fire-proof enclosure of agreed sign and location, to which the supplier shall at all times have access for the purpose of housing is high or extra-high voltage apparatus and metering equipment, or where the provision of a separate building or enclosure is impracticable, the consumer has segregated the aforesaid apparatus of the supplier from any other part of his own apparatus:

Provided that such segregation shall be by the provision of fire-proof walls, if the Inspector considers it to be necessary:

Provided further that in the case of an out-door installation the consumer shall suitably segregate the aforesaid apparatus belonging to the supplier from his own to the satisfaction of the Inspector.

c) all pole type substations are constructed and maintained in accordance with Rule 69.

2) The following provisions shall be observed where energy at high or extra-high voltage is supplied, converted, transformed or used:

a) All conductors or live parts of any apparatus shall ordinarily be inaccessible.

b) All windings, at high or extra-high voltage of motors or other apparatus within reach from any position in which a person may require to be suitably protected so as to prevent danger.

c) Where transformer or transformers are used, suitable provision shall be made, either by connecting with earth voltage or otherwise, to guard against danger by reason of the said circuit becoming accidentally charged above its normal voltage by leakage from or contact with the circuit at the higher voltage.

d) i) A substation or switch station with apparatus having more than 2 000 litres of oil shall not ordinarily be located in the basement where proper oil drainage arrangements cannot be provided.

ii) Where a substation or switch station with apparatus having more than 2 000 litres of oil is installed whether indoors or outdoors, the following measures shall be taken, namely:

(a) baffle walls shall be erected between the apparatus containing more than 2 000 litres of oil and the adjacent apparatus to prevent spread of fire and avoid damage;

(b) a drain valve of adequate size which shall be capable of being safely operated even when the apparatus has caught fire shall be provided, and such a valve shall be easily accessible to being operated and at the same time not susceptible to being operated inadvertently;

(c) the drain valve shall let out the oil to a covered drainage system which shall take away the oil to a place away from the danger zone;

iii) the above measures shall be taken in addition to other fire protection arrangements to be provided for quenching the fire in the apparatus;

iv) cable trenches inside the substations and switch stations containing cables shall be filled with sand, pebbles or similar non-inflammable materials, or completely covered with non-inflammable slabs.

e) Unless the conditions are such that all the conductors and apparatus for use at high or extra-high voltage may be made dead at the same time for other work thereon, the said conductors and apparatus shall be so arranged that they may be made dead in sections, and that work on any section made dead may be carried on by an authorised person without danger.

f) Only persons authorised under sub-rule (1) of Rule 3 carry out the work on live lines and apparatus.

g) Adequate precautions shall be taken to prevent unauthorised access to any part of the installation designed to be electrically charged at high or extra-high voltage.

ANNEX C

[*Clause* 4.2.4(b)]

AREA REQUIRED FOR TRANSFORMER ROOM AND SUBSTATION FOR DIFFERENT CAPACITIES

C-1 The requirement for area for transformer room and substation for different capacities of transformers is given below for guidance:

Sl No.	*Capacity of Transformer(s)* kVA	*Total Transformer Room Area, Minimum,* m^2	*Total Substation Area (In Coming, HV, MV Panels, Transformer Roof but Without Generators), Minimum*	*Suggested Minimum Face Width* m
(1)	(2)	(3)	(4)	(5)
i)	1 × 160	14.0	90	9.0
ii)	2 × 160	28.0	118	13.5
iii)	1 × 250	15.0	91	9.0
iv)	2 × 250	30.0	121	13.5
v)	1 × 400	16.5	93	9.0
vi)	2 × 400	33.0	125	13.5
vii)	3 × 400	49.5	167	18.0
viii)	2 × 500	36.0	130	14.5
ix)	3 × 500	54.0	172	19.0
x)	2 × 630	36.0	132	14.5
xi)	3 × 630	54.0	176	19.0
xii)	2 × 800	39.0	135	14.5
xiii)	3 × 800	58.0	181	14.0
xiv)	2 × 1 000	39.0	149	14.5
xv)	3 × 1 000	58.0	197	19.0

NOTES

1 The above dimensions are overall area required for substation excluding generating set.

2 The clear height required for substation equipment shall be minimum of 3.0 m below the soffit of the beam.

ANNEX D

[*Clause* 4.2.4(j)]

ADDITIONAL AREA REQUIRED FOR GENERATOR IN ELECTRIC SUBSTATION

D-1 The requirement of additional area for generator in electric substation for different capacities of generators is given below for guidance:

Sl No.	*Capacity* kW	*Area* m^2	*Clear Height below the Soffit of the Beam* m
(1)	(2)	(3)	(4)
i)	25	56	3.6
ii)	48	56	3.6
iii)	100	65	3.6
iv)	150	72	4.6
v)	248	100	4.6
vi)	350	100	4.6
vii)	480	100	4.6
viii)	600	110	4.6
ix)	800	120	4.6
x)	1 000	120	4.6
xi)	1 250	120	4.6
xii)	1 600	150	4.6

NOTE — The area and height required for generating set room given in the above table are for general guidance only and may be finally fixed according to actual requirements.

ANNEX E

(*Clause* 9.3.2.6)

FORM OF COMPLETION CERTIFICATE

I/We certify that the installation detailed below has been installed by me/us and tested and that to the best of my/our knowledge and belief, it complies with *Indian Electricity Rules,* 1956.

Electrical Installation at _____

Voltage and system of supply

Particulars of Works:

a) Internal Electrical Installation

	No.	Total Load	Type of system of wiring
i) Light point			
ii) Fan point			
iii) Plug point			
3-pin 6 A			
3-pin 16 A			

b) Others	Description	hp/kW	Type of starting
1) Motors:			
i)			
ii)			
iii)			
2) Other plants:			

c) If the work involves installations of
over head line and/or underground cable

1) i) Type and description of overheadline.
   ii) Total length and number of spans.
   iii) No. of street lights and its description.
2) i) Total length of underground cable and its size:
   ii) No. of joints:
   End joint:
   Tee joint:
   Straight through joint:

Earthing:

i) Description of earthing electrode
ii) No. of earth electrodes
iii) Size of main earth lead

Test Results:

a) Insulation Resistance
   i) Insulation resistance of the whole system of conductors to earth..... Megaohms.
   ii) Insulation resistance between the phase conductor and neutral
   Between phase R and neutral ..... Megaohms.
   Between phase Y and neutral ..... Megaohms.
   Between phase B and neutral ..... Megaohms.
   iii) Insulation resistance between the phase conductors in case of polyphase supply.
   Between phase R and phase Y ..... Megaohms
   Between phase Y and phase B ..... Megaohms
   Between phase B and phase R ..... Megaohms

c) Earth continuity test:

Maximum resistance between any point in the earth continuity conductor including metal conduits and main earthing lead ..... Ohms.

d) Earth electrode resistance:

Resistance of each earth electrode.

i) ..... Ohms.
ii) ..... Ohms.
iii) ..... Ohms.
iv) ..... Ohms.

e) Lightning protective system.

Resistance of the whole of lightning protective system to earth before any bonding is effected with earth electrode and metal in/on the structure.....Ohms.

Signature of Supervisor	Signature of Contractor
Name and Address	Name and Address
.....	.....
.....	.....
.....	.....
.....	.....

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of the enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

	IS No.	*Title*
(1)	8270 (Part 1) : 1976	Guide for preparation of diagrams, charts and tables for electrotechnology: Part 1 Definitions and classification
	1885 (Part 16/Sec 3) 1967	Electrotechnical vocabulary: Lighting, Section 3 Lamps and auxiliary apparatus
	(Part 17) : 1979	Switchgear and controlgear (*first revision*)
	(Part 32) : 1993	Electrical cables (*first revision*)
	(Part 78) : 1993	Generation, transmission and distribution of electricity — General
	12032	Graphical symbols for diagrams in the field of electrotechnology:
	(Part 6) : 1987	Protection and conversion of electrical energy
	(Part 7) : 1987	Switchgear, controlgear and protective devices
(2)	7752 (Part 1) : 1975	Guide for improvement of power factor in consumer installation: Part 1 Low and medium supply voltages
(3)	5216	Recommendations on safety procedures and practices in electrical work:
	(Part 1) : 1982	General (*first revision*)
	(Part 2) : 1982	Life saving techniques (*first revision*)
(4)	10118 (Part 2) : 1982	Code of practice for selection, installation and maintenance of switchgear and controlgear: Part 2 Selection
(5)	1646 : 1997	Code of practice for fire safety of buildings (general): Electrical installations (*second revision*)

	IS No.	Title
(6)	732 : 1989	Code of practice for electrical wiring installations (*third revision*)
	1255 : 1983	Code of practice for installation and maintenance of power cables (up to and including 33 kV rating) (*second revision*)
(7)	13947 : 1993	Specification for low-voltage switchgear and controlgear
(8)	2148 : 1981	Specification for flame-proof enclosures of electrical apparatus (*second revision*)
(9)	5578 : 1985	Guide for marking of insulated conductors (*first revision*)
(10)	1777 : 1978	Industrial luminaire with metal reflectors (*first revision*)
	2206	Flameproof electric lighting fittings:
	(Part 1) : 1984	Well-glass and bulkhead types (*first revision*)
	(Part 2) : 1976	Fittings using glass tubes
	3287 : 1965	Industrial lighting fittings with plastic reflectors
	3528 : 1966	Waterproof electric lighting fittings
	3553 : 1966	Specification for watertight electric lighting fittings
	4012 : 1967	Specification for dust-proof electric lighting fittings
	4013 : 1967	Dust-tight electric lighting fittings
	5077 : 1969	Decorative lighting outfits
	10322 (Part 5/ Sec 5) : 1987	Luminaires: Part 5 Particular requirements, Section 5 Flood lights
(11)	8828 : 1996	Electrical accessories — Circuit-breakers for over current protection for household and similar installations (*second revision*)
	13947	Specification for low-voltage switchgear and controlgear:
	(Part 1) : 1993	General rules
	(Part 2) : 1993	Circuit-breakers
	(Part 3) : 1993	Switches, disconnectors, switch disconnectors and fuse combination units
	(Part 4/Sec 1) : 1993	Contactors and motor-starters, Section 1 Electro-technical contactors and motor starters
	(Part 5/Sec 1) : 1993	Control circuit devices and switching elements, Section 1 Electro-technical control circuit devices
(12)	3961	Recommended current ratings for cables:
	(Part 1) : 1967	Paper insulated lead sheathed cables
	(Part 2) : 1967	PVC insulated and PVC sheathed heavy duty cables
	(Part 3) : 1968	Rubber insulated cables
	(Part 5) : 1968	PVC insulated light duty cables
(13)	2086 : 1993	Specification for carriers and bases used in rewirable type electric fuses for voltages upto 650 V (*third revision*)
	13703 (Part 1) : 1993	LV fuses for voltages not exceeding 1 000 V ac or 1 500 dc : Part 1 General requirements
(14)	2672 : 1966	Code of practice for library lighting
	4347 : 1967	Code of practice for hospital lighting
	6665 : 1972	Code of practice for industrial lighting
	8030 : 1976	Specification for luminaires for hospitals
(15)	732 : 1989	Code of practice for electrical wiring installations (*third revision*)
(16)	4648 : 1968	Guide for electrical layout in residential buildings
(17)	900 : 1992	Code of practice for installation and maintenance of induction motors (*second revision*)
(18)	2412 : 1975	Link clips for electrical wiring (*first revision*)
(19)	2667 : 1988	Fittings for rigid steel conduits for electrical wiring (*first revision*)
	3419 : 1989	Fittings for rigid non-metallic conduits (*second revision*)
	9537	Conduits for electrical installations:

IS No.	Title
(Part 1) : 1980	General requirements
(Part 2) : 1981	Rigid steel conduits
(Part 3) : 1983	Rigid plain conduits of insulating materials
14772 : 2000	Specification for accessories for household and similar fixed electrical installations
(20) 1913 (Part 1) : 1978	General and safety requirements for luminaires: Part 1 Tubular fluorescent lamps (*second revision*)
(21) 1258 : 1987	Bayonet lamp holders (*third revision*)
(22) 418 : 1978	Tungsten filament general service electric lamps (*third revision*)
1534 (Part 1) : 1977	Ballasts for fluorescent lamps: Part 1 For switch start circuits (*second revision*)
1569 : 1976	Capacitors for use in tubular fluorescent high pressure mercury and low pressure sodium vapour discharge lamp circuit (*first revision*)
2215 : 1983	Specification for starters for fluorescent lamps (*third revision*)
2418	Specification for tubular fluorescent lamps for general lighting service:
(Part 1) : 1977	Requirements and tests (*first revision*)
(Part 2) : 1977	Standard lamp data sheets (*first revision*)
(Part 3) : 1977	Dimensions of G-5 and G-13 lc-pin caps (*first revision*)
(Part 4) : 1977	Go and no-go gauges for G-5 and G-13 lc-pin caps (*first revision*)
3323 : 1980	Bi-pin lampholders for tubular fluorescent lamps (*first revision*)
3324 : 1982	Holders for starters for tubular fluorescent lamps (*first revision*)
9900	Basic environmental testing procedures for electronic and electrical items:
(Part 1) : 1981	General
(Part 2) : 1981	Cold test
(Part 3) : 1981	Dry heat test
(Part 4) : 1981	Damp test (steady state)
(23) 374 : 1979	Electric ceiling type fans and regulators (*third revision*)
(24) 3043 : 1987	Code of practice for earthing
(25) 8623 (Part 1) : 1993	Specification for low-voltage switchgear and controlgear assemblies: Part 1 Requirements for type-tested and partially type-tested assemblies (*first revision*)
(26) 10028 (Part 2) : 1981	Code of practice for selection, installation and maintenance of transformers: Part 2 Installation
11353 : 1985	Guide for uniform system of marking and identification of conductors and apparatus terminals
(27) 2309 : 1989	Code of practice for the protection of buildings and allied structures against lightning (*second revision*)

NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 3 Air Conditioning, Heating and Mechanical Ventilation

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section deals with various aspects of installation of air conditioning equipments and systems in buildings. The aspects covered include design goals and criteria, design of systems, performance requirements, available system options, pre-planning requirements, noise and vibration, safety aspects, energy conservation and management, building management systems and inspection, installation, testing and commissioning requirements.

Though all aspects of the air conditioning, heating and mechanical ventilation plant have been touched upon in this revision, care has been taken right through to look at them from the specific point of view of how they can be fashioned to impact beneficially on the building as a whole. Thus, topics like pre-planning, safety requirements, adequate provisions for maintenance, energy management, conservation strategies and noise pollution considerations have qualified for special attention.

Space requirements for various air conditioning systems vary considerably with the system adopted. In the scenario of ever-increasing available system options, it has become all the more necessary to consult an air conditioning engineer in this connection at the stage of pre-planning.

Weather data has now been included for as many as 58 stations based on data obtained from India Meteorological Department, Government of India. Till such information is collected for other cities, it is recommended that design work in these cities may be carried out according to the present (local) practice.

The first version of this Part was prepared in 1970 which was subsequently revised in 1983. As a result of experience gained in implementation of 1983 version of this Section and feedback received, a need to revise this Part was felt.

This revision has therefore been prepared. The significant modifications made in this revision include the following:

a) Definitions of several new terms like ozone depletion potential, global warming potential, indoor air quality, sick building syndrome, buildings related illnesses and thermal energy storage have been included.
b) A new clause on design criterion has been incorporated.
c) 'Indoor air quality' has been included as one of the factors that need to be controlled in the conditioned space.
d) For large and multi-storeyed buildings, independent air handling unit rooms have been recommended for each floor.
e) Inside design conditions for various applications have been included; they replace earlier Table 2 and Table 3.
f) The text on minimum outside fresh air has been revised in the light of currently accepted international norms. Recommended values for outside air requirements for ventilation purposes have been furnished for a wider variety and a larger number of applications.
g) New details have been added on temperature, humidity, and vibration and noise.
h) Application considerations, covering a wide variety of commercial applications, offices, hotels, restaurants, computer rooms, etc, have now been given in more details.
j) A new clause on statutory regulation/safety considerations has now been included.
k) Under the clause on design considerations, various system options available have been described.
m) The characteristics and application of options available in piping, water distribution systems and piping layout have been given prominently.
n) The text on air filters has been revised; focus is now on the approach to filtration in preference to a detailed description of ever increasingly available option of filter types.
p) The clause on energy conservation and energy management has been thoroughly revised. The concepts like energy targets, demand targets and consumption targets; the factors to be considered in system

design that influence energy aspects; the need for analysis of operation of systems during various seasons of the year, and the need to incorporate energy recovery strategies have been incorporated in this clause.

q) 'Automatic Controls' given in the 1983 version has now been replaced by Building Management System, which addresses not only the control function, but also has a telling impact on operation and maintenance as well, most importantly on the opportunities afforded to implement various energy conservation strategies.

r) The text on packaged air conditioners and room air conditioners has been revised and elaborated.

s) The text on heating has been completely revised.

t) The text had been thoroughly revised and additional details have been included under Symbols, Units, Colour Code and Identification of Services; Pipe Work Services; Duct Work Services; Valve Labels and Charts; and Inspection, Commissioning and Testing.

u) List of various parameters to be checked for performance of air handling unit, hydronic system balancing, and finally, the hand-over procedure, have been given.

This revision aims to make a difference in the quality of environment and in building usage, in response to growing concerns and expectations in with regard to indoor air quality, energy conservation, environmental impact and building safety.

The provisions on natural ventilation are given in Part 8 'Building Services, Section 1 Lighting and Ventilation'.

The provisions of this Section are without prejudice to the various Acts, Rules and Regulations including the *Factories Act*, 1948 and the rules and regulations framed thereunder.

The information contained in this Section is based largely on the following Indian Standards:

IS No.	*Title*
659 : 1964	Safety code for air conditioning (*revised*)
1391	Specification for room air conditioners:
(Part 1) : 1992	Unitary air conditioners (*second revision*)
(Part 2) : 1992	Split air conditioners (*second revision*)
2379 : 1990	Colour code for identification of pipelines (*first revision*)
3315 : 1994	Specification for evaporative air coolers (desert coolers) (*second revision*)
7896 : 2001	Data for outside design conditions for air conditioning for Indian cities (*first revision*)
8148 : 2003	Specification for packaged air conditioners (*first revision*)

Assistance has also been derived from the following publications in preparation of this Section:

BS 5720 : 1979 Code of practice for mechanical ventilation and air conditioning in building

Guidelines, Standards and Handbooks of American Society of Heating Refrigerating and Air Conditioning Engineers

Handbooks of Indian Society of Heating, Refrigerating and Air Conditioning Engineers

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 3 Air Conditioning, Heating and Mechanical Ventilation

1 SCOPE

This Section covers the design, construction and installation of air conditioning and heating systems and equipment installed in buildings for the purpose of providing and maintaining conditions of air temperature, humidity, purity and distribution suitable for the use and occupancy of the space.

2 TERMINOLOGY

2.0 For the purpose of this Section the following definitions shall apply.

2.1 Air Conditioning — The process of treating air so as to control simultaneously its temperature, humidity, purity, distribution and air movement and pressure to meet the requirements of the conditioned space.

2.2 Atmospheric Pressure — The weight of air column on unit surface area of earth by atmospheric column. At sea level, the standard atmospheric or barometric pressure is 760 mm of mercury (1 033 mm of water column/101.325 kPa).

Generally atmospheric pressure is used as a datum for indicating the system pressures in air conditioning and accordingly, pressures are mentioned above the atmospheric pressure or below the atmospheric pressure considering the atmospheric pressure to be zero. A 'U' tube manometer will indicate zero pressure when pressure measured is equal to atmospheric pressure.

2.3 Buildings Related Illnesses (BRI) — The illness attributed directly to the specific air-borne building contaminants like the outbreak of the Legionnaire's disease after a convention and sensitivity pneumonitis with prolonged exposure to the indoor environment of the building.

Some of the other symptoms relating to BRI are sensory irritation of eyes, ears and throat, skin irritation, headache, nausea, drowsiness, asthma like symptoms in non-asthmatic persons. The economic consequences of BRI is decreased productivity, absenteeism and the legal implications if occupants IAQ complaints are left unresolved.

2.4 Dewpoint Temperature — The temperature at which condensation of moisture begins when the air is cooled at same pressure.

2.5 Dry-Bulb Temperature — The temperature of the air, read on a thermometer, taken in such a way as to avoid errors due to radiation.

2.6 Duct System — A continuous passageway for the transmission of air which, in addition to the ducts, may include duct fittings, dampers, plenums, and grilles and diffusers.

2.7 Enthalpy — A thermal property indicating the quantity of heat in the air above an arbitrary datum, in kilo Joules per kg of dry air (or in Btu per pound of dry air).

2.8 Evaporative Air Cooling — The evaporative air cooling application is the simultaneous removal of sensible heat and the addition of moisture to the air. The water temperature remains essentially constant at the wet-bulb temperature of the air.

2.9 Fire Damper — A closure which consists of a normally held open damper installed in an air distribution system or in a wall or floor assembly and designed to close automatically in the event of a fire in order to maintain the integrity of the fire separation.

2.10 Fire Separation Wall — The wall providing complete separation of one building from another or part of a building from another part of the same building to prevent any communication of fire or heat transmission to wall itself which may cause or assist in the combustion of materials of the side opposite to that portion which may be on fire.

2.11 Global Warming Potential (GWP) — The potential of a refrigerant to contribute to global warming.

Global warming can make our planet and its climate less hospitable and more hostile to human life, thus necessitating reduction in emission of green house gases such as CO_2, SO_x, NO_x and refrigerants. Long atmospheric life time of refrigerants results in global warming unless the emissions are controlled.

GWP values of some of the refrigerants are given below:

Sl No.	*Refrigerant*	*GWP Values*
(1)	(2)	(3)
i)	R-12	10 600
ii)	R-22	1 900
iii)	R-134a	1 600
iv)	R-123	120
v)	R-407c	1 980
vi)	R-407a	2 340
vii)	R-410a	2 340

The values indicated above are for an integration period of 100 years.

2.12 Hydronic Systems — The water systems that convey heat to or from a conditioned space or process with hot or chilled water. The water flows through piping that connects a chiller or the water heater to suitable terminal heat transfer units located at the space or process.

2.13 Indoor Air Quality (IAQ) — Air quality that refers to the nature of conditioned air that circulates throughout the space/area where one works or lives, that is, the air one breathes when indoors.

It not only refers to comfort which is affected by temperature, humidity, air movement and odours but also to harmful biological contaminants and chemicals present in the conditioned space. Poor IAQ may be serious health hazard. Carbon dioxide has been recognized as the surrogate ventilation index.

2.14 Infiltration/Exfiltration — The phenomenon of outside air leaking into/out of an air conditioned space.

2.15 Ozone Depletion Potential (ODP) — The potential of refrigerant or gases to deplete the ozone in the atmosphere.

The ODP values for various refrigerants are as given below:

R-11	1.000
R-12	0.820
R-22	0.050
R-123	0.012
R-134a	0.000
R-407a	0.000
R-407c	0.000
R-410a	0.000

Due to high ODP of R-11, R-12 and R-22, their use in the air conditioning and refrigeration is being phased-out. R-123 is also in the phase-out category of refrigerants.

2.16 Plenum — An air compartment or chamber to which one or more ducts are connected and which forms part of an air distribution system.

The pressure drop and air velocities in the plenum should be low. Generally, the velocity in plenum should not exceed 1.5 m/s to 2.5 m/s.

2.17 Positive Ventilation — The supply of outside air by means of a mechanical device, such as a fan.

2.18 Psychrometry — The science involving thermodynamic properties of moist air and the effect of atmospheric moisture on materials and human comfort. It also includes methods of controlling thermal properties of moist air.

2.19 Psychrometric Chart — A chart graphically representing the thermodynamic properties of moist air.

2.20 Recirculated Air — The return air that has been passed through the conditioning apparatus before being re-supplied to the space.

2.21 Refrigerant — The fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and low pressure of the fluid and rejects heat at a higher temperature and higher pressure of the fluid, usually involving changes of state of the fluid.

2.22 Relative Humidity — Ratio of the partial pressure of actual water vapour in the air as compared to the partial pressure of maximum amount of water that may be contained at its dry bulb temperature.

When the air is saturated, dry-bulb, wet-bulb and dewpoint temperatures are all equal, and the relative humidity is 100 percent.

2.23 Return Air — The air that is collected from the conditioned space and returned to the conditioning equipment.

2.24 Shade Factor — The ratio of instantaneous heat gain through the fenestration with shading device to that through the fenestration.

2.25 Sick Building Syndrome (SBS) — A term, which is used to describe the presence of acute non-specific symptoms in the majority of people caused by working in buildings with an adverse indoor environment. It could be a cluster of complex irritative symptoms like irritation of the eyes, blockened nose and throat, headaches, dizziness, lethargy, fatigue irritation, wheezing, sinusitis, congestion, skin rash, sensory discomfort from odours, nausea, etc. These symptoms are usually short-lived and experienced immediately after exposure; and may disappear when one leaves the building.

SBS is suspected when significant number of people spending extended time in a building report or experience acute on-site discomfort. The economic consequences of SBS, like BRI, are decreased productivity, absenteeism and the legal implications if occupants IAQ complaints are left unresolved.

2.26 Smoke Damper — A damper similar to fire damper, however, having provisions to close automatically on sensing presence of smoke in air distribution system or in conditioned space.

2.27 Static Pressure — The pressure that is required to be created by the fan over the atmospheric pressure

to overcome the system resistances such as resistances in ducts, elbows, filters, dampers, heating/cooling coils, etc.

Static pressure is measured by a U tube manometer relative to the atmospheric pressure, which is considered as zero pressure. In exhaust systems, fan produces negative static pressure, which is again used to overcome the system resistances.

2.28 Supply Air — The air that has been passed through the conditioning apparatus and taken through the duct system and distributed in the conditioned space.

2.29 Supply and Return Air Grilles and Diffusers — Grilles and diffusers are the devices fixed in the air conditioned space for distribution of conditioned supply air and return of air collected from the conditioned space for re-circulation.

2.30 Thermal Transmittance — Thermal transmission per unit time through unit area of the given building unit divided by the temperature difference between the air or some other fluid on either side of the building unit in 'steady state' conditions.

2.31 Thermal Energy Storage — Storage of thermal energy, sensible, latent or combination thereof for use in central system for air conditioning or refrigeration. It uses a primary source of refrigeration for cooling and storing thermal energy for reuse at peak demand or for backup as planned.

2.32 Water Conditioning — The treatment of water circulating in a hydronic system, to make it suitable for air conditioning system due to its effect on the economics of air conditioning plant.

Untreated water used in air conditioning system may create problems such as scale formation, corrosion and organic growth. Appraisal of the water supply source including chemical analysis and determination of composition of dissolved solids is necessary to devise a proper water-conditioning programme.

2.33 Water Hardness — Hardness in water represented by the sum of calcium and magnesium salts in water, which may also include aluminium, iron, manganese, zinc, etc. A chemical analysis of water sample should provide number of total dissolved solids (TDS) in a water sample in parts per million (ppm) as also composition of each of the salts in parts per million.

Temporary hardness is attributed to carbonates and bi-carbonates of calcium and/or magnesium expressed in parts per million (ppm) as $CaCO_3$. The remainder of the hardness is known as permanent hardness, which is due to sulphates, chloride, nitrites of calcium and/or magnesium expressed in ppm as $CaCO_3$.

Temporary hardness is primarily responsible for scale formation, which results in poor heat transfer resulting in increased cost of energy for refrigeration and air conditioning. Permanent hardness (non-carbonate) is not as serious a factor in water conditioning because it has a solubility which is approximately 70 times greater than the carbonate hardness. In many cases, water may contain as much as 1 200 ppm of non-carbonate hardness and not deposit a calcium sulfate scale.

The treated water where hardness as ppm of $CaCO_3$ is reduced to 50 ppm or below, is recommenced for air conditioning applications.

*p*H is a measure of acidity, *p*H is a negative logaritham base 10, of the concentration of hydrogen ion in grams per litre. Water having a *p*H of 7.0 is neutral, a *p*H value less than 7 is acidic and *p*H value greater than 7 is alkaline. Water with *p*H less than 5 is quite acidic and corrosive to ordinary metals and needs to be treated.

2.34 Wet-Bulb Temperature — The temperature registered by a thermometer whose bulb is covered by a wetted wick and exposed to a current of rapidly moving air of velocity not less than 4.5 m/s.

Wet-bulb temperature is indicated by a wet bulb psychrometer constructed and used according to specifications.

3 PLANNING DESIGN CRITERIA

3.1 Fundamental Requirements

3.1.1 The object of installing ventilation and air conditioning facilities in buildings shall be to provide conditions under which people can live in comfort, work safely and efficiently.

3.1.2 Ventilation and air conditioning installation shall aim at controlling and optimizing following factors in the building:

a) Air purity and filtration,
b) Air movement,
c) Dry-bulb temperature,
d) Relative humidity,
e) Noise and vibration,
f) Energy efficiency, and
g) Fire safety.

3.1.3 All plans, specifications and data for air conditioning, heating and mechanical ventilation systems of all buildings and serving all occupancies within the scope of the Code shall be supplied to the Authority, where called for *see* Part 2 'Administration'.

3.1.4 The plans for air conditioning, heating and mechanical ventilation systems shall include all

details and data necessary for review of installation such as:

a) building: name, type and location;
b) owner: name;
c) orientation: north direction on plans;
d) general plans: dimensions and height of all rooms;
e) intended use of all rooms;
f) detail or description of wall construction, including insulation and finish;
g) detail or description of roof, ceiling and floor construction, including insulation and finish;
h) detail or description of windows and outside doors, including sizes, weather stripping, storm sash, sills, storm doors, etc;
j) internal equipment load, such as number of people, motor, heaters and lighting load;
k) layout showing the location, size and construction of the cooling tower (apparatus), ducts, distribution system;
m) information regarding location, sizes and capacity of air distribution system, refrigeration and heating plant, air handling equipment;
n) information on air and water flow rates;
p) information regarding location and accessibility of shafts;
q) information regarding type and location of dampers used in air conditioning system;
r) chimney or gas vent size, shape and height;
s) location and grade of the required fire separations;
t) water softening arrangement; and
u) information on presence of any chemical fumes or gases.

3.2 Pre-planning

3.2.1 *Design Considerations*

3.2.1.1 Cooling load estimate shall be carried out prior to installing air conditioning equipment. Calculation of cooling load shall take into account the following factors:

a) Recommended indoor temperature and relative humidity;
b) Outside design conditions as specified in **4.4**;
c) Details of construction and orientation of exposures like roof, floor, walls, partition and ceiling;
d) Fenestration area and shading factors;
e) *Occupancy* — Number of people and their activity;
f) *Ventilation* — Requirement for fresh air;
g) *Internal Load* — Lighting and other heat generating sources like computers, equipment and machinery; and
h) Hours of use.

3.2.1.2 The design of system and its associated controls shall also take into account the following:

a) Nature of application,
b) Type of construction of building,
c) Permissible control limits,
d) Control methods for minimizing use of primary energy,
e) Opportunities for heat recovery,
f) Energy efficiency,
g) Filteration standard,
h) Hours of use,
j) Diversity factor, and
k) Outdoor air quality.

3.2.1.3 The operation of system in the following conditions should be considered when assessing the complete design:

a) Summer,
b) Monsoon,
c) Winter,
d) Intermediate seasons,
e) Night, and
f) Weekends and holidays.

3.2.1.4 Consideration should be given to changes in building load and the system designed so that maximum operational efficiency is maintained.

3.2.1.5 Special applications like hospitals/operating theatres, computer rooms, clean rooms, laboratories, libraries, museums/art galleries, sound recording studios, shopping malls, etc shall be handled differently.

3.2.2 *Planning of Equipment Room for Central Air Conditioning Plant*

3.2.2.1 In selecting the location for plant room, the aspects of efficiency, economy and good practice should be considered and wherever possible it shall be made contiguous with the building. This room shall be located as centrally as possible with respect to the area to be air conditioned and shall be free from obstructing columns.

In the case of large installations (500 TR and above), it is advisable to have a separate isolated equipment room where possible. The clear headroom below soffit of beam should be minimum 4.5 m for centrifugal plants, and minimum 3.6 m for reciprocating and screw type plants.

3.2.2.2 The floors of the equipment rooms should be light coloured and finished smooth. For floor loading, the air conditioning engineer should be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

3.2.2.3 Supporting of pipe within plant room spaces should be normally from the floor. However, outside plant room areas, structural provisions shall be made for supporting the water pipes from the floor/ceiling slabs. All floor and ceiling supports shall be isolated from the structure to prevent transmission of vibrations.

3.2.2.4 Equipment rooms, wherever necessary, shall have provision for mechanical ventilation. In hot climate, evaporative air-cooling may also be considered.

3.2.2.5 Plant machinery in the plant room shall be placed on plain/reinforced cement concrete foundation and provided with anti-vibratory supports. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement may also be considered.

3.2.2.6 Equipment room should preferably be located adjacent to external wall to facilitate equipment movement and ventilation.

3.2.2.7 Wherever necessary, acoustic treatment should be provided in plant room space to prevent noise transmission to adjacent occupied areas.

3.2.2.8 Air conditioning plant room should preferably be located close to main electrical panel of the building in order to avoid large cable lengths.

3.2.2.9 In case air conditioning plant room is located in basement, equipment movement route shall be planned to facilitate future replacement and maintenance. Service ramps or hatch in ground floor slab should be provided in such cases.

3.2.2.10 Floor drain channels or dedicated drain pipes in slope shall be provided within plant room space for effective disposal of waste water. Fresh water connection may also be provided in the air conditioning plant room.

3.2.2.11 *Thermal energy storage*

In case of central plants, designed with thermal energy storage its location shall be decided in consultation with the air conditioning engineer. The system may be located in plant room, on rooftop, in open space near plant room or buried in open space near plant room.

For roof top installations, structural provision shall take into account load coming due to the same.

For open area surface installation horizontal or vertical system options shall be considered and approach ladders for manholes provided.

Buried installation shall take into account loads due to movement above, of vehicles, etc.

Provision for adequate expansion tank and its connection to thermal storage tanks shall be made.

3.2.3 *Planning Equipment Room for Air Handling Units and Package Units*

3.2.3.1 This shall be located as centrally as possible to the conditioned area and contiguous to the corridors or other spaces for carrying air ducts. For floor loading, air conditioning engineer shall be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

3.2.3.2 In the case of large and multistoried buildings, independent air handling unit should be provided for each floor. The area to be served by the air-handling unit should be decided depending upon the provision of fire protection measures adopted. Air handling unit rooms should preferably be located vertically one above the other.

3.2.3.3 Provision should be made for the entry of fresh air. The fresh air intake shall have louvers having rain protection profile, with volume control damper and bird screen.

3.2.3.4 In all cases air intakes shall be so located as to avoid contamination from exhaust outlets or to the sources in concentrations greater than normal in the locality in which the building is located.

3.2.3.5 Exterior openings for outdoor air intakes and exhaust outlets shall preferably be shielded from weather and insects.

3.2.3.6 No air from any dwelling unit shall be circulated directly or indirectly to any other dwelling unit, public corridor or public stairway.

3.2.3.7 All air handling rooms should preferably have floor drains and water supply. The trap in floor drain shall provide a water seal between the air conditioned space and the drain line.

3.2.3.8 Supply/return air duct shall not be taken through emergency fire staircase. However, exception can be considered if fire isolation of ducts at wall crossings is carried out.

3.2.3.9 Waterproofing of air handling unit rooms shall be carried out to prevent damage to floor below.

3.2.3.10 The floor should be light coloured, smooth finished with terrazzo tiles or the equivalent. Suitable floor loading should also be provided after consulting with the air conditioning engineer.

3.2.3.11 Where necessary, structural design should avoid beam obstruction to the passage of supply and return air ducts. Adequate ceiling space should be made available outside the air handling unit room to permit installation of supply and return air ducts and fire dampers at air handling unit room wall crossings.

3.2.3.12 The air handling unit rooms may be acoustically treated, if located in close proximity to occupied areas.

3.2.3.13 Access door to air handling unit room shall be single/double leaf type, air tight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas. It is desired that access doors in air conditioned spaces should be provided with tight sealing, gaskets and self closing devices for air conditioning to be effective.

3.2.3.14 It should be possible to isolate the air handling unit room in case of fire. The door shall be fire resistant and fire/smoke dampers shall be provided in supply/ return air duct at air handling unit room wall crossings and the annular space between the duct and the wall should be fire-sealed using appropriate fire resistance rated material.

3.2.3.15 For buildings with large structural glazing areas, care should be taken for providing fresh air intakes in air handling unit rooms. Fire isolation shall be provided for vertical fresh air duct, connecting several air handling units.

3.2.4 *Planning of Pipe Shafts*

3.2.4.1 The shafts carrying chilled water pipes should be located adjacent to air handling unit room or within the room.

3.2.4.2 Shaft carrying condensing water pipes to cooling towers located on terrace should be vertically aligned.

3.2.4.3 All shafts shall be provided with fire barrier at floor crossings (*see* Part 4 'Fire and Life Safety').

3.2.4.4 Access to shaft shall be provided at every floor.

3.2.5 *Planning for Supply Air Ducts and Return Air*

3.2.5.1 Duct supports, preferably in the form of angles of mild steel supported using stud anchors shall be provided on the ceiling slab from the drilled hole. Alternately, duct supports may be fixed with internally threaded anchor fastners and threaded rods without damaging the slabs or structural members.

3.2.5.2 If false ceiling is provided, the supports for the duct and the false ceiling, shall be independent. Collars for grilles and diffusers shall be taken out only after false ceiling/boxing framework is done and frames for fixing grilles and diffusers have been installed.

3.2.5.3 Where a duct penetrates the masonry wall it shall either be suitably covered on the outside to isolate it from masonry, or an air gap shall be left around it to prevent vibration transmission. Further, where a duct passes through a fire resisting compartment/barrier, the annular space shall be sealed with fire sealant to prevent smoke transmission (*see also* Part 4 'Fire and Life Safety').

3.2.6 *Cooling Tower*

3.2.6.1 Cooling towers are used to dissipate heat from water cooled refrigeration, air conditioning and industrial process systems. Cooling is achieved by evaporating a small proportion of recirculating water into outdoor air stream. Cooling towers are installed at a place where free flow of atmospheric air is available.

3.2.6.2 Range of a cooling tower is defined as temperature difference between the entering and leaving water. Approach of the cooling tower is the difference between leaving water temperature and the entering air wet bulb temperature.

3.2.6.3 *Types of cooling tower*

3.2.6.3.1 *Natural draft*

This type of tower is larger than mechanical draft tower as it relies on natural convection to obtain the air circulation. A natural draft tower needs to be tall to obtain the maximum chimney effect or rely on the natural wind currents.

3.2.6.3.2 *Mechanical draft*

The fans on mechanical draft towers may be on the inlet air side (forced draft) or exit air side (induced draft). Typically, these have centrifugal or propeller type fans, depending on pressure drop in tower, permissible sound levels and energy usage requirement. On the basis of direction of air and water flow, mechanical draft cooling towers can be counter flow or cross flow type.

3.2.6.4 Factors to be considered for cooling tower selection are:

a) Design wet-bulb temperature and approach of cooling tower.
b) Height limitation and aesthetic requirement.
c) Location of cooling tower considering possibility of easy drain back from the system.
d) Placement with regard to adjacent walls and

windows, other buildings and effects of any water carried over by the air stream.

e) Noise levels, particularly during silent hours and vibration control.

f) Material of construction for the tower.

g) Direction and flow of wind.

h) Quality of water used for make-up.

j) Maintenance and service space.

k) Ambient air quality.

3.2.6.5 The recommended floor area requirement for various types of cooling tower is as given below:

a)	Natural draft cooling tower	0.15 to 0.20 m^2/t of refrigeration
b)	Induced draft cooling tower	0.10 to 0.13 m^2/t of refrigeration
c)	Fibre-reinforced plastic	0.07 to 0.08 m^2/t of refrigeration

3.2.6.6 Any obstruction to free flow of air to the cooling tower shall be avoided.

3.2.6.7 Structural provision for the cooling tower shall be taken into account while designing the building. Vibration isolation shall be an important consideration in structural design.

3.2.6.8 Special design requirements are necessary where noise to the adjoining building is to be avoided.

3.2.6.9 As given below, certain amount of water is lost from circulating water in the cooling tower:

a) *Evaporation loss* — In a cooling tower, the water is cooled by evaporating a part of the circulating water into the air stream. The amount of circulating water so evaporated is called 'evaporation loss'. Usually it is about 1 percent of the rate of water circulation.

b) *Drift loss* — A small part of circulating water is lost from the cooling tower as liquid droplets entrained in the exhaust air stream. Usually the drift loss is 0.1 percent to 0.2 percent of rate of water circulation.

c) *Blow-down/bleed-off* — To avoid concentration of impurities contained in the water beyond a certain limit, a small percentage of water in the cooling water system is often purposely drained off or discarded. Such a treatment is called 'blow-down' or 'bleed-off'. The amount of blow-down is usually 0.8 percent to 1 percent of the total water circulation.

If simple blow-down is inadequate to control scale formation, chemicals may be added to inhibit corrosion and limit microbiological growth.

Provision shall be made to make-up for the loss of circulating water.

3.2.6.10 Provision for make-up water tank to the cooling tower shall be made. Make-up water tank to the cooling tower shall be separate from the tank serving drinking water.

3.2.6.11 Make-up water having contaminants or hardness, which can adversely affect the refrigeration plant life, shall be treated.

3.2.6.12 Cooling tower should be so located as to eliminate nuisance from drift to adjoining structures.

3.2.7 *Glazing*

3.2.7.1 Glazing contributes significantly to heat addition in air conditioned space; measures shall, therefore, be adopted to minimize the gain.

3.2.7.2 While considering orientation of the building, (*see* Part 8 'Building Services, Section 1 Lighting and Ventilation') glazing in walls subjected to heavy sun exposure shall be avoided. In case it is not possible to do so, double glazing or heat resistant glass should be used. Glazing tilted inward at about 12° also helps curtail transmission of direct solar radiation through the glazing.

3.2.7.3 Where sun breakers are used, the following aspects shall be kept in view:

a) The sun breakers shall shade the maximum glazed area possible, specially from the altitude and azimuth angle of the sun, which is likely to govern the heat load.

b) The sun breakers shall preferably be light and bright in colour so as to reflect back as much of the sunlight as possible.

c) The sun breakers shall preferably be 1 m away from the wall face, with free ventilation, particularly from top to bottom and are meant for carrying away the heat which is likely to get boxed between the sun breakers and the main building face.

d) The sun breakers shall be installed as to have minimum conduction of heat from sun breakers to the main building.

3.2.7.4 Where resort is taken to provide reflecting surfaces for keeping out the heat load, care should be taken regarding the hazards to the traffic and people on the road from the reflected light from the surfaces.

3.2.7.5 Day light transmittance for various type of glass is given in Table 1.

Table 1 Day Light Transmittance for Various Types of Glass

Sl No.	Type of Glass	Visible Transmittance W/(m² °C)
(1)	(2)	(3)
i)	3 mm regular sheet or plate glass	0.86 to 0.91
ii)	3 mm grey sheet glass	0.31 to 0.71
iii)	5 mm grey sheet glass	0.61
iv)	5.5 mm grey sheet glass	0.14 to 0.56
	6 mm grey sheet glass	0.52
v)	6 mm green/float glass	0.75
vi)	6 mm grey plate glass	0.44
vii)	6 mm bronze plate glass	0.49
viii)	13 mm grey plate glass	0.21
ix)	13 mm bronze plate glass	0.25
x)	Coated glasses (single, laminated, insulating)	0.07 to 0.50

3.2.8 *Roof Insulation*

3.2.8.1 Under-deck or over-deck insulation shall be provided for exposed roof surface using suitable insulating materials. Over-deck insulation should be properly waterproofed to prevent loss of insulating properties.

3.2.8.2 The overall thermal transmittance from the exposed roof should be kept as minimum as possible and under normal conditions, the desirable value should not exceed 0.58 W/(m² °C).

3.2.8.3 The ceiling surface of floors which are not to be air conditioned may be suitably insulated to give an overall thermal transmittance not exceeding 1.16 W/(m² °C)

4 DESIGN OF AIR CONDITIONING

4.1 General

A ventilation and air conditioning system installed in a building should clean, freshen and condition the air within the space to be air conditioned. This can be achieved by providing the required amount of fresh air either to remove totally or to dilute odours, fumes, etc (for example, from smoking). Local extract systems may be necessary to remove polluted air from kitchens, toilets, etc. Special air filters may be required to remove contaminants or smells when air is recirculated.

It is desirable that access doors to air conditioned space are provided with tight sealing gaskets and self closing devices for air conditioning to be effective.

Positions of air inlets and extracts to the system are most important and care should be taken in their location. Consideration should be given to relatively nearby buildings and any contaminated discharges from those buildings. Inlets should not be positioned near any flue outlets, dry cleaning or washing machine extraction outlets, kitchen, water-closets, etc. When possible, air inlets should be at high level so as to induce air from as clean an area as possible. If low level intakes are used, care should be taken to position them well away from roadways and car parks.

4.2 Design Considerations

4.2.1 *Types of System*

Systems for air conditioning need to control temperature and humidity within predetermined limits throughout the year. Various types of refrigerating systems are available to accomplish the tasks of cooling and dehumidifying, which are an essential feature of air conditioning. Systems for air conditioning may be grouped as all-air type, air and water type, all water type or unitary type.

4.2.1.1 *All-air system*

This type of air conditioning system provides complete sensible and latent cooling, preheating and humidification in the air supplied by the system. Most plants operate on the recirculation principle, where a percentage of the air is extracted and the remainder mixed with incoming fresh air.

Low velocity systems may be used. High velocity systems although require smaller ducts, are high on fan energy, require careful acoustic treatment and higher standards of duct construction.

4.2.1.1.1 *Constant volume system*

Accurate temperature control is possible, according to the system adopted. Low velocity system variations include dehumidification with return air bypass, and multi-zone (hot deck/cold deck mixing). High velocity system may be single or dual duct type.

4.2.1.1.2 *Variable volume system*

Most Indian air conditioning systems operate at partial load for most of the year and the variable air volume (VAV) system is able to reduce energy consumption by reducing the supply air volume to the space under low load conditions. The VAV system can be applied to interior or perimeter zones, with common or separate fans, with common or separate air temperature control. The greatest energy saving associated with VAV occurs at the perimeter zones, where variation in solar and outside temperature allow the supply air quantity to be reduced. Good temperature control is possible but care should be taken at partial load to ensure adequate fresh air supply and satisfactory control of air distribution and space humidity.

4.2.1.2 *Air and water system*

Control of conditions within the space is achieved by initial control of the supply air from a central plant but with main and final control at a terminal unit within the conditioned space. The supply air provides the

by water through a coil in the terminal unit, which can be either a fan coil unit or an induction unit.

Depending on the degree of control required, the water circulating system can be either of two, three or four pipe arrangement. With two pipe circulation a single flow and a single return circulate chilled or hot water as required. Such a system can only provide heating or cooling to the system on a changeover basis, so it is ineffective where wide modulations of conditions over short periods are required. The installed cost however is naturally the lowest of all the circulation systems. The three pipe system is a way of overcoming the disadvantages of the two pipe system without raising the installed cost too high. In this system a separate hot water flow and chilled water flow is taken to the terminal units but a common return is taken from these units to the plant room. The best system from a control point of view is the four pipe system, where separate hot water and chilled water supply and returns are taken from the plant room to the terminal units. Although the most expensive method of circulating the water, it is the only satisfactory one, if reasonable control is required throughout the year.

4.2.1.3 *All water system*

In the simplest layout, the fan coil units may be located against an outside wall with a direct, fresh air connection. A superior arrangement utilizes a ducted, conditioned, fresh air supply combined with mechanical extract ventilation,

Control of unit out put may be achieved by fan speed and water flow/temperature control. Electric power is required at each terminal unit.

Provision of variable volume water flow system for chilled water circulation is recommended for varying load conditions. This may be incorporated with the help of constant volume primary chilled water circuit and variable flow secondary chilled water circuit having pumps with variable speed drives and pressure sensor to control the speed. This system allows better control on energy consumption under partial load conditions due to diversity or seasonal load variations.

4.2.1.4 *Unitary systems*

Such systems are usually those incorporating one or more units or packaged air conditioners having a direct expansion vapour compression refrigeration system. Similar units using chilled water from a central plant would be designated fan coil systems. Most units are only suitable for comfort applications but specially designed units are also available for process and industrial applications.

These normally contain the complete refrigerating system, comprising the compressor, condenser, expansion device and evaporator together with the automatic control panel. The unit can be set down on to a solid foundation on resilient mountings. Pipe connection require flexible couplings; these should be considered in conjunction with the design of the pump mountings and the pipe supports.

Capacity control is normally arranged to maintain an approximately constant temperature of the chilled water leaving the evaporator. This may be adequate for one or two packages, but a more elaborate central control system may be necessary for a large number. The design of the refrigeration control system should be integrated, or be compatible, with the control system for the heat transfer medium circulated to the air cooler.

It is normal for installation to have several water chilling packages, both to provide for stand-by and enable the cooling load to be matched with the minimum consumption of power. Although most packages can reduce capacity to match the cooling demand, the consumption of the power per unit of cooling increases; the resulting drop in efficiency is most serious below one-third capacity.

Power consumption can be reduced by taking advantage of a fall in the ambient temperature, which permits a corresponding fall in the condensing temperature and consequent reduction in the compressor power. It is important, for economy in the operation, that the optimum equipment selection and design of the control system is achieved.

The classification of the water chilling packages is by the type of compressor.

4.2.2.1 *Centrifugal compressors*

These compressors have an impeller that imparts to the refrigerant vapour a high kinetic energy, which is then transformed into pressure energy. For water chilling applications, compressors with one or two stage of compression are used. Two stage units often incorporate an interstate economizer for improving efficiency.

The compressor can be modulated down to approaching 10 percent of full load capacity, with some control of the condensing pressure. Because of the nature of compression process, the flow through the compressor can become unstable if the compressor is called upon to produce a pressure rise in excess of its design limits. This phenomenon, known as surging, is a serious problem but occurs only under a fault condition. Typical faults are excessive fouling of the condenser, a partial failure of the condenser coolant flow or an

accumulation of a non-condensable gas (air) in the condenser. Unchecked surging can lead to damage to the compressor or its drive and does increase the noise level.

The use of low pressure refrigeration to suit the characteristics of the compressor in the smaller size range, means that the evaporator operates at below atmospheric pressure, thus a leak can draw in air and atmospheric moisture. These should be prevented from accumulating, since these interfere with the operation of the plant and cause corrosion.

The compressors may be driven either directly by electric motor or via a speed-increasing gear train. Units are available in 'open' form, that is, compressor and motor are separate items, or in semi-hermetic form where the motor and compressor are contained in a common pressure-tight casing that is bolted together. The latter type eliminates the drive shaft gland seal (a potential point of leakage), which is necessary on the former.

Certain types of open centrifugal compressors could conveniently be directly driven by a steam or gas turbine. This arrangement could be advantageous when the refrigeration plant forms part of total energy system.

The centrifugal compressor type water chilling packages normally include a shell-and-tube water cooled condenser and a flooded shell-and-tube evaporator, but unit are also available incorporating an air cooled condenser The expansion device is commonly an electronic expansion valve or high pressure float regulating valve.

4.2.2.2 *Screw compressors*

Two types of screw compressors are available, that is, single and twin screw, and both are positive displacement machines. Compression of the refrigerant vapour is achieved by the progressive reduction of the volume contained with in the helical flutes of the cylindrical rotor(s) as they rotate.

Oil is injected into the rotor chamber for sealing and lubrication purposes and is removed from the refrigerant discharge gas in an oil separator before the refrigerant passes on to the condenser. No oil separator is 100 percent efficient and so a small quantity of oil always passes through with the refrigerant. On systems using a direct expansion evaporator the oil is trapped in the evaporator and an oil recovery system is necessary.

With some systems oil cooler is required in the oil circulation system, to remove the heat gathered by the oil during compression cycle. On other systems liquid refrigerant is injected into the compressor to remove the heat of compression instead of using the conventional oil cooler. Such an arrangement can impose a small penalty on the plant capacity.

The condenser most commonly used on packaged units is the water cooled shell-and-tube type, but equipment with air cooled condensers is also available. The expansion device used will depend on the evaporator type but it is often a electronic expansion valve (single or in multiple) of conventional or modified form.

Screw compressors are available in open and semi-hermetic form (*see* **4.2.2.1**) and are generally coupled direct to two-pole motors. The capacity of the compressor can be modulated down to 10 percent of full load capacity.

4.2.2.3 *Reciprocating compressors*

These are available in a wide range of sizes and designs. They are almost invariably used in packages up to 120 TR cooling capacity.

Because the cylinders have automatic valves, a single compressor may be used over wide range of operating conditions with near optimum efficiency, whereas other types of compressor require detailed modification to give optimum efficiency at different conditions. This is, however, of minor importance for normal air conditioning duties.

Capacity control is achieved by making cylinders inoperative, usually by propping open the suction valves, thus, capacity reduction is in a series of steps rather than by modulation. Typically, a four-cylinder compressor would be unloaded in four steps. It is therefore necessary to allow for this stepwise operation in designing the chilled water temperature control system.

The evaporator is normally of the dry expansion type, to permit oil from the compressor to circulate round the system with the refrigerant. Shell-and-tube water cooled condensers are common, but any type of condenser can be used. With air cooled condensers it is normal practice to build the machine package so that it may be located on the roof in a package including the condenser.

It is common for the electric drive motors to be built into the compressor assembly; this is known as a 'semi-hermetic' drive to distinguish it from the 'hermetic', in which the compressor and motor are enclosed within a pressure vessel and cannot therefore be serviced.

The semi-hermetic compressor is more compact and is quieter in operation than the 'open' drive compressor, but involves a more difficult service operation in the event of a motor failure. It gains in reliability, however, by avoiding the shaft seal of the 'open' compressor.

It is recommended that multiple hermetic or semi-hermetic compressor unit should not be connected to a common refrigerant system, as failure of one motor can precipitate failure of the others. Separate refrigerant circuits for each compressor should be used.

4.2.3 *Absorption System*

The absorption cycle uses a solution that by absorbing the refrigerant replaces the function of the compressor. The absorbent/refrigerant mixture is then pumped to a higher pressure where the refrigerant is boiled off by the application of heat, to be condensed in the condenser.

Absorption machines are mostly used in liquid-chilling applications. These are most suitable for hotels and hospitals where steam is readily available from the boilers.

4.2.3.1 *Indirect firing*

The lithium bromide/water absorption system can be powered by medium or high temperature hot water and low or medium pressure steam. Water is the refrigerant and the lithium bromide the absorbent. The four compartments enclosing the heat exchanger tube bundles for the condenser, evaporator, generator and absorber can be in a single or multiple pressure vessel arrangement. The whole assembly has to be maintained under a high vacuum, which is essential for the correct functioning of the unit. Water and absorbent solutions are circulated within the unit by electrically driven pumps.

Capacity control down to 10 percent of full load capacity is achieved by modulating the flow of the heating medium in relation to the cooling demand. There is some loss in performance at part load, which can be compensated by refinements in the system design and control.

4.2.3.2 *Direct firing*

Direct fired lithium bromide/water absorption plants have become common, by incorporating precise control of generator temperature necessary to avoid crystallization.

Ammonia/water systems can be and are direct fired, but are rarely used for water chilling duties except for small sized units, which are installed outside the building. There are two reasons or this, firstly capital costs are higher and secondly the danger to personnel in the event of leakage of the refrigerant.

Direct firing has the advantage that the losses in an indirect heating system are avoided, but in an air conditioning installation where a boiler system is installed to provide heating, the advantage is minimal.

4.3 System Design

4.3.1 *Ductwork and Air Distribution*

4.3.1.1 *Materials*

Ductwork is normally fabricated, erected and finished to the requirements in accordance with accepted standard [8-3(1)]. Designers should specify the requirements as appropriate for the velocity and pressure, and materials to be employed. Ductwork is generally manufactured from galvanized steel sheet. Ductwork may also be manufactured from aluminium sheet for applications like operation theatres and intensive care units where stringent cleanliness standards are a functional requirement. Galvanized steel sheets shall be in accordance with the accepted standard [8-3(2)] whereas aluminium sheet shall be in accordance with the accepted standard [8-3(3)]. Where building materials, such as concrete or brick, are used in the formation of airways, the interior surface should be fire resistant, smooth, airtight and not liable to erosion.

4.3.1.2 *Ductwork design*

Design calculations made to determine the size and configuration of ductwork in respect of pressure drop and noise generation should conform to standard methods.

Ductwork design should also take into account the recommendations for fire protection (*see* Part 4 'Fire and Life Safety') relating to the design of air handling system to fire and smoke control in buildings.

4.3.1.3 *Layout consideration*

When designing ductwork, consideration should be given to:

a) Co-ordination with building, architectural and structural requirements;
b) Co-ordination with other services;
c) Simplifying installation work;
d) Providing facilities and access for commissioning and testing;
e) Providing facilities and access for operating and maintenance;
f) Meeting fire and smoke control requirement; and
g) Prevention of vibration and noise transmission to the building/space.

4.3.2 *Piping and Water Distribution System*

4.3.2.1 *Materials*

Steel piping with welded or flanged joints is commonly used. Flanges for flanged joints are welded to pipes. The choice of materials or any installation will be

governed by economic considerations, but care should be taken to minimize the possibility of corrosion when choosing material combinations.

4.3.2.2 *Design principles*

The system design should achieve the following two main objectives:

a) A good distribution of water to the various heat exchangers/cooling coils at all conditions of load. This will be influenced by the method chosen to control the heat transfer capacity of air handling units. Failure to achieve good hydraulic design may lead to difficulties with system balancing. Adequate provision should be made for measuring flow rates and pressure differentials.

b) An economic balance between pipe size and piping cost.

Excessive water velocities should be avoided, as they may lead to noise at pipe junctions and bends.

When multiple water-chilling packages have to be used in a large system, the control of the machines and the arrangement of the water circulation should be considered as an integrated whole. It is not possible to obtain satisfactory result by considering control and system design separately.

Temperature changes in the system lead to changes in the volume of water, which has to be allowed to expand into a suitable expansion tank. It is essential that the point at which the expansion tank is connected into the system be such that it is never shutoff. It is normal practice to locate the expansion tank above the highest point in the system, so that a positive pressure is maintained when all the pumps are stopped; if this is not possible, a closed tank can be installed at a lower level and pressurized by an inert gas. Closed expansion tank with air separator in the chilled water system helps in improving the life and efficiency of chilled water piping and heat exchange equipment.

For central chilled water air conditioning systems, water is the usual heat transfer medium use to convey the heat from the air-handling units to the primary refrigerant in the evaporator. In certain special cases, when temperatures lower than 5°C are required, an anti-freeze such as ethylene glycol may be added to depress the freezing point.

4.3.2.3 *Piping design*

The arrangement of the water piping will depend upon the cooling or heating systems chosen as being the most suitable for the building.

The water velocity normally used are dependent on pipe size but are usually in the range 1 m/s to 3 m/s. Main headers in the plant room are designed for very low velocity around 1 m/s. Noise can be caused by velocities in excess of 4 m/s but this is more likely to be caused by air left in the pipes by inadequate venting. Where materials other than steel are used, erosion can occur at the higher velocities particularly if the water is allowed to become acidic.

Friction factor in piping should not exceed 5 m of water for 100 m of pipe length. The power consumed in circulating the water around the system is proportional to the pressure loss (due to friction) and the flow. It is therefore an advantage to design system with a water temperature rise say 5°C-7°C which results in minimising the flow rate.

Air-conditioning system operate for a large part of the time at less than the design load, and this means that operating costs can be minimized if the water quantity circulated can be reduced at partial load. This should be done with variable speed pumping systems.

4.3.2.4 *Layout considerations*

The layout of the main pipe runs should be considered in relation to the building structure, which will have to support their weight and carry the imposed axial loads. The positioning of expansion joints should be considered in relation to the branches, which may only accommodate small movements. The pumps should not be subjected to excessive loads from the piping.

Provision should be made for venting air and any gas formed by corrosion processes from the high points in the system: failure to do this can lead to restricted water flows and poor performance.

New systems invariably contain debris of one sort or another left during construction, and this can cause trouble by blocking pipes, control valves and pumps if it is not removed during testing and commissioning. Piping system should be designed to permit proper cleaning and flushing and should include suitable strainers at appropriate locations.

4.3.3 *Thermal Insulation*

4.3.3.1 Air conditioning and water distribution systems carry chilled or heated fluids. Thermal insulation is required to prevent undue heat gain or loss and also to prevent internal and external condensation; a vapour seal is essential if there is a possibility of condensation within the insulating materials.

4.3.3.2 The selection of suitable thermal insulating materials requires that consideration be given to physical characteristics as follows:

a) *Fire Properties* — Certain insulating materials are combustible or may, in a fire,

produce appreciable quantities of smoke and noxious and toxic fumes.

b) Materials and their finishes should inherently be proof against rotting, mould and fungal growth, and attack by vermin, and should be non-hygroscopic.

c) Material should not give rise to objectionable odour at the temperature at which they are to be used.

d) The material should not cause a known hazard to health during application, while in use, or, on removal, either from particulate matter or from toxic fumes.

e) It should have a low thermal conductivity throughout the entire working temperature range.

f) It should be non flammable and should not support nor spread fire.

g) It should have good mechanical strength and rigidity otherwise it would have to be cladded for protection.

4.4 Design Conditions

4.4.1 *Temperature*

4.4.1.1 *General consideration*

Certain minimum temperatures may be required depending on type of application and by local regulations. Maximum permitted cooling temperatures may be stipulated by relating to energy conservation.

From the comfort aspect, it is important to take into account the effect of radiant temperature in fixing the desired air temperatures to maintain comfortable conditions.

When large windows/curtain walls are used, it may be necessary to provide shading/north orientation to protect the occupants from solar radiation and to reduce the cooling load on the system. It is not practical to fully compensate for solar heating, owing to its intermittent nature, simply by lowering air temperature.

A person's heat loss, and hence his feeling of comfort, depends not only on the air temperature but also on the radiant heat gain, the air movement and the humidity of the air. Many attempts have been made to devise a single index that combines the effect of two or more of these separate variables. In practice the difference between these indices is small, provided the various parameters do not vary beyond certain limits.

4.4.1.2 *Design temperatures*

It should be noted that, although comfort conditions are established in terms of resultant temperature, the design air temperature for air conditioning should be as specified in this Section in terms of dry-bulb temperature and relative humidity or wet-bulb temperature.

4.4.2 *Humidity*

4.4.2.1 *Comfort considerations*

The controlled temperature levels should also be considered in relation to the humidity of the air. A high humidity reduces evaporative cooling from the body and hence creates the sensation of a higher temperature. Beyond certain limits, however, humidity produces disagreeable sensations.

For normal comfort conditions, relative humidity (RH) values between 40 percent and 70 percent are acceptable.

4.4.3 *Inside Design Conditions*

The inside design conditions for some of the applications are indicated in Table 2.

4.4.4 *Outside Design Conditions*

The outside design conditions (dry-bulb and mean coincidental wet-bulb) taken shall be in accordance with the summary of the conditions given in the Table 3.

Values of ambient dry-bulb and wet-bulb temperatures against the various annual percentiles represent the value that is exceeded on average by the indicated percentage of the total number of hours. The 0.4 percent, 1.0 percent, 2.0 percent values are exceeded on average 35, 88 and 175 h in a year. The 99.0 percent and 99.6 percent values are defined in the same way but are usually reckoned as the values for which the corresponding weather elements are less than the design conditions for 88 h and 35 h, respectively.

Mean coincidental values are the average of the indicated weather element occurring concurrently with the corresponding design value.

After the calculation of design dry-bulb temperatures, the programme located the values of corresponding wet-bulb temperatures from the database for that particular station, the average of these values were computed, which were then called mean of coincidental wet-bulb temperature.

In the same way design wet-bulb temperatures and coincidental dry-bulb temperatures were evaluated.

Selection: The design values of 0.4 percent, 1.0 percent and 2.0 percent annual cumulative frequency of occurrence may be selected depending upon application of air conditioning system.

For normal comfort jobs values under 1 percent column could be used for cooling loads and 99 percent column

Table 2 Inside Design Conditions for Some Applications

(*Clause* 4.4.3)

Sl No.	Category	Inside Design Conditions	
		Summer	Winter
(1)	(2)	(3)	(4)
i)	Restaurants	DB 23 to 26°C RH 55 to 60%	DB 21 to 23°C RH not less than 40%
ii)	Office buildings	DB 23 to 26°C RH 50 to 60%	DB 21 to 23°C RH not less than 40%
iii)	Radio and television studios	DB 23 to 26°C RH 45 to 55%	DB 21 to 23°C RH 40 to 50%
iv)	Departmental stores	DB 23 to 26°C RH 50 to 60%	DB 21 to 23°C RH not less than 40%
v)	Hotel guest rooms	DB 23 to 26°C RH 50 to 60%	DB 23 to 24°C RH not less than 40%
vi)	Class rooms	DB 23 to 26°C RH 50 to 60%	DB 23 to 24°C RH not less than 40%
vii)	Auditoriums	DB 23 to 26°C RH 50 to 60%	DB 23 to 24°C RH not less than 40%
viii)	Recovery rooms	DB 24 to 26°C RH 45 to 55%	
ix)	Patient rooms	DB 24 to 26°C RH 45 to 55%	
x)	Operation theatres	DB 17 to 27°C RH 45 to 55%	
xi)	Museums and libraries	DB 20 to 22°C RH 40 to 55%	
xii)	Telephone terminal rooms	DB 22 to 26°C RH 40 to 50%	

Table 3 Summary for Outdoor Conditions

(*Clause* 4.4.4)

Station	Cooling DB/MCWB						Cooling WB/MCDB						Heating DB/MCWB			
	0.4%		1.0%		2.0%		0.4%		1.0%		2.0%		99.6%		99.0%	
	DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	DB	MCWB	DB	MCWB
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Ahmedabad	42.3	24.1	41.2	23.5	40.0	24.3	28.7	34.3	28.2	33.6	27.8	33.1	11.5	9.0	12.9	9.8
Akola	43.4	24.0	42.2	23.3	41.0	23.6	27.6	37.8	26.7	34.4	26.1	33.5	12.7	10.3	13.9	10.6
Allahabad	43.7	23.4	42.2	23.5	40.8	22.7	28.8	33.0	28.4	32.8	28.0	32.6	7.9	7.0	9.1	8.3
Amritsar	41.6	23.2	40.3	24.6	38.9	24.4	29.3	34.8	28.8	34.8	28.4	33.4	2.7	2.3	4.0	3.5
Aurangabad	40.3	22.1	39.3	22.9	38.3	21.3	26.3	36.2	25.3	33.1	24.7	31.4	10.6	8.2	12.0	9.1
Bangalore	34.7	19.6	34.0	19.6	33.1	19.2	23.5	28.9	22.9	28.2	22.5	27.7	14.9	13.0	15.7	13.8
Barmer	43.1	24.2	42.0	23.6	41.0	23.3	28.5	37.9	27.8	35.3	27.2	33.3	9.5	5.1	10.7	5.5
Belgaum	36.5	19.4	35.7	19.6	34.7	19.2	24.3	29.2	23.8	29.5	23.4	28.2	13.2	11.3	14.3	12.2
Bhagalpur	42.4	26.8	40.7	27.4	38.9	25.6	30.0	37.1	29.6	36.4	29.2	35.2	11.4	10.3	12.6	12.4
Bhopal	41.7	22.0	40.5	21.7	39.3	21.3	26.0	31.0	25.6	30.3	25.2	29.9	9.8	6.8	11.0	8.0
Bhubaneshwar	38.9	25.5	37.6	26.6	36.3	26.3	29.4	35.2	28.9	33.3	28.5	32.7	14.4	13.1	15.4	14.0
Bikaner	44.8	22.4	43.4	22.4	42.0	23.1	28.5	34.6	27.9	33.1	27.3	34.7	3.8	2.2	5.3	3.1
Chennai	38.4	26.2	37.3	26.7	36.3	26.4	29.1	33.8	28.6	33.2	28.1	31.9	19.5	20.2	18.7	19.3
Chitradurg	36.6	18.8	35.8	19.0	35.0	19.6	23.9	28.9	23.5	28.2	23.2	28.5	15.4	12.5	16.4	13.3
Dehradun	37.8	23.5	36.3	23.9	34.8	22.8	27.0	31.3	26.5	30.1	26.0	29.8	5.9	5.0	6.8	5.8
Dibrugarh	34.0	27.4	33.2	26.8	32.3	26.7	28.3	32.6	27.8	31.8	27.4	31.3	7.5	7.2	8.7	8.4
Gorakhpur	41.4	26.2	40.3	26.0	39.1	26.4	29.9	35.2	29.7	35.5	29.4	34.7	7.9	7.5	9.0	8.4
Guwahati	34.4	26.9	33.4	27.3	32.7	26.8	28.8	32.4	28.3	31.8	27.9	31.5	10.2	9.8	11.3	10.8

Table 3 — *Concluded*

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Gwalior	43.9	23.0	42.5	22.9	41.3	23.5	27.9	32.9	27.6	32.4	27.3	32.7	4.9	3.8	6.4	5.3
Hissar	44.7	26.5	43.3	25.8	41.7	27.9	30.1	40.2	29.9	39.0	29.4	36.8	5.0	4.2	6.1	5.2
Hyderabad	40.4	22.5	39.2	22.5	38.2	22.4	25.6	33.7	25.2	32.4	24.8	32.0	14.4	12.4	15.5	12.9
Imphal	31.1	23.3	30.2	23.5	29.6	22.9	25.0	29.5	24.6	28.6	24.3	28.3	3.9	3.6	5.0	4.6
Indore	41.1	20.7	40.4	20.6	38.9	21.0	25.7	31.0	25.2	30.0	24.8	29.8	8.2	5.0	9.7	6.5
Jabalpur	42.6	22.7	41.2	23.2	39.8	22.5	26.8	31.8	26.4	32.0	26.0	31.2	7.8	6.7	9.3	7.6
Jagdelpur	39.4	22.3	38.6	22.5	37.4	22.4	26.4	32.4	25.9	31.8	25.4	30.7	8.9	7.9	10.1	8.7
Jaipur	42.8	22.5	41.4	22.6	39.4	22.6	27.4	33.1	27.0	32.1	26.6	31.7	6.4	4.5	8.0	5.8
Jaisalmer	43.7	23.7	42.5	23.1	41.4	23.5	27.7	34.8	27.3	34.5	26.9	34.4	5.0	2.5	6.5	3.7
Jamnagar	37.1	24.4	36.1	25.6	35.3	25.1	29.2	33.0	28.4	32.5	27.9	32.0	10.0	8.6	11.7	10.5
Jodhpur	42.0	23.2	40.8	23.0	39.6	22.7	28.0	35.4	27.4	33.7	26.9	33.8	7.5	4.3	8.7	5.4
Jorhat	34.4	28.2	33.6	27.7	32.9	27.3	28.7	32.7	28.3	32.1	28.0	31.8	9.6	9.0	10.6	10.1
Kolkata	37.2	25.4	36.2	26.1	35.2	26.5	29.5	34.3	29.0	33.4	28.6	32.7	12.0	10.9	13.1	12.9
Kota	43.5	23.0	42.4	22.6	41.2	22.6	27.3	35.2	26.8	33.0	26.5	31.8	9.9	6.7	10.8	7.6
Kurnool	41.6	23.2	40.3	24.6	38.9	24.4	29.3	34.8	28.8	34.8	28.4	33.4	2.7	2.3	4.0	3.5
Lucknow	42.0	24.2	40.8	24.8	39.3	24.5	28.8	33.3	28.4	32.4	28.0	32.2	7.5	6.8	8.4	7.7
Mangalore	33.9	24.4	33.9	24.0	33.4	24.2	27.1	31.0	26.7	31.0	26.4	30.7	19.7	17.0	20.5	18.1
Mumbai	35.3	22.8	34.3	23.3	33.5	24.0	27.9	31.8	27.5	31.3	27.2	31.1	16.5	13.9	17.8	14.8
Nagpur	43.8	23.6	42.6	23.9	41.4	23.6	27.3	31.2	26.6	33.2	26.2	31.9	11.5	9.4	12.8	10.2
Nellore	40.4	27.8	39.0	28.1	37.8	27.2	30.0	37.1	29.4	35.4	28.8	34.0	19.4	18.3	20.2	19.3
New Delhi	41.8	23.6	40.6	23.8	39.4	23.5	28.4	33.3	28.0	33.3	27.6	32.7	6.0	5.2	7.1	6.3
Panjim	34.0	24.8	33.5	25.2	33.0	25.2	27.7	32.3	27.4	31.5	27.0	30.9	19.6	17.8	20.3	18.7
Patna	40.7	23.4	39.5	23.7	38.0	24.7	29.0	33.9	28.6	33.1	28.3	32.6	8.0	7.6	9.2	8.6
Pune	38.4	20.5	37.4	20.4	36.3	20.6	24.8	30.9	24.4	30.6	24.0	29.6	9.2	8.0	10.3	9.2
Raipur	43.6	23.3	42.2	23.3	40.8	23.0	27.1	31.8	26.8	32.0	26.5	31.2	11.3	9.9	12.6	10.4
Rajkot	40.8	23.1	39.9	23.8	38.9	23.4	28.1	33.9	27.6	33.3	27.1	32.3	10.9	6.5	12.2	7.7
Ramagundam	43.4	25.6	42.2	25.1	40.7	25.8	28.3	37.3	27.9	35.6	27.4	34.4	12.5	11.2	13.7	12.5
Ranchi	38.9	22.1	37.7	21.8	36.4	21.5	26.2	31.7	25.6	30.4	25.2	29.2	9.1	7.2	10.4	8.3
Ratnagiri	34.1	22.4	33.4	23.2	32.8	23.6	27.6	31.1	27.3	30.8	27.0	30.2	18.3	14.9	19.2	16.5
Raxaul	38.6	23.1	36.9	24.5	35.5	24.6	28.9	33.0	28.4	32.0	28.1	31.8	7.5	7.3	8.5	8.2
Saharanpur	41.3	23.8	39.6	24.6	38.1	24.0	28.5	33.6	28.1	32.9	27.8	32.5	1.7	1.5	3.0	2.7
Shillong	24.2	19.7	23.5	19.4	22.8	18.9	20.7	23.3	20.3	22.7	19.9	22.2	–1.0	–1.1	0.1	–0.5
Sholapur	41.1	21.6	40.1	21.6	39.1	21.2	26.6	32.6	25.8	32.1	25.1	31.5	16.3	12.4	17.2	12.5
Sundernagar	36.1	19.1	34.6	19.9	33.1	19.4	25.2	30.1	24.8	29.2	24.4	28	1.8	1.3	2.8	2.2
Surat	38.4	22.7	36.9	23.9	35.7	23.4	28.3	32.4	27.9	31.7	27.6	31.4	14.8	12.6	16.2	12.5
Tezpur	34.2	27.4	33.3	26.5	32.5	27.1	28.9	32.8	28.4	31.8	28.0	31.4	10.5	10.0	12.4	10.9
Tiruchirapalli	39.6	24.6	38.7	25.1	37.8	24.9	27.7	34.5	27.2	33.7	26.9	33.3	19.3	18.2	20.1	18.7
Thiruvananthapuram	33.9	26.0	33.4	26.1	32.9	25.9	27.7	32.4	27.4	31.9	27.0	31.0	21.6	20.1	22.2	20.8
Veraval	35.2	23.9	33.8	23.5	32.8	26.6	29.1	32.3	28.7	31.6	28.4	31.1	14.3	10.1	15.6	12.3
Visakhapatnam	36.4	26.5	35.6	27.3	35.0	27.1	29.2	33.8	28.8	33.0	28.4	32.5	15.4	14.9	16.8	16.2

NOTE — Abbreviations used:

DBT — Dry-bulb temperature
WBT — Wet-bulb temperature
MCDB — Mean coincidental dry-bulb temperature
MCWB — Mean coincidental wet-bulb temperature.

for heating loads. For critical applications values under 0.4 percent column could be used for cooling loads and 99.6 percent column for heating loads.

For critical jobs and high energy consumption applications, hourly load analysis should be evaluated using computer programmes.

For industrial and other specific applications, the design conditions shall be as per user's requirement.

Adequate movement of air shall always be provided in an air conditioned enclosure, but velocities in excess of 0.5 m/s in the zone between floor level and 1.5 m level shall generally be avoided; in the case of comfort air conditioning, recommended air velocity is 0.13 m/s to 0.23 m/s in this zone, except in the vicinity of a supply or return air grille.

4.4.5 *Minimum Outside Fresh Air*

The fresh air supply is required to maintain an acceptably non-odorous atmosphere (by diluting body odorous and tobacco smoke) and to dilute the carbon dioxide exhaled. This quantity may be quoted per person and is related to the occupant density and activity within the space. Table 4 gives minimum fresh air supply rates for mechanically ventilated or air conditioned space. The quantity and distribution of introduced fresh air should take into account the natural infiltration of the building.

Table 4 specifies requirements for ventilation air quantities for 100 percent outdoor air when the outdoor air quality meets the specifications for acceptable outdoor air quality. While these quantities are for 100 percent outdoor air, they also set the amount of air required to dilute contaminants to acceptable levels. Therefore, it is necessary that at least this amount of air be delivered to the conditioned space at all times the building is in use.

The proportion of fresh air introduced into a building may be varied to achieve economical operation. When the fresh air can provide a useful cooling effect the quantity shall be controlled to balance the cooling demand. However, when the air is too warm or humid the quantity may be reduced to a minimum to reduce the cooling load.

For transfer of heat/moisture, air circulation is required to transfer the heat and humidity generated within the building. In simple systems the heat generated by the occupants, lighting, solar heat and heat from electrical and mechanical equipment may be removed by the introduction and extraction of large quantities of fresh air. In more elaborate systems air may be re-circulated through conditioning equipment to maintain the desired temperature and humidity. The air circulation rates are decided in relation to the thermal or moisture loads and the practical cooling and heating range of the air.

4.4.6 *Air Movement*

a) *In air conditioned spaces* — Air movement is desirable, as it contributes a feeling of freshness, although excessive movement should be avoided as this leads to complaints of draughts. The speed of an air current becomes more noticeable as the air temperature falls, owing to its increased cooling effect. The design of the air distribution system therefore has a controlling effect of the quantity and temperature of the air that may be introduced into a space. The quantity of fresh air should not be increased solely to create air movement; this should be effected by air re-circulation within the space or by inducing air movement with the ventilation air system.

b) *In buildings* — Air flow within a building should be controlled to minimize transfer of fumes and smells, for example from kitchens to restaurants and the like. This is achieved by creating air pressure gradients within the building, by varying the balance between the fans introducing fresh air and those extracting the stale air. For example, the pressure should be reduced in a kitchen below that of the adjacent restaurant.

Care should be taken, however, to avoid excessive pressure differences that may cause difficulty in opening door or cause them to slam. In other cases, such as computer room, the area may be pressurized to minimize the introduction of dust from adjacent areas.

4.4.6.1 *Fire and smoke control*

Air circulation system may be designed to extract smoke in event of a fire, to assist in the fire fighting operation and to introduce fresh air to pressurize escape routes.

4.4.6.2 *Removal of particulate matter from air*

Efficient air filtration prevents fouling of the system and is of special importance in urban areas, where damage is likely to be caused to decorations and fittings by discoloration owing to airborne dust particles. In order to obtain maximum filtration efficiency within the minimum capital and maintenance expenditure, the utmost care should be given to the location of the air intake in relation to the prevailing wind, the position of chimneys and the relative atmospheric dust concentration in the environs of the building; the recommendation for siting of air inlets given in **4.1**

Table 4 Outdoor Air Requirements for Ventilation[1] of Air Conditioned Areas and Commercial Facilities

(*Clause* 4.4.5)

Sl No.	Application	Estimated Maximum[2] Occupancy	Outdoor Air Requirement		Remarks
		Persons/100 m^2	l/s/Person	(l/s)/m^2	
(1)	(2)	(3)	(4)	(5)	(6)
i)	**Commercial dry cleaner**	30	15		
ii)	**Food and Beverage Service**				
	Dining rooms	70	10		
	Cafeteria, fast food	100	10		
	Bars, cocktail lounges	100	15		Supplementary smoke removal equipment may be required.
	Kitchen (cooking)	20	8		Make up air for food exhaust may require more ventilating air. The sum of the outdoor air and transfer air of acceptable quality from adjacent spaces shall be sufficient to provide an exhaust rate of not less than 27.5 $m^3/h.m^2$ (7.5 $l/s.m^2$).
iii)	**Hotels, Motels, Resorts, Dormitories**				Independent of room size.
	Bedrooms		15		
	Living rooms			15	
	Baths			18	Installed capacity for intermittent use.
	Lobbies	30	8		
	Conference rooms	50	10		
	Assemble rooms	120	8		
	Dormitory sleeping areas	20	8		*See also* food and beverage services, merchandising, barber and beauty shops, garages, offices.
	Office space	7	10		Some office equipment may require local exhaust.
	Reception areas	60	8		
	Telecommunication centers and data entry areas	60	10		
	Conference rooms	50	10		
iv)	**Public Spaces**				
	Corridors and utilities			0.25	
	Public restrooms, l/s/wc or urinal		25		Normally supplied transfer air.
	Locker and dressing rooms			2.5	Local mechanical exhaust with no re-circulation recommended.
	Elevators			5.0	Normally supplied by transfer air.
	Retail stores, sales floors and show room floors				
	Basement and street	30		1.50	
	Upper floors	20		1.00	
	Storage rooms	15		0.75	
	Dressing rooms			1.00	
	Malls and arcades	20		1.00	
	Shipping and receiving	10		0.75	
	Warehouses	5		0.25	
	Smoking lounge	70	30		Normally supplied by transfer air, local mechanical exhaust; exhaust with no re-circulation recommended.
v)	**Specialty Shops**				
	Barber Shop	25	8		
	Beauty Parlour	25	13		
	Florists	8	8		Ventilation to optimize growth may dictate requirements.
	Clothiers, furniture			1.50	
	Hardware, drugs, fabric	8	8		
	Supermarkets	8	8		
	Pet shops			5.00	
vi)	**Sports and Amusement**				
	Spectator areas	150	8		When internal combustion engines are operated for maintenance of playing surfaces, increased ventilation rates may be required.
	Game rooms	70	13	2.50	
	Ice arenas (playing areas)				

Table 4 — *Concluded*

(1)	(2)	(3)	(4)	(5)	(6)
	Swimming pools (pool and deck area)			2.50	Higher values may be required for humidity control.
	Playing floors (gymnasium)	30	10		
	Ballrooms and discos	100	13		
	Bowling alleys (seating area)	70	13		
vii)	**Theatre**				
	Ticket booths	60	10		
	Lobbies	150	10		Special ventilation will be needed to eliminate special stage effects (for example, dry ice vapours, mists, etc).
	Auditorium	150	8		
	Stages, studios	70	8		
viii)	**Transportation**				
	Waiting rooms	100	8		
	Platforms	100	8		Ventilation within vehicles may require special consideration.
	Vehicles	150	8		
ix)	**Workrooms**				
	Meat processing	10	8		Spaces maintained at low temperature at (–10°F to + 50°F or –23°C to + 10°C) are not covered by these requirements unless the occupancy is continuous. Ventilation from adjoining spaces is permissible. When the occupancy is intermittent, infiltration will normally exceed the ventilation requirement.
	Photo studios	10	8		
	Darkrooms	10		2.50	
	Pharmacy	20	8		
	Bank vaults	5	8		
	Duplicating, printing			2.50	Installed equipment shall incorporate positive exhaust and control (as required) of undesirable contaminants (toxic and otherwise).
x)	**Education**				
	Classrooms	50	8		
	Laboratories	30	10		Special contaminant control systems may be required for processes or functions including laboratory animal occupancy.
	Training shop	30	10		
	Music rooms	50	8		
	Libraries	20	8		
	Locker rooms			2.50	
	Corridors			0.50	
	Auditoriums	150	8		
xi)	**Hospital, Nurses and Convalescent Homes**				
	Patient rooms	10	13		Special requirements or codes provisions and pressure relationships may determine minimum ventilation rates and filter efficiency.
	Medical procedure	20	8		
	Operating rooms	20	15		
	Procedure Recovery and ICU		20	8	Generating contaminants may require higher rates.
	Autopsy			2.50	Air shall not be re-circulated into other spaces.
	Physical therapy	20	8		
	Correctional Cells	20	10		
	Dining halls	100	8		
	Guard stations	40	8		

[1] This table prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.

[2] Net occupiable space.

should also be taken into account. Air filtration equipment should be regularly serviced.

Air borne dust and dirt may be generated within the building, from the interior finishes such as partitions, laminations, carpets, upholstery, etc, personnel and their movements as well as by machines such as, printers and fax machines.

The degree of filtration necessary will depend on the use of the building or the conditioned space. Certain specialized equipment, normally associated with computers, will require higher than normal air filter efficiencies for satisfactory operation. It is important to ascertain the necessary standard of air cleanliness required for equipment of this type.

The choice of filtration systems will depend on the degree of contamination of the air and on the cleanliness required. A combination of filter types may well give the best service and the minimum operating costs.

The normal standard for intake filters in ventilating and air conditioning applications is an efficiency of 95 percent for a particle size up to 15 μm although there may be a requirement for a higher efficiency to give increased protection against atmospheric staining.

Special applications, such as computer server rooms, clean rooms, healthcare, pharmaceutical or food processing, and air systems having induction units, require a higher standard that is achieved by two stage filtration. The exact requirements will depend on the equipment or process involved.

4.4.6.3 *Removal of fumes and smells from air*

Fumes and smells may be removed from air by physical or chemical processes. These may be essential when ambient air is heavily polluted.

The decision to use odour-removing equipment will normally be made on economic grounds, this may become necessary by the currently rising cost of fuel. Once such equipment is installed, it has to be regularly serviced to ensure satisfactory performance. Failure to do this may result in unacceptable conditions within the building.

4.5 Statutory Regulation and Safety Considerations

4.5.1 *Authorities and Approval of Schemes*

A ventilation or air conditioning system should comply with the requirements laid down in the current statutory legislation or any revisions currently in force and consideration should also be given to any relevant insurance company requirements.

4.5.2 *Fire and Safety Considerations*

Fire protection requirements of air conditioning systems shall be in accordance with Part 4 'Fire and Life Safety'.

4.5.2.1 *Design principles*

The design of air conditioning system and mechanical ventilation shall take into account the fire risk within the building, both as regards structural protection and means of escape in case of fire.

The extent and detail of statutory control and other specialist interest may vary considerably according to the design, use, occupation and location of the building, and the type of system of mechanical ventilation and air conditioning proposed. It is therefore particularly important that the appropriate safeguards are fully considered at the concept design stage of the building.

The degree of control and the requirements vary according to the application.

Full details may have to be approved by the Authority in following cases:

a) From the point of view of the means of escape (except dwelling houses) where recirculation of air is involved and/or where pressurized staircases are contemplated as part of the smoke control arrangements;

b) Places of public entertainment; and

c) Large car parks, hotels, parts of building used for trades or processes involving a special risk, and departmental stores and similar shop risks in large buildings.

4.5.2.2 *Ductwork and enclosures*

All ductwork including connectors fittings and plenums should be constructed of steel, aluminium or other approved metal or from non-combustible material. All exhaust ducts, the interior of which is liable in normal use to accumulate dust, grease or other flammable matter, should be provided with adequate means of access to facilitate cleaning and inspection. Also, the concerned provisions of Part 4 'Fire and Life Safety' shall be complied with.

4.5.2.3 *Thermal and acoustic insulation*

To reduce the spread of fire or smoke by an air conditioning system, care should be taken for the choice of materials used for such items as air filters, silencers and insulation both internal and external (*see* Part 4 'Fire and Life Safety' and Part 5 'Building Materials').

4.5.2.4 *Fire and smoke detection*

When the system involves the recirculation of air, consideration should be given to the installation of detection devices that would either shut off the plant and close dampers or discharge the smoke-laden air to

atmosphere. Detectors may be advisable in certain applications even when the system is not a recirculatory one. Exhausts should not be positioned near the fire escapes, main staircases or where these could be a hindrance to the work of fire authorities. The local fire authorities should be consulted.

A careful study of the operating characteristics of each type of sensing device should be made before selection. Smoke detectors are normally either of the optical or ionization chamber type. These can be used to either sound an alarm system or operate a fire dampers. Care should be taken with their location as various factors affect the satisfactory operation.

Ionization type detectors are sensitive to high velocity air streams and if used in ductwork the manufacturer should be consulted. Activation of smoke detector should stop the air handling unit supply air fan, close the fire damper in supply and return air duct and operate a suitable alarm system.

In all the above instances the appropriate controls would require manual re-setting.

4.5.2.5 *Smoke control*

While it is essential that the spread of smoke through a building to be considered in the design of air conditioning systems for all types of applications, it assumes special significance in high rise buildings, because the time necessary for evacuation may be greater than the time for the development of untenable smoke conditions on staircases, in lift shafts and in other parts of the building far away from the fire. Lifts may be filled with smoke or unavailable, and, if mass evacuation is attempted, staircase may be filled with people.

One or more escape staircase connecting to outdoors at ground level, should be pressurized, to enable mass evacuation of high rise buildings (*see also* Part 4 'Fire and Life Safety').

Therefore all air handling systems of a building should be designed with fire protection and smoke control aspects incorporating, where appropriate, facilities to permit their operation for the control of smoke within the building in event of fire.

The pressurization systems for staircases use large volumes of outside air. The system may be designed to operate continuously at low speed, being increased to high speed in the event of fire, or to operate only in emergency. Noise and droughts are not considered a problem in an emergency situation. Fan motor and starter should be protected from fire and connected to the emergency electrical supply through cables with special fire resistant coating (*see also* Part 4 'Fire and Life Safety').

4.6 Application Factors

4.6.1 *General*

This clause gives general guidance, for various applications, for the factors that usually influence the selection of the type, design and layout of the air conditioning or ventilating system to be used.

4.6.1.1 *Commercial applications*

The primary objective of the application described under this heading is provision of comfort conditions for occupants.

4.6.1.2 *Offices*

Office building may include both external and internal zones.

The external zone may be considered as extending from approximately 4 m to 6 m inwards from the external wall, and is generally subjected to wide load variation owing to daily and annual changes in outside temperature and solar radiation. Ideally, the system(s) selected to serve an external zone should be able to provide summer cooling and winter heating. During intermediate seasons the external zone of one side of the building may require cooling and at same time the external zone on another side of the building may require heating. The main factors affecting load are usually window area and choice of shading devices. The other important factors are the internal gain owing to people, light and office equipment. Choice of system may be affected by requirements to counteract down draughts and chilling effect due to radiation associated with single glazing during winter.

Internal zone loads are entirely due to heat gain from people, lights and office equipment, which represent a fairly uniform cooling load throughout the year.

Other important considerations in office block applications may include requirements for individual controls, partitioning flexibility serving multiple tenants, and requirement of operating selected areas outside of normal office hours. Areas such as conference rooms, board rooms, canteens, etc, will often require independent systems.

For external building zones with large glass areas, for example, greater than 60 percent of the external façade, the air-water type of system, such as induction or fan coil is generally economical than all air systems and has lower space requirements. For external zones with small glass areas, an all air system, such as variable volume, may be the best selection. For building with average glass areas, other factors may determine the choice of system.

For internal zones, a separate all-air system with volume control may be the best choice. Systems

employing reheat or air mixing, while technically satisfactory, are generally poor as regards energy conservation.

4.6.1.3 *Hotel guest rooms*

In ideal circumstances, each guest room in a hotel or motel should have an air conditioning system that enables the occupant to select heating or cooling as required to maintain the room at the desired temperature. The range of temperature adjustment should be reasonable but, from the energy conservation view point, should not permit wasteful overcooling or overheating.

Guest room systems are required to be available for operation on a continuous basis. The room may be unoccupied for most of the day and therefore provision for operating at reduced capacity, or switching off, is essential. Low operating noise level, reliability and ease of maintenance are essential. Treated fresh air introduced through the system is generally balanced with the bathroom extract ventilation to promote air circulation into the bathroom. In tropical climates, where the humidity is high an all-air system with individual room reheat (and/or recool) may be necessary to avoid condensation problems. Fan coil units are generally found to be most suitable for this kind of application with speed control for fan and motorised/modulating valve for chilled water control for cooling.

4.6.1.4 *Restaurants, cafeteria, bars and night-clubs*

Such applications have several factors in common; highly variable loads, with high latent gains (low sensible heat factor) from occupants and meals, and high odour concentrations (body, food and tobacco smoke odours) requiring adequate control of fresh air extract volumes and direction of air movement for avoidance of draughts and make up air requirements for associated kitchens to ensure an uncontaminated supply.

This type of application is generally best served by the all-air type of system preferably with some reheat or return air bypass control to limit relative humidity. Either self-contained packaged units or split systems, or air-handling unit served from a central chilled system may be used. Sufficient control flexibility to handle adequately the complete range of anticipated loads is essential.

4.6.1.5 *Department stores/shops*

For small shops and stores unitary split type air conditioning systems offer many advantages, including low initial cost, minimum space requirement and ease of installation.

For large department stores a very careful analysis of the location and requirement of individual department is essential as these may vary widely, for example, for lighting departments, food halls, restaurants, etc. some system flexibility to accommodate future changes may be required.

Generally, internal loads from lighting and people predominate. Important considerations include initial and operating costs, system space requirements, ease of maintenance and type of operating personnel who will operate the system.

The all-air type of system, with variable volume distribution from local air handling units, may be the most economical option. Facilities to take all outside air for 'free-cooling' under favourable conditions should be provided.

4.6.1.6 *Theatres/Auditoria*

Characteristics of this type of application are buildings generally large in size, with high ceiling, low external loads, and high occupancy producing a high latent gain and having low sensible heat factor. These give rise to the requirements of large fresh air quantities and low operating noise levels. Theatres and auditoria may be in use only a few hours a day.

4.6.1.7 *Special applications*

4.6.1.7.1 *Hospitals/Operating theatres*

In many cases proper air conditioning can be a factor in the therapy of the patient and in some instances part of the major treatment. For special application areas of hospitals such as operation theatres, reference may be made to specialist literature.

The main difference in application compared with other applications are:

a) Restriction of air movement between various departments and control of air movement within certain departments, to reduce the risk of airborne cross infection;

b) Specific need for the ventilation and filtration equipment to dilute and/or remove particulate or gaseous contamination and airborne micro-organisms;

c) Close tolerances in temperatures and humidities may be required for various areas; and

d) The design should allow for accurate control of environmental conditions.

For (a) and (b) the air movement patterns should minimize the spread of contaminants as for instance, in operating departments where the air flow should be such as to reduce the risk of periphery or floor-level

air returning to the patient owing to secondary air currents whilst the general pressurization pattern should cause air to flow through the department from sterile to less sterile rooms in progression. In operating theatres 100 percent fresh air system is normally provided and air pressures in various rooms are set by use of pressure stabilizers. Many types of air distribution pattern within operation theatres are in use but generally they conform to high-level supply and low-level pressure relief or exhaust. There is also need for a separate scavenging system for exhaled and waste anaesthetic gases with in theatre suites where general anaesthetic may be administered.

When zoning air distribution systems to compensate for building orientation and shape, consideration should be given to ensure that the mixing of air from different departments is reduced to a minimum. This can be accomplished by the use of 100 percent conditioned fresh air with no re-circulation or, where re-circulation is employed, by providing separate air handling systems for different departments based on the relative sensitivity of each to contamination. A degree of stand-by is provided by this system so that breakdown will affect only a limited section of the hospital.

Laboratories and other areas dealing with infectious diseases or viruses, and sanitary accommodation adjacent to wards, should be at a negative air pressure compared to any other area to prevent exfiltration of any airborne contaminants. In extreme cases any exhaust to atmosphere from these areas has to pass through high efficiency sub-micron particulate air (HEPA) filters.

4.6.1.7.2 *Computer rooms*

The equipment in computer rooms generates heat and contains components that are sensitive to sudden variations of temperature and humidity. These are sensitive to the deposition of dust. Exposure beyond the prescribed limits may result in improper operation or need for shut-down of the equipment. The temperature and humidity in computer rooms need to be controlled within reasonably close limits, although this depends on the equipment involved. The relative humidity may be controlled within + 5 percent in the range 40 percent to 60 percent. Manufacturers normally prescribe specific conditions to be maintained. Typical conditions are air dry-bulb: 21 ± 1.6°C; relative humidity 50 ± 5 percent; and filtration 90 percent down to 10 microns.

A low velocity re-circulation system may be used with 5 percent to 10 percent fresh air make-up which is allowed to exfiltrate from the room and ensure a positive pressure to prevent entry of dust and untreated air. The air distribution should be zoned to minimize temperature variations owing to fluctuation in heat load. Overhead air supply through ceiling plenums utilizing linear diffuser or ventilated ceilings is eminently suited to computer room application, permitting high air change rates to be achieved without undue discomfort to personnel.

The air conditioning system should be reliable because failure to maintain conditions for even a short duration can cause substantial monetary loss and possibly more serious consequence. As such standby equipment is recommended.

4.6.1.8 *Residential buildings*

Very few residences are air conditioned. Some individual houses have unitary systems comprising of window/split air conditioners. Some large houses have VRV based splits and some luxury block of flats are provided with air-water systems. VAV also works well for some luxury applications with chilled water applications. In the latter case, most of the considerations of **4.6.1.3** apply.

5 NOISE AND VIBRATION CONTROL

5.1 General

Noise is unwanted sound. All ventilating and air conditioning systems will produce noise, and this may cause annoyance or disturbance in:

a) the spaces being treated;
b) other rooms in the building;
c) the environment external to the building.

In the case of external environment particular care should be taken to avoid a nuisance in the 'silent' hours, and local authorities have statutory powers to ensure that noise from plant is limited.

It is important that expert advice be sought in dealing with noise and vibration problems, as for obvious reasons the most economical solutions should be used, without impairing the performance.

5.2 Types of Noise in Building

5.2.1 *Externally Created Noise*

Reduction of externally created noise is mainly dealt with by choice of building profile and window construction. The air conditioning designer should, however, ensure that noise does not enter via air inlets or exhausts: it may be reduced by suitable attenuators.

5.2.2 *Generated Noise*

Noise produced by the components of air conditioning and ventilation plant installed within the building can escape via ventilation grilles or door openings and can cause nuisance to neighbours. Equipment mounted

outside the building may well need to be selected or installed with the noise problem in mind.

Another type of generated noise is created by the air-circulating system itself and its associated equipment. Fans are an obvious source, but noise can be produced by turbulence, which may cause vibration of the ducts and noise transmission by air diffusers. This problem can be avoided by careful selection of and installation equipment or by the noise absorbing devices.

5.2.3 *Transmitted Noise*

Noise transmitted through the building structure is particularly acute in modern frame and reinforced concrete buildings. Such noise can be controlled by isolating the machines from the structures, and from pipe work connected to the building, by suitable mountings and pipe couplings.

Another problem is the transmission of sound from one room to another via air ducting, ventilated ceilings or other continuous air space. Such sound includes the noise from machines and equipment and also of conversation, transmission of which can be embarrassing as well as annoying. Again, this problem can be tackled by careful design and the inclusion of sound absorbing devices in ducts.

5.2.4 *Intermittent Noise*

Such noise arises from the stopping and starting of equipment, and the opening and closing of valves and dampers. This may or may not cause problems in the air conditioned spaces, but it is often objectionable to plant operators and maintenance engineers. This should be considered by air conditioning designer.

5.3 The source of noise in the air conditioning system could be from the following:

a) Chillers,
b) Pumps,
c) Pipe supports,
d) Ducts,
e) External noise in filteration though openings,
f) Fans,
g) Air noise through ducts, and
h) Compressors.

5.4 The approach must always be to reduce the source noise rather than controlling them in the path

5.5 Noise Control

5.5.1 *From Room Air Conditioners (RAC)*

The following measures should be adopted:

a) Selection of RAC which has the least noise at various fan speeds.
b) Install it at a serviceable height.
c) Install preferably in a wall or on a rigid window.
d) Provide only necessary slope as specified by the manufacturer, to avoid any unusual noise from the compressor because of tilting.
e) Install it preferably in the middle portion of the wall/window to avoid additional directivity (do not install at the end of a wall.
f) Ensure all leaks are sealed properly.
g) Avoid condenser facing any high noisy areas, such as road/factory to avoid any such noise predominantly entering into the room.
h) Do not provide any props at the back side bottom of the air conditioner unless specified by the manufacturer.
j) Prepare the opening to suit the chassis with wooden frame of adequate rigidity and thickness.

5.5.2 *From Split Air Conditioner/Furred Inn*

The following measures should be adopted:

a) Install the evaporator only on a rigid wall/ ceiling or on a pedestal.
b) Avoid installation over wooden/gypsum board partition. Should a need arise anchor the evaporator rigidly by using mild steel frame work from the roof to avoid vibration.
c) Provide proper 'u' trap in the condensate water line to ensure a good water seal, which will also avoid sound penetration into the room from outside.
d) If the capillary is in the evaporator, ensure that flow noise is avoided.
e) Ensure proper return air entry back to the coil, since blowers working at higher *static pressure* will create higher noise.
f) Select the condensers with top/side discharge depending upon location to avoid nuisance to neighbours.
g) Place condensers on rigid platform, properly supported propped and fixed firmly.
h) Ensure all screws, bolts and nuts are firmly tightened since stiffening is more advantageous in higher frequencies for vibration reduction.

5.5.3 *Air Handling Units (Floor Mounted and Ceiling Suspended)*

The following measures should be adopted:

a) Selected indoor machine for specific air quantity and static pressure.
b) Suspend the indoor machine and ducts

without touching the members of the false ceiling or partitions.

c) Ensure that ducts/duct supports do not touch the evaporator.

5.5.4 *From Plenum Chamber*

The following measures should be adopted/considered:

a) If possible and if pressures allow, expand the air to a plenum chamber (of 2.5 m/s for normal office), which is acoustically lined inside.

b) Stiffening of the plenum body is very critical since it could create a drumming noise.

c) Plenum chambers with sound absorbing material are frequently used as silencers in air conditioning and ventilating systems and in testing facilities to reduce flow velocity and turbulence. The attenuation of these devices may be due to both dissipative and reactive effects.

5.5.5 *From Fans*

5.5.5.1 *Centrifugal fans*

There are three basic types of centrifugal fans, backward curved, forward curved, and radial. Noise from centrifugal fans is dominantly a superimposition of discrete tones at the varying frequencies and broadband aerodynamic noise.

5.5.5.2 *Axial fans*

Axial fans derive their name from the fact that the airflow is along the axis of the fan. To avoid a circular flow pattern and to increase performance, guide vanes are usually installed downstream of the rotor. Axial fans with exit guide vanes are called vane axial and those without guide vanes are called tube axial. Axial fans generally operate at higher pressures than centrifugal fans and are usually considered noisier. Common applications include heating and ventilation systems. Because of the large number of blades and high rotational speeds, noise from axial fans is generally characterized by strong discrete blade passing tones.

Variable inlet vane system may generate significantly low frequency noise as the vanes shut down. Additional attenuation with a corresponding additional pressure drop is required to attenuate the noise generated by the inlet vanes.

Variable speed motors and drives and variable pitch fan blade systems are actually quieter at reduced air output than at full output. The designer has the option of designing for maximum output as if the system were constant volume, or selecting the sound attenuation for a more normal operating point and allowing fan noise to exceed the design criteria on the rare occasions when the fan operates at full output.

5.5.5.3 To reduce fan noise, the following should be adopted:

a) Design the air distribution system for minimum resistance, since the sound generated by a fan, regardless of type, increase by the square of the static pressure. Turbulence can increase the flow noise generated by duct fittings and dampers in the air distribution systems especially at low frequencies.

b) Examine the specific sound power levels of the fan designs for any given job. Different fans generate different levels of sound and produce different octave band spectra. Select a fan that will generate the lowest possible sound level, commensurate with other fan selection parameters.

c) Fans with relatively few blades (less than 15) tend to generate tones, which may dominate the spectrum. These tones occur at the blade passage frequency and its harmonies. The intensity of these tones depends on resonance with the duct system, fan design, and inlet flow distortions.

d) Select a fan to operate as near as possible to its rated peak efficiency when handling the required quantity of air and static pressure. Also, select a fan that generates the lowest possible noise but still meets the required design conditions for which it is selected. Using an oversized or undersized fan, that does not operate at or near rated peak efficiency, may result in substantially higher noise levels.

e) Design duct connections at both the fan inlet and outlet for uniform and straight airflow. Avoid unstable, gusting, and swirling inlet airflow. Deviation from accepted applications can severely degrade both the aerodynamic and acoustic performance of any fan and invalidate manufacturers ratings or other performance predictions.

f) Select duct silencers that do not significantly increase the required fan total static pressure.

5.5.6 *From Chillers, Pumps and Pipes*

Sizing and selecting a chiller is an important aspect in noise control. The following guidelines may be considered for noise control:

a) For roof top installation of chillers, these may be placed on beams connected on the elevated levels of pillars on correctly chosen vibration isolators.

b) Water cooled chillers have less vibration. However, if air cooled chillers have to be chosen, choose them with fan of less speeds and compressors must be jacketed without compromising their ventilation requirement.

c) If much more silencing is required, plan a silencer on the exhaust of the fans and also an acoustic enclosure around the chillers. Care must be taken for the additional static demand in the fan.

5.5.7 *From Ducting Work*

The following measures should be adopted:

a) Shorter ducts with flanges and bracings is very advantageous for noise reduction.

b) Choose the right thickness of sheets for ducting.

c) Provide calculated turning vanes in all bends.

d) Provide take off pieces in all branches and collars.

e) Minimize the number of terminals since each terminal of equal noise will create a higher overall noise inside the room — Two equal noise source increase the noise by 3 dB.

f) Velocities of supply and return ducts and also terminals are important for noise control.

g) For auditoriums, conference halls etc, choose the right silencers in the supply. Define a clear opening for return air and fix return air silencers (parallel baffle silencer). The pressure drop expected across these silencers varies from 6 mm to 10 mm of water column.

h) Selecting double skin air handling unit should be done with care. If used without supply and return air silencers it adds to the noise in the duct patch. However, by using double skin air handling unit the noise inside the plant room can be lowered.

j) Instead of insulating the plant room, increasing the density of the plant room wall and providing return air baffles in the return air patch is more helpful in noise reduction. The doors to the air handling unit room should be either with an attic entry or dense enough to avoid noise transmission.

k) Avoid terminal dampers and grilles if the noise criteria is of the order of NC 20 (recording studios).

m) If ducts have to be routed outside the conditioned space, the density of the insulating materials over the duct surface is very critical. Higher the density, lower is its noise transmitality and hence break in noise inside the duct can be avoided. The density is to be decided based on the outside noise level.

n) Selection of a proper terminal device helps in noise reduction.

p) VAV shall be planned along with relevant VFD or bypass arrangement. Otherwise the duct is subjected to variable pressures resulting in variable noise pattern.

q) Minimize flow-generated noise by elbows or duct branch takeoffs, whenever possible, by locating them at least four to five duct diameters from each other. For high velocity systems, it may be necessary to increase this distance to up to ten duct diameters in critical noise areas.

r) Keep airflow velocity in the duct as low as possible (7.5 m/s or less) near critical noise areas by expanding the duct cross-section area. However, do not exceed an included expansion angle of greater than 15°. Flow separation, resulting from expansion angles greater than 15°, may produce rumble noise. Expanding the duct cross-section area reduces potential flow noise associated with turbulence in these areas.

s) Use turning vanes in large 90° rectangular elbows and branch takeoffs. This provides a smoother transmission in which the air can change flow direction, thus reducing turbulence.

t) Place grilles, diffusers and registers into occupied space as far as possible from elbows and branch takeoffs.

u) Minimize the use of volume dampers near grilles, diffusers and registers in acoustically critical situations.

v) Vibration isolate ducts and pipes, using spring and/or neoprene hangers for atleast the first 15 m from the vibration-isolated equipment.

5.6 Structure Borne Noise

Most obvious paths for solid-borne noise are the attached piping and pump support systems. Oscillatory energy generated near the pump can be conducted as solid-borne noise for substantial distances before it is radiated as acoustic noise. It can be controlled using flexible couplings and mechanical isolation.

5.7 Measurement

Measurements should be taken with a sound level meter either using the 'A' weighting scale or to draw up a noise criteria curve (*see* Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control'). Measurements should be taken in the following locations:

a) Plant rooms;
b) Occupied rooms adjacent to plant rooms;
c) Outside plant rooms facing air intakes and exhausts and condenser discharge, to assess possible nuisance to adjacent occupied areas;
d) In the space served by the first grille or diffuser after a fan outlet; and
e) In at least two of the spaces served by fan coil units or high velocity system terminal units (where applicable).

6 MECHANICAL VENTILATION (FOR NON AIR CONDITIONED AREAS) AND EVAPORATIVE COOLING

6.1 Ventilation

Ventilation is the process of changing air in an enclosed space. A proportion of the air in the space should be continuously withdrawn and replaced by fresh air drawn from outside to maintain the required level of air purity. Ventilation is required to control the following:

a) *Oxygen Content* — Prevent depletion of the oxygen content of the air;
b) *Carbondioxide and Moisture* — To prevent undue accumulation;
c) *Contaminants* — To prevent undue rise in concentration of body odours and other contaminants such as tobacoo smoke;
d) *Bacteria* — To oxidize colonies of bacteria and fungas to prevent their proliferation.
e) *Heat* — To remove body heat and heat dissipated by electrical or mechanical equipment or solar heat gains.

Mechanical ventilation is one of several forms of ventilation options available. It usually consists of fans, filters, ducts, air diffusers and outlets for air distribution within the building. It may include either mechanical exhaust system or exhaust can occur through natural means.

Natural ventilation and natural exhaust are also options (*see* Part 8 'Building Services, Section 1 Lighting and Ventilation'). The scope of this section is therefore restricted to mechanical ventilation.

Ventilation controls heat, odours and hazardous chemical contaminants (in a building) that could affect the health and safety of the occupants. For better control, heat and contaminants, air may need to be exhausted at their sources by local exhaust systems. Usually such systems require lower air flows than general (dilution) ventilation.

Following considerations provide details regarding the various parameters that affect the type of ventilation system selected for a particular application, and the sizing of the ventilation plant:

a) The climatic zone in which the building is located is a major consideration. An important distinction that must be made is between hot-dry and warm-moist conditions. Hot-dry work situations occur around furnaces, forges, metal-extruding and rolling mills, glass-forming machines, and so forth.

   Typical warm-moist operations are found in textile mills, laundries, dye houses, and deep mines where water is used extensively for dust control.

   Warm-moist conditions are more hazardous than the hot-dry conditions.
b) Siting (and orientation) of the building is also an important factor. Solar heat gain and high outside temperature increase the load significantly; how significantly depends, on the magnitude of these gains particularly in relation to other gains for example the internal load.
c) The comfort level required is another consideration. In many cases, comfort levels (as understood in the context of Residential Buildings, Commercial Blocks, Office Establishments) cannot be achieved at all and therefore, what is often aimed at will be 'acceptable working conditions' rather than 'comfort'.

   Having surveyed the considerations above, there are many options available in mechanical ventilation — spot cooling, local exhaust, changes in work pattern — to choose from, for achieving the desired acceptable working conditions. The options available may need to be extended to evaporative cooling in order to achieve more acceptable working conditions when confronted with more hostile environmental conditions.

   It will be thus seen that there are many considerations involved in the selection and sizing of suitable ventilation and evaporative cooling plants to meet the requirements of any particular building and/or process. It is the interplay of these various factors listed above like climatic conditions, internal load, exposure to heat and hazardous substances and level of working conditions aimed at, that determines the option, which best meets the requirement and also, the capacity and other attributes of the option selected.

   Ventilation control measures alone are

frequently inadequate for meeting heat stress standards. Optimum solutions may involve additional controls, such as local exhausts, spot cooling, changes in work-rest patterns, and radiation shielding.

As a rule, it is the mechanical system that provides the best results and controls, for the more complex situations and more stringent requirements arising out of harsher environment and need for better working conditions.

6.2 Beneficial Effects of Ventilation

6.2.1 *Fresh Air Supply*

Ventilation system provides the fresh air flow that is required to maintain an acceptable non-odorous atmosphere (by diluting body odours and tobacco smoke) and to dilute the carbon dioxide exhaled.

The quantity and distribution of introduced outside air takes into account infiltration, exhaust and dilution requirements of the building. Proportion of fresh air introduced into a building may be varied to achieve economical operation. When fresh air can provide useful cooling effect, the quantity should be controlled to match the cooling demand.

6.2.2 *Transfer of Heat/Moisture*

Ventilation system helps air circulation that is required to transfer the heat and humidity generated within the building. Heat generated by the occupants, electrical and mechanical equipment, and solar heat gains may be removed by the introduction of adequate quantities of fresh air and by expelling or extracting of stale air.

6.2.3 *Air Movement*

Ventilation system provides air movement that is necessary to create a feeling of freshness and avoid discomfort, although excessive movement should be avoided as this may lead to complaints of draughts. The quantity of fresh air should not be increased solely to create air movement; this should be effected by air recirculation within the space or by inducing air movement with the ventilation air system.

Air flow should be controlled to minimize transfer of fumes and smells. In addition, air pressure gradients may be created within the building, by varying the balance between the fresh air and extracting the stale air.

Care should be taken, however, to avoid excessive pressure differences that can cause difficulty in opening doors or cause them to slam.

6.2.4 *Air Purity and Filteration*

Ventilation system installed in a building should deliver clean, fresh air to the space served. This may be achieved by providing the required amount of fresh air either to remove totally or to dilute odours, fumes, etc. Local extract systems may be necessary to remove polluted air from kitchens, toilets, slaughter houses, crematoria, etc. Special air filters may be provided to remove contaminants or smells when air is recirculated.

6.2.5 *Removal of Particulate Matter from Air*

Efficient air filteration to prevent fouling of the system should be considered, where damage is likely to be caused by discolouration owing to airborne dust particles. In order to obtain the best performance from the filters provided, care should be taken to locate the air intake appropriately in relation to the prevailing wind, position of chimneys and relative atmospheric dust concentration in the environs of the building.

This will promote cleaner interiors and reduce dust loading of the filters. Adequate (space) provisions should be incorporated in plant layout to ensure that filters can be serviced regularly.

6.2.6 *Fire and Smoke Control*

Ventilation system can be designed to extract smoke in the event of a fire, to assist in the fire fighting operations and to introduce fresh air to pressurize escape routes.

6.2.7 *Removal of Fumes and Smells from Air*

Fumes and smell may be removed from air by physical or chemical processes. Their removal may be essential when the ambient air is heavily polluted, although consideration must be given to limit the thermal loads caused by the introduction of large quantities of fresh air.

6.3 Industrial Ventilation

Industrial buildings form a major application of mechanical ventilation.

In industrial buildings, ventilation is needed to provide the fresh air normally required for health and hygiene and also, to mitigate thermal working conditions by assisting in removal of surplus heat due to equipment, people and building heat gains.

Following are some of the factors that should be considered in the system design:

a) A supply system would not be satisfactory without a complementary exhaust system. Similarly any exhaust system would require for complementary supply system.

b) Air should be supplied equitably through grilles, diffusers — and such other devices. Directional grilles, diffusers and nozzles designed specifically to alleviate the thermal conditions should be considered. Drafts should be avoided.

c) Ventilation systems may need to be supplemented by exhaust hoods and canopies designed to capture the unwanted fumes or dust right at the source irrespective of other air currents in the vicinity.

Many industrial ventilation systems shall handle simultaneous exposures to heat, toxic and hazardous substances. The number of contaminant sources, their generation rate and effectiveness of exhaust hoods are rarely known; there is no option but to depend on common ventilation/industrial hygiene practice in such situations.

Reference may also be made to good practice [8-3(4)].

6.4 Types of Ventilation Systems

In the interest of efficient use of energy and comfort to the occupants, it is imperative that all modes of ventilation should be considered in relation to the thermal characteristics of the building.

6.4.1 *Mechanical Extract/Natural Supply*

This is simplest form of extract system comprising one or more fans, usually of the propeller, axial flow or mixed flow type, installed in outside walls or on the roof. The discharge should terminate in louvers or cowls or a combination of both.

Alternatively, the system may comprise of ductwork arranged for general extraction of the vitiated air or for extraction from localized sources of heat, moisture, odours, fumes and dust. Such duct work may be connected to centrifugal or axial flow fans that discharge through the wall or roof, terminating in louvers or cowls or a combination of both.

It is essential that provision for make-up air is made and that consideration is given to the location and size of inlet. Inlet should not be located in the vicinity of exhaust fan.

6.4.2 *Mechanical Supply/Natural Extract*

This system is similar in form to the extract system but arranged to deliver fresh air positively into the enclosed space. Such a system necessitates provision for the discharge of vitiated air by natural means. Where there is a requirement for the enclosed space to be at a slightly higher pressure than its surroundings (to exclude dust or smoke, for example), the discharge may be through natural leakage paths or balanced pressure relief dampers, as may be required.

6.4.3 *Combined Mechanical Supply and Extract*

This system is a combination of those described above and may comprise supply and exhaust ductwork systems or may employ a common fan with a fresh air inlet on the low pressure side.

6.5 Ventilation Rate and Design Coniderations for Non Air Conditioned Areas

6.5.1 *General Ventilation*

The rate of air circulation recommended for different general areas is as given in Table 5.

Table 5 Recommended Rate of Air Circulation for Different Areas

(*Clause* 6.5.1)

Sl No. (1)	Application (2)	Air Change per Hour (3)
1.	Assembly rooms	4-8
2.	Bakeries	20-30
3.	Banks/building societies	4-8
4.	Bathrooms	6-10
5.	Bedrooms	2-4
6.	Billiard rooms	6-8
7.	Boiler rooms	15-30
8.	Cafes and coffee bars	10-12
9.	Canteens	8-12
10.	Cellars	3-10
11.	Churches	1-3
12.	Cinemas and theatres	10-15
13.	Club rooms	12, *Min*
14.	Compressor rooms	10-12
15.	Conference rooms	8-12
16.	Dairies	8-12
17.	Dance halls	12, *Min*
18.	Dye works	20-30
19.	Electroplating shops	10-12
20.	Engine rooms	15-30
21.	Entrance halls	3-5
22.	Factories and work shops	8-10
23.	Foundries	15-30
24.	Garages	6-8
25.	Glass houses	25-60
26.	Gymnasium	6, *Min*
27.	Hair dressing saloon	10-15
28.	Hospitals-sterlising	15-25
29.	Hospital-wards	6-8
30.	Hospital domestic	15-20
31.	Laboratories	6-15
32.	Launderettes	10-15
33.	Laundries	10-30
34.	Lavatories	6-15
35.	Lecture theatres	5-8
36.	Libraries	3-5
37.	Living rooms	3-6
38.	Mushroom houses	6-10
39.	Offices	6-10
40.	Paint shops (not cellulose)	10-20
41.	Photo and X-ray darkroom	10-15
42.	Public house bars	12, *Min*
43.	Recording control rooms	15-25
44.	Recording studios	10-12
45.	Restaurants	8-12
46.	Schoolrooms	5-7
47.	Shops and supermarkets	8-15
48.	Shower baths	15-20
49.	Stores and warehouses	3-6
50.	Squash courts	4, *Min*
51.	Swimming baths	10-15
52.	Toilets	6-10
53.	Utility rooms	15-20
54.	Welding shops	15-30

NOTE — The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below ground.

6.5.2 *Kitchen (Industrial and Commercial) Ventilation*

Desired ventilation rates in the kitchens depend upon the type of equipment in use and the released impurity loads (including surplus heat). Ventilation Standards set up the guide lines for ventilation volumes, whereas surplus heat and impurity loads determine the actual airflows based on thermal considerations. The design for kitchen airflow must allow for sufficient ventilation.

Suggested design standards for exhaust airflows from different kitchen equipment based on their input power are as given in Table 6.

Table 6 Design Exhaust Air Flow in l/s per kW of the Kitchen Equipment

(*Clause* 6.5.2)

Sl No.	Kitchen Equipment	Electricity based Equipment	Gas based Equipment
(1)	(2)	(3)	(4)
i)	Cooking pot	8	12
ii)	Pressure cooker cabinet	5	—
iii)	Convection oven	10	—
iv)	Roasting oven (salamander)	33	33
v)	Griddle	32	35
vi)	Frying pan	32	35
vii)	Deep fat fryer	28	—
viii)	Cooker/stove	32	35
ix)	Grill	50	61
x)	Heated table/bath	30	—
xi)	Coffee maker	3	—
xii)	Dish washer	17	—
xiii)	Refrigeration equipment	60	—
xiv)	Ceramic cooker/stove	25	—
xv)	Microwave oven	3	—
xvi)	Pizza oven	15	—
xvii)	Induction cooker/stove	20	—

It is desirable to use compensating exhaust hoods for kitchen equipment installed within air conditioned spaces. The ventilation rates may be confirmed from the kitchen equipment supplier.

6.5.3 *Car Parking Ventilation*

Ventilation is essential, in car parking areas to take care of pollution due to emission of carbon monoxide, oxides of nitrogen, presence of oil and petrol fumes and diesel engine smoke. These contaminants cause undesirable effect like nausea, headache, fire hazards, if applicable permissible limits for each of the contaminants noted are exceeded. Although four contaminants are listed above, the capacity of a system designed to tackle concentration of carbon monoxide, will be adequate to keep the other three contaminants also within their respective permissible limits.

The recommended ventilation rate will ensure that the CO level will be maintained within 29 mg/m^3 with peak levels not to exceed 137 mg/m^3.

For partially open garages, the requirement is stated in terms of area of wall/slab openings required to provide adequate ventilation. The value applicable is 2.5 percent to 5 percent of the floor area for free opening.

It is necessary to ensure at planning stage itself that adequate head room is available in the car parks for installing ventilation ducts if such ducting is involved.

6.5.4 *Sizing the Plant*

Sizing the ventilation plant is essentially arriving at the air flow rate required. Based on various considerations already reviewed the sizing of the plant will be influenced by the following requirements:

a) Removal of sensible heat,

b) Removal of latent heat,

c) Make-up air — the flow rate required will depend upon local exhaust, and

d) Removal or dilution of the contaminants down to the permissible level.

The air flow rate arrived at will be the maximum of the flow rates calculated for the above requirements.

6.5.4.1 Ventilation plant size is often expressed in terms of number of air changes per hour or cmh/m^2 of floor area. These expressions fail to evaluate the actual heat release provided by the plant. The unit, cmh/m^2 gives a relationship which is independent of the building height. This is a more rational approach than speaking in terms of air changes per hour. This is because, with the same internal load, the same amount of ventilation air, properly applied to the work zone with adequate velocity, will provide the desired heat relief quite independently of the ceiling height of the space, with few exceptions. Ventilation rates of 30 to 60 m^3/h per m^2 have been found to give good results in many plants. Notwithstanding these general observations, detailed design should be based on detailed thorough calculations after all necessary data has been evaluated and relevant considerations have been reviewed.

6.6 Evaporative Cooling

6.6.1 Evaporative cooling is defined as the reduction of air dry-bulb temperature by the evaporation of water.

6.6.2 When water evaporates into the air to be cooled, simultaneously humidifying it, the process is called direct evaporative cooling. When the air to be cooled is kept separate from evaporation process, and therefore is not humidified as it is cooled, then the process is called indirect evaporative cooling.

It is good practice to use 100 percent fresh air in the evaporative cooling. Re-circulation is not recommended, as it will lead to continuous increase in

wet-bulb temperature of the air. When evaporative cooling is provided for comfort application, it may be supplemented by devices like ceiling fans and fan coolers to enhance air movement for circulation of air in internal areas in order to maximize evaporation of moisture from the skin.

6.6.3 The geographic range for the evaporative cooling is based on cooler's ability to create or approximate human comfort and is limited by relative humidity in the atmosphere. It is more effective in dry climates (hot-dry climate zone) where wet-bulb depression is comparatively large. Factors to be considered — include those listed in **6.5.4**; In addition the following also apply:

a) Saturation efficiency of the cooler — higher the better;
b) Ambient weather design data;
c) Permissible temperature rise; and
d) Type of cooling application — residential, industrial, etc.

6.6.4 The cooling load control, especially for industrial application shall be carried out in the following manner for effective evaporative cooling:

a) Minimize external heat loads by shading, use of heat reflective paints, roof insulation and sealing of gaps.
b) Minimize internal heat loads by shielding, use of reflective paints, insulation and installation of exhaust fans over the hot processes and machines.
c) Make building tight.
d) Wherever possible, exhaust of used washed air must be directed towards roof to partly cool the surface and trusses thereby reducing heat radiation.

6.6.5 Two types of water distribution systems may be provided:

a) Once through or pump-less type.
b) Recirculating or pump type.

The first type is simpler and cheaper but consumes more water, needs constant drainage and has lower efficiency depending upon the temperature of water. The second type has higher cooling efficiency due to recirculate water approaching wet-bulb temperature conserves water and can operate with intermittent drainage. It is recommended to provide periodic bleed-off or blow down to remove accumulated mineral additions. This helps in reducing scaling of pads also.

6.6.6 The air velocity across wetting pad is recommended between 1.0 and 1.5 m/s. The lower face velocity reduces evaporation as damp air film isolates the dry air from the wet surface. Higher face velocity may provide insufficient air-water contact time.

6.6.7 Pad material should be such which provides maximum clean wet surface area with minimum airflow resistance. Materials, which have either good 'wick' characteristics or surface that spread water rapidly by capillary action, should be selected.

6.6.8 In the ducted systems, all supply air diffusers, grilles and registers should be preferably adjustable.

6.6.9 General room cooling *should* be supplemented with spot cooling in the hot workplaces.

6.6.10 Reference may also be made to good practice [8-3(5)].

6.7 Planning

6.7.1 *Planning of Equipment Room for Ventilation*

6.7.1.1 In selecting the location of equipment room, aspects of efficiency, economy and good practice should be considered and wherever possible, it shall be made contiguous with the building. This room shall be located as centrally as possible with respect to the area served and shall be free from obstructing columns.

Proper location helps achieve satisfactory air distribution and also results in a less expensive installation.

6.7.1.2 Equipment room should preferably be located adjacent to external wall to facilitate equipment movement and ventilation. It should also close to main electrical panel of the building, if possible, in order to avoid large cable lengths.

6.7.1.3 Location and dimensions of shafts, for ducting, cables, pipes, etc (if envisaged), should be planned at the virtual stages itself if planning. They should be located adjacent to the equipment or within the room itself.

Evaporative cooling units (air washers) should be located preferably on summer-windward side. They should be painted white or with reflective coating or thermally insulated, so as to minimize solar heat absorption.

In locating the units, care should be taken to ensure that their noise level will not be objectionable to the neighbours. Appropriate acoustic treatment should be considered, if the noise levels cannot be kept down to permissible limits.

Exhaust air devices, preferably to leeward and overhead side may be provided for effective movement of air.

In the case of large installations it is advisable to have a separate isolated equipment room if possible.

The equipment room should be adequately dimensioned keeping in view the need to provide required movement space for personnel, space for entry and exit of ducts, the need to accommodate air intakes and discharge, operation, maintenance and service requirements.

6.7.1.4 The floors of the equipment rooms should be light coloured and finished smooth. For floor loading, the air conditioning, heating and ventilation engineer should be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

Arrangements for draining the floors shall be provided. The trap in floor drain shall provide a water seal between the equipment room and the drain line. Water proofing shall be provided for floor slabs of equipment rooms housing, evaporative cooling units.

6.7.1.5 Supporting of pipe within equipment rooms spaces should be normally from the floor. However, outside Equipment room areas, structural provisions shall be made for supporting the water pipes from the floor/ceiling slabs. All floor and ceiling supports make-up and drain connections pipes, ducting cables/cable trays etc, shall be isolated from the structure to prevent transmission of vibrations.

6.7.1.6 Plant machinery in the plant room shall be placed on plain/reinforced cement concrete foundation and provided with anti-vibratory supports. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement may also be considered.

6.7.1.7 Wherever necessary, acoustic treatment should be provided in plant room space to prevent noise transmission to adjacent occupied areas.

6.7.1.8 In case the equipment is located in basement, equipment movement route shall be planned to facilitate future replacement and maintenance. Service ramps or hatch in ground floor slab should be provided in such cases. Also arrangements for floor draining should be provided.

The trap in floor drain shall provide a water seal between the equipment room and the drain line.

6.7.1.9 In the case of large and multi-storied buildings, independent Ventilation/Air Washer Units should be provided for each floor. The area to be served by the air-handling unit should be decided depending upon the provision of fire protection measures adopted. The Units should preferably be located vertically one above the other to simplify location of pipe shafts, cable shafts, drainers.

6.7.1.10 Openings of adequate size should be provided for intake of fresh air. Fresh air intake shall have louvers having rain protection profile, with volume control damper and bird screen.

6.7.1.11 Outdoor air intakes and exhaust outlets shall be effectively be shielded from weather and insects.

6.7.1.12 In all cases air intakes shall be so located as to avoid contamination from exhaust outlets or to from sources whose contamination concentration levels are greater than normal in the locality in which the building is located.

6.7.1.13 Supply/Return air duct shall not be taken through emergency fire staircase. However, exception can be considered if fire isolation of ducts at wall crossings is carried out.

6.7.1.14 Where necessary, structural design should avoid beam obstruction to the passage of supply and return air ducts. Adequate ceiling space should be made available outside the equipment room to permit installation of supply and return air ducts and fire dampers at equipment room wall crossings.

6.7.1.15 Access doors to Equipment rooms should be through single/double leaf type, air tight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas.

6.7.1.16 It should be possible to isolate the equipment room in case of fire. The door shall be fire resistant. Fire/smoke dampers shall be provided in supply/return air duct at air handling unit room wall crossings and the annular space between the duct and the wall should be fire sealed using appropriate fire resistance rated material.

6.7.2 In the planning stages itself, provision should be made for the following (if they are envisaged):

a) Space/routing/supports, etc for ducting; and
b) Openings in walls, slabs, roof etc, for passage of ducts, pipes, cables, etc, and for air intake, air exhaust, etc.

6.7.3 Bleed-off and chemical water treatment, depending on quality of water available for make-up, should be planned.

7 UNITARY AIR CONDITIONER

7.1 These are self-contained air conditioning units comprising a compressor and evaporator with fans for evaporator and air-cooled condenser. Unitary air conditioners are generally installed in windows and, therefore, they are also known as window air conditioners. It is designed to provide free delivery of conditioned air to an enclosed space, room or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulation and filtration of air. It may also include provision to exhaust room air as also induce fresh air for ventilation in the room. In addition to basic cooling unit, there are several other optional features available, such as:

a) Means for heating during winter months.
b) Reciprocating or rotary compressor.
c) Swing louvers for better distribution of air in the room.
d) In addition to normal, dust filters, indoor air quality filters, such as bactericidal enzyme filters for killing bacteria, low temperature catalyst filter for removal of unpleasant odours, electrostatic filters to trap particles of smoke as well as suspended matters present in the air.
e) Digital LCD remote control which also indicates room temperature.

7.2 Capacity

Most of the manufacturers supply unitary air conditions in capacities of 3 500 W (1 TR), 5 250 W (1.5 TR) and 7 000 W (2 TR). However, some of them may be able to supply window air conditioners of 1 750 W (0.5 TR) and upto 10 500 W (3 TR) alongwith intermediate range. The capacity of windows air conditioners is rated at outside dry bulb temperature of 35°C and wet bulb temperature of 30°C and they are suitable for 230 V, single phase 50 Hz power supply. Nominal capacity of all the window air conditioners has to be de-rated due to high ambient temperatures in summer months in most of Indian cities. Also, generally a voltage stabilizer has to be installed to ensure that window air conditioner gets stabilized rated voltage.

7.3 Suitability

Unitary air conditioners are suitable for bedrooms, office cabins, general office area, hotel rooms and similar applications where normal comfort conditions are required upto a distance of 6 m from unitary air conditioner.

7.4 Power Consumption

Power consumption of window air conditioners of 1 TR (3 500 W) rated capacity should not exceed 1.55 kW/TR. However, in smaller sizes, the power consumption may exceed. Rotary compressors normally consume 7 percent to 8 percent less power compared to the above value for reciprocating compressors.

7.5 Noise Level

Noise level of window air conditioner inside the conditioned room should be as low as possible. However it should not exceed 65 dBA for 5 250 W (1.5 TR) or smaller capacity window air conditioners. Air conditioners with rotary compressors will have lower noise level as compared to those provided with reciprocating compressors.

7.6 Location

Unitary air conditioners should be mounted preferably at the window sill level on an external wall where hot air from air-cooled condenser may be discharged without causing nuisance. There should not be any obstruction to the inlet and discharge air of the condenser. Also while deciding location of the window air conditioners, care should be taken to ensure that the condensate water dripping does not cause nuisance. The opening for the air conditioner is generally made a part of windows or wall construction at the planning stage.

7.7 Limitations

Room air conditioners are not generally recommended in the following situations:

a) The width of the area exceeds 6 m.
b) Area requiring close control of temperature and relative humidity.
c) Internal zones where no exposed wall is available for the installation of room air conditioners.
d) Sound recording rooms where criteria for acoustics are stringent.
e) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
f) Operation theatres where 100 percent fresh air is needed and fire hazard exists depending on the type of anaethesia being used.
g) Where required to comply with the recommended fresh air requirement for ventilation.

7.8 For detailed information regarding constructional and performance requirements and methods for establishing ratings of room air conditioners, reference may be made to accepted standard [8-3(6)].

8 SPLIT AIR CONDITIONER

8.1 Split air conditioner has an indoor unit and an outdoor unit interconnected with refrigerant piping and power and control wiring. Indoor unit comprises of a filter, evaporator and evaporator fan for circulation of air in the conditioned space. Outdoor unit has a compressor, air-cooled condenser with condenser fan housed in a suitable cabinet for outdoor installation. Split air conditioner includes primary source of refrigeration for cooling and dehumidification and means for circulation and cleaning of air, with or without external air distribution ducting.

Split air conditioners may be provided with either reciprocating compressor or scroll compressor. Scroll

compressor generally consumes about 10 to 12 percent less power compared to reciprocating compressor.

Various split air conditioners available may be categorised as under:

a) Exposed indoor unit, which is either a high wall unit or a floor-mounted unit.
b) Furred-in units (ceiling suspended unit), which is mounted in the ceiling and provided with a duct collar and grille.
c) Ducted indoor unit, which requires ducting for air distribution.

8.2 Suitability

Split air conditioners are suitable for wide range of applications including residences, small offices, clubs, restaurants, showrooms, departmental stores, etc.

8.3 Capacity

Split air conditioners are available in following capacities:

a) Indoor exposed units, 3 500 W (1 TR), 5 250 W (1.5 TR), 7 000 W (2 TR) or two indoor units of 3 500 W (1 TR) or 5 250 W (1.5 TR), connected with one outdoor unit of 7 000 W (2 TR) or 10 500 W (3 TR) capacity. These units are available with corded and cordless remote control.
b) Furred-in Units are available in capacities of 3 500 W (1 TR) and 5 250 W (1.5 TR) and may be provided with one outdoor unit or two outdoor units with two furred-in indoor units. These units are available with corded and cordless remote control.
c) Ducted split air conditioners (ceiling suspended ducted units) are available in capacities of 10 500 W (3 TR), 17 500 W (5 TR), 26 250 W (7.5 TR) and 52 500 W (15 TR). Ducted split air conditioners with scroll compressors are available in sapacities of 19 250 W (5.5 TR) and 29 750 W (8.5 TR).

8.4 Location

Split air conditioner indoor unit is mounted within the air conditioned space or above the false ceiling from where the air distribution duct is taken to the conditioned space to distribute the air. When the indoor unit is mounted in the false ceiling, inspection panel must be kept in the false ceiling to attend to the indoor unit including periodic cleaning of air filter. Outdoor unit is mounted at the nearest open area where unobstructed flow of outside air is available for air cooled condenser.

8.5 Installation

Ceiling suspended indoor units are provided with rubber grommet to reduce vibration. Outdoor units are mounted on a steel frame in an open area so that the fan of the air cooled condenser can discharge hot air to the atmosphere without any obstruction. Care should be taken to ensure that free intake of air is available to the outdoor air cooled condenser. Also precaution should be taken that hot air from any other outdoor unit does not mix with the intake of the other outdoor air cooled condenser.

8.6 Limitations

Split air conditioners are generally not recommended for:

a) For areas where fresh air is required for ventilation.
b) Where distance between indoor exposed unit or furred-in unit exceeds 5 m from the outdoor unit for units up to 7 000 W (2 TR) capacity. For larger ducted split air conditioners, the vertical distance between the indoor unit and the outdoor unit should not exceed about 6 m for units with reciprocating compressors. The horizontal distance between the indoor unit and outdoor unit should not exceed about 10 m for reciprocating compressors.
c) Area requiring close control of temperature and relative humidity.
d) Sound recording rooms where criteria for acoustics are stringent.
e) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
f) Large multi-storey buildings where multiplicity of the compressors may entail subsequent maintenance problems.
g) Where the length of air distribution ducting may exceed about 20 m.

8.7 Reference may be made to accepted standard [8-3(7)].

9 PACKAGED AIR CONDITIONER

9.1 Packaged air conditioner is a self-contained unit primarily for floor mounting, designed to provide conditioned air to the space to be conditioned. It includes prime source of refrigeration for cooling and dehumidification and means for circulation and cleaning of air, with or without external air distribution ducting. It may also include means for heating, humidifying and ventilating air.

The unit comprises a compressor, condenser and evaporator, which are interconnected with copper

refrigerant piping and refrigerant controls. It also includes fan for circulation of air and filter. The unit is provided with compressor and fan motor starter and factory-wired safety controls.

Compressor is a device, which compresses low-pressure low temperature refrigerant gas to high-pressure high temperature super heated refrigerant gas. Compressors may be reciprocating type or scroll type for packaging unit applications.

Condenser condenses high pressure high temperature refrigerant gas to liquid refrigerant at approximately the same temperature and pressure by removal of sensible heat of refrigerant by external means of water cooling or air cooling.

The packaged units are also available with microprocessor-based controller installed in the unit for digital display of faults as also several other functions. The packaged unit can also be provided with winter heating package or humidification package. The packaged unit may be provided with either water-cooled condenser or a remote air cooled condenser with interconnected copper refrigerant piping. The units are available with reciprocating compressor as also scroll compressor, which consume about 10 to 12 percent lesser power. In a water-cooled condenser unit, condenser-cooling water is circulated through the cooling tower with necessary piping and pumpsets.

The water cooled condenser packaged unit gives higher capacity at lower power consumption as compared to an air cooled condenser packaged unit which gets considerably de-rated in capacity and also consumes more power in peak summer months in most of the cities of our country due to high ambient temperature.

Packaged units are generally available with vertical air discharge or horizontal air discharge.

9.2 Suitability

Packaged units are suitable for wide range of applications including offices, clubs and restaurants, showrooms and departmental stores, and computer rooms, etc.

9.3 Capacity

Normally the packaged air conditioners are manufactured in sizes of 17 500 W (5 TR), 26 250 W (7.5 TR), 35 000 W (10 TR) and 52 500 W (15 TR). Packaged units with scroll compressors are also available in capacity up to 58 100 W (16.6 TR).

9.4 Location

The packaged unit can be mounted within the air conditioned space with discharge air plenum or in a separate room from where the air distribution duct is taken to the conditioned space. While deciding location for the packaged unit, provision must be kept for proper servicing of the unit.

9.5 Installation

The packaged units are normally mounted on a resilient pad which prevents vibration of the unit from being transmitted to the building.

9.6 Limitations

Packaged air conditioner are not generally recommended for:

a) Large multi-storey buildings where multiplicity of the compressors may entail subsequent maintenance problems.
b) Where the length of air distribution ducting may exceed approx 20 m.
c) Where the vertical distance of air-cooled condenser from the packaged unit exceeds about 10 m. The sum of horizontal and vertical distances should be generally kept within 15 m.
d) Special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.
e) Operation theatres where 100 percent fresh air is needed and fire hazard exists depending on the type of anesthesia being used.

9.7 For detailed information regarding constructional and performance requirements and methods for establishing ratings of packaged air conditioners, reference may be made to accepted standard [8-3(8)].

10 HEATING

10.1 The installations for air conditioning system may be used advantageously for the central heating system with additions such as hot water or boiler and hot water coils or strip heater banks.

10.2 The heating equipments as described in **10.2.1** and **10.2.2** are generally used:

10.2.1 *Hot Water Heated Coils*

Central heating systems using hot water usually required not more than one or two rows of tubes in the direction of air flow, in order to produce the desired heating capacity. To achieve high efficiency without excessive water pressure drop through the coil, various circuit arrangements are used.

Generally, the resistance to the hot water flow through the heater should not exceed 4 kPa in low pressure hot water heating installations. In high pressure hot water installations, the resistance to the water flow will probably be determined by other factors, for example, the need to balance circuits.

The heaters should be served from hot water flow and return mains with sufficient connections to each row or bank of tubes or sections to give uniform distribution of the heating medium.

The flow connections to the heater should generally be arranged at the lowest point of the heater, and the return connections at the highest, to aid venting. The expansion of the tubes when the heater is in operation should be considered and the necessary arrangements made to accommodate expansion and contraction.

Thermometer wells should be fitted in the pipes near the inlets and outlets of all air-heating coils so that the temperature drop through the heater can be readily observed.

10.2.2 *Electric Air Heater*

The air velocity through the heaters should be sufficient to permit the absorption of the rated output of the finned tube heaters within its range of safe temperatures and the exact velocity determined in conjunction with the manufacturers of the heater. Electrical load should be balanced across the three-phase of the electrical supply.

Where automatic temperature control is required the heater should be divided into a number of sections dependent upon the degree of control to be effected.

Each section of heater elements, which may be two rows of elements should have its own busbars and connection and be capable of withdrawal from the casing, thus enabling the elements to be cleaned or repaired whilst the remainder is in operation. Each section should be capable of being isolated electrically before being withdrawn from the casing.

All heaters should be electrically interlocked with the fan motors, so that the electric heater will be switched off when the fan is stopped or when the air velocity is reduced to a level below that for which the heater has been designed.

The air velocity over the face of the heater is of particular importance in the design of electric air heaters, and the manufacturers should be given details of the maximum and minimum air velocities likely to occur.

With all electric air heaters, care should be taken to preclude the risk of fire under abnormal conditions of operation, by the use of a suitably positioned temperature sensitive trip of the manual reset type to cut off the electric supply.

11 SYMBOLS, UNITS, COLOUR CODE AND IDENTIFICATION OF SERVICES

11.1 Units and symbols to be used in air conditioning, ventilation and refrigeration system shall be in accordance with good practice [8-3(9)].

11.2 Colour code for identification for various items in air conditioning installations for easy interpretation and identification is advisable. This shall promote greater safety and shall lessen chances of error, confusion or inaction in times of emergency. Colour shade shall be generally in accordance with good practice [8-3(10)].

11.3 Colour bands shall be 150 mm wide, superimposed on ground colour to distinguish type and condition of fluid. The spacing of band shall not exceed 4.0 m.

11.4 Further identification may also be carried out using lettering and marking direction of flow.

11.5 Services Identification

11.5.1 *Pipe Work Services*

11.5.1.1 The scheme of colour code for painting of pipe work services for air conditioning installation shall be as indicated in Table 7.

11.5.1.2 In addition to the colour bands specified above, all pipe work shall be legibly marked with black or white letters to indicate the type of service and the direction of flow, identified as follows:

High Temperature Hot Water	HTHW
Medium Temperature Hot Water	MTHW
Low Temperature Hot Water	LTHW
Chilled Water	CHW
Condenser Water	CDW
Steam	ST
Condensate	CN

11.5.2 *Duct Work Services*

11.5.2.1 For duct work services and its insulation, colour triangle may be provided. The size of the triangle will depend on the size of the duct and viewing distance but the minimum size should not be less than 150 mm length per side.

The colour for various duct work services shall be as given below:

Services	*Colour*
Conditioned Air	Red and Blue
Ward Air	Yellow
Fresh Air	Green
Exhaust/Extract/Recalculated Air	Grey
Foul Air	Brown
Dual Duct System Hot Supply Air	Red
Cold Supply Air	Blue

Table 7 Scheme of Colour Code of Pipe Work Services for Air Conditioning Installation

(Clause 11.5.1.1)

Sl No.	Description	Ground Colour	Lettering Colouring	First Colour Band
(1)	(2)	(3)	(4)	(5)
i)	Cooling water	Sea green	Black	French blue
ii)	Chilled water	Sea green	Black	Black
iii)	Central heating below 60°C	Sea green	Black	Canary yellow
iv)	Central heating 60°C to 100°C	Sea green	Black	Dark violet
v)	Drain pipe	Black	White	
vi)	Vents	White	Black	
vii)	Valves and pipe line fittings	White with black handles	Black	
viii)	Belt guard	Black yellow diagonal strips		
ix)	Machine bases, inertia bases and plinth	Charcoal grey		

11.5.3 *Valve Labels and Charts*

Each valve shall be provided with a label indicating the service being controlled, together with a reference number corresponding with that shown on the Valve Charts and 'as fitted' drawings. The labels shall be made from 3 ply (black/white/black) traffolyte material showing white letters and figures on a black background. Labels shall be tied to each valve with chromium plated linked chain.

12 ENERGY CONSERVATION, ENERGY MANAGEMENT, AUTOMATIC CONTROLS AND BUILDING MANAGEMENT SYSTEM

12.1 In the context of this Code, energy conservation signifies the optimum use of energy to operate the air conditioning, heating and ventilation system of a building.

12.2 It is axiomatic that general standards of comfort or specific environmental requirements within the building should not be compromised in an endeavour to achieve lower consumption of energy. Similarly nothing in this Code overrides regulations related to health and safety.

12.3 Considerations for Energy Conservation and Management

12.3.1 *Energy Targets*

For the purpose of assessing energy conservation efficiency of one system design against another, or in an existing building comparing one period of energy use against another, target consumptions may be established.

12.3.2 *Demand Targets*

Energy demand is mainly determined by location of the building, its structure and the equipment installed within it. Demand targets are readily applied to designs for new buildings and are quoted as an 'average rate' of energy use (W/m^2).

12.3.3 *Consumption Targets*

The energy actually consumed in a building is determined by the manner in which the building and its services are used and is measured in units of energy (Wh/m^2). Targets may be established according to varying climatic conditions and varying pattern of building use.

12.3.4 *Air Conditioning/Ventilation*

Some of the more important aspects of establishing energy conservation requirements for air conditioning and ventilation system are given below.

12.3.5 The design of the system and its associated controls should take into account the following:

a) The nature of the application;
b) The type of construction of building;
c) External and internal load patterns;
d) The desired space conditions;
e) Permissible control limits;
f) Control methods for minimizing use of primary energy;
g) Opportunities for heat recovery;
h) Economic factors (including probable future cost and availability of fuel).
j) Opportunity for optimizing electrical installation and energy conservation by using thermal energy storage.

12.3.6 The operation of the system for the following conditions has to be considered when assessing the complete design:

a) in summer;
b) in winter;
c) in intermediate seasons;
d) at night;
e) at weekends; and
f) restoration of power supply after intermittent failure.

12.3.7 Consideration should be given to changes in building load in the system design so that maximum

operational efficiency is maintained under part load conditions. Similarly, the total system should be separated into smaller increments having similar load requirements so that each area can be separately controlled to maintain optimum operating conditions.

12.3.8 The temperature of heating or cooling media circulated with in the system should be maintained at the level necessary to achieve the required output to match the prevailing load conditions with the minimum consumption of energy.

12.3.9 Energy recovery has to be maximized.

12.3.10 Operation and maintenance procedures have to be properly planned.

12.3.11 *Equipment Consideration*

12.3.11.1 All equipment and components should be tested in accordance with the relevant Indian Standards; where no applicable standard exists, an agreed international or other standard and test procedure may be adopted.

12.3.11.2 The equipment suppliers should furnish upon request the energy input and output of the equipment, which should cover full and partial loads and standby conditions as required in order that the energy consumption can be assessed over the whole range of operating conditions.

12.3.11.3 Where components from more than one supplier are used in combination, for which published performance data do not exist then the system designer should take the responsibility for ensuring that their combination leads to optimum energy use.

12.3.11.4 Equipment preventive maintenance schedule should be furnished along with all other required information.

12.4 Control System

The designer should aim to select the simplest system of control capable of producing the space conditions required. It is uneconomical to provide controls with a degree of accuracy greater than the required by the application. Consideration should be given to the provision of centralised monitoring and control, thus achieving optimum operation.

12.5 Automatic Controls and Building Management System

12.5.1 *Types of Equipment*

The basic components that are designed, selected to work together to form a complete control system, together with their function, are shown as follows:

The basic components of a control system are:

Element or Component	*Function*
Sensing and measuring element of the controller (for example, sensor, transmitters, transducers, meters, detector)	Measuring changes in one or more controlled conditions or variables.
Controller mechanism	Translating the changes into forces or energy of a kind that can be used by the final control element.
Connecting members of the control circuit; wiring for electric linkages for mechanical devices	Transmitting the energy or forces from the point of translation to the point of corrective action.
Controlled devices or actuator such as motor or valve	Using the force or energy to motivate the final control element and effect a corrective change in the controlled condition.
Controller mechanism, connecting means, and actuator or control device	Terminating the call for corrective change, to prevent over-correction.

12.5.2 *Sensing and Measuring Elements*

12.5.2.1 *Temperature elements*

a) A bimetal element comprises two thin strips of dissimilar metals fused together and arranged as a straight, U-shaped or spiral element. The two metals have different coefficients of thermal expansion, so a change in temperature causes the element to bend and produce a change in position.

b) A rod and tube element is composed of a high expansion metal tube inside which is located a low expansion rod with one end fixed to the rear of the tube so that temperature changes cause the free end of the rod to move.

c) Sealed bellows element is evacuated of air and charged with a liquid, gas or vapour, which changes in pressure or volume as surrounding temperature changes to result in change of force or movement.

d) Remote bulb element consists of a sealed bellows or diaphragm to which a bulb or capsule is attached by means of capillary tubing, the entire system being filled with liquid, gas or vapour. Temperature changes at the bulb are communicated as pressure or volume changes through the capillary tube to the bellows or diaphragm.

e) Resistance temperature detectors (RTDs) are temperature sensors containing either a fine

wire or a thin metallic element whose resistance increases with temperature and varies in a known manner. RTDs are characterised by their high degree of linearity, good sensitivity and excellent stability. RTDs are used with electronic controllers.

f) Thermocouple element comprises a junction between two dissimilar metals that generates a small voltage related to the temperature.

12.5.2.2 *Humidity devices*

a) These devices have a hygroscopic organic polymer deposited on a water permeable substrate. The polymer film absorbs moisture until it is in balance with the ambient air. This causes a change in resistance or capacitance.

b) Resistance elements, as employed in electronic systems, consist usually of two interleaved grids of gold foil, each connected to a terminal and mounted on a thin slab of insulating plastic material with a coating of hygroscopic salt (lithium chloride) on the block. A conductive path between adjacent strips of foil is formed, and the high electric resistance of this circuit changes as the chemical film absorbs and releases moisture with changes in the relative humidity of surrounding air.

12.5.2.3 *Pressure elements*

a) Low-pressure measuring elements for low positive pressure or for vacuum conditions, for example, static pressure in an air duct, usually comprise a large slack diaphragm, or large flexible bellows. In one type of static pressure regulator two bells are suspended from a lever into a tank of oil, so that positive pressure under one of the bells moves the bell and lever up (or down) to complete an electric circuit. The majority of these elements sense differential pressure, and when combined with pitot tubes, orifice plates, and venturi meters may be used to measure velocity, flow rate or liquid level.

b) High-pressure measuring elements, for pressure or vacuum measurements in the kPa range, are usually of bellows, diaphragm or Bourdon tube type. If one side of the element is left open to atmosphere the element will respond to pressure above or below atmospheric.

12.5.2.4 *Special elements*

a) Special elements for various measuring or detecting purposes are often necessary for complete control in air conditioning or ventilating systems, for example a 'paddle-blade' type of air flow switch may be interlocked with an electric heater battery to prevent battery from operating and overheating in the event of an air flow failure.

b) Other elements employed from time-to-time are measuring smoke density, carbon monoxide (for example in road traffic tunnels or underground car parks) and carbon dioxide, and for flame detection.

12.5.2.5 *Controllers*

Controlling elements normally regulate the application of either electrical or pneumatic energy. Controllers are mainly of three types: thermostat, humidistats and pressure controllers.

12.5.2.6 *Thermostats*

The following types of thermostats are in common use:

a) The room type responds to room air temperature and is designed for mounting on a wall.

b) The insertion thermostats respond to the temperature of air in a duct and are designed for mounting on the outside of a duct with its measuring element extending into the air stream.

c) The immersion type responds to the temperature of a fluid in a pipe or tank is designed for mounting on the outside of a pipe or tank with a fluid-tight connection to allow the measuring element to extend into the fluid.

d) The remote bulb thermostat is used where the point of temperature measurement is some distance from the desired thermostat location, which may often be in central panel. A differential type employing two remote bulbs may be used to maintain a given temperature difference between two points.

e) The surface type is designed for mounting on a pipe or similar surface and measuring its temperature, or to give an approximate measurement of temperature of the fluid with in the pipe.

f) The day/night room thermostat is arranged to control at a reduce temperature at night, and may be changed from day to night operation at a remote point by hand or time clock, or from a time switch built into the thermostat itself.

g) The heating/cooling (or summer/winter) thermostat can have its action reversed and, where required, its set points raised or lowered by remote control. This type of thermostat is used to actuate controlled devices, such as

h) The multi-step thermostat is arranged to operate in two or more successive steps.

j) A master thermostat measures conditions at one point of another (sub-master) thermostat or controller.

12.5.2.7 *Humidistats*

Humidistats may be of the room or insertion type. For example, a sub master room humidistat may be used with an outdoor master thermostat to reduce humidity in cold weather and prevent condensation on windows. A wet-bulb thermostat is often used for accurate humidity control, working in conjunction with a dry bulb controller.

12.5.2.8 *Pressure controllers*

Pressure or static pressure controllers are made for mounting directly on a pipe or duct. The controller may also be mounted remotely on a panel.

12.5.2.9 *Controlled devices*

12.5.2.9.1 *Automatic control valves*

An automatic control valve consists of a valve body to control the flow of fluid passing through it by use of a variable orifice that is positioned by an operator in response to signals from the controller. The fluid handled is generally steam or water, and the operator is usually of the electric motor or pneumatic actuator type. As 75 percent or more of all air conditioning and mechanical ventilation systems utilize a valve of some sort as the final control element, proper control valve selection is one of the most important factors in attaining good systems performance.

Following are the details of various valve types and valve operators:

a) *Valve types* — The main type and their characteristics are summarized below:

1) Single seated valves are designed for tight shut-off.

2) Double seated valves are designed so that the fluid pressure on the two discs is essential balanced, reducing the power required to operate; this type of valve does not provide a tight shut-off.

3) Pilot operated valves utilize the pressure difference between upstream and downstream sides to act upon a diaphragm or piston to move the valve, and are usually single seated, for two piston applications only, and used where large forces are required for valve operation.

5) Three way mixing valves have two inlets and one outlet, and operate to vary the proportion of fluid entering each of the two inlets.

6) Three way diverting valves have one inlet and two outlets and operate to divert or proportion the inlet flow to either of the two outlets.

7) Two way modulating valves have one inlet and one outlet and operate to modulate or proportion the flow through the heat exchange equipment.

8) Butterfly valves comprise a heavy ring enclosing a disc that rotates on an axis at or near its centre and may be used for shut-off where low differential pressures exist.

9) Special multi-port valves for various type of modulating/sequences operation are available for control of both hot and chilled water to three and four pipe fan coil and induction unit systems.

b) *Valve operators* — Valve operators usually comprise an electric solenoid, electric motor, or pneumatic actuator, brief details of which are given below:

1) A solenoid is a magnetic coil that operates a movable plunger to provide two-piston operation.

2) An electric motor is arranged to operate the valve stem through a gear train and linkage. Various types are available for different applications, such as:

i) A unidirectional motor is used for two position operation, the valve opening during one half revolution of the output shaft and closing during the next half revolution.

ii) A spring return motor for two position control operation is energized electrically, driven to one position, and held there until the circuit is broken, when the spring returns the valves to its normal position.

iii) A reversible motor is used for floating or proportional operation and can run in either direction and stop in any position.

3) A pneumatic actuator usually comprises a spring opposed flexible diaphragm or bellows connected to the valve stem, so

that an increase in air pressure acts on the diaphragm or bellows to move the valve stem compress the spring. When the air pressure is removed the spring will return the operator to its normal position.

12.5.2.9.2 *Automatic control dampers*

Control dampers are designed to control the flow of air in a ductwork system in much the same as an automatic valve operates in a fluid circuit, that is by varying the resistance to flow. Following are the details of various damper valves and damper operators:

a) *Damper valves*
   1) The single blade damper is generally restricted to small sizes since it does not provide accurate control. When fitted in circular ductwork it may be referred to as a butterfly damper.
   2) A multi-leaf damper is two or more blades linked together, which may be:
      i) A parallel action multi-leaf damper, having its blades linked so that when operated they all rotate in the same direction.
      ii) An opposed action multi-leaf damper, having adjacent blades linked to rotate in opposite directions when operated.

b) *Damper operators*

   These may be electric motors of the unidirectional, spring return or reversible type fitted with suitable linkage mechanisms, or may be pneumatic actuators of a type designed for damper operation.

12.5.2.9.3 *Centralized control/monitoring equipment*

The centralized control system, which is shown diagrammatically in Fig.1, comprises three main parts: the remote location equipment, the transmission links, and the central equipment.

12.5.2.9.4 *Remote location equipment*

This includes:

a) Input devices or sensors, which measure the condition of a variable;
b) Signal conditioning devices, which convert the sensor signal to a type compatible with the requirements of the remote panel, transmission system, or the central equipment;
c) Output devices, which provide a means for converting a command instruction, appearing at the remote panel, into a signal suitable for performing an operational function on external equipment; and

Remote data collection panels or remote enclosure, which act as termination points for the remote ends of the transmission links and for connections to the remote input and output devices.

12.5.2.9.5 *Transmission links*

The transmission links provides the means for communication between the central equipment and the remote data collection panel and may be classified according to a number of variables, which includes:

a) Medium (wires or cables, telephone lines, micro wave);
b) Transmission mode (one direction only, one direction at a time, etc);
c) Data sequence (series, for 2-wire, parallel for multi-conductor etc);
d) Wire or cable types;
e) Signal types; and
f) Message format.

Other considerations include the physical arrangement of the transmission system, security and supervisory aspect.

12.5.2.9.6 *Central equipment*

This may comprise:

a) An interface, which provides a connection point and the signal conversion between the central processor and transmission links.
b) The central processor, which is the collection of equipment at the central control room containing the logic for management of the centralized control and monitoring system; the processor has the means to receive, transmit and present information, with the ability to process all data in an orderly fashion, and may or may not include a computer.
c) Peripheral devices such as typewriters, printers, displays (digital type, projectors, or cathode ray tubes, etc).

12.5.3 *Selection Factors*

12.5.3.1 *Common factors*

There are a number of factors to be considered in the selection of almost all control system components. These common factors include:

a) Supply and working electricity voltage, phase, frequency and number of wires;
b) Maximum and/or minimum temperatures, humidities or pressures to which components may be subjected;
c) Restrictions or location, mounting positions,

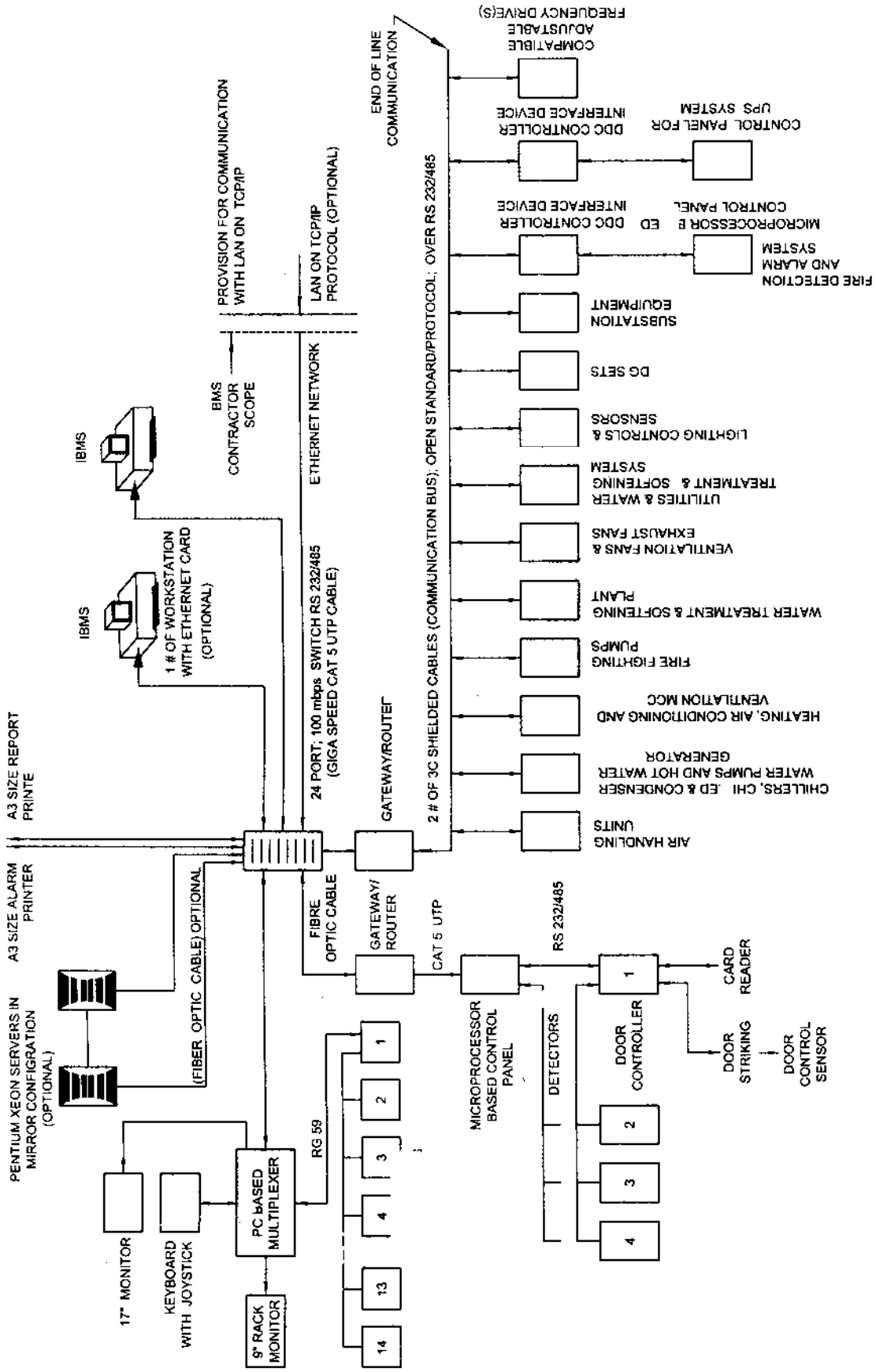

FIG. 1 SYSTEM CONNECTIVITY ARRANGEMENT FOR BUILDING MANAGEMENT SYSTEM

etc, or possible problems due to duct, vibration etc;

d) Dimensions and mass;

e) Finish and type of enclosure; and

f) Required accessories or fittings.

NOTE — These common factors, should only be used as a general guide, and control manufacturers should be consulted in establishing exact requirements.

12.5.4 *Sensing/Measuring Elements*

Sensing and measuring elements frequently form an integral part of a controller and the selection factors to be considered for this arrangement may be as given in **12.5.3.1**. However, a sensor may be designed and arranged for operation with a remote controller and other components, in that case some of the more important selection factors for temperature elements, for example, may be as follows:

a) Control operations, for example reverse or direct-acting;

b) Sensing range, adjustable or non-adjustable;

c) Provision for air filter;

d) Pressure output;

e) Provision for branch pressure indication:

f) Application, for example room, duct or immersion in pipeline;

g) Application, for example room, duct immersion in pipeline;

h) Electronic;

j) Function, for example for primary or secondary control;

k) Temperature range;

m) Authority range of throttling range adjustment;

n) Nominal resistance and sensitivity; and

p) Provision for temperature indication.

13 INSPECTION, COMMISSIONING AND TESTING

13.1 Inspection, commissioning and testing should be carried out meticulously if a satisfactory installation is to be handed over to the client. It should be ensured that these are carried out thoroughly and all results are properly documented. It is recommended that the whole commissioning procedure should be under the guidance and control of a single authority, to be identified by the client.

13.2 Inspection and Testing

All equipment and components supplied may be subjected to inspection and tests during manufacture, erection/installation and after completion. No tolerances at the time of inspection shall be allowed other than those specified or permitted in the relevant approved standards, unless otherwise stated. Approval at the time of inspection shall not be construed as acceptance unless the equipment proves satisfactory in service after erection.

High pressure air duct system should also be tested in accordance with the procedures.

13.2.1 *Inspection and Testing at Works*

The air conditioning system will consist of various items of equipment produced by various manufacturers. Each manufacturer should give facilities for the inspection of his equipment during manufacturing and on completion, as specified.

13.2.2 *Inspection and Testing on Site*

Prior to commissioning, testing, adjusting and balancing, preliminary checks and charging of the complete system should be carried out. It is important that all water systems should have been thoroughly flushed through and hydraulically pressure tested to 1.5 times the working pressure for a period of not less than 8 h.

13.3 Commissioning, Testing, Adjusting and Balancing

13.3.1 *Basic Considerations*

13.3.1.1 The basic considerations are:

a) to test to determine quantitative performance of equipment;

b) to adjust to regulate for specified fluid flow rates and air patterns at terminal equipment (for example reduce fan speed, throttling etc); and

c) to balance to proportion within distribution system (sub mains, branches and terminals) in accordance with design quantities.

13.3.1.2 The objective of testing, adjusting and balancing of air conditioning, heating and mechanical ventilation system shall be to:

a) verify design conformity;

b) establish fluid flow rates, volume and operating pressures;

c) test all associated electrical panels and electrical installation for earthing continuity and earth resistance;

d) take electrical power readings for each motor;

e) establish operating sound and vibration levels;

f) adjust and balance to design parameters; and

g) record and report results as per the specified formats.

13.3.2 *System Testing, Adjusting and Balancing*

13.3.2.1 *Refrigeration plant*

The refrigeration plant may be tested for the following:

a) Adjusting water flow rate through chiller and condenser by use of balancing valves.
b) Ascertaining the capacity by measurement of water flow rate and temperature of water at inlet and outlet of chilling machine.
c) Computation of power consumption.
d) Verifying operating noise level as per manufacturer instructions.

13.3.2.2 *Air system*

13.2.2.2.1 *Air handlers performance*

The testing, adjusting and balancing procedure shall establish the right selection and performance of the air handling units with the following results:

a) Air-in dry-bulb and wet-bulb temperature,
b) Air-out dry-bulb and wet-bulb temperature,
c) Leaving air dew point temperature,
d) Fan air volume,
e) Fan air outlet velocity,
f) Fan static pressure,
g) Fan power consumption,
h) Fan speed, and
j) Check for zero water retention in the condensate drain pan.

13.3.2.2.2 *Air distribution*

Both supply and return air distribution for each air handling unit and for areas served by the air handling unit shall be determined and adjusted as necessary to provide design air quantities. It shall cover balancing of air through main and branch ducts.

13.3.2.2.3 *Hydronic system*

The hydronic system shall involve the checking and balancing of all water pumps, piping network (main and branches), heat exchange equipment like cooling and heating coils, condensers, chillers and cooling towers in order to provide design water flows.

The essential preparation work, shall be done by the air conditioning contractor prior to actual testing, adjusting and balancing and shall ensure the following:

a) Hydronic system is free of leaks, hydrostatically tested and is thoroughly cleaned, flushed and refilled.
b) Hydronic system is vented.
c) Check pumps operation for proper rotation and motor current drawn etc;
d) Confirm that provisions for tabulation of measurements (temperature, pressure and flow measurements) have been made; and
e) Open all shut-off valves and automatic control valves to provide full flow through coils. Set all balancing valves in the preset position, if these values are known. If not, shut all riser balancing valves except the one intended to be balanced first.

Balancing work for both chilled water system and condenser water system shall be carried out in a professional manner and test reports in the specified format shall be prepared.

13.4 Controls

Since most of the control equipment used for air conditioning system is factory calibrated, hence physical verification before installation shall be carried out. In addition, manufacturers instructions should be followed for site calibration, if any.

13.5 Noise and Sound Control

Measurements should be taken with a sound level meter either using the 'A' weighting scale or to draw up a noise criteria curve. Measurements should be taken in the following locations:

a) Plant rooms;
b) Occupied rooms adjacent to plant rooms;
c) Outside plant rooms facing air intakes and exhausts and condenser discharge, to assess possible nuisance to adjacent occupied areas;
d) In the space served by the first grille or diffuser after a fan outlet;
e) In at-least two of the spaces served by fan coil units or high velocity system terminal units (where applicable);
f) In any space; and
g) Air handling unit (AHU) rooms and adjoining areas.

13.6 Handover Procedure

Handover documentation should contain all information that the user needs to enable the installation and equipment to be efficiently and economically operated and maintained. It should also provide a record of the outcome of any site testing, balancing and regulation carried out prior to handover.

Handover documentation should include the following:

a) Description of the installation, including

simplified line flow and balance diagrams for the complete installation;

b) As-built installation drawings;

c) Operation and maintenance instructions for equipment, manufacturer's service maintenance manuals, manufacturer's spare parts list and spares ordering instructions;

d) Schedules of electrical equipment;

e) Schedules of mechanical equipment;

f) Test results and test certificates as called for under the contract including any insurance or statutory inspection authority certificate;

g) Copies of guarantee certificates for plant and equipment; and

h) List of keys, tools and spare parts that are handed over.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	655 : 1963	Specification for metal air ducts (*revised*)
(2)	277 : 2003	Specification for galvanized steel sheet (plain and corrugated) (*sixth revision*)
(3)	737 : 1986	Specification for wrought aluminium alloy sheet and strip for general engineering purpose (*third revision*)
(4)	3103 : 1975	Code of practice for industrial ventilation (*first revision*)
(5)	3315 : 1994	Specification for evaporative air coolers (desert coolers) (*second revision*)
(6)	1391	Specification for room air conditioners:
	(Part 1) : 1992	Unitary air conditioners (*second revision*)
(7)	(Part 2) : 1992	Split air conditioners (*second revision*)
(8)	8148 : 2003	Specification for packaged air conditioners (*first revision*)
(9)	4831 : 1968	Recommendation on units and symbols for refrigeration
(10)	5 : 1994	Specification for colours for ready mixed paints and enamels (*fourth revision*)

NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 4 Acoustics, Sound Insulation and Noise Control

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section covers the acoustical, sound insulation and noise control requirements in buildings. Emphasis is laid on planning of buildings *vis-a-vis* its surroundings to reduce noise and in addition sound insulation aspects of different occupancies are covered for achieving acceptable noise levels.

This Section was first published in 1970 and was subsequently revised in 1983. In the last revision mainly the following changes were made:

a) The approximate measured noise levels due to various types of traffic (air, rail and road) were given; and planning and design features of buildings against outdoor noise were elaborated;
b) Impact sound insulation in residential buildings was modified to grade system of impact sound insulation;
c) Recommendations regarding planning of open plan schools against noise were given;
d) Planning of office buildings with light weight partitions was specified;
e) Planning and design aspects of hotels and hostels, laboratories and test houses, and other miscellaneous buildings, such as, law courts and councils chambers, libraries, museums and art galleries, auditoria and theatres had been given;
f) Hearing damage risk criteria in industrial buildings were modified based on permissible exposure limits for a steady state noise level; and
g) The public address system was elaborated to cover public address system at passenger terminals.

In this revision, the following important changes have been made:

a) Large number of important definitions have been added in line with the present international practice of usage of terms in the field of acoustics, sound insulation and noise control.
b) Under Planning and Design against Outdoor Noise, a new clause on Highway Noise Barrier has been included.
c) The clause on public address system has been deleted.
d) A new clause on cinema has been added.
e) Existing Appendix A 'Constructional Measures for Sound Insulation of Buildings' and Appendix B 'Sound Insulation Values for Various Types of Materials and Construction' have been deleted and the following new informative annexes have been added:
    1) Annex A Noise Calculations
    2) Annex B Specification of Sound Insulation
    3) Annex C Noise Rating
    4) Annex D Outdoor Noise Regulations in India
    5) Annex E Special Problems Requiring Expert Advice
    6) Annex F Airborne and Impact Sound Insulation
    7) Annex G Basic Design Techniques for Noise Control in Air Conditioning, Heating and Mechanical Ventilation System
    8) Annex H Suggested Equipment Noise Data Sheet

There are two types of noises, that is, air-borne and structure-borne noise. To reduce the intensity of air-borne noise, sound absorbent materials may be used.

An absorbent material is one which reduces the intensity of sound reflected from its surface. It may be applied to walls, floors, ceilings or used as furnishings to reduce the sound level by absorption. However, the materials selected for sound absorption shall be consistent with fire safety requirements of the buildings.

To reduce the transmission of air-borne noise, sound insulating materials may be used. Sound insulating materials block the passage of noise through them by virtue of their mass and physical properties. The extent of noise reduction provided by a single homogeneous panel is proportional to the logarithm of mass per unit area. For high values of sound insulation, normally heavy panels are required. Thin sheets of materials do not have adequate mass for providing any appreciable sound transmission loss by themselves. However, when thin sheet materials are used in a double panel construction with an intervening air cavity, this special construction can give extremely high sound transmission loss values considering the mass of the partition, if designed properly. Porous materials lack the mass required to provide any appreciable sound transmission loss, and readily allow sound at most frequencies to be transmitted through them.

To reduce the transmission of structure-borne noise (such as, noise generated by impacts) special construction methods and elastic discontinuity in the structure may be used. Structure-borne noise reduction is effected by corner joints, changes in cross-section, changes in materials, etc, in construction. The reduction by these construction methods is, however, not appreciable specially when a large amount of noise reduction is required over a short distance. In such cases, introduction of an elastic discontinuity in the structure can result in a very large amount of noise reduction. The noise transmission is affected only above a certain lower frequency which depends on the material thickness and the elastic properties of the material. Bonded fibrous materials, rubber elastomers, cork, etc, are suitable for curtailing structure-borne noise transmission.

This Section is largely based on the following standards:

IS 1950 : 1962	Code of practice for sound insulation of non-industrial buildings
IS 3483 : 1965	Code of practice for noise reduction in industrial buildings
IS 4954 : 1968	Recommendations for noise abatement in town planning
IS 11050	Rating of sound insulation in buildings and of building elements:
(Part 1) : 1984	Airborne sound insulation in buildings and of interior building elements
(Part 2) : 1984	Impact sound insulation
BS 8233 : 1999	Code of practice for sound insulation and noise reduction for buildings

In this revision, opportunity has been taken to update all references to relevant Indian Standards referred to in the text.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

1 SCOPE

This Section covers requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions shall apply.

2.1 Ambient Noise — The sound pressure levels associated with a given environment. Ambient noise is usually a composite of sounds from near and far sources none of which are particularly dominant.

2.2 Audible Frequency Range — The range of sound frequencies normally heard by the human ear. The audible range spans from 20 Hz to 20 000 Hz.

2.3 A-Weighted Sound Pressure, p_A — Value of overall sound pressure, measured in pascals (Pa), after the electrical signal derived from a microphone has been pased through an A-weighting network.

NOTE — The A-weighting network modifies the electrical response of a sound level meter with frequency in approximately the same way as the sensitivity of the human hearing system.

2.4 A-Weighted Sound Pressure Level, L_{pA} — Quantity of A-weighted sound pressure, given by the following formula in decibels (dBA):

$$L_{pA} = 10 \log_{10} (p_A/p_o)^2$$

where

p_A = is the A-weighted sound pressure in pascals (Pa); and

p_o = is the reference sound pressure (20 μ Pa).

NOTE — Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with subjective assessments of loudness, and are usually made to assist in judging the effects of noise on people. The size of A-weighting in 1/3 octave bands, is shown in Annex A (*see* A-5). An increase or decrease in level of 10 dBA corresponds roughly to a doubling or halving of loudness.

2.5 Background Noise — The sound pressure levels in a given environment from all sources excluding a specific sound source being investigated or measured.

2.6 Break-in — Unwanted sound transmission into a duct from outside.

2.7 Break-out — Unwanted sound transmission from inside a duct to the outside.

2.8 Broad Band Noise — Spectrum consisting of a large number of frequency components, none of which is individually dominant.

2.9 Cross-Talk — Unwanted sound transmission between one room and another room or space via a duct.

2.10 Decibels — Ten times the logarithm (to the base 10) of the ratio of two mean square values of sound pressure, sound power or sound intensity. The abbreviation for 'decibels' is dB.

2.11 Effective Perceived Noise Level in Decibel (EPN dB) — The number for rating the noise of an individual aircraft flying overhead is the effective perceived noise level in decibels (EPN dB). The effective perceived noise decibel value takes into account the subjectively annoying effects of the noise including pure tones and duration. In principle, it is a kind of time-integrated loudness level.

2.12 Equivalent Continuous A-Weighted Sound Pressure Level, $L_{Aeq,T}$ — Value of the A-weighted sound pressure level in decibels (dB) of a continuous, steady sound, that within a specified time interval, T, has the same mean squared sound pressure as the sound under consideration that varies with time, given by the formula:

$$L_{Aeq,T} = 10 \log_{10} \left\{ \frac{1}{T} \int_0^T \frac{p_A^2(t)}{p_o^2} dt \right\}$$

where

$p_A(t)$ = is the instantaneous A-weighted sound pressure in pascals (Pa); and

p_o = is the reference sound pressure (20 μ Pa).

NOTE — Equivalent continuous A-weighted sound pressure level is mainly used for the assessment of environmental noise and occupational noise exposure.

2.13 Equivalent Sound Absorption Area of a Room, A — Hypothetical area of a totally absorbing surface without diffraction effects, expressed in square metres (m^2) which, if it were the only absorbing element in the room, would give the same reverberation time as the room under consideration.

2.14 Facade Level — Sound pressure level measured 1 m to 2 m in front of the façade.

NOTE — Facade level measurements of L_{pA} are usually 2 dB to 3 dB higher than corresponding free-field measurements.

2.15 Free-Field Level — Sound pressure level measured outside, far away from reflecting surfaces.

NOTE — Measurements made 1.2 m to 1.5 m above the ground and at least 3.5 m away from other reflecting surfaces are usually regarded as being free-field measurements. To minimize the effect of reflections the measuring position should be at least 3.5 m to the side of the reflecting surface (that is, not 3.5 m from the reflecting surface in the direction of the source). Estimates of noise from aircraft overhead usually include a correction of 2 dB to allow for reflections from the ground.

2.16 Frequency — The number of cyclical variations per unit time. Frequency is generally expressed in cycles per second (cps) and is also denoted as Hertz (Hz).

2.17 Impact Sound Pressure Level, L_i — Average sound pressure level in a specific frequency band in a room below a floor, when it is excited by a standard tapping machine.

2.18 Indoor Ambient Noise — Pervasive noise in a given situation at a given time, usually composed of noise from many sources, inside and outside the building, but excluding noise from activities of the occupants.

2.19 Insertion Loss (L_{IL})

Insertion loss is generally defined as the difference, in decibels, between two sound pressure levels (or power levels or intensity levels) which are measured at the same point in space before and after a muffler or any other noise control device is inserted between the measurement point and the noise source.

2.20 Noise — Unwanted sound which may be hazardous to health, intrerferes with communications or is disturbing.

2.21 Noise Exposure Forecast (NEF) — The noise exposure forecast at any location is the summation of the noise levels in EPN dB from all aircraft types, on all runways, suitably weighted for the number of operations during day time and night time.

2.22 Noise Rating (NR) — Graphical method for rating a noise by comparing the noise spectrum with a family of noise rating curves.

NOTE — Noise rating is described in Annex C.

2.23 Noise Reduction Co-efficient (NRC)

A single figure descriptor of the sound absorption property of a material. It is the arithmetic mean of the sound absorption co-efficients at 250, 500, 1 000 and 2 000 Hz rounded off to the nearest multiple of 0.05.

2.24 Normalized Impact Sound Pressure Level, L_n — Impact sound pressure level normalized for a standard absorption area in the receiving room.

NOTE — Normalized impact sound pressure level is usually used to characterize the insulation of a floor in a laboratory against impact sound in a stated frequency band (*see* Annex B).

2.25 Octave Band — Band of frequencies in which the upper limit of the band is twice the frequency of the lower limit.

2.26 Percentile Level, $L_{AN,T}$ — A-weighted sound pressure level obtained using time-weighting '*F*', which is exceeded for *N* percent of a specified time interval.

Example:

$L_{A90,1h}$ is the A-weighted level exceeded for 90 percent of 1 h. Percentile levels determined over a certain time interval cannot accurately be extrapolated to other time intervals. Time-weighting '*F*' or '*S*' can be selected on most modern measuring instruments and used to determine the speed at which the instrument responds to changes in the amplitude of the signal. Time-weighting '*F*' is faster than '*S*' and so its use can lead to higher values when rapidly changing signals are measured.

2.27 Pink Noise — Sound with an uninterrupted frequency spectrum and a power which is steady within frequency band and proportional to centre frequency. An example is constant power level per octave band.

2.28 Pure Tone — A sound emitted at a single frequency.

2.29 Rating Level, L_{Ar},T_r — Equivalent continuous A-weighted sound pressure level of the noise, plus any adjustment for the characteristic features of the noise.

NOTE — This definition is used for rating industrial noise, where the noise is the specific noise from the source under investigation.

2.30 Reverberation Time, *T* — Time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped.

NOTE — Reverberation time is usually measured in octave or third octave bands. It is not necessary to measure the decay over the full 60 dB range. The decay measured over the range 5 dB to 35 dB below the initial level is denoted by T_{30}, and over the range 5 dB to 25 dB below the initial level by T_{20}.

2.31 Sound — A vibrational disturbance, exciting hearing mechanisms, transmitted in a predictable manner determined by the medium through which it propagates. To be audible the disturbance shall have to fall within the frequency range of 20 Hz to 20 000 Hz.

2.32 Sound Exposure Level, L_{AE} — Level of a sound, of 1 s duration, that has the same sound energy as the actual noise event considered.

NOTES

1 The L_{AE} of a discrete noise event is given by the formula:

$$L_{AE} = 10 \log_{10} \left\{ \frac{1}{t_o} \int_{t_1}^{t_2} \frac{p_A^2(t)}{p_o^2} dt \right\}$$

where

$P_A(t)$ = is the instantaneous A-weighted sound pressure in pascals (Pa);

$t_2 - t_1$ = is a stated time interval in seconds (s) long enough to encompass all significant sound energy of the event;

p_o = is the reference sound pressure level (20μ Pa); and

t_o = is the reference time interval (1 s).

2 L_{AE} is also known as L_{AX} (single-event noise exposure level).

2.33 Sound Power — The acoustic power of a sound source, expressed in Watts.

2.34 Sound Power Level, L_w — The acoustic power radiated from a given sound source as related to a reference power level (typically 10^{-12} watts) and expressed in decibels as:

$$L_w = 10 \log \left\{ \frac{W}{10^{-12}} \right\}$$

where

W = Acoustic power in watts.

By definition, 1 W therefore corresponds to 120 dB for L_w.

2.35 Sound Pressure, p — Root-mean-square value of the variation in air pressure measured in pascals (Pa), above and below atmospheric pressure, caused by the sound.

2.36 Sound Pressure Level, L_p — Quantity of sound pressure, in decibels (dB), given by the formula:

$$L_p = 10 \log_{10} (p/p_o)^2$$

where

p = is the root mean square sound pressure in pascals (Pa); and

p_o = is the reference sound pressure (20μ Pa).

NOTE — The range of sound pressures for ordinary sounds is very wide. The use of decibels gives a smaller, more convenient range of numbers. For example, sound pressure levels ranging from 40 dB to 94 dB correspond to sound pressures ranging from 0.002 Pa to 1 Pa. A doubling of sound energy corresponds to an increase in level of 3 dB.

2.37 Sound Receiver — One or more observation points at which sound is evaluated or measured. The effect of sound on an individual receiver is usually evaluated by measurements near the ear or close to the body.

2.38 Sound Reduction Index, R — Laboratory measure of the sound insulating properties of a material or building element in a stated frequency band.

NOTE — For further information *see* Annex B.

2.39 Sound Source — Equipment or phenomena which generate sound. Source room is the room containing sound source.

2.40 Spectrum — A quantity expressed as a function of frequency, such as sound pressure *versus* frequency curve.

2.41 Standardized Impact Sound Pressure Level, L_{nT} — Impact sound pressure level normalized to a reverberation time in the receiving room of 0.5 s.

NOTE — Standardized impact sound pressure level is used to characterize the insulation of floors in buildings against impact sound in a stated frequency band (*see* Annex B).

2.42 Speech Interference Level (SIL) — A descriptor for rating steady noise according to its ability to interfere with conversation between two people. SIL is the arithmetic average of the sound pressure levels in the three octave bands with centre frequencies at 500, 1 000 and 2 000 Hz.

2.43 Standardized Level Difference, D_{nT} — Difference in sound level between a pair of rooms, in a stated frequency band, normalized to a reverberation time of 0.5 s.

NOTE — Standardized level difference takes account of all sound transmission paths between the rooms (*see* Annex B).

2.44 Structure Borne Noise — Generation and propagation of time dependent motions and forces in solid materials which result in unwanted radiated sound.

2.45 Transient Sound — Sound which is audible for a limited period of time, for example sound from over flight of an airplane.

2.46 Third Octave Band — Band of frequencies in which the upper limit of the band is $2^{1/3}$ times the frequency of the lower limit.

2.47 Threshold of Hearing — The lowest continuous sound pressure level which will create an auditory sensation for the average human ear. Any sound below these levels will be inaudible and any sound above the threshold will vary in loudness dependent on intensity.

2.48 Vibration Isolation — Reduction of force or displacement transmitted by a vibratory source, often attained by use of a resilient mount.

2.49 Wavelength — The length in space of one complete cycle of a sound wave.

$$\lambda = \frac{\text{(Speed of sound)}}{\text{(frequency)}} = \frac{(C)}{(f)}$$

2.50 Weighted Level Difference, D_w — Single-number quantity that characterizes airborne sound insulation between rooms but which is not adjusted to reference conditions.

NOTE — Weighted level difference is used to characterize the insulation between rooms in a building as they are; values cannot normally be compared with measurements made under other conditions [*see* good practice [8-4(1)]].

2.51 Weighted Sound Reduction Index, R_w — Single number quantity which characterizes the airborne sound insulating properties of a material or building element over a range of frequencies.

NOTE — The weighted sound reduction index is used to characterize the insulation of a material or product that has been measured in a laboratory (*see* Annex B).

2.52 Weighted Standardized Impact Sound Pressure Level, $L'_{nT,w}$ — Single number quantity used to characterize the impact sound insulation of floors over a range of frequencies.

NOTE — Weighted standardized impact sound pressure level is used to characterize the insulation of floors in buildings (*see* Annex B).

2.53 Weighted Standardized Level Difference, $D_{n,Tw}$ — Single-number quantity, which characterizes the airborne sound insulation between rooms

NOTE — Weighted standardized level difference is used to characterize the insulation between rooms in a building (*see* Annex B).

2.54 Weighted Normalized Impact Sound Pressure Level, $L'_{n,w}$ — Single number quantity used to characterize the impact sound insulation of floors over a range of frequencies.

NOTE — Weighted normalized impact sound pressure level is usually used to characterize the insulation of floors tested in a laboratory (*see* Annex B).

2.55 White Noise — A noise whose spectrum (level) density is substantially independent of frequency over a specified range and has equal power for any range of frequencies of constant band width.

3 PLANNING AND DESIGN AGAINST OUTDOOR NOISE

3.1 General

Planning against noise should be an integral part of town and country planning proposals, ranging from regional proposals to detailed zoning, and three-dimensional layouts and road design within built-up areas. Noise nuisance should be fully recognized in zoning regulations.

3.1.1 Noise is either generated by traffic (road, rail and underground railway) or it arises from zones and buildings within built-up areas (industry, commerce, offices and public buildings). For planning, the noise survey should examine all the possible causes of noise and consider the various factors causing actual nuisance.

3.1.2 Noise by night, causing disturbance of sleep, is more of nuisance than noise by day. For this reason, housing colonies that adjoin areas with heavy traffic movement during the night are liable to cause serious complaints. Also, the factories that work by night are liable to cause serious complaints if housing estates adjoin them. While planning, care should be taken that housing colonies are adequately setback from busy airports, state and national highways, factories, main railway lines and marshalling yards.

3.1.3 There are two aspects of defence by planning. The first is to plan so as to keep the noise at a distance. Under this aspect comes the separation of housing from traffic noise by interposing buffer zones, and the protection of schools and hospitals by green belts, public gardens, etc. The second is the principle of shading or screening. This consists of deliberately interposing a less vulnerable building to screen a more vulnerable one or by providing a solid barrier, such as a wall, between the source and the location to be protected.

3.2 Traffic Noise Levels

3.2.1 *For Air Traffic*

For guidance, approximate noise levels due to various types of aircrafts, measured on ground, when the aircrafts fly overhead at a height of 450 m, are given in Table 1.

Table 1 Typical Noise Levels of Some Aircarft Types

(*Clause* 3.2.1)

Sl No.	Type of Aircraft	Flyover Noise Levels at 450 m with Take-off Thrust (EPN dB)
(1)	(2)	(3)
i)	Boeing 737	107
ii)	Boeing 747-200	103
iii)	Airbus A 300	101
iv)	Concorde SST	114

3.2.2 *For Rail Traffic*

Noise levels of some typical railway traffic are given in Table 2.

Table 2 Typical Noise Levels of Railway Trains

(*Clause* 3.2.2)

Sl No.	Type of Train	Noise Level at 30 m, Measured on the Side or in the Direction of Train, dB (A)
(1)	(2)	(3)
i)	Steam train, 60 km/h	85
ii)	Diesel train, 60 km/h	83
iii)	Electric train, 60 km/h	77

3.2.3 *For Road Traffic*

The level of noise generated by road traffic depends upon such factors as the number of vehicles passing per hour, the type of traffic, the preponderance of heavy vehicles, average speed, gradient and smoothness of traffic flow. The smoothness of traffic flow also affects variability of the noise and is governed by such things as roundabouts and traffic lights, and the volume of traffic and pedestrian movement with their effects on stopping, starting and overtaking. The level of traffic noise fluctuates continuously and the way it does has a considerable effect on the nuisance caused. For assessing traffic noise, noise is measured in dB(A). Because of the fluctuating nature of traffic, noise levels due to different volumes of traffic flow with a varying mix of vehicles are given in Table 3.

Table 3 Typical Noise Levels Due to Free-Flowing Road Traffic

(*Clause* 3.2.3)

Sl No.	Type of Traffic	L_{10} 30 m from Edge of Road, dB(A)
(1)	(2)	(3)
i)	5 000 vehicles per 18 hour day (10 percent heavy vehicles), 50 kmph	65
ii)	10 000 vehicles per 18 hour day (20 percent heavy vehicles), 60 kmph	70
iii)	10 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 kmph	75
iv)	20 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 kmph	77

NOTE — The values are applicable to free flowing traffic without honking.

3.3 Outdoor Noise Regulations

The outdoor noise regulations in force from time-to-time shall be complied with (*see also* Annex D).

3.4 Planning and Design

3.4.1 *For Air Traffic*

Near airports two sources of aircraft noise should be considered.

a) *Flyover noise* — Flyover noise is that which occurs under flight paths close to airports and is the most serious and common problem. As the aircraft passes overhead the noise level at any particular location rises to a peak and then decreases.

b) *Ground noise* — The noise emitted by an aircraft during ground operations is less variable in direction than flyover noise, but is usually of a longer duration.

3.4.1.1 Aircraft noise may disturb sleep, rest and communication, and as such may be considered potentially harmful to health. It is important that no new development is carried out within areas where the expected noise levels will cause mental and physical fatigue or permanent loss of hearing. In case development in such areas is essential, adequate sound insulation shall be provided for the building.

3.4.1.2 As the problems caused by aircraft noise have become more acute, a number of methods have been devised for evaluating noise exposure in the vicinity of airports. They all combine many factors into a single number evaluation. A commonly used criterion is the noise exposure forecast (NEF). The NEF is used primarily to develop noise contours for areas around airports. It has been accepted generally that noise exposure forecast levels greater than NEF 40 are unacceptable to people while levels less than NEF 25 are normally acceptable.

3.4.1.3 While it is theoretically possible to provide sufficient insulation to achieve an acceptable indoor noise environment in the area of very high outdoor noise, there is a level above which aircraft noise seriously affects living conditions no matter how much sound insulation has been applied to the dwelling unit. For this reason it is recommended that no residential development be allowed beyond the NEF 35 level.

3.4.1.4 During summer months, the windows are normally kept open for adequate ventilation. In view of this, no matter how much sound insulation is provided for the building structure, the noise level inside the room can never be less than 10 dB below the outdoor noise level. For very critical buildings, such as buildings necessary for maintaining and supplementing the airport services, and for commercial development, such as hotels, it is possible to provide sealed windows and to centrally air-condition the entire building. However, it is not feasible for most of the residential developments in the country. In such cases proper zoning regulations and siting of vulnerable buildings away from aircraft noise are of vital importance.

3.4.2 *Rail Traffic*

This is a very serious source of noise in built-up areas, both by day and by night. Railway cuttings reduce the spread of noise, whereas embankments extend it. The elevated railway on viaducts or embankment is very common in built-up areas. The elevation increases exposure to noise but in addition the construction of the viaduct may effect the propagation of noise. In this respect solid embankments are preferable to built-up arches, which tend to act as sound boxes. Worst of all are the steel bridges, which greatly magnify the noise due to vibration. Uphill gradients are another feature tending to increase noise, especially of heavy goods trains.

3.4.2.1 Wherever possible, no residential or public building zone should abut onto railway lines, especially on the marshalling yards which is particularly objectionable because of the shrill, clanging and intermittent noise they generate, often at night. The appropriate zones along side railway lines are industrial and commercial buildings other than office buildings. Where these precautions are not practicable and housing has to abut on to railway lines, every attempt may be made to house as few people as possible in the vicinity of the railway lines.

3.4.2.2 Underground transportation system can be a major cause of disturbance for the neighbouring community. Very high noise levels are propagated to long distances by the underground high speed railway, as a result of wheel rail interaction. Both air-borne noise and ground or structure-borne vibration are potential sources of complaints. Noise control measures, therefore, need to be considered for the following:

a) In stations, where high noise levels are produced at the arrival and departure of trains;
b) In tunnels, during high speed train movement;
c) Where an underground rail transit system passes close to existing structures or high rise buildings adequate attention should also be paid to the problem of ground vibration transmitted to the building, and proper isolation should be provided for critical areas;
d) Wherever elevated railway tracks are provided, adequate measures should be taken to avoid the spread of noise in the surrounding built up areas; and
e) In transit cars, where sound insulation is of vital importance to provide comfortable conditions for the commuters.

3.4.3 *Road Traffic*

3.4.3.1 Convoys of long distance heavy trucks at night moving past through built-up areas cause serious noise complaints. On busy roads, the noise of continuous traffic may be a worse nuisance than that of railways. At least the same precautions may, therefore, be taken in the planning of dwellings in relation to arterial and trunk roads as with railways. Care may be taken that local housing roads do not provide short cuts for heavy traffic through residential areas. Hilly roads present the additional noise of gear changing. Trees with heavy foliage planted on both sides of carriageway help slightly to muffle the noise, provided the foliage extends for a considerable distance (30 m or above).

3.4.3.2 Road traffic may give rise to serious nuisance particularly on busy thorough fares, between continuous high buildings in main streets, at the traffic lights, near bus stops, on steep slopes and in parking spaces and enclosed yards.

3.4.3.3 For zoning and planning new buildings in urban areas it is recommended that external L_{A10} is limited to a maximum of 70 dB(A) when the dwellings are proposed to have sealed windows and 60 dB(A) when the dwellings are proposed to have open windows. Indeed it is desirable to confine major new residential development to locations subject to L_{A10} levels substantially lower than those given above.

It is recognized, however, that within the large urban areas, the use of sites where the external L_{A10} is greater than 60-70 dB(A) can not always be avoided. In that case it is suggested to utilize such design solutions as barrier blocks in order to reduce external L_{A10} noise levels to at least 60-70 dB(A) at any point 1.0 m from any inward looking façade. When the orientation of site and the density of development are such that this cannot be fully achieved some form of dwelling insulation will have to be provided. It should be appreciated that where open windows are a must, the occupants would have to put up with discomfort if the above conditions are not met.

3.4.3.4 Certain other methods can often be utilized to provide economical and effective protection from noise:

a) Methods may be adopted to improve the smoothness of flow and reduce number of stopping and starting. This leads to an improvement even if it leads to increased flows. Flow linking of traffic lights, for example, may reduce noise nuisance.
b) Use of roads passing through residential areas may be prohibited to heavy commercial vehicles. An alternative would be to limit use by commercial vehicles to certain times of the day.
c) Use of honking may be prohibited near sensitive buildings, such as hospitals and the like.
d) Barriers may be provided to shield sites from noise.

3.5 Zoning

The zoning of the different cities shall be done by the town planning authorities, taking into account besides other aspects, the noise levels from different occupancies. Wherever necessary, experts in the field may be consulted. For detailed information on noise reduction for town planning schemes, reference may be made to good practice [8-4(2)].

3.6 Green Belts and Landscaping

Where relief from noise is to be provided by means of

green belts these may be of considerable width and be landscaped. (In case of railway tracks, a minimum distance of 50 m to 70 m may be provided between the buildings and the tracks.) The extent of relief that may be derived from the above may be estimated only after considering other environmental factors. Only thick belts of planting (greater than 30 m) are of real value. Strong leafy trees may be planted to act as noise baffles. Shrubs or creepers may also be planted for additional protection between tree trunks; artificial mounds and banks should be formed where practicable. As little hard paving and as much grass as possible may be used. The creation of green belt is particularly advisable on the perimeter of aerodromes, along railway lines and arterial roads, through or past built-up areas and adjoining noisy industrial zones.

3.7 Highway Noise Barriers

Barriers are often the most effective means of reducing traffic noise around residential areas. They have the great advantage that they generally protect most or all of the site. In nearly all situations, a well-designed barrier of even a modest height (say 3 m) can at least ensure that all areas of open space are free from excessive noise levels.

There are two types of barriers that can be built to protect sites; one which are built solely for the purpose of reducing noise and two, which form part of the building complex (barrier blocks). Free standing walls and artificial mounds are typical examples of the first type while single and multi-storeyed dwellings and/or garages are the most common form of the second.

Of the two types, barrier blocks are more widely used because they are cheaper and also tend to form a more effective barrier overall because of their greater height and width. Barrier walls or mounds are more limited in their effect than barrier blocks for they protect little more than the area of the site close to ground level essentially because of the lack of height, as continuous walls much higher than 3 m are often difficult to construct.

3.8 Special Problems Requiring Expert Advice

The purpose of noise control is to ensure that people are neither harmed not disturbed by noise. In addition to provisions given in this Section, special advice may be required for more complex situations, such as those listed in Annex E.

4 PLANNING AND DESIGN AGAINST INDOOR NOISE

4.1 Acceptable Indoor Noise Levels in Buildings

The generally acceptable noise levels inside buildings are given in Table 4.

Table 4 Acceptable Indoor Noise Levels for Various Buildings

(*Clause* 4.1)

Sl No.	Location	Noise Level dB(A)
(1)	(2)	(3)
i)	Auditoria and concert halls	20-25
ii)	Radio and TV studios	20-25
iii)	Cinemas	25-30
iv)	Music rooms	25-30
v)	Hospitals and cinema theatres	35-40
vi)	Apartments, hotels and homes	35-40
vii)	Conference rooms, small offices and libraries	35-40
viii)	Court rooms and class rooms	40-45
ix)	Large public offices, banks and stores	45-50
x)	Restaurants	50-55

4.2 Vulnerable Buildings

Some buildings or parts of buildings are specially vulnerable to noise, for example, recording and radio studios, hospitals and research laboratories. These should not be sited near loud noise sources. Most vulnerable buildings contain some areas which are themselves noisy and in such buildings the less vulnerable elements should be planned to act as noise buffers. Most noisy buildings also contain quiet accommodation, which equally may be planned to act as a buffer between the noisy part of the building and adjoining vulnerable buildings.

4.3 The details of site and internal planning and insulation requirements are covered under individual occupancies (**5** to **12**) as applicable to the respective character and sources of noise in different buildings.

4.4 Sound Insulation of Non-Industrial Buildings by Constructional Measures

The desired (acceptable) noise levels and the recommended insulation values for the various areas may be achieved by providing sound insulation treatments by constructional measures. The details of the same are given in Annex F. The recommendations given in Annex F are applicable to non-industrial buildings like residences, educational buildings, hospitals and office buildings.

4.5 Special Problems Requiring Expert Advice — (*see* **3.8** and Annex E).

5 RESIDENTIAL BUILDINGS

5.1 Sources of Noise Nuisance

5.1.1 *Outdoor Noise*

The main sources of outdoor noise in residential areas are traffic (aeroplane, railways, roadways), children playing, hawkers, services deliveries, road repairs

blaring loud-speakers and various types of moving machinery in the neighbourhood and building operations.

5.1.2 *Indoor Noise*

5.1.2.1 As far as indoor noises are concerned, conversation of the occupants, footsteps, banging of doors, shifting of the furniture, operation of the cistern and water closet, playing of radio, television, music system, cooling and ventilation machinery, etc. contribute most of the noise emanating from an adjacent room or an adjacent building. Noise conditions vary from time-to-time and noise which may not be objectionable during the day may assume annoying proportions in the silence of the night when quiet conditions are essential.

5.1.2.2 In the case of flats the main sources of noise are from other flats and from stairs, lifts and access balconies. Plumbing noise is another cause. In semi-detached buildings, outdoor noises from streets are noticed more than indoor noises from neighbours.

5.2 Recommendations

5.2.1 *Site Planning*

The most desirable method is to locate the residential buildings in a quiet area away from the noisy sources like the industrial areas, rail tracks, aerodromes, roads carrying heavy traffic, etc.

5.2.1.1 To minimize ground reflection, the dwellings should be surrounded by the maximum amount of planting and grassed areas and the minimum amount of hard surfacing. This applies particularly to high density areas. Where for maintenance reasons a large amount of hard paving is necessary, it should be broken up by areas of planting and grassing. Narrow hard paved courts should be avoided between adjacent tall buildings.

5.2.1.2 Roads within a residential area should be kept to a minimum both in width and length, and should be designed to discourage speeding. Area-wise planning, with zones from which vehicular traffic is altogether excluded will greatly help to reduce noise. Roads with through traffic should be excluded from residential areas, but where sites have to be developed adjacent to existing major roads the same principles should be observed in the siting of blocks as with railway lines as covered under **3.4.2.1.**

5.2.1.3 Play areas for older children should be sited as far away from dwellings as possible. Special care should be taken with old peoples' dwellings. They should not be placed immediately adjacent to service entries, play spaces, or to any entrances where children may tend to congregate.

5.2.2 *Internal Planning*

The orientation of buildings in a locality should be planned in such a way as to reduce the noise disturbance from neighbourhood areas. The non-critical areas, such as corridors, kitchens, bathrooms, elevators and service spaces may be located on the noisy side and the critical areas, such as bedrooms and living space, on the quiet side.

5.2.2.1 *Windows and doors*

Windows and doors should be kept away from the noisy side of the building as given below, wherever possible:

a) When windows of a building, particularly those of bedrooms in apartments or flats, face roads carrying heavy traffic or other noises where the external noise is of the order of 80 to 90 dB(A), the building should be located at a distance of about 30 m from the road, but a distance of 45 m or more, where possible, should be aimed at for greater relief from noise;

b) When the windows are at right angles to the direction of the above type of noise, the distance from the road should be arranged to be about 15 to 25 m; and

c) In case another building, boundary wall or trees and plantations intervene between the road traffic and the house/flat further noise reduction is achieved and in such cases the above distances may be reduced suitably.

5.2.2.2 *Layout plans*

It is desirable that rooms adjoining party walls and above/below party floors should be of similar use. By this means, bedrooms are not exposed to noise from adjoining living rooms, and there is less risk of disturbance of sleep.

In semi-detached houses, the staircase, hall and kitchen should adjoin each other on each side of the party wall, thus providing a sound baffle between rooms requiring quiet conditions.

Bedrooms should not be planned alongside access balconies, and preferably not underneath them. Where the approach is by an internal corridor, a sound baffle may usefully be provided by arranging internal passages and bathrooms between the corridor and the living room or bedrooms.

Water-closets should not be planned over living rooms and bedrooms, whether within the same dwelling or over other dwellings. Soil pipes should not be carried in ducts which adjoin living rooms or bedrooms unless the side of the duct next to these rooms is a solid wall containing

no inspection openings. Refuse chutes should not be planned next to living rooms or bedrooms.

5.2.3 *Sound Insulation*

5.2.3.1 *Reduction of air-borne noise*

The weighted sound reduction index, R_w, of partitions between individual rooms or apartments of a building unit shall be as given in Table 5. These values may, however, be suitably increased, where required, for critical areas.

Table 5 Sound Insulation Between Individual Rooms (Air-Borne)

(*Clause* 5.2.3.1)

Sl No.	Situation	R_w, dB
(1)	(2)	(3)
i)	Between the living room in one house or flat and the living room and bedrooms in another	50
ii)	Elsewhere between houses or flats	45
iii)	Between one room and another in the same house or flat	35

NOTES

1 Where communicating doors are provided, all doors should be so designed as to provide recommended insulation between the rooms.

2 There are cases when a set of houses or flats have to be built for the people who work at night and sleep during the day. It is desirable to consider the design of at least one such room in each of the houses or flats which will provide an insulation of about 45 dB in that room.

3 The insulation values referred to are applicable with doors and windows shut.

5.2.3.2 *Suppression of noise at the source itself*

All items of equipment that are potentially noisy should be selected with care. Water-closet cisterns should not be fixed on partitions next to bedrooms or living rooms. Plumbing pipes should be isolated from the structures. Lift motors should be mounted on resilient supports. Access doors from machine rooms to internal staircases should be well fitting and of solid construction. Special noise control measures may be required for electrical and mechanical services such as diesel generators, outdoor air conditioning units, cooling towers, etc.

5.2.3.3 *Reduction of air-borne noise transmitted through the structure*

Reduction of air-borne noise requires the use of rigid and massive walls without any openings. Openings are the major cause of penetration of noise through a barrier. While designing it should be borne in mind that all components should provide a sound transmission compatible with that of the rest of the barrier so that an equivalent amount of sound energy is transmitted through each portion of the barrier.

Ventilating ducts or air transfer openings where provided should be designed to minimize transmission of noise. For this purpose, some sound attenuating devices may be installed in these openings.

All partitions should be sealed effectively where they butt against rest of the structure. All doors and windows should be properly gasketed where a high degree of sound insulation is desired.

5.2.3.4 *Reduction of structure-borne noise*

This requires the use of discontinuous or non-homogeneous materials in the construction of the structure.

5.2.3.5 *Reduction of impact noise*

The floor of a room immediately above the bedroom or living room shall provide impact sound pressure level ($L_{n,Tw}$) not greater than 60 dB. For example, 150 mm thick concrete floor with thick carpet (12 mm) covering would satisfy this requirement.

5.2.3.6 Main staircases in blocks of flats are often highly reverberant. Some of the surfaces at least (for example, the soffits of stairs and landings) should be finished with sound absorbent materials wherever required.

6 EDUCATIONAL BUILDINGS

6.1 Sources of Noise Nuisance

6.1.1 *Outdoor Noise*

The outdoor sources of noise produced on school premises, which cause disturbance within the school, include the noise arising from playgrounds, playing fields and open-air swimming pools. Though playgrounds are used mainly during break periods, they are also used for games and physical education at times when teaching is in progress in the adjoining class rooms.

6.1.2 *Indoor Noise*

Indoor sources of noise are as follows:

a) Singing, instrumental and reproduced music which may take place in class rooms and in dining and assembly halls particularly in primary schools. In secondary schools, specialized music rooms are generally provided;

b) The movement of chairs, desks and tables at the end of one period may disturb a class engaged in a lesson in a room below;

c) The shutting and openings of doors and windows which may occur at any time during teaching periods;

d) Audio-visual presentations in class rooms;

e) Wood and metal workshops, machine shops (engineering laboratories), typing rooms etc,

which produce continuous or intermittent sound of considerable loudness;

f) Practical work carried out in general teaching areas;

g) Gymnasia and swimming pools;

h) School kitchens and dining spaces where food preparation and the handling of crockery and utensils persist for the greater part of the school day;

j) Corridors and other circulation spaces; and

k) Plumbing and mechanical services.

6.2 Recommendations

6.2.1 *Site Planning*

Where outdoor noise nuisance exists from local industry, busy roads, railway, airfields, sport grounds or other sources beyond the control of the school authority, school buildings should be sited as far as possible from the sources of noise.

6.2.1.1 Rooms should be planned in a manner so that the minimum amount of glazing is placed on the side facing the external noise.

6.2.1.2 Noises arising from the activities of a school and from the use of the buildings after school hours may constitute a nuisance to occupants of surrounding property; therefore, it is desirable to place playgrounds, workshops, swimming pools, music rooms, assembly halls and gymnasia as far away as possible from buildings which require a quiet environment.

6.2.2 *Internal Planning*

The following principles should be observed in the detailed planning of educational buildings:

a) *Grouping* — Noisy rooms should be separated from quiet ones, if possible. In general, it is desirable that rooms should be grouped together in accordance with the classification given in **6.2.4.1**.

b) *Windows and ventilators* — Windows of noisy and quiet rooms should not open on to the same courtyard or be near to one another. Roof lights and ventilators over noisy rooms should be avoided, if they are likely to be a source of nuisance to adjacent upper floors.

c) *Doors* — Swing doors into rooms should only be used where no problem of sound transmission exists. Reduction of insulation between rooms and corridors due to doors must be borne in mind. The type and method of fitting of doors is important and necessary care shall be paid in this respect.

d) Sliding partitions should only be used where essential.

e) *Open planning and circulation areas* — Where open planning is used to permit spaces, such as assembly halls, dining rooms or entrance halls to be used in association with each other or for circulation, the degree of disturbance caused by interfering noise to teaching areas needs careful consideration; traffic through such areas should be strictly controlled; full use should be made of sound absorbent treatments to reduce the spread of noise from one space to another (*see* **6.2.3**).

If rooms have large glazed panels or ventilation openings facing directly on the circulation areas, human traffic passing by the rooms should be controlled. Preferably baffled ventilation system or double windows should be used. (Fan-lights over doors should be fixed and glazed).

f) *Furniture* — In all educational buildings, regardless of the character of the floor finish, rubber buffers should be fitted to the legs of chairs and tables.

6.2.3 *Noise Reduction within Rooms*

Sound absorbent materials play a useful part in reducing the built-up or air-borne noise at source. In rooms, such as, classrooms, assembly halls and music rooms, a fairly short reverberation time under occupied conditions is one of the requirements of the acoustic design. The maximum reverberation times permissible for this purpose are usually short enough to give adequate noise control but in addition, the reverberation time should not be excessive under empty conditions, because noise may occur in these rooms with very few occupants. Table 6 gives the reverberation times often arranged in occupied rooms for acoustic reasons and the maximum times recommended in the empty rooms for noise reduction; the times given are for a frequency of 500 Hz, but they should not be greatly exceeded at any frequency. When rooms are used for a variety of purposes, the reverberation period appropriate to the major use should be adopted.

6.2.3.1 Special attention should be given to noise reduction in schools for the deaf and schools for the blind. Deaf children are taught by means of hearing aids which cannot be used satisfactorily in high noise levels or in reverberant conditions. Blind children depend on good hearing for understanding speech and for detecting changes in environment. In both these types of schools, noise levels should be kept low and reverberation times short. As an example, the reverberation times in empty class-rooms should not exceed one second in schools for the blind or 0.5 second in schools for the deaf.

Table 6 Reverberation Times in Schools

(*Clause* 6.2.3)

Sl No.	Room	Reverberation Time, s	
		Usual for Acoustic Reasons (Full)	Maximum[1] for Noise Control (Empty)
(1)	(2)	(3)	(4)
i)	Assembly halls	1.0-1.25 according to size	1.5-2.5 according to volume of hall
ii)	Music teaching rooms	0.75-1.25	1.5
iii)	Gymnasia and indoor swimming pools	—	1.5
iv)	Dining rooms	—	1.25
v)	Classrooms	0.75	1.25
vi)	Headmasters room and staff rooms	0.5-1.00	1.0

[1] Shorter reverberation times are desirable for noise control whenever possible.

6.2.4 *Sound Insulation*

6.2.4.1 *Air-borne noise*

For purposes of sound insulation, rooms in educational buildings may be classified as follows:

Class A	Noise Producing	Workshops Kitchens Dining rooms Gymnasiums Indoor swimming pools
Class B	Producing but needing quiet at times	Assembly halls Lecture halls Music rooms Typing rooms
Class C	Average	General classrooms Practical rooms Laboratories Offices
Class D	Rooms needing quiet	Libraries Studies
Class E	Rooms needing privacy	Medical rooms Staff rooms

6.2.4.2 The recommended minimum sound reduction (D_w) between rooms of the same class is as follows:

Class A	–	25 dB
Class C or D	–	35 dB
Class B or E	–	45 dB

6.2.4.3 Where a room is likely to have a dual use, for example, a dining room to be used as a classroom, the higher sound insulation value should be used.

6.2.4.4 The recommended minimum sound reduction (D_w) between rooms in different classes is 45 dB subject to the following:

a) In schools or institutes with a technical bias where noisy activities, such as sheet metal work, plumbing and woodwork, are likely to be practised extensively in normal hours, workshops should be regarded as a special category requiring more than 45 dB isolation (D_w) from rooms of any other class.

b) Assembly halls and music rooms are special cases in that, as well as producing noise, they also require protection from it and may need more than 45 dB isolation (D_w) from rooms in Class A, if the latter are very noisy.

c) Circulation spaces may vary from a long and frequented corridor to a small private lobby and it is therefore difficult to give precise recommendations to cover them. For partitions between rooms in Class C and most corridors, a R_w of 35 dB for the partition itself is adequate. For partitions between rooms in other classes and corridors, more or less insulation may be necessary, depending upon the specific usage.

d) The problem of noise in circulation areas is as a rule greatly mitigated in schools by the fact that classes usually change rooms together at regular times. In colleges and evening institutes, however, this is much less true and in such buildings particular attention should be paid to insulation between rooms and corridors.

6.2.4.5 *Open plan schools*

A new concept in school planning is the use of a large teaching area with simultaneous instructions imparted to several groups of students. These open plan teaching areas offer a different set of problems. Because of the limitations in achieving a great deal of attenuation across the space and related difficulties in noise control and speech interference, lecturing to a large number of students is not possible without interfering with neighbouring groups. The shape of such spaces may be as linear as possible with a width to height ratio of 5:1 or greater.

In addition, special measures are required to be introduced to reduce the level of intruding speech to an acceptable value so that the various teaching groups are not disturbed and adequate privacy is maintained. Judicious positioning of partial height barriers 1.8 m to 2.1 m in height can improve the sound attenuation between teaching groups and the use of reflective screens can reinforce the speech locally without reflecting it to unwanted areas.

6.2.4.6 *Impact noise*

In the case of schools, the concrete floor of the room

immediately above the teaching rooms shall provide an impact sound pressure level, $L'_{n,Tw}$ not greater than 70 dB. For example, a covering of 6 mm linoleum or cork tiles on concrete floor (hollow or solid) weighing not less than 220 kg/m^2 will usually meet the above requirement.

7 HOSPITAL BUILDINGS

7.1 General

Problems of noise control vary from hospital to hospital but the principles outlined below apply to all types. A quiet environment in hospitals is desirable for patients who are acutely ill. Staff require quiet conditions for consultations and examinations and also in their living and sleeping quarters. There have been rapid rises in noise levels in hospitals due to the higher levels of outdoor noise, increasing use of mechanical and mobile equipment (some of which is now brought much nearer to the patient in order to facilitate nursing procedure) and the introduction of loudspeaker, radio, television and call systems. Noise control in the hospital is made much more difficult by the extensive use of hard washable surfaces which reflect and intensify the noise. In most hospitals, windows to the open air and fanlights to corridors are usually open for the purpose of ventilation, admitting noise from outside and allowing it to spread through the building.

7.2 Sources of Noise Nuisance

7.2.1 *Outdoor Noise*

This may be classified into two main categories:

a) Noise from sources outside the hospital premises, for example, traffic and industrial noises; and

b) Noise from sources outside the building but usually within the control of the hospital authority, for example, ambulances, motor-cars and service vehicles, fuel and stores deliveries, laundries, refuse collection, trucks and trolleys.

7.2.2 *Indoor Noise*

A hospital is a complex building with many services and the numerous internal sources of structure-borne and air-borne noises are grouped into three main categories:

a) Noise consequent upon hospital routines. This category includes sources which transmit noise through both structure-borne and air-borne paths, many of which may be quite near to patients particularly those in wards, such as the following:

1) Wheeled trolleys of various kinds, for food and medical supplies;
2) Sterilizing equipment;
3) Sluice room equipment including bedpan washers;
4) Ward kitchen equipment;
5) Footsteps;
6) Doors banging;
7) The handling of metal or glass equipment;
8) Noises caused during maintenance and overhaul of engineering services; and
9) Vacuum cleaners, mechanical polishers, etc.

b) Loudspeaker, radio or television, audible call system, telephone bells and buzzers, and other air-borne noises, such as loud conversation; and

c) Noises from fixed or mobile equipment and services not directly concerned with hospital routines. These include all the fixed services as given below:

1) Plumbing and sanitary fittings;
2) Steam hot and cold water and central heating pipes;
3) Ventilation shafts and ducts;
4) Fans
5) Boilers;
6) Pumps;
7) Air compressors;
8) Pneumatic tubes;
9) Electrical and mechanical motors and equipment;
10) Lifts;
11) Laundry equipment; and
12) Main kitchen equipment (refrigerators, mixers, steam boilers, etc).

7.3 Recommendations

7.3.1 *Site Planning*

Hospital sites with their high degree of sensitivity to outside noise should be as far away from outside sources as may be compatible with other considerations, such as accessibility and availability of services. The building should be so arranged on the site that sensitive areas like wards, consulting and treatment rooms, operating theatres and staff bedrooms are placed away from outdoor sources of noise, if possible, with their windows overlooking areas of acoustic shadow.

7.3.2 *Detailed Planning*

There is a very large number of unit and room classification in hospital design and in planning the units in relation to each other and to the common services (such as X-ray departments, operating theatre

suits and main kitchens), noise reduction in the sensitive areas should be weighed carefully against other design factors. Special care in overall planning and internal planning against noise is required in the planning within the building of units which are themselves potential noise sources, for example, children's wards and outpatients' departments, parts of which require protection against noise.

7.3.2.1 Unloading bays, refuse disposal areas, boiler houses, workshops and laundries are examples of service units which should be as far from sensitive areas as possible.

7.3.2.2 The kitchen is a constant source of both air-borne and structure-borne noise and should preferably be in a separate building away from or screened from the sensitive areas. If this is not possible and the main kitchens must form part of a multi-storey building, noise control is easier if they are placed below and not above the wards and other sensitive rooms so as to facilitate the insulation of the equipment and machinery in order to reduce the transmission of structure-borne noise to a minimum.

7.3.2.3 In ward units, the kitchens, sluice rooms, utility rooms, sterilizing rooms and other ancillary rooms, need to be placed quite near to the beds if they are to fulfil their purposes, which are all sources of noise. Some form of noise baffling between open wards and rooms of this kind will be needed.

7.3.3 *Reduction of Noise at Source*

In view of the difficulty of suppressing noise in hospital buildings, it is important to eliminate noise at its source wherever possible.

7.3.3.1 *Use of resilient material*

Mats of rubber or other resilient material on draining boards and rubber-shod equipment will greatly reduce noise from utility rooms, sluice rooms and ward kitchens. The use of plastics or other resilient materials for sinks, draining boards, utensils and bowls would also reduce the noise. Many items of equipment especially mobile equipment, such as trolleys and beds, may be silenced by means of rubber-tyred wheels and rubber bumper and the provision of resilient floor finishes (*see* **7.3.4.1**). The latter also reduces footstep noise. Silent type curtain rails, rings and runners should be used. Lift gates and doors should be fitted with buffers and silent closing gear. Fans and other machinery should be mounted on suitable resilient mountings to prevent the spread of noise through the structure.

7.3.3.2 *Other measures*

Noise from water or heating pipes may be reduced by installing systems which operate at comparatively low pressure and velocities. Silencing pipes and specially designed flushing action reduce water closet noise at source and make structural measures easier to apply. The ventilation system should be designed so as not to create a noise problem. Silent closers should be fitted to doors.

7.3.4 *Reduction of Noise by Structural Means*

7.3.4.1 *Insulation*

Since the various departments or units may be planned in many ways, only general guidance on the insulation values for walls and partitions is given as below:

a) It is recommended that walls or partitions between rooms should normally have a R_w of at least 40 dB. Higher values of R_w of at least 45 dB are necessary where a noisy room is adjacent to one requiring quiet conditions. Doors should be solid with close fitting in the frames.

b) There is little insulation value in double swing doors and where these are fitted to a noisy room the opening should be planned so that it is screened from areas requiring quiet by a baffle lobby lined with absorbent material. Very high insulation values may be necessary in special cases and exceptional measures may be required.

c) Solid floors with floating finishes and resilient surfaces are necessary particularly between wards and other parts of the building. Ordinary timber board on joist floors should never be used.

d) Conduits, ventilation ducts, chases, etc, should be constructed so as not to form easy by-pass for disseminating noise about the building, and should be provided with sufficient sound insulation. Pipe ducts should be completely sealed around the pipes where they pass through walls or floors. Ducts carrying waste or water pipes should be lined with sound insulating material to prevent noise from the pipes passing through duct walls into the rooms through which they pass.

7.3.4.2 *Absorption*

Most surfaces in hospitals should be easily cleanable, so as to prevent the build-up of bacteria which may cause cross-infection. Many sound absorbent materials of a soft nature and difficult to clean are unsuitable for use in some hospital areas and lose much of their effectiveness, if painted for hygienic reasons.

Some porous materials with very thin non-porous coverings (like mineral wool covered with thin plastic sheets) have good sound absorption and when covered

with a perforated sheet metal facing can be used in most areas requiring a washable acoustical treatment. In noisy areas, such as corridors and waiting rooms, however, a wider choice of absorbents is available.

In the ward, bed curtains, window curtain etc. add to the absorbent properties of the room and help reduce reverberation in otherwise hard surfaced surroundings.

7.3.5 Sensitive areas such as operation theatres, Doctors' consultation rooms, intensive care units (ICU) require special consideration against noise control. Apart from outdoor noise, a common problem is the transmission of sound between the consulting room and the waiting room. To ensure silence, a sound isolation D_w of 45 dB (A), between the rooms shall be provided. If the doors are directly connected by a single communicating door it will not be possible to achieve these values of isolation D_w. To obtain 40-45 dB(A) insulation between communicating rooms, it is necessary to provide two doors separated by an air gap, such as a lobby or corridor.

8 OFFICE BUILDINGS

8.1 General

Modern office buildings are often noisier than older buildings due to the use of thinner and more rigid forms of construction, harder finishes, more austere furnishings and use of business machines.

8.2 Sources of Noise Nuisance

8.2.1 *Indoor Noise*

Main sources of indoor noise include the following:

a) Office machines, such as typewriters, and printers;
b) Telephonic conversation;
c) Noise from the public admitted to the building;
d) Footsteps, voices and slamming of doors in circulation spaces, lift doors and gates;
e) Sound reproduction in staff training rooms, conference rooms and recreation rooms, etc;
f) Handling of crockery and utensils in canteens and kitchens; and
g) HVAC and lift machinery.

8.3 Recommendations

8.3.1 *Site Planning*

Rooms demanding quiet conditions should be placed on the quiet side of the site. Even on quiet thoroughfares, these rooms should also not be planned at street level. They should also not be planned on enclosed yards used for the parking of cars, scooters, etc. Where, however, the problems cannot be resolved by planning, the provision of double windows may be necessary.

8.3.2 *Detailed Planning*

8.3.2.1 *Noise reduction within rooms*

The reverberation time should not exceed 1.0 s in all general offices of the types listed in **8.3.2.2** to **8.3.2.6**. In small private offices, the reverberation time should not exceed 0.75 second, in very large offices the reverberation time may be increased to 1.25 s. For canteens, the recommended maximum reverberation time is 1.25 s.

8.3.2.2 *Large general offices*

The grouping of departments and machines together in one room should be avoided wherever possible. Where supervision is necessary the provision of glazed screens carried up to the ceiling should be considered. If it is essential to the work of an office for machine operators and clerks to work side by side in the same room, the machines should be enclosed by panels or low screens lined with absorbent material and the ceiling should be sound absorbent. In addition, the machines should be as quiet as possible in operation and mounted on suitable resilient mountings.

NOTE — A quiet area should be planned for prolonged telephonic conversation.

8.3.2.3 *Light weight construction*

Modern construction methods and economy dictate the use of light weight construction for many office buildings. While the light weight materials lead to fast fabrication and erection and also effect considerable economy in the building structure, they may lead to tremendous sound insulation problems between adjacent offices and areas. Light weight construction is also frequently employed for the sub-division of large space into executive cabins and secretarial areas. Where such construction is considered desirable, efforts should be made to provide a double-skin panel. The panels should be isolated from each other as far as possible either by the use of separate framing or by the use of elastic discontinuities in the construction, and a sound absorbing material may be introduced in the air cavity between the panel. The partitions should be full height up to the bottom of the roof above and any openings required for air movement should be provided with sound attenuators compatible with the rest of the partition.

When light weight floors are provided in multi-use buildings, adequate attention shall be paid to the question of air-borne and structure-borne noise transmission from the upper floors to the floors below. For effective reduction of air-borne noise, a double panel hollow floor construction may be employed with

some heavy sound damping material introduced between the panels and the panel isolated from each other. The sound damping material could be sand, mineral wool, etc. In case impact noise isolation is also required, the upper panel should be effectively isolated from the rest of the floors and building structure. The choice of the isolation layer would of course depend upon the lowest frequency of interest.

Another point to be kept in mind when going in for light weight construction is to ensure that the light weight panels are not in resonance with the natural frequencies of any mechanical equipment installed inside the building. Light weight materials have high natural frequencies well within the audio range and may resonate or vibrate due to an applied vibratory force. This vibratory force is caused by mechanical equipment, road traffic, rail traffic, etc. Special measures also need be taken to isolate either the source or the building so as to reduce the amount of vibration transmitted to the building structure.

8.3.2.4 *Open plan offices*

A new concept in office planning is the use of open plan offices. Large open floor spaces are converted into an office area with senior executives, junior executives and secretarial staff all seated within the same area without the use of any partitions or walls. While this method of planning is appreciated, it leads to a problem of inadequate acoustical privacy between adjacent work spaces. Speech privacy in open plan offices is defined by the speech interference level of intruding noise. Speech privacy between two adjacent rooms or spaces is, therefore, a function of two key parameters; noise reduction of the intervening partition and background noise levels.

Special design measures are, therefore, required to reduce the level of intruding sounds at work places to acceptable low value so that people are not disturbed and adequate privacy is maintained. Some special measures which might be considered for such open plan offices are the use of an acoustical ceiling together with partial height barriers between work spaces, all designed to provide adequate privacy between adjacent work spaces. In addition use may have to be made of an electronic background masking noise system which provides a constant level of a generally acceptable background noise in the entire office area. The masking noise system is a very useful concept in open plan office design because by raising the background level at every workplace, intruding noises are made less disturbing. A background music system cannot serve as a noise masking system because the music does not have a constant spectrum or sound level. In fact the background noise masking system must be introduced gradually without the knowledge of employees. The air conditioning system can also be used to generate background masking noise if the noise level from the fans, ducts and grills is suitably tailored to generate the desired frequency spectrum. However, it is not simple to predict the noise level of air conditioning components accurately. On the other hand, the electronic system enables both the level and the spectrum of the background noise to be accurately adjusted to suit individual job requirements.

8.3.2.5 *Office equipment rooms*

It is important that machines like typewriters, printer, etc, should be quiet in themselves and also be fitted with resilient pads, to prevent the floors or tables on which they stand from acting as large radiating panels. It is desirable to locate machines further apart and to apply sound absorbent treatment to the ceiling.

8.3.2.6 *Banking halls*

If banking halls are large and lofty, noise nuisance tends to be aggravated. It is advisable to avoid high reflective ceilings. The worst effects may be reduced by segregating the noise from the quiet operations and screening one from the other and by applying sound absorbent materials to the surfaces of the ceilings, screens and nearby walls. Resilient flooring is also recommended.

8.3.2.7 *Public offices and waiting spaces*

Noise nuisance may be minimized by the provision of resilient flooring, sound absorbent ceilings and heavy full height screens between the public space and the clerical office.

8.3.2.8 *Canteens*

The provision of a sound absorbent ceiling, resilient flooring and the use of plastics trays and tables with 'quiet' tops are recommended.

8.3.2.9 *Circulation spaces*

The effective length of long corridors should be limited by providing swing doors at intervals. Hard floor finishes and board and batten floors in corridors should be avoided. The provision of a sound absorbent ceiling in corridors is recommended. Floor ducts should be planned on one side of corridors.

The noise from slamming of doors may be reduced by fitting automatic quiet action type door closers. Door buffers are useful but may reduce insulation of air-borne sound due to the inevitable gaps between buffers. Continuous soft, resilient strip let into the door frames is preferable. The use of quiet action door latches is recommended.

Staircases and lifts should be isolated from quiet rooms and should have silent type doors.

8.3.3 *Requirement of Sound Insulation*

With open window (single or double) the sound reduction (D_w) will be 5-10dB, and with sealed double windows it will be 40-45dB. Intermediate values are obtainable with closed openable windows (single or double) but only, of course, at such times as ventilation may be dispensed with. Having to choose between ventilation and noise exclusion is a serious handicap to efficient working in offices. In large office blocks on noisy sites, consideration should be given to the provision of sealed double windows and mechanical ventilation at least in the offices on the sides of the building exposed to noise.

8.3.3.1 The insulation necessary between adjoining rooms, both horizontally and vertically, depends upon the amount of noise created within the rooms, the amount of intruding noise and whether it is important that conversation should not be overheard between rooms. Generally a sound isolation value (D_w) of 30 dB between one room and another room in office is recommended.

8.3.3.2 The following list may be considered as broad classification of noise producing rooms and rooms requiring quiet though many offices fall into both categories. Where rooms in opposing categories are planned adjacent to each other, a sound reduction (D_w) of at least 45 dB should be provided between them.

Noise Producing Rooms	*Rooms Requiring Quiet Conditions*
Entrance halls, staircases and corridors used by the public	Executive's rooms, Conference rooms and Board rooms
Lifts and lift halls	Interview rooms
Motor and plant rooms	Offices for one or two persons
Lavatories	Medical officer's rooms
Public offices	Sick rooms
Canteen and kitchens	Rest rooms
Office machine rooms and typing pools	Libraries
Recreation rooms	Telephoning rooms
Large general offices	
Cinemas and projection rooms	

	D_w
a) rooms requiring quiet (as listed above) on a quiet site where privacy is required	45 dB
b) Rooms requiring quiet (as listed above) but on a noisy site or where a lower degree of privacy is tolerable	40 dB
c) Clerical offices in which noise does not constitute a major nuisance	20-30 dB

8.3.3.3 It is recommended that the minimum sound reduction index, R_w for floors should be 45 dB, and the floors should have a resilient finish.

9 HOTELS AND HOSTELS

9.1 General

Hotels and hostels are primarily used as dwelling units, and hotels also provide for public entertainment. The most serious risk of course is disturbance to sleep, and adequate care, therefore, need be taken to protect the occupants from being disturbed by outdoor and indoor noise.

9.1.1 *Outdoor Noise*

Hotels near railway stations, airports, highways and those situated in highly urbanized areas are specially vulnerable to outdoor noise. The outdoor noise in many of the areas is of a high level even late at night and in the early morning. The noise could also be due to other types of activities such as building construction activity (pile driving, concrete mixing etc) and various types of portable utility equipment, such as compressors or generators.

9.1.2 *Indoor Noise*

In so far as indoor noise is concerned, the noise could be due to the occupants themselves, which is transmitted from one room to the other. It could also be due to public functions and late night use of restaurants located in the hotel as also due to miscellaneous utility equipment installed for providing and maintaining the services in the hotel, such as, air conditioning equipment, pumping equipment, power laundry and kitchen. Sometimes hotels equipped with standby generators are a potential source of noise. Another source which could lead to disturbance to the occupants is the plumbing.

9.2 Recommendations

9.2.1 *Site Planning*

While it is desirable to locate the hotel, or hostel away from an area where there is a high ambient noise level, many a time these have to be located in noisy areas for public convenience. Hotels near airports and railway stations are becoming popular because they are convenient for passengers in transit. Hotels located in the commercial areas of a city are also a commercially viable proposition and many a time this factor outweighs the other problems associated with such a location. When a reasonably quiet location is not possible, it is desirable that adequate measures be considered to provide a comfortable acoustical environment for the occupants.

9.2.2 *Internal Planning*

Where a hotel is located in a noisy environment, the

provision of sealed windows (single or double) and provision of an air conditioning system is desirable for rooms exposed to noise. The requirements for the windows would of course depend upon the level and character of noise in the area.

The general recommendations for satisfactory acoustical design of hotels and hostels are given in **9.2.2.1** to **9.2.2.7.**

9.2.2.1 Hotels of all classes shall by necessity provide good protection against indoor noise. Since hotels can be considered as flats, the standards of protection recommended for flats are also applicable to hotels. Partition between guest rooms and between rooms, corridors and floors shall not be less than 115 mm brick wall plastered or equivalent. The floors shall have proper impact insulation. Special attention should be paid to built-in wall cupboards as these are potential areas of sound leakage. These will not serve as sound insulating partitions and may not be relied upon to increase the insulation value of partitions against which they may be built. In fact, partitions between adjoining rooms should be continuous behind the cupboards. Use of silent type door gear and cupboard catches is also highly desirable.

9.2.2.2 Door openings on opposite sides of corridors shall be staggered and doors be provided with gaskets on head, sides and threshold. Inter-communicating doors should be double doors, fully gasketed. Doors should also have quiet action latches. Whenever possible, rooms should be entered through a baffle lobby. Wherever possible, corridor walls should not have ventilators unless they are double glazed and non-openable.

9.2.2.3 Corridors and staircases may have resilient floor coverings and sound absorbent ceilings are desirable unless the corridor is fully carpeted. Staircases and lift wells may be cut off from corridors by means of swing doors and, if possible, isolated from guest rooms by linen stores or similar rooms. Room service pantries on floors can also be a source of noise and may be separated from corridors by baffle lobbies, unless the rooms themselves have baffle lobbies.

9.2.2.4 Except within the same suite, bathrooms should not be planned next to bedrooms. Where this is unavoidable, internal pipe shafts with heavy walls, unpierced on bedrooms side may be used as means of separation. It is important to choose quiet type of sanitary fittings and to design the plumbing system so as not to create noise, that is by avoiding sharp bends, restrictions of flow, quick-action valves that might cause water hammer, etc.

9.2.2.5 Air conditioning system should be quiet in operation. Care should also be taken that the air conditioning ducts do not lead to a cross-talk problem between rooms. Suitable acoustical lining would need to be provided in the ducts consistent with the fire safety requirements of the buildings.

9.2.2.6 Large hotels often have banquet halls and conference halls which are separately hired out for public and private functions. Late night restaurants and night clubs are also popular and functions in all these areas may go on well into the night. It is therefore essential that these rooms be effectively isolated from bedrooms and effective insulation from all possible noise source is considered. Here it is not only necessary to consider the air-borne sound insulation but it is also necessary to consider the question of structure-borne and impact noise transmitted from areas where there might be dancing late into the night.

9.2.2.7 While most of the noise problems encountered in hotels are applicable to hostels, the latter are normally of more economical construction and, therefore, cannot cater for special sound insulation provisions. However, as far as possible, precautions should be taken to provide comfortable conditions in hostel rooms. This is specially true for student hostels where each room is also a living room. Students might play music or have loud discussions late into the night.

This may disturb sleep or study of other students. Proper precautions should, therefore, be taken to provide satisfactory conditions.

10 INDUSTRIAL BUILDINGS

10.1 General

Industrial buildings are primarily producers rather than receivers of noise. The level of industrial noise commonly exceeds that from any other source with the exception of aircraft. As compared with traffic noise, its effects are less widespread but it is often more annoying in character.

10.1.1 Many industrial noises contain very strong high frequency whines, screeches and clatter — these components are relatively more attenuated by passage through the air and by the insulation of light structure than are lower frequencies.

10.1.2 Intermittent noises are either isolated explosions or reports, or noises of a periodic nature, such as those of pressure relief valves of blow off, or the noises of work occurring at random intervals, for example, hammering, grinding and sawing operations; the latter class may be especially irritating because of high frequency components.

10.2 Sources of Industrial Noise

10.2.1 Noises in industrial buildings are mainly of indoor origin. Noise in factories and workshops is generally caused by machine tools and by operations

involved in making and handling the product and they are classified into the following groups, depending upon how the noise energy is generated.

10.2.1.1 *Impact*

Noise caused by impact is the most intense and widespread of all industrial noises. It is normally coupled with resonant response of the structural members connected to the impacting surface. Common sources of this type of noise are forging, riveting, chipping, pressing, tumbling, cutting, weaving, etc. Intense impact noise may also be produced during handling of materials as in the case of sheared steel plates falling one over another in collecting trays in a steel factory. Impact noise is usually intermittent and impulsive in character, but it may also be continuous as in the case of tumbling.

10.2.1.2 *Friction*

Most of the noise due to friction is produced in such processes as sawing, grinding and sanding. Friction also occurs at the cutting edge on lathes and other machine tools and in brakes and from bearings. The spectrum of frictional noise often predominates in high frequency and is very unpleasant in character.

10.2.1.3 *Rotation and reciprocation*

A rotating or reciprocating machine generates noise due to unbalanced forces and/or pressure fluctuations in the fluids inside the machines. In many cases, the moving surfaces radiate noise directly and in other cases, the pressure fluctuations are transmitted to the outer casings of the machine from where they are radiated as noise. Interaction of rotating component with the fluid stream can also give rise to pure tone components, such as the whine in a turbine. Since most machine casings have radiation efficiencies of unity in the higher frequency range, the amount of sound radiated is often substantial.

10.2.1.4 *Air turbulence*

Noise may be generated by rapid variation in air pressure caused by turbulence from high velocity air, steam or gases. Common examples are the exhaust noise from pneumatic tools and air jets. The noise is intense, and broad based in character and the frequency criteria depends on the size of the jet. The intensity increases rapidly with the velocity of the air stream.

10.2.1.5 *Noises with pure tone components*

Whining noise from turbines and humming noise from transformers come under this group.

10.3 Noise Criteria

10.3.1 *Hearing Damage-Risk Criteria*

Continuous exposure to high noise levels may result in permanent noise induced hearing loss in the course of time. Damage-risk criteria specify the maximum levels and duration of noise exposure that may be considered safe. Generally accepted damage-risk criteria for exposure to continuous, steady broad band noise are shown in Table 7. Whenever the sound levels at the workers position in a factory exceed the levels and the duration suggested, feasible engineering controls shall be utilized to reduce the sound to the limits shown. If such controls fail to reduce sound levels within the levels of Table 7, personal hearing protection equipment shall be provided and used to reduce sound levels within the level shown.

10.3.2 *Interference with Communication*

In factories where audible warning signals are used, or where an operator follows the operation of his machine by ear, the background noise should not be so loud as to mask the signal or desired sound (the information sound) to be heard. Noise may be the cause of accidents by hindering communication or by masking warning signals.

10.4 Methods of Reducing Noise

10.4.1 *Noise Control by Location*

Machines, processes and work areas which are approximately equally noisy should be located together as far as possible. Areas that are particularly noisy should be segregated from quiet areas by buffer zones that produce and may tolerate intermediate noise levels.

10.4.2 *Noise Reduction by Layout*

The office space in a factory should be as far as possible located preferably in a separate building. This building should not have a wall common with the production area. Where a common wall is unavoidable, it should be heavy with few connecting doors and no permanent openings.

10.4.3 *Noise Reduction at Source*

10.4.3.1 *Selection of machinery*

Noise should be reduced as near the source as possible. While the operational processes in a factory may be fixed and may have no quieter alternative, careful selection of the machine tools and equipment to be used may considerably help attaining lower noise levels in the machine shop.

10.4.3.2 *Reducing noise from potential sources*

Impact that is not essential to a process should be quietened. Noise from handling and dropping of materials on hard surface may be reduced by using soft resilient materials on containers, fixing rubber tyres on trucks, trolleys, etc. Machine noise may be kept to a minimum by proper maintenance. Proper lubrication will reduce noise by friction conveyors, rollers, etc.

Table 7 Permissible Exposure Limits for Steady-State Noise

(*Clause* 10.3.1)

Sound Level dB(A) (Slow Response) (1)	Time Permitted, T h min (2)
85	16-00
86	13-56
87	12-08
88	10-34
89	9-11
90	8-00
91	6-58
92	6-04
93	5-17
94	4-36
95	4-00
96	3-29
97	3-02
98	2-50
99	2-15
100	2-00
101	1-44
102	1-31
103	1-19
104	1-09
105	1-00
106	0-52
107	0-46
108	0-40
109	0-34
110	0-30
111	0-26
112	0-23
113	0-20
114	0-17
115	0-15

NOTES

1 Where the table does not reflect the actual exposure times and levels, the permissible exposure to continuous noise at a single level shall not exceed the time T (in hours) computed from the formula:

$$T = \frac{16}{2^{[0.2\,(L-85)]}}$$

where

L is the work place sound level measured in dB(A).

2 When the daily noise exposure is composed of two or more periods of different levels, their combined effect should be considered rather than the individual effect of each. The combined levels may not exceed a daily noise dose, D of unity where D is computed from the formula:

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots\ldots + \frac{C_n}{T_n}$$

where, C_1, C_2 ..... C_n indicate the total duration of exposure (in hours) at a given steady-state noise level; and T_1, T_2, ...T_n are the noise exposure limits (in hours) for the respective levels given in the table or computed by the equation in Note 1. Exposure to continuous noise shall not exceed 115 dB(A) regardless of any value computed by the formula for the daily noise dose, D or by the equation given in Note 2.

10.4.3.3 The noise from the radiating surfaces may be reduced by reducing the radiating area. For example, if the area is halved, the noise intensity will be reduced by 3 dB and at low frequencies the reduction will be much greater.

10.4.3.4 Supporting structures for vibrating machines and other equipment should be frames rather than cabinets or sheeted enclosures. If an enclosure is used, precaution should be taken to isolate it and line it on the inside with sound-absorbent material. The noise radiated by machinery guards can be minimized by making them of perforated sheet or of wire mesh.

10.4.3.5 *Reducing transmission of mechanical vibration*

A vibrating sources does not usually contain a large radiating surface but the vibration is conducted along mechanically rigid paths to surfaces that can act as effective radiator. If the rigid connecting paths are interrupted by resilient materials, the transmission of vibration and consequently the noise radiated may be greatly reduced. The reduction depends on the ratio of the driving (forcing) frequency of the source to the natural frequency of the resilient system. The natural frequency may be determined from static deflection under actual load as given in Fig. 1. Higher the ratio between the two frequencies, lesser is the transmissibility, which is defined as the ratio of the force transmitted through the resilient isolator to the exciting force applied to it. Transmissibility and the equivalent noise reduction for various frequency ratios are given in Fig. 2. For satisfactory operation, a ratio of 3:1 or more between the driving and natural frequencies is recommended.

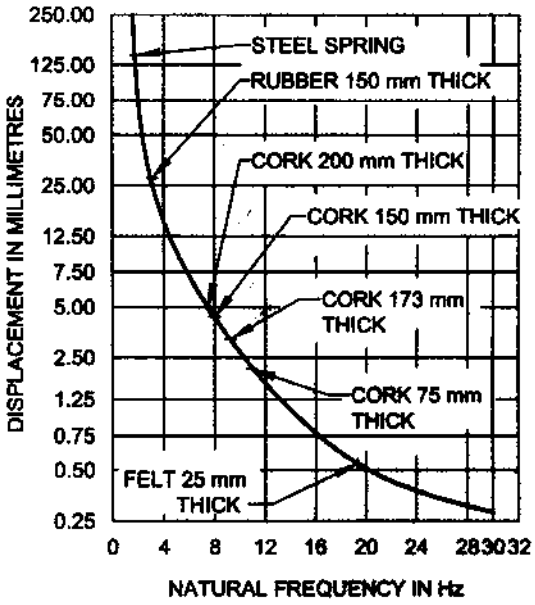

FIG. 1 RELATION BETWEEN STATIC DEFLECTION AND NATURAL FREQUENCY

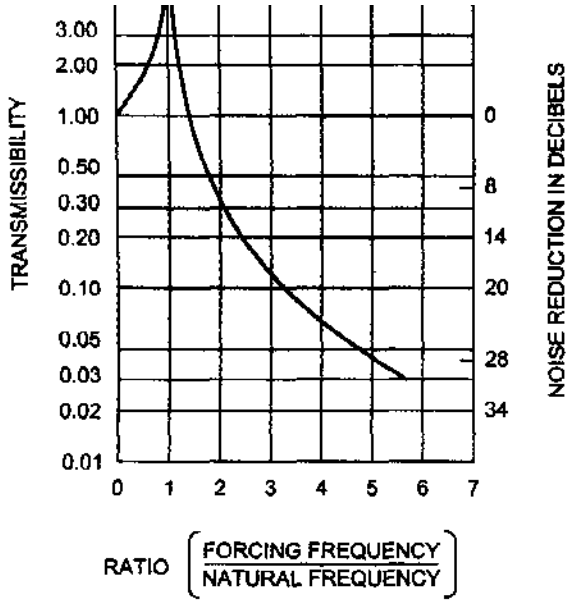

FIG. 2 TRANSMISSIBILITY AND EQUIVALENT NOISE REDUCTION FOR DIFFERENT RATIOS OF FORCING AND NATURAL FREQUENCIES

Materials for isolators and their position are given below:

a) *Material for Isolators* — Vibration isolators are usually made of resilient materials like steel in the form of springs, rubber cork and felt.

   1) Because of the large range of deflections obtainable in coil springs, they may isolate vibrations over a large spectrum of low frequencies. Metal springs transmit high frequency (from about two hundred to several thousand c/s) very readily. Transmission of these frequencies can be reduced by eliminating direct contact between the spring and the supporting structure. Rubber or felt pads may be inserted between the ends of the spring and the surfaces to which it is fastened.

   2) Rubber in the form of pads may be used to isolate very effectively engines, motors, etc. It may be used in compression or in shear. Some rubber mountings use rubber-in-shear as the primary elastic elements and rubber-in-compression as a secondary element which furnishes snubbing action if the mounting is subjected to an overload.

   3) Felt or cork or both may be used as resilient mats or pads under machine bases. The load per unit area shall be that at this deflection, it is not loaded beyond its elastic limit.

b) *Position of Isolator* — The normal position of the isolators is between the machine and its foundation. However, if the forcing frequency of the machine is low (less than 10 H_z) and vibration isolators with the requisite deflection for this location are not available, the machine may be bolted directly to an independent heavy inertia concrete base and the available vibration isolators used below the concrete base.

   1) Large press and drop hammers which create serious impact vibration in heavy machine shops may be mounted rigidly on very massive blocks of concrete having weights several times greater than the weights of the supported machines. The inertia blocks may, in turn, be isolated from the building structure by large wooden blocks and with thick pads of cork.

   2) In critical installations (*see* Note), attempt should be made to locate the resilient mounts in a plane which contains the centre of gravity of the mounted assembly. It is also preferable to locate the mounts laterally as far away as possible from the centre of the machine.

      NOTE — Critical installations are those installations where transmission of vibration from these installations will seriously hamper the normal working.

   3) Rigid mechanical ties between vibrating machine and building structure, short-circuit or reduce the effectiveness of isolators. Loose and flexible connections should be inserted in all pipes and conduits leading from the vibrating machine. Where flexible connections are impracticable, bends should be inserted into the pipes or the pipes themselves should be supported on vibration mounts for a considerable distance from the source.

   4) *Flexibility of foundation* — The effect of flexibility of the foundation on the isolator transmissibility shall be considered in the selection of practical vibration isolating mountings. The simplified vibration isolation theory assumes a completely rigid foundation. However, in practice, this can never be

achieved. The foundation is never actually completely rigid. Generally, the relatively low stiffness of the isolation system permits the assumption of the foundation to be rigid. However, if the stiffness of the isolator is allowed to become comparable to the foundation stiffness (or greater), the deflection of the isolator will become smaller and the foundation will also deflect with increased transmissibility and decreased isolator efficiency. In a dynamic sense, supporting foundation or floors should have natural frequency as high and be as stiff as possible compared to the system being isolated. Good design practice requires that the isolators should be designed assuming a rigid foundation with the stipulation that the selected machine isolation system frequency should be well below the foundation frequency. This point should specially be kept in mind when installing machines at upper levels in buildings because supported slabs generally have lower natural frequencies (low stiffness) than slabs on grade in basement or ground floor locations.

10.4.4 *Noise Reduction by Enclosures and Barriers*

10.4.4.1 *Enclosures*

Air-borne noise generated by a machine may be reduced by placing the machine in an enclosure or behind a barrier. The enclosure may be in the form of close-fitting acoustic box around the machine such that the operator performs his normal work outside the box and thus is not subjected to the high noise levels of the machine. The enclosure may be made of sheet metal lined inside with an acoustical material.

Where size of the machine, working area and the operation do not permit close-fitting enclosures, the machine may be housed in a room of its own. The inside of the enclosure should be lined with sound-absorbing materials to reduce the noise level of the contained sound. The bounding walls of the enclosures shall also have adequate transmission loss to provide desired insertion loss.

10.4.4.2 *Barriers*

A partial reduction of noise in certain directions may be obtained by 'barriers' or partial enclosures or partial height walls. Two-sided or three-sided barrier, with or without a top and invariably covered on the machine side with acoustic absorption material should face a wall covered with sound-absorbing material. If the top of the enclosure is open, the reduction may be increased by placing sound-absorbing material on the ceiling overhead.

10.4.5 *Acoustical Absorption Devices*

10.4.5.1 *Acoustical treatment of ceilings and side walls*

In order to reduce the general reverberant noise level in machine shops, acoustical material may be placed on the ceiling and side walls. With this treatment 3 to 6 dB reduction of middle and high frequency noise may be achieved. While the noise level at the source, affecting the operator, may not be reduced materially, the treatment would bring down the general noise level away from the source in reverberant field.

10.4.5.2 *Functional sound absorbers*

For efficient noise reduction 'functional sound absorbers' may be clustered as near the machines as possible. These units may be suspended and distributed in any pattern to obtain lower noise levels within the machine shop. Compared on the basis of equal total exposed surface areas, functional sound absorbers have higher noise reduction coefficients (NRC) than conventional acoustical materials placed directly on ceilings and walls.

11 LABORATORIES AND TEST HOUSES

11.1 Sources of Noise

11.1.1 *Outdoor Noise*

In a test house or laboratory, where research workers and scientists are engaged in performing sophisticated experiments, the external noise is mostly contributed by noise emitting buildings (workshops, machine rooms), airports, railway stations and general traffic noises. The outdoor sources of noise in a college laboratory include noises produced in a playground as well.

11.1.2 *Indoor Noise*

The following sources mainly contribute to indoor noises in research institutions/college laboratories:

a) Workshops, machine rooms, cafeteria, etc;
b) Air-conditioning and exhaust fans;
c) Noise produced within the test house or laboratory while performing experiments; and
d) Typing or other machine noises, telephone service, lift, sanitary services, etc.

11.2 Recommendations

11.2.1 *Site Planning*

While planning for a laboratory or test house, care

However, where outdoor noises exist, such as from local factory, heavy traffic airports, railway lines, sport grounds or busy markets, buildings should be kept as far away as possible from the source of noise.

11.2.1.1 The window and door openings towards the noise sources should be minimum. Minimum amount of glazing should be placed on walls directly facing the noise sources.

11.2.2 *Internal Planning*

11.2.2.1 Noisy places should be kept separate from the quiet ones. The location of laboratories or test houses should be so chosen that it is cut off from the noisy zones. Where there are offices attached to a laboratory, provision should be made to treat the offices and to use acoustical partitions, to achieve a sound isolation D_w of at least 35 dB.

11.2.2.2 In a laboratory, mostly hard reflecting surfaces and bare furnishings are found, which produce very reverberant conditions. The noise condition still deteriorates when noise producing instruments are switched on or a heavy object is dropped on the floor. Under these conditions, sound absorbing treatment of the space is very essential. Sound absorbing ceilings are recommended to deaden such noises. Rubber buffers may also be fitted to the legs of furniture.

11.2.2.3 In large span laboratories or test houses where scientists and researchers are engaged in work and/or simultaneously busy in calculations or desk work requiring high degree of mental concentration, use of sound absorbing screens is recommended.

11.2.2.4 Noise reduction between the test house or laboratory and corridors or general circulation space should be well kept in mind and due care should be taken of the type of doors and the manner of their fittings etc. Transmission of noise through service ducts, pipes, lifts and staircases should also be guarded.

Telephones should preferably be placed in a separate small enclosure or acoustically efficient telephone booth.

11.2.2.5 To isolate a laboratory or a test house from structure borne noises originating from upper floor, sandwich type floor construction is recommended.

11.2.2.6 Wherever the provision of double glazed windows is necessary to reduce the heat losses, care should be taken to provide sealed double windows rather than double glazing in a single window.

NOTE — Double glazed windows for sound insulation should have a minimum gap of 100 mm between the two glasses.

12.1 Law Courts and Council Chambers

It is important that law courts and council chambers be protected from the intrusion of outdoor noise and from indoor noise arising both from ancillary offices and circulation spaces. The general recommendations on site planning given in **3** apply to law courts and municipal buildings, but in the larger buildings at least, further protection against outdoor noise can be obtained by planning offices and other rooms around the court rooms or chambers, and separating the offices from the central rooms by means of corridors. This arrangement is usually convenient to the function of the buildings.

12.1.1 The wall between the corridors and the central rooms should have a sound reduction index, R_w of not less than 50 dB (for example 230 mm brick) to insulate against air-borne noise in the corridors. Entrances from halls or corridors into court rooms or council chambers should be through baffle lobbies with two sets of quiet action doors. Sound absorbing treatment on ceilings and upper parts or walls or entrance lobbies is recommended.

12.1.2 The whole of the floor of the court room or chamber including steps and seating areas set aside for the public should have a resilient floor finish to reduce the noise of footsteps and shuffling of feet. Any tip-up seats should be quiet in action.

12.1.3 Sound absorbing treatment applied for acoustic purposes serves also to reduce the build-up of noise within the room and, part of the treatment should be applied in a band to the perimeter of the ceiling to absorb intruding outdoor noise. It is often desirable to keep the centre part of the ceiling free of absorbent material for acoustic reasons.

12.2 Libraries, Museums and Art Galleries

Quiet conditions for reading and study are essential in these types of buildings and, since their occupancy is not noise producing, intruding noise is more noticeable and distracting. Every opportunity therefore should be taken to plan for noise defence, both in respect of siting of the building and internal planning. When possible, stack rooms, store rooms and administrative offices should be planned to screen reading rooms, print rooms and lecture rooms from noise sources. In public libraries, the reference library and lecture rooms should receive first consideration; the lending library, newspaper and periodical rooms have a higher background noise and are secondary in importance.

12.2.1 In large libraries, museums and art galleries

echoes from lofty, large domed or concave ceilings are often a nuisance. Small noises such as footsteps, coughs, chair scraping and closing of books are reinforced by reverberation, and concave surfaces even when treated with a sound absorbent may focus these noises. Treated flat ceilings, if not too high, obviate these troubles. Books on shelves in libraries constitute a valuable wall absorbent.

12.2.2 Floor finishes are important. The impact noise of footsteps on marble, terrazzo or wood block flooring, and especially on hardwood strip and batten flooring, can be disturbing both within the room in which the noise is generated and the rooms below. On solid floors, resilient floor finishes, such as rubber, cork and linoleum on an underlay, are highly desirable. In the children's sections of libraries and museums they are essential. In existing buildings, rubber linoleum or vinyl asbestos tiles laid over the floor in the traffic areas are often a solution to the problem.

12.2.3 Reference libraries in universities, research establishments, office buildings and science buildings having machines and testing benches, should be planned in a quiet part of the building. Walls enclosing the library should normally have a sound reduction index, R_w of not less than 50 dB (for example 230 mm brick) and baffle lobbies should be planned between the library and halls and corridors. Walls facing on to corridors or other noisy areas should not have fanlights unless they are double glazed and non-operable.

12.3 Auditoria and Theatres

The sources of noise that have to be considered in concert halls, opera house, theatres and similar auditorium buildings are as follows:

a) Outdoor noise entering through walls, roofs, doors, windows or ventilation openings;

b) Noise from any other hall in the same building, especially if let out separately for revenue;

c) Noise from foyers, service rooms and other ancillary rooms, particularly rehearsal rooms; and

d) Noise from air conditioning plant, etc, and the cross-transmission of other internal noises via ventilating duct system.

12.3.1 Because of greatly increased outdoor noise, all auditorium buildings now need more care in siting than formerly. For listening to speech or music, a very low background noise level is desirable; in concert halls especially the quietest possible conditions should be provided because the pauses and moments of silence which are an essential element of music cannot otherwise be given full value. Therefore, sites at cross-roads or close to steel railway bridges, religious places or near churches where bell ringing is practiced, should be avoided unless very high standards of structural sound insulation are contemplated. Sites adjoining underground railways may also prove unsatisfactory at basement levels owing to low-pitched noise or rumble transmitted through the ground; special isolation measure need to be adopted for isolating large buildings from ground vibration of this sort.

12.3.2 Whenever possible, for concert halls and theatres on city sites a noise survey of the site should be made; a suitable sound reduction value for the structure of the building can then be chosen so as to keep down to certain maximum noise levels within the auditorium. The maximum octave-band sound pressure levels (SPL) recommended are given in Table 8.

Table 8 Maximum Sound Pressure Levels Due to External and Mechanical Equipment Noise in Auditoria (dB)

(*Clause* 12.3.2)

Type of Auditorium	Centre Frequency (Hz)							
	63	125	250	500	1 000	2 000	4 000	8 000
Concert Halls [dB(A)-25]	51	39	31	24	20	17	14	13
Drama Theatres and Cinemas [dB(A)-30]	55	44	35	29	25	22	20	18

12.3.3 The minimum standard of sound reduction index, R_w likely to be required for the envelope of an auditorium in a city to protect it against external noise is of the order of 65 dB for a concert hall or 55-60 dB for a theatre. This reduction should be provided on all sides, but it would be reasonable to make the R_w for the roof 5 to 10 dB less provided the building is not unduly exposed to noise from aircraft in flight. Surrounding the auditorium with ancillary rooms and foyers is an obvious and invaluable planning method of obtaining the required insulation against outdoor noise.

12.3.4 Ventilation intakes and returns are vulnerable features in the defence against external noise. They should be positioned so as to avoid exposure to noise, and in addition sufficient length of both inlet and outlet ducts should be provided with carefully designed silencers. The ventilation system should also be designed to avoid transmitting or adding to internal noise.

12.3.5 The most serious internal noise problem arises when there are two halls meant for separate use in the same building, especially if one of them is a concert hall. The latter is a very loud potential source of noise

and requires a high standard of protection against extraneous noise. In these circumstances it is doubtful whether a 'single' wall can be adequate for insulating the two halls unless it is designed with a wide unbridged cavity. Separation by planning is preferable.

12.3.6 Other sources of internal noise are rehearsal rooms, scenery bays and workshops, stages of other halls where rehearsals or erection of stage sets might be in progress and foyers and bars where loud conversation might occur. The insulation of the internal walls should be adequate to protect the auditorium from these noise sources and the insulation should not be by-passed by openings, doorways, etc. The general noise due to banging of doors also needs to be taken care of; soft sealing materials should be provided for all doors to ensure quiet closing.

12.3.7 For detailed acoustical design of auditoria and conference halls reference may be made to good practice [8-4(3)].

12.4 Cinemas

The main objective of the design should be to control noise from adjacent screens, the projection area, the foyer, and outside the cinema. The first of these, controlling noise from adjacent screens, is likely to be the most difficult with modern digital sound systems. As most cinemas are air conditioned, there will be some noise from services. To ensure reasonable listening conditions, this should be limited to 30 dBA. This will provide some masking of the noise from adjacent screens, but a high performance partition will still be essential. Masonry or lightweight construction may be used, and a typical performance specification for a lightweight wall separating two screens is given in Table 9. Cinema design, however, normally requires specialist acoustic advice.

Table 9 Typical Sound Insulation Specification for Wall Separating Two Cinema Screens

(*Clause* 12.4)

Octave Band Hz	Sound Reduction Index R, dB
63	38
125	44
250	50
500	61
1 000	57
2 000	58
4 000	57
8 000	55

13 NOISE FROM BUILDING SERVICES

13.1 Mechanical, electrical, air conditioning, heating and mechanical ventilation, and other services are provided in almost all large buildings excluding residential, commercial and industrial buildings. Noise control measures should be incorporated during the design and installation of such services to adhere to the recommended outdoor and indoor noise criteria for the kind of occupancy. For detailed design of noise control for services, specialist advice should be sought.

Some basic design techniques for noise control in air conditioning, heating and mechanical ventilation system are given in Annex G.

13.2 Control of noise from mechanical equipments can also be done by specifying noise control requirements while purchasing the equipments (*see* Annex H).

ANNEX A

(*Clause* 2.4)

NOISE CALCULATIONS

A-1 GENERAL

Some of the simpler types of noise calculation are described in this Annex.

A-2 ADDITION OF TWO NOISE LEVELS

To determine the combined sound pressure level (L_c) resulting from the sound pressure levels of two or more noise sources (L_1, L_2, etc), it is necessary to calculate and add the mean square values of their individual sound pressures and then convert this back to a sound pressure level. This can be done using the following formula:

$$L_c = 10 \log_{10}(10^{L1/10} + 10^{L2/10})$$

As the individual sound pressure levels are logarithms of the mean square sound pressures, they cannot simply be added arithmetically. Figure 3 shows a graphical method for adding the sound pressure levels from two independent sources to obtain the combined sound pressure level at a particular place. This graph may also be used for multiple sources by combining sources two at a time to produce virtual sources that can then be combined. The most accurate approach is to start with the lowest levels and work towards the highest.

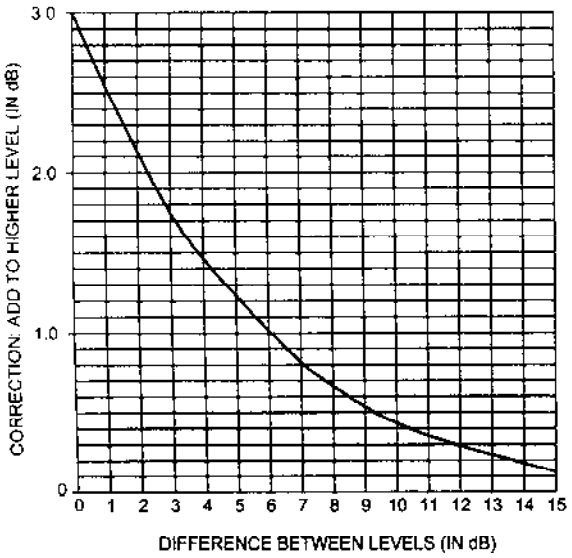

FIG. 3 THE ADDITION OF TWO NOISE LEVELS

The graph should be used with caution where the noise sources are not independent. For example, the sound pressure level from two large transformers fed with currents in phase will be very sensitive to the receiving position. This is because the effect of the constructive and destructive interference of the sounds from the two sources is very dependent on position.

A-3 SUBTRACTION OF TWO NOISE LEVELS

When measuring noise from a source, the true noise level of the source alone will be less than that shown by the meter if the level of extraneous noise is less than about 10 dB below the total noise level. An estimate of the true source level can be obtained from Fig. 4.

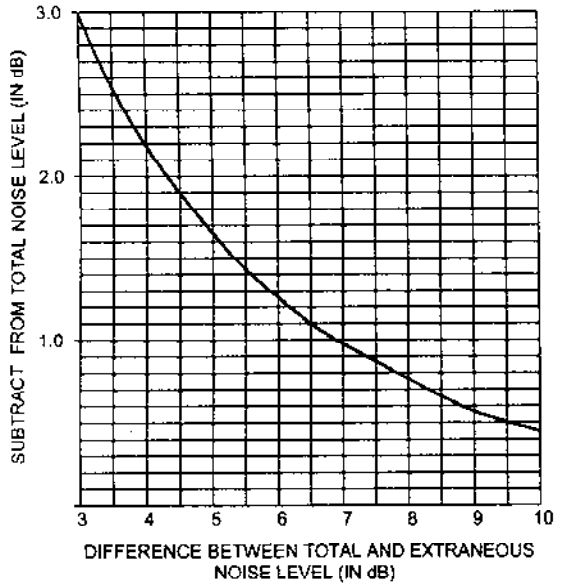

FIG. 4 SUBTRACTION OF NOISE LEVELS

A-4 NON-UNIFORM COMPOSITE PARTITIONS

Figure 5 how to calculate the overall sound insulation of a composite partition consisting of two parts having different sound — insulating properties, for example a window in a wall. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

A-5 A-WEIGHTING CALCULATIONS

The equivalent A-weighted level is often required when data on a noise source is available as a set of octave band or one-third octave band levels. The conversion can be done manually, using the standard A-weighting values (Table 10) and the graph for combining levels (Fig. 3). For all but the simplest situations it is more convenient to use a computer spreadsheet to do the conversion.

Table 10 Standard A-Weighting Values (dB)

Third Octave Band Center Frequency	A-Weighting	Third Octave Band Centre Frequency	A-Weighting
Hz	dB	Hz	dB
(1)	(2)	(3)	(4)
10	–70.4	500	–3.2
12.5	–63.4	630	–1.9
16	–56.7	800	–0.8
20	–50.5	1 000	0
25	–44.7	1 250	0.6
31.5	–39.4	1 600	1.0
40	–34.6	2 000	1.2
50	–30.2	2 500	1.3
63	–26.2	3 150	1.2
80	–22.5	4 000	1.0
100	–19.1	5 000	0.6
125	–16.1	6 300	–0.1
160	–13.4	8 000	–1.1
200	–10.9	10 000	–2.5
250	–8.6	12 500	–4.3
315	–6.6	16 000	–6.6
400	–4.8	20 000	9.3

A-6 REVERBERATION TIME CALCULATION

An estimate of the reverberation time (T) of a room can be obtained from the Sabine formula:

$$T = \frac{(0.16V)}{\Sigma A_i}$$

where

V = is the volume of the room in cubic metres (m^3);

A_i = is the equivalent sound absorbing area in the room in square metres (m^2).

The A_i are the absorbing areas of each surface, or other permanent fixture in the room. Each A_i is determined by multiplying the area of that surface in square

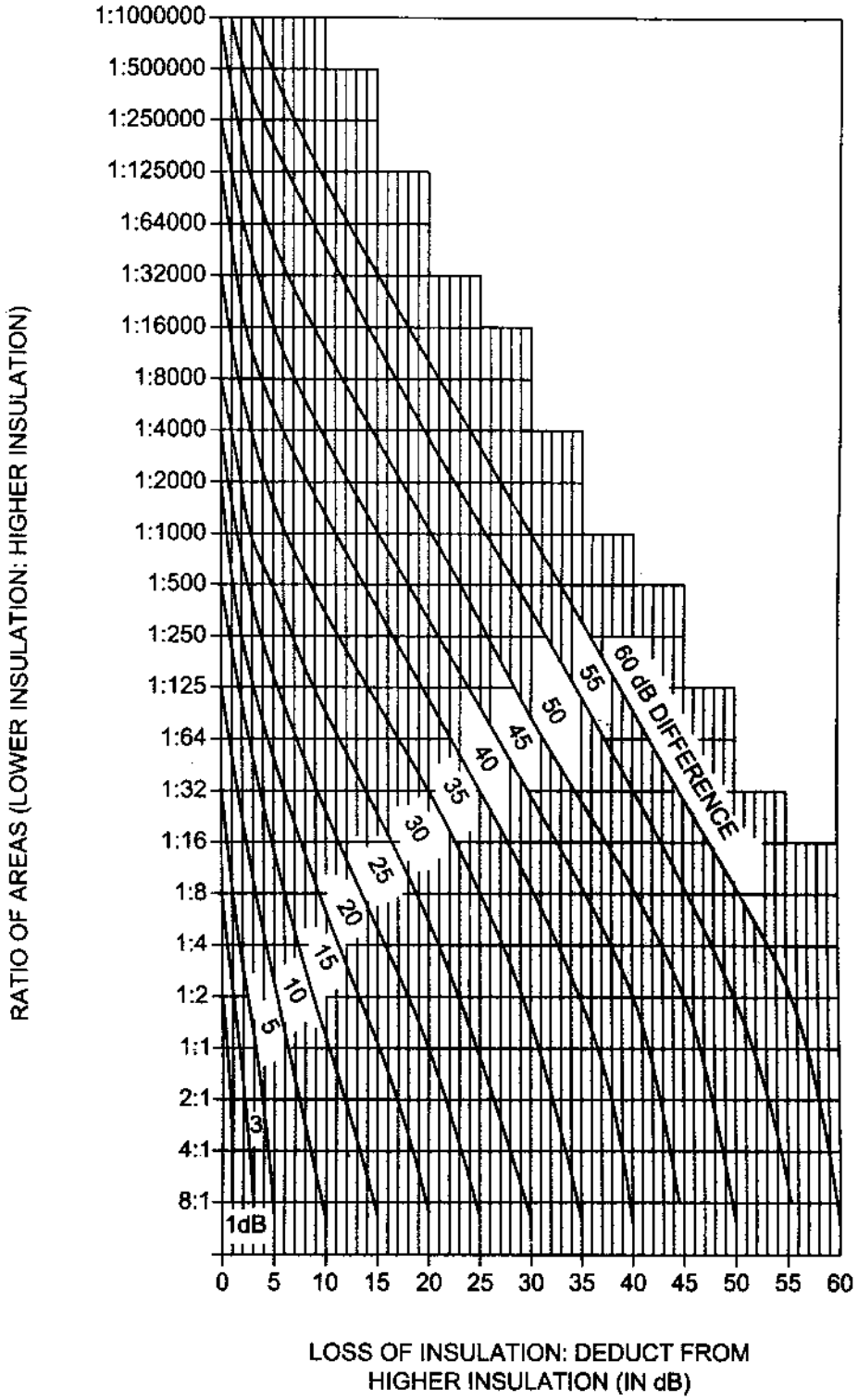

FIG. 5 SOUND INSULATION OF NON-UNIFORM PARTITIONS

metres (m^2) by its absorption coefficient α_{si}. The surface of each significant fixture or feature of the room should be considered as well as the walls, ceiling and floor.

The total absorption is obtained by summing the individual A_i values. As the values of α_{si} are frequency dependent, this calculation should be repeated for each octave band of interest.

An allowance should also be made for people and furnishings in the room.

ANNEX B

(*Clauses* 2.24, 2.38, 2.41, 2.50, 2.51, 2.52 *and* 2.53)

SPECIFICATION OF SOUND INSULATION

B-1 GENERAL

Sound insulating elements work mainly by reflecting sound energy back into the source room, not by absorbing it. The methods of measurement and the terms used are described in **B-2** to **B-4**.

B-2 INSULATION AGAINST AIR-BORNE SOUND

As per the standard tests, the insulation between a pair of rooms is measured either in third octave bands having centre frequencies which cover at least the range 100 Hz to 3 150 Hz, or in octave bands which cover at least the range 125 to 2 000 Hz. The noise is produced by a loudspeaker in one of the rooms (called the source room) and at each frequency the average noise levels are measured in the source room (L_S) and in the adjacent receiving room (L_R). The difference between these two levels (D) is a measure of the sound insulation between the rooms regardless of the transmission path(s) the sound energy followed to travel between the rooms. The equation is as follows:

$$D = L_S - L_R$$

The actual level in the receiving room depends on:

a) the sound insulation of the separating wall or floor,

b) the area of the separating wall or floor;

c) the volume of the receiving room;

d) the amount of flanking transmission (that is the importance of transmission paths other than the separating wall or floor); and

e) the amount of absorbing material (for example furniture) in the receiving room.

For field measurements, apart from the amount of absorption, these factors are a property of the building and should be taken into account by the measurement procedure. As the amount of absorbing material (for example soft furniture) in the room at the time of measurement is arbitrary, it should be allowed for separately. This is achieved by measuring the reverberation time (T) of the room in seconds (s), which is a measure of how long it takes a sound to die away after the source has been switched off. As the sound energy is dissipated as heat in the absorbing material (T), it is related to the total amount of absorption in the room. The receiving room level may then be corrected to the level it would be if the room had a standard reverberation time (T_0) which is typical of furnished rooms, and is taken to be 0.5 s. The corrected level difference is known as the standardized level difference, which has the symbol D_{nT} and is calculated using the following equation:

$$D_{nT} = L_S - L_R + 10 \log_{10} (T/T_0)$$

For laboratory measurements, the insulation of the separating wall or floor being tested is required in a way which is independent of the actual measuring laboratory. For this reason, laboratories are designed to have minimal flanking transmission and a different correction is applied to account for the other factors. This correction is $10 \log_{10} (S/A)$.

where

S = is the common area of the separating wall or floor in square metres (m^2); and

A = is the equivalent absorption area in the receiving room in square metres (m^2).

The laboratory corrected level difference at each frequency is known as the sound reduction index, which has the symbol R and is calculated using the following equation:

$$R = L_S - L_R + 10 \log_{10} (S/A)$$

If the test wall or floor is mounted in a realistic way in the laboratory and flanking transmission will be low in the field, the sound reduction index may be used to predict its performance in the field. The relation between D_{nT} and R is $D_{nT} = R - 10 \log_{10} (3S/V)$

where

S = is the area of the separating wall or floor in the field in square metres (m^2); and

V = is the volume of the receiving room in the field in cubic metres (m^3).

This equation shows that if the source and receiving rooms have different volumes, D_{nT} will depend on which is used as the source room; using the larger room as the source room will give lower value.

B-3 INSULATION AGAINST IMPACT SOUND

The procedure to measure the impact insulation of floors is rather different. Instead of a loudspeaker, a machine containing five small hammers is placed on the floor. While the hammers strike the floor at a rate of 10 blows a second, the resulting noise level (L_i) is measured in the receiving room below at each of the same frequency bands used for airborne insulation. In the field, the receiving room levels are again

'corrected' to a standard reverberation time (T_o) of 0.5 s to give the standardized impact sound pressure level, L_{nT}, which is calculated as follows:

$$L_{nT} = L_i - 10 \log_{10} (T/T_o)$$

In the laboratory, the noise level depends mainly on the characteristics of the floor being tested and the amount of absorption (A m^2) in the laboratory. It is therefore appropriate to correct the noise level to a standard area of absorption. The area used is 10 m^2. The resulting normalized impact sound pressure level is given the symbol L_n and calculated as follows:

$$L_n = L_i + 10 \log_{10} (A/10)$$

B-4 RATING SOUND INSULATION

Measurements of insulation against both air-borne and impact sound yield values in a number of frequency bands. To make this information more manageable, rating methods such as those in accordance with [8-4(1)] are used to reduce the frequency band values to single figure ratings. These single figure ratings should be good predictors of subjective assessments of insulation. However, this is not always the case and it is prudent to examine the full measurement data in critical situations. The impact insulation measured on a floor with a carpet is likely to be overestimated by this method.

The more common indices used to describe sound insulation are summarized in Table 11.

Table 11 Common Indices Used to Describe Air-borne and Impact Sound Insulation

(*Clause* B-4)

Air-borne (*A*) Impact (*I*)	Lab (*L*) Field (*F*)	Measured Values		Single Number Quantity	
		Name	Symbol	Name	Symbol
(1)	(2)	(3)	(4)	(5)	(6)
A	*F*	Standardized level difference	D_{nT}	Weighted standardized level difference	$D_{nT,w}$
A	*L*	Sound reduction index	*R*	Weighted sound reduction index	R_w
I	*F*	Standardized impact sound pressure level	L'_{nT}	Weighted standardized impact sound pressure level	$L'_{nT,w}$
I	*L*	Normalized impact sound pressure level	L'_n	Weighted normalized impact sound pressure level	$L'_{n,w}$

ANNEX C

(*Clause* 2.22)

NOISE RATING

C-1 Noise rating (NR) is a graphical method for assigning a single number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability of a noise spectrum for a particular application. The method was originally proposed for use in assessing environmental noise, but was later also found suitable for describing noise from mechanical ventilation systems in buildings. To make a rating, the noise spectrum is superposed on a family of NR contours; the NR of the spectrum corresponds to the value of the first NR contour that is entirely above the spectrum. The data for drawing NR contours (from NR 0 to NR 75) is given in Table 12 for the frequency range 31.5 Hz to 8 kHz.

C-2 For computational methods the curves are defined by the equation:

$$L = a + bN$$

where

L = is the octave band sound pressure level corresponding to NR level N; and

a and b = are constants for each frequency band, as given in Table 13.

NOTE — NR values can not be converted directly to dBA values but the following approximate relationship applies:

$$NR = dBA - 6$$

C-3 Although the NR system is currently the preferred method for rating noise from mechanical ventilation system, other methods which are more sensitive to noise at low frequencies are available, but they are not yet widely accepted. Low frequency noise may be disturbing or fatiguing to occupants, but may not have much effect on the dBA or NR value.

Table 12 Noise Rating Values

(*Clause* C-1)

Noise Rating	Octave Band Centre Frequency, Hz Sound Pressure Levels dB_{re} 20μPa								
	31.5	63	125	250	500	1 000	2 000	4 000	8 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NR75	106	95	87	82	78	75	73	71	69
NR70	103	91	83	77	73	70	68	66	64
NR65	100	87	79	72	68	65	62	61	59
NR60	96	83	74	68	63	60	57	55	54
NR55	93	79	70	63	58	55	52	50	49
NR50	89	75	66	59	53	50	47	45	43
NR45	86	71	61	54	48	45	42	40	38
NR40	83	67	57	49	44	40	37	35	33
NR35	79	63	52	45	39	35	32	30	28
NR30	76	59	48	40	34	30	27	25	23
NR25	72	55	44	35	29	25	22	20	18
NR20	69	51	39	31	24	20	17	14	13
NR15	66	47	35	26	19	15	12	9	7
NR10	62	43	31	21	15	10	7	4	2
NR5	59	39	26	17	10	5	2	−1	−3
NR0	55	35	22	12	5	0	−4	−6	−8

Table 13 Values of *a* and *b*

(*Clause* C-2)

Octave Band Centre Frequency Hz	*a*	*b*
(1)	(2)	(3)
31.5	55.4	0.681
63	35.4	0.790
125	22.0	0.870
250	12.0	0.930
500	4.2	0.980
1 000	0.0	1.000
2 000	−3.5	1.015
4 000	−6.1	1.025
8 000	−8.0	1.030

ANNEX D

(*Clause* 3.3)

OUTDOOR NOISE REGULATIONS IN INDIA

D-1 Government notifications are issued from time-to-time on the allowable ambient noise levels in general and specifically in different zones of various metropolitan cities of India.

D-2 Noise regulations and notifications are also issued from time-to-time specifying the maximum permissible sound levels from equipments commonly used in and around the residential areas and around sensitive buildings, specifically with regard to noise levels from electricity generating sets, construction equipment and HVAC utility equipment installed outdoors.

D-3 These regulations should be referred to by the designer for the design of measures for control of external noise.

ANNEX E

(*Clauses* 3.8 *and* 4.5)

SPECIAL PROBLEMS REQUIRING EXPERT ADVICE

E-1 GENERAL

Certain design problems require reliable advice of a kind which is not easy to find in published material. The advice of an expert should be sought for these kinds of problems, some examples of which are given in **E-2** to **E-9**.

E-2 ACOUSTIC TEST ROOMS

The design of rooms in which acoustic measurements are carried out, such as reverberation chambers, free-field anechoic rooms and audiometric test rooms, usually requires the advice of an expert.

E-3 PERFORMING SPACES

The design of theatres, opera houses, concert halls and similar performing spaces usually requires expertise in room acoustics and noise control. The intrusion of quite low levels of noise may seriously interfere with the enjoyment of the performance and distract the performers. The requirements for low noise levels often mean that more room has to be allocated for low velocity ventilation ductwork and the impact on the design of the ventilation system is often substantial.

E-4 BROADCASTING AND RECORDING STUDIOS

Broadcasting and recording studios have requirements similar to those of performing spaces. For some infrequent intrusive noises, the requirements are sometimes relaxed on the grounds that a re-take of a

recording can be done, but this can result in higher operating costs.

E-5 AIRCRAFT NOISE

As there are many variables affecting the level of aircraft noise heard on the ground, expert advice is almost always required. Contours of daytime $L_{Aeq,T}$ levels are available from most major airports. Where measurements of façade insulation are necessary a standard test method may be referred.

E-6 GROUND-BORNE NOISE

Projects involving ground-borne noise from underground trains usually require expert advice.

E-7 LOW-FREQUENCY NOISE

Projects involving low-frequency noise usually require expert advice as accurate measurement is difficult and there is a shortage of reliable data below 100 Hz.

E-8 ACTIVE NOISE CONTROL

Active noise control is the reduction of noise by cancellation with a similar noise (anti-noise) generated by electro-acoustic means. The technique is still under development, but commercial systems are available which successfully reduce low frequency noise from mechanical ventilation systems.

E-9 NOISE SURVEYS

Noise surveys are carried out for a variety of reasons, for example:

a) before construction, to establish the existing noise climate at the site of a proposed development where reliable prediction is impracticable, as an aid to the design of the building envelope, either to protect against external noise or contain internally produced noise;
b) during construction, to monitor noise from building activity, either to assess the likely nuisance to the local community or the risk of hearing damage to the work force;
c) at the end of a building contract to check the insulation of the building envelope, or the noise levels produced by the services;
d) as part of a planning requirement; and
e) to provide objective evidence to support or defend a legal action.

The expense of carrying out a comprehensive noise survey of any kind is likely to be high, so the cost-effectiveness of a full or partial survey should be weighed against alternatives such as prediction. A survey will generally be more accurate and can take account of factors such as prevailing wind conditions.

ANNEX F

(*Clause* 4.4)

AIR-BORNE AND IMPACT SOUND INSULATION

F-1 GENERAL

Air-borne sound refers to sources which produce sound by directly setting the air around them into vibration. Impact sound refers to sources which produce sound by impulsive mechanical excitation of part of a building (for example by footsteps, electric light switches, slamming doors). Many sources of impact sound also produce significant levels of airborne sound. The term structure-borne sound has no very precise meaning as the structure can be excited by both airborne and impact sources; it is often used to refer to sound that travels for long distances via the structure, especially in connection with vibrating machinery linked directly to the structure.

F-2 DIRECT AND INDIRECT TRANSMISSION

Figure 6 shows diagrammatically a pair of rooms in a house where the construction consists of solid walls, etc bonded together. Sound travelling from room 1 to room 2 may travel via the direct path *a-a* and by the many indirect, or flanking, paths shown. The term flanking transmission is usually used to mean transmission paths involving the structure, while the term indirect transmission includes flanking paths and airborne paths through gaps and ducts, etc. The indirect paths may limit the sound insulation attainable no matter how much the direct sound is reduced by the separating wall or floor. The indirect transmission can be reduced by measures such as the following:

a) Increasing the mass of the flanking walls;
b) Increasing the mass of the partition and bonding it to the flanking walls;
c) Introducing discontinuities in the indirect paths;
d) Erecting independent wall linings adjacent to the flanking walls to prevent energy entering the flanking construction; and
e) Sealing any air gaps and paths through ducts.

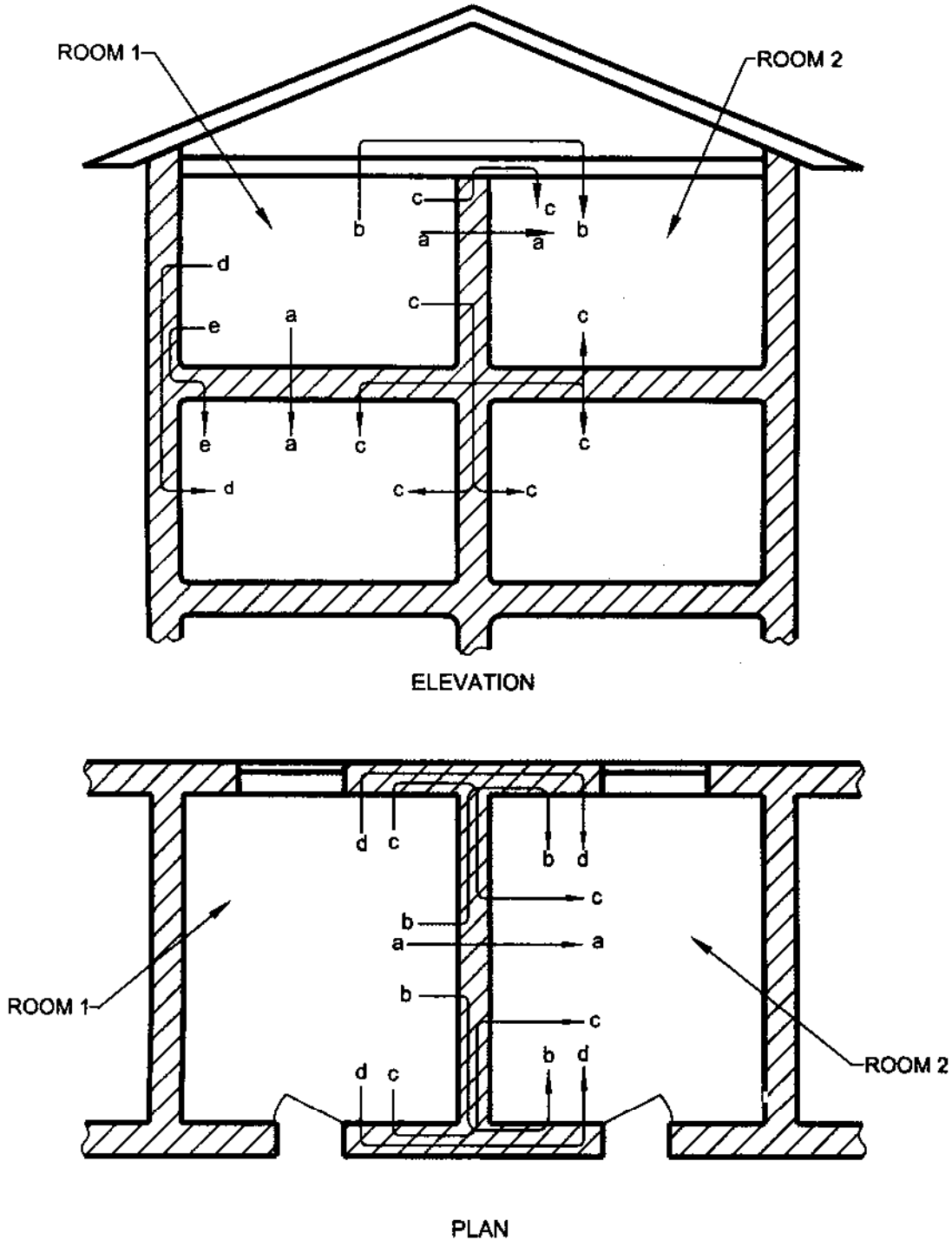

FIG. 6 TRANSMISSION PATHS (VIA THE STRUCTURE) OF NOISE ORIGINATING IN ROOM 1 (DIAGRAMMATIC)

Figure 7 shows a number of indirect paths that have been found in offices.

It is important to remember that standard test laboratories are designed to minimize transmission by all paths other than the direct path. This makes it difficult to relate the results of laboratory measurements to those likely to be obtained in the field.

F-3 AIR-BORNE SOUND INSULATION

F-3.1 General

The sound insulation of structural elements such as

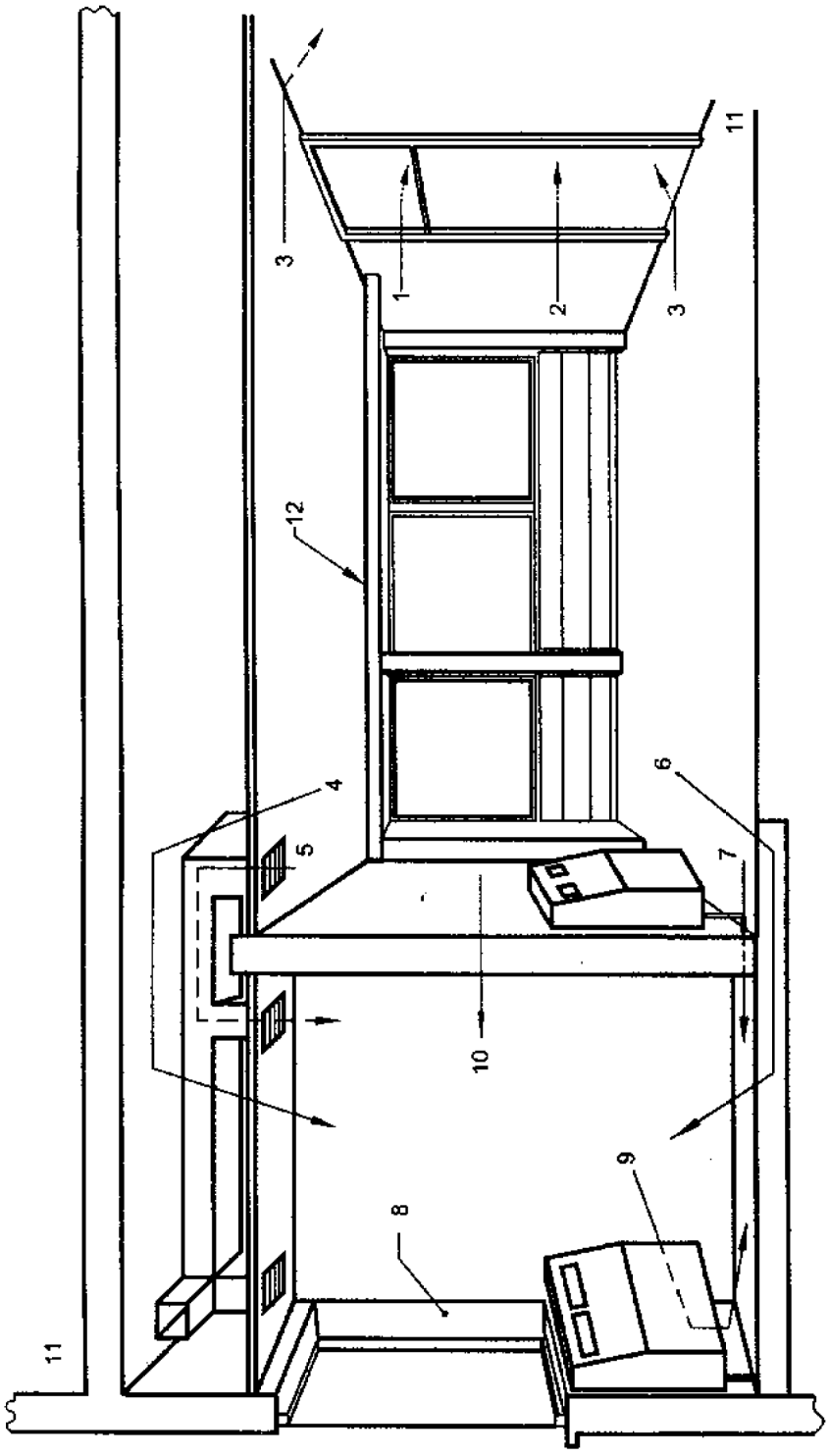

FIG. 7 INDIRECT SOUND LEAKAGE PATHS

walls and floors always varies with frequency, the insulation rising in general as the frequency rises.

F-3.2 Terminology

Results from field measurements are usually expressed in terms of the weighted standardized level difference, while laboratory measurements are usually expressed in terms of the sound reduction index. In the absence of significant flanking transmission, the numerical difference between the weighted standardized level difference and the sound reduction index of a wall or floor is usually small for furnished rooms in dwellings, and so either quantity may be used in considering principles; for this purpose it is, therefore, convenient to use the general term insulation.

F-3.3 Mass Law

An approximate empirical relationship has been established between sound insulation and mass for single leaf constructions as shown in Fig. 8. This so called 'mass law' gives a useful first approximation to the behaviour of a single sheet or plate. In practice, the sound insulation predicted by the mass law may not be attained because of factors such as the coincidence effect, which is outlined in **F-3.4**. Results for specific materials vary around the value given by the mass law relationship, and so measured data should be used when available. Table 14 gives a lists of materials and indicates the sound insulation of a single, imperforate sheet when fixed to a suitable wood or metal framework. These values are useful, for example when assessing existing structures.

Table 14 Sound Insulation of Imperforate Sheet Materials

(*Clause* F-3.3)

Material	Surface Mass	Typical Weighted Sound Reduction Index, R_w
	kg/m^2	dB
(1)	(2)	(3)
3 mm glass sheet	7.0	26
12.5 mm plasterboard	10.5	31
18 mm wood particle board	8.0	27
19 mm plywood	3.0	24
16 mm plywood	4.5	24
1 mm steel sheet	11.0	29
6 mm hardboard	5.0	25
12 mm wood fibre insulation board	4.0	24
13 mm mineral fibre board	4.0	24
50 mm wood-wool screeded one side	35.0	33

F-3.4 The Coincidence Effect

The coincidence effect occurs when the wavelength of the wave impressed on the panel by the incident sound wave is close to the wavelength of free bending waves in the panel. The effect of coincidence is to lower the sound insulation of a construction by as much as 10 dB below the level expected from its mass per unit area over a limited frequency range. The coincidence effect can be pronounced with thin lightweight partitions, resulting in loss of insulation at middle and high frequencies. Reducting the stiffness without a corresponding reduction of mass can raise the critical frequency above 3 150 Hz, and so improve the insulation over the important 100 Hz

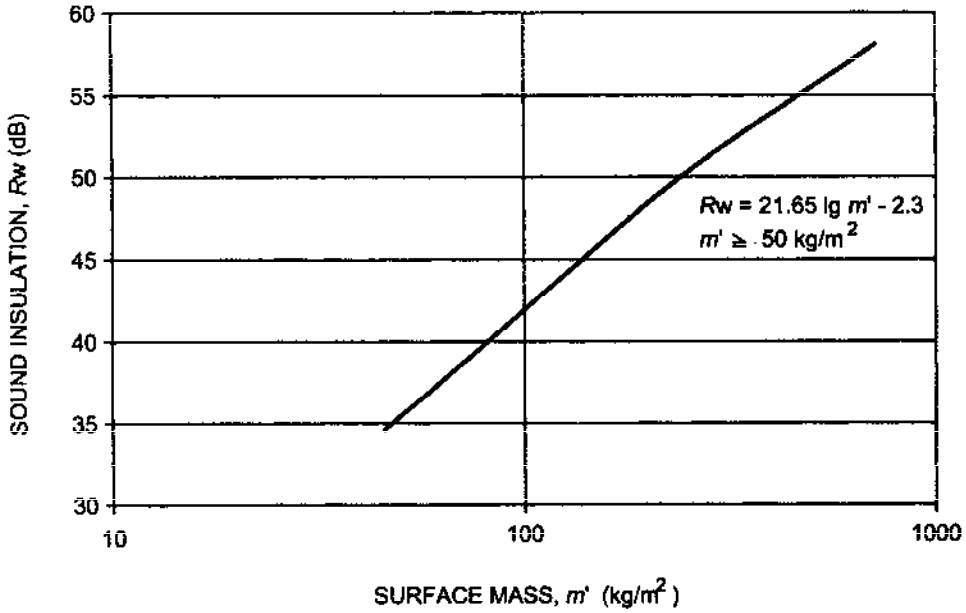

FIG. 8 MASS LAW CURVE

to 3 150 Hz range. An increase of stiffness will have the reverse effect.

It is possible to design lightweight stud partitions so that they perform to their maximum effect in the speech frequency region between 250 Hz and 2 000 Hz, that is between the mass-spring-mass and coincidence regions respectively.

The worst coincidence dips occur in materials such as plate glass and rigid metal sheets. Heavily damped materials such as lead sheets are least affected.

F-3.5 Mass-Spring-Mass Frequency

A double leaf wall can perform better than a single leaf wall of similar mass because the sound has to pass through two barriers. If the two leaves are not connected to each other, the insulation values of the two leaves may be added together. However, in practice the leaves are often connected by ties or studs, and the full insulation cannot be achieved. Even where the two leaves are isolated from each other, the full benefit can only be obtained above a certain frequency that depends on the cavity width. This is because the air in the cavity behaves like a spring connecting the leaves together, and causes a resonance at the mass-spring-mass frequency. Below this frequency, the two leaves behave more like an equivalent single leaf.

Making the cavity width wide can reduce the mass-spring-mass frequency, as in the case of sound insulating secondary glazing. The mass-spring-mass frequency (F_0) may be estimated from the following equation:

$$F_0 = 59.6\sqrt{\frac{1}{d}\left(\frac{1}{m_1}+\frac{1}{m_2}\right)}$$

where

m_1 and m_2 = the surface masses of the two leaves in kilograms per square metre (kg/m^2); and

d = the cavity width in metres (m).

F-3.6 Impact Sound Control

A structure that receives an impact or has a vibrating source in contact with it behaves more like an extension of the source rather than an intervening element between source and listener. For this reason, a relatively small amount of impact energy may produce a loud sound and, if the structure is continuous, the sound may travel a long distance. Control is usually obtained by inserting a resilient surface at the point of contact with the source (for example laying a carpet on a floor) or by introducing a structural discontinuity.

Floating floors, which are an example of the latter approach, are a common method of controlling impact sound from footsteps. However, it should be noted that an effective floating floor may result in increased sound from impacts on the source side of the floor. The conventional forms of floating floor may be unsatisfactory if protection against the low-frequency content of impact noise is required (e.g. a dance floor over a restaurant).

F-4 AIR-BORNE INSULATION VALUES OF WALLS AND AIR-BORNE AND IMPACT INSULATION VALUES OF FLOORS

Table 15 and Table 16 give examples of common types of wall and floor construction with sound insulation in the ranges shown. The insulation indices are for field measurements accessed in accordance with [8-4(5)]. The insulation values given are necessarily approximate since examples of nominally identical constructions may show variations of several decibels. All the figures represent values expected in the field, that is in actual buildings. Many are based directly on field measurements, though other (in the absence of representative field measurements) have been assessed from laboratory data, with an allowance for typical flanking conditions in normal buildings. Variation in the amount of indirect transmission may affect significantly the insulation between two rooms separated by a given barrier. For example, the sound insulation of some types of floor may be reduced by indirect transmission along the walls supporting them, particularly if these walls are of lightweight masonry and carried past the floor.

Table 15 Air-borne Sound Insulation of Walls and Partitions

(*Clause* F-4)

Sound Insulation $D_{nT,w}$ dB	Type of Wall or Partition
(1)	(2)
26 to 33	a) 1 mm steel sheet panels fixed to steel frame members to form demountable partition units 50 mm overall thickness. Mineral wool cavity insulation.
	b) Plywood or wood fibre board 12 mm thick nailed both sides of 50 mm × 50 mm timber framing members spaced at 400 mm centres.
	c) Paper faced strawboard or wood wool 50 mm thick panels plastered both sides.
	d) Chipboard hollow panels 50 mm thick tongued and grooved edges, hardboard faced. Joints covered with wood trim.
33 to 37	a) Lightweight masonry blockwork. Plaster or drylining on at least one side. Overall mass per unit area not less than 50 kg/m^2.
	b) Laminated plasterboard at least 50 mm thick fixed to timber perimeter framing, any suitable finish. Approximate mass per unit area 35 kg/m^2.

Table 15 — *Continued*

(1)	(2)
	c) Timber stud partitions any size timbers greater than 50 mm × 50 mm, 400 mm centers, cross noggins, 9.5 mm plasterboard lining on both sides, any suitable finish.
	d) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 18 kg/m^2.
	e) 50 mm lightweight masonry blockwork, plastered both sides to 12 mm thickness or drylined with 9.5 mm plasterboard.
37 to 43	a) Lightweight masonry blockwork, plaster or dry lining on at least one side. Overall mass per unit area not less than 75 kg/m^2.
	b) Either 75 mm or 100 mm × 50 mm timber studs spaced 600 mm apart, 50 mm mineral fibre quilt in stud cavity. Frame lined on both sides with one layer 12.5 mm plasterboard. Approximate mass per unit area 19 kg/m^2.
43 to 50	a) Masonry wall, joints well filled. Either plaster or dry lining on both sides. Overall mass per unit area not less than 150 kg/m^2.
	b) 100 mm metal stud partition, 'C' section studs not greater than 600 mm spacing, not less than nominal 50 mm web depth. Clad on both sides with two layers of plasterboard of not less than 22 mm combined thickness. Mineral fibre quilt hung between studs. Approximate mass per unit area 35 kg/m^2.
	c) 75 mm × 50 mm timber framing using staged studs at 300 mm spacing with 25 mm stagger forward and back. Frame clad with two layers of 12.5 mm of plasterboard on both sides. Mineral fibre quilt hung between studs. Approximate mass per unit area 36 kg/m^2.
	d) 50 mm × 25 mm timber stud partition to form a 25 mm cavity, clad on both sides with minimum 38 mm wood wool slabs having their outer faces screeded or plastered.
	e) Solid autoclaved aerated concrete block 215 mm thick plaster or dry lined finish on both sides, blockwork joints well filled. Overall mass per unit area not less than 160 kg/m^2.
50 to 54	a) Two separate frames of timber studs not less than 89 mm × 38 mm, or boxed metal studwork with 50 mm minimum web depth. Studs at 600 mm maximum centres. A 25 mm mineral wool quilt suspended between frames. Frames spaced to give a minimum 200 mm overall cavity. Clad on outside of each frame with a minimum of 30 mm plasterboard layers (for example 19 mm plus 12.5 thickness). Approximate mass per unit area 54 kg/m^2.[1)]
	b) Either *in-situ* or pre-cast concrete wall panel not less than 175 mm thick and not less than 415 kg/m^2. All joints well filled.[1)]
	c) Brick wall nominal 230 mm thickness, weight (including plaster) not less than 380 kg/m^2. Plaster or dry-lined finish both sides. Brick work joints well filled.[1)]
	d) 'No fines' concrete 225 mm thickness, weight (including plaster) not less than 415 kg/m^2. Plaster or dry-lined finish both sides.[1)]

Table 15 — *Concluded*

(1)	(2)
	e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2.[1)]
	f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in block work well filled. Overall mass per unit area not less than 415 kg/m^2.[1)]
	g) Autoclaved aerated concrete block cavity wall consisting of two leaves, 100 mm blocks not less than 75 mm apart, with wall ties of the butterfly type. Plaster or dry line finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 150 kg/m^2.[1)]
54 to 60	a) Two separate frames of timber studs not less than 100 mm × 50 mm spaced at 600 mm maximum centres. A 50 mm mineral wool quilt in each frame between studs. Frames spaced to give a minimum 300 mm overall cavity. Each frame clad on outside with three layers of 12.5 mm plasterboard nailed to framing. Approximate mass per unit area 51 kg/m^2.[1)]
	b) Two separate frames of boxed 'C' section galvanized nominal 150 mm steel studs 100 mm apart with a 400 mm overall cavity. 50 mm mineral wool quilt fixed to the back of one frame each frame clad on outside with three layers of 12.5 mm plasterboard by self drilling or tapping screws. Approximate mass per unit area 47 kg/m^2.[1)]
	c) Solid masonry with an overall mass per unit area of not less than 700 kg/m^2 fully sealed both sides.[1)]
	d) Dense aggregate concrete block solid wall 215 mm thick plaster finish to both surfaces. Overall mass per unit area not less than 415 kg/m^2.[1)]
	e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2.[1)]
	f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m^2.[1)]
	NOTES 1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved. 2 Where plasterboard is specified it is assumed that the surface mass will be at least 6.5 kg/m^2 for 9.5 mm thick board, at least 8.5 kg/m^2 for 12.5 mm thick board, and at least 14.5 kg/m^2 for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] When considering these constructions for separating walls, expert advice should be sought.

Table 16 Air-borne and Impact Sound Insulation of Floor Constructions

(*Clause* F-4)

Sound Insulation dB	Type of Wall or Partition
(1)	(2)
$D_{nT,w}$ = 49 to 54 $L'_{nT,w}$ = 56 to 65	a) A concrete floor having mass per unit area not less than 365 kg/m², including any screed or ceiling finish directly bonded to the floor slab; together with a floating floor or resilient floor covering equivalent to rubber or sponge rubber underlay or thick cork tile (for example carpet and underlay or sponge rubber backed vinyl flooring). b) A solid floor consisting of: 1) a solid slab; or 2) concrete beams and infilling blocks; or 3) hollow concrete planks; together with a floating floor. A ceiling finish is required for a beam and block floor. In each case the slab should have a mass per unit area of at least 300 kg/m² including any screed or ceiling finish directly bonded to it. Where a floating floor is laid over a floor of beams and hollow infill blocks or hollow beams along the top of the structural floor, it should be sealed and levelled before the resilient layer is put down. It is also essential to have due regard for conduits and pipework which should be laid and covered so as to prevent any short circuit of the floor's isolating properties. If precast units are used as a structural floor, it is essential that the joints are filled to ensure that the sound insulation performance is maintained. The resilient material is laid to cover completely the structural floor and turned up against the surrounding wall along all edges. The resilient layer is usually of mineral fibre, or a special grade of expanded polystyrene. When the screed is laid, it is important that none of the mix finds its way through the resilient layer to the structural floor, as this will short circuit the isolation between the two decks and significantly reduce the sound insulation. c) A floor consisting of boarding nailed to battens laid to float upon an isolating layer of mineral fibre capable of retaining its resilience under imposed loading. With battens running along the joists, a dense fibre layer can be used in strips. The ceiling below to be of metal lath and plaster not less than 29 mm thick, with pugging on the ceiling such that the combined mass per unit area of the floor, ceiling and pugging is not less than 120 kg/m². This construction will only give values for $D_{nT,w}$ of 50 to 53 dB, and a value for $L'_{nT,w}$ of 75 dB. d) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard laid on battens running parallel to the joists and supported on 25 mm thick mineral wool of about 90 kg/m³ to 140 kg/m³ density; 100 mm of fibre absorbent (as used for insulation in roof spaces) laid between the joists on top of the plasterboard ceiling.[1)] e) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard floating on a 25 mm thick mineral wool layer of about 60 kg/m³ to 80 kg/m³ density; this on a 12.5 mm plywood platform; 100 mm of fibre absorbent laid between the joists on top of the plasterboard ceiling.[1)]
$D_{nT,w}$ = 32 to 36 $L'_{nT,w}$ = 80 to 85	Timber joist floor consisting of 22 mm tongued and grooved floor boarding or equivalent fixed directly to floor joists. Ceiling of 12.5 mm plasterboard and skim with no floor covering.

NOTES

1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

2 Where plasterboard is specified it is assumed that the surface mass will be at least 8.5 kg/m² for 12.5 mm thick board, and at least 14.5 kg/m² for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] In these types of floor construction, the ceiling may be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.

In many cases, simple solid partitions give insulation values according to their mass (*see* **F-3.3**). Moreover, with partitions of this type there is usually little variation between field and laboratory test results unless the laboratory insulation exceeds 45 dB. Exceptions may occur in buildings that have not been specially designed to minimize common cavities and strongly coupled elements in lightweight panelling. The examples given are not exhaustive. Flanking structures are not listed since these can vary widely and are often dependent upon other factors such as thermal insulation, which are outside the scope of this Code.

ANNEX G

(Clause 13.1)

BASIC DESIGN TECHNIQUES FOR NOISE CONTROL IN AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION SYSTEM

G-1 When selecting fans and other related mechanical equipment and when designing air distribution systems to minimize the sound transmitted from different components to the occupied spaces that they serve, the following recommendations should be considered:

a) Design the air distribution system to minimize flow resistance and turbulence. High flow resistance increases the required fan pressure, which results in higher noise being generated by the fan. Turbulence increases the flow noise generated by duct fittings and dampers in the air distribution system, especially at low frequencies.

b) Select a fan to operate as near as possible to its rated peak efficiency when handling the required quantity of air and static pressure. Also, select a fan that generates the lowest possible noise but still meets the required design conditions for which it is selected. Using an oversized or undersized fan that does not operate at or near rated peak efficiency may result in substantially higher noise levels.

c) Design duct connections at both the fan inlet and outlet for uniform and straight air flow. Failure to do this may result in severe turbulence at the fan inlet and outlet and in flow separation at the fan blades. Both of these may significantly increase the noise generated by the fan.

d) Select duct silencers that do not significantly increase the required fan total static pressure.

e) Place fan-powered mixing boxes associated with variable volume air distribution systems away from noise-sensitive areas.

f) Minimize flow-generated noise by elbows or duct branch take-offs, whenever possible, by locating them at least four to five duct diameters from each other. For high velocity systems, it may be necessary to increase this distance to up to ten duct diameters in critical noise areas.

g) Keep airflow velocity in the duct as low as possible (7.5 m/s or less) near critical noise areas by expanding the duct cross-section area. However, do not exceed an included expansion angle of greater than 15°. Flow separation, resulting from expansion angles greater than 15°, may produce rumble noise. Expanding the duct cross-section area will reduce potential flow noise associated with turbulence in these areas.

h) Use turning vanes in large 90° rectangular elbows and branch takeoffs. This provides a smoother transmission in which the air can change flow direction, thus reducing turbulence.

j) Place grilles, diffusers and registers into occupied spaces as far as possible from elbows and branch takeoffs.

k) Minimize the use of volume dampers near grills, diffusers and registers in acoustically critical situations.

m) Vibration isolate all vibrating reciprocating and rotating equipment if mechanical equipment is located on upper floors or is roof-mounted. Also, it is usually necessary to vibration isolate the mechanical equipment that is located in the basement of a building as well as piping supported from the ceiling slab of a basement, directly below tenant space. It may be necessary to use flexible piping connectors and flexible electrical conduit between rotating or reciprocating equipment and pipes and ducts that are connected to the equipment.

n) Vibration isolate ducts and pipes, using spring and/or neoprene hangers for at least the first 15 m from the vibration-isolated equipment.

p) Use barriers near outdoor equipment when noise associated with the equipment will disturb adjacent properties if barriers are not used. In normal practice, barriers typically produce no more than 15 dB of sound attenuation in the mid-frequency range.

q) Table 17 lists several common sound sources associated with mechanical equipment noise. Anticipated sound transmission paths and recommended noise reduction methods are also listed in Table 18. Air-borne and/or structure-borne sound can follow any or all of the transmission paths associated with a specified sound source.

Table 17 Sound Sources, Transmission Paths and Recommended Noise Reduction Methods

[*Clause* G-1(q)]

Sound Source	Path No. (*see* Table 18)
Circulating fans, grilles, registers, diffusers, unitary equipment in room	1
Induction coil and fan-powered VAV mixing units	1, 2
Unitary equipment located outside of room served; remotely located air-handling equipment, such as fans, blowers, dampers, duct fitting, and air washers	2, 3
Compressors, pumps, and other reciprocating and rotating equipment (excluding air-handling equipment)	4, 5, 6
Cooling towers; air-cooled condensers	4, 5, 6, 7
Exhaust fans; window air conditioners	7, 8
Sound transmission between rooms	9, 10

Table 18 Sound Transmission Paths and Recommended Noise Reduction Methods

[*Clause* G-1(q) and *Table* 17]

Path No.	Transmission Paths	Noise Reduction Methods
(1)	(2)	(3)
1	Direct sound radiated from sound sources to ear.	Direct sound can be controlled only by selecting quiet equipment.
	Reflected sound from walls, ceiling and floor.	Reflected sound is controlled by adding sound absorption to the room and to equipment location.
2	Air and structure-borne sound radiated from casings and through walls of ducts and plenums is transmitted through walls and ceiling into rooms.	Design duct and fittings for low turbulence; locate high velocity ducts in non-critical areas; isolate ducts and sound plenums from structure with neoprene or spring hangers
3	Airborne sound radiated through supply and return air ducts to diffusers in room and then to listener by Path 1.	Select fans for minimum sound power; use ducts lined with sound-absorbing material; use duct silencers or sound plenums in supply and return air ducts.
4	Noise transmitted through equipment room walls and floors to adjacent rooms.	Locate equipment rooms away from critical areas; use masonry blocks or concrete for equipment room walls and floor.
5	Vibration transmitted via building structure to adjacent walls and ceilings, from which it radiates as noise into room by Path 1.	Mount all machines on properly designed vibration isolators; design mechanical equipment room for dynamic loads; balance rotating and reciprocating equipment.
6	Vibration transmission along pipes and duct walls.	Isolate pipe and ducts from structure with neoprene or spring hangers; install flexible connectors between pipes, ducts, and vibrating machines.
7	Noise radiated to outside enters room windows.	Locate equipment away from critical areas; use barriers and covers to interrupt noise paths; select quiet equipment.
8	Inside noise follows Path 1.	Select quiet equipment.
9	Noise transmitted to an air diffusers in a room, into a duct, and out through an air diffuser in another room.	Design and install duct attenuation to match transmission loss of wall between rooms.
10	Sound transmission through, over, and around room partition.	Extend partition to ceiling slab and tightly seal all around; seal all pipe, conduit, duct and other partition penetrations.

ANNEX H

(*Clause* 13.2)

SUGGESTED EQUIPMENT NOISE DATA SHEET

It is recommended that an equipment noise data sheet be furnished to intending bidders of mechanical equipment such as air conditioning, heating and mechanical ventilation machinery or diesel generating units specifying noise requirements at the time of request for quotation. Following is a sample noise data sheet suggested for the purpose:

Sample of Equipment Noise Data Sheet for Noise Specification to be Sent to Suppliers

Equipment Description _____ **Type** _____ **Item No.** _____

Octave-Band Centre Frequency, Hz	*Desired Sound Pressure Level,* L_p	*Supplier to Complete*		
		Actual	Special Design	Special Noise Control Measures Recommended
(1)	(2)	(3)	(4)	(5)
63				
125				
250				
500				
1 000				
2 000				
4 000				
8 000				

NOTES

1 The measurements of SPL shall be at a distance of 1.0 m from the equipment and 1.5 m above grade or floor. The measurement method shall be described and the point of maximum levels furnished.

2 Complete col 3 for actual levels of standard equipment.

3 Complete col 4 for special design for low noise (if such alternative is available).

4 Complete col 5 for noise control measures such as enclosure.

5 Indicate if the equipment meets the specified noise levels without modification (Yes/No).

6 If no, additional costs required:

For col 4 _____

For col 5 _____

It will be observed from the col 3, 4 and 5 that the buyer would get quotation for supply of a standard equipment at a price P-1, whose noise characteristics would be as per col 3. Col 4 would indicate acoustical performance for a special design at a price P-2. Col 5 would indicate the acoustical performance if the owners were to provide special noise control measures for the installation (whose broad details and approximate estimated cost is also furnished by the vendor).

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 11050 (Part 1) : 1984	Rating of sound insulation in buildings and of building elements: Part 1 Air-borne sound insulation in buildings and of interior building elements
(2) 4954 : 1968	Recommendations for noise abatement in town planning
(3) 2526 : 1963	Code of practice for acoustical design of auditoriums and conference halls
(4) 11050	Rating of sound insulation in buildings and of building elements:
(Part 1) : 1984	Air-borne sound insulation in buildings and of interior building elements
(Part 2) : 1984	Impact sound insulation

NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 5 Installation of Lifts and Escalators

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section was first published in 1970 and was subsequently revised in 1983. This Section covers the essential requirements for installation of lifts and escalators in buildings. This Section shall, however, be read with Part 4 'Fire and Life Safety' from fire safety requirements point of view. The major changes in the last revision were addition of outline dimensions of different types of lifts and detailed requirements of escalators in buildings. Emphasis was laid on coordination between the engineer/architect and the lift manufacturer to arrive at the number and position of lifts for attaining optimum efficiency in serving the building with safety.

As a result of experience gained in implementation of 1983 version of the Code and feedback data received as well as revision of Indian Standards on which this Section was based, a need was felt to revise this Section. This revision has, therefore, been prepared to take care of these. The significant changes incorporated in this revision includes:

a) New clauses/recommendations have been added on Building Management System.
b) New clauses have been added on fireman's lift, infra-red light curtain safety and Braille button for blind people.
c) The provisions have been updated as per the revised standards on lifts on which this Section is based.
d) The list of Indian Standards as good practices/accepted standards has been updated.

The information contained in this Section is largely based on the following Indian Standards:

IS No.	*Title*
962 : 1989	Code of practice for architectural and building drawings (*second revision*)
4591 : 1968	Code of practice for installation and maintenance of escalators
14665	Specification for electric traction lifts:
(Part 1) : 2000	Guidelines for outline dimensions of passenger, goods, service and hospital lifts
(Part 2/Sec 1 & 2) : 2000	Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts, Section 2 Service lifts
(Part 3/Sec 1 & 2) : 2000	Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts
(Part 4/Sec 1 to 9) : 2001	Components, Section 1 Lift buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices
(Part 5) : 1999	Inspection manual

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 5 Installation of Lifts and Escalators

1 SCOPE

1.1 This Section covers the essential requirements for the installation, operation and maintenance and also inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb waiter) and escalators so as to ensure safe and satisfactory performance.

1.2 This Section gives information that should be exchanged among the architect, the consulting engineer and the lift/escalator manufacturer from the stage of planning to installation including maintenance.

NOTE — The provisions given in this Section are primarily for electric traction lift; however, most of these provisions are also applicable to hydraulic lifts {*see* good practice [8-5(1)}.

2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions shall apply.

2.1 Automatic Rescue Device — A device meant to bring a lift stuck between floors due to loss of power, to the nearest level and open the doors in order to allow trapped passengers to be evacuated. Such a device may use some form of internal auxiliary power source for such purpose, complying with all the safety requirements of a lift during normal run. The speed of travel is usually lower than the normal speed. In the case of manual doors on reaching the level, the device shall allow the door to be opened and in case of power operated doors the device shall automatically open the door.

2.2 Baluster — A short pillar slender above and bulging below.

2.2.1 *Balustrade* — A row of balusters meant for supporting moving handrails.

2.3 Bottom Car Runby — The distance between the car buffer striker plate and the striking surface of the car buffer when the car is in level with the bottom terminal landing.

2.4 Bottom Coutnerweight Runby — The distance between the counter weight buffer striker plate and the striking surface of the counterweight buffer when the car is in level with the top terminal landing.

2.5 Buffer — A device designed to stop a descending car or counter weight beyond its normal limit of travel by storing or by absorbing and dissipating the kinetic energy of the car or counterweight.

2.5.1 *Oil Buffer* — A buffer using oil as a medium which absorbs and dissipates the kinetic energy of the descending car or counterweight.

2.5.1.1 *Oil buffer stroke* — The oil displacing movement of the buffer plunger or piston, excluding the travel of the buffer plunger accelerating device.

2.5.2 *Spring Buffer* — A buffer which stores in a spring the kinetic energy of the descending car or counterweight.

2.5.2.1 *Spring buffer load rating* — The load required to compress the spring by an amount equal to its stroke.

2.5.2.2 *Spring buffer stroke* — The distance, the contact end of the spring can move under a compressive load until the spring is compressed solid.

2.6 Call Indicator — A visual and audible device in the car to indicate to the attendant the lift landings from which calls have been made.

2.7 Car Bodywork — The enclosing bodywork of the lift car which comprises the sides and roof and is built upon the car platform.

2.8 Car Door Electric Contact — An electric device, the function of which is to prevent operation of the driving machine by the normal operating device unless the car door is in the closed position.

2.9 Car Frame — The supporting frame or sling to which the platform of the lift car, its safety gear, guide shoes and suspension ropes are attached.

2.10 Car Platform — The part of the lift car which forms the floor and directly supports the load.

2.11 Clearance

2.11.1 *Bottom Car Clearance* — The clear vertical distance from the pit floor to the lowest structural or mechanical part, equipment or device installed beneath the car platform aprons or guards located within 300 mm, measured horizontally from the sides of the car platform when the car rests on its fully compressed buffers.

2.11.2 *Top Car Clearance* — The shortest vertical distance between the top of the car crosshead, or between the top of the car where no crosshead is provided, and the nearest part of the overhead structure or any other obstruction when the car floor is level with the top terminal landing.

2.11.3 *Top Counterweight Clearance* — The shortest vertical distance between any part of the counterweight

structure and the nearest part of the overhead structure or any other obstruction when the car floor is level with the bottom terminal landing.

2.12 Control — The system governing starting, stopping, direction of motion, acceleration, speed and retardation of moving member.

2.12.1 *Single-Speed Alternating Current Control* — A control for a driving machine induction motor which is arranged to run at a single-speed.

2.12.2 *Two-Speed Alternating Current Control* — A control for a two-speed driving machine induction motor which is arranged to run at two different synchronous speeds either by pole changing of a single motor or by two different armatures.

2.12.3 *Rheostatic Control* — A system of control which is accomplished by varying resistance or reactance or both in the armature or field circuit or both of the driving machine motor.

2.12.4 *Variable Voltage Motor Control (Generator Field Control)* — A system of control which is accomplished by the use of an individual generator for each lift wherein the voltage applied to the driving machine motor is adjusted by varying the strength and direction of the generator field.

2.12.5 *Electronic Devices* — A system of control which is accomplished by the use of electronic devices for driving the lift motor at variable speed.

2.12.6 *Alternating Current Variable Voltage (ACVV) Control* — A system of speed control which is accomplished by varying the driving and braking torque by way of voltage variation of the power supply to the driving machine induction motor.

2.12.7 *Alternating Current Variable Voltage Variable Frequency (ACVVVF) Control* — A system of speed control which is accomplished by varying the voltage and frequency of the power supply to the driving machine induction motor.

2.12.8 *Solid-State d.c. Variable Voltage Control* — A solid-state system of speed control which is accomplished by varying the voltage and direction of the power supply to the armature of driving machine d.c. motor.

2.13 Counterweight — A weight or series of weights to counter-balance the weight of the lift car and part of the rated load.

2.14 Deflector Sheave — An idler pulley used to change the direction of a rope lead.

2.15 Door

2.15.1 *Door, Centre Opening Sliding* — A door which slides horizontally and consists of two or more panels which open from the centre and are usually so interconnected that they move simultaneously.

2.15.2 *Door, Mid-Bar Collapsible* — A collapsible door with vertical bars mounted between the normal vertical members.

2.15.3 *Door, Multipanel* — A door arrangement whereby more than one panel is used such that the panels are connected together and can slide over one another by which means the clear opening can be maximized for a given shaft width. Multipanels are used in centre opening and two speed sliding doors.

2.15.4 *Door, Single Slide* — A single panel door which slides horizontally.

2.15.5 *Door, Two Speed Sliding* — A door which slides horizontally and consists of two or more panels, one of which moves at twice the speed of the other.

2.15.6 *Door, Vertical Bi-parting* — A door which slides vertically and consists of two panels or sets of panels that move away from each other to open and are so interconnected that they move simultaneously.

2.15.7 *Door, Vertical Lifting* — A single panel door, which slides in the same plane vertically up to open.

2.15.8 *Door, Swing* — A swinging type single panel door which is opened manually and closed by means of a door closer when released.

2.16 Door Closer — A device which automatically closes a manually opened door.

2.17 Door Operator — A power-operated device for opening and closing doors.

2.18 Dumb Waiters — A lift with a car which moves in guides in a vertical direction; has a net floor area of 1 m^2, total inside height of 1.2 m, whether or not provided with fixed or removable shelves; has a capacity not exceeding 250 kg and is exclusively used for carrying materials and shall not carry any person.

2.19 Electrical and Mechanical Interlock — A device provided to prevent simultaneous operation of both up and down relays.

2.20 Electro-Mechanical Lock — A device which combines in one unit, electrical contact and a mechanical lock jointly used for the landing and/or car doors.

2.21 Emergency Stop Push or Switch — A push button or switch provided inside the car designed to open the control circuit to cause the lift car to stop during emergency.

2.22 Escalator — A power driven, inclined, continuous stairway used for raising or lowering passengers.

2.23 Escalator Installation — It includes the escalator, the track, the trusses or girders, the balustrading, the step treads and landings and all chains, wires and machinery directly connected with the operation of the escalator.

2.24 Escalator Landing — The portion of the building or structure which is used to receive or discharge passengers into or from an escalator.

2.25 Escalator Landing Zone — A space extending from a horizontal plane 40 cm below a landing to a plane 40 cm above the landing.

2.26 Escalator Machine — The mechanism and other equipment in connection therewith used for moving the escalator

2.27 Floor Levelling Switch — A switch for bringing the car to level at slow speed in case of double speed or variable speed machines.

2.28 Floor Selector — A mechanism forming a part of the control equipment, in certain automatic lifts, designed to operate controls which cause the lift car to stop at the required landings.

2.29 Floor Stopping Switch — A switch or combination of switches arranged to bring the car to rest automatically at or near any pre-selected landing.

2.30 Gearless Machine — A lift machine in which the motive power is transmitted to the driving sheave from the motor without intermediate reduction gearing and has the brake drum mounted directly on the motor shaft.

2.31 Goods Lift — A lift designed primarily for the transport of goods, but which may carry a lift attendant or other persons necessary for the loading or unloading of goods.

2.32 Guide Rails — The members used to guide the movement of a lift car or counterweight in a vertical direction.

2.33 Guide Rails Fixing — The complete assy. comprising the guide rails bracket and its fastenings.

2.34 Guide Rails Shoe — An attachment to the car frame or counterweight for the purpose of guiding the lift car or counter weight frame.

2.35 Hoisting Beam — A beam, mounted immediately below the machine room ceiling, to which lifting tackle can be fixed for raising or lowering parts of the lift machine.

2.36 Hospital Lift — A lift normally installed in a hospital/dispensary/clinic and designed to accommodate one number bed/stretcher along its depth, with sufficient space around to carry a minimum of three attendants in addition to the lift operator.

2.37 Landing Call Push — A push button fitted at a lift landing, either for calling the lift car, or for actuating the call indicator.

2.38 Landing Door — The hinged or sliding portion of a lift well enclosure, controlling access to a lift car at a lift landing.

2.39 Landing Zone — A space extending from a horizontal plane 400 mm below a landing to a plane 400 mm above the landing.

2.40 Levelling Devices

2.40.1 *Levelling Device, Lift Car* — Any mechanism which either automatically or under the control of the operator, moves the car within the levelling zone towards the landing only, and automatically stops it at the landing.

2.40.2 *Levelling Device, One Way Automatic* — A device which corrects the car level only in case of under run of the car but will not maintain the level during loading and unloading.

2.40.3 *Levelling Device, Two-Way Automatic Maintaining* — A device which corrects the car level on both under run and over-run and maintains the level during loading and unloading.

2.40.4 *Levelling Device, Two Way Automatic Non-Maintaining* — A device which corrects the car level on both under run and over run but will not maintain the level during loading and unloading.

2.41 Levelling Zone — The limited distance above or below a lift landing within which the levelling device may cause movement of the car towards the landing.

2.42 Lift — An appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car or platform. The word 'elevator' is also synonymously used for 'lift'.

2.43 Lift Car — The load carrying unit with its floor or platform, car frame and enclosing bodywork.

2.44 Lift Landing — That portion of a building or structure used for discharge of passengers or goods or both into or from a lift car.

2.45 Lift Machine — The part of the lift equipment comprising the motor and the control gear therewith, reduction gear (if any), brake(s) and winding drum or sheave, by which the lift car is raised or lowered.

2.46 Lift Pit — The space in the lift well below the level of the lowest lift landing served.

2.47 Lift Well — The unobstructed space within an enclosure provided for the vertical movement of the

lift car(s) and any counterweight(s), including the lift pit and the space for top clearance.

2.48 Lift Well Enclosure — Any structure which separates the lift well from its surroundings.

2.49 Operation — The method of actuating the control of lift machine.

2.49.1 *Automatic Operation* — A method of operation in which by a momentary pressure of a button the lift car is set in motion and caused to stop automatically at any required lift landing.

2.49.2 *Non-Selective Collective Automatic Operation* — Automatic operation by means of one button in the car for each landing level served and one button at each landing, wherein all stops registered by the momentary actuation of landing or car buttons are made irrespective of the number of buttons actuated or of the sequence in which the buttons are actuated. With this type of operation, the car stops at all landings for which buttons have been actuated making the stops in the order in which the landings are reached after the buttons have been actuated but irrespective of its direction of travel.

2.49.3 *Selective Collective Automatic Operation* — Automatic operation by means of one button in the car for each landing level served and by up and down buttons at the landings, wherein all stops registered by the momentary actuation of the car made as defined under non-selective collective automatic operation, but wherein the stops registered by the momentary actuation of the landing buttons are made in the order in which the landings are reached in each direction of travel after the buttons have been actuated. With this type of operation, all 'up' landing calls are answered when the car is travelling in the up direction and all 'down' landing calls are answered when the car is travelling in the down direction, except in the case of the uppermost or lowermost calls which are answered as soon as they are reached irrespective of the direction of travel of the car.

2.49.4 *Single Automatic Operation* — Automatic operation by means of one button in the car for each landing level served and one button at each landing so arranged that if any car or landing button has been actuated, the actuation of any other car or landing operation button will have no effect on the movement of the car until the response to the first button has been completed.

2.49.5 *Group Automatic Operation* — Automatic operation of two or more non-attendant lifts equipped with power-operated car and landing doors. The operation of the cars is co-ordinated by a supervisory operation system including automatic dispatching means whereby selected cars at designated dispatching points automatically close their doors and proceed on their trips in a regulated manner.

Typically, it includes one button in each car for each floor served and up and down buttons at each landing (single buttons at terminal landings). The stops set up by the momentary actuation of the car buttons are made automatically in succession as a car reaches the corresponding landings irrespective of its direction of travel or the sequence in which the buttons are actuated. The stops set up by the momentary actuation of the landing buttons may be accomplished by any lift in the group, and are made automatically by the first available car that approaches the landing in the corresponding direction.

2.49.6 *Car Switch Operation* — Method of operation by which the movement of lift car is directly under the operation of the attendant by means of a handle.

2.49.7 *Signal Operation* — Same as collective operation, except that the closing of the door is initiated by the attendant.

2.49.8 *Double Button (Continuous Pressure) Operation* — Operation by means of buttons or switches in the car and at the landings any of which may be used to control the movement of the car as long as the button or switch is manually pressed in the actuating position.

2.50 Operating Device — A car switch, push button or other device employed to actuate the control.

2.51 Overhead Beams — The members, usually of steel, which immediately support the lift equipment at the top of the lift well.

2.52 Over Speed Governor — An automatic device which brings the lift car and/or counter weight to rest by operating the safety gear in the event of the speed in a descending direction exceeding a predetermined limit.

2.53 Passenger Lift — A lift designed for the transport of passengers.

2.54 Position and/or Direction Indicator — A device which indicates on the lift landing or in the lift car or both, the position of the car in the lift well or the direction or both in which the lift car is travelling.

2.55 Rated Load (Lift) — The maximum load for which the lift car is designed and installed to carry safely at its rated speed.

2.56 Rated Load (Escalator) — The load which the escalator is designed and installed to lift at the rated speed.

2.57 Rated Speed (Lift) — The mean of the maximum speed attained by the lift car in the upward and downward direction with rated load in the lift car.

2.58 Rated Speed (Escalator) — The speed at which the escalator is designed to operate. It is the rate of travel of the steps, measured along the angle of inclination, with rated load on the steps or carriage.

2.59 Retiring Cam — A device which prevents the landing doors from being unlocked by the lift car unless it stops at a landing.

2.60 Roping Multiple — A system of roping where, in order to obtain a multiplying the factor from the machine to the car, multiple falls of rope are run around sheave on the car or counterweight or both. It includes roping arrangement of 2 to-1.3 to 1 etc.

2.61 Safety Gear — A mechanical device attached to the lift car or counterweight or both, designed to stop and to hold the car or counterweight to the guides in the event of free fall, or, if governor operated, of over-speed in the descending direction. Any anticipated impact force shall be added in the general drawing or layout drawing.

2.62 Service Lift — A passenger *cum* goods lift meant to carry goods along with people.

Typically in an office building this may be required to carry food or stationeries, in a residential building to carry a bureau or accommodate a stretcher and in a hotel to be used for food trolleys or baggage. There is a need in such lifts, to take care of the dimensions of the car and the door clear opening in line with the type of goods that may have to be carried based on mutual discussion between supplier and customer. Also, such lifts shall have buffer railings in the car at suitable height to prevent damage to the car panels when the goods are transported. Typically such lifts, if provided with an automatic door, may use some means to detect trolleys and stretcher movement in advance to protect the doors against damage. The car floor load calculations and car area of such a lift is as in the case of a passenger lift except that these are not meant to carry heavy concentrated loads.

2.63 Sheave — A rope wheel, the rim of which is grooved to receive the suspension ropes but to which the ropes are not rigidly attached and by means of which power is transmitted from the lift machine to the suspension ropes.

2.64 Slack Rope Switch — Switch provided to open the control circuit in case of slackening of rope(s)

2.65 Suspension Ropes — The ropes by which the car and counter weight are suspended.

2.66 Terminal Slow Down Switch — A switch when actuated shall compulsorily cut off the high speed and switch on the circuitry to run the lift in levelling speed before reaching on terminal landings.

2.67 Terminal Stopping Switch Normal — Switch for cutting all the energizing current in case of car travelling beyond the top bottom landing or a switch cuts off the energizing current so as to bring the car to stop at the top and bottom level.

2.68 Terminal Stopping Device Final — A device which automatically cause the power to be removed from an electric lift driving machine motor and brake, independent of the functioning of the normal terminal stopping device, the operating device or any emergency terminal stopping device, after the car has passed a terminal landing.

2.69 Total Headroom — The vertical distance from the level of the top lift landing to the bottom of the machine room slab.

2.70 Travel — The vertical distance between the bottom and top lift handing served.

2.71 Geared Machine — A machine in which the power is transmitted to the sheave through worm or worm and spur reduction gearing.

3 GENERAL

3.1 The appropriate aspect of lift and escalator installation shall be discussed during the preliminary planning of the building with all the concerned parties, namely, client, architect, consulting engineer and/or lift/escalator manufacturer. This enables the lift/escalator manufacturer to furnish the architect and/or consulting engineer with the proposed layout on *vice-versa*.

3.2 Exchange of Information

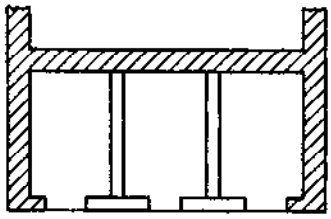
3.2.1 If the proposed installation is within the scope of **6**, the guidelines laid down together with Fig. 1 will enable the preliminary scheme for the installation to be established.

Figure 1 shows only some of the typical arrangements and variations are possible with respect to number of lifts and the layout.

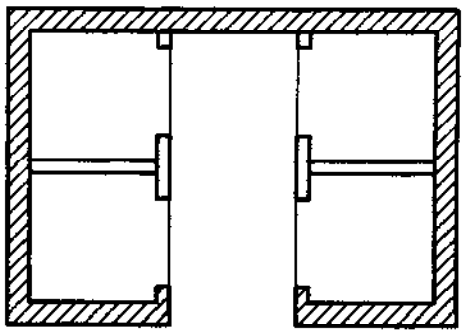
Although the recommended outline for the various classes of lifts given in **6** enables the general planning details to be determined by the architect, these should be finally settled at the earliest possible stage by detailed investigation with the purchaser's representative reaching agreement with the lift maker where necessary before an order is finally placed. This will enable a check to be made and information to be exchanged on such vital matters as:

a) the number, capacity, speed and disposition of the lifts necessary to give adequate lift service in the proposed building.

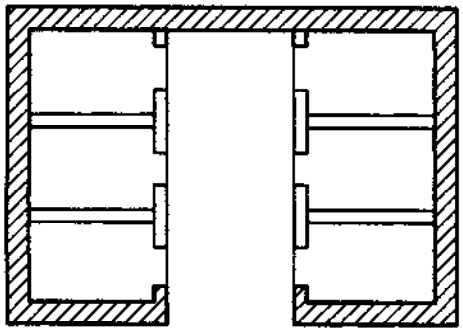
b) the provision of adequate access to the machine room.



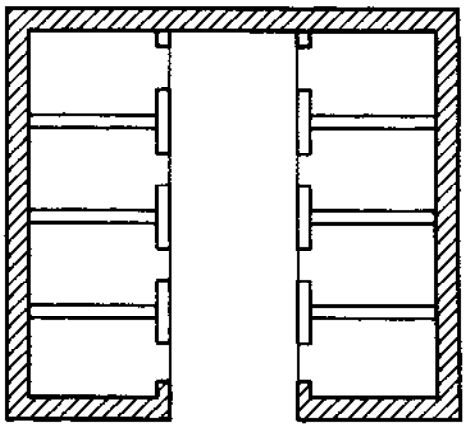
1A STRAIGHT LINE
ARRANGEMENT FOR THREE LIFTS



1B ALCOVE ARRANGEMENT FOR
FOUR LIFTS



1C ARRANGEMENT FOR SIX LIFTS



1D ARRANGEMENT FOR EIGHT LIFTS

FIG. 1 ARRANGEMENT OF LIFTS

c) The loads which the lift will impose on the building structure, and the holes to be left in the machine room floor and cut-outs for wall boxes for push-buttons and signals;

d) The necessity for and type of insulation to minimize the transmission of vibration and noise to other parts of the building;

e) The special requirements of local authorities and other requirements set out in the 'planning permit';

f) The need for the builder to maintain accuracy of building as to dimensions and in plumb;

g) The periods of time required for preparation and approval of relevant drawings for manufacturing and the installation of the lift equipment;

h) The requirements for fixing guide brackets to the building structure;

j) The time at which electric power will be required before completion to allow for testing;

k) The requirements for electrical supply feeders, etc;

m) The requirements for scaffolding in the lift well and protection of the lift well prior to and during installation of equipment; and

n) Delivery and storage of equipment.

3.2.2 *Information to be Provided by Architect or Engineer*

As a result of preliminary discussion (*see also* **6**), the drawings of the building should give the following particulars and finished sizes:

a) Number, type and size of lifts and position of lift well;

b) Particulars of lift well enclosure;

c) Size, position, number and type of landing doors;

d) Number of floors served by the lift;
e) Height between floor levels;
f) Number of entrances;
g) Total headroom;
h) Provision of access to machine room;
j) Provision of ventilation and, if possible, natural lighting of machine room;
k) Height of machine room;
m) Depth of lift pit;
n) Position of lift machine, above or below lift well;
p) Size and position of any trimmer joists or stanchions adjacent to the lift well at each floor;
q) Size and position or supporting steel work at roof levels;
r) Size and position of any footings or grillage foundations, if these are adjacent to the lift pit; and
s) In the case of passenger lifts whether the lift cage is required to carry household luggage, such as refrigerator, steel almirah, etc.

3.2.2.1 The lift lobby should be designed appropriately since this has bearing on the traffic handling especially when more number of lifts are involved. In a dual line arrangement (lifts opposite to each other) the lobby can be between 1.5 times to 2.5 times the depth of one car. Typically, the more the number of lifts the bigger the multiple to be used. As an example a quadruplex may use 1.5 to 2 times where as an octoplex will need 2 to 2.5 times. For in-line (single line) arrangements, the lobby can be typically half of the above recommendations.

It is preferable that the lift lobby is not used as a thoroughfare but in such cases the lift corridor shall take into account space for people who are moving.

3.2.2.2 The architect/engineer should advise the lift manufacturer, if the Authority has any special requirements regarding lifts in buildings in the administrative area concerned.

3.2.2.3 The information contained under **3.2.1** and **3.2.2** is applicable for the installation of lifts only and in the case of escalator installations, the drawings shall provide the appropriate information.

3.2.2.4 The architect/engineer should inform the lift/escalator manufacturer of the dates when the erection of the lift/escalator may be commenced and is to be completed so that sufficient time is allowed for the manufacture and erection of the lift/escalator.

3.2.2.5 When submitting application for a building permit to the local Authority, the building plans shall include the details of lifts (number of lifts duly numbered, location, type, type of doors, passenger capacity and speed).

3.2.3 *Working Drawings to be Prepared by the Lift/Escalator Manufacturer*

The lift/escalator manufacturer requires sufficient information for the preparation of working drawings and is usually obtained from architect's drawings supplemented by any information obtained from the site and by collaboration with the other contractors.

3.2.3.1 Working drawings showing the layout of lift/escalator duly numbered, details of builders work, for example, holes in walls for guide fixing, holes in machine room floor for ropes and conduits, recesses for landing sills, supports for lift/escalator machine and loads imposed on the building should be submitted by the lift/escalator manufacturer to the architect/engineer for written approval.

3.3 Electrical Requirement

For information of the electrical engineer, the lift/escalator manufacturer should advise the architect/engineer of his electrical requirements. This information should be available early in the planning stage so that the electrical supply requirements of the lift(s)/escalator(s) may be included in the electrical provisions of the building and that suitable cables and switchgear may be provided.

3.4 The requirements given under **4** to **13** deal with installation of lifts and **14** deal with the installation of escalators.

4 ESSENTIAL REQUIREMENTS

4.1 Conformity with *Lifts Act* and *Rules*

The installation shall be generally carried out in conformity with *Lifts Act* and *Rules* thereunder, wherever they are in force.

4.1.1 It is the responsibility of the owner of the premises where the lift will be installed, to obtain necessary permission from the Authority before and after the erection of lifts and for subsequent operation of lift(s).

4.2 Conformity with *Indian Electricity Act and Rules*

All electrical work in connection with installation of electric lifts shall be carried out in accordance with the provisions of *The Indian Electricity Act*, 2003 and the provisions framed thereunder as amended from time to time, and shall also comply with the other provisions of Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

4.3 Conformity with Indian Standards

4.3.1 All materials, fittings, appliances etc used in electrical installation shall conform to Indian Standard specifications wherever these exist. In case of materials for which Indian Standard specifications do not exist, the materials shall be approved by the competent authority. For detailed specification for lifts, reference shall be made to accepted standards [8-5(2)].

4.4 Conformity with Fire Regulations

4.4.1 The installation shall be carried out in conformity with Part 4 'Fire and Life Safety' and local fire regulations and rules thereunder wherever they are in force.

4.5 Factor of Safety

The minimum factor of safety for any part of the lift shall not be less than five. Higher factor of safety for various parts shall be applicable in accordance with accepted standards [8-5(3)].

4.6 Additional Requirements for Passenger and Goods Lifts

4.6.1 *Bottom and Top Car Clearances*

4.6.1.1 *Bottom car clearance*

When the car rests on its fully compressed buffer there shall be a vertical clearance of not less than 600 mm between the pit floor and the buffer striker plate or the lowest structural or mechanical part equipment or device installed. The clearance shall be available beneath the whole area of the platform except for:

a) guide shoes or rollers, safety jaw blocks, platform aprons, guards of other equipment located within 300 mm measured horizontally from the sides of the car platform; and
b) compensating sheaves.

Provided that in all the cases, including small cars, a minimum clearance of 600 mm is available over a horizontal area of 800 mm × 500 mm.

Provided also that in all the cases, when the car rests on its fully compressed buffers, there shall be a vertical clearance of not less than 50 mm between any part of the car and any obstruction of device mounted in the pit.

4.6.1.2 *Top car clearance*

The vertical clearance between the car cross-head and the nearest overhead obstruction within 500 mm measured horizontally to the nearest part of the crosshead when the car platform is level with the top landing, shall be not less than the sum of the following;

a) The bottom counterweight runby.
b) The stroke of the counterweight buffer used.
c) One-half of the gravity stopping distance based on:
   1) 115 percent of the rated speed where oil buffers are used and no provision is made to prevent the jump of the car at counterweight buffer engagement; and
   2) Governor tripping speed where spring buffers are used.

   NOTE — The gravity stopping distance based on the gravity retardation from any initial velocity may be calculated according to the following formula

   $$S = 51\ V^2$$

   where

   S = Free fall in mm (gravity stopping distance), and

   V = Initial velocity in m/s
d) 600 mm.

Where there is a projection below the ceiling of the well and the projection is more than 500 mm, measured horizontally from the centre line of the cross-head but over the roof of the car, a minimum vertical clearance not less than that calculated above shall also be available between the roof of the car and the projection.

Provided that the vertical clearance between any equipment mounted on top of the car and the nearest overhead obstruction shall be not less than the sum of the three items (a), (b) and (c) as calculated above plus 150 mm.

4.6.2 *Bottom Runby for Cars and Counterweights*

4.6.2.1 The bottom runby of cars and counterweights shall be not less than the following:

a) 150 mm where oil buffers are used;
b) Where spring-buffers are used;
   1) 150 mm for controls as in **2.12.4** to **2.12.8**.
   2) Not less than the following for controls as in **2.12.2** to **2.12.3**.

Rated speed m/s	*Runby* mm
Up to 0.125	75
0.125 to 0.25	150
0.25 to 0.50	225
0.50 to 1	300

4.6.3 *Maximum Bottom Runby*

In no case shall the maximum bottom runby exceed the following:

a) 600 mm for cars; and
b) 900 mm for counterweights.

4.6.4 *Top Counterweight Clearances*

The top counterweight clearance shall be not less than the sum of the following four items:

a) the bottom car runby;

b) the stroke of the car buffer used;

c) 150 mm; and

d) one-half the gravity stopping distance based on

1) one hundred and fifteen percent of the rated speed where oil buffers are used and no provision is made to prevent jump of the counterweight at car buffer engagement; and

2) governor tripping speed where spring buffers are used.

4.7 Additional Requirements for Service Lifts

4.7.1 *Top and Bottom Clearances for Car and Counterweights*

4.7.1.1 *Top car clearance*

The top car clearance shall be sufficient to avoid any protruding part fixed on the top of the car coming in direct contact with the ceiling or diverting sheave.

The clearance shall be calculated taking into account the following and shall not be less than the sum of the following four items:

a) The bottom counterweight runby,

b) The stroke of the counterweight buffer used,

c) The dimensions of the portion of the diverting sheave hanging underneath the ceiling in the lift well, and

d) 150 mm for compensating for gravity stopping distance and future repairs to the rope connections at counterweight and at the car or at the suspension points.

4.7.1.2 *Bottom car clearance*

The bottom car clearance shall be maintained in such a way that the counterweight shall not come in contact with the ceiling or any part hanging underneath the ceiling, when the car completely rests on fully compressed buffers, provided the buffers are spring type mounted on solid concrete or steel bed.

In case of wooden buffers the bottom car clearance shall be maintained in such a way that the total downward travel of the car from the service level of the immediate floor near the pit, shall not be more than the top counterweight clearance, when the wooden buffers are completely crushed.

4.7.1.3 *Top counterweight clearance*

The top clearance for the counterweight can be calculated taking into account the following and shall not be less than the sum of the following three items:

a) Car runby,

b) Compression of the buffer spring or height of the wooden block used as buffer, and

c) 150 mm to compensate for gravity stopping distance for counterweight and any future repairs to rope connections at the counterweight at the car ends or at the suspension points.

4.7.1.4 *Runby for Cars and Counterweights*

The bottom runby for cars and counterweights shall not be less than 150 mm.

4.7.1.5 *Maximum bottom runby*

In no case shall the maximum bottom runby exceed 300 mm.

4.8 In order to maintain a safe work environment, and to avoid potential hazards, the following shall be provided:

a) caution sign shall be installed in the areas listed below where potential hazard exists:

1) Trip hazard in machine room; and

2) Caution notice against unauthorized use of rescue devices (for example, brake release device).

b) Use the hard hats for entry in pit and car top during construction period.

c) Warning sign shall be provided on the controller so also eliminate, the possibility of contact with any exposed or concealed power circuit.

d) Car top barricade system shall be provided as primary protection against fall, on car top.

e) Whenever work is carried out on the lift and lift is not required to be moved on power, notice shall be put on electrical main switch indicating requirement of de-energized condition.

f) During lift installation/maintenance, protection against fall shall be provided with suitable barricades for all open lending entrances.

4.9 Planning for Dimensions

4.9.1 *General*

The dimensions of lift well have been chosen to accommodate the doors inside the well which is the normal practice. In special cases, the door may be accommodated in a recess in the front wall, for which prior consultation shall be made with the lift manufacturer.

4.9.2 *Plan Dimensions*

4.9.2.1 All plan dimensions of lift well are the

minimum clear plumb sizes. The architect/engineer, in conjunction with the builder, shall ensure that adequate tolerances are included in the building design so that the specified minimum clear plumb dimensions are obtained in the finished work.

NOTE — The words 'clear plumb dimensions' should be noted particularly in case of high rise buildings.

4.9.2.2 Rough opening in concrete or brick walls to accommodate landing doors depend on design of architrave. It is advisable to provide sufficient allowances in rough opening width to allow for alignment errors of opening at various landings.

4.9.2.3 When more than one lift is located in a common well, a minimum allowance of 100 mm for separator beams shall be made in the widths shown in Tables 1 to 4.

4.9.2.4 Where the governor operated counterweight safety is required under conditions stipulated in good practice [8-5(3)], the tabular values should be revised in consultation with the lift manufacturer.

4.9.2.5 For outline dimensions of lifts having more than one car entrance, lift manufacturers should be consulted.

4.9.3 *Outline Dimensions*

4.9.3.1 The outline dimensions of machine-room, pit depth, total headroom, overhead distance and sill for four classes of lifts to which the standard applies are specified in Tables 1 to 4 as indicated below:

Passenger lifts	Table 1 and 1A
Goods lifts	Table 2
Hospital lifts	Table 3
Service lifts	Table 1 and 1A
Dumb Waiter	Table 4

Table 1 Recommended Dimensions of Passenger Lifts and Service Lifts

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.

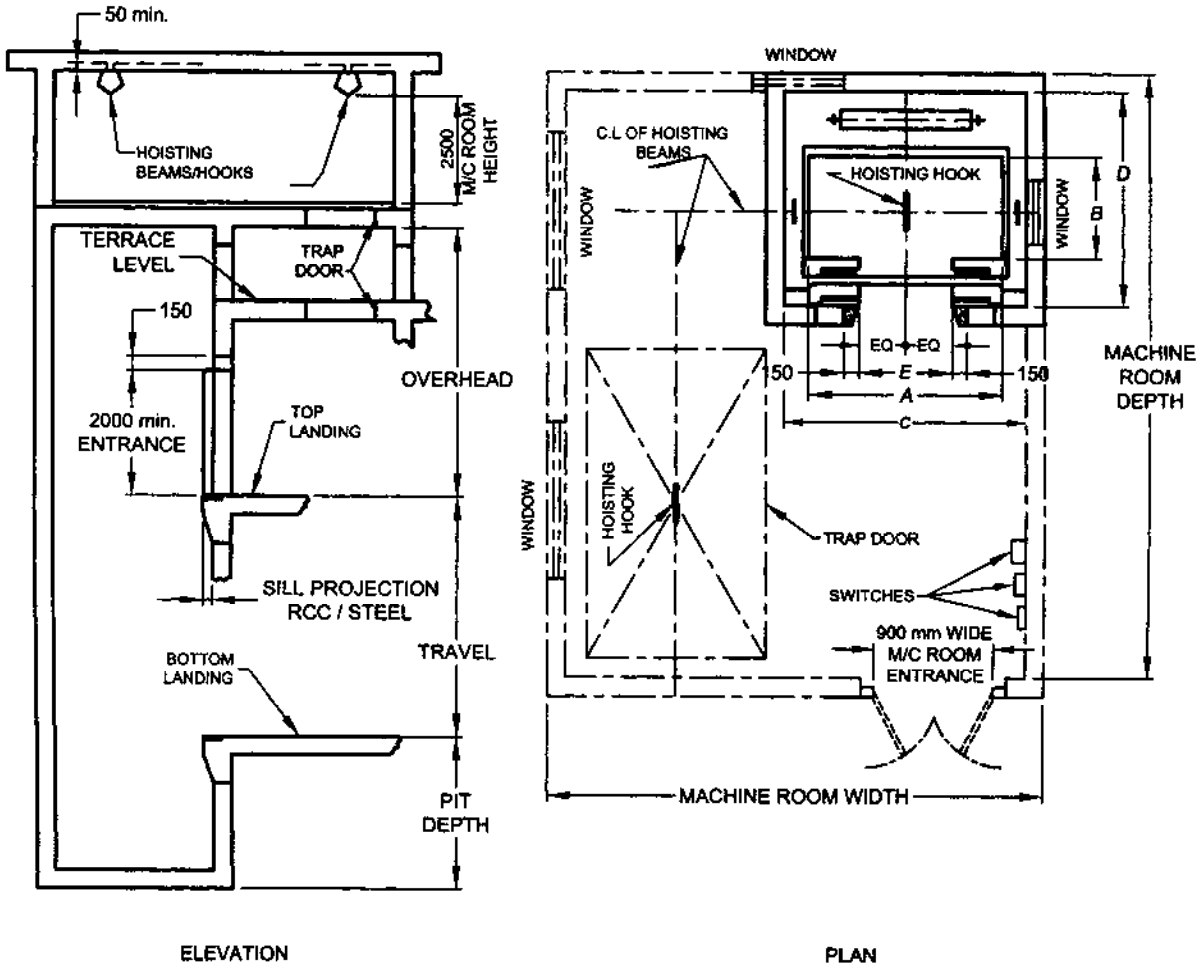


Table 1 — *Concluded*

Load		Car Side		Lift Well		Entrance
Persons	kg	*A*	*B*	*C*	*D*	*E*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4	272	1 100	700	1 900	1 300	700, *Min*
6	408	1 100	1 000	1 900	1 700	700, *Min*
8	544	1 300	1 100	1 900	1 900	800
10	680	1 300	1 350	1 900	2 100	800
13	884	2 000	1 100	2 500	1 900	900
16	1 088	2 000	1 300	2 500	2 100	1 000
20	1 360	2 000	1 500	2 500	2 400	1 000

Table 1A Recommended Dimensions of Pit, Overhead and Machine-Room for Passenger Lifts and Service Lifts

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.

Speed in m/s	Up to 0.70	> 0.70 ≤ 1.00	> 1.00 ≤ 1.50	> 1.50 ≤ 1.75	> 1.75 ≤ 2.00	> 2.00 ≤ 2.50
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Pit depth	1 350	1 500	1 600	2 150	2 200	2 500
Overhead	4 200	4 250	4 800	4 800	5 200	5 400
Machine-room Depth	*D* + 2 000			*D* + 2 500		
Machine-room Width	*C* + 1 000		*C* + 1 200		*C* + 1 500	

NOTES

1 The total overhead dimension has been calculated on the basis of car height of 2.3 m.

2 In case of manually operated doors, clear entrance will be reduced by the amount of projection of handle on the landing door.

3 All dimensions given above for lifts having centre opening power operated doors with counterweight at rear, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser are permitted. However, variation in:

a) Car inside dimensions shall be within the maximum area limits specified in accordance with accepted standards [8-5(4)].

b) Entrance width on higher side is permitted.

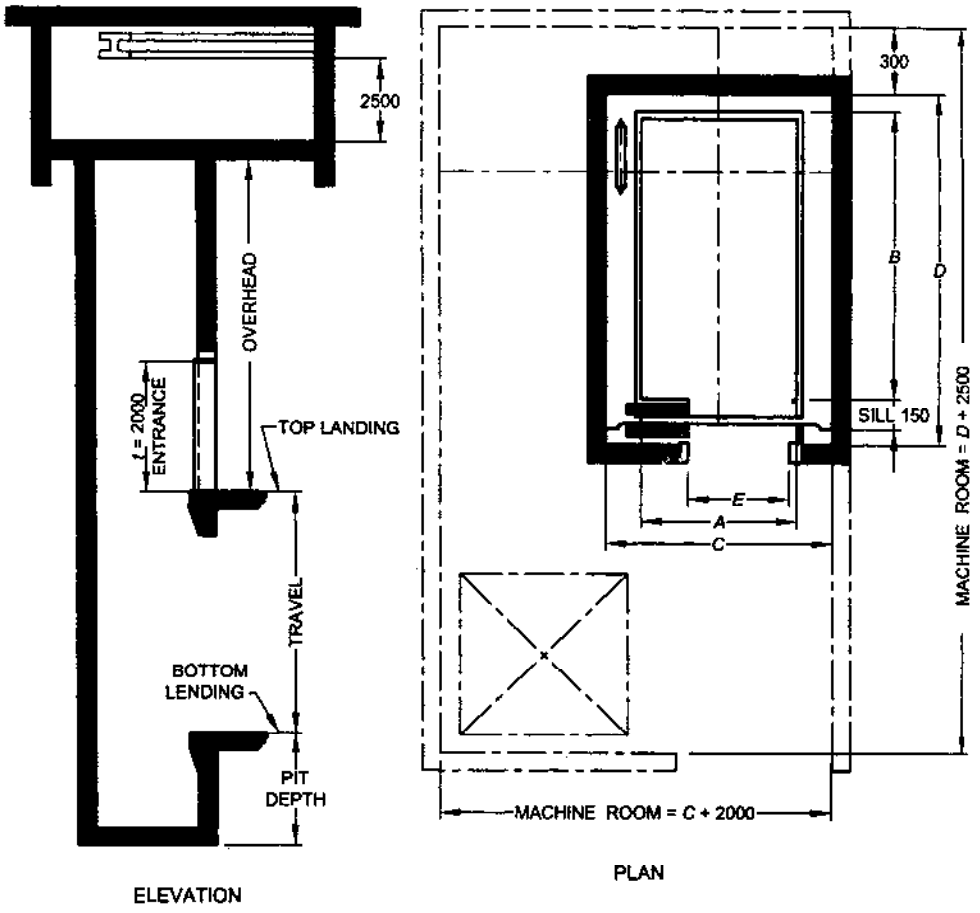
c) Entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

4 Dimensions of pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in Table 1A. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8-5(5)].

Table 2 Recommended Dimensions of Goods Lifts
(For Speeds Up to 0.5 m/s)

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.



Load	Car Inside		Lift Well		Entrance
kg	*A*	*B*	*C*	*D*	*E*
(1)	(2)	(3)	(4)	(5)	(6)
500	1 100	1 200	1 900	1 500	1 100
1 000	1 400	1 800	2 300	2 100	1 400
1 500	1 700	2 000	2 600	2 300	1 700
2 000	1 700	2 500	2 600	2 800	1 700
2 500	2 000	2 500	2 900	2 800	2 000
3 000	2 000	3 000	2 900	3 300	2 000
4 000	2 500	3 000	3 400	3 300	2 500
5 000	2 500	3 600	3 400	3 900	2 500

NOTES

1 The width of machine room shall be equal to be lift well width '*C*' subject to minimum of 2 500 mm.

2 The total headroom has been calculated on the basis of a car height of 2.2 m.

3 Clear entrance width '*E*' is based on vertical lifting car-door and vertical biparting landing doors. For collapsible mid-bar doors the clear entrance width will be reduced by 200 mm (maximum 1 800 mm).

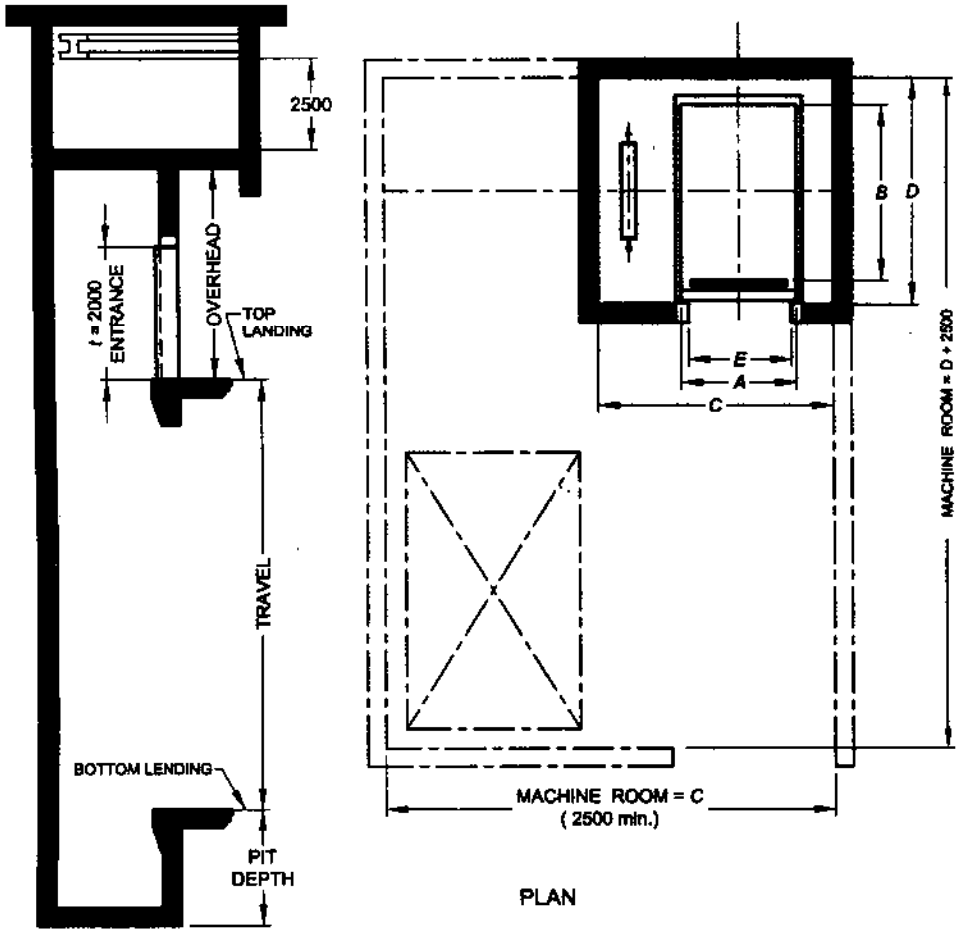
4 All dimensions given above are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser are permitted. However, variation in car inside dimensions shall be within the maximum area limits in accordance with accepted standards [8-5(4)].

5 Dimensions of pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with accepted standards [8-5(5)].

Table 3 Recommended Dimensions of Hospital Lifts
(For Speeds Up to 0.5 m/s)

(Clauses 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.



Load		Car Inside		Lift Well		Entrance
Persons	kg	*A*	*B*	*C*	*D*	*E*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
15	1 020	1 000	2 400	1 800	3 000	800
20	1 360	1 300	2 400	2 200	3 000	1 200
26	1 768	1 600	2 400	2 400	3 000	1 200

NOTES

1 The total headroom has been calculated on the basis of a car height of 2.2 m.

2 In the case of manually-operated doors, clear entrance will be reduced by the amount of projection of handle on the landing door.

3 Although 15 persons capacity lift is not standard one, this is included to cover lifts of smaller capacity which can be used in small hospitals.

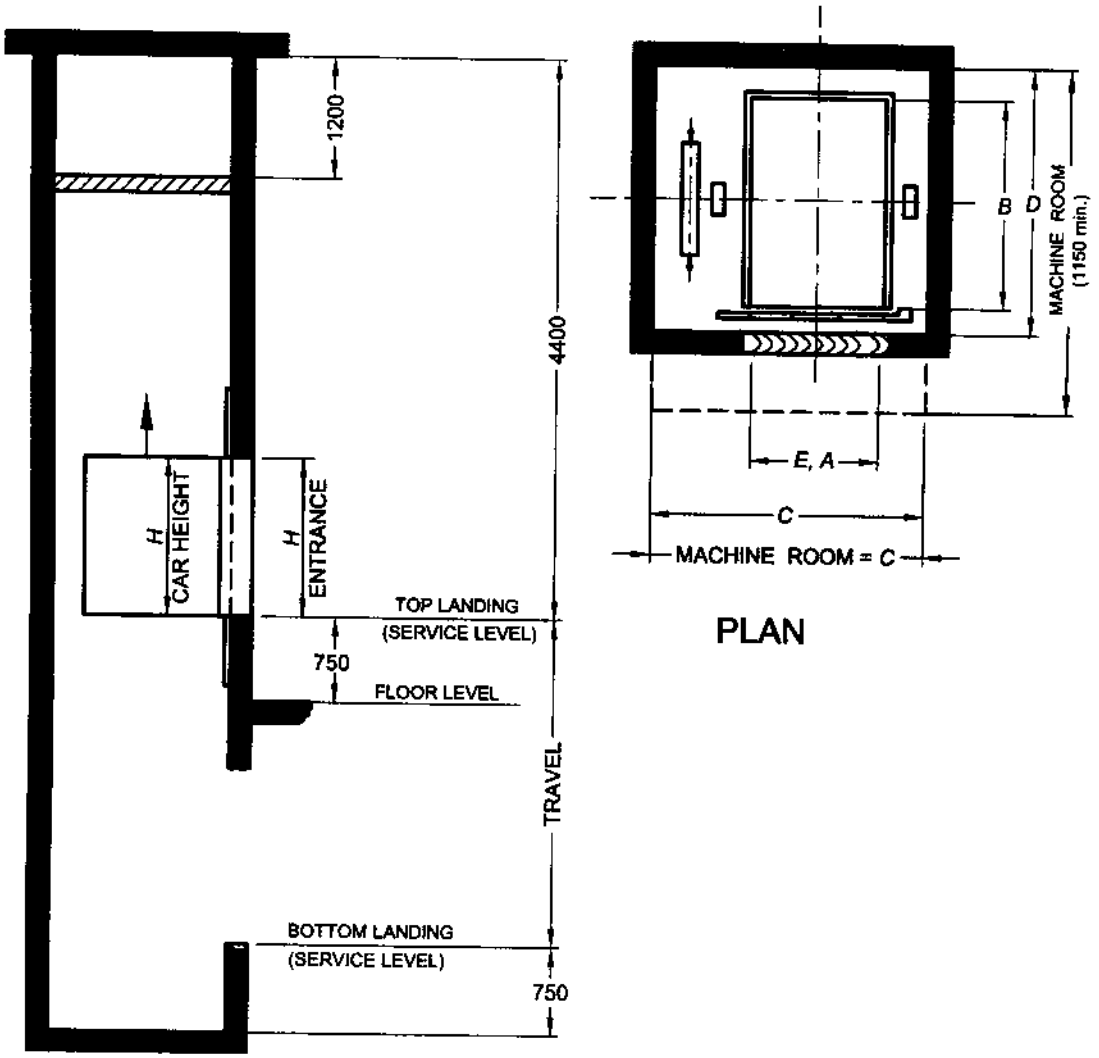
4 All dimensions given above are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser are permitted. However, variation in car inside dimensions shall be within the maximum area limits in accordance with accepted standards [8-5(4)].

5 Dimensions of pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with accepted standards [8-5(5)].

Table 4 Recommended Dimensions of Dumb Waiter
(For Speeds Up to 0.5 m/s)

(*Clauses* 4.9.2.3 *and* 4.9.3.1)

All dimensions in millimetres.



Load	Car Inside			Lift Well		Entrance
kg	*A*	*B*	*H*	*C*	*D*	*E*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
100	700	700	800	1 200	900	700
150	800	800	900	1 300	1 000	800
200	900	900	1 000	1 400	1 100	900
250	1 000	1 000	1 200	1 500	1 200	1 000

NOTE — Entrance width '*E*' is based on assumption of provision of vertical biparting doors (no car door is normally provided).

4.9.3.2 *Travel*

The tables have been established for a maximum travel of 30 m. For travels above 30 m, the lift manufacturer should be consulted.

4.9.3.3 *Pit*

The pit depth of the lifts will normally accommodate compensating chains. If compensating ropes are required, pit depth shall be increased for all loads and speeds and lift manufacturer should be consulted.

4.9.3.4 *Minimum floor to floor height*

Minimum floor to floor height for landings on same side for horizontally sliding door is $f + 750$ mm and for vertically biparting doors is $1.5f + 250$ mm, where 'f' is clear entrance height in mm.

4.10 Lift Wells and Lift Well Enclosures

4.10.1 *Lift Wells*

4.10.1.1 No equipment except that forming a part of the lift or necessary for its operation and maintenance shall be installed in the lift well. For this purpose, the main supply lines shall be deemed to be a part of the lift and the underground cable, if laid along the lift well shaft, shall be properly clamped to the wall.

4.10.1.2 Sufficient space shall be provided between the guides for the cars and the side walls of the lift well enclosure to allow safe and easy access to the parts of the safety gears for their maintenance and repairs; safety gears provided shall be in accordance with good practices [8-5(3)].

4.10.1.3 Lift wells, together with the whole of the contained equipment and apparatus, shall be rendered fire resistant to the greatest possible extent (*see also* **4.4.1**).

4.10.1.4 Every counterweight shall travel in juxtaposition to its car in the same lift well.

4.10.1.5 It is undesirable that any room, passage or thoroughfare be permitted under any lift well. If unavoidable spaces for other uses may be permitted under the lift well, with the prior approval of the Lift Inspectorate Authority and the following provisions shall be made:

a) Spring or Oil buffers shall be provided for lift car and counterweight;

b) The pit shall be sufficiently strong to withstand successfully the impact of the lift car with rated load or the impact of the counterweight when either is descending at rated speed or at governor tripping speed;

c) The car and the counterweight shall be provided with a governor-operated safety gear; and

d) The forces required on the structure in the event of car buffering directly without safety gear application to be indicated in the general arrangement drawing.

4.10.2 *Lift Well Enclosures*

4.10.2.1 Lift well enclosures shall be provided and shall extend on all sides from floor-to-floor or stair-to-stair, and shall have requisite strength and in proper plumb.

4.10.2.2 The inner sides of the lift well enclosures facing any car entrance shall, as far as practicable form a smooth, continuous flush surface devoid of projections or recesses.

NOTE — This requirement may be met in existing lift wells by filling any recesses or spaces between projections or alternatively by covering them with suitable sheet material. If it is not possible to render flush any objection or tops of recesses, they should be beveled on the under side to an angle of 60°, from the horizontal by means of metal plates, cement rendering or other fire-resisting materials. Where a car-levelling device is operative with car door opening, such interior surfaces shall always form a smooth flush surface below each landing level for a depth to at least the depth of the car-levelling zone plus the distance through which the lift car may travel of its own momentum when the power is cut-off.

4.10.2.3 Where an open lift well would increase the fire risk in a building, the lift well enclosure shall be of fire-resisting construction (*see* Part 4 'Fire and Life Safety').

4.10.2.4 Where wire grill or similar constructions is used, the mesh or opening shall be such that the opening between the bars shall reject the ball of 30 mm in diameter and the lift well enclosure shall be of sufficient strength to resist accidental impact by users of the staircase or adjoining floors or by materials or trucks being moved in the vicinity.

4.10.2.5 Where the clearance between the inside of an open-type lift well enclosure and any moving or movable part of the lift equipment of apparatus is less than 50 mm, the openings in the enclosure shall be further protected by netting of square mesh of aperture not greater than one centimeter and of wire not smaller than one mm. (The provisions of this clause need not be adhered to for lift wells in factory premises, coming under the purview of *Factories Act*. In such cases provisions of **4.10.2.4** is sufficient.)

4.10.2.6 There shall be no opening in the lift well enclosure permitting access to the lift car by passing under the counterweight.

4.10.2.7 In case of a completely enclosed lift well, a notice with the word 'Lift' may be placed outside of each landing door.

4.10.2.8 *Indicator*

Where lifts are installed in totally enclosed wells,

not provided, at least direction indicators or 'In Use' indicators shall be provided at each landing.

4.10.2.9 *Landing doors*

Every lift well shall, on each side from which there is access to a car, be fitted with a door. Such a door shall be fitted with efficient electromechanical locking so as to ensure that it cannot be opened except when the lift car is at landing and that the lift car cannot be moved away from the landing until the door is closed and locked. If the door is mechanically locked, means should be provided for opening the same by means of special key during emergency or inspection.

4.10.2.10 *Automatic devices for cutting off power*

An efficient automatic device shall be provided and maintained in each lift whereby all power shall be cut off from the motor before the car or counterweight lands on buffer.

4.10.3 *Lift Pits*

4.10.3.1 A lift pit shall be provided at the bottom of every lift.

4.10.3.2 Pits shall be of sound construction and maintained in a dry and clean condition. Where necessary, provision shall be made for permanent drainage and where the pit depth exceeds 1.5 m suitable descending arrangement shall be provided to reach the lift pit. And a suitable fixed ladder or other descending facility in the form of permanent brackets grouted in the wall extending to a height of 0.75 m above the lowest floor level shall be provided. A light point with a switch shall also be provided for facility of maintenance and repair work.

4.11 Machine Rooms and Overhead Structures

4.11.1 The lift machine, controller and all other apparatus and equipment of a lift installation, excepting such apparatus and equipment as function in the lift well or other positions, shall be placed in the machine room which shall be adequately lighted and rendered fire-proof and weather-proof.

4.11.2 The motor generators controlling the speed of multi-voltage or variable voltage machines, secondary sheaves, pulleys, governors, floor selecting equipment may be placed in a place other than the machine room, but such position shall be adequately lighted, ventilated and rendered fire-proof and weather-proof.

4.11.3 The machine room shall have sufficient floor area as well as permit free access to all parts of the machines and equipment located therein for purposes of inspection, maintenance or repair.

of the equipment. When the electrical voltage exceeds 220/230 V ac, a danger notice plate shall be displayed permanently on the outside of the door and on or near the machinery. Where standby generator is provided, it is necessary to connect fireman lift to the standby generator. Depending upon the capacity of the standby generator one or more other lifts may also be connected to the supply.

Rescue instruction with required tools and tackles if any shall be made available in the machine room.

All lifts which do not have any automatic transfer facility to an alternate supply, such as generators, shall be equipped with Battery Operated Automatic Rescue Device to bring the lift to the nearest floor and open the door in the event of power failure.

4.11.5 The machine room shall be equipped with an insulated portable hand lamp provided with flexible cord for examining the machinery.

4.11.6 If any machine room floor or platform does not extend to the enclosing walls, the open sides shall be provided with hand rails or otherwise suitably guarded.

4.11.7 The machine room shall not be used as a store room or for any purpose other than housing the lift machinery and its associated apparatus and equipment.

4.11.8 Machine room floor shall be provided with a trap door, if necessary. The size of the trap door shall be as per manufacturer's recommendation.

4.11.9 The height of the machine room shall be sufficient to allow any portion of equipment to be accessible and removable for repair and replacement and shall be not less than 2 m clear from the floor or the platform of machine whichever is higher.

4.11.10 It will be noted that generally lifts have machine rooms immediately over the lift well, and this should be arranged whenever possible without restricting the overhead distance required for normal safety precautions. In case where machine room provision on top is a limitation, either machine room less lift or basement drive or side drive lift can be considered.

4.11.11 For detailed information regarding nomenclature of floors and storeys, reference may be made to good practice [8-5(6)].

4.11.12 There should be a proper access planned for approach to the machine room taking into account need for maintenance personnel to access the machine room at all times of day and night and also the need to take heavy equipment. Any fixture such as a ladder

provided should be secured permanently to the structure and should have railings to reduce the risk of falling.

4.11.13 It is desirable that emergency exit may be provided in case of large machine rooms having four or more lifts.

4.11.14 Where the machine room occupies a prominent position on roof of a building, provision should be made for lightning protection in accordance with good practice [8-5(7)] and Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

4.11.15 Wherever the machine room is placed, it should be properly ventilated. The ambient temperature of machine room shall be maintained between + 5°C and + 40°C.

4.11.16 If located in the basement, it should be separated from the lift well by a separation wall.

4.12 Essential Features Required

4.12.1 Power operated car doors on automatically operated lifts shall be so designed that their closing and opening is not likely to injure a person. The power operated car door shall be provided with a sensitive device which shall automatically initiate reopening of the door in the event of a passenger being struck or is about to be struck by the door, while crossing the entrance during closing movement. The effect of the device may be neutralized:

a) during the last 58 mm of travel of door panel in case of side opening doors
b) when panels are within 58 mm of each other in case of center opening doors.

The force needed to prevent the door from closing shall not exceed 150 N and this measurement shall not be made in the first third of the travel of the door.

In order to achieve this it is desirable that all power operated doors have a full length (covering at least 80 percent of the car door height from the bottom) infra red light curtain safety to retract the door in the event of coming across any obstacle during closing of the door.

4.12.2 Single speed and two speed drives which are poor in levelling accuracy and energy consumption shall not be used for new lifts in view of availability of latest technology energy efficient Variable Voltage Variable Frequency drive systems with improved leveling accuracy.

4.12.3 For passenger lifts with car call button control in car and with capacities of 16 passenger and above, it is recommended to have an additional car operating panel with call buttons on the opposite side to main panel for ease of access to buttons.

4.12.4 Passenger lifts shall be provided with power operated doors which are imperforate.

5 DIMENSIONAL TOLERANCES

5.1 Lift Well Dimensions

Plan dimensions of lift wells given by the lift maker represent the minimum clear plumb sizes. The purchaser's representative, in conjunction with the builder, should ensure that adequate tolerances are included in the building design so that the specified minimum plumb dimensions are obtained in the finished work.

Dimensions in excess of these minimum plumb dimensions for lift well and openings (but not less) can be accommodated by the lift maker up to certain maximum values beyond which changes in design may be necessary involving additional expense or work by the builder. The purchaser's representative should take these factors into account when specifying the lift well structural dimensions on the basis of the constructional tolerance appropriate to the building technique.

5.2 Landing Door Openings

It is very important that finished landing openings should be accurate to design size and plumb one above the other for the full travel of the lift. In constructing the structural openings in concrete walls to lift wells it is not possible to achieve a degree of accuracy vertically which will allow doors and frames to be inserted in the opening without some form of masking or packing to overcome inaccuracies. Provisions should therefore be made in design by increasing the nominal height from design finished floor level and width of openings to each jamb and head.

In addition, the alignment of the outer face of the front wall of the lift well is of importance when architrave of fixed dimensions are called for, and in this case the alignment of the outer face from floor to floor should not vary to a greater extent than can be accommodate by the subsequent front wall finish, the architrave being set accurately plumb.

To facilitate accurate alignment of landing sills it is common practice to provide at each landing an independent threshold, the position of which can be adjusted.

5.3 Structural Limits for Lift Wells at any Level

If the net plumb well (dimensions *A* and *B* of Fig. 2) and the nominal structural entrance openings (dimensions *C* and *D* of Fig. 2) are defined by plumb lines, the actual wall should not encroach on these dimensions.

Dimension *K* (inside face of wall of Fig. 2) should fall within the following limits:

For wells upto 30 m	–	0-25 mm
For wells upto 60 m	–	0-35 mm
For wells upto 90 m	–	0-50 mm

When architrave are to be supplied by the lift maker dimension *L* (side of structural opening of Fig. 2) should fall within the limits of 0 and 25 mm and dimension *M* (outer face of the front wall of Fig. 2) should not vary to a greater extent than can be accommodated by the subsequent front wall finish, the architrave being set accurately plumb.

When the entrance linings are supplied by the builder, corresponding provision should be made for the finished openings to be accurately plumb one above the other for the full travel of the lift end to design size.

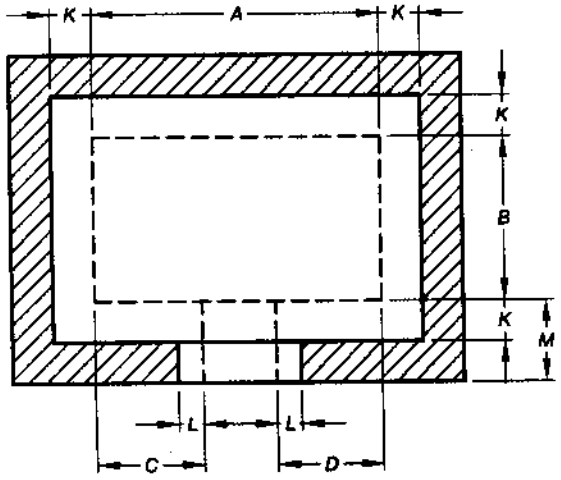


FIG. 2 LIFE WELL TOLERANCE

6 PRELIMINARY DESIGN

6.1 Number of Lifts and Capacity

6.1.1 Two basic considerations, namely, the quantity of service required and the quality of service desired, determine the type of lifts to be provided in a particular building. Quantity of service gives the passenger handling capacity of the lifts during the peak periods and the quality of service is measured in terms of waiting time of passengers at various floors. Both these basic factors require proper study into the character of the building, extent and duration of peak periods, frequency of service required, type and method of control, type of landing doors etc. In busy cities patience, coefficient being low satisfaction cannot be obtained if lifts with adequate capacities and speeds are not provided. In view of many variables, no simple formula is possible for determining the most suitable lifts.

NOTE — It is recommended to do Traffic Analysis Study to ensure optimum provision of lifts for the building in consultation with lift manufacturers. In view of the dynamic situation it is recommended that a computerised software is used for Traffic Analysis Study.

6.1.2 The number of passenger lifts and their capacities, that is load and speed, required for a given building depend on the characteristics of the building. The most important of these are:

a) Number of floors to be served by the lift;
b) Floor to floor distance;
c) Population of each floor to be served; and
d) Maximum peak demand; this demand may be unidirectional, as in up and down peak periods, or a two-way traffic movement.

It should be appreciated that all calculations on the traffic handling capabilities of lifts are dependent on a number of factors which vary according to the design of lift and the assumptions made on passenger actions. It follows, therefore, that the result of such calculations can only be put to limited use of a comparative nature. For instance, they can with advantage be used to compare the capabilities of lifts in a bank with different loads and speeds provided the same set of factors are used for all cases. On the other hand, they cannot be used to compare the capabilities of different makes of lift used for a given bank of lifts.

Different authorities and manufacturers differ widely in their methods of calculation, due to the variations in lift performance, especially with regard to rates of acceleration and deceleration and door operation times which form the components of performance time. Therefore, the calculations made by different organizations will not necessarily agree.

6.2 Preliminary Lift Planning

6.2.1 *General*

Methods of calculating the traffic handling capabilities of lifts were first devised for office buildings. In due course detailed modifications were devised to suit other applications without altering the basic principles. The application to office buildings is still the most frequently used.

Therefore, the following method may be used as general guidance on preliminary lift planning for offices, bearing in mind the differences set out in **6.1.2**.

A lift installation for office building is normally designed to populate the building at a given rate and the three main factors to be considered are:

a) population or the number of people who require lift service.

b) handling capacity of the maximum flow rate required by these people.

c) interval or the quality of service required.

6.2.2 *Population*

The first point to be ascertained from the eventual occupier is the total building population and whether this is likely to increase in the future.

If a definite population figure is unobtainable an assessment should be made from the net area and probable population density. Average population density can vary from about one person per 4 m^2 to one person per 20 m^2. It is essential, therefore, that some indication of the probable population density should be obtained from the building owner. If no indication is possible (a speculative development for example) population in the region of 5 m^2 per person for general office buildings is usually assumed.

6.2.3 *Quantity of Service*

The quantity of service is a measure of the passenger handling capacity of a vertical transportation system. It is measured in terms of the total number of passengers handled during each five-minute peak period of the day. A five-minute base period is used as this is the most practical time over which the traffic can be averaged.

The recommended passenger handling capacity for various buildings is as follows:

Type of Building	*Handling Capacity*
Office — Diversified tenants	10 to 15 percent
Office — Single tenant	15 to 25 percent
Residential	7.5 percent

6.2.4 *Quality of Service*

The quality of service on the other hand is generally measured by the passenger waiting time at the various floors. The following shall be the guiding factor for determining this aspect.

Quality of Service or Acceptable Interval

20 to 25 seconds	Excellent
30 to 35 seconds	Good
34 to 40 seconds	Fair
45 seconds	Poor
Over 45 seconds	Unsatisfactory

NOTE — For residential buildings longer intervals should be permissible.

6.2.5 *Traffic Peaks*

The maximum traffic flow during the up peak period is usually used as a measure of the vertical transportation requirement in an office building. The employees of all offices are subject to discipline and are required to be at their place in time. Consequently, the incoming traffic flow is extremely high and the arrival time is over a short period.

Sometimes it becomes necessary to reduce the maximum traffic flow by staggering the arrival of the employees so that different groups arrive at different times. This reduces the peak and also the requirement of lifts. However, many organizations may object to staggering and prefer to have all employees arrive at the same time since it is claimed that staggering will affect the proper co-ordination of business.

6.2.6 *Capacity*

The minimum size of car recommended for a single purpose buildings is one suitable for a duty load of 884 kg. Generally, for large office buildings cars with capacities up to 2 040 kg are recommended according to the requirements.

6.2.7 *Speed*

It is dependent upon the quantity of service required and the quality of service desired (*see* **6.2.3** and **6.2.4**). Therefore, no set formulae for indicating the speed can be given. However, the following general recommendations are made:

No. of Floors	*Speed*
4 to 5	0.5 to 0.75 m/s
6 to 12	0.75 to 1.5 m/s
3 to 20	1.5 m/s to 2.5 m/s
Above 20	2.5 m/s and above

6.2.8 *Layout*

The shape and size of the passenger lift car bears a distinct relation to its efficiency as a medium of traffic handling. A study of the most suitable proportions for these lifts reveal that the width of the lift well entrance is in reality, the basic element in the determination of the best proportions. In other words, the width of the car is determined by the width of the entrance and the depth of the car is regulated by the loading per square metre permissible under this Code. Centre opening doors are more practicable and efficient entrance units for passenger lifts.

6.2.9 *Determination of Transportation or Handling Capacity During the Up Peak*

6.2.9.1 The handling capacity is calculated by the following formula:

$$H = \frac{300 \times Q \times 100}{T \times P}$$

where

H = Handling capacity as the percentage of the peak population handled during 5 min period,

Q = Average number of passengers carried in a car,

T = Waiting interval in seconds, and

P = Total population to be handled during peak morning period. (It is related to the area served by a particular bank of lifts.)

The value of Q depends on the dimensions of the car. It may be noted that the car is not loaded always to its maximum capacity during each trip and, therefore, for calculating H the value of Q is taken as 80 percent of the maximum carrying capacity of the car.

The waiting interval is calculated by the following formula:

$$T = \frac{RTT}{N}$$

where

T = Waiting interval in seconds,

N = Number of lifts, and

RTT = Round trip time, that is, the average time required by each lift in taking one full load of passengers from ground floor, discharging them in various upper floors and coming back to ground floor for taking fresh passengers for the next trip.

RTT is the sum of the time required in the following process:

a) Entry of the passengers on the ground floor,

b) Exit of the passengers on each floor of discharge,

c) Door closing time before each starting operation,

d) Door opening time on each discharging operation,

e) Acceleration periods,

f) Stopping and levelling periods,

g) Periods of full rated speeds between stops going up, and

h) Periods of full rated speeds between stops going down.

It is observed that the handling capacity is inversely proportional to waiting interval which in turn is proportional to RTT. Reducing the RTT of a lift from 120 to 100 increases its handling capacity by 20 percent.

The round trip time can be decreased not only by increasing the speed of the lift but also by improving the design of the equipment related to opening and closing of the landing and car doors, acceleration, deceleration, levelling and passenger movement. These factors are discussed below:

a) The most important factor in shortening the time consumed between the entry and the exit of the passengers to the lift car is the correct design of the doors and the proper car width. For comfortable entry and exit for passengers it has been found that most suitable door width is 1 000 mm and that of car width is 2 000 mm.

b) The utilization of centre opening doors has been a definite factor in improving passenger transfer time, since when using this type of door the passengers, as a general rule, begin to move before the doors have been completely opened. On the other hand, with a side opening door the passengers tend to wait until the door has completely opened before moving.

The utilization of centre opening doors also favours the door opening and closing time periods. Given the same door speed, the centre opening door is much faster than the side opening type. It is beyond doubt that the centre opening door represents an increase in transportational capacity in the operation of a lift.

6.2.9.2 An example illustrating the use of the above consideration is given below:

Gross area per floor	1 100 m^2
Net usable area per floor	950 m^2
No. of landings including ground	15
Assuming population density	9.5 m^2 per person
Probable population in	

$$P = \frac{14 \times 950}{9.5}$$

Upper floors	1 400 persons
Taking 20 passengers lift with 2.5 m/s the calculated RTT	165 s

$$Q = 20 \times 0.8 = 16$$

a) Taking No. of lifts, $N = 4$

$$T = \frac{RTT}{N} = \frac{165}{4} = 41 \text{ s}$$

$$H = \frac{300 \times Q \times 100}{T \times P} = \frac{300 \times 16 \times 100}{41 \times 1400}$$

$$= 8.3 \text{ percent}$$

b) Taking No. of lifts, $N = 6$

$$T = \frac{165}{6} = 27.6 \text{ s}$$

$$H = \frac{300 \times Q \times 100}{T \times P} = \frac{300 \times 16 \times 100}{27.6 \times 1\,400}$$

= 12 percent

6.3 Quiet Operation of Lifts

Every precaution should be taken with passenger lifts to ensure quiet operation of the lift doors and machinery. The insulating of the lift machine and any motor generator from the floor by rubber cushions or by a precast concrete slab with rubber cushions, prevents transmission of most of the noise. In this connection, *see also* good practice [8-5(8)] and Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' for some useful recommendations.

6.4 Positioning of Lifts

A thorough investigation should be made for assessing the most suitable position for lift(s) while planning the building. It should take into account future expansions, if any. Though each building has to be considered individually for purposes of location of lifts, factors influencing the locations of passenger and goods lifts are given in **6.4.2** to **6.4.4.**

The location of lifts may also conform to the travel distance requirements specified in Part 4 'Fire and Life Safety'.

6.4.1 *Arrangement of Lifts*

The lifts should be easily accessible from all entrances to the building. For maximum efficiency, they should be grouped near the centre of the building. It is preferably not to have all the lifts out in straight line and, if possible, not more than three lifts should be arranged in this manner. It has to be kept in mind that the corridor should be wide enough to allow sufficient space for waiting passengers as well as for through passengers.

6.4.1.1 In some cases when there are more than three lifts, the alcove arrangement is recommended. With this arrangement, the lift alcove lead off the main corridor so that there is no interference by traffic to other groups or to other parts of the ground floor. This arrangement permits the narrowest possible corridors and saves space on the upper floors. Walking distance to the individual lift is reduced and passenger standing in the center of the group can readily see all the lift doors and landing indicators. The ideal arrangement of the lifts depends upon the particular layout of the respective building and should be determined in every individual case. Some typical recommended arrangements are given in Fig. 1.

6.4.2 *Passenger Lifts*

6.4.2.1 *Low and medium class flats*

Where a lift is arranged to serve two, three or four flats per floor, the lift may be placed adjoining a staircase, with the lift entrances serving direct on to the landings. Where the lift is to serve a considerable number of flats having access to balconies or corridors, it may be conveniently placed in a well ventilated tower adjoining the building.

6.4.2.2 *Office buildings, hotels and high class flats*

In general the arrangement as recommended in **6.4.1** is to be followed. However, in case this is not possible, it is desirable to have at least a battery of two lifts at two or more convenient points of a building. If this is not possible, it is advisable to have at least two lifts side by side at the main entrance and one lift each at different sections of the building for inter-communication. When two lifts are installed side by side, the machine room shall be suitably planned with sufficient space for housing the machine equipment. The positioning of lifts side by side gives the following advantages:

a) all machines and switch gear may be housed in one machine room,
b) the lifts can be inter-connected more conveniently from an installation point of view, and
c) greater convenience in service owing to the landing openings and each floor being adjacent.

6.4.2.3 *Shops and departmental stores*

Lifts in shops and stores should be situated so as to secure convenient and easy access at each floor.

6.4.2.4 For buildings with more than 12 floors, it is recommended to have provision of 1 stretcher/service lift in addition to the passenger lifts.

6.4.2.5 For buildings with more than 12 floors, where passenger and service lifts are provided in one lobby it is recommended to have group control for all the lifts.

6.4.3 *Goods Lifts*

The location of lifts in factories, warehouses and similar buildings should be planned to suit the progressive movement of goods throughout the buildings, having regard to the nature of position of the loading platforms, railway sidings, etc. The placing of a lift in a fume or dust laden atmosphere or where it may be exposed to extreme temperatures, should be avoided wherever possible. Where it is impossible to avoid installing a lift in an adverse atmosphere, the

electrical equipment should be of suitable design and construction to meet the conditions involved.

6.4.3.1 Normally goods lifts have lower speeds than passenger lifts for the same travel because traffic conditions are less demanding, and more time is required for loading and unloading.

6.4.3.2 As loads for goods lifts increase in size and weight, so the operation of loading and unloading becomes more difficult. Therefore, it is usual to require greater accuracy of levelling as the capacity of the goods lift increases.

6.4.3.3 A large capacity goods lift at high speed is often a very uneconomical preposition. The inherent high cost is enhanced due to the very small demand for such equipment, much of which is custom made. The high capital cost of the lift, building work and electrical supply equipment usually shows a much smaller return as an investment than more normal sizes of lifts.

6.4.4 *Hospital Bed Lifts*

Hospital bed lifts should be situated conveniently near the ward and operating theatre entrances. There shall be sufficient space near the landing door for easy movement of stretcher.

It is convenient to place the passenger lifts in a hospital, near the staircases.

6.5 Structural Considerations

6.5.1 Lift well enclosures, lift pits, machine rooms and machine supports besides conforming to the essential requirements given in **4**, should form part of the building construction and comply with the lift manufacturer's drawings.

6.5.2 *Machine Room*

Floors shall be designed to carry a load of not less than 350 kg/m^2 over the whole area and also any load which may be imposed there on by the equipment used in the machine room or by any reaction from any such equipment both during periods of normal operation and repair.

6.5.3 The side wall of the lift well may be made of reinforced cement concrete at least 150 mm thick so as to provide satisfactory anchoring arrangement for fixing. Reference shall also be made to Part 6 'Structural Design, Section 5 Plain, Reinforced and Prestressed Concrete, 5A Plain and Reinforced Concrete'.

6.5.4 The total load on overhead beams shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams.

6.5.5 The factor of safety for all overhead beams and supports based on ultimate strength of the material and load in accordance with **6.5.4** shall be not less than the following:

For Steel	5
For Reinforced Concrete	7

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

6.6 Access to Machine Room and Lift Pits

6.6.1 Access to machine room above a lift well may be either from the roof or by an internal staircase with a proper arrangement for fixing.

6.6.2 Access between a secondary floor and a machine room may be by ladder. Where a machine room entrance is less than 1.5 m above or below the adjacent floor or roof surfaces, a substantial permanently attached ladder may be used. Ladders shall be fixed at least 150 mm clear of any wall, beam or obstruction and shall extend at least to the landing level. Above the landing level and for a height of at least 1.15 m, either the ladder stringers shall be extended or suitable hand grips shall be provided.

6.6.3 Where the machine room entrance is 1.5 m or more above or below the adjacent floor or roof surface, access shall be provided by means of stairs in accordance with the requirements given in **6.6.3.1** to **6.6.3.6**.

6.6.3.1 The angle of inclination of the stair shall not exceed 50° from the horizontal and the clear width of the stair shall be not less than 600 mm.

6.6.3.2 The tread shall have a non-slip surface which shall be not less than 150 mm wide for open stair construction and not less than 20 cm wide for closed stair construction.

6.6.3.3 The rise of the stair shall not exceed 250 mm.

6.6.3.4 A hand rail shall be provided on the outer stringer of all stairways fixed at a convenient height, but not less than 500 mm high measured vertically from the nosings, and not less than 1 m high on landings and platforms. Such hand rail shall have atleast 50 mm clearance between nearest permanent object at the corresponding side of the stair.

6.6.3.5 Headroom clearance of not less than 2 m measured from the nosings of the stairway, shall be provided on every stairway.

6.6.3.6 Heights of stairs over 5 m in length shall be provided with intermediate landings.

NOTE — Where compliance with any of the requirements specified in **6.61** to **6.6.3** is impracticable, applications for variation shall be made to the Authority, who may, vary such requirements.

6.6.4 Access to a machine room in a basement may be provided from a corridor.

6.6.5 Access to a machine room via the lift well shall be prohibited.

6.6.6 The lift pit should be capable of being examined by a separate access. In the case of a battery of two lifts, it is possible to examine the lift pit through the adjoining one.

6.7 Fire Protection

To prevent fire from spreading by means of the lift well, lift well enclosures shall conform to the requirements given in Part 4 'Fire and Life Safety'. The machine room should be constructed of a suitable grade of fire-resisting material and precautions should be taken to minimize spread of fire from the machine room into the lift well (*see also* **7.3.14**).

6.8 Requirements for Fireman's Lift

6.8.1 For buildings having height of 15 m or more atleast one lift shall meet the requirements of fireman's lift as given in **6.8.2**.

6.8.2 The fireman's lift shall have the following minimum requirements:

a) Lift car shall have floor area of not less than 1.44 square meters. It shall also have a loading capacity of not less than 544 kg (8 persons).

b) Lift landing doors shall have a minimum of fire resistance of one hour.

c) Doors shall be of automatic operation for car and landing.

6.8.3 Fireman's lifts in a building having more than 15 m or more height, shall work at or above the speed of 1.0 m/s so as to reach the top floor from ground level within one minute.

6.8.4 *Operation Requirements of Fireman's Lift*

The lift shall be provided with the following as a minimum:

a) A two position switch at evacuation floor (normally main entrance floor) (ON/OFF), and

b) Buzzer and 'Fireman's lift' — light in car

6.8.4.1 *Sequence of operation*:

a) *Return to evacuation floor (Phase 1):*

1) Shall start when the switch at the evacuation floor is turned to the "ON" position or the signal from smoke detector (if provided by the Building Management System) is on. All lift(s) controlled by this switch shall cancel all existing car calls and separate from landing calls and no landing or car calls shall be registered. The buzzer and "fireman's lift" light shall be turned on. All heat and smoke sensitive door re-opening devices shall be rendered inoperative.

2) If the lift is travelling towards the evacuation floor, it shall continue driving to that floor.

3) If the lift is travelling away from the evacuation floor, it shall reverse its direction at the nearest possible floor without opening its doors and return non-stop to the evacuation floor.

4) If the lift is standing at a floor other than the evacuation floor, it shall close the doors and start travelling non-stop to the evacuation floor.

5) When at the evacuation floor the lift shall park with doors open.

6) The buzzer is turned off after this return drive.

b) *Fireman's service (Phase 2):*

The phase 2 operation of the lift shall be as defined below.

1) The phase 2 is started after phase 1, if the switch is "ON".

2) The lift does not respond to landing calls but registers car calls. All heat and smoke sensitive door reopening devices are rendered inoperative.

3) When the car call button is pressed the doors start closing. If the button is released before the doors are fully closed, they re-open. The car call is registered only when the doors are fully closed.

4) After registering a car call the lift starts driving to the call. If more than one car call is registered, only the nearest call is answered and the remaining calls will be cancelled at the first stop.

5) At the floor the doors are opened by pushing the door open button. If the button is released before the doors are fully open, they re-close.

6) The lift returns to normal service when it stands at the evacuation floor with doors open and the switch is "OFF".

6.9 Supply Cables and Switches

Each lift should be provided with a main switch or circuit breaker of a capacity determined by the lift

manufacturer and the incoming supply cable should terminate in this switch. For a single lift, this switch should be fixed adjacent to the machine room entrance inside the machine room. In a machine room common to more than one lift, each main switch should be conveniently situated with respect to the lift it controls. Switches and fuses (which may form part of a distribution switch-board) should be provided for isolating the supply cables to the machine room.

6.10 The detailed design considerations for different types and selection of the lifts shall be done in accordance with good practice [8-5(5)].

7 POWER AND CONTROL SYSTEMS

7.1 Features Associated with Power Systems

7.1.1 *Industrial Switchgear*

Switchgear for controlling lift power systems is characterized by its high duty cycle and its high rupturing capacity. Switchgear must be robust enough and shall be so designed as to withstand the high duty cycle and high rupturing capacity introduced during the operation of the lifts.

7.1.2 *Levelling Accuracy*

The levelling tolerances in accordance with good practice [8-5(4)] are those which can be reasonably expected between no load and full load in either direction.

Where greater levelling accuracy is required, careful examination should be made to see whether such increased precision is justified or practical. Advice should also be obtained, as additional apparatus and cost may be involved, and in some cases the requirement may not be practicable.

7.1.3 *Corrective Levelling*

This should only be used when it is impossible otherwise to achieve the required levelling tolerances or on long travel lifts to maintain the required levelling tolerances during loading and unloading.

7.1.4 *Levelling with Variable Voltage*

A variable voltage system is one using continuous regulation which minimizes speed differences due to load variation. Therefore, the actual levelling speed is of less importance than the general refinement of its regulation control. In fact no levelling speed as such may be identifiable.

7.1.5 *Overload Tests*

A lift is designed to operate and transport the contract load at the required duty cycle, and should not by intention or habitually be used to carry overloads. During test as a safeguard to cover variable supply and temperature conditions a lift is checked for the car to complete one round trip with contract load plus 10 percent at nominal supply voltage and nominal ambient temperature. There is also a static test with contract load plus 25 percent to check that the brake will sustain the car.

It is unnecessary to specify and additional overload test or capacity and in fact it is detrimental to the normal running efficiency and safety of the lift to do so.

7.1.6 *Occasional Extra Load*

It is not good practice to request that a lift should be designed to carry an occasional extra load. It is tantamount to specifying an excessive overload test which is detrimental to the normal running efficiency and safety of the lift.

7.2 Description of Operation Systems

7.2.1 *Methods of Control Systems*

The methods of control systems are as follows:

a) Attendant and dual control (*see* **7.2.2**), and
b) Automatic push button operation (*see* **7.2.2**).

7.2.1.1 *Types of control systems*

a) Collective control (*see* **7.2.3**),
b) Single push button collective control (*see* **7.2.4**),
c) Down collective control (*see* **7.2.5**),
d) Directional collective control for one car (*see* **7.2.6**),
e) Directional collective control for two or three cars (*see* **7.2.7**), and
f) Group supervisory control (*see* **7.2.8**).

Features of control systems are described in **7.3**.

7.2.2 *Automatic Push Button Operation*

Automatic control is a method of operation by which a momentary pressure on a push button sets the car in motion and causes it to stop automatically at any required lift landing. This is the simplest control system and it is sometimes referred to as push button control.

A car answers a landing or car call whichever is actuated first by momentary pressure provided the lift is not in use. Momentary pressure of a car push button will send the car to the designated floor. The car always responds to a car push button in preference to a landing push button.

With this type of control, a RED landing signal light or direction arrow indicates that the car is in use that is the lift is travelling.

This type of control is recommended for the following applications.

a) A single passenger lift serving up to 4 floors.
b) Goods lifts serving any number of floors where it is usually the most suitable form of control.

For special purposes, the following two systems may be considered:

a) Despatch from landings as an additional feature for a goods lift with manually operated doors. The call is registered by pressing the car push button and when the doors are closed the car will travel to the designated floor.
b) Automatic with attendant control as an additional feature on goods lifts with a key operated switch in the car to transfer the control from normal automatic to attendant operation. There is also a visual call indicator with buzzer in the car to indicate to the attendant the landing floors at which push buttons have been pressed when the car is under attendant control.

7.2.3 *Collective Control*

Collective control is a generic term for those methods of automatic operation by which calls made by pressing push buttons in the car and at lift landings are registered and answered by the car stopping in floor sequence at each lift landing for which calls have been registered irrespective of the order in which the calls have been made, and until all calls have had attention.

Collective control of any form is usually not suitable for goods lifts except where loading is not expected to fill the car and additional loads can be taken at other stops.

7.2.4 *Single Push Button Collective Control*

Single push button collective control has a single push button at each landing. It is not recommended, as the direction in which it is desired to travel cannot be registered by the intending passenger.

7.2.5 *Down Collective Control*

Down collective is a control system where landing calls are registered from a single push button, irrespective of the car being in motion or the landing door being open and calls are stored until answered. Any number of car calls can be registered and the car will stop in sequence in the down direction at each of the designated floors. The car will travel in the up direction to the highest call registered stopping only in response to car calls. It will then travel downwards answering calls in floor sequence. If only one call has been registered the car travels to the floor of call.

This system is suitable where there is traffic between the ground and upper floors only and no interfloor traffic. Two or three car banks have interconnected control.

With this type of control the following signals are included:

a) A landing signal light indicates that the call has been registered and will be answered.
b) Illuminated car position indicator above car entrance.

7.2.6 *Directional Collective Control for One Car*

Directional collective control for one car is a control system having UP and DOWN push buttons at intermediate landings whereby the call is registered for the intended direction of travel. Calls from the car or landing push buttons are registered and stored until answered. The car will answer calls in floor sequence in one direction of travel. Calls for the opposite direction of travel are answered when the direction of travel is reversed.

This system is suitable for single lifts serving 4 or more floors with interfloor traffic, such as small office blocks, hotels and blocks of flats.

With this type of control the following signals are included:

a) A landing signal light for each landing push button indicates that the call has been registered and will be answered.
b) Illuminated car position indicator above the entrance in the car.
c) Arrow shaped signal lights in the back of the car or on the landing to indicate to the entering person in which direction the car is going to depart.

7.2.7 *Directional Collective Control for Two or Three Cars*

Directional collective control for two or three cars is a system covering a control in which the two or three cars in a bank are interconnected. One push button unit with UP and DOWN push buttons or floor buttons (in case of car control from floor) are required at each landing and the call system is common to all lifts. If for architectural balance, in the case of a three car bank, extra push button units are required, these should be specified. Each landing call is automatically allocated to the best placed car. The control is designed so that cars are effectively spaced and thus give even service. When a car reaches the highest floor to which there is a call its direction of travel is automatically reversed when it next starts. One or more cars will return to the parking floor.

Automatically bypassing of landing calls when a car is fully loaded is an essential feature for three-car

banks. It is also necessary for two-car banks in offices. Other cars will continue to provide service to all floors.

When three-car banks serve 7 or 8 floors and over, some form of automatic supervisory control (*see* **7.2.8**) is generally necessary in the interest of efficiency.

With this type of control the following signals are included:

a) A landing signal light for each landing push button to indicate that the call has been registered and will be answered.
b) Illuminated car position indicator above the entrance in the car.
c) Arrow shaped signal lights in conjunction with an audible single stroke gong or an indication on the landing call push button station above each landing entrance to indicate to the waiting person(s) which car is going to stop and in which direction it will continue its course.

7.2.8 *Group Supervisory Control*

A bank or group of intensive traffic passengers lifts requires a supervisory system to co-ordinate the operation of individual lifts which are all on collective control and are interconnected.

The very nature of intensive service calls for a sophisticated automatic supervisory control system so as to match the speed capacity of these lifts.

The supervisory system regulates the despatching of individual cars and provides service to all floors as different traffic conditions arise minimizing such unproductive factors as idle cars, uneven service and excessive waiting time. The system will respond automatically to traffic conditions such as UP and DOWN peaks, balanced or light traffic and provides for other specialized features.

If desired, a master station can be provided in the lift lobby which gives by indicators, visual information regarding the pattern under which the system is operating. Where the system is based on a definite programme, control means are provided for altering the type of traffic programme. There are other facilities, such as the removal of any lift from service.

7.3 Features of Operation Systems

7.3.1 *Car Preference*

Sometimes it is necessary to give a special personal service or a house service. When this service is required and for whatever purpose, it should be specified as 'car preference' is by a key operated switch in the car. The operation is then from the car only and the doors remain open until a car call is registered for a floor destination. All landing calls are bypassed and car position indicators on the landing for this lift are not illuminated. The removal of the key when the special operation is completed restores the control to normal service.

7.3.2 *Landing Call Automatic Bypass*

For collective operation, automatic bypassing of landing calls can be provided. This device will bypass landing calls when a car is fully loaded but the calls are not cancelled.

7.3.3 *Motor Generator Shut Down*

Lifts controlled by variable voltage system automatically shutdown when subject to an over-riding control which puts them out of service under certain conditions; for example, no demand for lift service. They are automatically put back into service as required.

7.3.4 *Basement Service*

For lifts with collective control when service is required below the main parking floor, which is usually the ground floor, to a basement and/or a sub-basement, the lift maker should be informed of the type of service required, as special technical considerations are then usually necessary.

7.3.5 *Hospital Service*

Lifts for carrying beds and stretchers require a car preference switch so than an attendant can have complete control of the car when required. This requirement should be specified as 'car preference' and it will function as described in **7.3.1**. Otherwise such lifts can have the same control systems as for normal passenger lifts, the choice depending on the number of floors served, the service required and the number of lifts.

7.3.6 *Manually Operated Doors (Without Closers)*

A 'door open' alarm should be provided to draw attention to a car or landing door which has been left open.

7.3.7 *Automatically Power Closed Doors*

For passenger operation when the car arrives at a landing the doors will automatically open and then close after lapse of a time interval. This time interval can be overruled by the pressure of a push button in the car to give instant door closing.

An 'open door' push button is provided in the car to reverse closing motion of the doors or hold them open.

7.3.8 *Controlled Power Closed Doors*

When there are conditions that particularly affect the safety of passengers or damage to vehicles or trucks, the closing of the doors should only be made by the

continuous pressure of push buttons in the car or on landings.

A 'door open' alarm should be provided to draw attention to a car or landing door which has been left open. This means of operation is required for some forms of goods lifts.

7.3.9 *Safe Operation of Doors*

The safety of passengers passing through lift entrances is fully covered by the provision of good practice [8-5(9)]. No modification of these provisions should be specified.

7.3.10 *Director Service*

There are many forms of giving special service for individuals, but they should always be avoided. They range from key operated switches at preferred landings to the complete segregation of one out of a bank of lifts. It is obvious that any preferential treatment of this nature can seriously jeopardize the efficiency of the service as a whole. When a bank of say three lifts is installed to meet the anticipated traffic requirements and then, when the building is occupies, one lift is detached permanently for directors' service, the traffic handling can be reduced by a half rather than a third.

When preferential service is imperative, then the car preference feature should be available (*see* **7.3.1**).

7.3.11 *Indication of Car Arrival*

As all lift cars are illuminated when available (in service). It is recommended that this illumination be used to signal the arrival of a car at a landing in preference to special signals such as LIFT HERE signs since signal lamps can fail when the lift is still operating satisfactorily.

The following is the practice adopted for vision panels in doors:

a) For lifts with manually operated car and landing doors, vision panels are provided in all doors;

b) For lifts with power operated car doors and manually operated landing doors, vision panels are provided in the landing doors only;

c) For lifts with automatically opened car and landing doors, no vision panels are required; and

d) When vision panels are provided they should comply with the requirements of good practice [8-5(4)].

7.3.12 *Service Switches*

When switches are provided to take cars out of service, that is because the remaining cars in the group can cater for the required passenger traffic, it is essential that such switches should not stop the fireman's control from being operative in the event of the lift being designated as a fireman's lift. Service switches should not be confused with maintenance switches which are only used when it is dangerous to attempt to operate the lift because maintenance work is actually in progress. A control station fitted on top of the car is regarded as a maintenance switch.

7.3.13 *Fire Switch*

When required by the fire authority a fire switch has to be provided, the function of which is to enable the fire authority to take over the complete control of one or more lifts in an installation {*see* good practice [8-5(4)]}.

7.3.14 *Push Buttons and Signals*

It is most important that the purpose of every push button and signal should be clearly understood by all passengers.

7.3.15 In public places where blind persons are expected to use the lifts it is recommended to provide Brailey buttons.

7.4 Electrical Installation Requirements

7.4.1 *General*

The good practices [8-5(4)] states the requirements for main switches and wiring with reference to relevant regulations. The lift maker should specify, on a schedule, particulars of full load current, starting current, maximum permissible voltage drop, size of switches and other details to suit requirements. For multiple lifts a diversity factor may be used to determine the cable size and should be stated by the lift manufacturer.

It is important that the switches at the intake and in the machine room which are provided by the electrical contractor are the correct size, so that correctly rated HRC fuses can be fitted. No form of 'NO VOLT' trip relay should be included anywhere in the power supply of the lift.

a) *Power supply mains* — The lift sub-circuit from the intake room should be separate from other building service.

   Each lift should be capable of being isolated from the mains supply. This means of isolation should be lockable.

b) For banks of interconnected lifts, a separate sub-circuit is required for the common supervisory system, in order that any car may be shut down without isolating the supervisory control of the remainder.

c) *Lighting* — Machine rooms and all other rooms containing lift equipment should be provided with adequate illumination and with a switch fixed adjacent to the entrance. At least one socket outlet, suitable for lamps or tools, should be provided in each room.

The supply to the car light should be from a separate circuit, and controlled by a switch in the machine room. For multiple lifts with a common machine room a separate supply should be provided for each car. The car lighting supply should be independent of the power supply mains. Plug should be provided with a light, the switch for which should be in the lift well, and accessible from the lower terminal floor entrance.

When the alarm system is connected to a transformer or trickle charger, the supply should be taken from the machine room lighting.

7.4.2 *Electric Wiring and Apparatus*

7.4.2.1 All electrical supply lines and apparatus in connection with the lift installation shall be so constructed and shall be so installed, protected, worked and maintained that there may be no danger to persons therefrom.

7.4.2.2 All metal casings or metallic coverings containing or protecting any electric supply lines of apparatus shall be efficiently earthed.

7.4.2.3 No bare conductor shall be used in any lift car as may cause danger to persons.

7.4.2.4 All cables and other wiring in connection with the lift installation shall be of suitable grade for the voltage at which these are intended to be worked and if metallic covering is used it shall be efficiently earthed.

7.4.2.5 Suitable caution notice shall be affixed near every motor or other apparatus in which energy is used at a pressure exceeding 250 V.

7.4.2.6 Circuits which supply current to the motor shall not be included in any twin or multicore trailing cable used in connection with the control and safety devices.

7.4.2.7 A single trailing cable for lighting control and signal circuit shall be permitted, if all the conductors of this trailing cable are insulated for maximum voltage running through any one conductor of this cable.

7.4.3 *Emergency Signal or Telephone*

It is recommendatory that lift car be provided either with an emergency signal that is operative from the lift car and audible outside the lift well or with a telephone.

When an alarm bell is to be provided each car is fitted with an alarm push which is wired to a terminal box in the lift well at the ground floor by the lift maker. This alarm bell, to be supplied by the lift maker (with indicator for more than one lift) should be fixed in an agreed position and wired to the lift well. The supply may be from a battery (or transformer) fixed in the machine room or, when available, from the building fire alarm supply.

When a telephone is to be provided in the lift car the lift maker should fit the cabinet in the car and provided wiring from the car to a terminal box adjacent to the lift well.

The type of telephone should be stated in the enquiry.

7.4.4 *Earthing*

7.4.4.1 The terminal for the earthing of the frame of the motor, the winding machine, the frame of the control panel, the cases and covers of the tappet switch and similar electric appliances which normally carry the main current shall be at least equivalent to a 5 mm diameter bolt, stud or screw. The cross-sectional area of copper earthing conductor shall be not smaller than half that of the largest current-carrying conductor subject to an upper limit of 65 mm^2 {*see also* good practice [8-5(10)]}.

7.4.4.2 The terminal for the earthing of the metallic cases and covers of door interlocks, door contacts, call and control buttons, stop buttons, car switches, limit switches, junction boxes and similar electrical fittings which normally carry only the control current (such terminal being one specially provided for this purpose), and the earth conductor should be appropriately sized in accordance with good practice [8-5(10)].

The size of earthing conductor shall be in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

7.4.4.3 The earthing conductor shall be secured to earthing terminal in accordance with the recommendations made in good practice [8-5(10)] and also in conformity with the latest provisions of *Electricity Act*, 2003 and Rules framed thereunder from time to time.

7.4.4.4 The exposed metal parts of electrical apparatus installed on a lift car shall be sufficiently bonded and eartherd.

7.4.4.5 Where screwed conduit screws into electric fittings carrying control current making the case and cover electrically continuous with the conduit, the earthing of the conduit may be considered to earth the fitting. Where flexible conduit is used for leading into a fitting, the fitting and such length of flexible conduit shall be effectively earthed.

7.4.4.6 One side of the secondary winding of bell transformers and their cases shall be earthed.

7.4.4.7 Where there are more than one lift in a building, there should be a separate earth pit for the lifts.

7.5 Building Management Systems — Interface for Lifts

7.5.1 Where more than three lifts are provided in a building and especially when these are provided at different locations in the building a form of central monitoring may be provided. Such central monitoring may be through a Building Management Systems, if provided in the building or through a display panel.

7.5.2 The following signals should be given to the building management interface from each lift.

a) Alarm button in car,
b) Door Zone or floor level information,
c) Lift moving information,
d) Power on information, and
e) Lift position information.

7.5.3 Each of these signals shall be provided through a potential free contact located in the lift machine room. The contacts shall be rated for 230 V ac/1A or 24 V dc/1A. A pair of wires should be used for each potential contact.

7.5.4 The wiring between lift machine room to Building Management Systems shall be planned and carried out by the builder along with other wiring in the building.

7.5.5 The building management system should ensure that any position information is read only when the lift is not moving (lift moving information) or is capable of reading several times to detect a stable state.

In addition to the signals above the following signals may be added if required for the benefit of monitoring the lift performance.

a) A summary fault output to indicate a lift in fault condition, which prevents the lift from providing service. This summary fault condition shall include the most common faults such as safety circuit open.
b) Service or inspection mode.
c) Attendant mode.
d) Fire mode.
e) Doors opening.
f) Doors closing.
g) Lift moving up.
(In combination with lift moving and lift moving up information, lift moving down information can be sensed by the Building Management Systems).
h) Door Reopen Request (Summary of Door Open, Light Curtain, Photocell, Safety Edge Signals).

7.5.6 Where it is desired that it should be possible to control the lift from Building Management Systems, the following control signals can be provided.

a) Normal to service/inspection mode change over
b) Fault Accept/Rest Input
(Using this input, the lift controller may be allowed to clear an existing fault if this is other wise safe. It will be decided by the Lift manufacturer as to what faults can be cleared)
c) Car call to top most floor and bottom most floor of each lift.

Where such control inputs are provided, it should be with a pass word and login feature that allows one to determine who has used these inputs and at what time. Always such inputs should be through authorized person only. The Building Management Systems should make all changeovers effective only when lift is not moving.

7.5.7 Control inputs from Building Management Systems should be through a potential free contact capable of carrying 24 V dc/1A or 230 V ac/1A. The wiring should be terminated in each lift machine room.

8 CONDITIONS FOR OPTIMUM PRACTICE

8.1 Lift Entrance Operation

8.1.1 *General*

Every lift journey involves two horizontal movements, in and out of the car, to one vertical movement. The type of door, and the operation of the doors, play a main part in the service given, and should receive careful consideration.

8.1.2 *Goods Traffic*

Most types of goods traffic require relatively longer loading and unloading times and manual doors are frequently used for economy and simplicity.

Power operation can be applied, especially for large entrances, to give automatic opening: the doors then always open fully, reducing the risk of damage. For many types of goods traffic, it is preferable for closing though powered, to be controlled by continuous pressure button, rather than being automatically initiated {*see* good practice [8-5(4)]}.

For heavy duty lifts, a power operated vertically sliding

8.2 Painting at Works and on Site

Lift equipment with normally receive a protective coat of paint at works before despatch to site. Further painting of lift equipment may be necessary and is normally in the form of a finishing coat and can take place on site. Alternatively, the further painting of the equipment may be carried out at works as a finishing coat with normal touching up after site erection as may be necessary.

Any additional painting, due to site conditions during erection and/or final operating conditions in the premises, is subject to negotiation between the lift maker and the purchaser.

Decorative finishes are a subject for separate negotiation.

8.3 Special Environments

Standard equipment is suitable for use inside normal residential, commercial and industrial buildings but when unusual environments are likely to be encountered, the advice of the lift maker should be sought at the earliest possible stage to enable the most economic satisfactory solution to be found. Special mechanical protection and or electrical enclosures may be necessary as well as compliance with statutory or other regulations and with the purchaser's particular requirements, which should be fully considered at the time of enquiry.

Examples of situations which necessitate special consideration are:

a) Exposure to weather, for example, car parks.
b) Low temperatures, for example, cold stores.
c) High temperatures, for example, boiler plant.
d) Hosing-down for example, for hygiene or decontamination.
e) Corrosive atmosphere, for example, chemical works.
f) Dusty atmospheres, for example, gas plant.
g) Explosive and inflammable atmosphere, for example gas plants, and petroleum and polyester industries.

8.4 Ventilation of Machine Rooms

Machine rooms shall be ventilated. They shall be such that the motors and equipment as well as electric cables etc, are protected as far as possible from dust, harmful dusts and humidity. The ambient temperature in the machine room shall be maintained between 5°C and 40°C.

space, and conditions provided to permit reliable operation of electrical switchgear and rotating machinery, and be conducive to good maintenance.

Lighting should be provided to give at least 200 lux around the controller and machine. The machine room walls, ceiling and floor should be faced in dust-resisting materials, tiles, etc, or painted as a minimum to stop dust circulation which otherwise could damage rotating machinery and cause failure of switchgear. Machine rooms should also be weatherproof and if ventilation louvers are provided they should be designed and sited to prevent snow being driven through or to the apparatus.

8.5.2 Lift wells should be constructed to be weatherproof and of a dust free surface material or should be painted to minimize dust circulation on to moving apparatus and from being pumped by the car movement into machine rooms or on to landings.

Sufficient number of light points should be provided in the lift shaft for proper illumination.

8.5.3 Should a lift entrance open out into an area expected to the weather the entrance should be protected by a suitable canopy and the ground level slope up to the entrance to prevent during rain or surface drainage from entering the lift well through the clearances around the landing doors. Any push buttons so enclosed should be of weatherproof type.

8.6 Stairwell Enclosures

The location of lifts in stairwells is not recommended.

The use of stair stringers for fixing of guides normally involves extensive site measurement in order to fabricate purpose-made brackets. The resulting attachments are often unreliable and lacking in robustness. For stairwells of normal width, the span required for the lift machine support beams is excessive and unless uneconomic sections are used the deflections under varying load adversely affect the motor of the lift.

The necessary provision of suitable continuous enclosures can be very expensive.

8.7 Handwinding Release Procedure and Indication

The release procedure by handwinding should only be carried out in an emergency and by authorized persons who have received the necessary instruction because it is dangerous for any other persons to attempt to do so.

Before attempting to move the car, it is imperative that any person in the car be warned of the intention to

move the car and that they do not attempt to leave the car until they are advised that it is safe to do so. Any failure to carry out this precaution may render the person concerned guilty of negligence should an accident occur.

Before attempting to handwind the lift machine, it is vital that the supply is switched off at the main switch.

It is usually necessary to have two persons in the machine room: one to operate the brake release and the other to carry out the handwinding. The exceptions are small lift machines where the handwinding and be easily controlled by one man and larger machines which need two men to operate the handwinding alone with an additional man to control the brake release.

If the car is stuck in the lift well and cannot be moved when an attempt is made to move it in a downward direction, then no attempt at handwinding should be made because the car safety gear may have set. Any further procedure should be carried out under the instruction of a qualified lift mechanic.

Provided the car is free to be moved in the downward direction, then it should be hand wound to the nearest floor. There is a preference to move the car in a downward direction. However, this may not always be practical owing to the distance involved and the time taken to complete the movement. In addition the amount of out of balance load on the counterweight side, due to the size of car and the small number of persons inside it, may make it necessary to wind the car upwards. In the case of higher speed lifts the direction of handwinding will usually be governed by the effort required to move the car because of the absence of a large gear reduction ratio.

It is essential that all detail operations be carried out according to the manufacturer's instructions for the lift concerned and these should be clearly stated and permanently displayed in the form of a notice in the machine room.

9 RUNNING AND MAINTENANCE

9.1 The lift installation should receive regular cleaning, lubrication, adjustment and adequate servicing by authorized competent persons at such intervals as the type of equipment and frequency of service demand. In order that the lift installation is maintained at all times in a safe condition, a proper maintenance schedule shall be drawn up in consultation with the lift manufacturer and rigidly followed. The provision of a log book to record all items relating to general servicing and inspection is recommended for all lifts. It is essential that the electrical circuit diagram of the lift with the sequence of operation of different components and parts should be kept readily available for the persons responsible for the maintenance and replacement where necessary.

9.2 Particular attention may be directed for thorough periodical examination of wire ropes when in service. Attention should also be directed to the thorough examination of the groove of drums, sheaves and pulleys when installing a new rope. A groove deepened by rope wear is liable to lead to early failure of a new rope unless the groove is returned.

9.3 Any accident arising out of operation of maintenance of the lifts should be duly reported to the Authority in accordance with the rules laid down. A notice may be put in the machine room to this effect.

10 LIFT ENQUIRY OR INVITATION TO TENDER

10.1 General

A period of four weeks is normally sufficient for return of tenders. This should be extended if large numbers of lifts or special requirements are involved.

The enquiry documents should be kept to the essential minimum, and should be strictly confined to material relevant to the lift work and to the particular project concerned

When enquiring for and ordering an electrical lift in accordance with this Section, the particulars given below shall be furnished:

PARTICULARS OF LIFTS

1) Type of lift (Passenger, goods, service or dumb waiter).....
2) Number of lifts required.....
3) Load: number of persons.....kg.....
4) Rated speed.....m/s
5) Travel.....m
6) Serving.....floors.....entrances.....
7) Number of floors served.....
8) Method of control.....(*see* **7.2**)
9) Position of machine room.....
10) Sizes of lift well(s).....
11) Position of counterweight.....
12) Internal size of lift car.....
13) Construction, design and finish of car bodywork.....
14) Car entrances:
    a) Number, size and type of doors
    b) Power or manual operation
15) Car light.....
16) Call indicator.....position indicator in car.....

or shutters (for goods lifts)

b) Location of landing entrances in different floors, if the car has more than one opening.

18) Electric Supply:

Power.....volts ac/dc.....

phase.....

Cycles....., wire system.....

19) Whether neutral wire available for control circuit?

20) Lighting.....volts ac/dc..... cycles.....

21) Are premises subject to Lifts Act/Rules?

22) Proposed date for commencement on site.....

23) Proposed date for completion.....

24) Additional items, if required.....

25) Booklet giving complete details of maintenance schedule and circuit diagram where so specified.....

10.2 Additional Items

The enquiry should state any additional items required beyond those specified in good practice [8-5(4)], such as fireman's control, radio interference suppression and dismantling of existing lift, etc.

Lifts to be installed in adverse conditions, such as chemical works, lifts used with power trucks, and similar specialized applications, required individual consideration according to the circumstances.

10.3 Finishes

Finishes should be specified at the enquiry stage or provisional sums should be included for them.

Finishes to be considered may include car body work, ceiling, floor, light fitting, ventilation, trims, car and landing doors, including vision panels if required, landing architrave push and indicator fittings, car and landings.

10.4 Inclusions and Exclusions

A number of peripheral items are associated with a lift installation, of which some should always be provided by the builder, and some are best included by the lift maker. The requirements vary to some extent with the type of installation.

It is important that the limits of responsibility are clearly understood, and the enquiry documents should be specific in this respect.

a) Guide brackets and wall inserts;

b) Buffers and any associated steelworks;

c) Pit screen to counterweight;

d) Steel beams of raft for machine and pulleys;

e) Sound insulation to machine where this is required;

f) Doors;

g) Door tracks;

h) Supporting steelworks for horizontal sliding doors and frames for hinged doors;

j) Wiring materials for the lift itself starting from the supplies furnished by the purchaser;

k) Over current protection (type to be specified) (*see* **7.4.1**);

m) Alarm push and bell or telephone (*see* **7.4.3**);

n) Alarm push and bell or telephone (*see* **7.4.3**);

p) Lifting tackle and small electric tools for use during the actual installation;

q) Services of erection staff to install and wire;

r) Services of testing engineer and provision of the necessary instruments and test weights; and

s) Guarantee of equipment.

The lift maker should exclude the supply and fixing of the items as the following:

a) Builders' work, such as forming lift well, pit and machine room and building in wall inserts;

b) Machine room floor including any reinforcement necessary for load bearing;

c) Lifting beams in machine room where necessary;

d) Steel surrounds for vertical bi-parting sliding doors;

e) Any necessary tanking, lining or reinforcement of the pit;

f) Dividing beams for multiple wells, and interwell pit screens;

g) Temporary guarding of openings;

h) Scaffolding, planks and ladders;

j) Off-loading and storage of materials;

k) Cutting away and making good;

m) Site painting of steel work, etc;

n) Working lights, temporary and permanent electricity supplies, etc; and

p) Mess rooms, sanitary accommodation and welfare facilities.

For more detailed discussion of the requirements for site preparation and work by other trades, reference

should be made to good practice [8-5(2)], and to other clauses **5**, **7.4** and **12**.

Apart from the items referred to in the preceding clauses, which are common to almost all lift installations, the following shall apply:

a) Sill support members with toe guards are included as part of the complete doors entrance except for general purpose goods lifts, for which the builder should supply the sill support; and

b) Architrave, or finish surrounds to doors: if of metal, these should be provided by the lift maker, with back filling by the general contractor and if of timber by the joinery contractor.

As referred to in **11.5**, facilities for the use of the main contractor's crane should be provided to assist in installing heavy equipment. In addition to other unloading facilities on site in the course of erection. The main contractor should be instructed to include these facilities in his own quantities.

Where the lift maker agrees to use mobile platforms in place of lift well scaffolding, the general contractor should provide 400/440 V 3-phase and 200/220 V single-phase supply in the lift shaft to operate such equipment, the supply to terminate at the position in the lift well required by the lift maker.

These mobile platforms are limited in use for erection personnel and the transportation of light equipment only, but use of crane will also be necessary to assist in the installation of the heavy machinery and also in the initial installation of the mobile platform equipment.

10.5 Site Programme

The enquiry should indicate as accurately as possible the contract programme as it affects the lift maker, in particular the target date for lift completion, and the date when the lift site will be prepared and the availability of a crane.

11 ACCEPTANCE OF TENDER AND SUBSEQUENT PROCEDURE

11.1 General

The procedure indicated below particularly relates to the most usual case, where the lift maker is a sub-contractor.

11.2 Order

The main contractor is instructed to place an order with the selected lift maker. If alternative schemes have been offered, the order should clearly indicate which has been accepted.

11.3 Programme

As noted in **10.5** the programme should have been indicated as accurately as possible at the time of enquiry. At the time of order, the programme for manufacture and installation of the lift should be agreed.

The programme should cover each lift separately, including dates such as:

a) The order date,

b) The date when the lift site will be ready,

c) The date for provision of lift electricity supplies, and

d) The lift completion date.

The period between order and delivery of material falls into two stages: first the finalizing of details and secondly the actual production of the equipment when depends on the first stage. Within the first stage, other dates may need to be considered, such as:

a) All relevant building information available,

b) Submission of lift maker's drawings,

c) Approval of drawings, and

d) Final selection of finishes.

Information relevant to programming the site work can be found in other clauses of this Section, such as in **12** and **13**.

11.4 Drawings

Following order, the lift maker should supply drawings showing builder's work required, together with point loadings. To enable these to be prepared, the purchaser's representative should furnish the relevant detail building drawings.

11.5 Approval of Drawings

The purchaser's representative should give written approval of the drawings (after modification if necessary), at the same time asking for such additional copies (up to five of each drawing) as he requires for distribution to other parties concerned.

11.6 Selection of Finishes

Where the contact provides for the purchaser's choice of decorative finishes, colours, etc, the decisions should be communicated by the purchaser's representative as early as possible, and preferably not later than the time of approval of drawings.

11.7 Electricity Supplies to Lift

Operation of the machine under power is required from a comparatively early stage of installation for the most efficient working, and supplies should be furnished

accordingly. Whilst temporary supplies may be sufficient for erection purposes, final testing and setting up can only be carried out with the permanent supplies connected. For this reason the timely provision of the permanent supplies is important.

12 CO-ORDINATION OF SITE WORK

12.1 Preparatory Work on Site

It is customary for the lift maker to make periodic visits to the site before his starting date to check progress on the lift well construction and discuss relevant matters with the contractor. The lift maker should assure himself that all building work has been completed in accordance with his requirements.

Immediately, before the time for lift erection to commence the lift maker should check that site conditions are fit to permit erection to proceed.

Building work to be completed before lift erection starts includes the following:

a) Pit lift well and machine room complete and weather tight. Pit dry and watertight including tanking if necessary and clear of rubbish.

NOTE — In certain systems building and buildings of over 10 floors, it may be necessary by prior agreement to start erection before the top portion of the lift well has been constructed, in which case the general contractor should temporarily deck out and waterproof.

b) Preparation for lift fixings in pit, lift well and machine room complete. If built-in wall inserts are used, these should be placed accurately and slots cleared of any seepage of concrete.

c) Steelwork items finally grouted or otherwise fixed in position after checking for correct position by the lift maker (for example lift well trimmers and machine beams).

d) Scaffolding in position, as arranged with the lift maker, lift well etc. properly fenced and guarded in accordance with current regulation.

e) Entrance preparations completed, including preparations for door frames, push boxes and indicators. In many cases, progress can be facilitated by omitting the front walls of the lift well until the lift car, doors, etc. are installed.

f) Datum line (in elevation) established at each floor to enable the lift maker to set metal sills and frames in relation to finished floor levels.

12.2 Delivery of Material

The lift maker should advise the contractor when equipment is ready for despatch, so that the contractor can make arrangements on site to receive and unload with appropriate hoisting tackle, slings and supports, as near as possible to the lift well.

12.3 Storage

Adequate provision should be made by the building contractor for storing, protecting and preserving against loss, deterioration or damage, all material on the site. Attention is drawn to the adverse affect of damp conditions on electrical equipment and on steel wire ropes.

12.4 Site Meetings

For the successful progress of the work, full co-operation among all parties is essential. In large sites, regular meetings of such parties are beneficial. Programmes for the constructional work in that part of the building containing the lift should be made in consultation among all parties concerned.

12.5 Service of Other Trades

The lift erector will require the services of joiners, bricklayers and other trades as the work proceeds, and it is essential that the lift erector should give due notice to the building contractor of the demands to be made on other trades, so that he can plan accordingly.

12.6 Scaffolding, Fencing Etc

Scaffolding timbers, rollers and similar items required for the unloading and erection of the lift, and also for the proper guarding and close fencing of the lift well should be provided, erected and maintained by the building contractor.

The lift well should not be used as a means of disposal for rubbish from the upper floors. Such practice is dangerous.

The lift well should be handed over to the lift contractor complete, and no other trades should be allowed to work above or below during the whole time of erection of the lift, except by arrangement with the lift contractor.

12.7 System Building Sites

If the building programme allows insufficient time for lift erection in conventional fashion after the well is completely built special procedures are needed. This applies particularly to industrialized and multi-storey buildings.

Methods differ in detail. In most cases however the building contractor's crane is used to lower and position pre-assembled batches of lift equipment into the progressively rising top of the lift well.

The building contractor should provide a suitable portable cover to the completed portion of the lift well in order to protect the lift erectors working below against the weather and falling objects.

When the top of the well has been reached it is normal to cap it immediately with a precase load bearing floor slab on to which is lowered the pre-assembled machine room equipment. It then remains for the building contractor to complete and weatherproof the machine room as swiftly as possible.

On all such projects as these the closest co-operation between the building contractor and the lift maker is essential.

12.8 Connecting to Power Supply

The lift maker should give prior warning to the building contractor of the date the power supply to the lift is required, so that suitable arrangements for connection can be made.

13 PROCEDURE FOLLOWING TEST, INCLUDING INSPECTION AND MAINTENANCE

13.1 Acceptance

The purchaser should make timely arrangements for accepting the lift on completion of test, and for insurance cover. Special arrangements (*see* **13.4**) are necessary if there is to be at interval before the lift goes into normal service.

13.2 Guarantee and Servicing

Any guarantee provided by the lift maker should be conditional upon the lift receiving regular and adequate servicing, and should cover the free replacement of parts which prove defective through reasons of fault, materials or workmanship in the guarantee period, which is generally twelve months.

To ensure the continuance of satisfactory and safe operation, the purchaser (or building occupier) should arrange for the completed lift to receive regular servicing by competent persons at such intervals as the type of equipment and intensity of operation demand. Such service can be secured under a service contract. It is desirable and normal for the lift maker to be entrusted with the servicing during the guarantee period of a new lift.

The scope of a service contract may be extended to cover not only regular servicing, but also intermediate service calls, repairs and replacement of worn parts.

The building owner should co-operate with the service engineer, and should ensure that the equipment is properly used, and that unauthorized persons are not permitted to enter the lift well or machine rooms.

Particular attention should be paid to methods of ensuring that lifts are not overloaded when they are used in connection with furniture and equipment removals, and internal redecoration and other similar activities, which may be undertaken within the building.

13.3 Statutory Examinations

Lifts in certain premises are required by statutory regulations to be examined at intervals, as specified by the Lift Act, by a competent person, who is required to report on a prescribed form. Such reports should normally be kept in a register.

Statutory examinations are not a substitute for servicing, the provision of statutory reports may be specially included in a service contract or may be arranged separately.

13.4 Lift not in Immediate Use (Shut Down Maintenance)

When conditions do not permit a lift to be taken to normal service immediately following completion and acceptance, it should be immobilized. The main contractor should take effective precautions against damage especially to finishes, or damage to equipment from dampness and builder's debris, until such time as the lift is required.

A separate service contract should be made with the lift maker to make regular visits during this period, to inspect, lubricate and report on the condition of the lift.

A date should also be agreed with the lift maker from which his guarantee period will commence.

13.5 Temporary Use of Lifts

If the purchaser intends to permit temporary use of a lift by some other party, such as the building contractor, before taking it into normal service, so that it is not immobilized, then the responsibilities of those concerned should be clearly defined and agreed. In addition to the precautions noted in **13.4**, temporary insurance cover should be arranged.

If temporary use of lifts is envisaged, it should preferably be given consideration at an early stage, having regard to the conditions under which it is likely to take place.

13.6 Cleaning Down

Acceptance following test should include checking the condition of decorative finishes, before the lift maker leaves the site.

After a shut down (or temporary service) period, the lift may require a further general cleaning down immediately before taking into normal service. The lift maker should be instructed accordingly to undertake this work and if any accidental damage has

occurred to repair this at the same time. Both these items should be the subject of extra costs.

14 ESCALATORS

14.1 Escalators are deemed essential where the movement of people, in large numbers at a controlled rate in the minimum of space, is involved, for example, railway stations, airports, etc. In exhibitions, big departmental stores and the like, escalators encourage people to circulate freely and conveniently.

14.1.1 As the escalators operate at a constant speed, serve only two levels and have a known maximum capacity, the traffic study is rather easy. Provided the population to be handled in a given time is known, it is easy to predict the rate at which the population can be handled.

14.1.2 For normal peak periods, the recommended handling capacities for design purposes should be taken as 3 200 to 6 400 persons per hour depending upon the width of the escalator.

The number of persons that may be theoretically carried by the escalator in 1 h can be calculated as follows:

a) For determination of theoretical capacity it is assumed that one step with an average depth of 0.4 m can carry 1 person for a step width of 0.6 m, 1.5 persons for a step width of 0.8 m and 2 persons for a step width of 1.0 m.

b) The theoretical capacity then is:

$$3\,600 \times (\text{rated speed in m/s} \times k)/0.4$$

where

k = 1, 1.5, or 2 for 0.6, 0.8 and 1.0 m step widths.

c) Some values calculated as per the above are:

Step Width	*Theoretical Capacity in Persons/hour*		
	0.5 m/s speed	0.65 m/s speed	0.75 m/s speed
0.6 m	4 500	5 850	6 750
0.8 m	6 750	8 775	10 125
1.0 m	9 000	11 700	13 500

14.2 Essential Requirements

14.2.1 Angle of inclination of an escalator from the horizontal shall not exceed 30°, but for rises not exceeding 6 m and rated speed not exceeding 0.5 m/s the angle of inclination is permitted to be increased up to 35°.

14.2.1.1 The rated speed of the escalator shall not exceed 0.75 m/s for an angle of inclination up to 30° and 0.5 m/s for an escalator with an angle of inclination of more than 30° but within 35°.

14.2.2 The horizontal distance (measured at right angles to the direction of travel) between the balustrade interior panellings at lower points shall be equal to or less than the horizontal distance measured at points higher up. The maximum distance between the balustrade interior panelling at any point shall be smaller than the distance between handrails.

14.2.3 The parts of the balustrade facing the steps shall be smooth. Covers or strips not in the direction of travel shall not project more than 3 mm. They shall be sufficiently rigid and have rounded or bevelled edges. Covers or strips of such nature are not permitted at the skirting.

Cover joints in the direction of travel (in particular between the skirting and balustrade interior panelling) shall be arranged and formed in such a manner that the risk of trapping is reduced to a minimum.

Gaps between interior panels of the balustrade shall not be wider than 4 mm. The edges shall be rounded off or bevelled. The balustrade interior paneling shall have adequate mechanical strength and rigidity. When a force of 500 N is applied at any point of the paneling at right angles on a area of 2 500 mm^2. There shall be no gap greater than 4 mm and no permanent deformation (setting tolerances are permitted).

The use of glass for balustrade interior panelling is permitted with the approval of the Authority; further, provided it is splinter free one layer safety (tempered) glass and has sufficient mechanical strength and rigidity. The thickness of the glass shall not be less than 6 mm.

14.2.3.1 There shall be no abrupt changes in the width between the balustrades on the two sides of the escalator. Where a change in width is unavoidable, such change shall not exceed 8 percent of the greatest width. In changing the direction of the balustrades resulting from a reduction in width the maximum allowable angle of change in balustrades shall not exceed 15° from the line of the escalator travel.

14.2.3.2 Where the skirting of the escalator is placed beside the steps the horizontal clearance shall not exceed 4 mm at either side and 7 mm for the sum of the clearances measured at both sides at two directly opposite points.

14.2.3.3 Where the building obstacles can cause injuries appropriate preventive measures shall be taken. In particular, at floor intersections and on criss-cross escalators, a vertical obstruction of not less than 0.3 m in height (not presenting any sharp cutting edge, for example as an imperforate triangle) shall be placed

above the balustrade decking. It is not necessary to comply with this requirement when the distance between the centreline of the handrail and any obstacle is equal to or greater than 0.5 m.

For escalators arranged adjacent to one another either parallel or criss-cross the distance between the edges of the handrails shall not be less than 120 mm.

14.2.4 *Handrails*

14.2.4.1 Each balustrade shall be provided with a handrail moving in the same direction and at substantially the same speed as the steps.

14.2.4.2 Each moving handrail shall extend at normal handrail height not less than 300 mm beyond the line of points of combplate teeth at the upper and lower landings.

14.2.4.3 Hand or finger guards shall be provided at the points where the handrails enters the balustrade.

14.2.4.4 The width of the handrail shall be between 70 mm and 120 mm. The distance between the handrail and the edge of the balustrade shall not exceed 50 mm. The distance between centreline of handrails shall not exceed the distance between the skirtings by more than 0.45 m.

14.2.5 *Step Treads*

14.2.5.1 The step depth in the direction of travel shall not be less than 0.38 m.

14.2.5.2 The surface of the step treads shall have grooves in the direction of movement, with which the teeth of the combs mesh. They shall be sensibly horizontal in the usable area of the escalator.

The width of the grooves shall be at least 5 mm and not exceed 7 mm. The depth of the grooves shall not be less than 10 mm. The web width shall be at least 2.5 mm and not exceed 5 mm.

14.2.6 *Landing*

The landing area of escalators shall have a surface that provides a secure foot hold for a minimum distance of 0.85 m measured from the root of the comb teeth. Exempted from this are the combs.

14.2.7 *Combplates*

There shall be a combplate at the entrance and at the exit of every escalator. The combplate teeth shall be meshed with and set into the slots in the tread surface so that the points of the teeth are always below the upper surface of the treads. Combplates shall be adjustable vertically.

14.2.8 *Trusses or Girders*

The truss or girder shall be designed to safety sustain the steps and running gear in operation. In the event of failure of the track system it shall retain the running gear in its guides.

14.2.9 *Step Wheel Tracks*

This shall be designed to prevent displacement of steps and running gear if a step chain breaks.

14.2.10 *Driving Machine, Motor and Brake*

14.2.10.1 The driving machine shall be connected to the main drive shaft by toothed gearing, a coupling, or a chain.

14.2.10.2 An electric motor shall not drive more than one escalator.

14.2.10.3 Each lift shall be provided with an electrically released, mechanically applied brake capable of stopping the up or down travelling escalator with any load up to rated load. This brake shall be located either on the driving machine or on the main drive shaft.

Where a chain is used to connect the driving machine to the main drive shaft, a brake shall be provided on this shalt, it is not required that this brake be of the electrically released type if an electrically released brake is provided on the driving machine.

14.2.10.4 *Speed governor*

Escalators shall be equipped in such a way that they stop automatically before the speed exceeds 1.2 times the rated speed. Where speed control devices are used for this purpose they shall have switched off the escalator before the speed exceeds 1.2 times the rated speed. It is permissible to disregard this requirement in case of a.c. motors with a non-friction connection with the drive for the steps and whose slip does not exceed 10 percent if thereby overspeed is prevented.

14.2.10.5 For operation and safety devices, electrical work, precautions and tests, reference may be made to good practice [8-5(11)].

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 14671 : 1999	Code of practice for installation and maintenance of hyraulic lifts
(2) 14665	Electric traction lifts:
(Part 1) : 2000	Guidelines for outline dimensions of passenger, goods, service and hospital lifts
(Part 3/Sec 1 & 2) : 2000	Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts
(Part 4/Sec 1 to 9) : 2001	Components, Section 1 Lift Buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices
(3) 14665 (Part 4/ Sec 1 to 9) : 2001	Electric traction lifts: Components, Section 1 Lift buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices
(4) 14665 (Part 3/ Sec 1 & 2) : 2000	Electric traction lifts: Part 3 Safety rules, Section 1 Passenger and goods lifts, Section 2 service lifts
(5) 14665 (Part 2/ Sec 1 & 2) : 2000	Electric traction lifts: Part 2 Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts, Section 2 Service lifts
(6) 962 : 1989	Code of practice for architectural and building drawings (*second revision*)
(7) 2309 : 1989	Code of practice for the protection of buildings and allied structures against lightning (*second revision*)
(8) 1950 : 1962	Code of practice for sound insulation of non-industrial buildings
(9) 14665 (Part 3/ Sec 1 & 2) : 2000	Electric traction lifts: Part 3 Safety rules — Section 1 Passenger and goods lifts, Section 2 Service lifts
(10) 3043 : 1987	Code of practice for earthing
(11) 4591 : 1968	Code of practice for installation and maintenance of escalators

NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES

Section 1 Water Supply, Drainage and Sanitation (Including Solid Waste Management)

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section covers the requirements of both water supply as well as drainage and sanitation.

The water supply provisions covered in this Section encompass the requirements of water supply, plumbing connected to public water supply, design of water supply systems, principles of conveyance and distribution of water within the premises, hot water supply system, inspection and maintenance of water supply systems. It also covers design of water supply systems in high altitudes and/or sub-zero temperature regions.

The drainage and sanitation provisions covered in this Section encompass the drainage and sanitation requirements of buildings, design, construction and maintenance of drains inside buildings and from the buildings up to the connection to the public sewer, private sewer, individual sewage disposal system, cesspool or to other approved point of disposal/treatment work. It also covers drainage systems peculiar to high altitudes and/or sub-zero temperature regions of the country.

In the first version of the Code formulated in 1970, three separate sections of Part 9 Plumbing Services, were brought out, namely, Section 1 Water Supply, Section 2 Drainage and Sanitation, and Section 3 Gas Supply. These sections were subsequently revised in 1983. The major changes incorporated in the first revision in Section 1 Water Supply, were:

a) Rationalization of definitions and addition of definitions for more terms.
b) Universal pipe friction diagram and nomogram of Hazen and Willam's equation were added for discharge computation, deleting the discharge curves based on Chezy's formula.
c) A detailed clause giving guidance on the design of water supply system for multi-storeyed buildings was introduced.
d) In regard to storage tanks for flushing, the requirements were modified to indicate that no separate storage need be provided for flushing and domestic purposes for health reasons and a single storage tank may be provided.
e) Provisions relating to domestic hot water supply installations were modified/amplified.
f) A detailed clause covering recommendations to be considered while planning and designing water supply systems peculiar to high altitude and/or sub-zero temperature regions of the country, were introduced.
g) Requirements relating to inspection, testing and maintenance applicable to hot water supply system were added.

The major changes incorporated in the first revision in Section 2 Drainage and Sanitation were:

a) Rationalization of definitions.
b) The requirements for fitments for drainage and sanitation in the case of buildings other than residences have been modified.
c) A table for sanitation facilities in fruit and vegetable markets has been added.
d) A table giving detailed guidance regarding the selection of plumbing system, depending on the nature of drainage load in buildings and height of buildings, has been introduced.
e) Provision relating to safeguards to be adopted in single stack system have been amplified.
f) The values of gradients, pipe sizes and the corresponding discharges have been modified.
g) Sizes of manholes/inspection chambers have been rationalized.
h) The sizing of rain water pipe for roof drainage has been modified to take into account rainfall intensities and recommend sizes on a more rational basis.
j) Provisions for drainage and sanitation system peculiar to high altitudes and/or sub-zero temperature regions of the country have been added.
k) Requirements of the refuse chute system have been covered.

As a result of experience gained in implementation of 1983 version of the Code and feedback received as well as revision of some of the standards based on which this Section was prepared, a need to revise this Section was felt. This revision has, therefore, been prepared to take care of these. In this revision, the erstwhile two sections have been merged and a combined and comprehensive section, namely Section 1 Water Supply, Drainage and Sanitation (Including Solid Waste Management), is being brought out. This elaborate restructuring has been done to make the document comprehensive and more user friendly, and at the same time to avoid repetition of common provisions. Gas Supply is now being brought out as Section 2. The significant changes incorporated in this combined revision on Water Supply, Drainage and Sanitaton include:

In Water Supply provisions:

a) Provision of water supply requirement has been modified.
b) A new clause on water supply for other purposes has been added.
c) A new clause on quality of water has been added which also includes a sub-clause on waste water reclamation.
d) The provision regarding storage of water has been modified and guidelines for calculating storage capacity have been introduced.
e) In design of distribution system provisions for discharge computation has been modified to include designed consumer pipes based on fixtures unit also taking into account probable simultaneous demand instead of earlier computation based on Reynold's Number.
f) An alternate option of variable speed drive pumping system to hydropneumatic system has been introduced.
g) A new clause on backflow prevention has been added.
h) Provision for suitability of galvanized mild steel tanks on the basis of *p*H of the water has been added.
j) Types of hot water heater has been extended.
k) Restructuring of the Section has been done to make it more user friendly.

In Drainage and Sanitation:

a) Rationalization and addition of new definitions under terminology.
b) Certain basic principles for water supply and drainage have been enunciated.
c) A new clause on sanitary appliances has been added.
d) Tables 1 to 14 of the existing version, regarding drainage and sanitation requirement have been updated.
e) Additional requirements under layout clause of design considerations have been added.
f) Provisions regarding choice of plumbing systems have been modified and rationalized.
g) New clause on drain appurtenances having details on trap, floor drain and cleanout has been added.
h) Provisions on indirect wastes, special wastes (covering laboratory wastes, infected wastes, research laboratory wastes, etc), grease traps, oil interceptors, radio-active wastes, etc have been incorporated.
j) Manhole details on size have been revised and construction clause has been enhanced.
k) Provisions on rain water harvesting have been included.
m) The minimum rainfall intensity which is drain design basis for discharge of storm water drain into a public storm water drain, has been revised to 50 mm/hour.
n) The table for Sizing of Rain Water Pipes for Roof Drainage has been modified with inclusion of rainfall data which were not available in the existing version.
p) Figure on detail of subsoil drainage has been included.
q) Details on Support/Protection of Pipes has been added.

This revision also incorporates for the first time the provisions on solid waste management.

This Section has been based largely on the following Indian Standards:

IS No.	*Title*
1172 : 1993	Code of basic requirements for water supply, drainage and sanitation (*fourth revision*)
1742 : 1983	Code of practice for building drainage (*second revision*)

IS No.	*Title*
2065 : 1983	Code of practice for water supply in buildings (*second revision*)
4111 (Part 1) : 1986	Code of practice for ancillary structures in sewage system: Part 1 Manholes (*first revision*)
5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)
6295 : 1986	Code of practice for water supply and drainage in high altitudes and or sub-zero temperature regions (*first revision*)
7558 : 1974	Code of practice for domestic hot water installations
12183 (Part 1) : 1987	Code of practice for plumbing in multi-storeyed buildings: Part 1 Water supply

A reference to SP 35 : 1987 'Handbook on water supply and drainage' may be useful, from where also, assistance has been derived.

All standards, whether given herein above or cross referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES

Section 1 Water Supply, Drainage and Sanitation (Including Solid Waste Management)

1 SCOPE

1.1 This Section covers the basic requirements of water supply for residential, business and other types of buildings, including traffic terminal stations. This Section also deals with general requirements of plumbing connected to public water supply and design of water supply systems.

1.1.1 This Section does not take into consideration the requirements of water supply for industrial plants and processes, which have to be provided for separately. It also does not provide the requirements of water supply for other purposes, such as fire fighting, and street cleaning.

1.2 This Section also covers the design, layout, construction and maintenance of drains for foul water, surface water and subsoil water and sewage; together with all ancillary works, such as connections, manholes and inspection chambers used within the building and from building to the connection to a public sewer, private sewer, individual sewage-disposal system, cess-pool, soakaway or to other approved point of disposal/ treatment work.

NOTE — A sanitary drainage system consists of a building sewer, a building drain, a soil and/or waste stack, horizontal branches or fixture drain, and vents. The sanitary drainage of a large building may have a number of primary and secondary branches, and several soil and/or waste stacks, each of them in turn may have a number of horizontal branches.

2 TERMINOLOGY

2.1 For the purpose of this Section, the following definitions shall apply.

2.1.1 *Access Panel* — Removable panel mounted in a frame, normally secured with screws and mounted in a wall or ceiling, to provide access to concealed appurtenances or items which may require maintenance.

2.1.2 *Air Gap* — The distance between the lowest point of a water inlet or feed pipe to an appliance and the spill-over level (or the overflowing level) of the appliance.

2.1.3 *Air Valve* — A valve that releases air from a pipeline automatically without loss of water, or introduce air into a line automatically if the internal pressure becomes less than that of the atmosphere.

2.1.4 *Authority Having Jurisdiction* — The Authority which has been created by a statute and which for the purpose of administering the Code/Part may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.1.5 *Available Head* — The head of water available at the point of consideration due to mains' pressure or overhead tank or any other source of pressure.

2.1.6 *Back Siphonage* — The flowing back of used, contaminated, or polluted water from a plumbing fixture or vessel into a water supply due to a reduced pressure in such pipe (*see* Backflow).

2.1.7 *Back Up* — A condition where the wastewater may flow back into another fixture or compartment but not back into the potable water system.

2.1.8 *Backflow*

a) The flow of water or other liquids, mixtures or substances into the distributing pipes of a system of supply of potable water from any source or sources other than its intended source.

b) The flow of a liquid in a direction reverse of that intended.

2.1.9 *Backflow Prevention Device* — Any approved measure or fitting or combination of fittings specifically designed to prevent backflow or backsiphonage in a water service.

2.1.10 *Barrel* — This portion of a pipe in which the diameter and wall thickness remain uniform throughout.

2.1.11 *Base* — The lowest portion or lowest point of a stack of vertical pipe.

2.1.12 *Battery of Fixtures* — Any group of two or more similar adjacent fixtures which discharge into a common horizontal waste or soil pipe.

2.1.13 *Bedding* — The material on which the pipe is laid and which provides support for the pipe. Bedding can be concrete, granular material or the prepared trench bottom.

2.1.14 *Benching* — Slopping surfaces constructed on

flow of sewage, avoiding the accumulation of deposits and providing a safe working platform.

2.1.15 *Branch*

a) Special form of sewer pipe used for making connections to a sewer or water main. The various types are called 'T', 'Y', 'T–Y', double Y and V branches, according to their respective shapes.

b) Any part of a piping system other than a main or stack.

2.1.16 *Branch Soil Pipe (BSP)* — A pipe connecting one or more soil appliances to the main soil pipe.

2.1.17 *Branch Soil Waste Pipe (BSWP)* — A pipe connecting one or more soil and/or waste appliances to the main soil waste pipe (one pipe system).

2.1.18 *Branch Ventilating Pipe (BVP)* — A pipe, one end of which is connected to the system adjacent to the trap of an appliance and the other to a main ventilating pipe or a drain-ventilating pipe. It is fitted to prevent loss of water seal from a trap owing to partial vacuum, back-pressure, or surging caused by air movement within the pipe system. It also provides ventilation for the branch waste pipe.

2.1.19 *Branch Waste Pipe (BWP)* — A pipe connecting one or more waste appliances to the main waste pipe.

2.1.20 *Building Drain, Combined* — A building drain which conveys both sewage and storm water or other drainage.

2.1.21 *Building Drain, Sanitary* — A building drain which conveys sewage and sullage only.

2.1.22 *Building Drain, Storm* — A building drain which conveys storm water or other drainage but no sewage.

2.1.23 *Building Sewer* — That part of the horizontal piping of a drainage system which extends from the end of the building drain and which receives the discharge of the building drain and conveys it to a public sewer, private sewer, individual sewage-disposal system or approved point of disposal.

2.1.24 *Building Sub-Drain* — That portion of a drainage system which cannot drain by gravity in the building sewer.

2.1.25 *Building Trap* — A device, fitting or assembly of fittings installed in the building drain to prevent trap.

2.1.26 *Cesspool*

a) An underground chamber for the reception and storage of foul water, the contents of which are periodically removed for disposal.

b) A box-shaped receiver constructed in a roof or gutter for collecting rainwater which then passes into a rainwater pipe connected thereto.

2.1.27 *Chair* — A bed of concrete or other suitable material on the trench floor to provide a support for the pipes at intervals.

2.1.28 *Channel* — The open waterway through which sewage, storm water or other liquid wastes flow at the invert of a manhole or an inspection chamber.

2.1.29 *Chute* — A vertical pipe system passing from floor to floor provided with ventilation and inlet openings for receiving refuse from successive floors and ending at the ground floor on the top of the collecting chambers.

2.1.30 *Cistern* — A fixed container for water in which water is at atmospheric pressure. The water is usually supplied through a float operated valve.

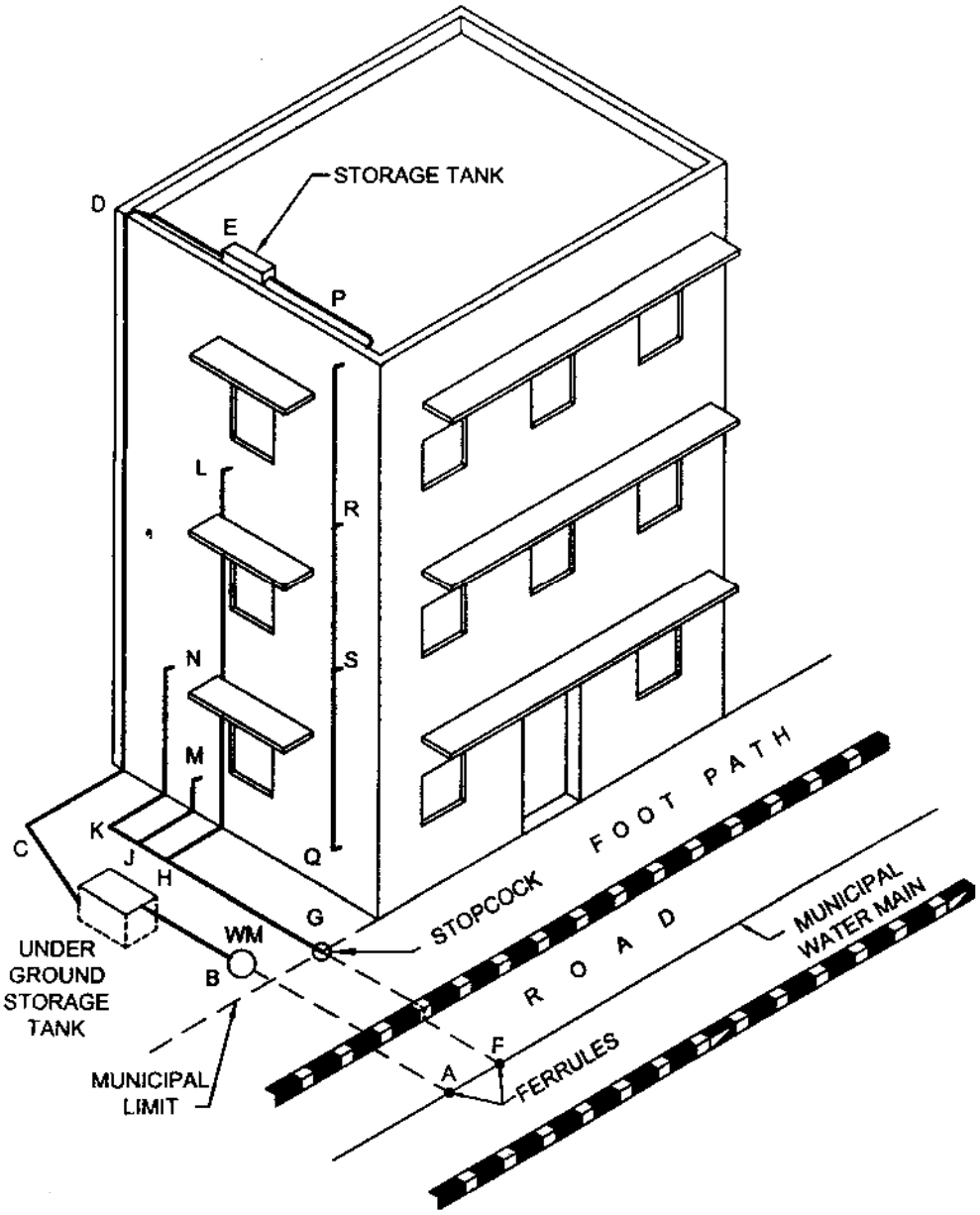
2.1.31 *Cleaning Eye* — An access opening in a pipe or pipe fitting arranged to facilitate the cleaning of obstructions and fitted with removable cover.

2.1.32 *Clear Waste Water* — Cooling water and condensate drainage from refrigeration and air conditioning equipment, cooled condensate from steam heating systems, cooled boiler blow-down water, waste water drainage from equipment rooms and other areas where water is used without an appreciable addition of oil, gasoline, solvent, acid, etc, and treated effluent in which impurities have been reduced below a minimum concentration considered harmful.

2.1.33 *Collection Chamber* — A compartment situated at the lower end of the chute for collecting and housing the refuse during the period between two successive cleanings.

2.1.34 *Communication Pipe* — That part of a service pipe which vests in the water undertakes. It starts at the water main and terminate at a point which differs according to the circumstances of the case.

2.1.35 *Connection* — The junction of a foul water drain, surface water drain or sewer from building or



NOTE — The illustration is not intended to indicate recommended positions of underground storage tank (where provided), pipes, etc and this will depend on local situations.

FIG. 1 TYPICAL SKETCH FOR IDENTIFICATION OF DIFFERENT TYPES OF WATER SUPPLY PIPES

building with public sewer treatment works, public sewer, private sewer, individual sewage-disposal system, cess pool, soakaway or to other approved point of disposal/treatment work.

2.1.36 *Consumer* — Any person who uses or is supplied water or on whose application such water is supplied by the Authority.

2.1.37 *Consumer's Pipe* — The portion of service pipe used for supply of water and which is not the property of the Authority (*see* Fig. 1).

2.1.38 *Cover*

a) A removable plate for permitting access to a pipe, fitting, vessel or appliance.

b) The vertical distance between the top of the barrel of a buried pipe or other construction and the surface of the ground.

2.1.39 *Cross-Connection* — A connection between two normally independent pipelines which permits flow from either pipeline into the other.

2.1.40 *Crown of Trap* — The topmost point of the inside of a trap outlet.

2.1.41 *Deep Manhole* — A manhole of such depth that an access shaft is required in addition to the working chamber.

2.1.42 *Depth of Manhole* — The vertical distance from the top of the manhole cover to the outgoing invert of the main drain channel.

2.1.43 *Diameter* — The nominal internal diameter of pipes and fittings.

2.1.44 *Direct Tap* — A tap which is connected to a supply pipe and is subject to pressure from the water main.

2.1.45 *Downtake Tap* — A tap connected to a system of piping not subject to water pressure from the water main.

2.1.46 *Drain* — A *conduit*, channel or pipe for the carriage of storm water, sewage, *waste water or other water-borne wastes in a building drainage system.*

2.1.47 *Drain Ventilating Pipe (DVP)* — A pipe installed to provide flow of air to or from a drain to prevent undue concentration of foul air in the drain. The main soil pipe or main waste pipe may serve as drain ventilating pipe wherever their upper portions, which do not receive discharges, are extended to the roof level and let open to air.

2.1.48 *Drainage* — The removal of any liquid by a system constructed for the purpose.

2.1.49 *Drainage Work* — The design and construction of a system of drainage.

2.1.50 *Drop Connection* — A length of conduit installed vertically immediately before its connection to a sewer or to another drain.

2.1.51 *Drop Manhole* — A manhole installed in a sewer where the elevation of the incoming sewer considerably exceeds that of the outgoing sewer; a vertical waterway outside the manhole is provided to divert the waste from the upper to the lower level so that it does not fall freely into the manhole except at peak rate of flow.

2.1.52 *Effective Opening* — The minimum cross-sectional area at the point of water supply, measured or expressed in terms of:

a) the diameter of a circle; and
b) the diameter of a circle of equivalent cross-sectional area, if the opening is not circular.

2.1.53 *Feed Cistern* — A storage vessel used for supplying cold water to a hot water apparatus, cylinder or tanks.

2.1.54 *Fittings* — Fittings shall mean coupling, flange, branch, bend, tees, elbows, unions, waste with plug, P or S trap with vent, stop ferrule, stop tap, bib tap, pillar tap, globe tap, ball valve, cistern storage tank, baths, water-closets, boiler, geyser, pumping set with motor and accessories, meter, hydrant, valve and any other article used in connection with water supply, drainage and sanitation.

2.1.55 *Fixture Unit* — A quantity in terms of which the load producing effects on the plumbing system of different kinds of plumbing fixtures is expressed on some arbitrarily chosen scale.

2.1.56 *Fixture Unit Drainage* — A measure of probable discharge into the drainage system by various types of plumbing fixtures. The drainage fixture unit value for a particular fixture depends on its volume rate of drainage discharge, on the time duration of a single drainage operation and on the average time between successive operations.

2.1.57 *Float Operated Valve* — Ball valves or ball taps and equilibrium valves operated by means of a float.

2.1.58 *Flushing Cistern* — A cistern provided with a device for rapidly discharging the contained water and used in connection with a sanitary appliance for the purpose of cleaning the appliance and carrying away its contents into a drain.

NOTE — The nominal size of a cistern is the quantity of water discharged per flush.

2.1.59 *Formation* — The finished level of the excavation at the bottom of a trench or heading prepared to receive the permanent work.

2.1.60 *French Drain or Rubble Drain* — A shallow trench filled with coarse rubble, clinker, or similar material with or without field drain pipes.

2.1.61 *Frost Line* — The line joining the points of greatest depths below ground level up to which the moisture in the soil freezes.

2.1.62 *General Washing Place* — A washing place provided with necessary sanitary arrangement and common to more than one tenement.

2.1.63 *Geyser* — An apparatus for heating water with supply control on the inlet side and delivering it from an outlet.

2.1.64 *Gully Chamber* — The chamber built of masonry round a gully trap for housing the same.

2.1.65 *Gully Trap* — A trap provided in a drainage system with a water seal fixed in a suitable position to collect waste-water from the scullery, kitchen sink, wash basins, baths and rain water pipes.

2.1.66 *Haunching* — Outward sloping concrete support to the sides of a pipe or channel above the concrete bedding.

2.1.67 *Heel Rest Bend or Duck-Foot Bend* — A bend, having a foot formed integrally in its base, used to receive a vertical pipe.

2.1.68 *High Altitudes* — Elevations higher than 1 500 m above mean sea level (MSL).

2.1.69 *Highway Authority* — The public body in which is vested, or which is the owner of, a highway repairable by the inhabitants collectively; otherwise the body or persons responsible for the upkeep of the highway.

2.1.70 *Horizontal Pipe* — Any pipe of fitting which makes an angle of more than 45° with the vertical.

2.1.71 *Hot Water Tank* — A vessel for storing hot water under pressure greater than atmospheric pressure.

2.1.72 *Inlet Hopper* — A receptacle fitting for receiving refuse from each floor and dropping it into the chute.

2.1.73 *Inspection Chamber* — A water-tight chamber constructed in any house-drainage system which takes wastes from gully traps and disposes of to manhole with access for inspection and maintenance.

2.1.74 *Interceptor* — A device designed and installed so as to separate and retain deleterious, hazardous or undesirable matter from normal wastes and permit normal sewage or liquid wastes to discharge into the disposal terminal by gravity.

2.1.75 *Interceptor Manhole or Interceptor Chamber* — A manhole incorporating an intercepting trap and providing means of access thereto.

2.1.76 *Invert* — The lowest point of the internal surface of a pipe or channel at any cross-section.

2.1.77 *Junction Pipe* — A pipe incorporating one or more branches.

2.1.78 *Lagging* — Thermal insulation or pipes.

2.1.79 *Licensed Plumber* — A person licensed under the provisions of this Code.

2.1.80 *Main Soil Pipe (MSP)* — A pipe connecting one or more branch soil pipes to the drain.

2.1.81 *Main Soil and Waste Pipe (MSWP)* — A pipe connecting one or more branch soil and waste pipes to the drain.

2.1.82 *Main Ventilating Pipe (MVP)* — A pipe which receives a number of branch ventilating pipes.

2.1.83 *Main Waste Pipe (MWP)* — A pipe connecting one or more branch waste pipes to the drain.

2.1.84 *Manhole* — An opening by which a man may enter or leave a drain, a sewer or other closed structure for inspection, cleaning and other maintenance operations, fitted with suitable cover.

2.1.85 *Manhole Chamber* — A chamber constructed on a drain or sewer so as to provide access thereto for inspection, testing or clearance of obstruction.

2.1.86 *Non-Service Laterine* — Other than 'service latrine'.

2.1.87 *Offset* — A pipe fitting used to connect two pipes whose axes are parallel but not in line.

2.1.88 *Period of Supply* — The period of the day or night during which water supply is made available to the consumer.

2.1.89 *Pipe System* — The system to be adopted will depend on the type and planning of the building in which it is to be installed and will be one of the following:

a) *Single stack system* (*see* Fig. 2) — The one-pipe system in which there is no trap ventilation.

b) *Single stack — Partially Vented* — A via media between the one-pipe system and the single stack system (*see* one-pipe system, partially ventilated).

c) *One-pipe system* (*see* Fig. 3) — The system of plumbing in which the wastes from the sinks, baths and wash basins, and the soil pipe branches are all collected into one main pipe, which is connected, directly to the drainage system. Gully traps and waste pipes are completely dispersed with, but all the traps of the water closets, basins, etc, are completely ventilated to preserve the water seal.

d) *One-pipe system — Partially vented* (*also called single stack, partially ventilated*) — A system in which there is one soil pipe into which all water closets, baths, sinks, and

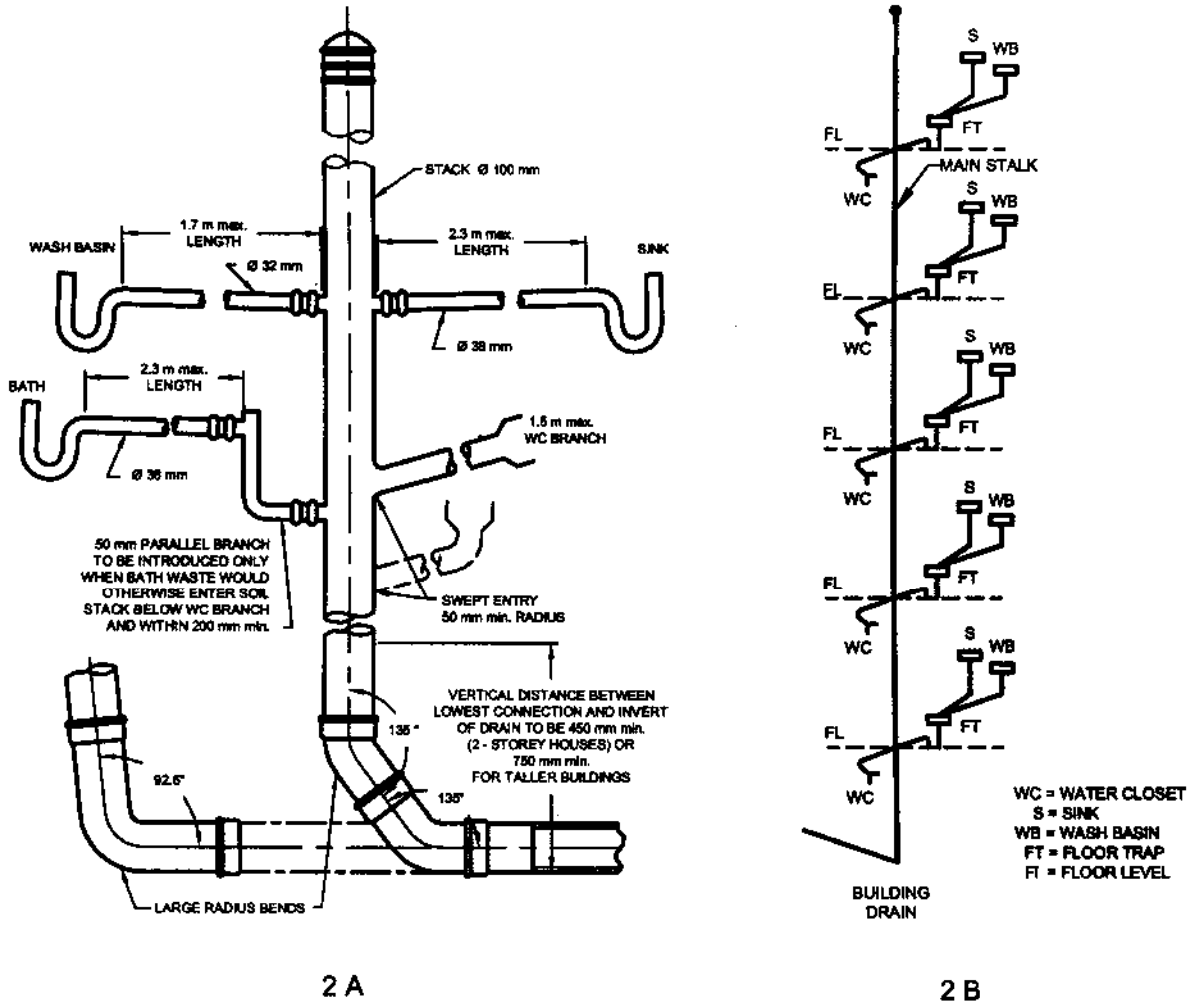


FIG. 2 SINGLE STACK SYSTEM — MAIN FEATURE OF DESIGN

basins discharge. In addition, there is a relief vent, which ventilates only the traps of water closets.

e) *Two-pipe system* (*see* Fig. 4) — The system of plumbing in which soil and waste pipes are distinct and separate. The soil pipes being connected to the drain direct and waste pipes through a trapped gully. All traps of all appliances are completely ventilated in this system.

2.1.90 *Pipe Work* — Any installation of piping with its fittings.

2.1.91 *Plumbing*

a) The pipes, fixtures and other apparatus inside a building for bringing in the water supply and removing the liquid and water borne wastes.

b) The installation of the foregoing pipes, fixtures and other apparatus.

2.1.92 *Plumbing System* — The plumbing system shall include the water supply and distribution pipes; plumbing fittings and traps; soil, waste, vent pipes and anti-siphonage pipes; building drains and building sewers including their respective connections, devices

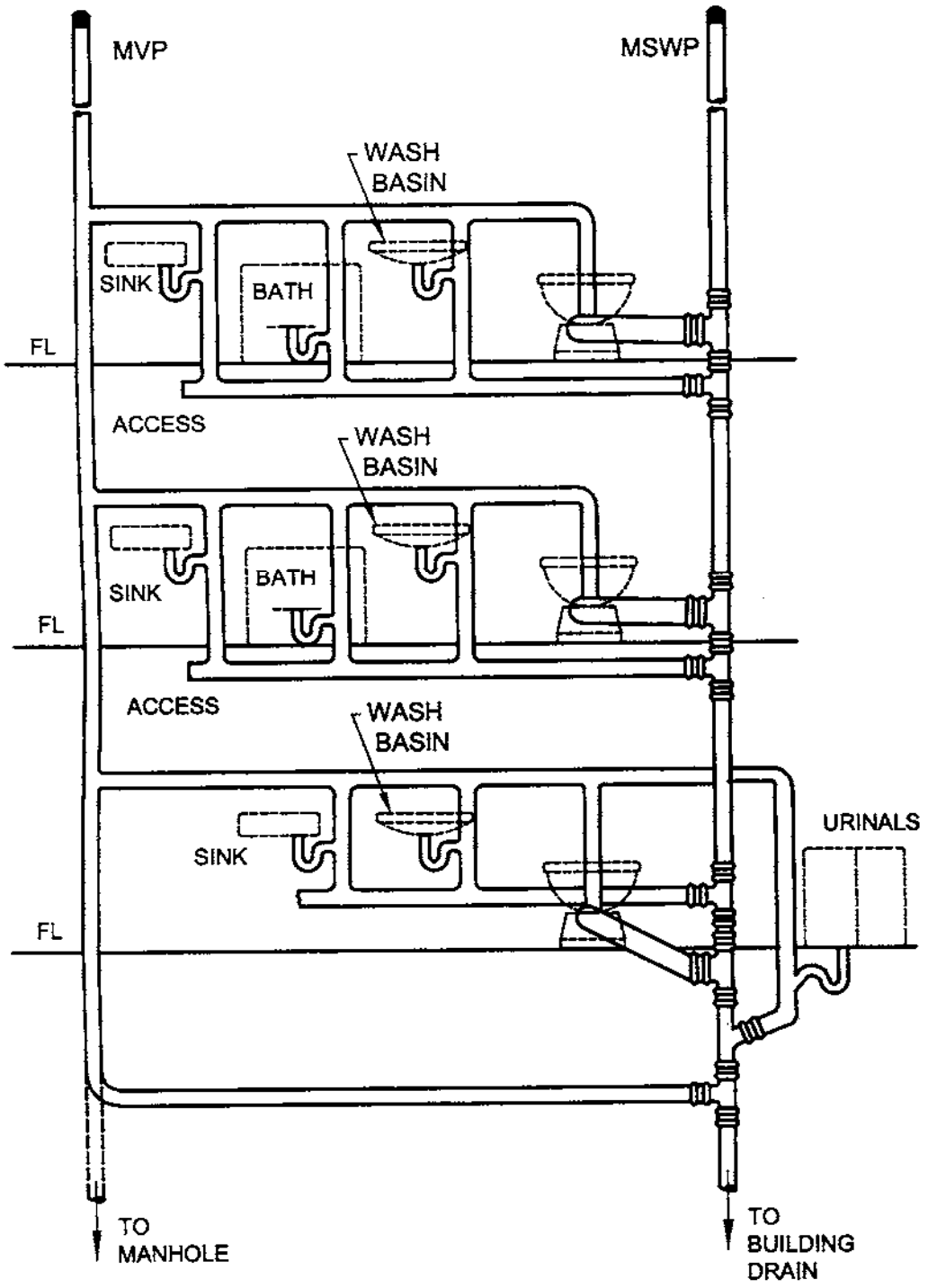


FIG. 3 DIAGRAM OF ONE-PIPE SYSTEM

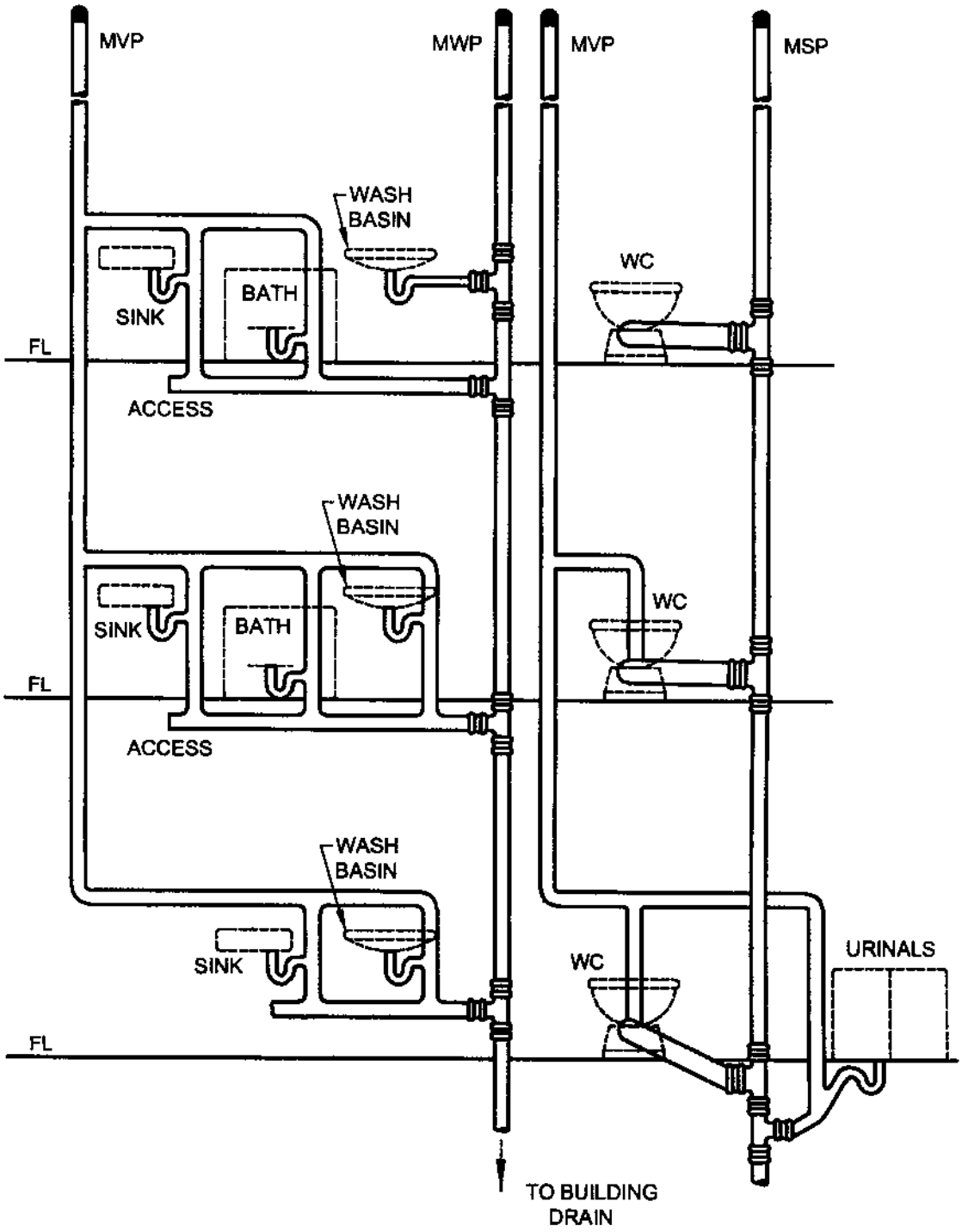


FIG. 4 DIAGRAM OF TWO-PIPE SYSTEM

and appurtenances within the property lines of the premises; and water-treating or water-using equipment.

2.1.93 *Potable Water* — Water which is satisfactory for drinking, culinary and domestic purposes and meets the requirements of the Authority.

2.1.94 *Premises* — Premises shall include passages, buildings and lands of any tenure, whether open or enclosed, whether built on or not, and whether public or private in respect of which a water rate or charge is payable to the Authority or for which an application is made for supply of water.

2.1.95 *Puff Ventilation* — The ventilation provided for waste traps in two-pipe system, in order to preserve the water seal.

2.1.96 *Residual Head* — The head available at any particular point in the distribution system.

2.1.97 *Saddle* — A purpose made fitting, so shaped as to fit over a hole cut in a sewer or drain used to form connections.

2.1.98 *Sanitary Appliances* — The appliances for the collection and discharge of soil or waste matter.

2.1.99 *Service Laterine* — A laterine from which the excreta are removed by manual agency and not by water carriage.

2.1.100 *Service Pipe* — Pipe that runs between the distribution main in the street and the riser in case of a multi-storeyed building or the water meter in the case of an individual house and is subject to water pressure from such main.

2.1.101 *Sewer* — A pipe or conduit, generally closed, but normally not flowing full for carrying sewage and/ or other waste liquids.

2.1.102 *Slop Hopper (Slop Sink)* — A hopper shaped sink, with a flushing run and outlet similar to those of a WC pan, for the reception and discharge of human excreta.

2.1.103 *Soakaway* — A pit, dug into permeable ground lined to form a covered perforated chamber or filled with hard-core, to which liquid is led, and from which it may soak away into the ground.

2.1.104 *Soffit (Crown)* — The highest point of the internal surface of a sewer or culvert at any cross-section.

2.1.105 *Soil Appliances* — A sanitary appliance for the collection and discharge of excretory matter.

2.1.106 *Soil Pipe* — A pipe that conveys the discharge of water closets or fixtures having similar functions, with or without the discharges from other fixtures.

2.1.107 *Soil Waste* — The discharge from water closets, urinals, slop hooper, stable yard or cowshed gullies and similar appliances.

2.1.108 *Stop-Cock* — A cock fitted in a pipe line for controlling the flow of water.

2.1.109 *Stop Tap* — Stop tap includes stop-cock, stop valve or any other device for stopping the flow of water in a line or system of pipes at will.

2.1.110 *Storage Tank* — A container used for storage of water which is connected to the water main or tube-well by means of supply pipe.

2.1.111 *Sub-Soil Water* — Water occurring naturally in the sub-soil.

2.1.112 *Sub-Soil Water Drain*

a) A drain intended to collect and carry away sub-soil water.

b) A drain intended to disperse into the sub-soil from a septic tank.

2.1.113 *Sub-Zero Temperature Regions* — Regions where temperatures fall below 0°C and freezing conditions occur.

2.1.114 *Sullage* — *See* **2.1.129.**

2.1.115 *Supply Pipe* — So much of any service pipe as is not a communication pipe.

2.1.116 *Supports* — Hangers and anchors or devices for supporting and securing pipe and fittings to walls, ceilings, floors or structural members.

2.1.117 *Surface Water* — Natural water from the ground surface, paved areas and roofs.

2.1.118 *Surface Water Drain* — A drain conveying surface water including storm water.

2.1.119 *Systems of Drainage*

a) *Combined system* — A system in which foul water (sewage) and surface water are conveyed by the same sewers and drains.

b) *Separate system* — A system in which foul water (sewage) and surface water are conveyed by the separate sewers and drains.

c) *Partially separate system* — A modification of the separate system in which part of the surface water is conveyed by the foul (sanitary) sewers and drains.

2.1.120 *Trade Effluent* — Any liquid either with or without particles of matter in suspension which is wholly or in part produced in the course of any trade or industry, at trade premise. It includes farm wastes but does not include domestic sewage.

2.1.121 *Trap* — A fittings or device so designed and constructed as to provide, when properly vented, a liquid seal which will prevent the back passage of air without materially affecting the flow of sewage or waste water through it.

2.1.122 *Vertical Pipe* — Any pipe or fitting which is installed in a vertical position or which makes an angle or not more than 45° with the vertical.

2.1.123 *Vent Stack/Vent Pipe* — A vertical vent pipe installed primarily for the purpose of proving circulation of air to and from any part of the drainage system. It also protects trap seals from excessive pressure fluctuation.

2.1.124 *Vent System* — A pipe or pipes installed to provide a flow of air to or from a drainage system or to provide a circulation of air with in such system to protect traps seals from siphonage and back-pressure.

2.1.125 *Warning Pipe* — An overflow pipe so fixed that its outlet, whether inside or outside a building, is in a conspicuous position where the discharge of any water therefrom can be readily seen.

2.1.126 *Wash-Out Valve* — A device located at the bottom of the tank for the purpose of draining a tank for cleaning, maintenance, etc.

2.1.127 *Waste Appliance* — A sanitary appliance for the collection and discharge of water after use for ablutionary, culinary and other domestic purpose.

2.1.128 *Waste Pipe* — In plumbing, any pipe that receives the discharge of any fixtures, except water-closets or similar fixtures and conveys the same to the house drain or soil or waste stack. When such pipe does not connect directly with a house drain or soil stack, it is called an indirect waste pipe.

2.1.129 *Waste-Water (Sullage)* — The discharge from wash basins, sinks and similar appliances, which does not contain human or animal excreta.

2.1.130 *Water Main (Street Main)* — A pipe laid by the water undertakers for the purpose of giving a general supply of water as distinct from a supply to individual consumers and includes any apparatus used in connection with such a pipe.

2.1.131 *Water Outlet* — A water outlet, as used in connection with the water distributing system, is the discharge opening for the water (a) to a fitting; (b) to atmospheric pressure (except into an open tank which is part of the water supply system); and (c) to any water-operated device or equipment requiring water to operate.

2.1.132 *Water Seal* — The water in a trap, which acts as a barrier to the passage of air through the trap.

2.1.133 *Water Supply System* — Water supply system of a building or premises consists of the water service pipe, the water distribution pipes, and the necessary connecting pipes, fittings, control valves, and all appurtenances in or adjacent to the building or premises.

2.1.134 *Waterworks* — Waterworks for public water supply include a lake, river, spring, well, pump with or without motor and accessories, reservoir, cistern, tank, duct whether covered or open, sluice, water main, pipe, culvert, engine and any machinery, land, building or a thing used for storage, treatment and supply of water.

3 GENERAL

3.1 Basic Principles

3.1.1 *Potable Water*

All premises intended for human habitation, occupancy, or use shall be provided with supply of potable water. This water supply shall not be connected with unsafe water resources, nor shall it be subject to the hazards of backflow.

3.1.2 *Water Provision*

Plumbing fixtures, devices and appurtenances shall be provided with water in sufficient volume and at pressures adequate to enable them to function properly and without undue noise under normal conditions of use.

There should be at least a residual head of 0.018 N/mm^2 at the consumer's tap.

NOTE — The residual head shall be taken at the highest/farthest outlets in the building.

3.1.3 *Water Conservation*

Plumbing system shall be designed, installed and adjusted to use the optimum quantity of water consistent with proper performance and cleaning.

3.1.4 *Safety Devices*

Plumbing system shall be designed and installed with safety devices to safeguard against dangers from contamination, explosion, overheating, etc.

3.1.5 *Plumbing Fixtures*

It is recommended that each family dwelling unit should have at least one water closet, one lavatory, one kitchen wash place or a sink, and one bathing wash place or shower to meet the basic requirements of sanitation and personal hygiene.

3.1.6 *Drainage System*

The drainage system shall be designed, installed and maintained to guard against fouling, deposit of solids

and clogging and with adequate cleanouts so arranged that the pipes may be readily cleaned.

3.1.7 *Materials and Workmanship*

The plumbing system shall have durable material, free from defective workmanship and so designed and installed as to give satisfactory service for its reasonable expected life.

3.1.8 *Fixture Traps and Vent Pipes*

Each fixture directly connected to the drainage system shall be equipped with a liquid seal trap. Trap seals shall be maintained to prevent sewer gas, other potentially dangerous or noxious fumes, or vemin from entering the building. Further, the drainage system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use by providing vent pipes throughout the system.

3.1.9 *Foul Air Exhaust*

Each vent terminal shall extend to the outer air and be so installed as to minimize the possibilities of clogging and the return of foul air to the building, as it conveys potentially noxious or explosive gases to the outside atmosphere. All vent pipes shall be provided with a cowl.

3.1.10 *Testing*

The plumbing system shall be subjected to required tests to effectively disclose all leaks and defects in the work or the material.

3.1.11 *Exclusion from Plumbing System*

No substance that will clog or accentuate clogging of pipes, produce explosive mixtures, destroy the pipes or their joints, or interfere unduly with the sewage-disposal process shall be allowed to enter the drainage system.

3.1.12 *Light and Ventilation*

Wherever water closet or similar fixture shall be located in a room or compartment, it should be properly lighted and ventilated.

3.1.13 *Individual Sewage Disposal Systems*

If water closets or other plumbing fixtures are installed in buildings where connection to public sewer is not possible, suitable provision shall be made for acceptable treatment and disposal.

3.1.14 *Maintenance*

Plumbing systems shall be maintained in a safe and serviceable condition.

3.1.15 *Accessibility*

All plumbing fixtures shall be so installed with regard to spacing as to be accessible for their intended use and for cleaning. All doors, windows and any other device needing access within the toilet shall be so located that they have proper access.

3.1.16 *Fixture for Disabled*

Special toilet fixtures shall be provided for the disabled with required fixtures and devices.

3.1.17 *Structural Safety*

Plumbing system shall be installed with due regard to preservation of the structural members and prevention of damage to walls and other surfaces.

3.1.18 *Protection of Ground and Surface Water*

Sewage or other waste shall not be discharged into surface or sub-surface water without acceptable form of treatment.

3.2 Water Supply Connection

3.2.1 *Application for Obtaining Supply Connection*

Every consumer, requiring a new supply of water or any extension or alteration to the existing supply shall apply in writing in the prescribed form (*see* Annex A) to the Authority.

3.2.2 *Bulk Supply*

In the case of large housing colonies or where new services are so situated that it will be necessary for the Authority to lay new mains or extend an existing main, full information about the proposed housing scheme shall be furnished to the Authority; information shall also be given regarding their phased requirements of water supply with full justification. Such information shall include site plans, showing the layout of roads, footpaths, building and boundaries and indicating thereon the finished line and level of the roads or footpaths and water supply lines and appurtenances.

3.2.3 *Completion Certificate*

On completion of the plumbing work for the water supply system, the licensed plumber shall give a completion certificate in the prescribed form (*see* Annex B) to the Authority for getting the water connection from the mains.

3.3 Drainage and Sanitation

3.3.1 *Preparation and Submission of Plan*

No person shall install or carry out any water-borne sanitary installation or drainage installation or any works in connection with anything existing or new buildings or any other premises without obtaining the previous sanction of the Authority.

The owner shall make an application in the prescribed form (*see* Annex C) to the Authority to carry out such a work.

3.3.2 *Site Plan*

A site plan of the premises on which the building is to be situated or any such work is to be carried out shall be prepared drawn to a scale not smaller than 1:500 (*see* Part 2 'Administration'). The site plan of the building premises shall show:

a) the adjoining plots and streets with their names;
b) the position of the municipal sewer and the direction of flow in it;
c) the invert level of the municipal sewer, the road level, and the connection level of the proposed drain connecting the building in relation to the sewer,
d) the angle at which the drain from the building joints the sewer; and
e) the alignment, sizes and gradients of all drains and also of surface drains, if any.

A separate site plan is not necessary if the necessary particulars to be shown in such a site plan are already shown in the drainage plan.

3.3.3 *Drainage Plan*

The application (**3.3.1**) shall be accompanied by a drainage plan drawn to a scale of not smaller than 1:100 and furnished along with the building plan (*see* Part 2 'Administration'). The plans shall show the following:

a) Every floor of the building in which the pipes or drains are to be used;
b) The position, forms, level and arrangement of the various parts of such building, including the roof thereof;
c) All new drains as proposed with their sizes and gradients;
d) Invert levels of the proposed drains with corresponding ground levels;
e) The position of every manhole, gully, soil and waste pipe, ventilating pipe, rain water pipe, water-closet, urinal, latrine, bath, lavatory, sink, trap or other appliances in the premises proposed to be connected to any drain and the following colours are recommended for indicating sewers, waste water pipes, rain-water pipes an existing work.

Description of Work	*Colour*
Sewers	Red
Waste water pipes and rain-water pipes	Blue
Existing work	Black

f) The position of refuse chute, inlet hopper and collection chamber.

3.3.3.1 In the case of an alteration or addition to an existing building, this clause shall be deemed to be satisfied if the plans as furnished convey sufficient information for the proposals to be readily identified with previous sanctioned plans and provided the locations of tanks and other fittings are consistent with the structural safety of the building.

3.3.3.2 The plans for the building drainage shall in every case be accompanied by specifications for the various items of work involved. This information shall be supplied in the prescribed from given in Annex D.

3.3.4 In respect of open drains, cross-sectional details shall be prepared to a scale not smaller than 1:50 showing the ground and invert levels and any arrangement already existing or proposed for the inclusion of any or exclusion of all storm water from the sewers.

3.3.5 *Completion Certificate*

At the completion of the plumbing installation work, the licensed plumber shall give a completion certificate in the prescribed form, which is given in Annex E.

3.4 Licencing/Registration of Plumbers

3.4.1 *Execution of Work*

The work which is required to be carried out under the provisions of this Section, shall be executed only by a licensed plumber under the control of the Authority and shall be responsible to carry out all lawful directions given by the Authority. No individual shall engage in the business of plumbing unless so licensed under the provisions of this Section.

3.4.1.1 No individual, firm, partnership or corporation shall engage in the business of installing, repairing or altering plumbing unless the plumbing work performed in the course of such business is under the direct supervision of a licensed plumber.

3.4.2 *Examination and Certification*

The Authority shall establish standards and procedure for the qualification, examination and licensing of plumbers and shall issue licences to such persons who meet the qualifications thereof and successfully pass the examination.

3.4.3 For guidelines for registration of plumbers including the minimum standards for qualifications for the grant of licences, reference may be made to good practice [9-1(1)].

4 WATER SUPPLY

4.1 Water Supply Requirements for Buildings

4.1.1 *Water Supply for Residences*

A minimum of 70 to 100 litres per head per day may

be considered adequate for domestic needs of urban communities, apart from non-domestic needs as flushing requirements. As a general rule the following rates per capita per day may be considered minimum for domestic and non-domestic needs:

a) For communities with population upto 20 000 and without flushing system:
   1) water supply through standpost — 40 lphd, *Min*
   2) water supply through house service connection — 70 to 100 lphd
b) For communities with population 20 000 to 100 000 together with full flushing system — 100 to 150 lphd
c) For communities with population above 100 000 together with full flushing system — 150 to 200 lphd

NOTE — The value of water supply given as 150 to 200 litres per head per day may be reduced to 135 litres per head per day for houses for Lower Income Groups (LIG) and Economically Weaker Section of Society (EWS), depending upon prevailing conditions.

4.1.1.1 Out of the 150 to 200 litres per head per day, 45 litres per head per day may be taken for flushing requirements and the remaining quantity for other domestic purposes.

4.1.2 *Water Supply for Buildings Other than Residences*

Minimum requirements for water supply for buildings other than residences shall be in accordance with Table 1.

Table 1 Water Requirements for Buildings Other than Residences

(*Clause* 4.1.2)

Sl No.	Type of Building	Consumption per Day, litres
(1)	(2)	(3)
i)	Factories where bath rooms are required to be provided	45 per head
ii)	Factories where no bath rooms are required to be provided	30 per head
iii)	Hospital (including laundry):	
	a) Number of beds not exceeding 100	340 per head
	b) Number of beds exceeding 100	450 per head
iv)	Nurses' homes and medical quarters	135 per head
v)	Hostels	135 per head
vi)	Hotel (up to 4 Star)	180 per head
vii)	Hotel (5 Star and above)	320 per head
viii)	Offices	45 per head
ix)	Restaurants	70 per seat
x)	Cinemas, concert halls and theatres	15 per seat
xi)	Schools:	
	a) Day schools	45 per head
	b) Boarding schools	135 per head

NOTE — For calculating water demand for visitors a consumption of 15 litres per head, per day may be taken.

4.1.3 *Water Supply Requirements of Traffic Terminal Stations*

The water supply requirements of traffic terminal stations (railway stations, bus stations, harbours, airports, etc) include provisions for waiting rooms and waiting halls. They do not, however, include requirements for retiring rooms. Requirements of water supply for traffic terminal stations shall be according to Table 2.

Table 2 Water Supply Requirements for Traffic Terminal Stations

(*Clause* 4.1.3)

Sl No.	Nature of Station/Terminal	Where Bathing Facilities are Provided litres/capita	Where Bathing Facilities are not Provided litres/capita
(1)	(2)	(3)	(4)
i)	Intermediate stations (excluding mail and express stops)	45	25
ii)	Junction stations and intermediate stations where mail or express stoppage is provided	70	45
iii)	Terminal stations	45	45
iv)	International and domestic airports	70	70

NOTES

1 The number of persons shall be determined by average number of passengers handled by the station daily; due consideration may be given to the staff and vendors likely to use facilities.

2 Consideration should be given for seasonal average peak requirements.

4.1.4 *Water Supply for Fire Fighting Purposes*

4.1.4.1 The Authority shall make provision to meet the water supply requirements for fire fighting in the city/area, depending on the population density and types of occupancy.

4.1.4.2 Provision shall be made by the owner of the building for water supply requirements for fire fighting purposes within the building, depending upon the height and occupancy of the building, in conformity with the requirements laid down in Part 4 'Fire and Life Safety'.

4.1.4.3 The requirements regarding water supply in storage tanks, capacity of fire pumps, arrangements of wet riser-cum-downcomer and wet riser installations for buildings above 15 m in height, depending upon the occupancy use, shall be in accordance with Part 4 'Fire and Life Safety'.

4.1.5 *Water Supply for Other Purposes*

4.1.5.1 Water supply in many buildings is also required for many other applications other than

domestic use, which must be identified in the initial stages of planning so as to provide the requisite water quantity, storage capacity and pressure as required for each application. In such instances information about the water use and the quality required may be obtained from the users. Some typical uses other than domestic use and fire fighting purposes are air conditioning and air washing, swimming pools and water bodies and gardening.

4.2 Water Sources and Quality

4.2.1 *Sources of Water*

The origin of all sources of water is rainfall. Water can be collected as it falls as rain before it reaches the ground; or as surface water when it flows over the ground or is pooled in lakes or ponds; or as ground water when it percolates into the ground and flows or collects as ground water; or from the sea into which it finally flows.

4.2.2 The quality of water to be used for drinking shall be as per good practices [9-1(2)].

4.2.3 For purposes other than drinking, water if supplied separately, shall be absolutely safe from bacteriological contamination so as to ensure that there is no danger to the health of the users due to such contaminants.

4.2.4 *Waste Water Reclamation*

Treated sewage or other waste water of the community may be utilized for non-domestic purposes such as water for cooling, flushing, lawns, parks, fire fighting and for certain industrial purposes after giving the necessary treatment to suit the nature of the use. This supply system shall be allowed in residences only if proper provision is made to avoid any cross connection of this treated waste water with domestic water supply system.

4.2.5 Whenever a building is used after long intervals, the water quality of the stored water must be checked so as to ensure that the water is safe for use as per water quality requirements specified in this Code.

4.3 Estimate of Demand Load

4.3.1 Estimates of total water supply requirements for buildings shall be based on the occupant load consistent with the provisions of **4.1**.

4.3.1.1 For residential buildings, the requirements of water shall be based on the actual number of occupants; where this information is not available, the number of occupants for each residential unit may be based on a family of five. For assessing the population in other occupants, reference may be made to Part 4 'Fire and Life Safety'.

4.3.1.2 In making assessment of water supply requirements of large complexes, the future occupant load shall be kept in view. Use may be made of the following methods for estimating future requirements:

a) demographic method of population projection,
b) arithmetic progression method,
c) geometrical progression method,
d) method of varying increment or incremental increase,
e) logistic method,
f) graphical projection method, and
g) graphical comparison method.

4.4 Storage of Water

4.4.1 In a building, provision is required to be made for storage of water for the following reasons:

a) to provide against interruptions of the supply caused by repairs to mains, etc;
b) to reduce the maximum rate of demand on the mains;
c) to tide over periods of intermittent supply; and
d) to maintain a storage for the fire fighting requirement of the building (*see* Part 4 'Fire and Life Safety').

4.4.2 The water may be stored either in overhead tanks (OHT) and/or underground tanks (UGT).

4.4.3 *Materials Used*

Reservoirs and tanks for the reception and storage of water shall be constructed of reinforced concrete brick masonry, ferrocement precast, mild steel, stainless steel or plastic.

4.4.3.1 Tanks made of steel may be of welded, riveted or pressed construction. The metal shall be galvanized coated externally with a good quality anti-corrosive weather-resisting paint. Lead-based paint shall not be used in the tank. Lead-lined tanks shall not be used. Rectangular pressed steel tanks shall conform to good practice [9-1(3)].

4.4.4 Each tank shall be provided with the following:

a) *Manholes* — Adequate number of manholes for access and repair. The manholes shall be made of corrosion resistant material (for example, cast iron, reinforced cement concrete, steel fibre reinforced concrete, galvanized steel, high density polyethylene, fibre glass reinforced plastic or such other materials acceptable to the Authority). Manholes shall be provided with locking arrangement to avoid misuse and tampering.
b) *Catch Rings and Ladders* — Tanks higher

than 900 mm deep shall be provided with corrosion resistant catch rings, steps or ladders according to the depth to enable a person to reach the bottom of the tank.

c) *Overflow Pipe* — Each tank shall be provided with an overflow pipe terminating above the ground/terrace level to act as a 'Warning Pipe' to indicate overflow conditions. The size of the overflow pipe shall be adequate to accept the flow. Normally the overflow pipe size shall be one size higher than the inlet pipe. When the inlet pipe diameter is large, two or more overflow pipes of equivalent cross-section may be provided.

d) *Vent Pipes* — Tanks larger than 5 000 l capacity shall be provided with vent pipes to prevent development pressure in the tank which might result in NO FLOW condition or inward collapse of the tank.

e) *Scour Pipe* — Each tank shall be provided with a scour pipe with an accessible valve for emptying the tank.

f) *Connection of Overflow and Scour Pipe* — Under no circumstances tank overflow and scour pipe shall be connected to any drain, gully trap or manhole to prevent back flow and contamination of the water. All such connections shall be discharged over a grating with an air gap of 50 mm. All overflow and vent pipes shall be provided with a mosquito proof brass grating to prevent ingress of mosquito, vermin and other insects.

g) The top slab of the tank must be suitable sloped away from its centre for proper drainage of the rainwater.

h) Tanks on terraces and above ground shall be supported by appropriate structural members so as to transfer the load of the tank and the water directly on the structural members of the building.

4.4.5 Every storage tank shall be easily accessible and placed in such a position as to enable thorough inspection and cleaning to be carried out. If the storage capacity required is more than 5 000 l, it is advantageous to arrange it in a series of tanks so interconnected that each tank can be isolated for cleaning and inspection without interfering with the supply of water. In large storage tanks, the outlet shall be at the end opposite the inlet to avoid stagnation of the water.

4.4.6 The outlet pipe shall be fixed 50 mm to 75 mm above the bottom of the tank and fitted with a strainer, preferably of brass.

4.4.7 In the case of underground storage tanks, the design of the tank shall be such as to provide for the draining of the tank when necessary and water shall not be allowed to collect around the tank. The tank shall be perfectly water-proof and shall be provided with a cement concrete cover, having a manhole opening, with a properly fitting hinged cast iron cover on a leak-proof cast iron frame.

The underground tanks should not be located in low lying areas or near any public or private sewer, septic tank, leaching pool or soakage pit to prevent any contamination. The overflow of the tank should be well above (preferably 600 mm) the external surface level and terminate as a warning pipe with a mosquito proof grating. Care must be taken to prevent backflow of local surface water into the tank in case of local flooding. Otherwise the overflow must be terminated in a more safer manner as per the site conditions. For tanks with atleast one side exposed to a basement, it is safer to discharge the overflow into the basement level.

The tank top slab shall also be designed to carry the load due to fire tender movement where anticipated as in the case of an extended basement.

There should be no common wall between the tanks storing safe water and tanks storing water from unsafe sources.

4.4.8 In case of overhead tanks, bottom of the tanks shall be placed clear off the terrace slab such that the elevation difference between the outlet pipe of the tank and the highest fixture at the top floor of the building is minimum 2 m, which shall also prevent leakage into the structural slab. In tall buildings, the top of the tank shall be provided with the safe ladder or staircase. The top slab shall be provided with railing or a parapet wall.

4.4.9 For jointing steel pipe to a storage tank, the end of the pipe shall be screwed, passed through a hole in the tank and secured by backnuts, both inside and outside. The pipe end shall be flush with the face of the inside backnut. For jointing copper pipe to steel or copper tank, a connector of non-ferrous material shall be used. The connector shall have a shoulder to bear on the outside of the tank and shall be secured by a backnut inside.

4.4.10 The quantity of water to be stored shall be calculated taking into account the following factors:

a) hours of supply at sufficiently high pressure to fill up the overhead storage tanks;

b) frequency of replenishment of overhead tanks, during the 24 h;

c) rate and regularity of supply; and

d) consequences of exhausting storage particularly in case of public buildings like hospitals.

If the water supply is intermittent and the hours of supply are irregular, it is desirable to have a minimum storage of half a day's supply for overhead tanks. For additional requirement of water storage for fire fighting purposes, reference may be made to Part 4 'Fire and Life Safety'.

NOTE — General guidelines for calculation of capacity of these storage tanks are as follows:

a) In case only OHT is provided, it may be taken as 33.3 to 50 percent of one day's requirement;
b) In case only UGT is provided, it may be taken as 50 to 150 percent of one day's requirement; and
c) In case combined storage is provided, it may be taken as 66.6 percent UGT and 33.4 percent OHT of one day's requirement.

4.4.11 When only one communication pipe is provided for water supply to a building, it is not necessary to have separate storage for flushing and sanitary purposes for health reasons. In such cases when only one storage tank has been provided, tapping of water may be done at two different levels (the lower tapping for flushing) so that a part of the water will be exclusively available for flushing purposes.

4.5 Materials, Fittings and Appliances

4.5.1 *Standards for Materials, Fittings and Appliances*

All materials, water fittings and appliances shall conform to Part 5 'Building Materials'.

4.5.2 *Materials for Pipes*

Pipes may be of any of the following materials:

a) cast iron, vertically cast or centrifugally (spun) cast,
b) steel (internally lined or coated with bitumen or a bituminous composition, and out-coated with cement concrete or mortar, where necessary),
c) reinforced concrete,
d) prestressed concrete,
e) galvanized mild steel tubes,
f) copper,
g) brass,
h) wrought iron,
j) asbestos cement,
k) polyethylene,
m) unplasticized PVC,
n) chlorinated PVC, or
p) stainless steel.

4.5.2.1 The material chosen shall be resistant to corrosion, both inside and outside or shall be suitably protected against corrosion.

4.5.2.2 Polyethylene and unplasticized PVC pipes shall not be installed near hot water pipes or near any other heat sources. For temperature limitations in the use of polyethylene and unplasticized PVC pipes to convey water, reference may be made to good practice [9-1(4)].

4.6 Design of Distribution Systems

4.6.1 *General*

All buildings shall conform to the general requirements given in **3.1**.

4.6.2 *Rate of Flow*

One of the important items that needs to be determined before the sizes of pipes and fittings for any part of the water piping system may be decided upon, is the rate of flow in the service pipe which, in turn depends upon the number of hours for which the supply is available at sufficiently high pressure. If the number of hours for which the supply is available is less, there will be large number of fittings in use simultaneously and the rate of flow will be correspondingly large.

The data required for determining the size of the communication and service pipes are:

a) the maximum rate of discharge required;
b) the length of the pipe; and
c) the head loss by friction in pipes, fittings and meters.

4.6.3 *Discharge Computation*

4.6.3.1 *Design of consumer's pipes based on fixture units*

The design of the consumers' pipes or the supply pipe to the fixtures is based on:

a) the number and kind of fixtures installed;
b) the fixture unit flow rate; and
c) the probable simultaneous use of these fixtures.

The rates at which water is desirably drawn into different types of fixtures are known. These rates become whole numbers of small size when they are expressed in fixture unit.

The fixture units for different sanitary appliances or groups of appliances are given in Table 3 and Table 4.

4.6.3.2 *Probable simultaneous demand*

The possibility that all water supply taps in any system in domestic and commercial use will draw water at the same time are extremely remote. Designing the water mains for the gross flow will result in bigger and uneconomical pipe mains and is not necessary. A probability study made by Hunter suggests the relationship shown in Fig. 5 and Table 5. In the absence

Table 3 Fixture Unit for Different Types of Fixtures with Inlet Pipe Diameter

(*Clause* 4.6.3.1)

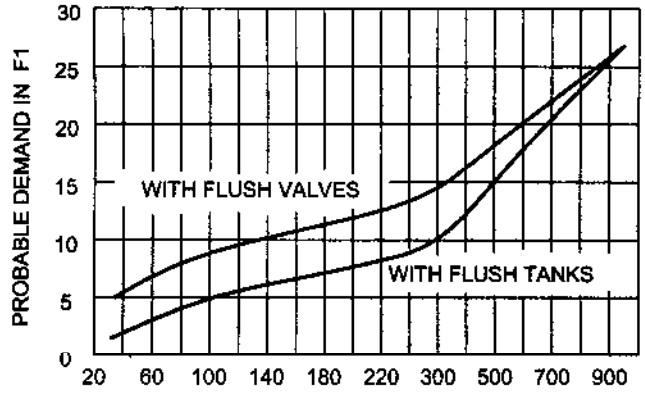
Sl No.	Type of Fixture	Fixture Unit FU as Load Factor	Minimum Normal Size of Fixture Branch, mm
(1)	(2)	(3)	(4)
i)	Ablution tap	1	15
ii)	Bath tub supply by spout	3	15
	Shower over tub does not add to the load		
iii)	Shower stall domestic	2	15
iv)	Shower in groups per head	3	15
v)	Wash basin domestic use	1	15
vi)	Wash basin public use	2	15
vii)	Wash basin surgical	2	15
viii)	Scrub station in hospitals per outlet	3	15
ix)	Drinking water fountain/water cooler	0.5	15
x)	Water-closet with cistern (single/ double flush)	1	15
xi)	Water-closet with flush or magic eye operated valve	8	25/32
xii)	Urinals with auto flushing cisterns	4	15/20
xiii)	Urinals with flush or magic eye operated valve	2	15/20
xiv)	Kitchen sink (domestic use)	2	15/20
xv)	Washing machine	3	15/20

Table 4 Fixture Unit for Different Types of Fixtures Based on Pipe or Trap Diameter

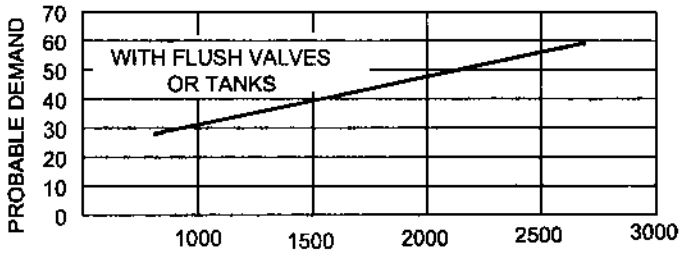
(*Clause* 4.6.3.1)

Sl No.	Drain or Trap Outlet Diameter	Fixture Unit
	mm	FU
(1)	(2)	(3)
i)	32 or smaller	1
ii)	40	2
iii)	50	3
iv)	65	4
v)	75	5
vi)	100	6

NOTE — Before using the above figures check the actual flow from the outlets of special equipment, for example, small period high discharges, for example, from washing machines, boiler blow downs, filter backwash and water tank emptying operations.



5A GRAPH FOR PROBABLE DEMAND ON PIPE LINES UPTO DEMAND OF 900 FU



5B GRAPH FOR PROBABLE DEMAND OVER 900 FU

FIG. 5 GRAPH FOR PROBABLE DEMAND

Table 5 Probable Simultaneous Demand

(*Clause* 4.6.3.2)

No. of Fixture Units	System with Flush Tanks Demand (Based on Fixture Units)		System with Flush Valves Demand (After Hunter)	
	Unit Rate of Flow[1]	Flow in Litre per Minute	Unit Rate of Flow[1]	Flow in Litre per Minute
(1)	(2)	(3)	(4)	(5)
20	2.0	56.6	4.7	133.1
40	3.3	93.4	6.3	178.4
60	4.3	121.8	7.4	209.5
80	5.1	144.4	8.3	235.0
100	5.7	161.4	9.1	257.7
120	6.4	181.2	9.8	277.5
140	7.1	201.0	10.4	294.5
160	7.6	215.2	11.0	311.5
180	8.2	232.2	11.6	328.5
200	8.6	243.5	12.3	348.3
220	9.2	260.5	12.7	359.6
240	9.6	271.8	13.1	370.9
300	11.4	322.8	14.7	416.2
400	14.0	396.4	17.0	481.4
500	16.7	472.9	19.0	538.0
600	19.4	549.3	21.1	597.5
700	21.4	606.0	23.0	651.3
800	24.1	682.4	24.5	693.7
900	26.1	739.0	26.1	739.0
1 000	28.1	795.7	28.1	795.7
1 500	36.1	1 022.2	36.1	1 022.2
2 000	43.9	1 243.1	43.9	1 243.1
2 500	51.1	1 446.9	51.1	1 446.9
3 000	57.8	1 636.7	57.8	1 636.7

[1] Unit rate of flow = Effective fixture units.

of similar studies in India, the curves based on Hunter's study may be followed. In making use of these curves, special allowances are made as follows:

a) Demands for service sinks are ignored in calculating the total fixture demand.

b) Demands of supply outlets such as hose connections and air conditioners through which water flows more or less continuously over a considerable length of time must be added to the probable flow rather than the fixture demand.

c) Fixtures supplied with both hot and cold water exert reduced demands upon main hot water and cold water branches (not fixture branches).

4.6.4 *Pipe Size Computation*

Commercially available standard sizes of pipes are only to be used against the sizes arrived at by actual design. Therefore, several empirical formulae are used, even though they give less accurate results. The Hazen and William's formula and the charts based on the same may be used without any risk of inaccuracy in view of the fact that the pipes normally to be used for water supply are of smaller sizes. Nomogram of Hazen and William's equation has been provided in Annex F.

4.7 Distribution Systems in Multi-Storeyed Buildings

4.7.1 There are four basic methods of distribution of water to a multi-storeyed buildings.

a) Direct supply from mains to ablutionary taps and kitchen with WCs and urinals supplied by overhead tanks.

b) Direct Pumping Systems

c) Hydro-Pneumatic Systems

d) Overhead Tanks Distribution

4.7.2 *Direct Supply System*

This system is adopted when adequate pressure is available round the clock at the topmost floor. With limited pressure available in most city mains, water from direct supply is normally not available above two or three floors. For details of this system, reference may be made to good practice [9-1(5)] may be referred.

4.7.3 *Direct Pumping*

4.7.3.1 Water is pumped directly into the distribution system without the aid of any overhead tank, except for flushing purposes. The pumps are controlled by a pressure switch installed on the line. Normally a jockey

pump of smaller capacity installed which meets the demand of water during low consumption and the main pump starts when the demand is greater. The start and stop operations are accomplished by a set if pressure switches are installed directly on the line. In some installation, a timer switch is installed to restrict the operating cycle of the pump.

4.7.3.2 Direct pumping systems are suitable for buildings where a certain amount of constant use of water is always occurring. These buildings are all centrally air conditioned buildings for which a constant make up supply for air conditioning cooling towers is required.

4.7.3.3 The system depends on a constant and reliable supply of power. Any failure in the power system would result in a breakdown in the water supply system.

4.7.3.4 The system eliminates the requirements of overhead tanks for domestic purposes (except for flushing) and requires minimum space (*see* Fig. 6).

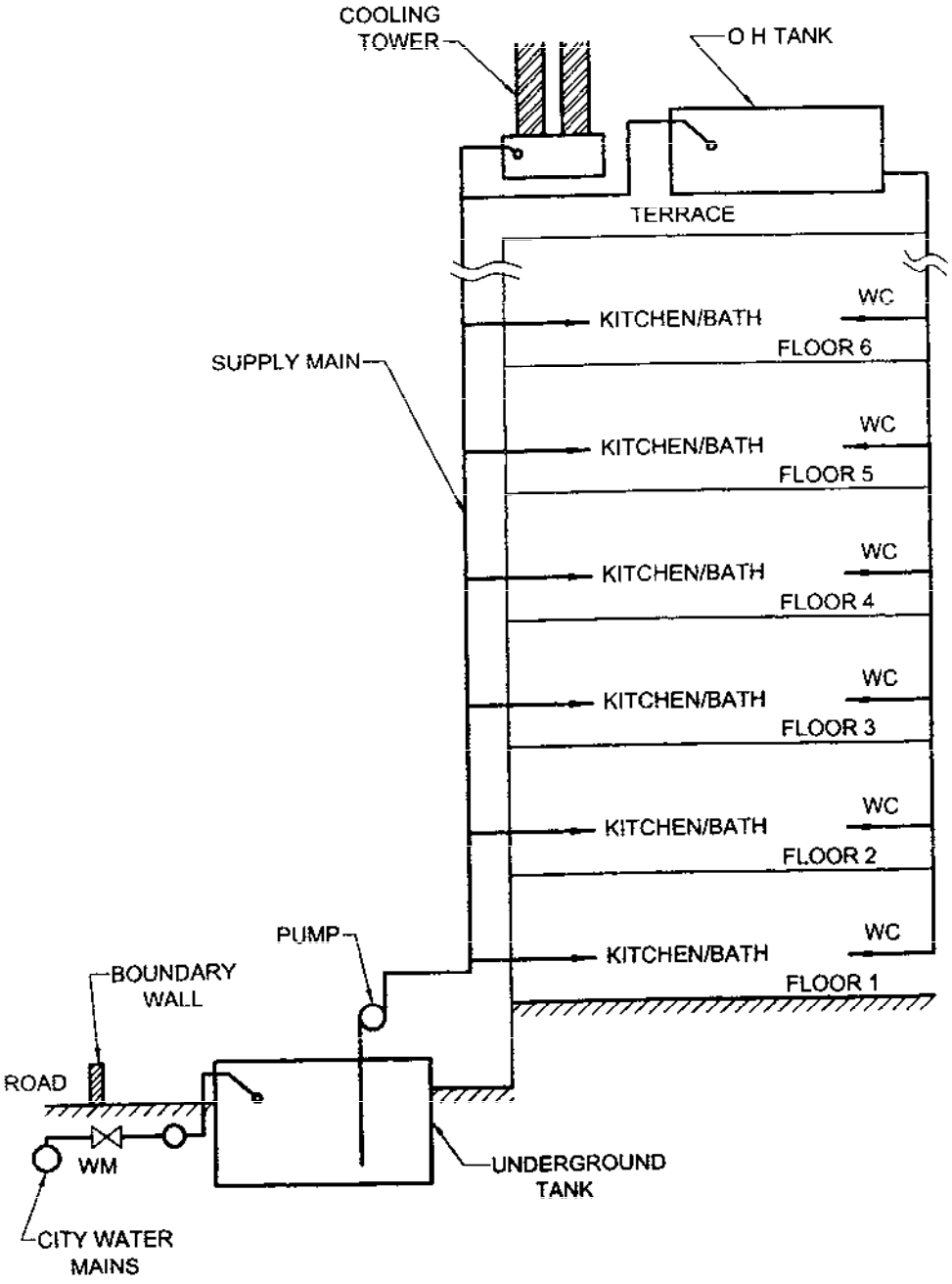


FIG. 6 DIRECT PUMPING SYSTEM APPLICABLE WHERE THERE IS CONTINUOUS DEMAND ON SYSTEM

4.7.4 *Hydro-Pneumatic Systems*

4.7.4.1 Hydro-pneumatic system is a variation of direct pumping system. An air-tight pressure vessel is installed on the line to regulate the operation of the pumps. The vessel capacity shall be based on the cut-in and cut-out pressure of the pumping system depending upon allowable start/stops of the pumping system. As pumps operate, the incoming water is the vessel, compresses the air on top. When a predetermined pressure is reached in the vessel, a pressure switch installed on the vessel switches off the pumps. As water is drawn into the system, pressure falls into the vessel starting the pump at preset pressure. The air in the pressure tank slowly reduces the volume due to dissolution in water and leakages from pipe lines. An air compressor is also necessary to feed air into the vessel so as to maintain the required air-water ratio. The system shall have reliable power supply to avoid breakdown in the water supply.

4.7.4.2 There is an alternate option of providing variable speed drive pumping system where a pump with a large variation in its pressure-discharge and speed of the pump is efficiently used to deliver water at rates of flow as required by the system by changing its speed by a varying its with the assistance of an electronic device which will reduce the rate of flow from speed of the motor from 960 rpm to 3 000 rpm. With this arrangement the same pump is able to deliver water as required at different times of the day. The system consumes energy in proportion to the work done and save considerable amount of power as compared to the fixed speed pumps used conventionally.

4.7.4.3 Hydro-pneumatic system generally eliminates the need for an over head tank and may supply water at a much higher pressure than available from overhead tanks particularly on the upper floors, resulting in even distribution of water at all floors (*see* Fig. 7).

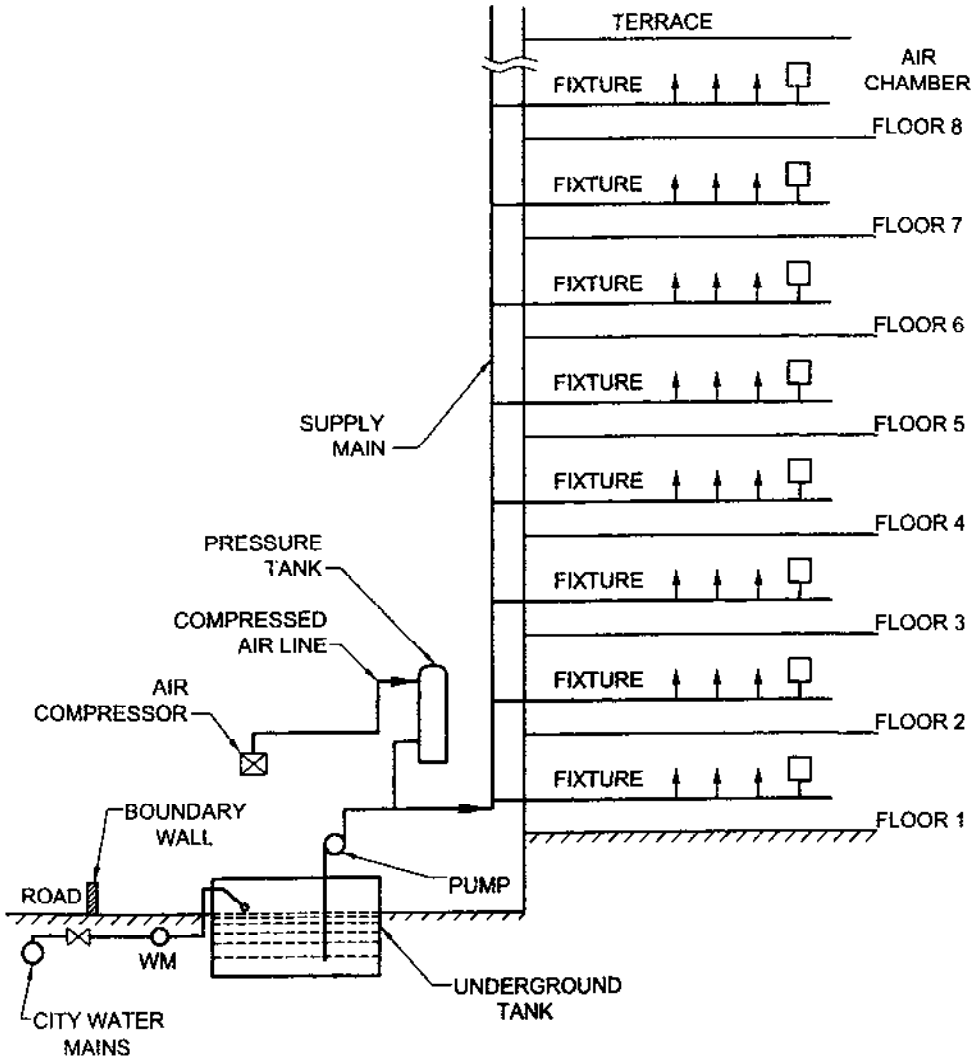


FIG. 7 HYDRO-PNEUMATIC SYSTEM

4.7.5 *Overhead Tank Distribution*

4.7.5.1 This is the most common of the distribution systems adopted by various type of buildings.

4.7.5.2 The system comprises pumping water to one or more overhead tanks placed at the top most location of the hydraulic zone.

4.7.5.3 Water collected in the overhead tank is distributed to the various parts of the building by a set of pipes located generally on the terrace.

4.7.5.4 Distribution is accomplished by providing down takes to various fixtures (*see* Fig. 8).

4.8 General Requirements for Pipe Work

4.8.1 *Mains*

The following principles shall apply for the mains:

a) Service mains shall be of adequate size to give the required rate of flow.

b) The mains shall be divided into sections by

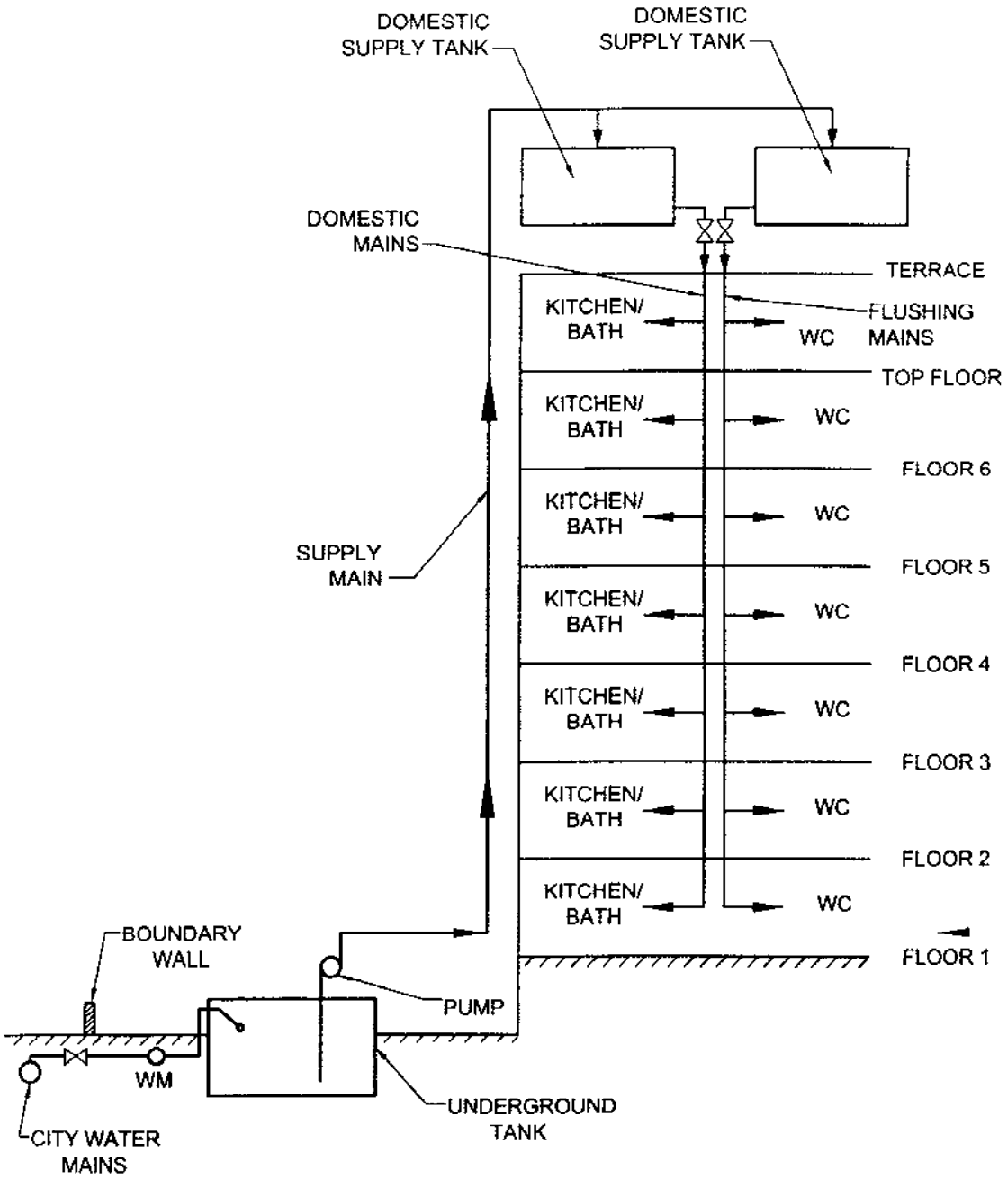


FIG. 8 OVERHEAD TANK DISTRIBUTION

the provisions of sluice valves and other valves so that water may be shut off for repairs.

c) To avoid dead ends, the mains shall be arranged in a grid formation or in a network.

d) Where dead ends are unavoidable, a hydrant shall be provided to act as a wash-out.

e) The wash-out valve shall not discharge directly into a drain or sewer, or into a manhole or chamber directly connected to it; an effectively trapped chamber shall be interposed, into which the wash-out shall discharge.

f) Air valves shall be provided at all summits, and wash-out at low points between summits.

g) Mains need not be laid at unvarying gradients, but may follow the general contour of the ground. They shall, however, fall continuously towards the wash-out and rise towards the air valves. The gradient shall be such that there shall always be a positive pressure at every point under working conditions.

h) The cover for the mains shall be at least 900 mm under roadways and 750 mm in the case of footpaths. This cover shall be measured from the top of the pipe to the surface of the ground.

j) The mains shall be located sufficiently away from other service linest like electric and telegraph cables to ensure safety and where the mains cannot be located away from such lines, suitable protective measures shall be accorded to the mains.

4.8.2 *Communication Pipes*

a) Every premises that is supplied with water by the Authority shall have its own separate communication pipe. In the case of a group or block of premises belonging to the same owner the same communication pipe may supply water to more than one premises with the prior permission of the Authority.

b) The communication pipe between the water main and the stop-cock at the boundary of the premises shall be laid by the Authority.

c) Connections up to 50 mm diameter may be made on the water main by means of screwed ferrules, provided the size of the connections does not exceed one-third the size of the water main. In all other cases, the connection shall be made by a T-branch off the water main.

d) As far as practicable, the communication pipe and the underground service pipe shall be laid at right angles to the main and in approximately straight lines to facilitate location for repairs. It is also recommended that the communication pipe be laid in a pipe in pipe sleeve of larger dia. Made of non-corrosive material to protect the communication pipe.

e) Every communication pipe shall have a stop-cock and meter inserted in it. The waterway of each such fitting shall not be less than the internal sectional area of the communication pipe and the fittings shall be located within the premises at a conspicuous place accessible to the Authority which shall have exclusive control over it.

4.8.3 *Consumer Pipes*

a) No consumer pipe shall be laid in the premises to connect the communication pipe without the approval of the Authority.

b) The consumer pipe within the premises shall be laid underground with a suitable cover to safeguard against damage from traffic and extremes of weather.

c) To control the branch pipe to each separately occupied part of a building supplied by a common service pipe, a stop tap shall be fixed to minimize the interruption of the supply during repairs. All such stop valves shall be fixed in accessible positions and properly protected. To supply water for drinking or for culinary purposes, direct taps shall be provided on the branch pipes connected directly to the consumer pipe. In the case of multi-storeyed buildings, downtake taps shall be supplied from overhead tanks.

d) Pumps shall not be allowed on the service pipe, as they cause a drop in pressure on the suction side, thereby affecting the supply to the adjoining properties. In cases where pumping is required, a properly protected storage tank of adequate capacity shall be provided to feed the pump.

e) No direct boosting (by booster pumps) shall be allowed from the service pipes (communication and consumer pipes).

f) Consumer pipes shall be so designed and constructed as to avoid air-locks. Draining taps shall be provided at the lowest points from which the piping shall rise continuously to draw-off taps.

g) Consumer pipes shall be so designed as to reduce the production and transmission of noise as much as possible.

h) Consumer pipes in roof spaces and unventilated air spaces under floors or in basements shall be protected against corrosion.

j) Consumer pipes shall be so located that they are not unduly exposed to accidental damage and shall be fixed in such positions as to facilitate cleaning and avoid accumulations of dirt.

All consumer pipes shall be so laid as to permit expansion and contraction or other movements.

4.8.4 *Prohibited Connections*

a) A service pipe shall not be connected into any distribution pipe; such connection may permit the backflow of water from a cistern into the service pipe, in certain circumstances, with consequent danger of contamination and depletion of storage capacity. It might also result in pipes and fittings being subjected to a pressure higher than that for which they are designed, and in flooding from overflowing cisterns.

b) No pipe for conveyance or in connection with water supplied by the Authority shall communicate with any other receptacle used or capable of being used for conveyance other than water supplied by the Authority.

c) Where storage tanks are provided, no person shall connect or be permitted to connect any service pipe with any distributing pipe.

d) No service or supply pipe shall be connected directly to any water-closet or a urinal. All such supplies shall be from flushing cisterns which shall be supplied from storage tank.

e) No service or supply pipe shall be connected directly to any hot water system or to any other apparatus used for heating other than through a feed cistern thereof.

4.9 Jointing of Pipes

4.9.1 *Cast Iron Pipes*

Jointing may be done by any of the following methods:

a) spigot and socket joints, or

b) flanged joints in accordance with good practice [9-1(6)]. The lead shall conform to the accepted standards [9-1(7)].

4.9.2 *Steel Pipes*

Plain-ended steel pipes may be jointed by welding. Electrically welded steel pipes shall be jointed in accordance with good practice [9-1(8)].

4.9.3 *Wrought Iron and Steel Screwed Pipes*

Screwed wrought iron or steel piping may be jointed with screwed and socketed joints. Care shall be taken to remove any burr from the end of the pipes after screwing. A jointing compound approved by the Authority and containing no red lead composition shall be used. Screwed wrought iron or steel piping may also be jointed with screwed flanges.

4.9.4 *Asbestos Cement Pipes*

Asbestos cement pipes may be jointed in accordance with good practice [9-1(9)].

4.9.5 *Copper Pipes*

Copper pipes shall be jointed by internal solder ring joint, end-brazing joint or by use of compression fitting. The flux used shall be non-toxic and the solder used shall be lead free. The use of dezincification fittings shall be made in case of jointing of copper pipe and steel pipe.

4.9.6 *Concrete Pipes*

Concrete pipes shall be jointed in accordance with good practice [9-1(10)].

4.9.7 *Polyethylene and Unplasticized PVC Pipes*

Polyethylene and unplasticized PVC pipes shall be jointed in accordance with good practice [9-1(11)].

4.10 Backflow Prevention

4.10.1 The installation shall be such that water delivered is not liable to become contaminated or that contamination of the public water supply does not occur.

4.10.2 The various types of piping and mechanical devices acceptable for backflow protection are:

a) Barometric loop,

b) Air gap,

c) Atmosphere vacuum breaker,

d) Pressure vacuum breaker,

e) Double check valve, and

f) Reduced pressure backflow device.

4.10.3 The installation shall not adversely affect drinking water:

a) by materials in contact with the water being unsuitable for the purpose;

b) as a result of backflow of water from water

fittings, or water using appliances into pipework connected to mains or to other fittings and appliances;

c) by cross-connection between pipes conveying water supplied by the water undertaker with pipes conveying water from some other source; and

d) by stagnation, particularly at high temperatures.

4.10.4 No pump or similar apparatus, the purpose of which is to increase the pressure in or rate of flow from a supply pipe or any fitting or appliance connected to a supply pipe, shall be connected unless the prior written permission of the water supplier has been obtained in each instance.

The use of such a pump or similar apparatus is likely to lead to pressure reduction in the upstream pipe work which, if significant, increase the risk of backflow from other fittings.

4.10.5 The water shall not come in contact with unsuitable materials of construction.

4.10.6 No pipe or fitting shall be laid in, on or through land fill, refuse, an ashpit, sewer, drain, cesspool or refuse chute, or any manhole connected with them.

4.10.7 No pipe susceptible to deterioration by contact with any substance shall be laid or installed in a place where such deterioration is likely to occur. No pipe that is permeable to any contaminant shall be laid or installed in any position where permeation is likely to occur.

4.10.8 If a liquid (other than water) is used in any type of heating primary circuit, which transfers heat to water for domestic use, the liquid shall be non-toxic and non-corrosive.

4.10.9 A backflow prevention device shall be arranged or connected at or as near as practicable to each point of delivery and use of water. Appliances with built-in backflow prevention shall be capable of passing the test. All backflow prevention devices shall be installed so that they are accessible for examination, repair or replacement. Such devices shall be capable of being tested periodically by the Authority to ensure that the device is functioning efficiently and no backflow is occurring at any time.

4.11 Conveyance and Distribution of Water Within the Premises

4.11.1 *Basic Principles*

Wholesome water supply provided for drinking and culinary purposes shall not be liable to contamination from any less satisfactory water. There shall, therefore, be no cross-connection whatsoever between the distribution system for wholesome water and any pipe or fitting containing unwholesome water, or water liable to contamination, or of uncertain quality, or water which has been used for any other purpose. The provision of reflux or non-return valves or closed and sealed stop valves shall not be construed as a permissible substitute for complete absence of cross-connection.

4.11.2 The design of the pipe work shall be such that there is no possibility of backflow towards the source of supply from any cistern or appliance, whether by siphonage or otherwise. Reflux non-return valves shall not be relied upon to prevent such backflow.

4.11.3 Where a supply of less satisfactory water than wholesome water becomes inevitable as an alternative or is required to be mixed with the latter, it shall be delivered only into a cistern and by a pipe or fitting discharging into the air gap at a height above the top edge of the cistern equal to twice its nominal bore and in no case less than 150 mm. It is necessary to maintain a definite air gap in all appliances or taps used in water-closets.

4.11.4 All pipe work shall be so designed, laid or fixed and maintained as to remain completely water-tight, thereby avoiding wastage, damage to property and the risk of contamination.

4.11.5 No water supply line shall be laid or fixed so as to pass into or through any sewer, scour outlet or drain or any manhole connected therewith nor through any ash pit or manure pit or any material of such nature that is likely to cause undue deterioration of the pipe, except where it is unavoidable.

4.11.5.1 Where the laying of any pipe through corrosive soil or previous material is unavoidable, the piping shall be properly protected from contact with such soil or material by being carried through an exterior cast iron tube or by some other suitable means as approved by the Authority. Any existing piping or fitting laid or fixed, which does not comply with the above requirements, shall be removed immediately by the consumer and relaid by him in conformity with the above requirements and to the satisfaction of the Authority.

4.11.5.2 Where lines have to be laid in close proximity to electric cables or in corrosive soils, adequate precautions/protection should be taken to avoid corrosion.

4.11.6 Underground piping shall be laid at such a depth that it is unlikely to be damaged by frost or traffic loads and vibrations. It shall not be laid in ground liable to subsidence, but where such ground cannot be avoided, special precautions shall be taken to avoid

damage to the piping. Where piping has to be laid across recently disturbed ground, the ground shall be thoroughly consolidated so as to provide a continuous and even support.

4.11.7 In designing and planning the layout of the pipe work, due attention shall be given to the maximum rate of discharge required, economy in labour and materials, protection against damage and corrosion, water hammer, protection from frost, if required, and to avoidance of airlocks, noise transmission and unslightly arrangement.

4.11.8 To reduce frictional losses, piping shall be as smooth as possible inside. Methods of jointing shall be such as to avoid internal roughness and projection at the joints, whether of the jointing materials or otherwise.

4.11.9 Change in diameter and in direction shall preferably be gradual rather than abrupt to avoid undue loss of head. No bend or curve in piping shall be made which is likely to materially diminish or alter the cross-section.

4.11.10 No boiler for generating steam or closed boilers of any description or any machinery shall be supplied direct from a service or supply pipe. Every such boiler or machinery shall be supplied from a feed cistern.

4.12 Laying of Mains and Pipes on Site

4.12.1 The mains and pipes on site shall be laid in accordance with good practice [9-1(12)].

4.12.2 *Excavation and Refilling*

The bottoms of the trench excavations shall be so prepared that the barrels of the pipes, when laid, are well bedded for their whole length on a firm surface and are true to line and gradient. In the refilling of trenches, the pipes shall be surrounded with fine selected material, well rammed so as to resist subsequent movement of the pipes. No stones shall be in contact with the pipes; when resting on rock, the pipes shall be bedded on fine-selected material or (especially where there is a steep gradient) on a layer of concrete.

4.12.2.1 The pipes shall be carefully cleared of all foreign matter before being laid.

4.12.3 *Laying Underground Mains*

Where there is a gradient, pipe laying shall proceed in 'uphill' direction to facilitate joint making.

4.12.3.1 Anchor blocks shall be provided to withstand the hydraulic thrust.

4.12.4 Iron surface boxes shall be provided to give access to valves and hydrants and shall be supported on concrete or brickwork which shall not be allowed to rest on pipes.

4.12.5 *Laying Service Pipes*

4.12.5.1 Service pipes shall be connected to the mains by means of right-hand screw down ferrule or T-branches. The ferrules shall conform to accepted standards [9-1(13)].

4.12.5.2 Precaution against contamination of the mains shall be taken when making a connection and, where risk exists, the main shall be subsequently disinfected. The underground water service pipe and the building sewer or drain shall be kept at a sufficient distance apart so as to prevent contamination of water. Water service pipes or any underground water pipes shall not be run or laid in the same trench as the drainage pipe. Where this is unavoidable, the following conditions shall be fulfilled:

a) The bottom of the water service pipe, at all points, shall be at least 300 mm above the top of the sewer line at its highest point.
b) The water service pipe shall be placed on a solid shelf excavated on one side of the common trench.
c) The number of joints in the service pipe shall be kept to a minimum.
d) The materials and joints of sewer and water service pipe shall be installed in such a manner and shall possess such necessary strength and durability as to prevent the escape of solids, liquids and gases therefrom under all known adverse conditions, such as corrosion strains due to temperature changes, settlement, vibrations and superimposed loads.

4.12.5.3 The service pipe shall pass into or beneath the buildings at a depth of not less than 750 mm below the outside ground level and, at its point of entry through the structure, it shall be accommodated in a sleeve which shall have previously been solidly built into the wall of the structure. The space between the pipe and the sleeve shall be filled with bituminous or other suitable material for a minimum length of 150 mm at both ends.

4.12.6 *Pipes Laid Through Ducts, Chases, Notches or Holes*

Ducts or chases in walls for piping shall be provided during the building of the walls. If they are cut into existing walls, they shall be finished sufficiently smooth and large enough for fixing the piping.

4.12.6.1 Piping laid in notches or holes shall not be subjected to external pressure.

4.12.7 *Lagging of Pipes*

Where lagged piping outside buildings is attached to walls, it shall be entirely covered all round with waterproof and fire insulating material and shall not be in direct contact with the wall. Where it passes through a wall, the lagging shall be continued throughout the thickness of the wall.

4.13 Hot Water Supply Installations

4.13.1 *Design Consideration*

4.13.1.1 *General*

In electric water heating practice for domestic purposes, the accepted method is to use storage heaters in which water is steadily heated up to a predetermined temperature and stored until required for use. The heating by electricity of a large quantity of water, such as water required for a hot bath, within the time normally taken to run the water into the bath, requires a heater of too high a rating to be practicable in normal domestic premises.

4.13.1.2 In modern hotels and apartment blocks and service apartments, centralized storage and distribution systems are adopted, where other energy sources such as oil, gas, solar panels, etc, may be used for the generation of hot water as these options prove more economical and convenient in heating large volumes of water for storage.

4.13.1.3 When water supplied to the buildings contain dissolved salts resulting in hardness of water, measures such as installation of water softening plants etc shall be taken to avoid formation of scales in the hot water installations.

4.13.2 *Storage Temperature*

4.13.2.1 The design of hot water supply system and its appliances shall be based on the temperatures at which water is normally required for the various uses, namely

Scalding	65°C
Sink	60°C
Hot bath	43°C as run, for use at 41°C
Warm bath	37°C
Tepid bath	29.5°C

4.13.2.2 In order to minimize the danger of scalding, precipitation of scale from hard water, standing heat losses, risk of steam formation and the possibility of damage to porcelain or other fittings and to surface finishes, a storage temperature of 60°C is recommended. If storage capacity is limited, a higher temperature up to 65°C may be adopted when soft water is used.

4.13.3 *Storage Capacity*

The size of the storage vessel is governed by the maximum short time demand of the domestic premises. Depending on local conditions this shall be 50 l to 75 l at 60 °C in a dwelling with a bath tub and 25 l at 60°C for a shower or a tap (for bucket supply). The capacity of the storage vessel shall not be less than 20 percent in excess of the required maximum short time demand. In larger houses where a single hot water heater is intended to supply hot water to more than one bathroom or kitchen or both, the maximum short time demand shall be estimated and the capacity decided accordingly. Small electric or gas storage heaters of 15 l to 25 l capacity may be used to supply one or two points of draw off depending on the use of hot water. Values of volume of hot water required for a bath, when cold water is mixed with it are given in Table 6.

Table 6 Volume of Hot Water Required for a Bath when Cold Water is Mixed with It

(*Clause* 4.13.3)

Storage temperature, °C	75	70	65	60	55	50
Percentage of hot water required	51	55	60	66	73	82.5
Quantity of hot water in litres required for a 115 litre bath	59	63	69	76	84	95

NOTE — Hot bath temperature at 41°C and cold water at about 5 to 5.5°C.

4.13.4 *Rate of Flow*

With storage type installation, the recommended minimum rates of flow for different types of fixtures are given in Table 7.

Table 7 Rate of Hot Water Flow

(*Clause* 4.13.4)

Sl No.	Fixtures	Rate of Flow litres/min
(1)	(2)	(3)
i)	Bath tub	22.5
ii)	Kitchen sink	18
iii)	Wash basin	7
iv)	Shower (spray type)	7

4.13.5 *Design of Storage Vessel*

Storage tanks shall be oblong or cylindrical in shape and shall be installed, preferably with the long side vertical in order to assist the effective stratification or 'layering' of hot or cold water. The ratio of height to width or diameter shall not be less than 2:1. An inlet baffle should preferably be fitted near the cold inflow pipe in order to spread the incoming cold water.

4.13.6 *Materials for Storage Vessel and Pipes*

4.13.6.1 Under no circumstances shall ungalvanized (black) mild steel pipes and fittings, such as sockets, bushes, etc, be used in any part of a hot water

installation, including the cold feed pipe and the vent pipe. Materials resistant to the chemical action of water supplied shall be used in construction of vessels and pipes. Each installation shall be restricted to one type of metal only, such as all copper or all galvanized mild steel. When water supplied is known to have appreciable salt content, galvanized iron vessels and pipes shall not be used. However, it is advisable to avoid use of lead pipes in making connection to wash basins. Where required it is also advisable to use vessels lined internally with glass, stainless steel, etc.

4.13.6.2 In general tinned copper and other metals such as monel metal etc are suitable for most types of water. The suitability of galvanized mild steel for storage tanks depends upon the *p*H value of the water and the extent of its temporary hardness. For values of *p*H 7.2 or less, galvanized mild steel should not be used. For values of *p*H 7.3 and above, galvanized mild steel may be used provided the corresponding temporary hardness is not lower than those given below:

*p*H *Value*	*Minimum Temporary Hardness Required* (mg/l)
7.3	210
7.4	150
7.5	140
7.6	110
7.7	90
7.8	80
7.9-8.5	70

4.13.7 *Location of Storage Vessel*

The loss of heat increases in proportion to the length of pipe between the storage vessel and the hot water outlet since each time the water is drawn, the pipe fills with hot water which then cools. The storage vessel shall therefore be so placed that the pipe runs to the most frequently used outlets are as short as possible.

4.13.8 *Immersion Heater Installation*

4.13.8.1 If a domestic storage vessel is to be adopted to electric heating by the provision of an immersion heater and thermostat, the following precautions shall be observed:

a) *Location of immersion heaters* — The immersion heater shall be mounted with its axis horizontal, except in the case of the circulation type which is normally mounted with its axis approximately vertical.

b) In a tank with a flat bottom, a space of not less than 75 mm below the immersion heater and 50 mm below the cold feed connection shall be provided to allow for accumulation of sludge and scale, where it will not affect the working of the immersion heater.

c) In a cylindrical storage vessel with inwardly dished bottom, the inlet pipe shall be so arranged that the incoming cold water is not deflected directly into the hot water zone. The lowest point of the immersion heater shall be 25 mm above the centre line of the cold feed inlet, which, in turn, is usually 100 mm above the cylinder rim.

d) *Location of thermostat* — Where the thermostat does not form an integral part of the immersion heater, it shall be mounted with its axis horizontal, at least 50 mm away from and not lower than the immersion heater.

e) *Dual heater installations* — If desired, the principle of the dual heater may be adopted. In this case, one heater and its thermostat shall be installed at a low level as indicated in (b) and (c). The second heater and its thermostat shall be similarly disposed in the upper half of the cylinder at a level depending on the reserve of hot water desired for ordinary domestic use. The bottom heater shall be under separate switch control.

f) *Clearance around storage vessel* — Adequate clearance shall be provided between the tank and the cupboard, door or walls to allow convenient insertion and adjustment of the immersion heater and thermostat and to give space for thermal insulation.

4.13.8.2 *Rating of Immersion Heaters*

The rating of an immersion heater shall be determined according to the following factors:

a) proposed hot water storage capacity (the maximum with cold water as indicated in **4.13.3** shall be taken into account),

b) rate of utilization (draw off frequency),

c) permissible recovery period, and

d) inlet water temperature.

For details regarding rated input of water, refer to good practice [9-1(14)].

4.13.9 *Thermal Insulation*

The hot water storage vessel and pipes shall be adequately insulated wherever necessary to minimize heat loss. The whole external surface of the storage vessel including the cover to the handhole, shall be provided with a covering equivalent to not less than 75 mm thickness of thermal insulating material having a conductivity of not more than 0.05 W/(m^2.°C)/mm at mean temperature of 50°C.

4.13.10 *Cold Water Supply to Heaters*

4.13.10.1 A storage water heater (pressure type) shall be fed from a cold water storage tank and under no circumstances connected directly to the water main, except the type which incorporates a feed tank with ball valves and overflow pipe arrangement (cistern type heaters) or non-pressure type heaters.

4.13.10.2 *Storage cisterns*

4.13.10.2.1 The storage capacity of a cold water tank shall be at least twice the capacity of the hot water heater. The capacity of the storage tank may, however, be 1.5 times when the number of heaters connected to one common tank exceeds 10.

4.13.10.2.2 The storage tank for supply of cold water to hot water heaters shall be separate, if practicable. In the case of a common tank which also supplies cold water to the fixtures, this cold water supply connection shall be so arranged that 50 percent of the net capacity, worked out as in **4.13.10.2.1**, shall be available for supply to the hot water heaters.

4.13.10.2.3 In the case of multi-storeyed buildings where a common overhead tank over the stair/lift well is generally installed, it is advisable to have one or more local tanks for supply to the hot water heaters. This arrangement shall help in reducing the length of the vent pipes (*see* Fig. 9).

4.13.10.2.4 In tall multi-storeyed buildings where the static pressure increases with the height, the total static pressure on the hot water heaters on the lowest floor shall not exceed the rated working pressure of the hot water heater installed. Should the height of the building so require, additional tanks shall be provided on the intermediate floors to restrict the static head to permissible limits (*see* Fig. 10).

4.13.10.2.5 As an alternative to the arrangements stated in **4.13.10.2.3** and **4.13.10.2.4** an individual storage tank in each flat may be provided for supply to hot water heaters (*see* Fig. 11).

4.13.11 *Cold Water Feed*

4.13.11.1 The feed pipe connecting cold water tank with the hot water heater shall not be of less than 20 mm bore and it shall leave the cold water tank at a point not less than 50 mm above the bottom of the tank and shall connect into the hot water heater near its bottom. The feed pipe shall not deliver cold water to any other connection, but into the hot water cylinders only.

4.13.11.2 In the case of multi-storeyed buildings, a common cold water feed pipe may be installed, but each hot water heater shall be provided with a check valve (horizontal type check valve shall be preferred to vertical type for easy maintenance).

4.13.11.3 Care shall be taken in installing the piping to prevent air locks in the piping and negative pressure in the hot water heater. Cold water feedpipe shall not be cross connected with any other source of supply under pressure (*see* Fig. 9).

4.13.12 *Hot Water Piping*

4.13.12.1 *Expansion pipe or vent pipe*

4.13.12.1.1 Each pressure type hot water heater or cylinder shall be provided with a vent pipe of not less than 20 mm bore. The vent pipe shall rise above the water line of the cold water tank by at least 150 mm plus 10 mm for every 300 mm height of the water line above the bottom of the heater. The vent shall discharge at a level higher than the cold water tank and preferably in the cold water tank supplying the hot water heaters. Care shall be taken to ensure that any accidental discharge from the vent does not hurt or scald any passerby or persons in the vicinity.

4.13.12.1.2 The vent pipe shall be connected to the highest point of the heater vessel and it shall not project downwards inside it, as otherwise air may be trapped inside, resulting in surging and consequent noises.

4.13.12.1.3 At no point, after leaving the vessel, shall the vent pipe dip below the level of its connection with the vessel.

4.13.12.1.4 A vent pipe may, however, be used for supply of hot water to any point between the cold water tank and the hot water heaters.

4.13.12.1.5 The vent pipe shall not be provided with any valve or check valves.

4.13.12.2 *Hot water heaters*

4.13.12.2.1 The common hot water delivery pipe shall leave the hot water heater near its top and shall be of not less than 20 mm bore generally, not less than 25 mm bore if hot water taps are installed on the same floor as that on which the hot water heater is situated.

4.13.12.2.2 Hot water taps shall be of such design as would cause the minimum friction. Alternatively, oversized tap may be provided, such as a 20 mm tap on a 15 mm pipe.

4.13.12.2.3 The hot water distributing system shall be so designed as to ensure that the time lag between opening of the draw-off taps and discharge of hot water is reduced to the minimum to avoid wastage of an undue amount of water which may have cooled while standing in the pipes when the taps are closed. With this end in view, a secondary circulation system with flow and return pipes from the hot water tank shall be

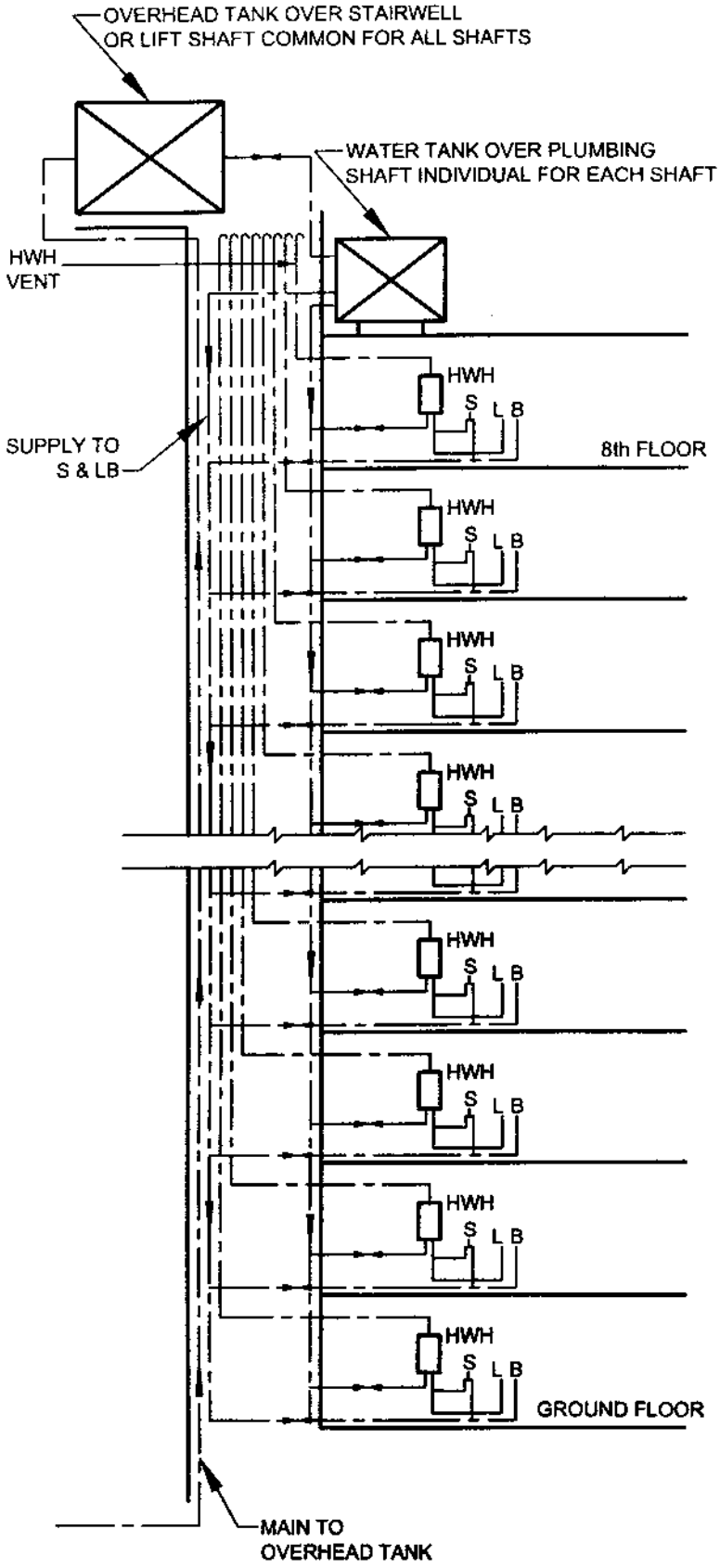


FIG. 9 INSTALLATION FOR 8-STOREYED BUILDING

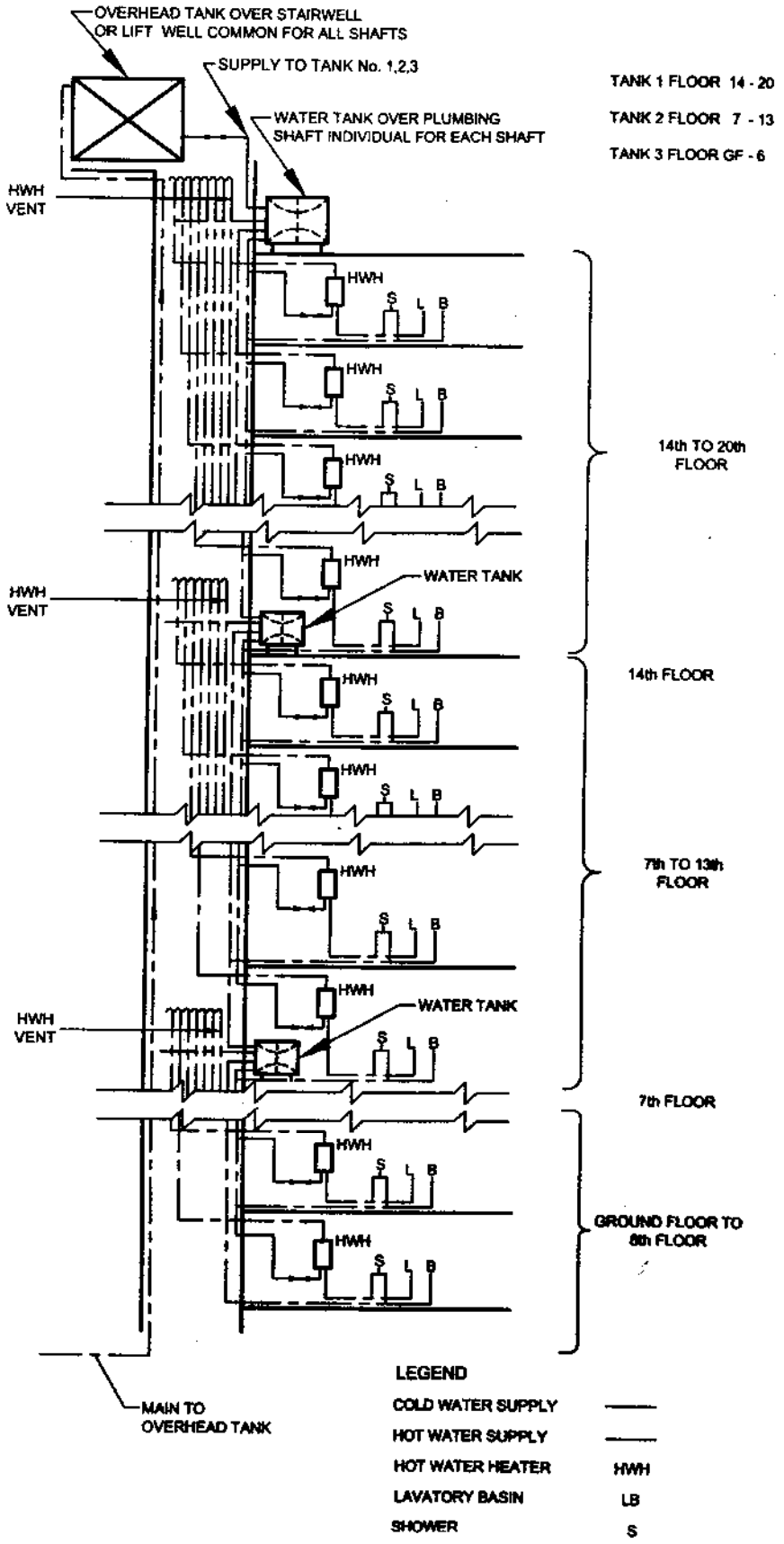


FIG. 10 INSTALLATION FOR 20-STOREYED BUILDING

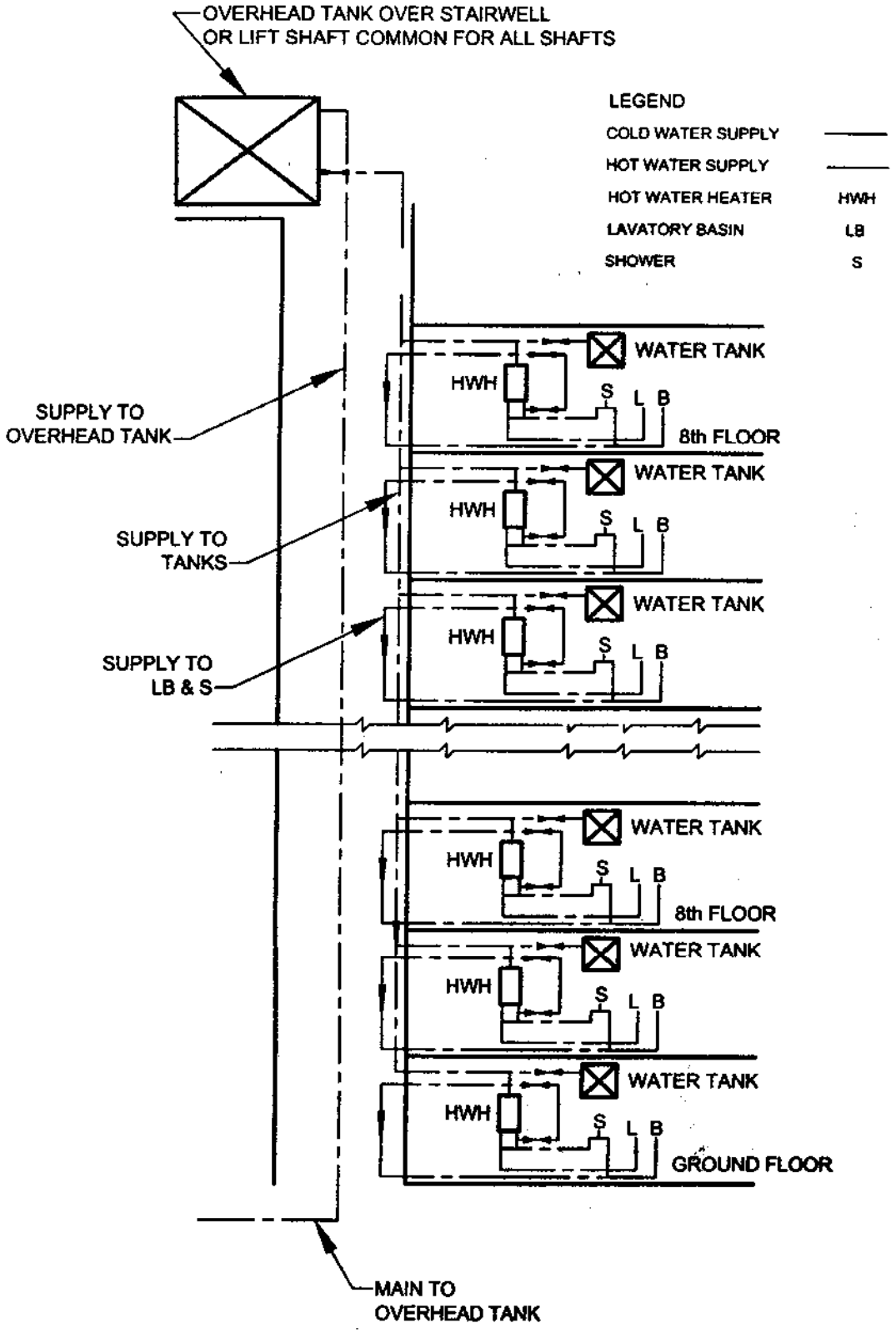


FIG. 11 INSTALLATION FOR 8-STOREYED BUILDING WITH INDIVIDUAL WATER TANKS

used where justified. Whether such a system is used or not, the length of pipe to a hot water draw-off tap, measured along the pipe from the tap to the hot water tank or the secondary circulation pipe, shall not exceed the lengths given in Table 8.

Table 8 Maximum Permissible Lengths of Hot Water Draw-off Pipes

(*Clause* 4.13.12.2.3)

Sl No.	Largest Internal Diameter of Pipe	Length m
(1)	(2)	(3)
i)	Not exceeding 20 mm	12
ii)	Exceeding 20 mm but not exceeding 25 mm	7.5
iii)	Exceeding 25 mm	3.0

NOTE — In the case of a composite pipe of different diameters, the largest diameter is to be taken into consideration for the purpose of this table.

4.13.12.2.4 Wherever mixing of hot and cold water is done by a mixing fitting, that is, hot and cold stop-cocks deliver to a common outlet of mixed water (that is, showers, basin or bath supply fittings), the pressure in the cold and hot water systems shall be equal. This can be achieved by connecting the cold water supply from an overhead tank at the same static height as the overhead tank supplying cold water to the hot water heaters. In case this is not possible, hot and cold water should be supplied to the fixtures by separate supply taps.

4.13.13 *Types of Hot Water Heaters*

The various types of water heaters used for preparation of hot water are as follows:

a) *Electric Storage Heaters*:
   1) Non-pressure or open outlet type,
   2) Pressure type,
   3) Cistern type, and
   4) Dual heater type.

b) *Gas Water Heaters*:
   1) Instantaneous type, and
   2) Storage type.

c) *Solar Heating Systems*:
   1) Independent roof mounted heating units, and
   2) Centrally banked heated system.

d) *Central Hot Water System*
   1) Oil fired, and
   2) Gas fired.

4.13.13.1 The quality and construction of the different types of hot water heaters shall be in accordance with good practice [9-1(15)].

4.13.13.2 Typical arrangement of water heater is shown in Fig. 12.

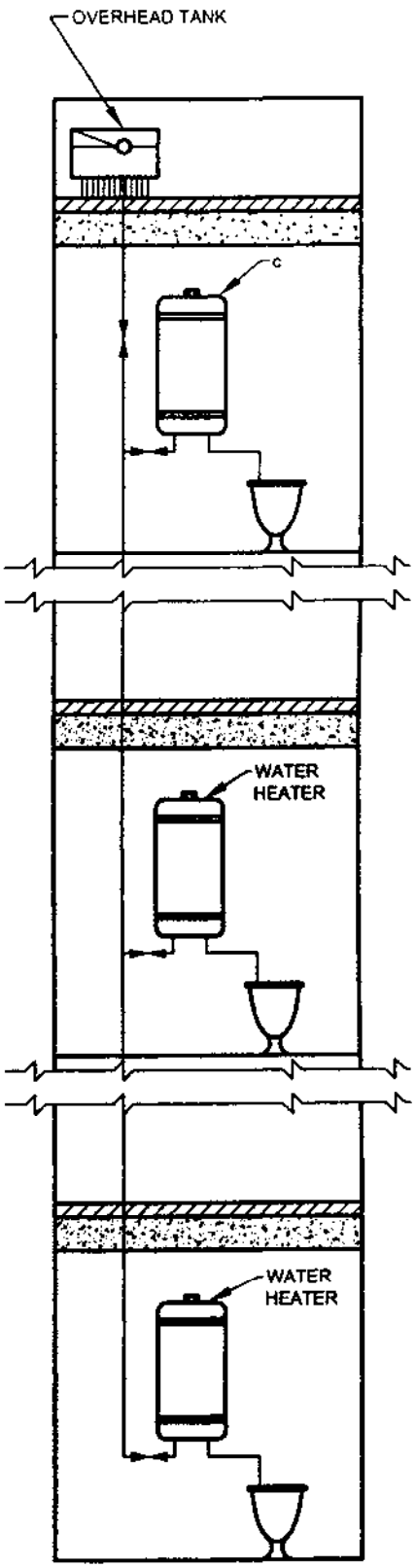


FIG. 12 NON-PRESSURE TYPE INSTALLATION

4.13.13.3 Requirements in regard to inspection and maintenance of hot water supply installations shall be in accordance with **4.14.1** to **4.14.4**.

4.14 Inspection and Testing

4.14.1 *Testing of Mains Before Commencing Work*

All pipes, fittings and appliances shall be inspected, before delivery at the site to see whether they conform to accepted standards. All pipes and fittings shall be inspected and tested by the manufacturers at their factory and shall comply with the requirements of this Section. They shall be tested hydraulically under a pressure equal to twice this maximum permissible working pressure or under such greater pressure as may be specified. The pipes and fittings shall be inspected on site before laying and shall be sounded to disclose cracks. Any defective items shall be clearly marked as rejected and forthwith removed from the site.

4.14.2 *Testing of Mains After Laying*

After laying and jointing, the main shall be slowly and carefully charged with water by providing a 25 mm inlet with a stop-cock, so that all air is expelled from the main. The main is then allowed to stand full of water for a few days if time permits, and then tested under pressure. The test pressure shall be 0.5 N/mm^2 or double the maximum working pressure, whichever is greater. The pressure shall be applied by means of a manually operated test pump, or, in the case of long mains or mains of a large diameter, by a power-driven test pump, provided the pump is not left unattended. In either case, due precaution shall be taken to ensure that the required test pressure is not exceeded. Pressure gauges shall be accurate and shall preferably have been recalibrated before the test. The pump having been stopped, the test pressure shall maintain itself without measurable loss for at least 5 min. The mains shall be tested in sections as the work of laying proceeds; it is an advantage to have the joints exposed for inspection during the testing. The open end of the main may be temporarily closed for testing under moderate pressure by fitting a water-tight expanding plug of which several types are available. The end of the main and the plug shall be secured by struts or otherwise, to resist the end thrust of the water pressure in the mains.

4.14.2.1 If the section of the main tested terminates into a sluice valve, the wedge of the valve shall not be used to retain the water; instead the valve shall be temporarily fitted with a blank flange, or, in the case of a socketed valve, with a plug, and the wedge placed in the open position while testing. End support shall be given as in **4.14.2**.

4.14.3 *Testing of Service Pipes and Fittings*

When the service pipe is complete, it shall be slowly and carefully charged with water, allowing all air to escape, care being taken to avoid all shock or water hammer. The service pipe shall then be inspected under working conditions of pressure and flow. When all draw-offs taps are closed, the service pipe shall be absolutely water-tight. All piping, fittings and appliances shall be checked for satisfactory support, and protection from damage, corrosion and frost. Because of the possibility of damage in transit, cisterns shall be re-tested for water-tightness on arrival at the site, before fixing.

4.14.4 In addition to the provisions given in **4.14.1**, provisions given in **4.14.4.1** to **4.14.4.3** shall also apply to hot water supply installations in regard to inspection and testing.

4.14.4.1 *Testing of the system after installation*

After the hot water system, including the hot water heaters, has been installed, it shall be carefully charged with water, so that all air is expelled from the system. The entire system shall then be hydraulically tested to a pressure of 0.5 N/mm^2 or twice the working pressure, whichever is greater, for a period of at least half an hour after a steady state is reached. The entire installation shall then be inspected visually for leakages, and sweating. All defects found shall be rectified by removing and remaking the particular section. Caulking of threads, hammering and welding of leaking joints shall not be allowed.

4.14.4.2 *Hot water testing*

After the system has been proved water-tight, the hot water heaters shall be commissioned by connecting the same to the electrical supply. The system shall then be observed for leakage in pipes due to expansion or overheating. The temperature of water at outlets shall be recorded. The thermostats of the appliances shall be checked and adjusted to temperatures specified in **4.13.2.1**.

4.14.4.3 *Electrical connection*

For relevant provisions regarding general and safety requirements for household and similar electrical appliances, reference may be made to good practice [9-1(14)]. The metal work of the water heating appliances and installation other than current carrying parts shall be bonded and earthed in conformity with the good practice [9-1(14)]. It should be noted that screwing of an immersion heater into a tank or cylinder cannot be relied upon to effect a low resistance earth connection, a satisfactory separate earthing of heater should be effected.

4.15 Cleaning and Disinfection of the Supply System

4.15.1 All water mains communications pipes, service pipes and pipes used for distribution of water for domestic purposes shall be thoroughly and efficiently

be subject to the approval of the Authority. The pipes shall also be periodically cleaned at intervals, depending upon the quality of water, communication pipes and the storage cisterns shall be thoroughly cleaned at least once every year in order to remove any suspended impurities that may have settled in the pipes or the tanks.

4.15.2 *Disinfection of Storage Tanks and Downtake Distribution Pipes*

The storage tanks and pipes shall first be filled with water and thoroughly flushed out. The storage tank shall then be filled with water again and a disinfecting chemical containing chlorine added gradually while the tanks are being filled, to ensure thorough mixing. Sufficient quantities of chemicals shall be used to give the water a dose of 50 parts of chlorine to one million parts of water. If ordinary bleaching powder is used, the proportions will be 150 g of powder to 1 000 litres of water. The powder shall be mixed with water to a creamy consistency before being added to the water in the storage tank. When the storage tank is full, the supply shall be stopped and all the taps on the distributing pipes opened successively working progressively away from the storage tank. Each tap shall be closed when the water discharged begins to smell of chlorine. The storage tank shall then be topped up with water from the supply pipe and with more disinfecting chemical in the recommended proportions. The storage tank and pipes shall then remain charged for at least 3 h. Finally, the tank and pipes shall be thoroughly flushed out before any water is used for domestic purposes.

4.16 Water Supply Systems in High Altitudes and/or Sub-zero Temperature Regions

4.16.1 *Selection and Source*

In general, the site selected for a water source shall be such as to minimize the length of transmission line so as to reduce the inspection and upkeep. Attempt shall be made, where feasible, to locate the source near the discharge of waste heat, such as of power plants provided it does not affect the potability of water.

4.16.2 *Pumping Installation*

Pump and pumping machinery shall be housed inside well-insulated chambers. Where necessary, arrangements shall be made for heating the inside of pump houses. Pump houses, as far as possible, should be built directly above the water intake structures.

4.16.3 *Protection of Storage Water and Treatment*

Where ambient temperatures are so low as to cause equipment. If necessary, means shall be provided for proper heating of the enclosure.

4.16.4 *Transmission and Distribution*

Freezing of the buried pipe may be avoided primarily by laying the pipe below the level of the frost line; well consolidated bedding of clean earth or sand, under, around or over the pipe should be provided. For the efficient operation and design of transmission and distribution work, the available heat in the water shall be economically utilized and controlled. If the heat which is naturally present in water is made equate to satisfy heat losses from the system, the water shall be warmed. Where economically feasible, certain faucets on the distribution system may be kept in a slightly dripping condition so as to keep the fluid in motion and thus prevent is freezing. If found unsuitable for drinking purposes, such water may be used for heating purposes. Heat losses shall be reduced by insulation, if necessary. Any material that will catch, absorb or hold moisture shall not be used for insulation purposes. Adequate number of break pressure water tanks and air release valves shall be provided in the distribution system.

NOTE — The level of frost line is generally found to be between 0.9 m and 1.2 m below ground level in the northern regions of India, wherever freezing occurs.

4.16.4.1 *Materials for pipes*

Distribution pipes shall be made of any of the following materials conforming to Part 5 'Building Materials':

a) high density polyethylene pipes,
b) asbestos cement pipes,
c) galvanized iron pipes,
d) cast iron pipes, and
e) unplasticized PVC pipes (where it is laid before frost line).

4.16.4.2 *Materials for insulation of pipes*

The normal practice in India is to surround the pipe with straw, grass or jute wrapped over with gunny and painted with bitumen; alternatively, other materials, like 85 percent magnesia, glasswool, etc, may also be used.

4.16.4.3 *Distribution methods*

Distribution by barrels or tank trucks shall be employed, where the water requirements are temporary and small. Utmost care shall be exercised for preventing the water from being contaminated by maintaining a residual of disinfecting agent at all times. Hoses, pails and the tank shall be kept free from dust and filth during all period of operation. Where winter

temperatures are low, making frost penetration depths greater during the winter, and where adequate facilities for heating the water in the distribution system do not exist, the use of tank trucks or barrels for delivery of water shall be considered only for cold weather; during the warm weather, piping system for seasonal use may be supplemented.

4.16.4.4 In the conventional distribution system involving the use of a network of pipelines requiring no auxiliary heat, it is essential that the pipelines are buried well below the frost line. Adequate facilities for draining the pipelines shall be provided where there is a danger of frost.

4.16.4.5 *House service connections*

House service connections shall be kept operative by the use of adequate insulation at exposed places extending below the frost line. Figure 10 shows a typical arrangement for providing insulation for house service connections.

4.16.5 For detailed information on planning and designing water supply system peculiar to high altitudes and/or sub-zero temperature regions of the country, reference may be made to good practice [9-1(16)].

4.17 Guidelines to Maintenance

4.17.1 Storage tanks shall be regularly inspected and shall be cleaned out periodically, if necessary. Tanks showing signs of corrosion shall be emptied, thoroughly wire brushed to remove loose material (but not scraped), cleaned and coated with suitable bituminous compositions or other suitable anti-corrosive material not liable to impart taste or odour or otherwise contaminate the water. Before cleaning the cistern, the outlets shall be plugged to prevent debris from entering the pipes. Tanks shall be examined for metal wastage and watertightness after cleaning.

4.17.2 Record drawings showing pipe layout and valve positions shall be kept up to date and inspection undertaken to ensure that any maintenance work has not introduced cross-connections or any other undesirable feature. Any addition or alterations to the systems shall be duly recorded from time-to-time.

4.17.3 Any temporary attachment fixed to a tap or outlet shall never be left in such a position that back-siphonage of polluted water may occur into the supply system.

4.17.4 All valves shall periodically be operated to maintain free movement of the working parts.

4.17.5 All taps and ball valves shall be watertight, glands shall be made good, washers shall be replaced and the mechanism of spring operated taps and ball valves shall be repaired where required.

4.17.6 All overflow pipes shall be examined and kept free from obstructions.

4.17.7 The electrical installation shall be checked for earth continuity and any defects or deficiencies corrected in the case of hot water supply installations.

5 DRAINAGE AND SANITATION

5.1 Types of Sanitary Appliances

5.1.1 *Soil Appliances*

5.1.1.1 *Water-closet*

It shall essentially consist of a closet consisting of a bowl to receive excretory matter, trap and a flushing apparatus. It is recommended to provide ablution tap adjacent to the water-closet, preferably on right hand side wall. The various types/style of water-closets may be:

a) Squatting Indian type water closet,
b) Washdown type water closet,
c) Siphonic washdown type water closet, and
d) Universal or Anglo-Indian water closet.

5.1.1.2 *Bidet*

It is provided with hot and cold water connection. The bidet outlet should essentially connect to soil pipe in a two-pipe system.

5.1.1.3 *Urinal*

It is a soil appliance and is connected to soil pipe after a suitable trap. Urinal should have adequate provision of flushing apparatus. The various types/style of urinal may be:

a) Bowl type urinal: Flat back or Angle back,
b) Slab (single) type urinal,
c) Stall (single) type urinal,
d) Squatting plate type urinal, and
e) Syphon jet urinal with integral trap.

5.1.1.4 *Slop sink and bed pan sink*

Slop sink is a large sink of square shape. The appliance is used in hospitals installed in the nurse's station, operation theatres and similar locations for disposal of excreta and other foul waste for washing bed pans and urine bottles/pans. It is provided with a flushing mechanism.

5.1.2 *Waste Appliances*

5.1.2.1 *Washbasin*

It is of one piece construction having a combined overflow and preferably should have soap holding recess or recesses that should properly drain into the bowl. Each basin shall have circular waste hole through which the liquid content of the basin shall drain.

5.1.2.2 *Wash-trough*

It is a linear trough for simultaneous use by number of persons.

5.1.2.3 *Sink*

It is used in kitchen and laboratory for the purpose of cleaning utensils/apparatus and also serve the purpose of providing water for general usage. The sink may be made with or without overflow arrangement. The sink shall be of one piece construction including combined over flow, where provided. The sink shall have a circular waste hole into which the interiors of the sink shall drain.

5.1.2.4 *Bath tub*

Bath tub may be of enamelled steel, cast iron, gel-coated, glass fibre reinforced plastic or may be cast *in-situ*. It shall be stable, comfortable, easy to get in and out, water tight, with anti-skid base, and easy to install and maintain. The bath tub shall be fitted with overflow and waste pipe of nominal diameter of not less than 32 mm and 40 mm respectively.

5.1.2.5 *Drinking fountain*

It is a bowl fitted with a push button tap and a water bubbler or a tap with a swan neck outlet fitting. It has a waste fitting, a trap and is connected to the waste pipe.

5.1.3 The requirements of various soil appliances and waste appliances shall be in accordance with accepted standards [9-1(17)].

5.2 Drainage and Sanitation Requirements

5.2.1 *General*

There should be at least one water tap and arrangement for drainage in the vicinity of each water-closet or group of water-closet in all the buildings.

5.2.2 Each family dwelling unit on premises (abutting on a sewer or with a private sewage disposal system) shall have, at least, one water-closet and one kitchen type sink. A bath or shower shall also be installed to meet the basic requirements of sanitation and personal hygiene.

5.2.3 All other structures for human occupancy or use on premises, abutting on a sewer or with a private sewage-disposal system, shall have adequate sanitary facilities, but in no case less than one water-closet and one other fixture for cleaning purposes.

5.2.4 *For Residences*

5.2.4.1 Dwelling with individual convenience shall have at least the following fitments:

a) One bathroom provided with a tap and a floor trap;
b) One water-closet with flushing apparatus with an ablution tap; and
c) One tap with a floor trap or a sink in kitchen or wash place.

5.2.4.1.1 Where only one water-closet is provided in a dwelling, the bath and water-closet *desirably* shall be separately accommodated.

NOTE — Water-closets, unless indicated otherwise, shall be of Indian style (squatting type).

5.2.4.2 Dwellings without individual conveniences shall have the following fitments:

a) One water tap with floor trap in each tenement,
b) One water-closet with flushing apparatus and one ablution tap bath for every two tenements, and
c) One bath with water tap and floor trap for every two tenements.

5.2.5 *For Buildings Other than Residences*

5.2.5.1 The requirements for fitments for drainage and sanitation in the case of buildings other than residences shall be in accordance with Table 9 to Table 22. The following shall be, in addition, taken into consideration:

a) The figures shown are based upon one (1) fixture being the minimum required for the number of persons indicated or part thereof.
b) Building categories not included in the tables shall be considered separately by the Authority.
c) Drinking fountains shall not be installed in the toilets.
d) Where there is the danger of exposure to skin contamination with poisonous, infectious or irritating material, washbasin with eye wash jet and an emergency shower located in an area accessible at all times with the passage/ right of way suitable for access to a wheel chair, shall be provided.
e) When applying the provision of these tables for providing the number of fixtures, consideration shall be given to the accessibility of the fixtures. Using purely numerical basis may not result in an installation suited to the need of a specific building. For example, schools should be provided with toilet facilities on each floor. Similarly toilet facilities shall be provided for temporary workmen employed in any establishment according to the needs; and in any case one WC and one washbasin shall be provided.
f) All buildings used for human habitation for dwelling, work, occupation, medical care or

Table 9 Office Buildings

(*Clause* 5.2.5.1)

Sl No	Fixtures	Public Toilets		Staff Toilets	
		Male	Females	Male	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	**Executive Rooms and Conference Halls in Office Buildings**				
	Toilet suite comprising one WC, one washbasin (with optional shower stall if building is used round the clock at user's option) Pantry optional as per user requirement	Unit could be common for Male/Female or separate depending on the number of user of each facility		For individual officer rooms	
ii)	**Main Office Toilets for Staff and Visitors**				
	a) Water-closets	1 per 25	1 per 15	1 per 25	1 per 15
	b) Ablution tap with each water-closet	← 1 in each water-closet →			
	c) Urinals	Nil up to 6 1 for 7-20 2 for 21-45 3 for 46-70 4 for 71-100 Add @ 3% for 101-200 Add @ 2.5 % Over 200	—	Nil up to 6	—
	d) Washbasins	1 per 25	1 per 25	1 per 25	1 per 25
	e) Drinking water fountain	1 per 100	1 per 100	1 per 100	1 per 100
	f) Cleaner's sink	← 1 per floor →			

Table 10 Factories

(*Clause* 5.2.5.1)

Sl No	Fixtures	Offices/Visitors		Workers	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets (Workers & Staff)	1 for up to 25 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 15 2 for 16-25 3 for 26-40 4 for 41-57 5 for 58-77 6 for 78-100	1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57 5 for 58-77 6 for 78-100
	For persons 101-200 add	3%	5%	3%	5%
	For persons over 200 add	2.5%	4%	2.50%	4%
ii)	Ablution tap	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
iii)	Urinals	Nil up to 6 1 for 7-20 2 for 21-45 3 for 46-70 4 for 71-100	—	Nil up to 6 1 for 7-20 2 for 21-45 3 for 46-70 4 for 71-100	—
	For persons 101-200 add	3%		3%	
	For persons over 200 add	2.50%		2.50%	
iv)	Washbasins Washbasins in rows or troughs and taps spaced 750 mm c/c	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof
v)	Drinking water fountain	1 per every 100 or part thereof with minimum one on each floor		1 per every 100 or part thereof with minimum one on each floor	
vi)	Cleaner's sink	1 on each floor	1 on each floor	1 on each floor	1 on each floor
vii)	Showers/Bathing rooms	← As per trade requirements →			
viii)	Emergency shower and eye wash fountain	—	—	1 per every shop floor per 500 persons	

NOTE — For factories requiring workers to be engaged in dirty and dangerous operations or requiring them to being extremely clean and sanitized conditions additional and separate (if required so) toilet facilities and if required by applicable Industrial and Safety Laws and the *Factories Act* must be provided in consultation with the user.

Table 11 Cinema, Multiplex Cinema, Concerts and Convention Halls, Theatres

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Public		Staff	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets	1 per 100 up to 400 Over 400 add at 1 per 250 or part thereof	3 per 100 up to 200 Over 200 add at 2 per 100 or part thereof	1 for up to 15	1 for up to 12
ii)	Ablution tap	1 in each water-closet	1 in each water-closet	1 in each water-closet	1 in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals			
iii)	Urinals	1 per 25 or part thereof	—	Nil up to 6 1 for 7-20 2 for 21-45	—
iv)	Washbasins	1 per 200 or part thereof		1 for up to 15 2 for 16-35	1 for up to 12 2 for 13-25
v)	Drinking water fountain	← 1 per 100 persons or part thereof →			
vi)	Cleaner's sink	← 1 per floor →			
vii)	Showers/Bathing rooms	← As per trade requirements →			

NOTES

1 Some WCs may be European style if desired.

2 Male population may be assumed as two-third and female population as one-third.

Table 12 Art Galleries, Libraries and Museums

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Public		Staff	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets	1 per 200 up to 400 Over 400 add at 1 per 250 or part thereof	1 per 100 up to 200 Over 200 add at 1 per 150 or part thereof	1 for up to 15 2 for 16-35	1 for up to 12 2 for 13-25
ii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals			
iii)	Urinals	1 per 50	—	Nil up to 6 1 per 7 to 20 2 per 21-45	—
iv)	Washbasins	1 for every 200 or part thereof. For over 400, add at 1 per 250 persons or part thereof	1 for every 200 or part thereof. For over 200, add at 1 per 150 persons or part thereof	1 for up to 15 2 for 16-35	1 for up to 12 2 for 13-25
v)	Drinking water fountain	← 1 per 100 persons or part thereof →			
vi)	Cleaner's sink	← 1 per floor, *Min* →			
vii)	Showers/Bathing rooms	← As per requirements →			

NOTES

1 Some WC's may be European style if desired.

2 Male population may be assumed as two-third and female population as one-third.

Table 13 Hospitals with Indoor Patient Wards

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Patient Toilets		Staff Toilets	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC and one washbasin and shower stall	Private room with up to 4 patients		For individual doctor's/officer's rooms	
	For General Wards, Hospital Staff and Visitors				
ii)	Water-closets	1 per 8 beds or part thereof	1 per 8 beds or part thereof	1 for up to 15 2 for 16-35	1 for up to 12 2 for 13-25
iii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals			
iv)	Urinals	1 per 30 beds	—	Nil up to 6 1 for 7 to 20 2 for 21-45	—
v)	Washbasins	2 for every 30 beds or part thereof. Add 1 per additional 30 beds or part thereof		1 for up to 15 2 for 16-35	1 for up to 12 2 for 13-25
vi)	Drinking water fountain	1 per ward		1 per 100 persons or part thereof	
vii)	Cleaner's sink	1 per ward		—	
viii)	Bed pan sink	1 per ward		—	
ix)	Kitchen sink	1 per ward		—	

NOTES

1 Some WC's may be European style if desired.

2 Male population may be assumed as two-third and female population as one-third.

3 Provision for additional and special hospital fittings where required shall be made.

Table 14 Hospitals Outdoor Patient Department

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Patient Toilets		Staff Toilets	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC and one washbasin (with optional shower stall if building used for 24 h)	For up to 4 patients		For individual doctor's/officer's rooms	
ii)	Water-closets	1 per 100 persons or part thereof	2 per 100 persons or part thereof	1 for up to 15 2 for 16-35	1 for up to 12 2 for 13-25
iii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals			
iv)	Urinals	1 per 50 persons or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21-45	—
v)	Washbasins	1 per 100 persons or part thereof	2 per 100 persons or part thereof	1 for up to 15 2 for 16-35	1 for up to 12 2 for 13-25
vi)	Drinking water fountain	1 per 500 persons or part thereof		1 per 100 persons or part thereof	

NOTES

1 Some WC's may be European style if desired.

2 Male population may be assumed as two-third and female population as one-third.

3 Provision for additional and special hospital fittings where required shall be made.

Table 15 Hospitals, Administrative Buildings

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Staff Toilets	
		Male	Female
(1)	(2)	(3)	(4)
i)	Toilet suite comprising one WC and one washbasin (with optional shower stall if building used for 24 h)	For individual doctor's/officer's rooms	
ii)	Water-closets	1 per 25 persons or part thereof	1 per 15 persons or part thereof
iii)	Ablution tap	One in each water-closet 1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals	One in each water-closet
iv)	Urinals	Nil up to 6 1 for 7 to 20 2 for 21-45	—
v)	Washbasins	1 per 25 persons or part thereof	1 per 25 persons or part thereof
vi)	Drinking water fountain	1 per 100 persons or part thereof	
vii)	Cleaner's sink	1 per floor, *Min*	
viii)	Kitchen sink	1 per floor, *Min*	

NOTE Some WC's may be European style if desired.

Table 16 Hospitals Staff Quarters and Nurses Homes

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Staff Quarters		Nurses Homes	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets	1 per 4 persons or part thereof	1 per 4 persons or part thereof	1 per 4 persons or part thereof 2 for 16-35	1 per 4 persons or part thereof 2 for 13-25
ii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals			
iii)	Washbasins	1 per 8 persons or part thereof		1 per 8 persons or part thereof	
iv)	Bath (Showers)	1 per 4 persons or part thereof		1 per 4 to 6 persons or part thereof	
v)	Drinking water fountain	1 per 100 persons or part thereof, minimum 1 per floor		1 per 100 persons or part thereof, minimum 1 per floor	
vi)	Cleaner's sink	1 per Floor		1 per Floor	

NOTES

1 Some WC's may be European style if desired.

2 For independent housing units fixtures shall be provided as for residences.

Table 17 Hotels

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Public Rooms		Non-Residential Staff	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC, Washbasin with Shower or a Bath tub	Individual guest rooms with attached toilets		—	
	Guest Rooms with Common Facilities				
ii)	Water-closets	1 per 100 persons up to 400 Over 400 add at 1 per 250 or part thereof	2 per 100 persons up to 200 Over 200 add at 1 per 100 or part thereof	1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57 5 for 58-77 6 for 78-100
iii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
	1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals				
iv)	Urinals	1 per 50 persons or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21-45 3 for 46-70 4 for 71-100	—
v)	Washbasins	1 per WC/Urinal	1 per WC	1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57
vi)	Bath (Showers)	1 per 10 persons or part thereof		—	—
vii)	Cleaner's sink	1 per 30 rooms, minimum 1 per floor			
viii)	Kitchen sink	1 per kitchen			

NOTES

1 Some WC's may be European style if desired.

2 Male population may be assumed as two-third and female population as one-third.

3 Provision for additional and special fittings where required shall be made.

Table 18 Restaurants

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Public Rooms		Non-Residential Staff	
		Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water-closets	1 per 50 seats up to 200 Over 200 add at 1 per 100 or part thereof	2 per 50 seats up to 200 Over 200 add at 1 per 100 or part thereof	1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57 5 for 58-77 6 for 78-100
ii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
	1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals				
iii)	Urinals	1 per 50 persons or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21-45 3 for 46-70 4 for 71-100	—
iv)	Washbasins	1 per WC	1 per WC	1 per WC	1 per WC
v)	Cleaner's sink	1 per each restaurant			
vi)	Kitchen sink/Dish washer	1 per kitchen			

NOTES

1 Some WC's may be European style if desired.

2 Male population may be assumed as two-third and female population as one-third.

3 Provision for additional and special fittings where required shall be made.

Table 19 Schools and Educational Institutions

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Nursery School	Non-Residential		Residential	
			Boys	Girls	Boys	Girls
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Water-closets	1 per 15 pupils or part thereof	1 per 40 pupils or part thereof	1 per 25 pupils or part thereof	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
ii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
	1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals					
iii)	Urinals	—	1 per 20 pupils or part thereof	—	1 per 25 pupils or part thereof	—
iv)	Washbasins	1 per 15 pupils or part thereof	1 per 60 pupils or part thereof	1 per 40 pupils or part thereof	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
v)	Bath/Showers	1 per 40 pupils or part thereof	—	—	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
vi)	Drinking water fountain or taps	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof
vii)	Cleaner's sink				1 per each floor	

NOTES

1 Some WC's may be European style if desired.

2 For teaching staff, the schedule of fixtures to be provided shall be the same as in case of office building.

Table 20 Hostels

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Resident		Non-Resident		Visitor/Common Rooms	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water-closets	1 per 8 or part thereof	1 per 6 or part thereof	1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57 5 for 58-77 6 for 78-100	1 per 100 up to 400 Over 400 add at 1 per 250	2 per 100 up to 200 Over 200 add at 1 per 100
ii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
	1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals						
iii)	Urinals	1 per 25 or part thereof	—	Nil up to 6 1 for 7-20 2 for 21-45 3 for 46-70 4 for 71-100	—	1 per 50 or part thereof	—
iv)	Washbasins	1 per 8 persons or part thereof	1 per 6 persons or part thereof	1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57 5 for 58-77 6 for 78-100	1 per WC/Urinal	1 per WC
v)	Bath/Showers	1 per 8 persons or part thereof	1 per 6 persons or part thereof	—	—	—	—
vi)	Cleaner's sink			1 per each floor			

NOTE — Some WC's may be European style if desired.

Table 21 Fruit and Vegetable Markets

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Shop Owners		Common Toilets in Market Building		Public Toilet for Floating Population	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water-closets	1 per 8 or part thereof		1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57 5 for 58-77 6 for 78-100	1 per 50, (Minimum 2)	1 per 50, (Minimum 2)
ii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
		1 water tap with draining arrangements shall be provided in receiving/sale area of each shop and for every 50 persons or part thereof in the vicinity of water-closets and urinals					
iii)	Urinals	—	—	Nil up to 6 1 for 7-20 2 for 21-45 3 for 46-70 4 for 71-100	—	1 per 50	—
iv)	Washbasins	1 per 8 percent or part thereof		1 for up to 15 2 for 16-35 3 for 36-65 4 for 66-100	1 for up to 12 2 for 13-25 3 for 26-40 4 for 41-57	—	—
v)	Bath/Showers	1 per 8 persons or part thereof	1 per 6 persons or part thereof	—	—	1 per 50 persons	1 per 50 persons

NOTES

1 Toilet facilities for individual buildings in a market should be taken same as that for office buildings.

2 Common toilets in the market buildings provide facilities for persons working in shops and their regular visitors.

3 Special toilet facilities for a large floating population of out of town buyers/sellers, labour, drivers of vehicles for whom special toilet (public toilets).

Table 22 Airports and Railway Stations

(*Clause* 5.2.5.1)

Sl No.	Fixtures	Junction Stations, Intermediate Stations and Bus Stations		Terminal Railway and Bus Stations		Domestic and International Airports	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water-closets	3 for up to 1 000 Add 1 per additional 1 000 or part thereof	4 for up to 1 000 Add 1 per additional 1 000 or part thereof	4 for up to 1 000 Add 1 per additional 1 000 or part thereof	5 for up to 1 000 Add 1 per additional 1 000 or part thereof	Minimum 2 For 200 5 For 400 9 For 600 12 For 800 16 For 1 000 18	Minimum 2 For 200 8 For 400 15 For 600 20 For 800 26 For 1 000 29
ii)	Ablution tap	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet	One in each water-closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water-closets and urinals					
iii)	Urinals	4 for up to 1 000 Add 1 per additional 1 000	—	6 for up to 1 000 Add 1 per additional 1 000	—	1 per 40 or part thereof	—
iv)	Washbasins	1 per WC/Urinal	1 per WC	1 per WC/Urinal	1 per WC	1 per WC/Urinal	1 per WC
v)	Bath/Showers	2 per 1 000		3 per 1 000		4 per 1 000	
vi)	Drinking water fountain or taps (in common lobby for male/female)	2 per 1 000 or part thereof		3 per 1 000 or part thereof		4 per 1 000 or part thereof	
vii)	Cleaner's sink	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's	1 per toilet compartment with 3 WC's
viii)	Toilet for Disabled	1 per 4 000	1 per 4 000	1 per 4 000	1 per 4 000	1 per 4 000 (Minimum 1)	1 per 4 000 (Minimum 1)

NOTES

1 Some WC's may be European style if desired.

2 Male population may be assumed as three-fifth and female population as two-fifth.

3 Separate provision shall be made for staff and workers.

any purpose detailed in the various tables, abutting a public sewer or a private sewage disposal system, shall be provided with minimum sanitary facilities as per the schedule in the tables. In case the disposal facilities are not available, they shall be provided as a part of the building design for ensuring high standards of sanitary conditions in accordance with this section.

g) Workplaces where creches are provided, they shall be provided with one WC for 10 persons or part thereof, one washbasin for 15 persons or part thereof, one kitchen sink with floor trap for preparing food/milk preparations. The sink provided shall with a drinking water tap.

h) In all types of buildings, individual toilets and pantry should be provided for executives, and for meeting/seminar/conference rooms, etc as per the user requirement.

j) Where food is consumed indoors, water stations may be provided in place of drinking water fountains.

5.3 Materials, Fittings and Appliances

5.3.1 *Standards for Materials, Fittings and Sanitary Appliances*

All materials, fittings and sanitary appliances shall conform to Part 5 'Building Materials'.

5.3.2 *Choice of Material for Pipes*

5.3.2.1 *Salt glazed stoneware pipe*

For all sewers and drains in all soils, except where supports are required as in made-up ground, glazed stoneware pipe shall be used as far as possible in preference to other types of pipes. These pipes are particularly suitable where acid effluents or acid sub-soil conditions are likely to be encountered. Salt glazed stoneware pipes shall conform to accepted standards [9-1(18)].

5.3.2.2 *Cement concrete pipes*

When properly ventilated, cement concrete pipes with spigot and socket or collar joints present an alternative to glazed stoneware sewers of over 150 mm diameter. These shall not be used to carry acid effluents or sewage under conditions favourable for the production of hydrogen sulphide and shall not be laid in those sub-soils that are likely to affect adversely the quality or strength of concrete. Owing to the longer lengths of pipes available, the joints would be lesser in the case of cements concrete pipes. These pipes may be used for surface water drains in all diameters. Cement concrete pipes shall conform to accepted standards [9-1(19)].

5.3.2.3 *Cast iron pipes*

5.3.2.3.1 These pipes shall be used in the following situation:

a) in bed or unstable ground where soil movement is expected;

b) in-made-up or tipped ground;

c) to provide for increased strength where a sewer is laid at insufficient depth, where it is exposed or where it has to be carried on piers or above ground;

d) under buildings and where pipes are suspended in basements and like situations;

e) in reaches where the velocity is more than 2.4 m/s; and

f) for crossings of watercourses.

NOTE — In difficult foundation condition such as in the case of black cotton soil, the cast iron pipes shall be used only when suitable supporting arrangements are made.

5.3.2.3.2 It shall be noted that cast iron pipes even when given a protective paint are liable to severe external corrosion in certain soils; among such soils are:

a) soils permeated by peaty waters; and

b) soils in which the sub-soil contains appreciable concentrations of sulphates. Local experiences shall be ascertained before cast iron pipes are used where corrosive soil conditions are suspected. Where so used, suitable measures for the protection of the pipes may be resorted to as an adequate safeguard.

5.3.2.3.3 Cast iron pipes shall conform to accepted standards [9-1(20)].

5.3.2.4 *Asbestos cement pipes*

Asbestos cement pipes are commonly used for house drainage systems and they shall conform to accepted standards [9-1(21)]. They are not recommended for underground situations. However, asbestos cement pressure pipes conforming to accepted standards [9-1(21)] may be used in underground situations also, provided they are not subject to heavy superimposed loads. These shall not be used to carry acid effluents or sewage under conditions favourable for the production of hydrogen sulphide and shall not be laid in those sub-soils which are likely to affect adversely the quality or strength of asbestos cement pipes. Where so desired, the life of asbestos cement pipes may be increased by lining inside of the pipe with suitable coatings like epoxy/polyester resins etc.

5.3.2.6 *PVC pipes*

Unplasticized PVC pipes may be used for drainage

purposes; however, where hot water discharge is anticipated, the wall thickness shall be minimum 3 mm irrespective of the size and flow load.

PVC and HDPE pipes shall conform to accepted standards [9-1(23)].

NOTE — Where possible, high density polyethylene pipes (HDPE) and PVC pipes may be used for drainage and sanitation purposes, depending upon the suitability.

5.4 Preliminary Data for Design

5.4.1 *General*

Before the drainage system for a building or group of buildings is designed and constructed, accurate information regarding the site conditions is essential. This information may vary with the individual scheme but shall, in general, be covered by the following:

a) *Site Plan (see* **3.3.2***).*

b) *Drainage Plan (see* **3.3.3***).*

c) *Use* — A description of the use for which the building is intended and periods of occupation in order that peak discharges may be estimated;

d) *Nature of Waste* — While dealing with sewage from domestic premises, special problems under this head may not arise; however, note shall be taken of any possibility of trade effluents being discharged into the pipes at a future date;

e) *Outlet Connection* — The availability of sewers or other outlets;

f) *Cover* — The depth (below ground) of the proposed sewers and drains and the nature and weight of the traffic on the ground above them;

g) *Sub-soil Condition*:

1) The approximate level of the subsoil water, and any available records of flood levels shall be ascertained, as also the depth of the water table relative to all sewer connections, unless it is known to be considerably below the level of the latter;

2) In the case of deep manholes, this information will influence largely the type of construction to be adopted. The probable safe bearing capacity of the sub-soil at invert level may be ascertained in the case of a deep manhole.

3) Where work of any magnitude is to be undertaken, trial pits or boreholes shall be put at intervals along the line of the proposed sewer or drain and the data therefrom tabulated, together with any information available from previous works carried out in the vicinity. In general the information derived from trial pits is more reliable than that derived from boreholes. For a long length of sewer or drain, information derived from a few trial pits at carefully chosen points may be supplemented by that obtained from number of intermediate boreholes. Much useful information is often obtained economically and quickly by the use of a soil auger;

4) The positions of trial pits or boreholes shall be shown on the plans, together with sections showing the strata found and the dates on which water levels are recorded.

h) *Location of Other Services* — The position, depth and size of all other pipes, mains, cables, or other services, in the vicinity of the proposed work, may be ascertained from the Authority, if necessary;

j) *Reinstatement of Surfaces* — Information about the requirements of the highway authority is necessary where any part of the sewer or drain is to be taken under a highway. Those responsible for the sewer or drain shall be also responsible for the maintenance of the surface until permanently reinstated. The written consent of the highway authority to break up the surface and arrangement as to the charges thereof and the method and type of surface reinstatement shall always be obtained before any work is commenced;

k) *Diversion and Control of Traffic*

1) In cases where sewers cross roads or foot-paths, cooperation shall be maintained with the police and Authorities regarding the control and diversion of vehicular and/or pedestrian traffic as may be necessary. Access to properties along the road shall always be maintained and adequate notice shall be given to the occupiers of any shops or business premises, particularly if obstruction is likely;

2) During the period of diversion, necessary danger lights, red flags, diversion boards, caution boards, watchmen, etc, shall be provided as required by the Authority;

m) *Way-leaves (Easements)* — The individual or authority carrying out the work is responsible for negotiating way-leaves where the sewer crosses land in other ownership. The full extend and conditions of such way-leaves shall be made known to the contractor

and his employees, and prior notice of commencement of excavation shall always be given to the owners concerned, and cooperation with them shall be maintained at all stages, where sewers run across fields or open ground, the exact location of manholes shall be shown on way-leaves or easement plans. The right of access to manhole covers and the right to maintain the sewer shall be specifically included in any way-leave or easement arrangements which may be made with the owner of the land; and

n) *Damage to Buildings and Structures* — When sewer trenches have to be excavated near buildings or walls a joint inspection with the owners of the property shall be made to establish whether any damage or cracks exist before starting the work, and a properly authenticated survey and record of the condition of buildings likely to be affected shall be made. Tell tales may be placed across outside cracks and dated, and kept under observation. Un-retouched photographs taken by an independent photographer may provide useful evidence.

5.4.2 *Drainage into a Public Sewer*

Where public sewerage is available, the following information is particularly necessary and may be obtained from the Authority:

a) the position of the public sewer or sewers in relation to the proposed buildings;
b) the invert level of the public sewer;
c) the system on which the public sewers are designed (combined, separate or partially separate), the lowest level at which connection may be made to it, and the Authority in which it is vested;
d) the material of construction and condition of the sewer if connection is not to be made by the Authority;
e) the extent to which surcharge in the sewer may influence the drainage scheme;
f) whether the connection to the public sewer is made, or any part of the drain laid, by the Authority, or whether the owner is responsible for this work; if the latter, whether the Authority imposes any special conditions;
g) whether an intercepting trap is required by the Authority on the drain near the boundary of the curtilage; and
h) where manholes are constructed under roads, the approval of the Highway Authority for the type of cover to be fitted shall be obtained.

5.4.3 *Other Methods of Disposal of Sewage*

5.4.3.1 Where discharge into a public sewer is not possible, the drainage of the building shall be on a separate system. Foul water shall be disposed of by adequate treatment approved by the Authority on the site. The effluent from the plant shall be discharged into a natural watercourse or on the surface of the ground or disposed of sub-soil dispersion preferably draining to a suitable outlet channel.

5.4.3.2 In the case of dilution into a natural stream course, the quality of the effluent shall conform and the requirements of the Authority controlling the prevention of pollution of streams.

5.4.3.3 In the case of sub-soil dispersion, the requirements of the Authority for water supply shall be observed to avoid any possible pollution of local water supplies or wells.

5.4.3.4 The general sub-soil water level and the subsoil conditions shall be ascertained, including the absorptive capacity of the soil.

5.4.3.5 A sub-soil dispersion is not desirable near a building or in such positions that the ground below the foundations is likely to be affected.

5.4.3.6 Where no other method of disposal is possible, foul water may be diverted to cesspools and arrangements made with the Authority for satisfactory periodical removal and conveyance to a disposal works.

5.4.3.7 Under the separate system, drainage of the building shall be done through septic tanks of different sizes or by stabilization ponds or by any other methods approved by the Authority.

For detailed information on the design and construction of septic tanks and waste stabilization ponds, reference may be made to good practice [9-2(24)].

5.4.4 *Disposal of Surface and Sub-soil Waters*

All information which may influence the choice of methods of disposal of surface and/or sub-soil waters shall be obtained. In the absence of surface water drainage system, and if practicable and permissible, disposal into a natural water-course or soakaway may be adopted. The location and flood levels of the water course as also the requirements of the Authority controlling the river or the waterway shall be ascertained.

5.5 Planning and Design Considerations

5.5.1 *Aim*

The efficient disposal of foul and surface water from a building is of great importance to public health and is

an essential part of the construction of the building. In designing a drainage system for an individual building or a housing colony, the aim shall be to provide a system of self-cleaning conduits for the conveyance of foul, waste, surface or subsurface waters and for the removal of such wastes speedily and efficiently to a sewer or other outlet without risk of nuisance and hazard to health.

5.5.1.1 To achieve this aim a drainage system shall satisfy the following requirements:

a) rapid and efficient removal of liquid wastes without leakage;
b) prevention of access of foul gases to the building and provision for their escape from the system.
c) adequate and easy access for clearing obstructions;
d) prevention of undue external or internal corrosion, or erosion of joints and protection of materials of construction; and
e) avoidance of air locks, siphonage, proneness to obstruction, deposit and damage.

5.5.1.2 The realization of an economical drainage system is added by compact grouping of fitments in both horizontal and vertical directions. This implies that if care is taken and ingenuity brought into play when designing the original building or buildings to be drained, it is possible to group the sanitary fittings and other equipment requiring drainage; both in vertical and horizontal planes, as to simplify the drainage system and make it most economical.

5.5.1.3 Efficient and an economical plumbing system can be achieved by planning the toilets in compact grouping with the layout of the bathrooms and observing the following guidelines:

a) Placing of plumbing fixtures around an easily accessible pipe shaft; in high rise buildings the pipe shafts may have to be within the building envelope and easy provision for access panels and doors should be planned in advance, in such cases.
b) Adopting repetitive layout of toilets in the horizontal and vertical directions.
c) Avoiding any conflict with the reinforced cement concrete structure by avoiding embedding pipes in it, avoiding pipe crossings in beams, columns and major structural elements.
d) Identifying open terraces and areas subject to ingress of rainwater directly or indirectly and providing for location of inlets at each level for down takes for disposal at ground levels.
e) Avoiding crossing of services of individual property through property of other owners.
f) Planning to avoid accumulation of rain water or any backflow from sewers particularly in planned low elevation areas in a building.

5.5.2 *Layout*

5.5.2.1 *General*

Rain-water should preferably be dealt separately from sewage and sullage. Sewage and sullage shall be connected to sewers. However, storm water from the courtyard may be connected to the sewer where it is not possible to drain otherwise; after obtaining permission of the Authority.

5.5.2.2 *Additional Requirement*

The following requirements are suggested to be considered in the design of drainage system:

a) The layout shall be as simple and direct as practicable.
b) The pipes should be laid in straight lines, as far as possible, in both vertical and horizontal planes.
c) Anything that is likely to cause irregularity of flow, as abrupt changes of direction, shall be avoided.
d) The pipes should be non-absorbent, durable, smooth in bore and of adequate strength.
e) The pipes should be adequately supported without restricting movement.
f) Drains should be well ventilated, to prevent the accumulation of foul gases and fluctuation of air pressure within the pipe, which could lead to unsealing of gully or water-closet traps.
g) All the parts of the drainage system should be accessible for feasibility of inspection and practical maintenance.
h) No bends and junctions whatsoever shall be permitted in sewers except at manholes and inspection chambers.
j) Sewer drain shall be laid for self-cleaning velocity of 0.75 m/s and generally should not flow more than half-full.
k) Pipes crossing in walls and floors shall be through mild steel sleeves of diameter leaving an annular space of 5 mm around the outer diameter of the pipe crossing the wall.
m) Pipes should not be laid close to building foundation.
n) Pipes should not pass near large trees because of possibility of damage by the roots.
p) Branch connections should be swept in the direction of flow.

q) Sewer pipes should be at least 900 mm below road and at least 600 mm below fields and gardens.

r) Pipes should not pass under a building unless absolutely necessary.

Where it is necessary to lay pipes under a building, the following conditions shall be observed:

1) Pipes shall be centrifugally cast (spun) iron pressure pipe as per good practice [9-2(20)];
2) The pipe shall be laid in straight line and at uniform gradient;
3) Means of access in form of manholes/ inspection chamber shall be provided at each end, immediately outside the building; and
4) In case the pipe or any part of it is laid above the natural surface of the ground, it shall be laid on concrete supports, the bottom of which goes at least 150 mm below the ground surface.

NOTE — It is desirable that pipe/drains should not be taken through a living room or kitchen and shall preferably be taken under a staircase room or passage.

s) Consideration shall be given to alternative layouts so as to ensure that the most economical and practical solution is adopted. The possibility of alterations shall be avoided by exercising due care and forethought.

5.5.2.3 *Protection against vermin and dirt*

The installation of sanitary fittings shall not introduce crevices which are not possible to inspect and clean readily.

Pipes, if not embedded, shall be run well clear of the wall. Holes through walls to taken pipes shall be made good on both sides to prevent entry of insects. Materials used for embedding pipes shall be rodent-proof. Passage of rodents from room-to-room or from floor-to-floor shall be prevented by suitable sealing. The intermediate lengths of ducts and chases shall be capable of easy inspection. Any unused drains, sewers, etc, shall be demolished or filled in to keep them free from rodents.

All pipe shafts shall be plastered before any pipes are installed in the shaft. This will provide a smooth surface and prevent location for survival of insects and vermins.

5.5.2.4 *Choice of plumbing system*

In selecting one or more of the type of piping systems, the building and the layout of toilets; relationship with other services; acceptability to the Authority; and any special requirements of users, shall be studied.

a) *Two-pipe system*
   1) This system is ideal when the location of toilets and stacks for the WCs and waste fittings is not uniform or repetitive.
   2) In large buildings and houses with open ground and gardens the sullage water from the waste system can be usefully utilized for gardening and agriculture.
   3) In larger and multi-storied buildings, the sullage is treated within the building for re-use as makeup water for cooling towers for air conditioning system and is also used for flushing water-closets provided it has absolutely no connection with any water supply line, tank or system used for domestic and drinking supply.

b) *One-pipe system*
   1) This system is suitable for buildings where the toilet layouts and the shafts are repetitive. It requires less space, and is economical.
   2) Continuous flow of water in the pipe from waste appliances makes it less prone to blockage and makes the system more efficient.
   3) The system eliminates the need for a gully trap which requires constant cleaning.
   4) The system is ideal when the main pipes run at the ceiling of the lowest floor or in a service floor. Two-pipe system may present space and crossing problems which this system eliminates.

c) *Single stack system*
   1) The single stack system (without any vent pipe) is ideal when the toilet layouts are repetitive and there is less space for pipes on the wall.
   2) In any system so selected there should be not more than two toilet connections per floor.
   3) The system requires minimum 100 mm diameter stack for a maximum of five floors in a building.
   4) All the safeguards for the use of this system given in **5.5.2.4.1** shall be complied with.

d) *Single stack system (partially ventilated)*

The system and the applicable safeguards under this system are the same as for single stack system. The prime modification is to

connect the waste appliances, such as wash basin, bath tub or sink to a floor trap.

For detailed information regarding design and installation of soil, waste and ventilating pies, reference may be made to good practice [9-2(25)].

5.5.2.4.1 *Safeguards for single stack system*

a) as far as practicable, the fixtures on a floor shall be connected to stack in order of increasing discharge rate in the downward direction;

b) the vertical distance between the waste branch (from floor trap or from the individual appliance) and the soil branch connection, when soil pipe is connected to stack above the waste pipe, shall be not less than 200 mm;

c) depth of water seal traps from different fixtures shall be as follows:

Water closets	50 mm
Floor traps	50 mm

Other fixtures directly connected to the stack.

1)	Where attached to branch waste pipes of 75 mm dia or more	40 mm
2)	Where attached to branch waste pipes of less than 75 mm dia	75 mm

NOTE — When connection is made through floor trap, no separate seals are required for individual fixtures.

d) branches and stacks which receive discharges from WC pans should not be less than 100 mm, except where the outlet from the siphonic water closet is 80 mm, in which case a branch pipe of 80 mm may be used. For outlet of floor traps 75 mm dia pipes may be used;

e) the horizontal branch distance for fixtures from stack, bend(s) at the foot of stack to avoid back pressure as well as vertical distance between the lowest connection and the invert of drain shall be as shown in Fig. 2A; and

f) for tall buildings, ground floor appliances are recommended to be connected directly to manhole/inspection chamber.

5.5.3 *Drainage (Soil, Waste and Ventilating) Pipes*

5.5.3.1 *General considerations*

5.5.3.1.1 Drainage pipes shall be kept clear of all other services. Provisions shall be made during the construction of the building for the entry of the drainage pipes. In most cases this may be done conveniently by building sleeves or conduit pipes into or under the structure in appropriate positions. This will facilitate the installation and maintenance of the services.

5.5.3.1.2 Horizontal drainage piping should be so routed as not to pass over any equipment or fixture where leakage from the line could possibly cause damage or contamination. Drainage piping shall never pass over switch-gear or other electrical equipment. If it is impossible to avoid these areas and piping must run in these locations, then a pan or drain tray should be installed below the pipe to collect any leakage or condensation. A drain line should run from this pan to a convenient floor drain or service sink.

5.5.3.1.3 All vertical soil, waste, ventilating and anti-siphonage pipes shall be covered on top with a copper or heavily galvanized iron wire dome or cast iron terminal guards. All cast iron pipes, which are to be painted periodically, shall be fixed to give a minimum clearance of 50 mm clear from the finished surface of the wall by means of a suitable clamps.

NOTE — Asbestos cement cowls may be used in case asbestos cement pipes are used as soil pipes.

5.5.3.1.4 Drainage pipes shall be carried to a height above the buildings as specified for ventilating pipe (*see* **5.5.3.4**).

5.5.3.2 *Soil pipes*

A soil pipe, conveying to a drain, any solid or liquid filth, shall be circular and shall have a minimum diameter of 100 mm.

5.5.3.2.1 Except where it is impracticable, the soil pipe shall be situated outside the building or in suitably designed pipe shafts and shall be continued upwards without diminution of its diameter, and (except where it is unavoidable) without any bend or angle, to such a height and position as to afford by means of its open end a safe outlet for foul air. The position of the open end with its covering shall be such as to comply with the conditions set out in **5.5.3.4** relating to ventilating pipe. Even if the pipes are laid externally, the soil pipes shall not be permitted on a wall abutting a street unless the Authority is satisfied that it is unavoidable. Where shafts for pipes are provided, the cross-sectional area of the shaft shall be suitable to allow free and unhampered access to the pipes and fittings proposed to be installed in the shaft. However in no case cross-section area of the shaft shall be less than a square of one meter side. All pipe shafts shall be provided with an access door at ground level and facilities for ventilation.

5.5.3.2.2 Soil pipes, whether insider or outside the

building, shall not be connected with any rain-water pipe and there shall not be any trap in such soil pipe or between it and any drain with which it is connected.

5.5.3.2.3 Soil pipes shall preferably be of cast iron. Asbestos cement building pipes may also be used as soil pipes only above ground level.

5.5.3.2.4 The soil pipe shall be provided with heel rest bend which shall rest on sound footing, if terminating at firm ground level. When the stack is terminating at the ceiling of a floor, the bend shall be provided with sufficient structural support to cater for the stack dead weight and the thrust developed from the falling soil/ waste. Vertical stack shall be fixed at least 50 mm clear of the finished surface of the wall by means of a suitable clamps of approved type.

5.5.3.3 *Waste pipes*

Every pipe in a building for carrying off the waste or overflow water from every bath, washbasin or sink to a drain shall be of 32 mm to 50 mm diameter, and shall be trapped immediately beneath such washbasins or sink by an efficient siphon trap with adequate means for inspection and cleaning. Such traps shall be ventilated into the external air whenever such ventilation is necessary to preserve the seal of the trap. Waste pipes, traps, etc, shall be constructed of iron, lead, brass, stoneware, asbestos cement or other approved material. The overflow pipe from washbasin, sinks, etc, shall be connected with the waste pipe immediately above the trap. Vertical pipes carrying off waste water shall have a minimum diameter of 75 mm.

NOTE — Whenever washbasins and sinks have in-built overflow arrangements, there is no need to provide overflow pipes in such cases.

5.5.3.3.1 Every pipe in a building for carrying off waste water to a drain shall be taken through an external wall of the building by the shortest practicable line, and shall discharge below the grating or surface box of the chamber but above the *inlet* of a properly trapped gully. The waste pipe shall be continued upwards without any diminution in its diameter and (except when unavoidable) without any bend or angle to such a height and position as to afford by means of the open end of the waste pipe, a safe outlet for foul air, the position of the open end and its covering being such as to comply with the conditions.

5.5.3.3.2 Except where it is impracticable, the common waste pipe shall be situated outside the building and shall be continued upwards without diminution of its diameter (except where it is unavoidable) without any bend or angle being formed to such a height and position as to avoid by means of the open end a safe outlet for foul air, the position of the open end and the covering threat being such as to comply with the conditions set out in **5.5.3.4** relating to ventilating pipe.

5.5.3.3.3 If the waste pipe is of cast iron, it shall be firmly attached 50 mm clear of the finished surface of the wall by means of a suitable clamps or with properly fixed holder bats or equally suitable and efficient means.

5.5.3.4 *Ventilating pipes*

Ventilating pipes should be so installed that water can not be retained in them. They should be fixed vertically. Whenever possible, horizontal runs should be avoided. Ventilating pipe shall be carried to such a height and in such a position as to afford by means of the open end of such pipe or vent shaft, a safe outlet for foul air with the least possible nuisance.

5.5.3.4.1 The upper end of the main ventilating pipe may be continued to the open air above roof level as a separate pipe, or it may join the MSP and/or MWP above the floor level of the highest appliance. Its lower end may be carried down to join the drain, at a point where air relief may always be maintained.

5.5.3.4.2 Branch ventilating pipes should be connected to the top of the BSP and BWP between 75 mm and 450 mm from the crown of the trap.

5.5.3.4.3 The ventilating pipe shall always be taken to a point 1500 mm above the level of the eaves or flat roof or terrace parapet whichever is higher or the top of any window within a horizontal distance of 3 m. The least dimension shall be taken as a minimum and local conditions shall be taken into account. The upper end of every ventilating pipe shall be protected by means of a cowl.

5.5.3.4.4 In case the adjoining building is taller, the ventilating pipe shall be carried higher than the roof of the adjacent building, wherever it is possible.

5.5.3.4.5 The building drain intended for carrying waste water and sewage from a building shall be provided with at least one ventilating pipe situated as near as practicable to the building and as far away as possible from the point at which the drain empties into the sewer or other carrier.

5.5.3.4.6 *Size of ventilating pipe*

a) The building drain ventilating pipe shall be of not less than 75 mm diameter when, however, it is used as MSP or MWP. The upper portion, which does not carry discharges, shall not be of lesser diameter than the remaining portion;

b) The diameter of the main ventilating pipe in any case should not be less than 50 mm;

c) A branch ventilating pipe on a waste pipe in both one-and two-pipe systems shall be of not less than two-thirds the diameter of the branch waste ventilated pipe; subject to a minimum of 25 mm; and

d) A branch ventilating pipe on a soil pipe in both one-and two-pipe systems shall be not less than 32 mm in diameter.

5.5.3.5 *Design of drainage pipes*

5.5.3.5.1 *Estimation of maximum flow of sewer*

a) *Simultaneously discharge flow*

1) The maximum flow in a building drain or a stack depends on the probable maximum number of simultaneously discharging appliances. For the calculation of this peak flow certain loading factors have been assigned to appliances in terms of fixture units, considering their probability and frequency of use. These fixture unit values are given in Table 23.

2) For any fixtures not covered under Table 23, Table 24 may be referred to for deciding their fixture unit rating depending on their drain or trap size.

3) From Tables 23 and 24, the total load on any pipe in terms of fixtures units may be calculated knowing the number and type of appliances connected to this pipe.

4) For converting the total load in fixture units to the peak flow in litres per minute, Fig. 13 is to be used.

5) The maximum number of fixture units that are permissible various recommended pipe size in the drainage system are given in Tables 25 and 26.

6) Results should be checked to see that the soil, waste and building sewer pipes are not reduced in diameter in the direction of flow. Where appliances are to be added in fixture, these should be taken into account in assessing the pipe sizes by using the fixture units given in Tables 23 and 24.

b) *Maximum discharge flow* — The maximum rate of discharge flow shall be taken as thrice the average rate, allowance being made in addition for any exceptional peak discharges. A good average rule is to allow for a flow of liquid wastes from buildings at the rate of 3 litres per minute per 10 persons.

5.5.3.5.2 *Gradients*

5.5.3.5.2.1 The discharge of water through a domestic drain is intermittent and limited in quantity and, therefore, small accumulations of solid matter are liable to form in the drains between the building and the public sewer. There is usually a gradual shifting of these deposits as discharges take place. Gradients should be sufficient to prevent these temporary accumulations building up and blocking the drains.

Table 23 Fixture Units for Different Sanitary Appliances or Groups

(*Clause* 5.5.3.5.1)

Sl No.	Type of Fixture	Fixture Unit Value as Load Factors
(1)	(2)	(3)
i)	One bathroom group consisting of water-closet, washbasin and bath tub or shower stall:	
	a) Tank water-closet	6
	b) Flush-valve water-closed	8
ii)	Bath tub[1)]	3
iii)	Bidet	3
iv)	Combination sink-and-tray (drain board)	3
v)	Drinking fountain	½
vi)	Floor traps[2)]	1
vii)	Kitchen sink, domestic	2
viii)	Wash basin, ordinary[3)]	1
ix)	Wash basin, surgeon's	2
x)	Shower stall, domestic	2
xi)	Showers (group) per head	3
xii)	Urinal, wall lip	4
xiii)	Urinal, stall	4
xiv)	Water-closet, tank-operated	4
xv)	Water-closet, valve-operated	8

[1)] A shower head over a bath tub does not increase the fixture unit value.

[2)] Size of floor trap shall be determined by the area of surface water to be drained.

[3)] Washbasins with 32 mm and 40 mm trap have the same load value.

Table 24 Fixture Unit Values for Fixtures Based on Fixture Drain on Trap Size

(*Clause* 5.5.3.5.1)

Sl No.	Fixture Drain on Trap Size	Fixture Unit Value
(1)	(2)	(3)
i)	32 mm and smaller	1
ii)	40 mm	2
iii)	50 mm	3
iv)	65 mm	4
v)	80 mm	5
vi)	100 mm	6

Table 25 Maximum Number of Fixture Units that can be Connected to Branches and Stocks

(*Clause* 5.5.3.5.1)

Sl No.	Diameter of Pipe	Maximum Number of Fixture Units[1] that can be Connected			
		Any Horizontal Fixture Branch[2]	One Stack of 3 Storeys in Height or 3 Intervals	More Than 3 Storeys in Height	
				Total for Stack	Total at One Storey or Branch Interval
	mm				
(1)	(2)	(3)	(4)	(5)	(6)
i)	30	1	2	2	1
ii)	40	3	4	8	2
iii)	50	6	10	24	6
iv)	65	12	20	42	9
v)	75	20	30	60	16
vi)	100	160	240	500	90
vii)	125	360	540	1 100	200
viii)	150	620	960	1 900	350
ix)	200	1 400	2 200	3 600	600
x)	250	2 500	3 800	5 600	1 000
xi)	300	3 900	6 000	8 400	1 500
xii)	375	7 000	- -	—	—

[1] Depending upon the probability of simultaneous use of appliances considering the frequency of use and peak discharge rate.

[2] Does not include branches of the building sewer.

Table 26 Maximum Number of Fixture Units that can be Connected to Building Drains and Sewers

(*Clause* 5.5.3.5.1)

Sl No.	Diameter of Pipe	Maximum Number of Fixture Units that can be Connected to Any Portion[1] of the Building Drain or the Building Sewer for Gradient			
	mm	1/200	1/100	1/50	1/25
(1)	(2)	(3)	(4)	(5)	(6)
i)	100	—	180	216	250
ii)	150	—	700	840	1 000
iii)	200	1 400	1 600	1 920	2 300
iv)	250	2 500	2 900	3 300	4 200
v)	300	3 900	4 600	5 600	6 700
vi)	375	7 000	8 300	10 000	12 000

[1] Includes branches of the building sewer.

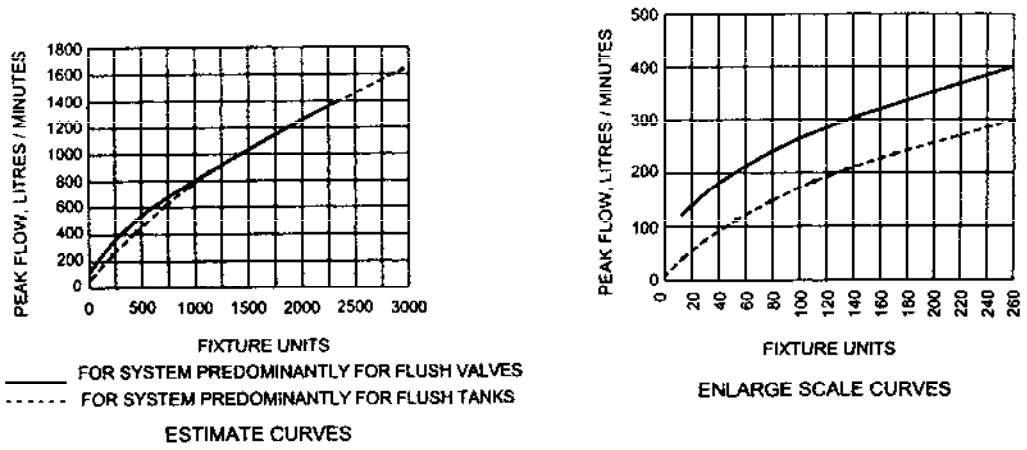


FIG. 13 PEAK FLOW LOAD CURVES

5.5.3.5.2.2 When flow occurs in drain piping, it should not entirely fill the cross-section of the pipe under flow condition. If the pipe were to flow full, pressure fluctuations would occur which could possibly destroy the seal of the traps within the building. Normally, the sewer shall be designed for discharging the peak flow as given in **5.5.3.5.1**, flowing half-full with a minimum self-cleansing velocity of 0.75 m/s. The approximate gradients which give this velocity for the sizes of pipes likely to be used in building drainage and the corresponding discharges when following half-full are given in Table 27.

5.5.3.5.2.3 In cases where it is practically not possible to conform to the ruling gradients, a flatter gradient may be used, but the minimum velocity in such cases shall on no account be less than 0.61 m/s and adequate flushing should be done.

NOTE — Where gradients are restricted, the practice of using a pipe of larger diameter than that required by the normal flow, in order to justify laying at a flatter gradient does not result in increasing the velocity of flow, further this reduces the depth of flow and thus for this reasons the above mentioned practice should be discouraged.

5.5.3.5.2.4 On the other hand, it is undesirable to employ gradients giving a velocity of flow greater than 2.4 m/s. Where it is unavoidable, cast iron pipes shall be used. The approximate gradients, which give a velocity of 2.4 m/s for pipes of various sizes and the corresponding discharge when flowing half-full are given in Table 27.

5.5.3.5.2.5 The discharge values corresponding to nominal diameter and gradient given in Table 27 are based on Manning's formula ($n = 0.015$).

NOTE — Subject to the minimum size of 100 mm, the sizes of pipes shall be decided in relation to the estimated quantity of flow and the available gradient.

Table 27 Different Dia Pipes Giving Velocity and Corresponding Discharge at Minimum and Maximum Gradient

(*Clauses* 5.5.3.5.2.2, 5.5.3.5.2.4, 5.5.3.5.2.5)

Sl No.	Diameter	Minimum Gradient (Velocity: 0.75 m/s)	Discharge at the Minimum Gradient	Maximum Gradient (Velocity: 2.4 m/s)	Discharge at the Maximum Gradient
	mm		(m^3/min)		(m^3/min)
(1)	(2)	(3)	(4)	(5)	(6)
i)	100	1 in 57	0.18	1 in 5.6	0.59
ii)	150	1 in 100	0.42	1 in 9.7	1.32
iii)	200	1 in 145	0.73	1 in 14	2.40
iv)	230	1 in 175	0.93	1 in 17	2.98
v)	250	1 in 195	1.10	1 in 19	3.60
vi)	300	1 in 250	1.70	1 in 24.5	5.30

5.5.3.6 *Drain appurtenances*

5.5.3.6.1 *Trap*

All traps shall be protected against siphonage and back pressure ensuring access to atmospheric air for air circulation and preserving the trap seal in all conditions.

5.5.3.6.1.1 A trap may be formed as an integral trap with the appliance during manufacture or may be a separate fitting called an attached trap which may be connected to the waste outlet of the appliance.

5.5.3.6.1.2 Traps should always be of a self-cleansing pattern. A trap, which is not an integral part of an appliance, should be directly attached to its outlet and the pipe should be uniform throughout and have a smooth surface.

5.5.3.6.1.3 The trap should have minimum size of outlet/exit, same as that of largest waste inlet pipe.

5.5.3.6.1.4 Traps for use in domestic waste installations and all other traps should be conveniently accessible and provided with cleansing eyes or other means of cleaning.

5.5.3.6.1.5 The minimum internal diameter for sanitary appliances shall be as follows:

Sanitary Appliance		*Minimum Internal Diameter of Waste Outlet* mm
Soil appliances		
a)	Indian and European type water-closets	100
b)	Bed pan washers and slop sinks	100
c)	Urinal with integral traps	75
d)	Stall urinals (with not more than 120 mm of channel drainage)	50
e)	Lipped urinal small/large	40
Waste appliances		
f)	Drinking fountain	25
g)	Wash basin	32
h)	Bidets	32
j)	Domestic sinks and baths	40
k)	Shower bath trays	40
m)	Domestic bath tubs	50
n)	Hotel and canteen sinks	50
p)	Floor traps (outlet diameter)	65

5.5.3.6.2 *Floor drains*

All toilets/bathrooms in a building desirably should be provided with floor drains to facilitate cleaning.

5.5.3.6.2.1 Floor drains shall connect into a trap so constructed that it can be readily cleaned and of a size to serve efficiently the purpose for which it is intended. The trap shall be either accessible from the floor drain or by a separate cleanout within the drain.

5.5.3.6.2.2 Floor drain also receives, waste piping which does not connect to the sanitary system, known

as indirect waste. This discharge from an indirect waste should be conveyed into a water supplied, trapped and vented floor drain.

5.5.3.6.2.3 Floor drain should be provided in mechanical equipment rooms, where pumps, boilers, water chillers, heat exchangers and other air conditioning equipments are periodically drained for maintenance and repair. Boiler requires drain at safety relief valve discharge.

5.5.3.6.2.4 Strategically floor drains are required to be located in buildings with wet fire protection sprinkler systems to drain water in case of activation of sprinkler heads.

5.5.3.6.3 *Cleanouts*

The cleanout provides access to horizontal and vertical lines and stacks to facilitate inspection and means to remove obstructions common to all piping systems, such as solid objects, greasy wastes, hair and the like.

5.5.3.6.3.1 Cleanouts in general should be gas and water-tight, provide quick and easy plug removal, allow ample space for rodding tools, have means of adjustments to finished floor level, be attractive and be designed to support whatever load is directed over them.

5.5.3.6.3.2 Waste lines are normally laid beneath the floor slab at a sufficient distance to provide adequate back-fill over the joints. Cleanouts are then brought up to floor level grade by pipe extension pieces.

5.5.3.6.3.3 The size of the cleanout within a building should be the same size as the piping up to 100 mm. For larger size piping 100 mm cleanouts are adequate for their intended purpose.

5.5.3.6.3.4 Cleanouts are suggested to be provided at the following locations:

a) Inside the building at a point of exit, Y junction branch or a trap.
b) At every change of direction greater than 45°.
c) At the base of all stacks.
d) At the horizontal header, receiving vertical stacks and serving the purpose of offset header.

5.5.4 *Indirect Wastes*

5.5.4.1 *General*

Waste, overflow and drain pipes from the following types of equipment shall not be connected into any drainage system directly to prevent backflow from the drainage system into the equipment/installation:

a) *Plumbing and kitchen appliances.*
   1) Underground or overhead water tanks.
   2) Drinking water fountains.
   3) Dishwashing sinks and culinary sinks used for soaking and preparation of food.
   4) Cooling counters for food and beverages.
   5) Kitchen equipment for keeping food warm.
   6) Pressure drainage connections from equipment.
b) *Air conditioning, heating and other mechanical equipments*
   1) Air handling equipment.
   2) Cooling tower and other equipments.
   3) Condensate lines from equipments.
   4) Storage tanks.
   5) Condensate lines.
   6) Boiler blow down lines.
   7) Steam trap drain lines.
c) *Laboratories and other areas*
   1) Water stills.
   2) Waste from laboratory in specified sinks.
   3) Sterlizers and similar equipments.
   4) Water purification equipments.

5.5.4.2 *Indirect waste receptors*

All plumbing fixtures or other receptors receiving the discharge of indirect waste pipes shall be of such shape and capacity as to prevent splashing or flooding and shall be located where they are readily accessible for inspection and cleaning.

5.5.4.3 *Pressure drainage connections*

Indirect waste connections shall be provided for drains, overflows or relief vents from the water supply system, and no piping or equipment carrying wastes or producing wastes or other discharges under pressure shall be directly connected to any part of the drainage system.

The above shall not apply to any approved sump pump or to any approved plumbing fixture discharging pressurized waste or device when the Authority has been satisfied that the drainage system has the capacity to carry the waste from the pressurized discharge.

5.5.5 *Special Wastes*

5.5.5.1 *General*

Wastes having characteristics which may be detrimental to the pipes in which it is disposed as well as to the persons handling it. Such wastes used in a building need to be specially identified and a suitable and safe method of its disposal installed to ensure that the piping system is not corroded nor the health and safety of the occupants is affected in any way.

Whenever the occupant or the user of any wastes is unaware of the dangers of the consequences of disposing the waste, he shall be made aware of the dangers of his action along with providing suitable warning and instruction for correct disposal be provided to him.

Piping system for all special wastes should be separate and independent for each type of waste and should not be connected to the building drainage system. Other applicable provisions for installation of soil and waste pipe system shall be however be followed.

5.5.5.2 *Laboratory wastes*

A study of the possible chemical and corrosive and toxic properties of wastes handled and disposed off in a laboratory need to be ascertained in advance. The relevant statutory rules and regulation regarding the method of disposal of strong and objectionable wastes shall be followed.

All sinks, receptacles, traps, pipes, fittings and joints shall of materials resistant to the liquids disposed off in the system.

In laboratories for educational, research and medical institutions, handling mildly corrosive and toxic wastes, they may be neutralized in chambers using appropriate neutralizing agents. The chamber shall be provided with chambers at inlet and outlet for collecting samples of the incoming and outgoing waste for monitoring its characteristics.

5.5.5.3 *Infected wastes*

Infected liquid wastes are generated in hospitals from patient excreta; operation theatres; laboratories testing samples of stools, urine, blood, flesh; etc which shall not be disposed off into the drainage system. Such waste shall be collected separately and pre-treated before disposal into the building drainage system.

Soiled and linen from infectious patients needs to be collected from the respective areas of the hospital in separate linen bins and pre-washed and sterilized in the laundry before final wash in the hospital laundry. Liquid wastes from the washing operations shall be neutralized to prevent any cross contamination before disposal in the building's drainage system.

5.5.5.4 *Research laboratory wastes*

Research laboratories conducting research in all areas of science and technology, for example chemical industry, pharmacy, metallurgy, bio-sciences, agriculture, atomic energy, medicine, etc, shall follow the established procedures laid down by statutory bodies to handle, treat and dispose wastes which are highly toxic, corrosive, infectious, inflammable, explosive and having bacterial cultures, complex organic and inorganic chemicals. Such wastes shall not be disposed off in a building drainage system or the city sewerage system unless they are pre-treated and meet the disposal criteria in accordance with the relevant rules/regulations.

5.5.6 *Grease Traps*

Oil and grease is found in wastes generated from kitchens in hotels, industrial canteens, restaurant, butcheries, some laboratories and manufacturing units having a high content of oil and greases in their final waste.

Waste exceeding temperature of 60^0 C should not be allowed in the grease trap. When so encountered it may be allowed to cool in a holding chamber before entering the grease trap.

Oil and greases tend to solidify as they cool within the drainage system. The solidified matter clogs the drains and the other matter in the waste stick to it due to the adhesion properties of the grease. Oil and greases are lighter than water and tend to float on the top of the waste water.

Grease traps shall be installed in building having the above types of wastes. In principle the grease laden water is allowed to retain in a grease trap which enables any solids to be settled or separated for manual disposal. The retention time allows the incoming waste to cool and allow the grease to solidify. The clear waste is then allowed to discharge into the building's drainage system.

5.5.7 *Oil Interceptors*

Oils and lubricants are found in wastes from vehicle service stations, workshops manufacturing units whose waste may contain high content of oils. Oils, for example, petroleum, kerosene and diesel used as fuel, cooking, lubricant oils and similar liquids are lighter than water and thus float on water in a pipe line or in a chamber when stored. Such oils have a low ignition point and are prone to catch fire if exposed to any flame or a spark and may cause explosion inside or outside the drainage system. The flames from such a fire spread rapidly if not confined or prevented at the possible source. Lighter oils and lubricants are removed from the system by passing them through an oil interceptor/petrol gully. They are chambers in various compartments which allow the solids to settle and allow the oils to float to the top. The oil is then decanted in separate containers for disposal in an approved manner. The oil free waste collected from the bottom of the chamber is disposed in the building drainage system.

5.5.8 *Radioactive Waste*

Scientific research institutions, hospital and many types

of manufacturing processes use radio active material in form of radio isotopes and other radio active sources for their activities. Manufacture, sale, use and disposal of radio active material is regulated by the statutory rules and regulation. Proposal for usage and disposal of radio active materials shall be done in consultation with and prior permission of the Authority by the users of the materials. No radio active material shall be disposed off in any building drainage system without the authorization of the Authority.

5.5.9 *Special Situations of Waste Water Disposal*

Buildings may generate uncontaminated waste water from various sources continuously, intermittently or in large volumes for a short time, for example, emptying any water tanks or pools, testing fire and water lines for flow conditions, etc. Connections from all such sources shall be made to the building drainage system indirectly through a trap. It should be ensured in advance that the building drain or a sump with a pump has the capacity to receive to rate of flow. In case the capacity is less the rate of discharge from the appliances should be regulated to meet the capacity of the disposal. Under no circumstances shall any waste water described above shall be disposed off in any storm water drains.

5.5.10 *Manholes*

5.5.10.1 *General*

A manhole or inspection chamber shall be capable of sustaining the loads which may be imposed on it, exclude sub-soil water and be water-tight. The size of the chamber should be sufficient to permit ready access to the drain or sewer for inspection, cleaning and rodding and should have a removable cover of adequate strength, constructed of suitable and durable material. Where the depth of the chamber so requires, access rungs, step irons, ladders or other means should be provided to ensure safe access to the level of the drain or sewer. If the chamber contains an open channel, benching should be provided having a smooth finish and formed so as to allow the foul matter to flow towards the pipe and also ensure a safe foothold.

No manhole or inspection chamber shall be permitted inside a building or in any passage therein. Further, ventilating covers shall not be used for domestic drains. At every change of alignment, gradient or diameter of a drain, there shall be a manhole or inspection chamber. Bends and junctions in the drains shall be grouped together in manholes as far as possible.

5.5.10.2 *Spacing of manholes*

The spacing of manholes for a given pipe size should be as follows:

Pipe Diameter mm	*Spacing of Manhole* m
a) Up to 300	45
b) 301 to 500	75
c) 501 to 900	90
d) Beyond 900	Spacing shall depend upon local condition and shall be gotten approved by the Authority

Where the diameter of a drain is increased, the crown of the pipes shall be fixed at the same level and the necessary slope given in the invert of the manhole chamber. In exceptional cases and where unavoidable, the crown of the branch sewer may be fixed at a lower level, but in such cases the peak flow level of the two sewers shall be kept the same.

5.5.10.3 *Size of manhole*

The manhole or chamber shall be of such size as will allow necessary examination or clearance of drains. The size of manhole shall be adjusted to take into account any increase in the number of entries into the chamber.

5.5.10.3.1 Manholes may be rectangular, arch or circular type. The minimum internal size of manholes, chambers (between faces of masonry) shall be as follows:

a) *Rectangular Manholes*

1) For depths less than 0.90 m	900 mm × 800 mm
2) For depths from 0.90 m and up to 2.5 m	1 200 mm × 900 mm

b) *Arch Type Manholes*

a) For depths of 2.5 m and above	1 400 mm × 900 mm

NOTE — The width of manhole chamber shall be suitably increased more than 900 mm on bends, junctions or pipes with diameter greater than 450 mm so that benching width in either side of channel is minimum 200 mm.

c) *Circular Manholes*

1) For depths above 0.90 m and upto 1.65 m	900 mm diameter
2) For depths above 1.65 m and upto 2.30 m	1 200 mm diameter
3) For depths above 2.30 m and upto 9.00 m	1 500 mm diameter
4) For depths above 9.00 m and upto 14.00 m	1 800 mm diameter

NOTES

1 In adopting the above sizes of chambers, it should be ensured that these sizes accord with full or half bricks with standard thickness of mortar joints so as to avoid wasteful cutting of bricks.

2 The sizes of the chambers may be adjusted to suit the availability of local building materials and economics of construction.

3 The access shaft shall be corbelled inwards on three sides at the top to reduce its size to that of the

cover frame to be fitted or alternatively the access shaft shall be covered over by a reinforced concrete slab of suitable dimensions with an opening for manhole cover and frame.

5.5.10.4 *Construction*

5.5.10.4.1 *Excavation*

The manhole shall be excavated true to dimensions and levels as shown on the plan. The excavation of deep manholes shall be accompanied with safety measures like timbering, staging, etc. In areas where necessary, appropriate measures for dewatering should be made.

5.5.10.4.2 *Bed Concrete*

The manhole shall be built on a bed of concrete 1:4:8 (1 cement: 4 coarse sand: 8 graded stone aggregate 40 mm nominal size). The thickness of bed concrete shall be at least 150 mm for manholes upto 0.9 m in depth, at least 200 mm for manholes from 0.90 m upto 2.5 m in depth and at least 300 mm for manholes of greater depth, unless the structural design demands higher thickness.

This thickness may be verified considering the weight of wall, cover, the wheel loads, impact of traffic which are transmitted through cover and the shaft walls and for water pressure, if any. In case of weak soil, special foundation as suitable shall be provided

5.5.10.4.3 *Brickwork*

The thickness of walls shall be designed depending upon its shape and taking onto account all loads coming over it, including earth pressure and water pressure.

Generally the brickwork shall be with first class bricks in cement mortar 1:5 (1 cement: 5 coarse sand). All brickwork in manhole chambers and shafts shall be carefully built in English Bond, the jointing faces of each brick being well "buttered" with cement mortar before laying, so as to ensure a full joint. The construction of walls in brickwork shall be done in accordance with good practice [9-1(26)].

For various depths the recommended thickness of wall may be as follows:

Depth of the Chamber	*Thickness of Wall*
a) Upto 2.25 m	200 mm (one brick length)
b) From 2.25 m upto 3.0 m	300 mm (one and half brick length)
c) From 3.00 m upto 5.0 m	400 mm (two brick length)
d) From 5.00 m upto 9.0 m	500 mm (two and half brick length)
e) Above 9.00 m	600 mm (three brick length)

The actual thickness in any case shall be calculated on the basis of engineering design. Typical sections of the manholes are illustrated in Fig. 14, 15 and 16.

NOTES

1 Rich mix of cement mortar, not weaker than 1:3, should be used in brick masonry, where sub-soil water conditions are encountered.

2 For arched type of manholes, the brick masonry in arches and arching over pipes shall be in cement mortar 1:3.

5.5.10.4.4 *Plastering*

The wall shall be plastered (15 mm, *Min*) both inside and outside within cement mortar 1:3 and finished smooth with a coat of neat cement. Where sub-soil water conditions exit, a richer mix may be used and it shall further waterproofed with addition of approved waterproofing compound in a quantity as per manufacturer specifications.

All manholes shall be so constructed as to be water-tight under test.

All angles shall be rounded to 75 mm radius and all rendered internal surface shall have hard impervious finish obtained using a steel trowel.

5.5.10.4.5 *Channels and benching*

These shall be semi-circular in the bottom half and of diameter equal to that of the sewer. Above the horizontal diameter, the sides shall be extended vertically 50 mm above the crown of sewer pipe and the top edge shall be suitably rounded off. The branch channels shall also be similarly constructed with respect to the benching, but at their junction with the main channel an appropriate fall, if required suitably rounded off in the direction of flow in the main channel shall be given.

The channel/drain and benching at the bottom of the chamber shall be done in cement concrete 1:2:4 and subsequently plastered with cement mortar of 1:2 proportion or weaker cement mortar with a suitable waterproofing compound and finished smooth, to the grade (where required). The benching at the sides shall be carried up in such a manner as to provide no lodgment for any splashing in case of accidental flooding of the chamber.

Channels shall be rendered smooth and benchings shall have slopes towards the channel.

5.5.10.4.6 *Rungs*

Rungs shall be provided in all manholes over 0.8 m in depth and shall be of preferably of cast iron and of suitable dimensions, conforming to accepted standards [9-1(27)]. These rungs may be set staggered in two vertical rungs which may be 300 mm apart horizontally as well as vertically and shall project a minimum of

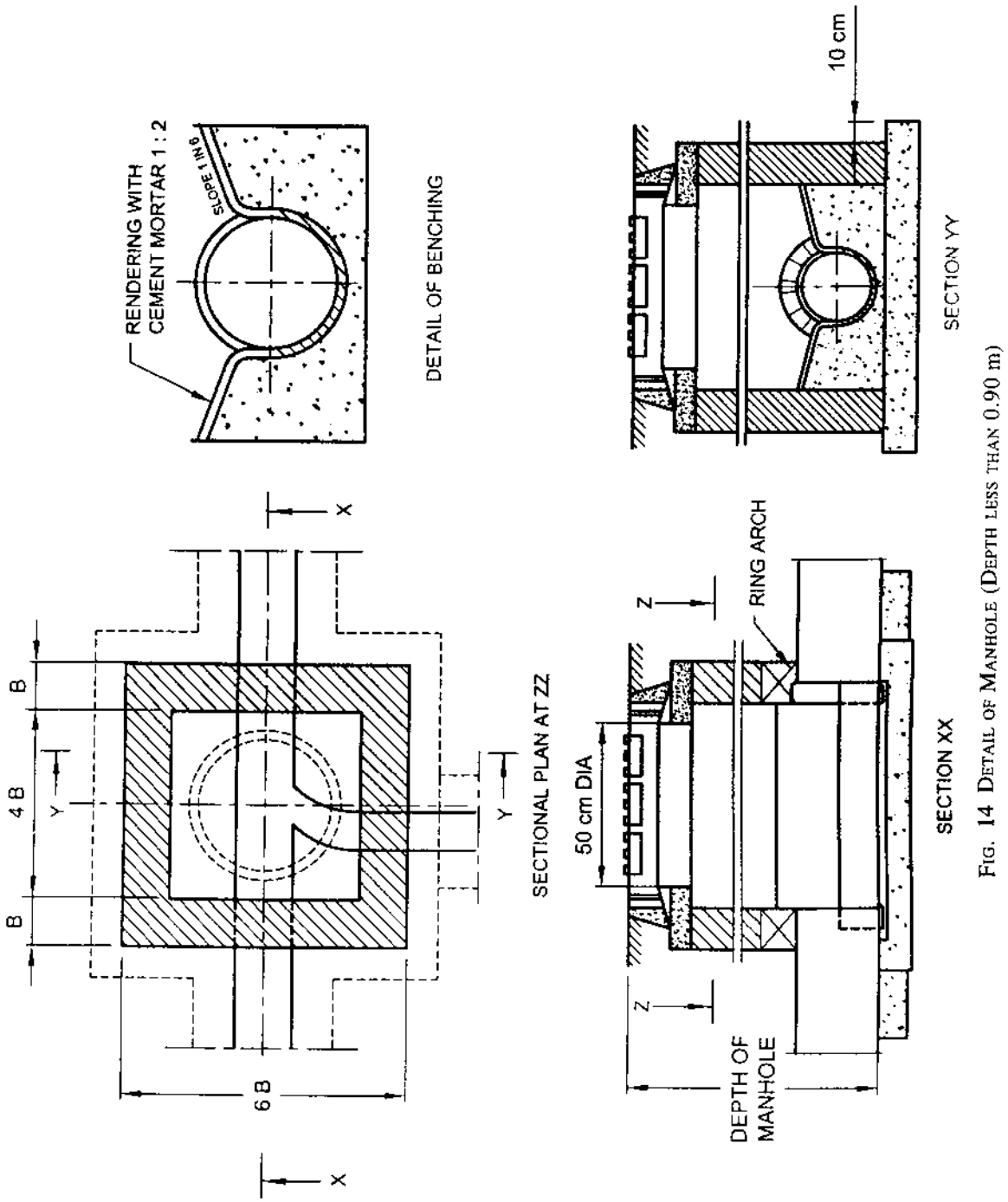
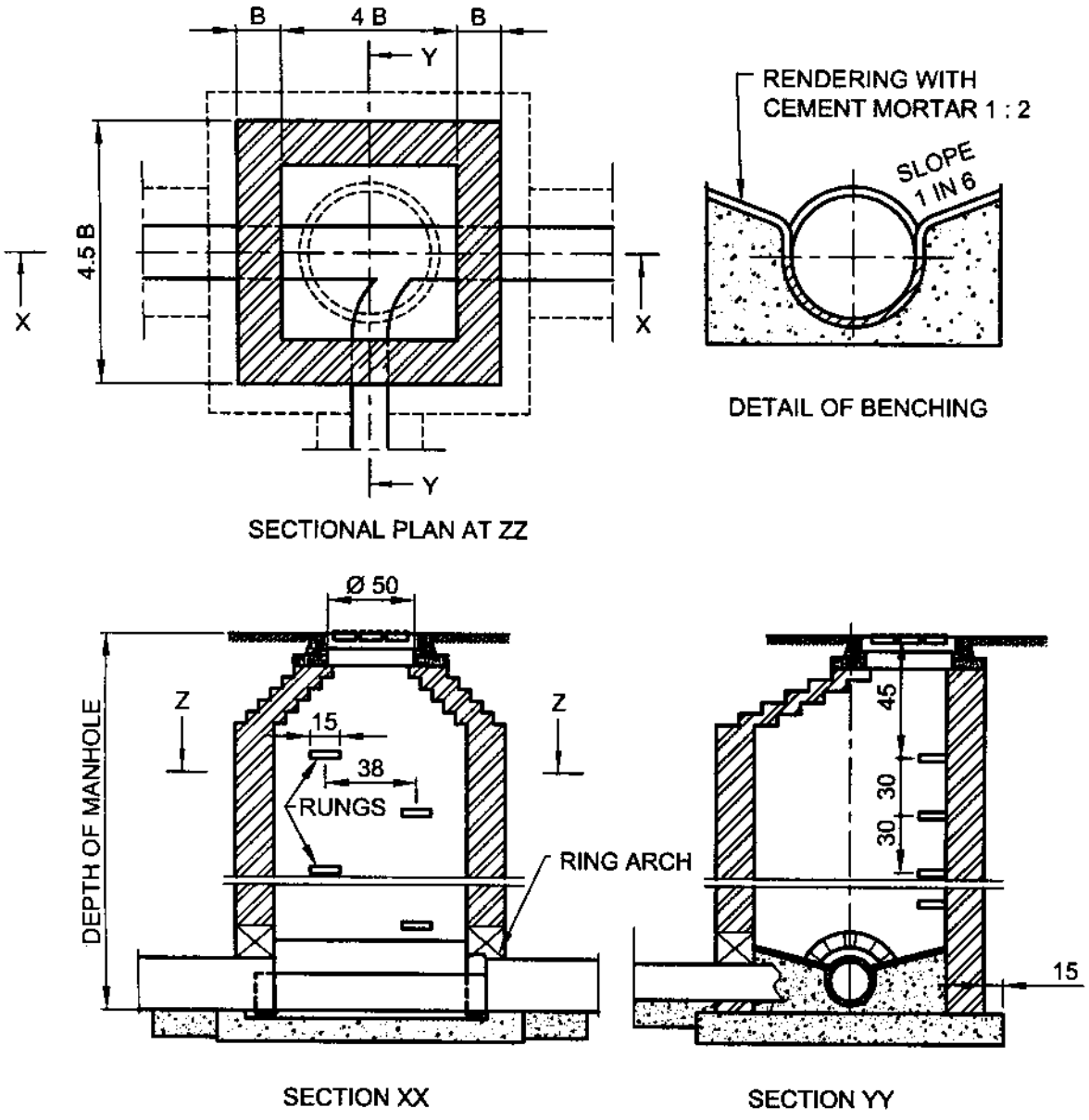
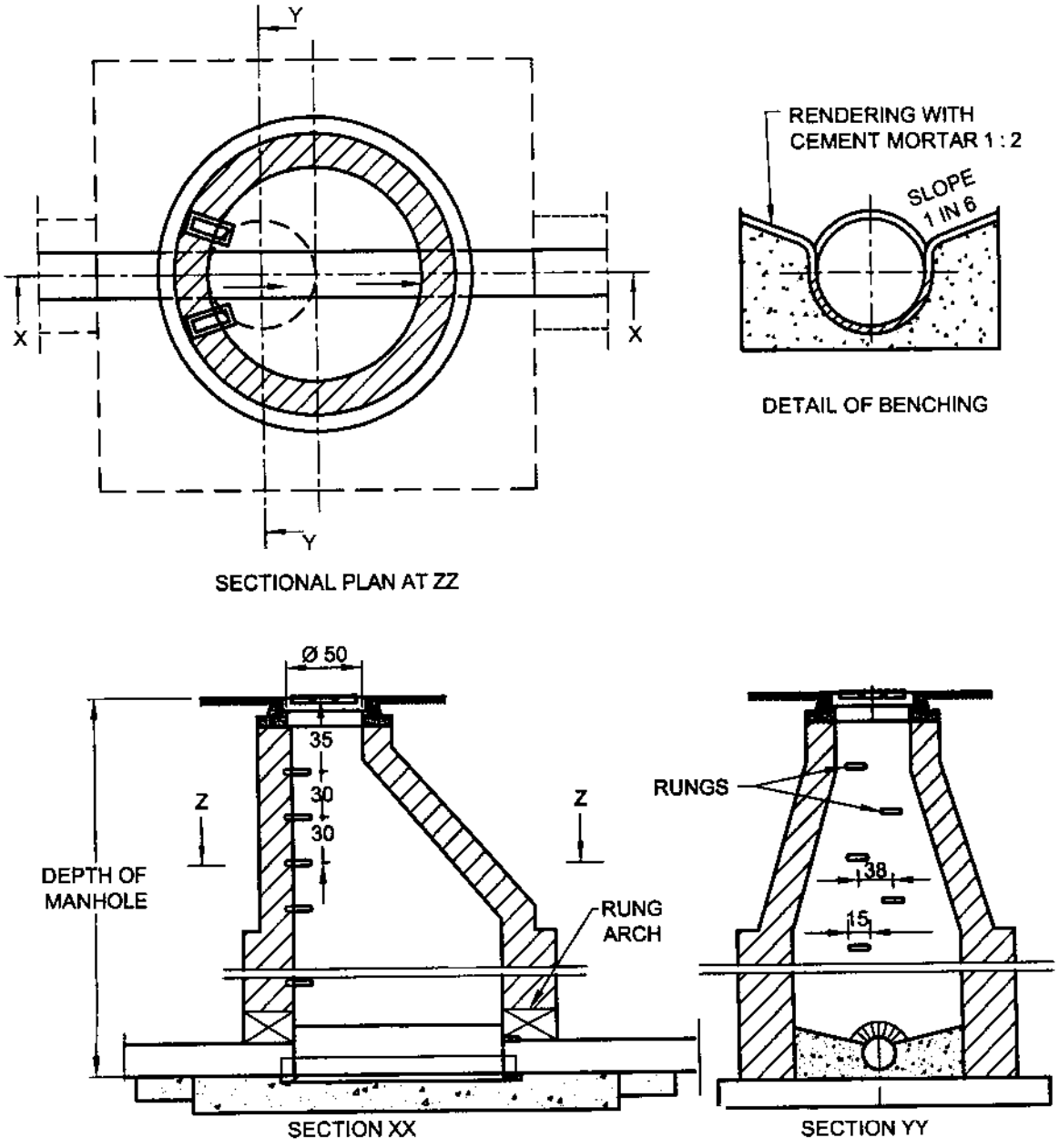


FIG. 14 DETAIL OF MANHOLE (DEPTH LESS THAN 0.90 m)



All dimensions in centimetres.

FIG. 15 DETAIL OF MANHOLE (DEPTH FROM 0.9 m AND UP TO 2.5 m)



All dimensions in centimetres.

FIG. 16 DETAIL OF MANHOLE (DEPTH 2.5 m AND ABOVE)

100 mm beyond the finished surface if the manhole wall. The top rung shall be 450 mm below the manhole cover and the lowest not more than 300 mm above the benching.

5.5.10.4.7 *Manhole covers and frames*

The size of manhole covers shall be such that there shall be a clear opening of at least 500 mm in diameter for manholes exceeding 0.90 m in depth. The manhole covers and frames are used they shall conform to accepted standards [9-1(28)].

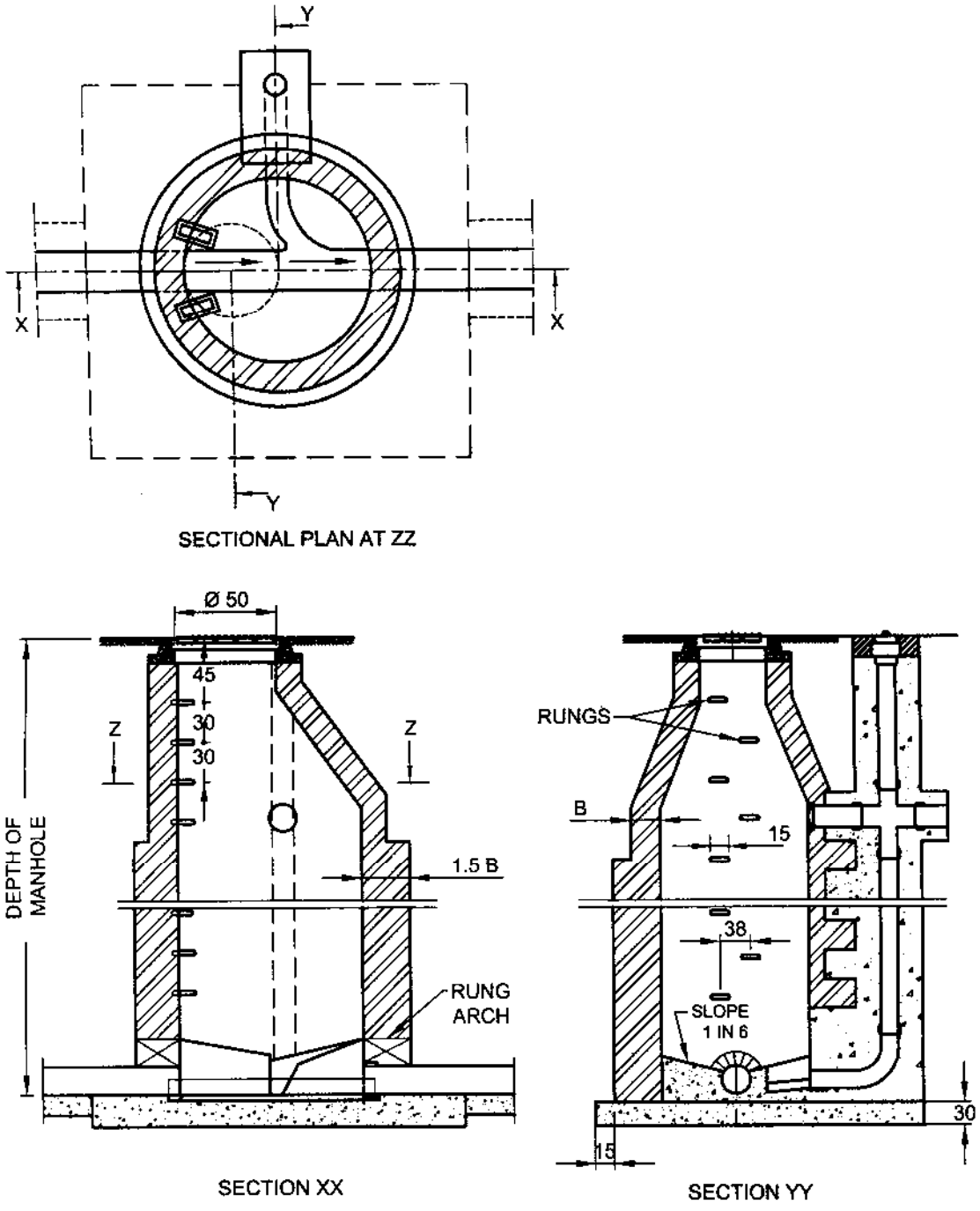
The frame of manhole shall be firmly embedded to concrete alignment and level in plain concrete on the top of masonry.

5.5.10.5 *Drop manhole*

Where it is uneconomic or impracticable to arrange the connection within 600 mm height above the invert of

the manholes, the connection shall be made by constructing a vertical shaft outside the manhole chamber, as shown in Fig. 17. If the difference in level between the incoming drain and the sewer does not exceed 600 mm, and there is sufficient room in the manhole, the connecting pipe may be directly brought through the manhole wall and the fall accommodated by constructing a ramp in the benching of the manhole.

For detailed information regarding manholes in sewerage system, reference may be made to good practice [9-1(29)].



NOTE — Wall thickness have been indicated in brick length to provide for use of modular bricks or traditional bricks. In the Fig. B = one brick length, $1.5B$ = one and a half brick length etc.

All dimensions in centimetres.

FIG. 17 DROP MANHOLE

5.5.11.1 *General*

The object of storm water drainage is to collect and carry, the rain-water collected within the premises of the building, for suitable disposal.

5.5.11.2 *Design factors*

Estimate of the quantity that reaches the storm water drain depends on the following factors:

a) Type of soil and its absorption capacity determined by its soil group.
b) Ground slope and the time in which the area is drained.
c) Intensity of the rainfall for a design period.
d) Duration of the rain/storm.

5.5.11.2.1 *Imperviousness*

The soil conditions and the ground slope determine the impermeability factor. Impermeability factor is the proportion of the total rainfall received on the surface which will be discharging into the a storm water drain after allowing for initial abstraction (in local pond and lakes), ground absorption by evaporation, vegetation and other losses. The net flow reaching the storm water drain is called runoff.

The percentage of imperviousness of the drainage area may be obtained from available data for a particular area. In the absence of such data, the following values may serve as a guide:

Type of area	*Imperviousness factor (percent)*
Commercial and industrial areas	70-90
Residential areas (high density)	60-75
Residential areas (low density)	35-60
Parks and underdeveloped areas	10-20

5.5.11.2.2 *Terrain modelling*

Areas planned for urbanization from agricultural land, forest or low grade land for example, low lying areas prone to flooding, marshy or abandoned quarries, etc need detailed and careful consideration with respect to its drainage. A detailed contour survey shall be carried out not only with respect to the site but also the surrounding areas to verify the quantity/area contributing runoff, presence of any low lying and natural water body acting as holding pond or any natural drain passing through the area and beyond whose filling up or diversion may cause water logging problem on the site or to the surrounding areas.

The planning of the area should ensure that:

a) All areas become self draining by gravity with higher.
b) As far as possible, natural drainage pattern with respect to the whole area be maintained except when low lying areas need to be filled up for grading purposes.
c) The drainage in the area shall be planned in accordance with the natural slopes.
d) Levels of the main highway or road connecting to the property shall be determined to ensure proper drainage and protection of the site.

The formation levels of the entire area shall be prepared to determine proposed formation levels by preparing a terrain model which will show the proposed the site contours, ground and road levels and connections to all services including storm water disposal system.

5.5.11.2.3 *Design frequency*

Storm water drainage system for an urbanized area is planned on the basis of the design frequency of the storm which shall be determined by the designer. Frequency is the period in which the selected design intensity recurs in a given period of time in years.

5.5.11.2.4 *Time of concentration*

Time of concentration is the time required for the rain-water to flow to reach the farthest point of the drainage system or the outfall under consideration. Time of concentration is equal to the inlet time plus the time required for the flow to reach the main or branch drain. The inlet time is the time dependent on the distance of the farthest point in the drainage area to the inlet of the manhole and the surface slopes, etc and will vary between 5 min to 30 min.

In highly developed sections for example with impervious surfaces it may be as low as 3 min or lower (with good slopes) as in building terraces and paved areas. Correspondingly the design intensity for the drainage for such areas will be much higher. Rain-water pipes have to be designed for an intensity for a very low time of concentration.

5.5.11.2.5 *Natural infiltration*

In planning any area with buildings, layout with paved and non-permeable surfaces, care should be taken to allow maximum discharge of the rain-water to flow directly or indirectly to permeate into the ground for enabling the ground water to be recharged. Some of the techniques which allow infiltration that may be considered are:

a) Use of brick paved open jointed storm water drains.
b) Providing bore holes in the storm water drains.

c) Using paving tiles with open joints which enable water to percolates as it flows on it.

5.5.11.3 *Combined system*

A combined system of drainage is one which carries the sewerage as well as the runoff from the storm water drainage. Relevant applicable statutory rules/ regulations may not allow such system in new areas and the sewerage and the storm water drainage have to be separate and independent of each other. Such systems are however existing in many old cities and the storm water may have to be discharged into the combined drainage system.

Where levels do not permit for connection to a public storm water drain, storm water from courtyards of buildings may be connected to the public sewer, provided it is designed to or has the capacity to convey combined discharge. In such cases, the surface water shall be admitted to the soil sewer through trapped gullies in order to prevent the escape of foul air.

5.5.11.4 *Discharging into a watercourse*

It may often be convenient to discharge surface water to a nearby stream or a watercourse. The invert level of the outfall shall be about the same as the normal water level in the watercourse or ideally should be above the highest flood level of the watercourse. The out-fall shall be protected against floating debris by a screen.

5.5.11.5 *Discharge to a public storm water drain*

Where it is necessary to connect the discharge rainwater into a public storm water drain, such drains shall be designed for the intensity of rain based on local conditions, but in no case shall they be designed for intensity of rainfall of less than 50 mm/hour. Rain-water from each building plot shall be connected to the storm water drainage through a separate pipe or an open public drain directly. No trap shall be installed before the connection.

5.5.11.6 *Rain-water pipes for roof drainage*

5.5.11.6.1 The roofs of a building shall be so constructed or framed as to permit effectual drainage of the rain-water therefrom by means of a sufficient number of rain-water pipes of adequate size so arranged, jointed and fixed as to ensure that the rain-water is carried away from the building without causing dampness in any part of the walls or foundations of the building or those of an adjacent building.

5.5.11.6.2 The rain-water pipes shall be fixed to the outside of the external walls of the building or in recesses or chases cut or formed in such external wall or in such other manner as may be approved by the Authority.

5.5.11.6.3 Rain-water pipes conveying rain- water shall discharge directly or by means of a channel into or over an inlet to a surface drain or shall discharge freely in a compound, drained to surface drain but in no case shall it discharge directly into any closed drain.

5.5.11.6.4 Whenever it is not possible to discharge a rain-water pipe into or over an inlet to a surface drain or in a compound or in a street drain within 30 m from the boundary of the premises, such rain-water pipe shall discharge into a gully trap which shall be connected with the street drain for storm water and such a gully-trap shall have a screen and a silt catcher incorporated in its design.

5.5.11.6.5 If such streets drain is not available within 30 m of the boundary of the premises, a rain-water pipe may discharge directly into the kerb drain and shall be taken through a pipe outlet across the foot path, if any, without obstructing the path.

5.5.11.6.6 A rain water pipe shall not discharge into or connect with any soil pipe or its ventilating pipe or any waste pipe or its ventilating pipe nor shall it discharge into a sewer unless specifically permitted to do so by the Authority, in which case such discharge into a sewer shall be intercepted by means of a gully trap.

5.5.11.6.7 Rain-water pipes shall be constructed of cast iron, PVC, asbestos cement, galvanized sheet or other equally suitable material and shall be securely fixed.

5.5.11.6.8 The factors that decide the quantity of rain water entering are:

a) Intensity of rainfall, and
b) Time of concentration selected for rain-water pipe.

A bell mouth inlet at the roof surface is found to give better drainage effect, provided proper slopes are given to the roof surface. The spacing of rain-water pipes depends on the locations available for the down takes and the area which each pipe serves. The spacing will also be determined by the amount of slopes that can be given to the roof. The recommended slopes for the flat roofs with smooth finish would be 1:150 to 1:133, with rough stone/tiles 1:100 and for gravel set in cement or losely packed concrete finish 1:75 to 1:66. The effective strainer area should preferably be 1.5 to 2 times the area of pipe to which it connects to considerably enhance the capacity of rain water pipes.

The rain water pipes of cast iron (coefficient of roughness 0.013) shall normally be sized on the basis of roof areas according to Table 28. The vertical down take rain-water pipes, having a bell mouth inlet on the roof surface with effective cross-sectional area of

grating 1.5 to 2 times the rain-water pipe area, may be designed by considering the outlet pipe as weir.

For full circumference of pipe acting as weir, the roof area (RA) for drainage may be worked out by using $RA = 0.084 \times d^{5/2}/I$

where

d = Pipe diameter; mm

I = Intensity of rainfall (mm/h).

Table 28 Sizing of Rain-Water Pipes for Roof Drainage

(*Clause* 5.5.11.6.8)

Dia of Pipe	Average Rate of Rainfall (mm/h)					
(mm)	50	75	100	125	150	200
	Roof Area (m^2)					
50	13.4	8.9	6.6	5.3	4.4	3.3
65	24.1	16.0	12.0	9.6	8.0	6.0
75	40.8	27.0	20.4	16.3	13.6	10.2
100	85.4	57.0	42.7	34.2	28.5	21.3
125	159.71	106.73	80.50	64.3	53.5	40.0
150	249.60	166.82	125.27	100.00	83.6	62.7

NOTE — For rain-water pipes of other materials, the roof areas shall be multiplied by (0.013/coefficient of roughness of surface of that material).

5.5.11.6.9 The storm water may be led off in a suitable open drain to a watercourse. The open drain, if not a *pucca* masonry through out, shall be so at least where there is either a change in direction or gradient.

5.5.12 *Rain-water Harvesting*

5.5.12.1 *General*

To supplement the ever growing shortage of protected, pure and safe water supply for human consumption rainwater is an ideal source which can be conserved and used in a useful manner by the people. The amount of rainfall available varies from region to region. Each area has to develop its own method and system to conserve, store and use it to suit its requirements and local conditions. There are several methods by which rain-water can be stored, used and conserved. Each system depends on the amount of precipitation, the period in which the rainfall occurs in a year and the physical infrastructure for example, space available to store the water, etc.

There are several techniques available for catching and storing the rain-water. Most of the techniques are applicable for large open areas, farms, sloping grounds etc, with a low population base. Two major systems that are ideal for urban and semi-urban developed areas are:

a) Artificial ground water recharge, and

b) Roof top rain-water harvesting.

5.5.12.2 *Artificial ground water recharge*

With increase in the impermeable surfaces in modern built up areas, a large quantity of water normally percolating into the ground runs off to the natural drains and into the rivers causing increased runoff and flooding of downstream areas as it also deprives the original catchment area of the natural percolation that would have recharged the area in the normal course if the ground was in its natural condition for example a farm, open ground, forest, etc. It is therefore essential to catch the runoff and use it for augmentation of ground water reservoir by modifying the natural movement of surface water by recharging it by artificial means for example, construction of recharge structures (*see* Fig. 18). The main objectives achieved may be:

a) Enhancement of sustainable yield in areas where there is over development and depletion of the aquifers.

b) Conservation and storage of excess surface water in the aquifers.

c) Improve the quality of the existing ground water through dilution.

d) Remove bacteriological and suspended impurities during the surface water transition within the sub-soil.

e) Maintain the natural balance of the ground water and its usage as the rain-water is a renewable supply source. A well managed and controlled tapping of the aquifers will provide constant, dependable and safe water supply.

In planning and designing the ground water recharge structures following should be taken into consideration:

a) Annual rainfall (for estimating approx rain-water recharge per year).

b) Peak intensity and duration of each storm.

c) Type of soil and sub-soil conditions and their permeability factor.

d) Ground slopes and runoff which cannot be caught.

e) Location of recharge structures and its overflow outfall.

f) Rainwater measuring devices for finding the flow of water in the system.

For artificial recharge to ground water, Guidelines for Artificial Recharge to Ground Water (*under preparation*) may be referred.

5.5.12.3 *Roof top rain-water harvesting*

5.5.12.3.1 *Harvesting in regular rainfall areas*

In areas having rainfall over a large period in a year

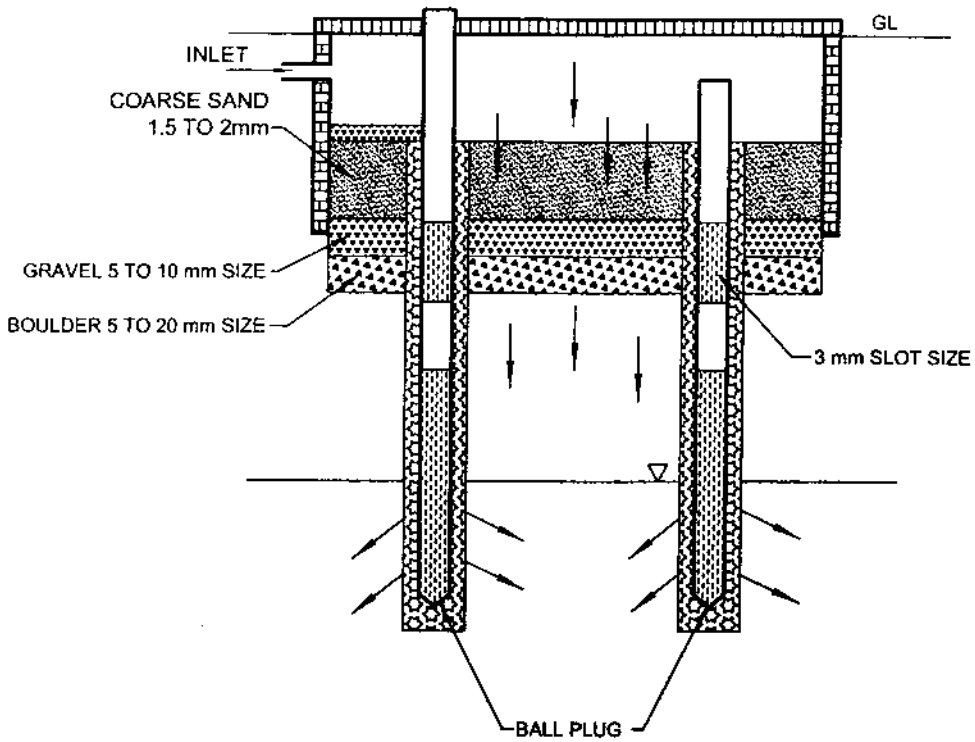


FIG. 18 ARTIFICIAL GROUND WATER RECHARGE STRUCTURE

for example, in hilly areas and coastal regions, constant and regular rainfall can be usefully harvested and stored in suitable water tanks. Water is collected through roof gutters and down take pipes. Provision should be made to divert the first rainfall after a dry spell so that any dust, soot, leaves etc, are drained away before the water is collected into the water tank. The capacity of the water tank should be enough for storing water required for consumption between two dry spells. The water tank shall be located in a well protected area and should not be exposed to any hazards of water contamination from any other sources. The water shall be chlorinated using chlorine tablets or solution to maintain a residual chlorine of approximately 1 mg/l. The tank must have an overflow leading to a natural water courses or to any additional tanks (*see* Table 29).

5.5.12.3.2 *Harvesting in urban areas*

In urban areas with the rainfall limited during the monsoon period (usually from 15-90 days) roof top rain-water cannot be stored and used as mentioned above and is best used for recharging the ground water. For individual properties and plots the roof top rain-water should be diverted to existing open or abandoned tubewells. In a well planned building complex the system should be laid out so that the runoff is discharged in bore-wells as per designs specified by the Central Ground Water Board of the Government of India.

For roof top rain water harvesting in hilly areas reference may be made to good practice [9-1(30)].

5.5.12.4 *Care to taken in rain-water harvesting*

Water conservation technique discussed above shall be constructed with due care taking following precautions:

a) No sewage or waste water should be admitted into the system.

b) No waste water from areas likely to have oil, grease or other pollutants should be connected to the system.

c) Each structure/well shall have an inlet chamber with a silt trap to prevent any silt from finding its way into the sub-soil water.

d) The wells should be terminated at least 5 m above the natural static sub-soil water at its highest level so that the incoming flow passes through the natural ground condition and prevents contamination hazards.

e) No recharge structure or a well shall be used for drawing water for any purpose.

5.5.13 *Sub-soil Water Drainage*

5.5.13.1 *General*

Sub-soil water is that portion of the rainfall which is absorbed into the ground.

The drainage of sub-soil water may be necessary for the following reasons:

Table 29 Rainwater Available from Roof Top Harvesting

(*Clause* 5.5.12.3.1)

Rain → Fall in mm	100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000
Roof Top Area m^2 ↓	Harvested Water from Roof Tops m^3 (80 percent of gross precipitation)																			
20	2	3	5	6	8	10	11	13	14	16	18	19	21	22	24	26	27	29	30	32
30	2	5	7	10	12	14	17	19	22	24	26	29	31	34	36	38	41	43	46	48
40	3	6	10	13	16	19	22	26	29	32	35	38	42	45	48	51	54	58	61	64
50	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
60	5	10	14	19	24	29	34	38	43	48	53	58	62	67	72	77	82	86	91	96
70	6	11	17	22	28	34	39	45	50	56	62	67	73	78	84	90	95	101	106	112
80	6	13	19	26	32	38	45	51	58	64	70	77	83	90	96	102	109	115	122	128
90	7	14	22	29	36	43	50	58	65	72	79	86	94	101	108	115	122	130	137	144
100	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160
110	9	18	26	35	44	53	62	70	79	88	97	106	114	123	132	141	150	158	167	176
120	10	19	29	38	48	58	67	77	86	96	106	115	125	134	144	154	163	173	182	192
130	10	21	31	42	52	62	73	83	94	104	114	125	135	146	156	166	177	187	198	208
140	11	22	34	45	56	67	78	90	101	112	123	134	146	157	168	179	190	202	213	224
150	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240
200	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320
250	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
300	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480
400	32	64	96	128	160	192	224	256	288	320	352	384	416	448	480	512	544	576	608	640
500	40	80	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800
1 000	80	160	240	320	400	480	560	640	720	800	880	960	1 040	1 120	1 200	1 280	1 360	1 440	1 520	1 600
2 000	160	320	480	640	800	960	1 120	1 280	1 440	1 600	1 760	1 920	2 080	2 240	2 400	2 560	2 720	2 880	3 040	3 200
3 000	240	480	720	960	1 200	1 440	1 680	1 920	2 160	2 400	2 640	2 880	3 120	3 360	3 600	3 840	4 080	4 320	4 560	4 800

a) to increase the stability of the surface;

b) to avoid surface flooding;

c) to alleviate or to avoid causing dampness in the building, especially in the cellars;

d) to reduce the humidity in the immediate vicinity of the building; and

e) to increase the workability of the soil.

5.5.13.2 *Depth of water table*

The standing level of the sub-soil water will vary with the season, the amount of rainfall and the proximity and level of drainage channels. Information regarding this level may be obtained by means of boreholes or trial pits, preferably the latter. It is desirable though not always practicable to ascertain the level of the standing water over a considerable period so as to enable the seasonal variations to be recorded and in particular the high water level. The direction of flow of the sub-soil water may usually be judged by the general inclination of the land surface and the main lines of the subsoil drains shall follow the natural falls, wherever possible.

5.5.13.3 *Precautions*

Sub-soil drains shall be so sited as not to endanger the stability of the buildings or earthwork. In some portions of the drain, it may be necessary to use non-porous jointed pipes.

5.5.13.3.1 No field pipe shall be laid in such a manner or in such a position as to communicate directly with any drain constructed or adopted to be used for conveying sewage, except where absolutely unavoidable and in such case a suitable efficient trap shall be provided between sub-soil drain and such sewer.

5.5.13.4 *Systems of sub-soil drainage*

Clay or concrete porous field drain pipes may be used and shall be laid in one of the following ways (*see also* Fig. 19):

a) *Natural* — The pipes are laid to follow the natural depressions or valleys of the site; branches discharge into the main as tributaries do into a river.

b) *Herringbone* — The system consists of a number of drains into which discharges from both sides smaller subsidiary branch drains parallel to each other, but an angle to the mains forming a series of herringbone pattern. Normally these branch drains should not exceed 30 m in length.

c) *Grid* — A main or mains drain is laid to the boundaries if the site into which subsidiary branches discharge from one side only.

d) *Fan-Shaper* — The drains are laid converging to a single outlet at one point on the boundary

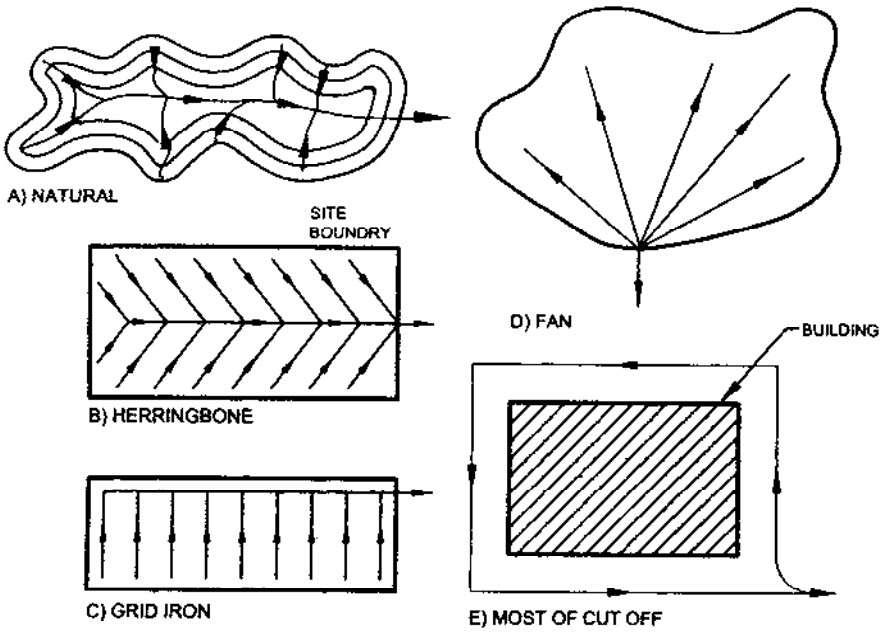


FIG. 19 DETAILS OF SUB-SOIL DRAINAGE SYSTEM

of a site, without the use of main or collecting drains.

e) *Moat or cut-off system* — This system consists of drains laid on one or more sides of a building to intercept the flow of subsoil water and carry it away, thereby protecting the foundations of a building.

The choice of one or more of these systems will naturally depend on the local conditions of the site. For building sites, the mains shall be not less than 75 mm in diameter and the branches not less than 65 mm in diameter and the branches not less than 65 mm in diameter but normal practice tends towards the use of 100 mm and 75 mm respectively. The pipes shall generally be laid at 600 to 900 mm depth, or to such a depth to which it is desirable to lower the water-table and the gradients are determined rather by the fall of the land than by considerations of self-cleansing velocity. The connection of the subsidiary drain to the main drain is best made by means of a clayware or concrete junction pipe. The outlet of a sub-soil system may discharge into a soakaway or through a catch pit into the nearest ditch or watercourse. Where these are not available, the sub-soil drains may be connected, with the approval of the Authority, through an intercepting trap to the surface water drainage system.

NOTE — Care shall be taken that there is no backflow from sub-surface drains during heavy rains.

5.5.14 *Waste Disposal Systems in High Altitudes and or Sub-zero Temperature Regions*

5.5.14.1 In general, all the cases to be exercised regarding water supply systems shall also be applicable in the case of waste disposal systems shall also be applicable in the case of waste disposal systems. The biological and chemical reduction of organic material proceeds slowly under low temperature conditions, consequently affecting the waste disposal systems. The waste disposal methods given in **5.5.14.2**, **5.5.14.3** and **5.5.14.4** shall be used only where it is not practical to install water carriage system.

5.5.14.2 *Box and can system*

Where box and can systems are employed, adequate arrangements shall be made for the cleaning and disinfection of the can after it is emptied of its contents. The excrement from the can shall be disposed of by burial in isolated spots far from habitation or by incineration, where feasible. The can shall be fitted with a tight fitting lid for use when it is carried for emptying.

5.5.14.3 *Trench or pit latrines*

Trench or pit latrines shall be used only where soil and sub-soil conditions favour their use. Whenever they are used, they shall not be closer than 18 m from any source of drinking water, such as well, to eliminate the possibility of bacterial pollution of water.

5.5.14.4 *Chemical toilets*

For the successful functioning of chemical toilets, they shall preferably be installed in heated rooms or enclosures.

NOTE — Chemical toilet essentially consists of small cylindrical tanks with a water-closet seat for the use of 8 to 10 persons. A

ventilation pipe is fitted to the seat. A strong solution of caustic soda is used as a disinfectant. It kills bacteria, liquefies the solids and thus checks the decomposition of organic matter. The tank is provided with a drain plug for which liquid runs to a soak pit at the time of disposal.

5.5.14.5 *Water-borne sanitation systems*

Water-borne sanitation systems shall be used, where practicable. Sanitation systems for the collection of sewage should be constructed in such a manner that maximum heat is retained by insulation, if necessary.

5.5.14.5.1 *Sewerage laying*

Under normal circumstances, sewers shall be laid below the frost line. Manholes shall be made of air-tight construction so as to prevent the cold air from gaining access inside and freezing the contents. The trenches for sewers shall be loosely filled with earth after laying sewers, since loose soil is a better insulator than compacted soil. Consequently, sewers laid under traffic ways and other places where soil compaction may be expected are required to be given adequate insulation. Where feasible, sewers shall be so located that the trench line is not in shadow, when the sun is shining. Concrete, cast iron and stoneware pipes conduct heat relatively rapidly and as such should be adequately insulated.

5.5.14.5.2 *Septic tanks*

Septic tanks can function only when it can be ensured that the contents inside these do not freeze at low temperature. For this purpose, the septic tanks shall be located well below the frost line. The location of manhole openings shall be marked by staves. Fencing around the septic tanks shall be provided for discouraging traffic over them. As the rate of biological activity is reduced by 50 percent for every 10°C fall in temperature, the capacity of septic tanks shall be increased by 100 percent for operation at 10°C over that for operation at 20°C.

5.5.14.5.3 *Seepage pits*

Seepage pits can function only when the soil and sub-soil conditions are favourable. Frozen soil extending to a great depth would preclude the use of such disposal devices in view of the lower water absorption capacity. The discharge of effluent should be made below the frost line.

5.5.14.5.4 *Sewage treatment plants*

Suitable design modifications for sedimentation, chemical and biological processes shall be applied to sewage treatment plants for satisfactory functioning.

NOTE — Lavatories and bathrooms shall be kept heated to avoid freezing of water inside traps and flushing cisterns.

5.6 Construction Relating to Conveyance of Sanitary Wastes

5.6.1 *Excavation*

5.6.1.1 *General*

The safety precautions as given in Part 7 'Constructional Practices and Safety' shall be ensured.

5.6.1.2 Turf, topsoil or other surface material shall be set aside, turf being carefully rolled and stacked for use in reinstatement. All suitable broken surface material and hard-core shall be set on one side for use in subsequent reinstatement.

5.6.1.3 Excavated material shall be stacked sufficiently away from the edge of the trench and the size of the spoil bank shall not be allowed to become such as to endanger the stability of the excavation. Spoil may be carried away and used for filling the trench behind the work.

5.6.1.4 Excavation shall proceed to within about 75 mm of the finished formation level. This final 75 mm is to be trimmed and removed as a separate operation immediately prior to the laying of the pipes or their foundations.

5.6.1.5 Unless specified otherwise by the Authority, the width at bottom of trenches for pipes of different diameters laid at different depths shall be as given below:

a) For all diameters, up to an average depth of 1 200 mm, width of trench in mm = diameter of pipe + 300 mm;

b) For all diameters for depths above 1 200 mm; width of trench in mm = diameter of pipe + 400 mm; and

c) Notwithstanding (a) and (b), the total width of trench at the top should not be less than 750 mm for depths exceeding 900 mm.

5.6.1.6 Excavation in roads shall be so arranged, in agreement with the proper authority, as to cause the minimum obstruction to traffic. The methods to be adopted shall depend on local circumstances.

5.6.1.7 All pipes, ducts, cables, mains or other services exposed in the trench shall be effectively supported by timber and/or chain or rope-slings.

5.6.1.8 All drainage sumps shall be sunk clear of the work outside the trench or at the sides of manholes. After the completion of the work, any pipes or drains leading to such sumps or temporary sub-soil drains under permanent work shall be filled in properly with sand and consolidated.

5.6.2 *Laying of Pipes*

Laying of pipes shall be done in accordance with good practice [9-1(31)].

5.6.3 *Jointing*

All soil pipes, waste pipes, ventilating pipes and other such pipes above ground shall be gas-tight. All sewers and drains laid below the ground shall be water-tight. Jointing shall be done in accordance with good practice [9-1(31)].

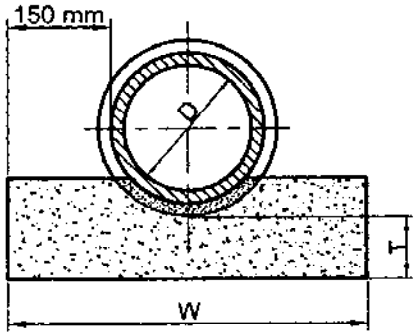
5.6.4 *Support or Protection for Pipes*

5.6.4.1 *General*

It may be necessary to support or surround pipe sewers or drains by means of concrete in certain circumstances. Some of the suggested methods are given in **5.6.4.2** to **5.6.4.4**.

5.6.4.2 *Bedding*

Bedding (*see* Fig. 20) shall be rectangular in section and shall extend laterally at least 150 mm beyond and on both sides of the projection of the barrel of the pipe. The thickness of the concrete below the barrel of the pipe shall be not less than 100 mm for pipes under 150 mm diameter and 150 mm for pipes 150 mm and over in diameter. Where bedding is used alone, the concrete shall be brought up at least to the invert level of the pipe to form a cradle and to avoid line contact between the pipe and the bed.



$W = D + 300$ mm

where D is external diameter of the pipe

$$T = \begin{cases} \text{100 mm for pipes under 150 mm nominal dia} \\ \text{150 mm for pipes of 150 mm nominal dia and over} \end{cases}$$

FIG. 20 BEDDING

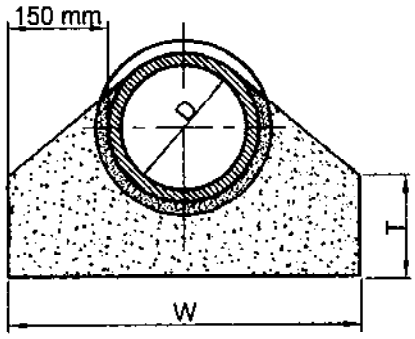
5.6.4.3 *Haunching*

Concrete haunching (*see* Fig. 21) shall consist of:

a) A concrete bed as described for bedding (*see* **5.6.4.2**);

b) The full width of the bed carried up to the level of the horizontal diameter of the pipe; and

c) Splays from this level carried up on both sides of the pipe, from the full width of the bed to meet the pipe barrel tangentially.



$W = D + 300$ mm

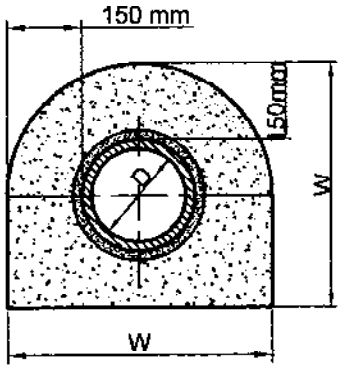
where D is external diameter of the pipe

$$T = \begin{cases} \text{100 mm for pipes under 150 mm nominal dia} \\ \text{150 mm for pipes of 150 mm nominal dia and over} \end{cases}$$

FIG. 21 HAUNCHING

5.6.4.4 *Surround or Encasing*

The surround or encasing (*see* Fig. 22) shall be similar to haunching up to the horizontal diameter of the pipe and the top portion over this shall be finished in a semi-circular form to give a uniform encasing for the top half of the pipe.



$W = D + 300$ mm

where D is external diameter of the pipe

FIG. 22 SURROUND OR ENCASING

5.6.5 *Connection to Existing Sewers*

The connection to an existing sewer shall, as far as possible, be done at the manholes. Where it is unavoidable to make connection in between two manholes, the work of breaking into the existing sewer and forming the connection shall be carried out by the Authority or under its supervision.

5.6.5.1 Breaking into the sewer shall be effected by the cautious enlargement of a small hole and every precaution shall be taken to prevent any material from entering the sewer. No connection shall be formed in such a way as to constitute a projection into the sewer or to cause any diminution in its effective size.

5.6.6 *Back-Filling*

5.6.6.1 Filling of the trench shall not be commenced until the length of pipes therein has been tested and passed (*see* **5.10.2**).

5.6.6.2 All timber which may be withdrawn with safety shall be removed as filling proceeds.

5.6.6.3 Where the pipes are unprotected by concrete haunching, the first operation in filling shall be carefully done to hand-pack and tamp selected fine material around the lower half of the pipes so as to buttress them to the sides of the trench.

5.6.6.4 The filling shall then be continued to 150 mm over the top of the pipe using selected fine hand-packed material, watered and rammed on both sides of the pipe with a wooden rammer. On no account shall material be tipped into the trench until the first 150 mm of filling has been completed. The process of filling and tamping shall proceed evenly so as to maintain an equal pressure on both sides of the pipeline.

5.6.6.5 Filling shall be continued in layers not exceeding 150 mm in thickness, each layer being watered and well rammed.

5.6.6.6 In roads, surface materials previously excavated shall be replaced as the top layer of the filling, consolidated and maintained satisfactorily till the permanent reinstatement of the surface is made by the Authority.

5.6.6.7 In gardens, the top soil and turf, if any, shall be carefully replaced.

5.7 Construction Relating to Conveyance of Rain or Storm Water

5.7.1 *Roof Gutters*

Roof gutters shall be of any material of suitable thickness. All junctions and joints shall be water-tight.

5.7.2 *Rain-Water Pipes*

Rain water pipes shall conform to the accepted standards [9-1(32)].

5.7.3 *Sub-soil Drain Pipes*

5.7.3.1 *Field drain pipes*

Suitable pipes for this purpose are plain cylindrical glazed water pipes, or concrete porous pipes though the latter may prove unsuitable where sub-soil water carries sulphates or is acidic. Trenches for these pipes need be just wide enough at the bottom to permit laying the pipes, which shall be laid with open joints to proper lines and gradients.

It is advisable to cover the pipes with clinker free from fine ash, brick ballast or other suitable rubble, or a layer of inverted turf, brush-wood or straw before refilling the trench, in order to prevent the infiltration of silt through the open joints. Where the sub-soil drain is also to serve the purpose of collecting surface water, the rubble shall be carried upto a suitable level and when required for a lawn or playing field, the remainder of the trench shall be filled with pervious top soil. When refilling the trenches, care shall be taken to prevent displacement of pipes in line of levels. When they pass near trees or through hedges, socket pipes with cement or bitumen joints shall be used to prevent penetration by roots.

5.7.3.2 *French Drain*

A shallow trench is excavated, the bottom neatly trimmed to the gradient and the trench filled with broken stone, gravel or clinker, coarse at the bottom and finer towards the top.

5.8 Selection and Installation of Sanitary Appliances

5.8.1 Selection, installation and maintenance of sanitary appliances shall be done in accordance with good practice [9-1(33)].

5.9 Refuse Chute System

5.9.1 Refuse chute system is provided in multi-storeyed buildings for transporting and collecting in a sanitary way the refuse from floors at different heights. The refuse is received from the successive floor through the inlets located on the vertical system of pipes that convey refuse through it and discharge it into the collecting chamber from where the refuse is cleared at suitable intervals.

5.9.2 This system has got three functionally important components, namely, the chutes, the inlet hopper and the collection chamber.

5.9.2.1 The chute may be carried through service shafts meant for carrying drainage pipes. However, the location shall be mostly determined by the position of the inlet hopper and the collecting chamber that is most convenient for the user. It should also be considered to locate the chute away from living rooms in order to avoid noise and smell nuisance.

5.9.2.2 In individual chute system, the inlet hopper shall be located in the passage near the kitchen and in the common chute system towards the end of the common passage. Natural ventilation should be adequate to prevent any possible odour nuisance. There

should be adequate lighting at this location. For ground floor (floor 1), the inlet hoppes may be placed at a higher level and a flight of steps may be provided for using the same.

5.9.2.3 The collection chamber shall be situated at ground level.

5.9.3 Requirements in regard to the design and construction of refuse chute system shall be in accordance with good practice [9-1(34)].

5.10 Inspection and Testing

5.10.1 *Inspection*

5.10.1.1 All sanitary appliances and fitments shall be carefully examined for defects before they are installed and also on the completion of the work.

5.10.1.2 Pipes are liable to get damaged in transit and, not withstanding tests that may have been made before despatch, each pipe shall be carefully examined on arrival on the site. Preferably, each pipe shall be rung with a hammer or mallet and those that do not ring true and clear shall be rejected. Sound pipes shall be carefully stored to prevent damage. Any defective pipes shall be segregated, marked in a conspicuous manner and their use in the works prevented.

5.10.1.3 Cast iron pipes shall be carefully examined for damage to the protective coating. Minor damage shall be made good by painting over with hot tar or preferably bitumen. But if major defects in coating exit, the pipes shall not be used unless recoated. Each pipe shall be carefully re-examined for soundness before laying.

5.10.1.4 Close inspection shall be maintained at every stage in the work, particularly as to the adequacy of timber supports used in excavation and the care and thoroughness exercised in filling.

5.10.1.4.1 Careful note shall be kept of the condition of any sewer, manhole or other existing work which may be uncovered and any defects evident shall be pointed out immediately to the Authority.

5.10.1.4.2 No work shall be covered over or surrounded with concrete until it has been inspected and approved by the Authority.

5.10.2 *Testing*

5.10.2.1 Comprehensive tests of all appliances shall be made by simulating conditions of use. Overflow shall be examined for obstructions.

5.10.2.2 *Smoke test*

All soil pipes, waste pipes, and vent pipes and all other pipes when above ground shall be approved gas-tight by a smoke test conducted under a pressure of 25 mm of water and maintained for 15 min after all trap seals have been filled with water. The smoke is produced by burning only waste or tar paper or similar material in the combustion chamber of a smoke machine. Chemical smokes are not satisfactory.

5.10.2.3 *Water test*

5.10.2.3.1 *For pipes other than cast iron*

Glazed and concrete pipes shall be subjected to a test pressure of at least 1.5 m head of water at the highest point of the section under test. The tolerance figure of 2 litres/cm of diameter/km may be allowed during a period of 10 min. The test shall be carried out by suitably plugging the low end of the drain and the ends of connections, if any, and filling the system with water. A knuckle bend shall be temporarily jointed in at the top end and a sufficient length of the vertical pipe jointed to it so as to provide the required test head, or the top end may be plugged with a connection to a hose ending in a funnel which could be raised or lowered till the required head is obtained and fixed suitably for observation.

Subsidence of the test water may be due to one or more of the following causes:

a) absorption by pipes and joints;
b) sweating of pipes or joints;
c) leakage at joints or from defective pipes; and
d) trapped air.

Allowance shall be made for (a) by adding water until absorption has ceased after which the test proper should commence. Any leakage will be visible and the defective part of the work should be cut out and made good. A slight amount of sweating which is uniform may be overlooked, but excessive sweating from a particular pipe or joint shall be watched for and taken as indicating a defect to be made good. A slight amount of sweating which is uniform may be overlooked, but excessive sweating from a particular pipe or joint shall be watched for and taken as indicating a defect to be made good.

NOTE — This test will not be applicable to sanitary pipe work above ground level.

5.10.2.3.2 *For cast iron pipes*

Cast iron sewers and drains shall be tested as for glazed and concrete pipes. The drain plug shall be suitably strutted to prevent their being forced out of the pipe during the test.

5.10.2.4 *Tests for straightness and obstruction*

The following tests shall be carried out:

a) by inserting at the high end of the sewer or drain a smooth ball of a diameter 13 mm

less than the pipe bore. In the absence of obstruction, such as yarn or mortar projecting through the joints, the ball should roll down the invert of the pipe, and emerge at the lower end; and

b) by means of a mirror at one end of the line and lamp at the other. If the pipeline is straight, the full circle of light may be observed. If the pipe line is not straight, this will be apparent. The mirror will also indicate obstruction in the barrel.

5.10.2.5 *Test records*

Complete records shall be kept of all tests carried out on sewers and drains both during construction and after being put into service.

5.11 Maintenance

5.11.1 *General*

Domestic drainage system shall be inspected at regular intervals. The system shall be thoroughly cleaned out at the same time and any defects discovered shall be made good.

5.11.2 *Cleaning of Drainage System*

5.11.2.1 Sewer maintenance crews, when entering a deep manhole or sewer where dangerous gas or oxygen deficiencies may be present, shall follow the following procedures:

a) allow no smoking or open flames and guard against parks.

b) erect warning signs.

c) use only safety gas-proof, electric lighting equipment.

d) test the atmosphere for noxious gases and oxygen deficiencies (presence of hydrogen sulphide is detected using lead acetate paper and that of oxygen by safety lamps).

e) if the atmosphere is normal, workmen may enter with a safety belt attached and with two men available at the top. For extended jobs, the gas tests shall be repeated at frequent intervals, depending on circumstances.

f) if oxygen deficiency or noxious gas is found, the structure shall be ventilated with pure air by keeping open at least one manhole cover each on upstream and downstream side for quick exit of toxic gases or by artificial means. The gas tests shall be repeated and the atmosphere cleared before entering. Adequate ventilation shall be maintained during this work and the tests repeated frequently.

g) if the gas or oxygen deficiency is present and it is not practicable to ventilate adequately before workers enter, a hose mask shall be worn and extreme care taken to avoid all sources of ignition. Workers shall be taught how to use the hose equipment. In these cases, they shall always use permissible safety lights (not ordinary flash lights), rubber boots or non-sparking shoes and non-sparking tools;

h) Workmen descending a manhole shaft to inspect or clean sewers shall try each ladder step or rung carefully before putting the full weight on it to guard against insecure fastening due to corrosion of the rung at the manhole wall. When work is going on in deep sewers, at least two men shall be available for lifting workers from the manhole in the event of serious injury; and

j) Portable air blowers, for ventilating manhole, are recommended for all tank, pit or manhole work where there is a question as to the presence of noxious gas, vapours or oxygen deficiency. The motors for these shall be of weather proof and flame-proof types; compression ignition diesel type (without sparking plug) may be used. When used, these shall be placed not less than 2 m away from the opening and on the leeward side protected form wind, so that they will not serve as a source of ignition for any inflammable gas which might be present. Provision should be made for ventilation and it should be of the forced type which can be provided by a blower located at ground level with suitable flexible ducting to displace out air from the manhole.

5.11.2.2 The following operations shall be carried out during periodical cleaning of a drainage system.

a) The covers of inspection chambers and manholes shall be removed and the side benching and channels scrubbed;

b) The interceptive trap, if fitted, shall be adequately cleaned and flushed with clean water. Care shall be taken to see that the stopper in the rodding arm is securely replaced;

c) All lengths of main and branch drains shall be rodded by means of drain rods and a suitable rubber or leather plunger. After rodding, the drains shall be thoroughly flushed with clean water. Any obstruction found shall be removed with suitable drain cleaning tools and the system thereafter shall be flushed with clean water;

d) The covers of access plates to all gullies shall be removed and the traps plunged and flushed

out thoroughly with clean water. Care shall be taken not to flush the gully deposit into the system;

e) Any defects revealed as a result of inspection or test shall be made good;

f) The covers or inspection chambers and gullies shall be replaced, bedding them in suitable grease or other materials; and

g) Painting of ladders/rings in deep manholes and external painting of manhole covers shall be done with approved paints.

5.11.3 All surface water drains shall be periodically rodded by means of drain rods and a suitable rubber or leather plunger. After rodding, they shall be thoroughly flushed with clean water. Any obstruction found shall be removed with suitable drain cleaning tools.

5.11.4 All sub-soil drains shall be periodically examined for obstruction at the open joints due to the roots of plants or other growths.

6 SOLID WASTE MANAGEMENT

6.1 General

6.1.1 Efficient collection and disposal of domestic garbage from a building or activity area is of significant importance to public health and environmental sanitation and, therefore, an essential part of the construction of the built environment. Notwithstanding the provisions given herein, the solid waste management shall have to comply with relevant statutory Rules and Regulations in force from time-to-time. In this regard, the provisions of the following shall govern the procedures for handling, treatment, etc of solid wastes as applicable to the concerned building occupancy:

a) *Manufacture, Storage and Import of Hazardous Chemical Rules*, 1989;

b) *Bio-Medical Waste (Management and Handling Rules*, 1998; and

c) *Municipal Solid Wastes (Management and Handling) Rules*, 2000.

6.1.2 The provisions relating to solid waste management given in **6.2** are applicable to wastes in general, and specifically exclude the hazardous chemical wastes and bio-medical waste.

6.2 Solid Waste Management Systems

6.2.1 In designing a system dealing with collection of domestic garbage for a built premises/community/ environment, the aim shall be to provide speedy and efficient conveyance as an essential objective for design of the system. The various available systems may be employed in accordance with **6.2.1** to **6.2.3**, which may be adopted individually or in combination as appropriate in specific situations.

6.2.2 *Refuse Chute System*

6.2.2.1 Refuse chute system is a convenient and safe mode of collection of domestic solid wastes from buildings exceeding 3 storeys. The internal diameter of the chute shall be at least 300 mm.

The access to the refuse chute shall be provided from well ventilated and well illuminated common corridor or lobby and preferably it should not be located opposite or adjacent to entry of individual flats or lift.

6.2.2.2 *Opening for feeding of refuse chute*

Opening, with top or bottom hinged shutters with appropriate lockable latch, shall be provided for convenient accessing of the refuse chute by users.

6.2.2.3 *Refuse collection chamber*

The collection chamber may be located in ground floor or basement level, provided appropriate arrangement is made for (a) drainage of the collection pit by gravity flow to ensure its dryness, (b) an appropriate ramp access is provided for convenient removal of garbage from the collection pit, and (c) satisfactory ventilation for escape of gas and odour. The floor of the chamber shall be provided with drainage through a 100 mm diameter trap and screen to prevent any solid matters flowing into the drain and the drain shall be connected to the sewer line. The floor shall be finished with smooth hard surface for convenient cleaning.

The height of the collection chamber and vertical clearance under the bottom level of garbage chute shall be such that the garbage trolley can be conveniently placed.

The collection chamber shall be provided with appropriate shutter to prevent access of all scavenging animals like the cattle, dogs, cats, rats, etc.

6.2.2.4 *Material for chute*

The chute may be of masonry or suitable non-corrosive material. Further the material should be rigid with smooth internal finish, high ductility and alkali/acid resistant properties.

6.2.2.5 *Size of trolley*

The size of the garbage trolley shall be adequate for the daily quantity of garbage from a chute. For working out quantity of garbage, a standard of approximately 0.75 kg/person may be taken.

6.2.3 *Dumb-Waiter*

In high rise buildings with more than 8 storeys,

electrically operated dumb-waiters may be used for carrying domestic garbage in packets or closed containers. For handling of garbage by dumb-waiters in a building, a garbage chamber shall have to provided either at ground floor or basement level and the provisions of garbage collection chamber for chute as given in **6.2.2** shall apply.

6.2.3.1 *Shutters for dumb-waiter*

The shutters for dumb-waiter and garbage collection chamber shall be provided with shutters with same consideration as in the case of garbage chute. However, the dumb-waiter shall be made child-proof.

6.2.3.2 *Sorting of garbage to remove toxic matters from garbage*

Before feeding the garbage to compost pits the following objects need to be removed:

a) inert matters like glass, metals, etc;
b) chemicals, medicines, batteries of any kind;
c) polythene and plastic materials; and
d) any other non-biodegradable material.

These separated items shall be handled separately, and may be scrapped or recycled, etc as appropriate.

6.2.4 *Treatment by Vermi-Composting*

Vermi-compost treatment shall be provided to the organic wastes in composting pits located in shade. The pits shall be used to receive the garbage in a predetermined (periodic) cyclic order. (For example 5 pits to receive garbage in 5 days and these 5 pits together accepting daily load of garbage.) The gross area of the composting pits may be about 0.1 m^2 per person.

6.2.4.1 The site for vermi-composting shall be enclosed from all sides with appropriate fencing (for keeping scavenging animals away) and provided with a small door for accessing the enclosed premises.

6.2.4.2 Composting pits shall be constructed either under the shade of trees (except Neem tree) or created by sheeting or shade net so as to keep the pits under shade. The pits shall be easily accessed for convenient shifting of garbage from trolleys carrying garbage.

6.2.4.3 The composting pits shall be made in a manner that the pits do not have the risk of inundation by water. This may be achieved by appropriately raising the base level of the pit and providing weep holes from sides. Height of side walls of compost pits need to be 0.6 m to 0.75 m high. The bottom of the pit without any lining is preferred.

6.2.4.4 Initiation of composting pits shall be done by providing a 75 mm thick layer of cow dung (fresh or partially decomposed) spreading 1 kg of vermi-compost and covering it with 75 mm to 100 mm thick layer of dry leaves/grass, etc and sprinkling of water and allowing to decompose naturally for about 10 to 15 days.

6.2.4.5 Sorted garbage free from inert and toxic matters shall be applied in the composting pit in layers of 75 mm and spread, and covered with a layer of 75 mm thick dry leaves followed by sprinkling of water.

6.2.4.6 The compost may be removed from the bottom of the compost pit after intervals of 3 to 6 months. The compost so made may be used in appropriate horticultural and related applications.

ANNEX A

(*Clause* 3.2.1)

APPLICATION FORM FOR TEMPORARY/PERMANENT SUPPLY OF WATER/FOR ADDITIONS AND/OR ALTERATIONS FOR SUPPLY OF WATER

I/We.....hereby make application to the*.....for the temporary/ permanent supply of water for the following additions and/or alterations to the water supply requirements and water fittings at the premises..... Ward No.....Street No. .....Road/ Street known as.....for the purpose described below and agreed to pay such charges as the Authority may from time-to-time be entitled to make and to conform to all their byelaws and regulations.....licensed plumber, has been instructed by me/us to carry out the plumbing work.

Description of the premises: .....

.....

Address: .....

.....

Purpose for which water is required: .....

.....

.....

The connection/connections taken by me/us for temporary use, shall not be used by me/us for permanent supply unless such a permission is granted to me/us in writing by the Authority.

I/We hereby undertake to give the*..... .....due notice of any additions or alterations to the above mentioned supply which I/we may desire to make.

My/Our requirements of water supply are as under:

a) I/We request that one connection be granted for the whole of the premises.

b) I/We request that separate connections may be granted for each floor and I/we undertake to pay the cost of the separate connections.

c) My/Our probable requirements for trade purpose are.....litres per day and for domestic purposes are..... litres per day.

d) Our existing supply is.....litres per day. Our additional requirement of supply is.....litres per day.

e) The details as regards proposed additions and alterations in fittings are as follows:

.....

.....

Signature of the licensed plumber .....

Name and address of the licensed plumber .....

.....

.....

.....

Date .....

Signature of the applicant .....

Name and address of the applicant .....

.....

.....

.....

Date .....

NOTES

1 Please strike out whatever is not applicable.

2 The application should be signed by the owner of the premises or his constituted attorney and shall be countersigned by the licensed plumber.

---

* Insert here the name of the Authority.

ANNEX B

(Clause 3.2.3)

FORM FOR LICENCED PLUMBER'S COMPLETION CERTIFICATE

Certified that I/we have completed the plumbing work of water connection No..... for the premises as detailed below. This may be inspected and connection given.

Ward No.....Road/Street.....

.....

Locality .....

.....

Block No.....House No.....

.....

Existing water connection No. (if any).....

.....

Owned by .....

Owner's address .....

.....

Applicant's name .....

son of .....

Address .....

.....

Situation .....

.....

Size of main.....on .....

Street .....

Where main is situated .....

.....

Size of service pipe .....

Size of ferrule .....

No. of taps ..... No. of closets .....

No. of other fittings and appliances .....

.....

Road cutting and repairing fee .....

.....

Paid Rs ..... (Receipt No .....

dated .....) (receipt enclosed)

Dated .....

Signature of the licensed plumber .....

Name and address of the licensed plumber .....

.....

.....

.....

The Authority's Report

Certified that the communication and distribution pipes and all water fittings have been laid, applied and executed in accordance with the provisions of bye-laws, and satisfactory arrangements have been made for draining off waste water.

Connection will be made on .....

Date .....

The Authority .....

.....

.....

.....

ANNEX C

(*Clause* 3.3.1)

APPLICATION FOR DRAINAGE OF PREMISES

I/We hereby make application to the * .....

.....

for permission to drain the premises .....

Ward No .....

Street No .....

Road/Street known as .....

.....

The sanitary arrangement and drains of the said premises are shown in the accompanying plans and a description of the specification of the work/material used is also appended (Annex D).

I/We undertake to carryout the work in accordance with Part 9 'Plumbing Services, Section 1 Water Supply, Drainage and Sanitation' of the Code.

.....

Signature of the licensed plumber

Name and address of the licensed plumber

.....

.....

Date .....

.....

Signature of the owner

Name and address

.....

.....

Date .....

NOTE — The application should be signed by the owner of the premises and shall be countersigned by the licensed plumber.

* Insert the name of the Authority.

ANNEX D

(*Clause* 3.3.3.2)

FORM FOR DETAILED DESCRIPTION OF WORK AND SPECIFICATION OF MATERIALS

1) Separation of rain-water and foul water .....
   .....
2) Rain-water drains, curbs and points of discharge .....
3) Rain-water gutters, pipes or spouts where discharging .....
4) Open-full-water drains, materials, sizes, curbs and other means places, verandahs, latrines
5) Silt-catcher and grating, size and position
   .....
6) Drains .....
   a) Main sewage drains: Fall .....
      Size .....
   b) Branch drains: Fall .....
      Size .....
   c) Materials .....
   d) Method of jointing .....
7) Bedding of pipes:
   a) Method of bedding .....
   b) Thickness and width of beds of concrete
      .....
   c) Thickness of concrete round pipes .....
      .....
8) Protection of drain laid under wall .....
9) Traps, description and intercepter:
   a) Lavatory waste pipes .....
   b) Bath waste pipes .....
   c) Sink .....
   d) Gully-traps .....
   e) Water-closet traps .....
   f) Grease traps .....
   g) Slop sink .....
   h) Urinal .....
   j) Others .....

10) Manholes and inspection chambers:
   a) Thickness of walls .....
   b) Description of bricks .....
   c) Description of rendering .....
   d) Description of invert channels .....
   e) Depth of chambers .....
   f) Size and description of cover and manner of fixing .....
11) Ventilation of drain:
   a) Position — Height above nearest ground level .....
   b) Outlet shaft position of terminal at top .....
12) Soil pipe, waste pipe and ventilating pipe connections:
   a) Lead and iron pipes .....
   b) Lead pipe of trap with cast iron pipe ....
   c) Stoneware pipe or trap with lead pipe ... .
   d) Lead soil pipe or trap with stoneware pipe or trap .....
   e) Cast iron pipe with stoneware drain ....
   f) Stoneware trap with cast iron soil pipe .....
13) Ventilation of water-closet trap sink, lavatory and other traps material and supports.
14) Water-closets (apartments):
   a) i) At or above ground level .....
      ii) Approached from .....
      iii) Floor material .....
      iv) Floor fall towards door .....
      v) Size of window opening in wall made to open .....
      vi) Position of same .....
      vii) Means of constant ventilation ....
      viii) Position of same .....
   b) Water-closet apparatus:
      i) Description of pan, basin, etc. ..... Kind .....
      ii) Flushing cistern .....
      iii) Material of flushing pipe .....
      iv) Internal diameter .....
      v) Union with basin .....
15) Sanitary fittings, water storage tank, etc:
   a) Number and description of sanitary fittings in room and rooms in which they are to be installed .....
   b) Capacity and position of water storage tanks .....
   c) Size and number of draw off taps and whether taken off storage tanks or direct from main supply .....
   d) Details of draw off taps, that is, whether they are of plain screw down pattern or 'waste not' and description of any other sanitary work to be carried out not included under above headings ....
16) Depth of sewer below surface of street ....
17) Level of invert of house drain at point of junction:
   a) with sewer .....
   b) Level of invert of sewer at point of junction with house drain .....
   c) Distance of nearest manhole on sewer from the point at which the drain leaves the premises .....
18) Schedule of pipes:

Description of Pipe/Drain	*Materials*	*Diameter*	*Weight*	*Method of Jointing*
a) Sub-soil drains				
b) Main sewage drains				
c) Branch sewage drains				
d) Soil pipes				
e) Ventilating pipes other than soil pipes				
f) Waste pipes				
g) Rain-water pipes				
h) Anti-syphon pipes				

Date .....

Signature of the licensed plumber .....
Name and address of the licensed plumber .....
.....
.....

ANNEX E

(*Clause* 3.3.5)

FORM FOR LICENCED PLUMBER'S COMPLETION CERTIFICATE

Certified that I/we have completed the plumbing work of drainage and sanitation system for the premises as detailed below. This may be inspected, approved and connection given.

Ward No .....

Street .....

Locality .....

Block No .....

House No .....

Details of work .....

.....

.....

.....

.....

The work was sanctioned by the Authority* vide

.....

Signature of the owner

Name and address .....

.....

.....

Date .....

.....

Signature of the licensed plumber .....

Name and address of the licensed plumber .....

.....

.....

The Authority's Report

Certified that the plumbing work of drainage and sanitation system for the premises, have been laid, applied, executed in accordance with Part 9 'Plumbing Services, Section 1 Water Supply, Drainage and Sanitation' of the Code.

Drainage connection to the main sewer will be made on .....

Date .....

The Authority .....

.....

.....

.....

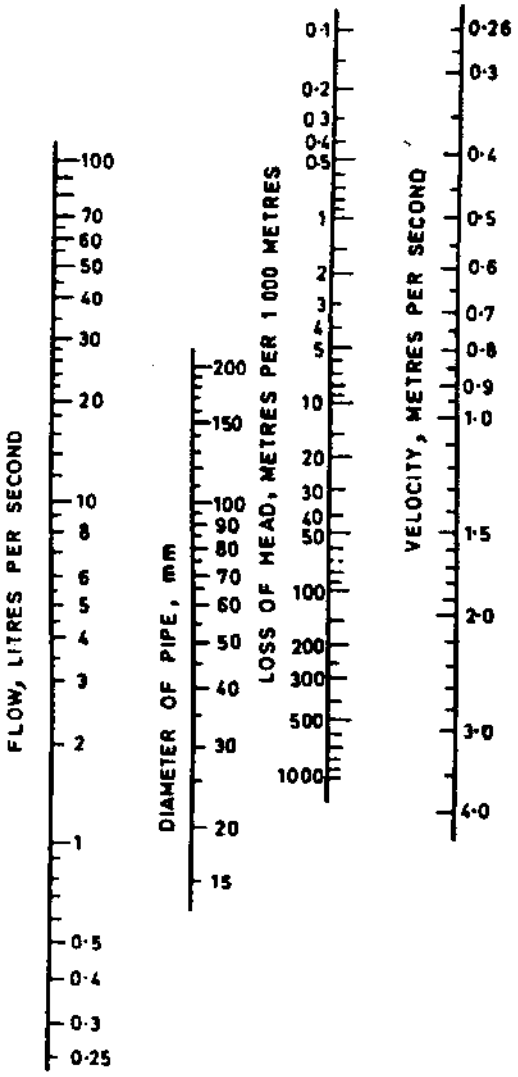
* Insert the name of the Authority.

ANNEX F

(*Clause* 4.6.4)

NOMOGRAM OF HAZEN AND WILLIAM'S EQUATION

E-1 Examples of the use of nomogram are given below:



Nomogram of Hazen & Williams Equation (c = 100)

Example 1

Find the total friction loss in 25 mm Ø G.I. Pipe discharging 0.25l/s in a total length of 300 m.

Procedure

Q = 0.25 l/s

Pipe Ø = 25 mm

Frictional loss from nomogram

= 30 m/1 000 m

Total friction loss in 300 m length

$$= \frac{30}{1000} \times 300 \text{ m} = 9 \text{ m}$$

Example 2

Find suitable diameter pipe to carry

15 l/s from service line to overhead tank.

Total length of service main = 200 m

Residual pressure available at the take off point on supply line is 15 m.

Procedure

Available head = 15 m

Deduct residual head = 2 m

Deduct 10 percent for losses in bends and specials = 1.3 m

Friction head available for loss in pipe of

$$= 1\,000 \text{ m} \frac{11.7 \times 1\,000}{2\,000} = 58.5/1\,000 \text{ m}$$

From the nomogram for a discharge of 15 l/s and friction loss of 58.5 m/1 000 m diameter of nearest commercial size of pipe is 100 mm diameter.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

	IS No.	*Title*
(1)	11208 : 1985	Guidelines for registration of plumbers
(2)	10500 : 1991	Specification for drinking water (*first revision*)
(3)	2041 : 1995	Specification for steel plates for pressure vessels used at moderate and low temperature (*second revision*)
	804 : 1967	Specification for rectangular pressed steel tanks (*first revision*)
(4)	3076 : 1985	Specification for low density polyethylene pipes for potable water supplies (*second revision*)
	4984 : 1995	Specification for high density polyethylene pipes for potable water supplies (*fourth revision*)
	4985 : 2000	Specification for unplasticized PVC pipes for potable water supplies (*third revision*)
(5)	2065 : 1983	Code of practice for water supply in buildings (*second revision*)
(6)	3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
(7)	782 : 1978	Specification for caulking lead (*third revision*)
(8)	5822 : 1994	Code of practice for laying of welded steel pipes for water supply (*second revision*)
(9)	6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
(10)	783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
(11)	7634	Code of practice for plastics pipe, work for potable water supplies:
	(Part 2) : 1975	Laying and jointing polyethylene (PE) pipes
	(Part 3) : 2003	Laying and jointing of UPVC pipes (*first revision*)
(12)	783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
	3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
	5822 : 1994	Code of practice for laying of welded steel pipes for water supply (*second revision*)
	6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
	7634	Code of practice for plastics pipe, work for potable water supplies:
	(Part 2) : 1975	Laying and jointing polyethylene (PE) pipes
	(Part 3) : 2003	Laying and jointing of UPVC pipes (*first revision*)
(13)	2692 : 1989	Specification for ferrules for water services (*second revision*)
(14)	302 (Part 1) : 1979	General and safety requirements for household and similar electrical appliances: Part 1 General (*fifth revision*)
	2082 : 1993	Stationary storage type electric water heaters (*third revision*)
(15)	7558 : 1974	Code of practice for domestic hot water installations
(16)	6295 : 1986	Code of practice for water supply and drainage in high altitudes and/or sub-zero temperature regions (*first revision*)
(17)	771	Specification for glazed fire-clay sanitary appliances:
	(Part 1) : 1979	General requirements (*second revision*)
	(Part 2) : 1985	Specific requirements of kitchen and laboratory sinks (*third revision*)

IS No.	Title
(Part 3/Sec 1) : 1979	Specific requirements of urinals, Section 1 Slab urinals (*second revision*)
(Part 3/Sec 2) : 1985	Specific requirements of urinals, Section 2 Stall urinals (*third revision*)
(Part 4) : 1979	Specific requirements of postmortom slabs (*second revision*)
(Part 5) : 1979	Specific requirements of shower trays (*second revision*)
(Part 6) : 1979	Specific requirements of bed-pan sinks (*second revision*)
(Part 7) : 1981	Specific requirements of slop sinks (*second revision*)
772 : 1973	Specification for general requirements for enamelled cast iron sanitary appliances (*second revision*)
773 : 1988	Specification for enamelled cast iron water-closets railway coaching stock type (*fourth revision*)
774 : 1984	Specification for flushing cistern for water-closets and urinals (other than plastic cistern) (*fourth revision*)
775 : 1970	Specification for cast iron brackets and supports for washbasins and sinks (*second revision*)
1700 : 1973	Specification for drinking fountains (*first revision*)
2326 : 1987	Specification for automatic flushing cisterns for urinals (*second revision*)
2548	Specification for plastic seats and covers for water-closets:
(Part 1) : 1996	Thermoset seats and covers (*fifth revision*)
(Part 2) : 1996	Thermo plastic seats and covers (*fifth revision*)
2556	Specification for vitreous sanitary appliances (vitreous china):
(Part 1) : 1994	General requirements (*third revision*)
(Part 2) : 1994	Specific requirements of wash-down water-closets (*fourth revision*)
(Part 3) : 1994	Specific requirements of squatting pans (*fourth revision*)
(Part 4) : 1994	Specific requirements of wash basins (*third revision*)
(Part 5) : 1994	Specific requirements of laboratory sinks (*third revision*)
(Part 6) : 1995	Specific requirements of urinals and partition plates (*fourth revision*)
(Part 7) : 1995	Specific requirements of accessories for sanitary appliances (*third revision*)
(Part 8) : 1995	Specific requirements of siphonic wash-down water-closets (*fourth revision*)
(Part 9) : 1995	Specific requirements of bidets (*fourth revision*)
(Part 14) : 1995	Specific requirements of integrated squatting pans (*first revision*)
(Part 15) : 1995	Specific requirements of universal water-closets (*first revision*)
(Part 16) : 2002	Specific requirements for wash-down wall mounted water-closets
(Part 17) : 2001	Specific requirements for wall mounted bidets
3489 : 1985	Specification for enamelled steel bath tubs (*first revision*)
6411 : 1985	Specification for gel-coated glass fibre reinforced polyester resin bath tubs (*first revision*)
7231 : 1994	Specification for plastic flushing cisterns for water-closets and urinals (*second revision*)
8718 : 1978	Specification for vitreous enamelled steel kitchen sinks
8727 : 1978	Specification for vitreous enamelled steel washbasins
9076 : 1979	Specification for vitreous integrated squatting pans for marine use
11246 : 1992	Specification for glass fibre reinforced polyester resins (GRP) squatting pans (*first revision*)

IS No.	*Title*
13983 : 1994	Specification for stainless steel sinks for domestic purposes
(18) 651 : 1992	Specification for salt glazed stoneware pipes and fittings (*fifth revision*)
3006 : 1979	Specification for chemically resistant salt glazed stoneware pipes and fittings (*first revision*)
(19) 458 : 2003	Specification for precast concrete pipes (with and without reinforcement) (*fourth revision*)
784 : 2001	Specification for prestressed concrete pipes (including specials) (*second revision*)
1916 : 1989	Specification for steel cylinder with concrete lining and coating (*first revision*)
4350 : 1967	Specification for concrete porous pipes for under drainage
7319 : 1974	Specification for perforated concrete pipes
(20) 1536 : 2001	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*fourth revision*)
1537 : 1976	Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*)
1538 : 1993	Specification for cast iron fittings for pressure pipes for water, gas and sewage (*third revision*)
3989 : 1984	Specification for centrifugally cast (spun) spigot and socket-soil, waste and ventilating pipes and fittings and accessories (*second revision*)
7181 : 1986	Specification for horizontally cast iron double flanged pipes for water, gas and sewage (*first revision*)
(21) 1592 : 2003	Specification for asbestos cement pressure pipes and joints (*fourth revision*)
1626	Specification for asbestos cement building pipes and pipe fittings, gutters and gutter fittings, and roofing fittings:
(Part 1) : 1994	Pipes and pipe fittings (*second revision*)
(Part 2) : 1994	Gutters and gutter fittings (*second revision*)
(Part 3) : 1994	Roofing accessories (*second revision*)
6908 : 1991	Specification for asbestos cement pipes and fittings for sewerage and drainage (*first revision*)
(22) 404 (Part 1) : 1993	Specification for lead pipes: Part 1 For other than chemical purposes (*third revision*)
(23) 13592 : 1992	Specification for UPVC pipes for soil and waste discharge systems inside buildings including ventilation and rainwater system
14333 : 1996	Specification for high density polyethylene pipe for sewerage
14735 : 1999	Specification for unplasticized polyvinyl chloride (UPVC) injection moulded fittings for soil and waste discharge system for inside and outside buildings including ventilation and rain water system
(24) 2470	Code of practice for installation of septic tanks:
(Part 1) : 1985	Design criteria and construction (*second revision*)
(Part 2) : 1985	Secondary treatment and disposal of septic tank effluent (*second revision*)
5611 : 1987	Code of practice for waste stabilization ponds (facultative type) (*first revision*)
(25) 5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)
(26) 2212 : 1991	Code of practice for brickwork (*first revision*)
(27) 5455 : 1969	Specification for cast iron steps for manholes
(28) 1726 : 1991	Specification for cast iron manhole covers and frames (*third revision*)

IS No.	*Title*
12592 : 2002	Specification for precast concrete manhole covers and frames (*first revision*)
(29) 4111 (Part 1) : 1986	Code of practice for ancillary structures in sewerage system: Part 1 Manholes (*first revision*)
(30) 14961 : 2001	Guidelines for rain water harvesting in hilly areas by roof water collection system
(31) 783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
1742 : 1983	Code of practice for building drainage (*second revision*)
3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
4127 : 1983	Code of practice for laying of glazed stoneware pipes (*first revision*)
6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
(32) 1729 : 2002	Specification for cast iron ductile iron drainage pipes and pipe fittings for grand non-pressure pipe line socket and spigot series (*second revision*)
(33) 2064 : 1993	Code of practice for selection, installation and maintenance of sanitary appliances (*second revision*)
(34) 6924 : 1973	Code of practice for the construction of refuse chutes in multi-storeyed buildings

NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES

Section 2 Gas Supply

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section covers the safe use of gas for fuel or lighting purposes in buildings.

The use of gas for fuel and lighting purposes in buildings has begun in some parts of the country and with the advent of new petroleum complexes, community gas supply is bound to become one of the important services like electricity and water supply in buildings.

The use of liquefied petroleum gas supplied in containers and cylinders is already quite popular. On release of pressure, by opening the valve, they readily convert into the gaseous phase. In this state they present a hazard comparable to any inflammable natural or manufactured gas, except that being heavier than air, low level ventilation is necessary to avoid inflammable concentration of gas.

A minimum set of safety regulations are, therefore, laid down to safeguard the gas piping installation and the mode of operation in the interest of public safety.

The first version of this part was prepared in 1970 and was subsequently revised in 1983. In the first revision, the safe distance between gas piping and electrical wiring system was modified as well as between gas piping and steam piping was incorporated. Additional information regarding the handling, use, storage and transportation of LPG in cylinders exceeding 500 ml water capacity were included. Provisions relating to LPG cylinders, installations regarding some aspects, such as jointing compound used at joints, painting of gas piping, details of fire extinguishers, total quantity of LPG at stationary and portable installations in proportion to the floor area were added. Also, some provisions of LPG bulk storage installations were introduced.

As a result of experience gained in implementation of 1983 version of the Code and feed back received a need to revise this part was felt. This revision has, therefore, been prepared to take care of these. The significant changes incorporated in this draft revision include:

a) Provision with regard to pressure regulations have been modified.
b) In the provision of service shut-off valves, number of additional shut-off valves have been specified.
c) In the provision of installation of gas pipe, new materials for pipes have also been mentioned. The minimum diameter for gas pipe has been reduced to 8 mm. The colour for pipe line for supplying natural gas has been specified. The provisions regarding protection against the corrosion have been modified. Also, the process of installation of meters have been clarified.
d) Additional method for detection of leakage of gas has been recommended.
e) Also, a few more terminologies have been added.

The information regarding the use of liquefied pertroleum gas has been largely based on the following Indian Standards:

IS No.	*Title*
6044	Code of practice for liquefied petroleum gas storage installations:
(Part 1) : 2000	Commercial and industrial cylinder installations (*first revision*)
(Part 2) : 2001	Commercial, industrial and domestic bulk storage installations (*first revision*)

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 9 PLUMBING SERVICES

Section 2 Gas Supply

1 SCOPE

1.1 This Section covers the requirements regarding the safety of persons and property for all piping uses and for all types of gases used for fuel or lighting purposes in buildings.

1.2 This Section does not cover safety rules for gas burning appliances.

2 TERMINOLOGY

2.1 For the purpose of this Section, the following definitions shall apply.

2.1.1 *Appliance Valve* — A device that will shut-off the gas supply to the burner(s).

2.1.2 *Authority Having Jurisdiction* — The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.1.3 *Customer's/Consumer's Connection* — Piping tapped on riser to supply each individual customer/ consumer.

2.1.4 *Gas Fitter* — An employee of the gas supplying organization.

2.1.5 *Pilot* — A small flame which is utilized to ignite the gas at the main burner(s).

2.1.6 *Pressure Regulator* — A device designed to lower the pressure of gas coming from the distribution main and to maintain it practically constants downstream. This normal operation pressure shall be practically in all cases that of the gas appliances used.

2.1.7 *Purge* — To free a gas conduit of air or gas or a mixture of gas and air.

2.1.8 *Qualified Installing Agency* — An individual, firm or agency which either in person or through a representative is engaged in and is responsible for the installation or replacement of gas piping on the outlet side of the gas meter, or the connection, installation or repair of gas supply piping and appliances within a building, and who is experienced in such work, familiar with all precautions required, and who has complied with all the requirements as to qualification, registration, licensing, etc, of the Authority.

2.1.9 *Riser* — Piping usually vertical on most of its length that supplies gas from the service to the various storeys of the building.

2.1.10 *Service Pipe* — Pipe that runs between the distribution main in the street and the riser in the case of multi-storeyed building or the meter in the case of an individual house.

2.1.11 *Service Shut-Off Valve (Isolation Valve)*

A device installed outside the premises to cut-off the main supply of gas from pipeline by the supplier.

2.1.12 *Vent Pipe* — A safety device to which certain regulators are connected to evacuate outside gas that may escape from the normal circuit when some part of system gets damaged or malfunctions or a safety valve is open.

3 PRESSURE REGULATIONS

3.1 Pressure regulation is required to economize the sizing of piping system. Where the pressure of gas supplied to domestic system or other low pressure gas piping system in buildings is in excess of the pressure to be used in the appliance, a gas pressure regulator of suitable specification shall be installed in service pipe of each system to prevent excess pressure reaching the appliance. The pressure regulators to be used can be from 400 kN/m^2 upstream pressure to 2.1 kN/m^2 for domestic consumers and 10 kN/m^2, 30 kN/m^2, 200 kN/m^2 for commercial consumers, as the case may be.

3.1.1 In some place the reduction of pressure from main distribution source of 400 kN/m^2 to intermediate pressure (say 7 kN/m^2) and then to operating pressure of 2.1 kN/m^2 is achieved.

3.1.2 Whereas in most of the other places the reduction of pressure from main distribution source of 400 kN/m^2 to directly operating pressure (say 2.1 kN/m^2, 10 kN/m^2, 30 kN/m^2, 200 kN/m^2) is achieved in single stage pressure reduction.

3.2 If located inside a building, the required regulator shall comply with the following:

a) If any of the diaphragms of the regulator ruptures, the gas shall be sent to an outlet vent pipe made of brass or plastic in order to ventilate or drain the gas out of the building. The vent pipe will, however, lead to outer air about 1 m above the topmost storey of the building. Means shall be employed to prevent water from entering this pipe and also to prevent stoppage of it by insects or other foreign bodies.

b) If the gas pressure at the outlet of the regulator falls below 50 percent of the operating gas pressure or rises above twice the operating gas pressure, the gas input to the pressure regulator shall be cut off.

c) In the event of malfunctioning of this safety device, a supplementary device shall connect the low pressure circuit to the outlet circuit (vent pipe) as soon as the exit pressure reaches 7 kN/m^2.

3.3 It shall also be ensured by the supply authority that the calorific value and supply pressure of gas shall not exceed the values for the type of gas used.

4 SERVICE SHUT-OFF VALVES

4.1 Service shut-off valves shall be installed on all new services including replacements in a readily accessible location.

4.2 Service shut-off valves shall be located upstream of the meter if there is no regulator or upstream of the regulator, if there is one.

4.2.1 Service shut-off valves shall be located in the upstream of the meter, if a single regulator is supplying more than one consumer and each such stream shall have one additional shut off valve upstream of regulator.

4.3 All gas services operating at pressure greater than 7 kN/m^2 shall be equipped with an approved service shut-off valve located on the service pipe outside the building.

4.4 Underground shut-off valves shall be located in a covered durable curb box, manhole, vault or stand pipe which is designed to permit ready operation of the valve and the covers of which shall be clearly marked 'Gas'.

5 EXISTING WORK

Nothing herein shall prohibit the continued use of existing system of the gas piping without further inspection or test, unless the Authority has reason to believe that defects which make the system dangerous to life or property exist.

6 RULES FOR TURNING GAS ON

6.1 No person, unless is the employ of the gas company or having permission from the gas company, shall turn on the gas at a service shut-off valve or at any valve that controls the supply of gas to more than one consumer.

6.2 Gas shall not be turned on at any meter valve without specific permission from the gas company or other authority if any of the following conditions exists:

a) If the gas piping appliances or meter supply through the meter valve are known to leak or otherwise to be defective (*see* **10**).

b) If required inspection of the piping or appliance has not been made.

c) If the gas company or other authority has requested that the gas be left turned off.

d) If the meter valve is found shut off for some reason not known to the gas fitter.

The gas shall not be turned on in the event of fire.

6.3 Gas shall not be turned on at any branch line valve if any of the conditions specified in **6.2** prevails. Where a branch line valve is found closed, a gas fitter shall again turn the gas on at such valve only if proper precautions to prevent leakage are taken and no other unsafe conditions are created thereby.

6.4 Gas shall not be turned on at either the meter valve or service line unless all gas keys or valves provided on all outlets in the piping system are closed or all outlets in the piping system are capped or plugged.

7 RULES FOR SHUTTING OFF THE GAS

7.1 The gas fitter shall put the gas off to any appliance, pipe or piping system and shall leave the gas turned off, until the causes for interrupting the supply has been removed in any one of the following cases:

a) If ordered to do so by the Authority.

b) If leakage of gas is noted, which appears to be sufficient to cause fire, explosion or asphyxiation.

c) If an installation of some gas appliance is found to be such as to cause a serious hazard to persons or property.

d) If any condition exists which threatens interruption of gas supply which may cause burner outage or otherwise prove dangerous.

7.2 It shall be the duty of the installing agency when the gas supply is to be turned off to notify all affected consumers.

7.3 Before turning off the gas at the meter, for the purpose of installation, repair, replacement or maintenance of piping or appliance, all burner and pilot valves on the premises supplied with gas through the meter shall be turned off and the meter test hand observed for a sufficient length of time to ascertain that there is no gas passing through the meter. Where there is more than one meter on the premises, precaution shall be exercised to ensure that the concerned meter is turned off.

8 INSTALLATION OF GAS PIPES

8.1 Installation, repair and replacement of gas piping

or appliances shall be performed only by a qualified installing agency.

8.2 Piping

8.2.1 Piping shall be of wrought iron, steel, copper or cast iron when the gas pressure is less than 7kN/m^2; with higher gas pressure use of cast iron shall be prohibited.

8.2.1.1 SS 316/304/321 Flexible PE coated flexible pipe in rolls shall be permitted in low pressure system provided the pipe meets the required standard, to avoid the bends, fittings and leakages from the joint which are potential leakage points. Also, reference may be made to accepted standard [9-2(1)]. Heavy rubber flexible tube shall be permitted only as direct connection to burner from appliance valve.

8.2.2 *Size of Gas Piping*

Gas piping shall be of such size and so installed as to provide supply of gas sufficient to meet the maximum demand without undue loss of pressure between the meter or service regulator when a meter is not provided, and the appliance(s).

8.2.2.1 The size of gas piping depends upon the following factors:

a) allowable loss in pressure from meter or service regulator, when a meter is not provided, to appliance;
b) maximum consumption to be provided;
c) length of piping and number of fittings; and
d) specific gravity of gas.

8.2.2.2 No gas pipe smaller than 8 mm shall be used.

8.2.3 As far as possible, straight lengths of piping should be used. Where there are bends in the pipe line, these should have a radius of at least five times the diameter of the pipe.

8.2.4 For any thread joint proper sealant shall be used on male threads only.

8.3 The gas piping shall be of the colour stipulated by explosive authority to distinguish it from other piping and the piping shall be painted silver grey with red band of 150 mm width. The gas pipeline shall be painted canary yellow in case of natural gas.

8.4 Piping Underground

8.4.1 *Protection of Piping*

Piping shall be buried to a minimum depth of 1 m or covered in a manner so as to protect the piping from physical damage.

8.4.2 *Protection against Corrosion*

Generally all the piping within the premises where it has to run on the wall shall be exposed and should not be in contact with wall to ensure that no corrosion takes place. Epoxy sealant or polyethylene conduit shall be used to ensure no contact of pipe with the wall in the situation of pipe crossing the wall. Under ground or concealed gas pipeline in contact with earth or other materials which may corrode the piping shall be protected against corrosion by application of adequate corrosion resistant coating backed up by cathodic protection system.

8.5 The building shall not be weakened by the installation of any gas piping.

8.6 Gas piping in building shall be supported with pipe hooks, metal pipe straps, bonds or hangers suitable for the size of piping and of adequate strength and quality and located at proper intervals so that the piping may not be moved accidentally from the installed position.

8.7 Pipe Entrance to Buildings

Where gas pipe enters a building through a wall or floor of masonry or concrete, any gas piping or other piping entering the walls or floors shall be suitably sealed against the entrance of water/moisture or gas. Regarding protection of openings in walls or floors, from fire, reference shall be made to Part 4 'Fire and Life Safety'.

8.7.1 *Piping in Floors*

Piping in solid floors, such as concrete, shall be laid in channels in the floor suitably covered to permit access to the piping with a minimum damage to the building.

8.7.2 Single pipe without joint shall be used for wall crossing in any building.

8.8 Gas pipe shall not be bent. Fittings shall be used when making turns in gas pipe.

8.9 Generally concealed piping shall not be allowed. However, if it is necessary then it shall be under the **8.4** of underground piping and all protection such as coating, cathodic protection shall be done.

8.10 A drip shall be provided in the gas distribution system, if the moisture contents in the gas is likely to reach saturation point at any stretch of pipe line in the system; a drip shall, however, be provided at any suitable point in the line of the pipe where condensate may collect and from where it can be easily removed. This drip should be so installed as to constitute a trap where in an accumulation of condensate will shut off the flow of gas before it will run back into the meter.

8.10.1 Drip has to be provided in the case of gas consisting moisture content.

8.11 Prohibited Devices

No device shall be placed inside the gas piping or fittings that will reduce the cross-sectional area or otherwise obstruct the free flow of gas.

8.12 Piping shall be electrically continuous throughout its length and properly earthed except in stretches where cathodic protection system is used for protection against corrosion. It shall not, however, be used to earth any electrical equipment.

8.12.1 The distance between gas piping and electrical wiring system shall be at least 60 mm and, where necessary, they shall be securely fixed to prevent contact due to movement. The gas piping should run above the electrical wiring. In this type of installation in the event of any leakage of natural gas, the gas would move up (natural gas being lighter than air) and would not come directly in contact with the electrical wiring. If the gas to be supplied is heavier than the air then the gas piping should run below the electrical wiring.

8.13 The distance between the gas piping and steam piping, if running parallel, shall be at least 150 mm. The gas piping should preferably run below the steam piping.

8.14 Piping installation shall be thoroughly gas-tight.

8.15 Smoking shall not be permitted when working on piping which contains or has contaminated gas.

8.16 Meters shall be installed in such a way that there shall be no load transfer from the pipeline to the inlet/outlet of the meter and shall be easily accessible.

9 INSPECTION OF SERVICES

9.1 No person shall use or permit the use of a new system or an extension of an old system of gas piping in a building or structure before the same has been inspected and tested to ensure the tightness of the system, and a certificate has been issued by the Authority.

9.1.1 *Test of Piping for Tightness*

Before any system of gas piping is finally put in service, it shall be carefully tested to ensure that it is gas-tight. Where any part of the system is to be enclosed or concealed, this test should precede the work of closing in. To test for tightness the piping may be filled with city gas, air or inert gas but not with any other gas or liquid. In no case shall oxygen be used. The piping shall stand a pressure of at least 20 kN/m^2 measured with a manometer or slope gauge, for a period of not less than 10 min without showing any drop in pressure.

9.1.2 When the gas pressure exceeds 7 kN/m^2, the piping shall withstand a pressure of 0.6 MN/m^2 for 4 h. (This test is for piping designed for working pressure less than 0.4 MN/m^2.)

9.2 The Authority shall, within a reasonable time after being requested to do so, inspect and test a system of gas piping that is ready for such inspection and test, and if the work is found satisfactory and test requirements are complied with, it shall issue the certificate.

10 LEAKAGE CHECK

10.1 Before turning gas under pressure into any piping, all openings from which gas may escape shall be closed.

10.2 Checking for Gas Leakage

No matches, flame or other sources of ignition shall be employed to check for gas leakage from meters, piping or appliances. Checking for gas leakage with soap and water solution is recommended.

10.3 Use of Lights

Artificial illumination used in connection with a search of gas leakage shall be restricted to electric hand flash lights (preferably of the safety type) or approved safety lamps. In searching for leaks, electric switches should not be operated. If electric lights are already turned on, they should not be turned off.

10.4 Checking for Leakage with Meter

Immediately after turning gas into the piping, the system shall be checked to ascertain that no gas is escaping. This may be done by carefully watching the test dial of the meter to determine whether gas is passing through the meter. In no case should a leakage test be made using a gas meter unless immediately prior to the test it has been determined that the meter is in operating condition.

10.5 Checking of Leakage Without Using a Meter

This may be done by attaching to an appliance, orifice or a manometer or equivalent device and momentarily turning on the gas supply and deserving the gauging device for pressure drop with the gas supply shut-off. No discernible drop in pressure shall occur during a period of 3 min.

10.6 After piping has been checked, all gas piping shall be fully purged. Piping shall not be purged into the combustion chamber of an appliance. A suggested method for purging the gas piping to an appliance is to disconnect the pilot piping at the outlet of the pilot valve.

10.7 After the gas piping has been effectively purged, all appliances shall be purged and the pilots lighted.

10.8 In addition to the checking of gas leakage with soap and water solution, a suitable gas detector is also recommended for use.

11 USE OF LIQUEFIED PETROLEUM GAS

11.1 The cylinders used for the storage and transportation of liquefied petroleum gas (LPG) shall conform to accepted standards [9-2(2)] approved by the statutory authority.

11.2 The handing, use, storage and transportation of liquefied petroleum gas in cylinders exceeding 500 ml water capacity shall be done in accordance with good practice [9-2(3)].

11.3 LPG Cylinder Installation

The following recommendations apply to installation in commercial, industrial, educational and institutional premises.

11.3.1 *General Recommendations*

11.3.1.1 Those responsible for the installation of cylinders, equipment and piping should understand the characteristics of LPG and be trained in good practice of handling, installing and maintaining installations.

11.3.1.2 The jointing compound used at different joints in the system shall be decided by the Qualified Installing Agency. Hemp and similar materials shall not be used at the joint. In any joint in which the thread provides a gas-tight seal, jointing compound shall be used only on the male thread.

11.3.1.3 Fire extinguishers of dry powder type or carbon dioxide type conforming to accepted standards [9-2(4)] shall be provided in places where LPG cylinder installations are situated and shall be located near such installations. Two buckets filled with sand and two with water shall also be installed nearby. The number, type and size of the fire extinguishers shall be as follows:

		Number	*Type*	*Capacity*
a)	For installations with LPG 40 kg to 200 kg	2	Dry Powder	10 kg
b)	For installations with LPG more than 200 kg and up to 320 kg	2	Dry powder	10 kg
c)	For installations with LPG more than 320 kg and up to 1 000 kg	3	Dry powder	10 kg

For electrical installations, one number CO_2 fire extinguisher (4.5 kg capacity) shall be provided.

11.3.1.4 Liquefied petroleum gas shall not be transferred from the cylinders in which it is received to any other container.

11.3.2 *Cylinder Location*

11.3.2.1 *Stationary installations*

a) Stationary installation not exceeding 40 kg of LPG may be installed indoors on any floor. It is recommended to have a minimum floor area of 5 m^2 for such an installation.

b) Stationary installations each not exceeding 40 kg of LPG may be installed indoors on any floor within the same workspace provided the minimum distance between two such installations is 3 m, the proportion of such installations to floor area is one installation per 5 m^2 and the aggregate quantity of gas of all such installations does not exceed 200 kg.

c) Stationary installation not exceeding 80 kg of LPG may be installed indoors on any floor provided the floor area for such an installation is not less than 12 m^2.

d) Stationary installations each not exceeding 80 kg of LPG may be installed indoors on any floor and within the same workspace provided the minimum distance between two such installations is 3 m, the proportion of such installations to floor area is one installation per 12 m^2 and the aggregate quantity of gas of all such installations does not exceed 200 kg.

e) Stationary installation not exceeding 320 kg of LPG may be installed indoors in an enclosed section of a building or a room reserved exclusively for this purpose and ventilated at low level directly to the outside air.

f) Stationary installation above 320 kg [200 kg in case provision as in (e) is not possible] but not exceed 1 000 kg shall be installed outdoors on ground level only. A minimum distance of 3 m shall be maintained between an installation and any building, public place, roadways, and other surroundings. The installation shall be protected from excessive weathering by sun, rain, etc, and from tampering by unauthorized persons. A lean-to-roof with expanded metal on angle-iron framework on the sides is considered suitable for this purpose. In any case, adequate ventilation at ground level to the outside air shall be provided. The distance between any two such installations shall be 3 m unless separated by a leakproof wall of fire-resistant

material up to at least 1 m above the height of the manifold valve.

g) The position of the cylinders shall facilitate:
   1) changing and quick removal of any cylinder in case of necessity, and
   2) access to cylinder valve connections and regulating devices.

h) Cylinders shall be installed upright with the valves uppermost.

j) Cylinder shall not be installed or used below ground level in cellars or basements.

k) Cylinders containing more than 20 kg of gas shall not be located on floors above ground level.

m) Cylinders shall be located on a concrete or brick floor, preferably raised in case of outdoor installations.

n) Cylinders shall not be placed close to steam pipes or any other source of heat and shall be protected from the weather and direct sun's heat. Cylinders shall be placed at a distance of 3 m away from any other source of heat which is likely to raise the temperature of cylinders above the room temperature unless separated by metal sheet or masonry partition.

p) When cylinders are being connected or disconnected, there shall be no open flame or similar source of ignition in the vicinity; and smoking shall be prohibited.

q) Cylinders shall not be installed at a place where they are likely to cause an obstruction, to be damaged or to be exposed to conditions likely to affect their safety.

r) In order to prevent the hazardous collection of gas, cylinders shall be placed at least 1 m away from culverts, depressions, or openings leading to below ground level compartment, and drains.

s) Cylinders which have safety relief valves or similar devices incorporated in them shall be so positioned that if the relief device operates, escaping gas is not hazardous.

11.3.2.2 *Portable installations*

When portability of cylinders is necessary the following requirements shall be fulfilled:

a) The sum total capacity of the cylinders connected to each manifold shall not exceed 80 kg of LPG. The total quantity of gas thus installed in a workspace shall not exceed 200 kg.

b) If cylinders are mounted on a trolley shall be stable. Where necessary, the cylinders shall be secured to prevent them from falling.

c) The regulator shall be connected directly to the cylinder valve or to a manifold which shall be connected to the cylinder valves by means of rigid connections to give adequate support to the regulator. The only exception to this requirement is where cylinders are mounted on a trolley and the manifold is rigidly supported on the trolley. In such a case flexible or semi-flexible connections may be used between the cylinder valves and the manifold but not between the manifold and the regulator.

d) At any time the total quantity of gas at portable installations shall be in proportion to the floor area as specified in **11.3.2.1**(a) to **11.3.2.1**(f).

e) At any time the provisions at **11.3.2.1** shall be ensured for all installations.

11.3.3 *Cylinder Manifolds*

11.3.3.1 All materials, fittings, etc, used in cylinder manifold systems shall comply with the distributing company's stipulations.

11.3.3.2 The individual component parts of manifolds, that is, piping, fittings, pigtails, etc, which are subject to cylinder pressure shall be capable of withstanding a test pressure without bursting of 2.5 N/mm^2 or one and a half times the maximum pressure corresponding in the maximum assessed temperature of the cylinder, whichever is more.

11.3.3.3 Where cylinder installations are made up with service and reserve batteries of cylinders, suitable change-over devices or valves shall be incorporated in the manifold header to prevent undue escape of the gas when cylinders are changed.

11.3.3.4 If pressure regulators, manifold headers, automatic change-over devices, etc, are connected to cylinders by semi-flexible connectors, they shall be rigidly supported. Copper tube pigtails are considered to be flexible or semi-flexible connectors for this purpose.

11.3.3.5 Suitable line shut-off valves shall be fitted for each appliance or burner when more than one appliance is connected to the gas supply. Both ends of the connection to portable appliances shall be securely attached by means of clips. Hose shall be of a type resistant to liquefied petroleum gas.

11.3.3.6 It is recommended that joints in manifold headers which do not have to be taken in normal use should be welded or brazed using a material and which shall have a melting point of at least 540°C.

11.3.3.7 All joints between manifold headers and cylinder connectors shall be readily accessible.

11.3.4 *Pressure Regulators*

11.3.4.1 Pressure regulators and other devices used to control the gas shall comply with the distributing company's stipulations and accepted standards [9-2(5)].

11.3.4.2 Pressure regulator fitted with a safety valve shall be either:

a) installed in the open air, or
b) vented to the open by means of a metal vent pipe connected to the safety valve outlet.

11.3.4.3 Care shall be taken that safety valve outlets do not become choked with dust or other foreign matter.

11.3.4.4 If the regulator is fitted with a relief valve, care should be taken in positioning the regulator to avoid unnecessary hazards if the relief valve functions.

11.3.4.5 Pressure regulators and other control devices shall be adequately supported.

11.3.5 *Instructions to Consumers*

A handbook containing all instructions with regard to the following aspects shall be supplied by the supplier to the consumers:

a) operation of the whole system;
b) how to recognize gas leaks;
c) action to be taken in case of leakage;
d) action to be taken in case of fire; and
e) action to be taken in case of damage to, or failure of any part of the installation.

11.3.6 For detailed information regarding installation of LPG cylinders in commercial, industrial, educational and institutional premises, reference may be made to good practice [9-2(6)].

11.4 LPG Bulk Storage Installations

11.4.0 The following recommendations apply to LPG bulk storage installations where storage tanks over 450 litres water capacity are used at industrial, commercial and domestic consumers' premises.

The maximum capacity of an individual tank and group of tanks at industrial, commercial and domestic premises shall be as follows:

Premises	*Maximum Water Capacity of an Individual Tank,* l	*Maximum Water Capacity of Group of Tanks,* l
Industrial	130 000	260 000
Commercial	40 000	80 000
Domestic	20 000	80 000

11.4.1 *Location and Spacing of Storage Tanks*

11.4.1.1 Storage tanks shall be located outside the buildings and shall not be installed one above the other.

11.4.1.2 Each individual tank shall be located with respect to the nearest important building or group of buildings or line of adjoining property which may be built in accordance with Table 1. The distances given refer to the horizontal distance in plan between the nearest point of the storage tank and building/property line.

11.4.1.3 In heavily populated or congested areas the authority may determine the need for other reasonable protective methods to be taken, such as provision of fire walls, etc. If fire walls are to be provided, the authority may determine the extent to which the safety distances for above ground tanks may be reduced.

11.4.1.4 No LPG tank(s) shall be located within the bunded enclosures of any petroleum installation. The minimum distance of separation between LPG storage tanks and any petroleum installation shall be as prescribed under the *Petroleum Rules*, 1976 or as specified in Table 1 whichever is more.

11.4.1.5 The number of storage tanks in one storage installation shall not exceed six. In case there are more than one storage installations, the safety distance between two installations shall be the same as the distance between the tanks and the property line in accordance with Table 1.

11.4.2 *Bunding*

Since LPG is heavier than air, storage tank shall not be enclosed within bund walls. The accumulation of flammable liquid under LPG tanks shall be prevented by suitably slopping the ground.

11.4.3 *Protection*

11.4.3.1 To prevent trespassing or tampering, the area which includes tanks, direct fired vapourisers, pumping equipment and loading and unloading facilities shall be enclosed by an industrial type fence at least 2 m high along the perimeter of the safety zone. Any fence shall have atleast two means of exit. Gates shall open outwards and shall not be self-locking.

11.4.3.2 When damage to LPG systems from the LPG tank lorry is a possibility, precautions against such damage shall be taken.

11.4.3.3 Underground tanks shall be protected from above ground loading by providing a suitable curb to prevent a possible accidental damage to the tank and its fittings by LPG tank lorry.

11.4.4 *Grass and Weed Removal*

Road ignitable material, such as weeds, long grass or any combustible material shall be removed from an

Table 1 Minimum Safety Distances

(*Clauses* 11.4.1.2, 11.4.1.4 *and* 11.4.1.5)

Sl No.	LPG Storage Water Capacity of Individual Tank	Distance from Building/Property Line		Distance between Tanks	
	l	Above Ground m	Under Ground m	Above Ground m	Under Ground m
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to 2 000	5	5	1	1.5
ii)	Above 2 000 and up to 10 000	10	7.5	1	1.5
iii)	Above 10 000 and up to 20 000	15	10	1.5	1.5
iv)	Above 20 000 and up to 40 000 adjacent	20	15	2	0.25 dia of vessel or 1.5 m, *Min*
v)	Above 40 000 and above adjacent	30	15	2	0.25 dia of vessel or 1.5 m, *Min*

NOTE — If the aggregate water capacity of a multi-tank installation is 40 000 litres or greater, the above minimum safety distances shall apply to the aggregate storage capacity rather than the capacity per individual storage tank.

area within 3 m from the shell of any LPG tank of up to 2 000 litres water capacity, and within 6 m from the shell of larger tanks. If weed killers are used, chemicals which are a potential source of fire hazard shall not be selected for this purpose.

11.4.5 *Warning Signs*

No smoking or naked flames shall be permitted within the safety zone of the installation. Prominent notices to this effect shall be posted at access point.

11.4.6 *Fire Protection*

The possibility of a major fire outbreak, leading to direct flame impingement of the storage tank, shall be minimized by sound engineering in plant design and layout, good operating practice, and proper education and training of personnel on both routine operations and on action to be taken in an emergency.

11.4.6.1 *Water supply*

Provision shall be made for an adequate supply of water and fire protection in the storage area according to the local hoses and mobile equipment, fixed monitors or by fixed spray systems which may be automatic. Control of water flow should be possible from outside any danger area.

11.4.6.2 *Fire extinguishers*

At least two dry chemical powder type fire extinguishers of 10 kg capacity each, conforming to the quality requirements in accordance with the accepted standards [9-2(7)], each shall be installed at points of access to the storage installations.

11.4.7 For detailed information regarding LPG bulk storage installations reference may be made to good practice [9-2(8)].

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

IS No.	*Title*
(1) 14885 : 2001	Specification for polyethylene pipe for the supply gaseous fuel
(2) 3196 (Part 1) : 1992	Specification for welded low carbon steel cylinders exceeding 5 litre water capacity for low pressure liquefiable gases: Part 1 Cylinders for liquefied petroleum gases (LPG) (*fourth revision*)
7142 : 1995	Specification for welded low carbon steel cylinders for low pressure liquefiable gases not exceeding 5 litre water capacity (*first revision*)
(3) 8198 (Part 5) : 1984	Code of practice for steel cylinders for compressed gases: Part 5 Liquefied petroleum gas (LPG) (*first revision*)

	IS No.	Title
(4)	2171 : 1999	Specification for portable fire extinguisher, dry powder (cartridge type) (*third revision*)
	2878 : 1986	Specification for fire extinguisher, carbon dioxide type (portable and trolley mounted) (*second revision*)
(5)	4784 : 1968	Specification for low pressure regulators for use with butane gases
	4785 : 1968	Specification for low pressure regulators for use with propane gas
	4786 : 1968	Specification for variable high pressure regulators for use with liquefied petroleum gas
(6)	6044 (Part 1) : 2000	Code of practice for liquefied petroleum gas storage installations: Part 1 Commercial and industrial cylinder installations (*first revision*)
(7)	2171 : 1999	Specification for portable fire extinguishers, dry powder (cartridge type) (*third revision*)
(8)	6044 (Part 2) : 2001	Code of practice for liquefied petroleum gas storage installations: Part 2 Commercial, industrial and domestic bulk storage installations (*first revision*)

NATIONAL BUILDING CODE OF INDIA

PART 10 LANDSCAPING, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 1 Landscape Planning and Design

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Part of the Code was first published in 1970 and subsequently revised in 1983, and covered provisions relating to only signs and outdoor display structures. In this revision, this Part has been sub-divided into two sections as follows by including a new section on landscaping:

Section 1 Landscape planning and design

Section 2 Signs and outdoor display structures

This Section covers the requirement of landscape planning and design with the aim of improving quality of outdoor built environment and protection of the land and its resources. With growing urban development and environmental degradation it has become imperative to determine landscape design parameters, and also provide rules, regulations, controls and procedures for the protection, preservation and modification of surrounding environment. A brief clause on street furniture has also been introduced in this Section.

The components of landscape design and external development were earlier covered in the Code in its various Parts/Sections but a comprehensive treatment has been given in this new Section in this revision.

PART 10 LANDSCAPING, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 1 Landscape Planning and Design

1 SCOPE

This Section covers requirements of landscape planning and design with the view to promoting quality of outdoor built environment and protection of land and its resources.

2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions shall apply.

2.1 Avenue — A wide road or pathway lined with trees on either sides.

2.2 Buffer — The use of landscape to curtail view, sound or dust with plants or earth berms, wall, or any such element.

2.3 Climber (Creeper/Vine) — A non-supporting plant, woody or herbaceous, which clings to a wall, trellis or other structures as it grows upward.

2.4 Columnar — A slender, upright plant form.

2.5 Contour — The form of the land, existing or proposed; a part of the topography, indicated by map lines at intervals as desired, to understand the landform clearly. The contour line though imaginary, indicates continuous elevation above mean sea level or an assumed datum line.

2.6 Contour Interval — The difference in elevation or the vertical distance measured between consecutive contour lines.

2.7 Egress — A way out, or exit.

2.8 Elevation — A contour line or notation of relative altitude, useful in plotting existing or proposed feature.

2.9 Exotic — A plant that is not native to the area in which it is planted.

2.10 Fencing — A barrier of plant or construction material used to set off the boundary of an area and to restrict visual or physical passage in or out of it.

2.11 Foliage — The collective leaves of a plant or plants.

2.12 Geo-textile — Any permeable textile (natural or synthetic) used with foundation, soil, rock, earth or any other geotechnical engineering-related material as an integral part of a human made project, structure or system.

2.13 Grade — The slope or lay of the land as indicated by a related series of elevations.

2.13.1 *Natural Grade* — Grade consisting of contours of unmodified natural landform.

2.13.2 *Finished Grade* — Grade accomplished after landscape features are installed and completed as shown on plan as proposed contours.

2.14 Gradient — The degree of slope of a pipe invert or road or land surface. The gradient is a measure of the slope height as related to its base. The slope is expressed in terms of percentage or ratio.

2.15 Grading — The cutting and/or filling of earth to establish smooth finish contours for a landscape construction project. Grading facilitates good drainage and sculpts land to suit the intent of landscape design.

2.16 Grasses — Plants that characteristically have joint stems, sheaths and narrow blades (leaves).

2.17 Groundcover — The planting material that forms a carpet of low height; these low-growing plants are usually installed as the final part of landscape construction.

2.18 Hard Landscape — Civil work component of landscape architecture such as pavement, walkways, roads, retaining walls, sculpture, street amenities, fountains and other built environment.

2.19 Hardy Plant — Plants that can withstand harsh temperature variations, pollution, dust, extreme soil conditions, and minimal water requirements and the likes. These plants have ability to remain dormant in such conditions and survive.

2.20 Hedge — Number of shrubs or trees (often similar species) planted closely together in a line. A hedge may be pruned to shape or allowed to grow to assume its natural shape.

2.21 Herb — An annual plant with a non-woody or fleshy structure. Certain herbs are highly useful for cooking or of high medicinal value.

2.22 Ingress — A way in, or entrance.

2.23 Invert — The low inside point of a pipe, culvert, or channel.

2.24 Kerb — A concrete or stone edging along a pathway or road often constructed with a channel to guide the flow of storm water and thereby serving dual purpose.

2.25 Mound — A small hill or bank of earth, developed as a characteristic feature in landscape.

2.26 Native — A plant indigenous to a particular locale.

2.27 Screen — A vegetative or constructed hedge or fence used to block wind, undesirable views, noise, glare and the like, as part of in landscape design; also known as 'screen planting' and 'buffer plantation'.

2.28 Sediment — The product of erosion processes; the solid material, both mineral and organic, that is in suspension, is being transported or has been moved from its site of origin by air, water, gravity or ice.

2.29 Shrub — A woody plant of low to medium height, deciduous or evergreen, generally having many stem.

2.30 Soft Landscape — The natural elements in landscape design, such as plant materials and the soil itself.

2.31 Spot Elevation — In surveying and contour layout, an existing or proposed elevation noted as a dot on the plan.

2.32 Street/Outdoor Furniture — Items of furnishing in outdoor landscape.

2.33 Swale — A linear wide and shallow depression used to temporarily store, route or filter runoff. A swale may be grassed or lined.

2.34 Topsoil — The uppermost layer of the soil.

2.35 Transplanting — Moving a plant from its place of origin to another location.

2.36 Tree — A woody plant, generally taller than 2.00 m, with a well-distinguished trunk or trunks below the leaf crown.

2.36.1 *Deciduous Tree* — Tree that sheds all its leaves in autumn or in dry season.

2.36.2 *Evergreen Tree* — Tree that remains green for most part of the year and sheds leave slowly throughout the year.

2.37 Tree Grate — A metal grille, installed at the base of a tree otherwise surrounded by pavement, that allows the free passage of air, water, and nutrients to the tree root, but does not interfere with the foot traffic.

2.38 Tree/Plant Guard — The protection constructed around a tree to deter vandalism and help to prevent damage. It could be made of metal, bamboo or concrete or the like.

3 PERMIT

3.1 Application for Licence or Permit and Required Drawings

Any development project for which a permit or licence is required, shall make application to the Authority on the prescribed form containing such particulars as the Authority may require. The form shall be signed by the owner and shall include the information given in **3.2** to **3.4**. For various aspects of obtaining the permit, etc reference shall be made to Part 2 'Administration'.

3.2 Site Plan Contents and Specifications

3.2.1 *Site Plan*

The site plan to be submitted with the application for permit shall be drawn to a scale of not less than 1 in 500 for a site up to one hectare and not less than 1 in 1 000 for site more than 10 hectare. The following information shall be provided in addition to requirements for Site Plan as stated in Part 2 'Administration':

a) Existing and proposed topographic contours at interval not exceeding 50 cm and/or spot elevations as pertinent and Bench Mark of site with reference to the City Datum relative to the Mean Sea Level.

b) Limits of the 100 year flood plain and water surface elevation (when applicable).

c) Location of existing major physical features, such as railway track, drainage ways etc.

d) Location of service utilities adjacent to the project with relevant top and invert levels clearly indicated.

e) Point of egress and ingress including locations and width of road.

f) Fully dimensioned loading spaces and maneuvering areas.

g) Parking including, location, parking spaces, size and number, and typical parking space details for both handicapped and standard spaces.

h) Vehicular, bicycle, pedestrian and handicapped circulation clearly identified.

j) Detail for parking areas including type of lighting, material for paving, and security rooms, rest rooms; and type of directional signage etc.

k) Drainage system, proposed finish ground elevations and finish grades.

m) Location of proposed fire hydrant points.

n) Location and dimension of fire lanes.

p) Proposed lighting layout.

q) Landscape irrigation points and source of water.

r) Fences, walls, or vegetation for screening by type, material, height, location, and spacing.

s) Location of proposed street furniture.

t) Refuse container location, size, and access.

u) Landscape paving materials with location.

v) Location, type, size, and height of existing and proposed signage.

w) List of existing trees with botanical and common names and height of the tree (*see* **4.1.2** for plant material schedule).

x) Prior approvals.

3.3 Landscape Plan Contents and Specifications

Landscape plan and drawings shall consist of the plans and details as given in **3.3.1** to **3.3.4**.

3.3.1 *Grading Plan*

The grading plan to be submitted with the application for permit shall be drawn to a scale of not less than 1 in 500 for a site up to 10 hectare and not less than 1 in 1 000 for site more than 10 hectare (*see also* **6.2**). The grading plan will include measures for soil and sedimentation control and also measures during construction to prevent soil erosion, and also water harvesting practices (*see also* **4** and **5**).

3.3.2 *Planting Plan*

The planting plan shall be drawn to a scale of not less than 1 in 200 for a site up to one hectare and not less than 1 in 500 for site more than 10 hectare with part plans at 1 in 200 of two of the design areas. Planting plan should include plant material schedule as shown in Table 1. The planting plan and landscape plan must show identical information to avoid conflict between both plans. The planting plan shall include the layouts as given below drawn to the scale:

a) Location of proposed trees, shrubs, ground covers and lawn area indicated clearly with appropriate symbols and legend.

b) The size of plant material indicated in the drawing should be shown as diameter of canopy for tree and spread for shrubs and ground cover. Two years growth will be considered as full maturity size for shrubs and ground covers and ten years growth will be considered for trees.

c) The Botanical name could be indicated as a symbol on the main drawing (for example *Delonix regia* as *Dr*). Plant names should to be tabulated in alphabetical order under heads Trees, Shrubs, Groundcovers, Climbers and Grass.

d) Functional attributes and growth pattern tabulation to be attached as Table 2, as an annex.

e) All existing vegetation shall be marked on the landscape plan and areas designated for preservation of existing vegetation on site shall be demarcated clearly (*see also* **4.1.2**).

f) A concept plan of scale not less than 1 in 1 000 indicating the intent of the design with respect to the functions for various parts of the scheme should be included.

Table 1 Plant Material Schedule

(*Clause* 3.3.2)

Tree No.	Code	Botanical Name	Common Name	Quantity
(1)	(2)	(3)	(4)	(5)

Table 2 Plant Material Schedule Showing Functional Attributes and Growth Pattern of Each Plant

[*Clause* 3.3.2 (d)]

Sl No.	Relevant Features	Description Plant -1
(1)	(2)	(3)
i)	Botanical name	
ii)	Common name	
iii)	Plant code	
iv)	Type (Evergreen/Deciduous)	
v)	Height	
vi)	Spread/Canopy	
vii)	Form of Tree	
viii)	Flower colour	
ix)	Seasonal duration	
x)	Zone (Functional Attributes)	
xi)	Characteristics	
xii)	Function	
xiii)	Remarks	

3.3.3 *Irrigation Plan*

The irrigation plan shall be drawn to a scale of not less than 1 in 500 for a site up to one hectare and not less than 1 in 1 000 for site more than one hectare. The Plan shall include the following information:

a) The source of irrigation water.

b) Type of water conserving irrigation systems proposed differentiating between systems for different water use zones on the site.

c) Extent of supplementary irrigation provided by water harvesting measures.

d) Arrangement of hydrants or sprinklers indicating location and type with typical details and specifications.

3.3.4 *Construction Details*

Construction details, specifications and methods used for the following landscape elements are to be included where applicable:

a) All paved areas for pedestrian and vehicular use, including edges, kerbs, bumper stops, steps, ramps, planters, railings or other protective devices; provision for wheel chair access and movement; Tree protection with tree grating, tree guard, etc.

b) Boundary wall, fence, retaining wall, etc.

c) Structures in landscape such as gatehouses, kiosks, toilets, pergolas, space frame, pools, ponds, water bodies, any other special features, etc.

d) Site utilities such as stormwater drains, manholes, catch basins, outdoor lighting fixtures, electric feeder pillars, junction box, fire hydrant, garbage collection points, litter bins, etc.

e) Outdoor signage and street furniture.

f) Play equipment and tot lots where appropriate.

g) Any other relevant detail or information.

4 PROTECTION OF LANDSCAPE DURING CONSTRUCTION

4.0 Development projects involve disturbance to the existing soil conditions, removal of existing trees and overall change in the microclimate and drainage pattern. Measures to minimize hazardous effects should be put into effect as explained below.

4.1 Pre-Construction Measures

Measures for the prevention of soil erosion, sediment control and management of storm water shall be implemented as given in **4.1.1** to **4.1.5**.

4.1.1 *Timing of Construction*

Construction work and erosion control applications shall be scheduled and sequenced during dry weather periods when the potential for erosion is the lowest. Slope protection techniques to control erosion shall be used when construction during wet season is unavoidable. Sedimentation collection systems, drainage systems, and runoff diversion devices shall be installed before construction activity. The Landscape Architect/Architect/Engineer-in-charge shall monitor the site conditions and progress of work and schedule appropriate timing and sequencing of construction.

4.1.2 *Preservation of Existing Vegetation*

4.1.2.1 Protection of existing vegetation (including trees, shrubs, grasses and other plants) where possible, by preventing disturbance or damage to specified areas during construction is recommended. This practice minimizes the amount of bare soil exposed to erosive forces. All existing vegetation shall be marked on a site survey plan. A tree survey in prescribed format shall be carried out as indicated in Table 3. The landscape plan should indicate trees, which have been preserved, and also those, which had to be transplanted or removed clearly differentiating between these three categories.

Table 3 Plant Material Schedule for Tree Survey

(*Clause* 4.1.2.1)

Tree No.	Botanical Name	Common Name	Girth	Height	Spread	Condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)

4.1.2.2 Trees retained on the project site shall be protected during the construction period by following measures:

a) Damage to roots shall be prevented during trenching, placing backfill, driving or parking heavy equipment, dumping of trash, oil, paint, and other materials detrimental to plant health by restricting these activities to outside the area of the canopy of the tree.

b) Trees will not be used for support; their trunks shall not be damaged by cutting and carving or by nailing posters, advertisements or other material.

c) Lighting of fires or carrying out heat or gas emitting construction activity within the ground, covered by canopy of the tree shall not be permitted.

d) Young trees or saplings identified for preservation (height less than 2.00 m, 0.10 m trunk girth at 1.00 m height from finish ground, 2.00 m crown diameter) within the construction site have to be protected using tree guards of approved specification.

e) Existing drainage patterns through or into any preservation area shall not be modified unless specifically directed by the Landscape Architect/Architect/Engineer-in-charge.

f) Existing grades shall be maintained around existing vegetation and lowering or raising the levels around the vegetation is not allowed unless specifically directed by the Landscape Architect/Architect/Engineer-in-charge.

g) Maintenance activities shall be performed as needed to ensure that the vegetation remains healthy.

h) The preserved vegetated area shall be inspected by the Landscape Architect/ Architect/Engineer-in-charge at regular intervals so that they remain undisturbed. The

date of inspection, type of maintenance or restorative action followed shall be recorded in the logbook.

4.1.3 *Staging Areas*

Measures shall be followed for collecting runoff from construction areas and material storage sites; diverting water flow away from such polluted areas, so that pollutants do not mix with storm water runoff from undisturbed areas.

Temporary drainage channels, perimeter dike/swale, etc shall be constructed to carry the pollutant-laden water directly to treatment device or facility. The plan shall indicate how the above is accomplished on site, well in advance of the commencing of the construction activity.

4.1.4 *Preservation of Topsoil*

Topsoil removal and preservation shall be mandatory for development projects larger than 1.00 hectare. Topsoil shall be stripped to a depth of 200 mm from areas proposed to be occupied by buildings, roads, paved areas and external services. Topsoil is rich in organic content and is essential to establish new vegetation. It shall be stockpiled to a height of 400 mm in designated areas and shall be re-applied to site during plantation of the proposed vegetation. Topsoil shall be separated from sub-soil debris and stones larger than 50 mm diameter. The stored topsoil may be used as finished grade for planting areas.

4.1.5 *Spill Prevention and Control*

Spill prevention and control plans shall be made, clearly stating measures to stop the source of the spill, to contain the spill, to dispose the contaminated material and hazardous wastes, and stating designation of personnel trained to prevent and control spills. Hazardous wastes include pesticides, paints, cleaners, petroleum products, fertilizers and solvents.

4.2 Measures During Construction

During construction soil becomes unconsolidated due to removal of stabilizing material such as vegetation and disturbance of stabilized existing grade resulting in loss of topsoil and also deposition in undesirable places. A soil erosion and sedimentation control plan to be prepared prior to construction. The soil erosion, sediment control and storm water practices should be considered whilst construction is proceeding, in accordance with **4.2.1** to **4.2.4**.

4.2.1 *Sedimentation Basin*

A temporary dam or basin at the lowest point of the site has to be constructed for collecting, trapping and storing sediment produced by the construction activities, together with a flow detention facility for reducing peak runoff rates. This would allow most of the sediments to settle before the runoff is directed towards the outfall.

4.2.2 *Contour Trenching*

Contour trenching is an earth embankment or ridge-and-channel arrangement constructed parallel to the contours along the face of the slope at regular intervals on long and steep slopes (in sloping areas with slopes greater than 10 percent) (*see* Fig. 1). They are used for reducing runoff velocity, increasing the distance of overland runoff flow, and to hold moisture and minimize sediment loading of surface runoff. Vegetative cover of tree and native grasses in the channels may be planted to stabilize the slopes and reduce erosion.

4.2.3 *Mulching*

Mulching shall be used with seeding and planting in steep slope areas (slopes greater than 33 percent) that are prone to heavy erosion. Netting or anchoring shall be used to hold it in place. Other surface runoff control measures like contour terracing to break up concentrated flows shall be installed prior to seeding and mulching. Materials such as straw, grass, grass hay and compost shall be placed on or incorporated into the soil surface. In addition to stabilizing soils, mulching will reduce the storm water runoff over an area. Together with seeding or planting, mulching aids plant growth by holding the seed, fertilizers and topsoil in place. It retains moisture and insulates the soil against extreme temperatures.

4.2.4 *Geo-grids*

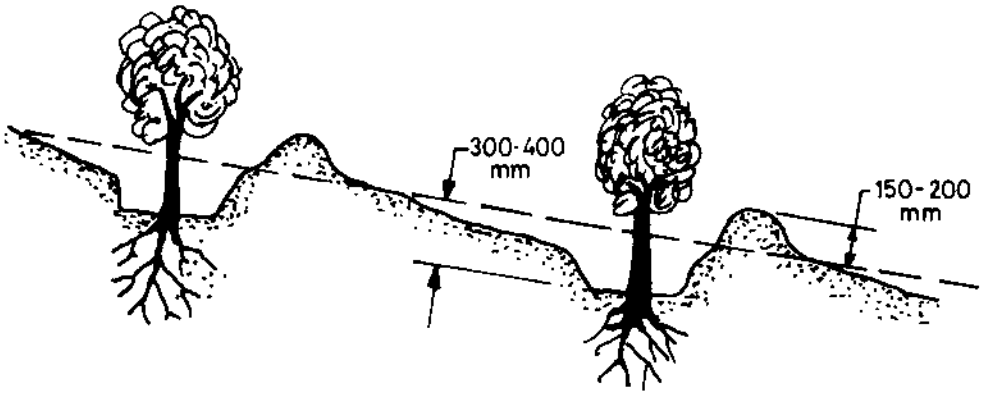
A deformed or non-deformed netlike polymeric material used with foundation, soil, rock, earth or any other geo-technical engineering-related material as an integral part of the human-made project structure or system, called geo-grids may be used as control measure. On filling with lightly compacted soil or fine aggregate, a monolithic structure is created providing an effective means of confinement for unconsolidated materials within the cells and preventing their movement even on steep slopes. If required the area can then be seeded to maintain 'green' environment. The junctions have a central opening through which water can permeate ensuring that organic material receives moisture for rapid growth.

5 SOIL AND WATER CONSERVATION

The soil conservation, sediment control and storm water management practices as given in **5.1** to **5.3** shall be followed after construction is completed.

5.1 Vegetative Measures

The vegetative measures shall include the following:



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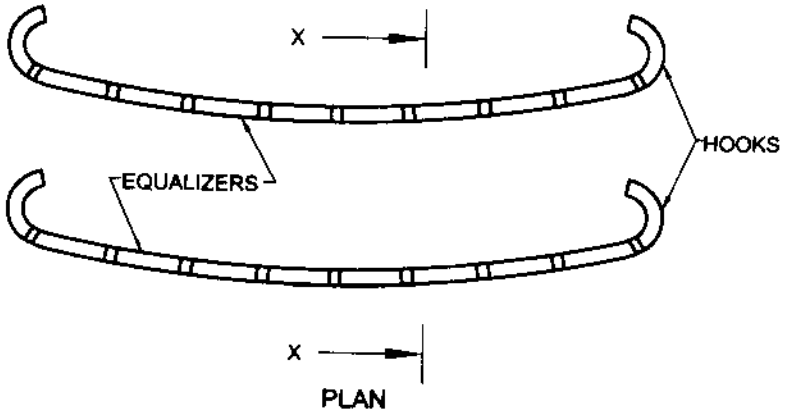


PLAN

FIG. 1 TYPICAL CONTOUR TRENCHES

5.1.1 *Topsoil Laying*

This includes the placement of topsoil or other suitable plant material over disturbed lands to provide suitable soil medium for vegetative growth. Topsoil laying shall involve replacing fertile topsoils that were stripped and stockpiled during earlier site development activities; the laid soil shall be stabilized before the next monsoon by planting grass, shrubs and trees.

The following guidelines shall apply to the placement of topsoil:

a) The existing or established grade of sub-soil should be maintained.

b) A *p*H of 6.0 to 7.5 and organic content of not less than 1.5 percent by mass is recommended for topsoil. Where *p*H is less than 6.0, lime shall be applied to adjust *p*H to 6.5 or higher up to 7.5. Any soils having soluble salt content greater than 500 parts per million shall not be used.

c) Prior to spreading the topsoil, the sub-grade shall be loosened to a depth of 50 mm to permit bonding. Topsoil shall be spread uniformly at a minimum compacted depth of 50 mm on grade of 1:3 or steeper slopes; a minimum depth of 100 mm on shallower slopes is essential. A depth of 300 mm is preferred on relatively flatter land.

5.1.2 *Planting/Vegetation Cover*

The most effective way to prevent soil erosion, sedimentation and to stabilize disturbed and undisturbed land is through the provision of vegetative cover by effective planting practices. The foliage and roots of plants provide dust control and a reduction in erosion potential by increasing the infiltration, trapping sediment, stabilizing soil, and dissipating the energy of hard rain. Temporary seeding shall be used in areas disturbed after rough grading to provide soil protection until final cover is established. Permanent seeding/

planting is used in buffer areas, vegetated swales and steep slopes. The vegetative cover also increases the percolation of rain-water thereby increasing the ground water recharge.

5.2 Storm Water Management and Filtration Techniques

The surface water flow is increased in urban areas due to predominance of hard surfaces. Storm water management techniques assure conservation of water thereby increasing the ground water recharge. Filters facilitate draining pollutants out from surface water runoff through straining before discharge into the drainage way. Rain-water harvesting and sullage recycle systems need to be implemented on all new constructions over 1 000 m^2 in urban areas (*see also* Part 9 'Plumbing Services, Section 1 Water Supply, Drainage and Sanitation').

5.2.1 *Rain Water Harvesting Structures in Urban Environment*

5.2.1.1 Water harvesting refers to the collection and storage of rain-water and also harvesting surface and ground water, prevention of loss through evaporation and seepage, and other hydrological and engineering interventions aimed at conserving water.

5.2.1.2 The advantages of using rain water harvesting structures in urban areas are as follows:

a) Water harvesting recharges ground water and is an ideal solution to water problems in areas with inadequate water resources.

b) Increase in ground water aquifer level due to methods enhancing infiltration.

c) Mitigation of the effect of drought.

d) Reduction of storm water runoff into the public drainage system.

e) Reduction of flooding of the roads during monsoons.

f) Removal of pollutants and soil from the storm water runoff.

g) Reduction of soil erosion.

5.2.1.3 Methods of ground water recharge may be as follows:

a) Recharge pits,

b) Recharge trenches,

c) Re-use of abandoned dug wells,

d) Re-use of abandoned hand pumps,

e) Recharge shafts,

f) Lateral shafts with bore wells, and

g) Spreading techniques like percolation ponds, check dams or gabion structures.

5.2.2 *Structures for Rain-Water Harvesting and Soil and Water Conservation*

These may be as given in **5.2.2.1** and **5.2.2.2**.

5.2.2.1 *Infiltration techniques*

a) *Infiltration trenches* — An infiltration trench is a rock filled trench that receives storm water runoff. Storm water passes through a combination of pre-treatment measures, a grass swale and into the trench to be stored in void spaces and then infiltrates into the soil matrix.

b) *Bio-filtration swale/grass swale* — Bio-filtration swales are vegetated channels with a slope similar to that of standard storm drain channels (less than 0.6 percent), but wider and shallower to maximize flow residence time and promote pollutant removal by filtration through the use of properly selected vegetation. It has to be designed to trap particulate pollutants (suspended solids and trace metals), promote infiltration and reduce the flow velocity of the storm water runoff. It shall be integrated with storm water system (*see* Fig. 2).

c) *Sand filter* — Sand filters are devices that filter storm water runoff through a sand layer into an underground drain system which conveys the water to a detention facility. They are effective in removing total suspended solids. The effectiveness of sand filtration is improved if it is preceded by a grass swale with infiltration trench.

5.2.2.2 *Detention facilities*

a) *Wet ponds* — Wet ponds are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). Wet ponds retain the storm water runoff in a permanent pool and facilitate pollution removal through settling and biological update.

b) *Storm water wet lands* — Storm water wet lands are structures similar to wet ponds, that incorporate wetland plants into the design. They have to be designed for treating storm water runoff, and typically have less bio-diversity than natural wetland systems. A distinction should be made between using a constructed wet land for storm water management and diverting storm water into natural wetland. The latter is not recommended because it would degrade the resource.

c) *Wet vaults and storage tanks* — Wet vaults

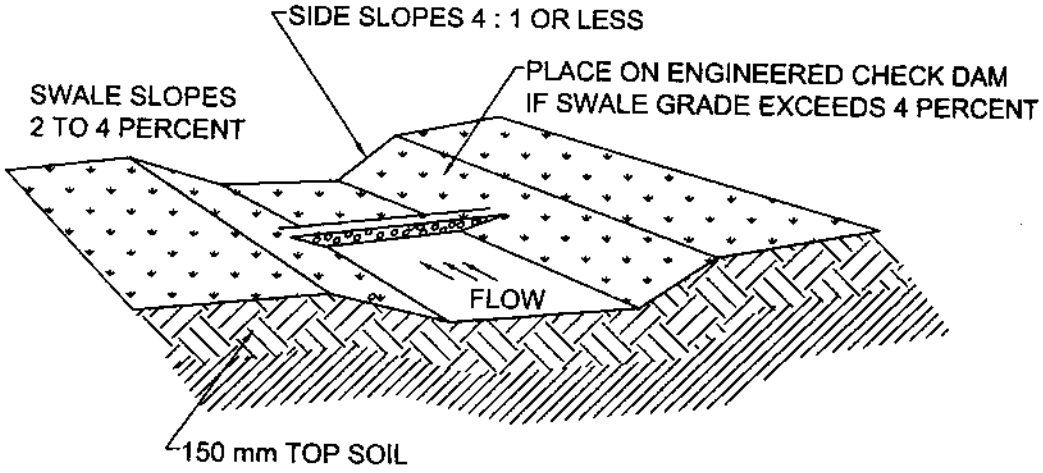


FIG. 2 GRASS SWALE

and tanks are underground facilities used for the storage of surface water, and typically constructed from reinforced cement concrete (vaults) or corrugated pipes (tanks). The water that is captured in these vaults and tanks may be used later for irrigation.

5.3 Conservation and Re-use of Water for Irrigation

The following measures shall be followed for design of irrigation systems for landscape works:

a) Water conserving irrigation systems should differentiate between systems for different water use zones on the site. Supplementary irrigation sources should be used by means of appropriate water harvesting measures.

b) The irrigation system should be designed considering the prevailing wind direction, slope and proposed grade, type of soil, soil percolation, and the type of vegetation to be watered.

c) Spray irrigation to be designed to provide total head to head cover to avoid dry spots and spray on to paved areas and unplanted surfaces.

d) Spray irrigation is to be avoided in areas of width less than 3.00 m.

e) Sullage recycle systems are ideal for large housing complexes and residential colonies. Sullage (or water from kitchens and bathrooms) is treated and recycled for gardening and toilet flushing reducing fresh water requirement by 60 percent. Irrigation system should be designed keeping sullage recycle in view.

f) For requirements regarding, the volume of water for different kinds of landscapes, *see* Part 9 'Plumbing Services, Section 1 Water Supply, Drainage and Sanitation' may be referred.

6 EARTH SLOPES AND GRADING REQUIREMENTS

6.1 Grading Design

Design for changes in elevation in the outdoor environment is a primary component of landscape development. Grading of proposed external development areas should relate to the existing topography of the site and it should direct surface water runoff to the designed drainage and water harvesting area. Grading design parameters are as follows:

a) The proposed grading design should respond to the function and purpose of the activities to be accommodated within the site.

b) New development and structures to be integrated with existing landform within the site and in its immediate surroundings.

c) Storm water to be directed away from buildings.

d) Terraces, levels and slopes in required areas to be created and to emphasize control, or negotiate circulation routes and views.

e) Steep slopes to be modified to minimize or eliminate erosion.

f) Legally, grades cannot be changed beyond the property line of the site.

g) The rate of storm water runoff leaving the site after construction to not exceed the pre-construction rate.

h) Grading design should optimize cut and fill.

6.2 Grading Plan

6.2.1 The submitted grading plan should include the following:

a) All existing features of the site, including all building with plinth level;
b) Structures such as walls, walks, steps, roads, etc;
c) Utilities such as water lines, sewer and storm water drainage, electrical lines, etc; and
d) Utility structures like manholes, junction boxes, sewage treatment plant, septic tank, soak pit, water tanks, water treatment plant, transformers and all underground structures indicated appropriately.

Proposed features shall be indicated in firm lines and existing features in dash.

6.2.2 The grading plan should represent:

a) General landform concept graphically represented with appropriate symbols and abbreviations (*see* **6.4**).
b) Proposed contour lines should be integrated with existing and proposed elevations within the project site.
c) Location of swales and surface water flow, surface and sub-surface soil drainage system or water harvesting systems.
d) Location of drainage catchments, areas of retention/detention or disposal/outfall point as the case may be.
e) Spot grades on road, walks, and swales including top level and relevant invert levels of all utilities and utilities structures as mentioned above; critical spot elevation to be established (*see* **6.2.3**).
f) Spot elevation of building floor finish level, steps, walls, terraces and other such structures.
g) Changes in direction or rate of slope.

6.2.3 *Spot Elevations*

Spot elevations shall be used to supplement contours in the following situations:

a) To indicate variations from the normal slope or gradient between contour lines.
b) To indicate elevations of intersecting planes and lines, like corners of buildings, walls, steps and kerbs.
c) To indicate elevations at top and bottom of vertical elements like walls, steps and kerbs.
d) To indicate floor and entrance elevations.
e) To indicate elevations of high and low points.
f) To indicate top elevations of utilities and utilities structure.

6.3 Slope Calculation

Slopes are expressed as follows:

a) Percentage (of slope) $= \frac{\text{Vertical Rise} \times 100}{\text{Horizontal distance}}$,

for example $\frac{1 \times 100}{50\ \text{m}} = 2$ percent

b) Proportion (of slope) $= \frac{\text{Vertical Rise (1.0 m)}}{\text{Horizontal distance}}$,

for example 1 m in 50 m or 1:50

c) Degree of slope, expressed as angle for example 10°, 15°, etc.

6.4 Typical Grading Symbols and Abbreviations

Symbol	*Description*
- -(100)- -	Existing contour
— 100 —	Proposed contour
(100.5)	Existing spot elevation
100.5 (Bold)	Proposed spot elevation
CB	Catch basin
FFL	Finished floor level
FGL	Finished ground level
TW/BW	Top of wall/Bottom of wall
TK/BK	Top of kerb/Bottom of kerb
HP/LP	High point/Low point
IL	Invert level

7 PLANTING DESIGN CONSIDERATIONS

Plant materials are a very important component of landscape design, and planting design is integral to the landscape plan. Designing with plants requires awareness and knowledge of a broad range of aspects including (a) ecology, (b) botany, (c) horticulture, (d) aesthetic value, (e) growth and survival, and (f) use of plants to fulfil environmental design functions.

7.1 Plant Material

The major sets of factors that influence the choice of plant material are related to the characteristics, both botanical and physical of plant material and the context in which the plant material is to be used. The inter-relationship of these sets of factors is the basis for developing a sound approach to the process of designing with plants.

7.1.1 *Physical and Botanical Characteristics of Plant Material*

The information on plant material should be available in a systematic format to include definition, significance and design implications of the following aspects:

a) Nomenclature (botanical and trade-name);
b) Origin, family and natural habitat;

c) Growth characteristic and form as a function of habit;

d) Physical characteristics, for example bark texture, foliage, etc;

e) Propagation and maintenance; and

f) Use in landscape design.

7.1.2 *Vegetation Types (Evergreen and Deciduous)*

Some examples of the functional implications of using evergreen and deciduous plant material for specific situations are:

a) Evergreen trees for:
   1) places requiring shade throughout the year,
   2) strong visual screening,
   3) part of windbreak or shelter planting, and
   4) areas where leaf litter is to be discouraged.

b) Deciduous trees for:
   1) greater visual variety,
   2) partial visual barrier,
   3) areas where under-planting is to be encouraged (for example grass),
   4) emphasis on branching and flowering pattern, and
   5) areas where shade is not required throughout the year.

7.1.3 *Growth Rate and Age of the Vegetation*

Growth rate is directly related to the life-span of a tree and slower growing trees have a life-span extending to hundreds of years. The fast growing trees to the exclusion of slower growing varieties is not recommended. Landscapes are developed to sustain future generations; slow growing long lived native trees shall be emphatically included in all major planting schemes, specially those related to institutional campuses and large urban development. However, fast growing species do have a limited role, and are appropriate in situations where:

a) Quick effects are required, for example in windbreaks and shelterbelts.

b) Immediate results with regards to stabilization of soil, etc are necessary, as for example, in soil conservation schemes.

c) As 'nurse plants' to protect slower growing sensitive species when necessary.

The slower growing species would generally be appropriate in situations where sustained environmental benefits are required such as roadside planting, campuses, townships, industrial areas, and other public landscapes.

7.1.4 *Growth Habits of Various Kinds of Vegetation and their Form*

The overall physical form of a plant is usually the result of the foliage density and branching pattern. It may also be expressed as the proportionate relations between height and canopy spread. The latter is direct expression of growth habit.

A number of classifications of tree by their overall form exist, but it is almost impossible to have a variety according to regional conditions. The following classification into basic types may be useful:

a) *Trees of fastigiated or columnar habit* — Examples of trees of this type are:

   Casurina equisitifolia (Beet-wood)
   Grevillea robusta (Silver oak)
   Polyathia longifolia (Ashok)
   Populus species (Poplar).

   Though the branching pattern of each is different, the overall shape is similar.

b) *Tall trees with broad canopy* — Examples of trees of this type are:

   Dalbergia sissoo (Sheesham)
   Tamarindus indica (Imli)
   Terminalia arjuna (Arjun).

   The canopy shape does not fit into any specific geometrical category.

c) *Trees of spreading habit* — Examples of trees of this type are:

   Delonix regia (Gulmohar)
   Lagerstromia flosreginae (Pride of India)
   Pithecolobium saman (Rain Tree).

   Though these trees vary greatly in size, their basic form is similar.

d) *Trees of weeping habit* — Examples of trees of this type are:

   Callistemon lanceolatus (Bottle brush)
   Salix babylonica (Weeping willow).

The above classification is helpful in choosing various combinations of the above types to achieve desired function and visual objectives.

7.1.5 *Foliage Characteristics of Plant Material*

Visual effects imparted by vegetation, for example, the perceived visual textures of plant forms depend on:

a) *Leaf size and shape* — Examples of plants with large leaves and bold foliage texture are:

   Alstonia scholaris (Chattin Saptporni)
   Delonix regia (Gulmohar)
   Jacaranda miosaefolia (Nili Gulmohar)
   Plumeria acutifolia (Temple Tree)

Pterospermum acerifolium (Kanak Champa).

Leaf shape can also determine the appearance of the foliage of the plant, as for example:

Acacia auriculaeformis (Australian Black wood) — Long narrow leaves

Callistemon lanceolatus (Bottle Brush) — Narrow leaves giving a feathery appearance

Polyalthia longifolia (Ashok) — Long narrow leaves

Salix babylonica (Weeping willow) — Narrow leaves giving a feathery appearance.

b) *Leaf texture* — The textural appearance of a plant is the result of the play of light and shade on the foliage. Plants with larger leaves generally appear bolder in texture than smaller leaves plants as the areas of light and shade are larger and therefore more clearly differentiated.

c) *Leaf and foliage colour* — Most trees in India have foliage in varying shades of green with variations in colour at the time of leaf fall and at the period when the tree is newly in leaf, when the leaves are fresh and much lighter in colour. Examples are:

Lagerstroemia speciosa (Jarul) — Leaves acquire reddish tinge before falling

Polyalthia longifolia (Ashok), *Delonix regia* (Gulmohar), *Erythrina indica* (India coral tree), etc — Leaves turn yellow before falling

Ficus, intectoria (*Pilkhan*) *Mangifera indica* (Mango) etc — Young leaves have reddish tinge.

d) *Foliage density and distribution* — An important consideration is the way in which particular kinds of vegetation are perceived. Tree masses are usually seen from greater distance than shrub areas; foliage texture of different distinctive kinds of trees growing together has to be markedly distinctive for individual species to be recognizably apparent. In shrub areas subtle differences in foliage texture may suffice for creating the required visual effect.

7.1.6 *Flowering Characteristics of Plant Material*

7.1.6.1 Important considerations while classifying plant material according to flowering characteristics are as follows:

a) Season,
b) Density and distribution of flowers on the plant,
c) Botanical characteristics of flowers (for example single/cluster, etc),
d) Colour, and
e) Presence or absence of foliage during flowering period.

7.1.6.2 For the purpose of understanding the visual effect of flowers, tree species may be divided into two types:

a) Trees on which flowers appear in profusion and therefore have a very strong visual impact, for example *Delonix regia, Cassia fistula, Lagerstroemia flosreginae.*
b) Those on which flowers are less profuse, or perhaps last for a shorter period and visual impact is more subtle, for example *Thespesia* spp., *Bauhinia* spp., etc.

An additional consideration when choosing shrubs for their flowering quality is the visual appearance of the flowers themselves, as shrubs are usually seen from quite close. Distinctive flowers are those of

a) *Beleperone guttata* (Shrimp plant),
b) *Hibiscus rosa-sinensis* (Clinex hibiscus),
c) *Jasminum sambac* (Chameli),
d) *Tabernaemontana coronaria* (Cape jasmine), and
e) *Thevetia peruviana* (Yellow oleander).

7.1.6.3 The olfactory characteristics, that is, odour, of flowers may be an added benefit of flowering plants. Flowers with distinctive scent include those of Harsingar (*Nyctanthes arbor-tristis*), Chameli (*Jasminum pubescens*), Raat Ki Rani (*Cestrum nocturnum*), etc.

7.1.6.4 Flowering characteristics of plant material may be classified as per the following format:

Botanical name	*Characteristics of flower*	*Seasonal duration*	*Visual impact*

7.1.7 *Growth Requirement of Plant Material*

Information about growth requirements of plant material applicable in landscape design pertains to the ability of particular plants to survive in specific environmental situations. These environmental conditions may arise from a number of aspects as given in **7.1.7.1** to **7.1.7.4**. Capacity of plants to grow in cultivated situations is related to the environmental conditions obtaining in their natural habitat.

soil are important. These may or may not be amenable to change, they would therefore affect the choice of plant material considerably. Physical properties include consideration of light (for example sandy) and heavy (for example clayey) soils, and their structure. Chemical properties pertain to the presence or absence of nutrients and salts; soil, alkalinity or acidity. A preliminary soil analysis is essential for implementing effective planting schemes.

7.1.7.2 *Availability and quality of water*

The water requirement may be derived by data of humidity and rainfall of plants natural habitat. The water table of the area where the plantation is to be done has a crucial bearing on the design with plants as well as a financial implication for reduced maintenance if planted appropriately.

7.1.7.3 *Availability of sunlight*

The growth rate of plants are directly related to sunlight availability; such as plants that require (a) full sunlight, (b) partial sunlight, (c) predominantly shade, and (d) complete shade.

7.1.7.4 *Quality of air*

Growth may be affected by chemical pollutants such as sulphur dioxide or physical pollution such as dust. Certain plants have the ability to withstand pollution, such plants are imperative for industrial areas, roads, highways, etc.

7.1.8 *Maintenance*

The success of a designed landscape depends upon the growth of vegetation over an extended period of time; therefore maintenance of landscape is also a design component. Maintenance needs and practices in any given situation arises out of the inter-relationship between the growth requirements of plant material chosen and the environmental conditions existing on site.

The likely degree of maintenance should be assessed based on the following:

a) Scale of the design project,
b) Financial and manpower resource,
c) Availability of manures,
d) Future intensity of site, and
e) Environmental conditions.

In small scale projects such as gardens and small parks, the natural environmental conditions can be changed and maintained by management practices such as irrigation and application of fertilisers. The choice of schemes, such as very large parks, campuses and townships, this kind of intensive maintenance may not be possible. The process of choosing plants shall therefore respond to the existing environmental conditions and also in such cases the choice of plant material is restricted by these conditions and suitable species become limited. The type of treatment adopted, as given below, may also serves as a guide to the degree of maintenance required:

a)	Low Maintenance	The lowest degree of maintenance is usually possible in areas treated with native species of trees only.
		A slightly higher degree is necessary where native shrubs are also used, as these may require pruning.
b)	Medium	Areas treated with a mixture of native and exotic trees.
		Exotic shrubs and trees.
c)	High	Exotic shrubs and ground covers.
		Lawns and maintained grass areas.
		Annual flowers and special schemes.

7.2 Functional Aspects of Design with Plants

Plant materials in landscape design may be used to:

a) improve existing environmental conditions with respect to soil, drainage, microclimate, air pollution;
b) create a designed physical environment through the organization of open space; and
c) interpret and express the contemporary understanding of the man-nature relationship, that is, design with plants on an ecological rather than horticultural basis.

7.2.1 *Choosing of Plant Material*

Two sets of factors influence the choice of plant material in landscape design. One relates to information about plant material itself, that determines the suitability of plant material from the point of view of growth requirements of plant material, and physical characteristics of the plant material. The second relates to the situation for which a planting proposal has to be made that pertains to the context in which the plant materials have to be used. Considerations of scale (that is, regional, local or very small scale situations), the

existing environmental conditions, and functions which the plant material has to fulfill are important. Also the level of maintenance which is likely to be kept up, has to be considered which is specially important on very large sites. The biological history and ecological need of exotic plant should be studied prior to introduction in the landscape schemes to avoid the hazard of the species that may become invasive.

The factors determining choice of plant materials may be thus summarized as follows:

a) *Environmental conditions existing on site* — These include climatic, soil characteristics, water table, etc.

b) *Functions which plant material has to fulfill in specific situations on a given site* — These may be either environmental functions (pertaining to improvement of soil conditions, modification or microclimate, etc) or design functions relating to creating spaces enclosure, framing views, providing visual relief, etc.

c) *Physical characteristics and growth requirements of plant material* — The former include foliage density, foliage texture, leaf size and shape, flower colour, rooting characteristics, etc. The latter include moisture requirements, whether the plant grows in sunny or shaded conditions, etc.

7.2.2 *Methodology of Design with Plants*

The process for designing with plants on a given site condition may be as per the format given below:

Zone	*Characteristics*	*Functions*	*Form*	*Species chosen*	*Remarks*

Plant material used in landscape design may be broadly classified as:

Tree	Large Medium Small
Shrub	Tall Low
Ground cover	Very low shrubs less than a 300 mm high

7.2.3 *Functions of Plant Material*

7.2.3.1 *Trees*

Trees perform the following functions:

a) Protecting soil,

b) Modifying microclimate,

c) Shade,

d) Habitat,

e) Enclosure,

f) Direction and framing views,

g) Screening,

h) Visual relief, and

j) Ornamental.

NOTE — For functions of plants/shrubs to reduce noise, 3.6 of Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' may be referred.

7.2.3.2 *Shrubs*

The functions are similar to those of trees. Shrubs may be used together with trees to reinforce the functions, for example, noise barrier, shelter belts, enclosures, etc.

Other forms in which shrubs may be used are:

a) *Hedges* — These require regular maintenance

b) *Shrubbery* — Here plants are allowed to retain their natural shape; they therefore require little maintenance.

Shrubs provide barriers, which may either be visual or physical (hedges). Barriers may be required in a range of situations, for example they may be only for defining space, or they may be required for security and have to be, therefore, necessarily impenetrable.

7.2.3.3 *Ground cover*

Ground cover plants are those which naturally grow to a very low height. Some of the uses for which they may be used are:

a) Stabilizing soil on steep slopes such as embankments.

b) As a low maintenance substitute for grass (where the surface is not to be used).

c) For providing variety in surface treatment.

d) Contrast with paving materials, for example to soften rigid lines of paving.

e) As a subtle means of demarcating space, as for example, in places where tall plants would be visually intrusive.

f) In combination with other plants to provide contrast or harmony in form.

7.2.3.4 *Climbers*

Certain climbers because of their spreading habits may also be used as ground cover (for example *Asparagus* spp.) Climbers are useful for shading exposed walls from direct sunlight. They may also be used for stabilizing soil on embankments (for example, *Ficus stipulata, Ipomea biloba*). On sites where a high degree of security makes fencing necessary, climbers and

spreading plants like *Bougainvillea species*, may be trained on boundary wall.

7.3 Planting for Shelter and Soil Conservation

The use of vegetation for controlling wind is widely recognized as an effective way of conserving soil and reducing erosion by wind. Vegetation may therefore be used for modifying the microclimate, by obstructing, guiding, deflecting or filtering wind current.

Vegetation areas designed to fulfill these general functions are usually classified as windbreakers and shelterbelts. Windbreaker is grown protective planting around gardens and orchards. Windbreakers generally consist of single or double row of trees. Shelterbelt provides an extensive barrier of trees with several rows of trees. Plant species are chosen with particular regard to their physical and growth characteristics, and their effectiveness in achieving the desired results. Both windbreakers and shelterbelts have considerable visual impact in the landscape in which they are situated, they therefore need to be designed so that they make a positive visual and aesthetic contribution to their environment.

7.3.1 *Function*

Windbreakers and shelterbelts fulfill essential micro-climatic functions in rural and urban environments. Benefits accruing from plantation of shelter planting may be as follows:

a) Reduction in wind velocity resulting in the arrest of movements of sand and soil particles.
b) Prevention of soil erosion.
c) Modification of micro-climate; moderation of change in air temperature.
d) Protection of crops from being blown by high winds.
e) Protection of livestock.
f) Reduction in evaporation of soil moisture. Increase in soil moisture content varies from 3 percent to 7.8 percent. Water loss due to evaporation is lessened.
g) Increase in soil moisture due to greater dewfall in sheltered areas has been found to be 200 percent higher than on exposed ground; heaviest dew fall is over a distance of 2 to 3 times the height of the shelterbelt.
h) Beneficial effect on growth of plants that are affected by high winds.
j) Extensive shelterbelts may also be used to augment the supply of fuel in rural areas.
k) The zone of influence of shelterbelt on crop yield extends to a distance of 20 times the height of the belt, with the maximum effect being observed 10 times the height of the tree belt, on the leeward side.

7.3.2 *Wind Erosion*

Some of the basic functions of windbreaks and shelterbelts in arid and semi-arid areas are to conserve soil and reduce erosion by wind (*see* 7.3). The latter is a natural phenomenon in and lands having very little rainfall (125 mm-250 mm) and in areas adjoining a river, lake or sea. Wind erosion is a serious problem in areas where the ground is virtually bare and devoid of vegetation.

Factors which influence the degree and kind of wind erosion are as follows:

a) *Features of wind* — Speed, direction, temperature, humility, burden carried, etc.
b) *Character of surface* — Rough or smooth plant cover, obstruction, temperature, etc.
c) *Topography* — Flat, undulating broken, etc.
d) *Character of soil* — Texture, organic matter, moisture content, etc.

7.3.2.1 *Techniques for control of wind erosion*

The principal method of reducing surface velocity of wind, upon which depends the abrasive and transportation capacity of wind, is by vegetation measures. Vegetation methods are found to be most effective in the form of windbreaks and shelterbelts. In aerodynamic terms, these provide protection as follows:

a) Sheltered zone on the leeward side extends to approximately 15-30 times the height of the belt.
b) A dense belt provides greater shelter immediately to leeward side but the sheltered area is not as extensive as when a more permeable zone of vegetation is provided.
c) Porosity is important in the effectiveness of shelterbelt and proper selection of tree species is necessary. Porosity near ground level is desirable.
d) Effectiveness of shelter planting depends more on height and permeability than on width. The width influences the general microclimate but above a certain minimum width, it does not effect greater reduction in wind velocity.

Protection obtained varies in relation to height (H) of shelterbelts, as given below:

Distance	*Wind Reduced by* (in percent)
H	90
2*H*	75
5*H*	50
10*H*	20

This indicates that it is better to have several windbreaks 5*H* to 6*H* apart rather than large forest stands with wide open spaces in between.

7.3.3 *Profiles*

A belt which rises and falls abruptly on windward and leeward sides is said to be more effective. Smaller trees and shrubs should occupy the inter-spaces between the tall tree.

NOTE — Some authorities maintain that triangular section of shelterbelt planting is more effective.

The depth of the shelterbelt should be approximately ten times its height. This is, however, only a thumb rule. Much lesser widths of 20 m to 30 m have also been found to be useful in particular situations; 15 m should be considered as minimum width.

Apart from factors such as climate, soil, fast rate of growth, one of the more significant considerations in choosing species for shelter planting is the possibility of a particular species serving the dual role of wood-production (for fuel, fodder) as well as shelter.

7.3.3.1 *Spacing of plants in windbreaks and shelterbelts*

Windbreaks usually consist of a single or double row of trees planted at 0.7 m to 1.5 m according to species. Normally, one year old trees are used. As the roots of tree extend for some distance beyond the rows in which they are planted, the same should be taken into account while planting windbreakers. The most common layout where shelter planting is part of an extensive planned programme, is that of tree belts arranged in a chessboard pattern, each field being-protected from every side. This pattern gives full protection to all the fields, provided that the right distance between the fields has been chosen. Efficient protection is achieved if belts are separated by a distance of not more than 20 times the height of the trees. A considerable mixture of species is recommended so as to compensate for different rates of growth and also to achieve variety in the form of crowns.

7.3.3.2 Within shelterbelts, close spacing of tree is the general practice. The recommended spacing for shrubs is 1 m and for tree such as *Casuarina* and Grevellia robusta (*Silver Oak)* 2.5 m. Spacing between rows should be 2.3 m to 3 m to enable mechanized cultivation. Five rows of tree and shrubs are considered necessary for protection.

7.3.4 *Management*

Shelterbelts should be regarded as living groups of trees to be managed in perpetuity and the following shall be taken into consideration for management thereof:

a) Thinnings are limited to a strict minimum.

b) Cutting is done individually by single tree selection method.

c) Continuous cultivation may be required in areas with scanty rainfall.

d) If individual trees do not survive, they should be replaced immediately to avoid gaps in the vegetation belt. The shelterbelt should be protected from cattle, either by fencing or other means, specially in the early stages.

The location of shelterbelt may be related to local features such as public and private road networks, buildings, irrigation and water conservation works and methods soil management practice (contour bunding, contour cultivation etc). Careful choice of site will provide maximum protection to adjacent land and give shelter and shade.

The application of the concept of shelterbelts to landscape planning and design may be effective in the creation of landscape structure of very large developments at the regional scale, or townships or campuses. Shelterbelts can also be established in association with, or instead of road side planting. This itself creates a distinctive landscape pattern. The advantage of using native species in shelter planting are:

a) New development is merged into the existing landscape. The original character of the landscape is therefore not obtruded upon.

b) The shelterbelt is a component of land management (previous waste or barren land is conserved).

c) Additional habitat for wildlife are brought into existence.

7.3.5 Species-suitable for wind breaks are:

a) *For Dry and Arid Regions*

Acacia auriculiformis (Australian Blackwood)
Ailanthus excelsa (Maharukh)
Albilzia lebbeck (Siris)
Azadiracta indica (Neem)
Casuarina equisetifolia (Beef-wood)
Dalbergia sissoo (Sisham)
Eugenia jambolana (Jamun)
Grevillea robusta (Silver oak)
Peltophorum ferrugineum (Cooper pod)
Tamarindus indica (Imli)

Pongamia glabra (Indian beech)
Tamarix articulata (Tamarisk)

b) *For Coastal Area*
Anacardium occidentale (Cashu)
Ailanthus malabarica (Alston)
Cassuarina equisetifolia (Beef-wood)
Pongamia glabra (Indian beech)
Sesbania aculeate (Sesban)
Thevetia peruvian (Yellow oleander)
Thespesia populnea (Indian Tulip)
Vitex negundo (Sephali)

7.4 Air Pollution Control by Plants

Air pollution may be caused by areas or point sources such as cities, industrial areas, factories or by linear sources such as highways. Vegetation buffers can minimize the build-up of pollution levels in urban areas, by acting as pollution sinks.

Studies have establised that air pollution, smoke and sulphur dioxide leads to an exacerbation of chronic respiratory diseases and they are linked to lung cancer, pnemonia, tuberculosis, chest disease in children, stomach cancer and cardiovascular diseases. Lead from vehicle exhausts may have an adverse effect on mental health of children, asbestos from disintegrating clutch and brake linings has been considered as a causal factor in lung cancer.

7.4.1 *Effect of Plants*

Plant leaves function as efficient gas exchange systems. Their internal structure allows rapid diffusion of water-soluble gases. These characteristics allow the plant to respire and photosynthesise, and they can also remove pollutant from the air. Some of the beneficial results of plantations may be:

a) They are good absorbers of sulphur dioxide.
b) Parks with trees have an SO_2 level lower than city streets.
c) Roadside hedges can reduce traffic generated air borne lead, on leeward side.
d) Heavy roadside planting in the form of shelterbelts can result in a reduction in airborne lead.
e) Complete dust interception can be achieved by a 30 m belt of trees. Even a single row of trees may bring about 25 percent reduction in airborne particulate.

7.4.2 *Choosing Plants*

The three main criteria for selection of plants may be:

a) Tree, shrubs should have a dense foliage with a large surface area, because leaves absorb pollutants.
b) Evergreen trees are found to be more effective.
c) The species chosen must be resistant to pollutants, particularly in the early stages of their growth.

The following species may be examined for their likely potential for pollution control:

Acacia arabica (Babul)
Citrus species
Dyospyros species
Ficus bengalensis (Banyan)
Ficus religiosa (Peepal)
Lilium spp. (Lily)
Polyalthia lotigifolia (Ashok)
Tamarindus indica (Imli)
Thuja occidentalis (Cedar)
Prosopis Juliflora (Mesquite)
Zizypus jujuba (Jujuba), etc.

Filtering of pollutants is most effective when plants are close to the source of pollution. The design of shelterbelts against pollution is similar to those for protection from wind. They should be permeable to encourage air turbulence and mixing within the belt. There should be no large gaps. The profile should be rough and irregular and should present a tall vertical leading edge to the wing. Spaces should be left within the shelterbelt to allow gravity settlement of particles.

7.4.3 *Applications*

Air pollution shelterbelts may be used to protect sensitive land uses from air pollution. For instance school playgrounds, children play area and residential estates close to major roads may be so protected. Shelterbelt protection may also be provided for hospitals, institutions, etc, where the vegetation may also be a visual screen and a partial noise barrier. Vegetation may also be used where the existing means of pollution control have proved inadequate.

8 SPECIFICATIONS FOR PLANTING WORKS

The requirements relating to plant materials and other materials; execution of work of tree planting, shrub planting and grassing; maintenance; etc shall be as given in **8.1** to **8.6**. The contractor shall furnish all materials, labour and related items necessary to complete the work indicated on drawing and specified herein and shall carry out maintenance of the premises for 12 months after completion of the work or as specified by the landscape architect.

8.1 Materials

8.1.1 *Plant Materials*

Plant materials shall be well formed and shaped true

to type, and free from disease, insects and defects such as knots, windburn, injuries, abrasion or disfigurement. All plant materials shall be healthy, sound, vigorous, free from disease, insect pests, or their eggs, and shall have healthy, well-developed root systems. All plants shall be hardy under climatic conditions similar to those in the locality of the project. Plants supplied shall conform to the names listed on both the plan and the plant list. No plant material will be accepted if branches are damaged or broken. All material shall be protected from sun and adverse weather until planted. Nursery stock shall be inspected and approved by the landscape architect and the horticulturist/botanist shall do the botanical authenticity of the selected species.

All plants shall conform to the requirements specified in the plant list, except those plants larger than specified may be used if approved, but use of such plants shall not increase the contract price. If the use of the larger plant is approved, the spread of roots or ball of earth shall be increased in proportion to the size of the plant. Plants shall be delivered with legible identification labels.

The minimum acceptable size of all trees after prunning, with branches in normal positions, will conform to the measurement specified in the bill of quantities unless stated otherwise. Caliper measurement will be taken at a point on the trunk 1.0 m above natural ground. All trees supplied shall have terminal shoots. All specimen trees shall have a minimum crown spread of not less than half the size of the overall height.

8.1.2 *Topsoil (Good Earth) with pH Range between 6.5 to 7.5*

Topsoil or good earth shall be a friable loam; typical of cultivated top soils of the locality contains at least 2 percent of decayed organic matter (humus). It shall be taken from a well-drained arable site. It shall be free of sub-soil, stones, earth clods, sticks, roots or other objectionable extraneous matter or debris. It shall contain no toxic material. No topsoil shall be delivered in a muddy condition.

8.1.3 *Fertilizer*

Dry farm yard manure shall be used. Measurement shall be in stacks, with 8 percent reduction for payment. It shall be free from extraneous matter, harmful bacteria insects or chemicals.

8.1.4 *Root System*

The root system shall be conducive to successful transplantation. Where necessary, the root-ball shall be preserved by support with hessian or other suitable material. On soils where retention of a good ball is not possible, the roots should be suitably protected in some other way which should not cause any damage to roots.

8.1.5 *Condition*

Trees and shrubs shall be substantially free from pests and diseases, and shall be materially undamaged. Torn or lacerated roots shall be pruned before dispatch. No roots shall be subjected to adverse conditions, such as prolonged exposure to adverse conditions, such as prolonged exposure to drying winds or subjection to waterlogging, between lifting and delivery.

8.1.6 *Marking*

Each specimen of tree and shrub, or each bundle, shall be legibly labelled with the following:

a) Its name.
b) Name of the supplier, unless otherwise agreed.
c) Date of dispatch from the nursery.

8.2 Execution

8.2.1 *Fine Grading*

Grades will be smooth and even on a uniform plane without abrupt changes or pockets and slope away from the buildings. The nominated landscape contractor will verify the surface drainage of planting areas and notify the landscape architect of any discrepancies, obstructions or other conditions considered detrimental to proper execution of the work and plant growth.

8.2.2 Landscape work will be tied to the existing condition such as existing trees palms, landscape features, utility lines, pavement kerbs, etc. Finished grade will bear proper relationship to such control. The nominated landscape contractor shall adjust all works as necessary to meet the conditions and fulfill the intention of the drawings.

After initial settlement the finish grade will be:

a) *Turf*: 20 mm lower than adjacent walks/ kerbs.
b) *Shrubs and Ground covers*: 40 mm lower than adjacent walks/kerbs.

Prior to planting operation, the contractor will ensure all planting areas free of weeds, debris, rocks over 25 mm in diameter and clumps of earth that do not break up.

8.3 Tree Planting

8.3.1 Trees should be supplied with adequate protection as approved. After delivery, if planting is not to be carried out immediately, balled plants should be placed cheek to cheek and the ball covered with sand to prevent drying out. Bare rooted plants can be

heeled in by placing the roots in a prepared trench and covering them with earth which should be watered in to avoid air pockets round the roots.

8.3.2 *Digging of Pits*

Tree pits shall be dug a minimum of three weeks prior to backfilling. The pits shall be 1 200 mm in diameter and 1 200 mm deep. While digging the pits, the topsoil up to a depth of 300 mm may be kept aside, if found good (depending upon site conditions), and mixed with the rest of the soil. If the soil is bad below, it shall be replaced with the soil mixture as specified further herein. If the soil is normal it shall be mixed with manure; river sand shall be added to the soil if it is heavy.

8.3.3 *Flooding of Pits to Reduce Air Pockets*

The soil backfilled, watered through and gently pressed down, a day previous to planting, to make sure that it may not further settle down after planting. The soil shall be pressed down firmly by treading it down, leaving a shallow depression all round for watering.

8.3.4 *Planting*

No tree pits shall be dug until final tree positions have been pegged out for approval. Care shall be taken that the plant sapling when planted is not buried deeper than in the nursery, or in the pot. Planting should not be carried out in waterlogged soil.

Trees should be planted up to the original soil depth; the soil marks on the stem is an indication of this and it should be maintained on the finished level, allowing for setting of the soil after planting. All plastic and other imperishable containers should be removed before planting. Any broken or damaged roots should be cut back to sound growth.

The bottom of the planting pit should be covered with 50 mm to 75 mm of soil. Bare roots should be spread evenly in the planting pit; and small mound in the centre of the pits on which the roots are placed will aid an even spread. Soil should be placed around the roots, gently shaking the trees to allow soil particles to shift into the root system to ensure close contact with all roots and to prevent air pockets. Back fill soil should be firm as filling proceeds, layer by layer, care being taken to avoid damaging the roots.

8.3.5 *Staking*

Newly planted trees shall be held firmly although not rigidly by staking to prevent a pocket forming around the stem and newly formed fibrous roots being broken by mechanical pulling as the tree rocks.

The main methods of staking shall be:

a) A single vertical stake, 900 mm longer than the clear stem of the tree, driven 600 mm to 900 mm into the soil.

b) Two stakes as above driven firmly on either side of the tree with cross-bar to which the stem is attached (suitable for small bare-rooted or balled material).

c) A single stake driven in at an angle 45° and leaning towards the prevailing wind, the stem just below the lowest branch being attached to the stake (suitable for small bare-rooted or balled material).

The end of stake should be pointed and the lower 1 m to 1.2 m should be coated with non-injurious wood preservative allowing at least 150 mm above ground level.

8.3.6 *Tying*

Each tree should be firmly secured to the stake so as to prevent excessive movement. Abrasion shall be avoided by using a buffer, rubber or hessian, between the tree and stake. The tree should be secured at a point just below its lowest branch, and also just above ground level; normally two ties should be used for tree. These should be adjusted or replaced to allow for growth.

8.3.7 *Watering*

The contractor should allow for the adequate watering in all newly planted trees and shrubs immediately after planting and shall, during the following growing season, keep the plant material well watered.

8.4 Shrub Planting in Planters and Beds

8.4.1 All areas to be planted with shrubs shall be excavated, trenched to a depth of 750 mm, refilling the excavated earth after breaking clods and mixing with manure in the ratio 8:1 (8 parts of stacked volume of earth after reduction by 20 percent; 1 part of stacked volume of manure after reduction by 8 percent).

Tall shrubs may need staking; which shall be provided if approved by the landscape architect depending upon the conditions of individual plant specimen.

For planting shrubs and ground cover shrubs in planters, good earth shall be mixed with manure in proportion as above and filled in planters.

Positions of shrubs to be planted should be marked out in accordance with the planting plan. When shrubs are set out, precautions should be taken to prevent root drying. Planting holes 400 mm in diameter and 400 mm deep should be excavated for longer shrubs. Polythene and other non-perishable containers should be removed and any badly damaged roots carefully pruned. The shrubs should then be set in holes so that the soil level, after settlement, will be at the original

soil mark on the stem of the shrub. The hole should be back-filled to half its depth and firmed by treading. The remainder of the soil may then be returned and again firmed by treading.

8.5 Grassing

8.5.1 *Preparation*

During the period prior to planting the ground shall be maintained free from weeds. Grading and final levelling of the lawn shall be completed at least three weeks prior to the actual sowing. Regular watering shall be continued until sowing by dividing the lawn area into portions of approximately 5 m^2 by constructing small bunds to retain water. These bunds shall be levelled just prior to sowing of grass plants. At the time of actual planting of grass, it shall be ensured that the soil has completely settled.

8.5.2 *Soil*

The soil itself shall be ensured to the satisfaction of the landscape architect to be a good fibrous loam, rich in humus.

8.5.3 *Sowing the Grass Roots.*

Grass roots shall be obtained from a grass patch, seen and approved beforehand. The grass roots stock received at site shall be manually cleared of all weeds and water sprayed over the same after keeping the stock in a place protected from sun and dry winds. Grass stock received at site may be stored for a maximum of three days. In case grassing for some areas is scheduled for a later date fresh stock of grass roots shall be ordered and obtained. Small roots shall be dibbled about 75 mm apart into the prepared grounds. Grass areas will only be accepted as reaching practical completion when germination has proved satisfactory and all weeds have been removed.

8.5.4 *Maintenance*

As soon as the grass is approximately 30 mm high it shall be rolled with a light wooden roller in fine, dry weather — and when it has grown to 50 mm to 80 mm above ground, weeds shall be removed and regular cutting with the scythe and rolling shall be begun. A top-dressing of farm yard manure, bone meal at the rate of 50 g/m^2 and NPK at the rate of 10 g/m^2 shall be applied when the grass is sufficiently secure in the ground to bear the mowing machine, the blades shall be raised 25 mm above the normal level for the first two or three cuttings. That is to say, the grass should be cut so that it is from 40 mm to 50 mm in length, instead of the 30 mm necessary for mature grass.

In the absence of rain, in the monsoon the lawn shall be watered with sprinklers every, three days soaking the soil to a depth of at least 200 mm. Damage, failure or dying back of grass due to neglect of watering specially for seeding out of normal season shall be the responsibility of the contractor.

Any shrinkage below the specified levels during the contract or defects liability period shall be rectified at the contractor's expense. The contractor shall exercise care in the use of rotary cultivator and mowing machines to reduce to a minimum the hazards of flying stones and brickbats. All rotary mowing machines are to be fitted with safety guards.

8.5.5 *Rolling*

Lawn mower with roller shall be used periodically, taking care that the lawn is not too wet and sodden.

8.5.6 *Edgings*

These shall be kept neat and shall be cut regularly with the edging shears.

8.5.7 *Watering*

Water shall be applied at least once in three days during dry weather. Water whenever done should be thorough and should wet the soil at least up to a depth of 200 mm.

8.5.8 *Weeding*

Prior to regular mowing the contractor shall carefully remove rank and unsightly weeds.

8.6 Maintenance

8.6.1 The landscape contractor shall maintain all planted areas within the landscape contract boundaries for one year until the area is handed over in whole or in phases. Maintenance shall include replacement of dead plants, watering, weeding, cultivating, control of insects, fungus and other diseases by means of spraying with an approved insecticide or fungicide, pruning, and other horticulture operations necessary for the proper growth of the plants and for keeping the landscape contract area neat in appearance.

8.6.2 *Pruning and Repairs*

Upon completion of planting work under the contract all trees should be pruned and all injuries repaired where necessary. The amount of pruning shall be limited to the minimum necessary to remove dead or injured twigs and branches and to compensate for the loss of roots and result of transplanting operations.

Pruning and removal of any part of plant materials should be done with clean sharp tools. Tools used to carry out the prunning work shall be appropriate for the task. The surface of tools and equipment will be sterilized after use on the plant materials that are suspected or known to be diseased. Cuts on plant materials shall be made into the living tissues to induce

callousing. Cut surface will be flat, sharp and without jagged or torn edges.

Pruning shall be done in such a manner as not to change the natural habitat or special shape of the trees. Pruning operation will consider carefully the natural growth pattern of branches on the tree, palm or shrub. Tree branches will be pruned back to the collar at the base of the branch.

8.6.3 *Tree guards*

Where tree guards are necessary, care should be taken to ensure that they do not impede natural movement or restrict growth.

8.6.4 *Nursery Stock*

Planting should be carried out as soon as possible after reaching the site. Where planting needs to be delayed, care should be taken to protect the plants from pilfering or damage from people or animals. Plants with bare roots should be heeled-in as soon as received or otherwise protected from drying out, and others set closely together and protected from the wind. If planting needs to be delayed for more than a week, packed plants should be unpacked, the bundles opened up and each group of plants heeled-in separately and clearly labelled. If for any reason the surface of the roots becomes dry the roots should be thoroughly soaked before planting.

8.6.5 *Protective Fencing*

According to local environment shrubs shall be protected adequately from vandalism until established.

8.6.6 *Routine Maintenance Work Schedule*

Operation	*Frequency*
i) Watering	Checking all planting areas and pits and water as often as necessary to ensure that planting material does not dry out
ii) Weeding	Monthly
iii) Edging	Monthly
iv) Fertilizing	
a) Trees/palms	Once every three months
b) Shrubs/ground covers	Monthly
c) Grass	Once every three months
v) Loosening of soil	Monthly
vi) Control of pest by applying appropriate insecticides	Fortnightly
vii) Control of disease by applying appropriate fungicides.	Monthly, increasing the frequency to fortnightly during rainy season
viii) Grass cutting	Fortnightly
ix) Pruning and shaping trees/palms	Once every six month for small and low sagging branches
x) Staking	As and when required.
xi) Trimming shrubs/ ground covers	Monthly or as when required

8.6.7 *Clean-Up Works*

There shall be areas designated by landscape architect for the contractor to carry out clean-up works. These shall include the following:

a) Removal of dead and/or overhanging branches of existing trees, palms, shrubs and groundcovers.
b) Removal of any garbage and unsightly foreign materials.
c) Removal of dead vines and plant materials.

The contractor shall prevent damages to the existing plant materials, identified to be conserved. The plant materials that are to be conserved if damaged beyond use during the clean-up operations, the contractor shall be liable to replace the plant materials at their own expense.

8.6.8 *Restoration*

The contractor is responsible for the use of all materials, labour and equipments and any injury to the plant material, labour and equipment will be repaired or the same replaced by the contractor at his own expense.

8.6.9 *Completion*

On completion, the ground shall be formed over and left tidy.

9 SERVICE UTILITIES IN LANDSCAPE

9.1 Designed integration of structures and elements related to external services (underground and over ground utilities) with landscape is most essential for any outdoor space.

The following services generally are the subject of design co-ordination work for external areas:

a) *Storm water drainage*
   1) Storm water network;
   2) Open drain and swale;
   3) Subsurface drainage system;
   4) Catch basin and manholes;
   5) Culvert and bridge;
   6) Percolation pits;
   7) Water harvesting units;
   8) Retention walls and tanks;

9) Connection of all service lines up to outfall; and

10) Other related structures.

b) *Sewage disposal system*

1) Sewerage network;

2) Manholes, inspection chambers and grease trap;

3) Septic tank, soak-pits, sewage treatment plant and root zone unit;

4) Solid waste management units;

5) Connection of all service lines up to outfall; and

6) Other related structures.

c) *Water supply*

1) Water supply network;

2) Inspection chamber and valve chamber;

3) Water tank and treatment plant;

4) Tube well, bore well and associated pump houses, etc; and

5) Service lines, elements associated with water features and pools.

d) *Fire lines*

1) Yard hydrant lines;

2) Yard or fire hydrants and hose reel box;

3) Fire water tank and pumps; and

4) Inspection chamber and valve chamber.

e) *Electrical works*

1) Electrical network;

2) Light fixtures for road, pedestrian paths; special landscape features and building facade;

3) Inspection chambers, junction boxes and feeder pillars;

4) Electric poles, high voltage lines and towers;

5) Transformer, substation and distribution box; and

6) Other related structures.

f) *Telephone and under ground cable network*

1) Telephone network;

2) Inspection chambers;

3) Telephone poles, transmission towers; and

4) Other related structures.

g) *Fuel and gas line*

1) Supply network;

2) Inspection chamber and valve chamber;

3) Fuel tank and gas tank; and

4) Other related structures.

9.1.1 The following guidelines shall be applied for the designed integration of external services networks and elements in the landscape proposal:

a) The manholes and inspection chamber covers for all external services should be adequately designed for the live load (pedestrian or vehicular) and the top finish level has to be in alignment or flushed with the pavement or finished ground level. The alignment of these structures should be such that it is in geometric perpendicular or parallel with adjacent building or landscape lines. This would facilitate easy and unobstructed movement for pedestrians and increase the accessibility for wheelchair users in public place and also aid the landscape geometry to be maintained.

b) Fire hydrants should be prominently located and integrated with the landscape. Aesthetically designed fire hose cabinet with clear access as per statutory norms for fire safety, to be located in geometric relation with adjacent building or landscape lines. These structures should not be a hindrance to vehicular or pedestrian movement.

c) Irrigation hydrants should be unobtrusively located and generally at the edge of shrub planting and additionally in close proximity to a drainage chamber or catch basin to avoid waterlog. Hydrants should not be located inside the chamber to minimize waterlog from leaking pipes causing various health related hazards. Hydrants should be located 200 mm above the ground level.

d) Landscape lighting is a specialized activity and illumination consultant or designer should develop the landscape lighting plan taking into consideration energy saving measures, safety aspects, lighting pollution and illumination level. Light fixtures are an important part of street furniture and it is advisable to use pole mounted light fixtures for public landscape than bollards that are prone to vandalism and damage.

e) Water body and fountains in public spaces should have filtration facility to avoid health hazards related to stagnant water. The piping should be concealed and the pump room, balancing tank and all other service structures to be designed as an integral part of landscape.

f) Storage facilities for inflammable liquid fuel and gas should be designed as a integral part of the landscape and should be housed in designed enclosures taking into consideration all statutory norms these structures are subjected to.

g) All underground service lines have to be well coordinated and stacked appropriately in the design stage to avoid overlaps and marked with indicators above the ground for ease in maintenance and servicing. Underground service stacks should be generally aligned in soft areas with no tree plantation, this would facilitate easy maintenance without disrupting the hard surface.

h) Designed façade for service structures that are above the ground in external areas is advisable so as to assist in developing aesthetically pleasing exterior environment. Such structures should be designed in a modular way so that it would be part of the street furniture.

10 PAVED SURFACES IN EXTERNAL AREAS

The paved areas that are used for movement of vehicles, pedestrians, and wheel chair users in outdoor environment have to be designed to facilitate easy accessibility, with well drained surface, and good visual clues achieved with varied colour and texture of finishing materials. The following guidelines may be applied for the design of paved outdoor spaces:

a) Roads should provide clear access to fire fighting vehicles, ambulance, sanitation vehicles, etc and also allow safe movement for vehicles, pedestrians and wheel chair users.

b) Kerbs are required on all roads to adequately control drainage within the road, prevent moisture from entering the sub-grade, separate the road from the pedestrian area, and provide adequate lateral support for the pavement structure.

c) Pedestrian circulation path consists of sidewalks, wheelchair ramp, and landings. Pathways of minimum width 1.50 m are required along the length of road for any public or private building where pedestrian traffic is excepted.

d) Path way should be physically separated by means of kerb, graded separation, barrier, railing, or other means. The cross slope of sidewalk will not exceed two percent. The longitudinal slope of path should not exceed 1 in 20, unless the longitudinal slope of the road exceeds this maximum, in that case the standards that conform to a ramp should be applied.

e) Benches, shelters, poles, signs, bus stops, etc should be located on edge of the sidewalk with clear minimum width of 1.20 m for circulation path.

f) All ramps should have minimum width of 1.20 m, excluding edge protection. The cross slope of ramp should not exceed 1 in 50. And longitudinal slope of ramp should not exceed 1 in 12. All ramps should have an unobstructed level landing both at top and bottom of the ramp. The landing should have the minimum width as the ramp. The landing should be minimum 1.50 m in length. Any ramp beside the road should be located in such a way so that vehicles cannot park blocking the access.

g) Handrail would be required for any ramp with greater vertical height than 300 mm to prevent pedestrians and wheelchair users slipping from the ramp. The height of the top handrail should be 900 mm from the top surface of the ramp. The ramp surface should be rough finished. All ramp and landing should be designed so that water does not collect on the surface of the ramp or landing.

h) Stone not less than 40 mm in thickness should be used as paving finish in external areas. Adequate slope and drainage facility to be considered for all external paved surface integrating it with the pavement design.

j) Smooth finish is not recommended for external areas except to convey any design concept.

k) Change in levels and steps may be depicted in different texture or colour as a visual clue.

11 STREET FURNITURE

The design elements for outdoor spaces may be classified under the following categories:

a) *Pavement and other pedestrian movement spaces, covering*
   1) Footpath with heavy pedestrian traffic,
   2) Footpath with light pedestrian traffic,
   3) Plaza and public assembly spaces,
   4) Kerb to footpath, and
   5) Steps and ramps.

b) *Parking and vehicular movement corridor, covering*
   1) Parking unit,
   2) Median and road divider,
   3) Road marking, and
   4) Speed breaker.

c) *Traffic management units, covering*
   1) Bollards,
   2) Barriers,

3) Crash guard,
4) Gate/Access control,
5) Vehicular height restrictors, and
6) Traffic separators.

d) *Outdoor public conveniences, covering*
1) Seating,
2) Drinking fountains, and
3) Toilet/Wash rooms.

e) *Shelter and kiosks, covering*
1) Bus shelters,
2) Police booth,
3) Telephone booth,
4) Milk booth/Food stall,
5) Florist,
6) Information desk, and
7) Snack and coffee stall.

f) *Outdoor illumination, covering*
1) Street light,
2) Facade light, and
3) Bollard light.

g) *Tree protection units, covering*
1) Tree guard,
2) Tree grate, and
3) Planter.

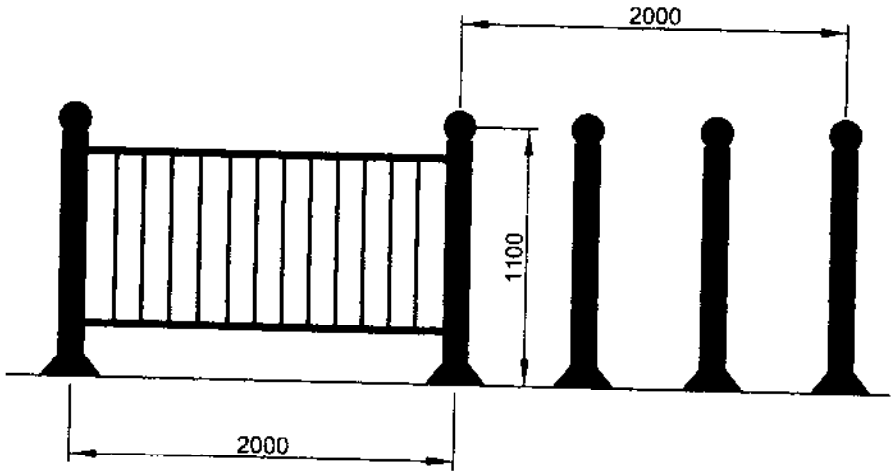
h) *Garbage collection units, covering*
1) Litter bin, and
2) Spittoons.

j) *Service utilities, relating to*
1) Water supply network,
2) Storm water network,
3) Sewerage network,
4) Electrical network,
5) Telephone lines,
6) Cable e-net, and
7) Gas.

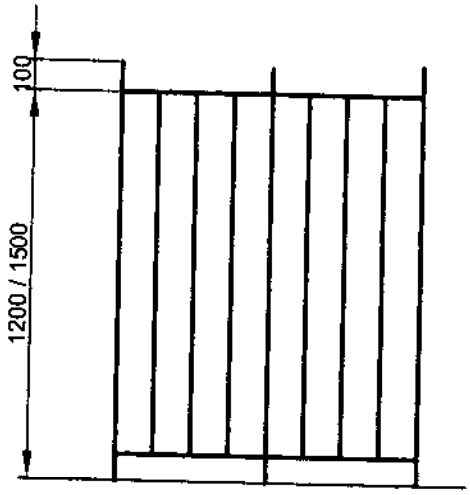
k) *Display and Signage*

Location of the street furniture has to coordinate with the traffic flow pattern of vehicles and pedestrians and external services.

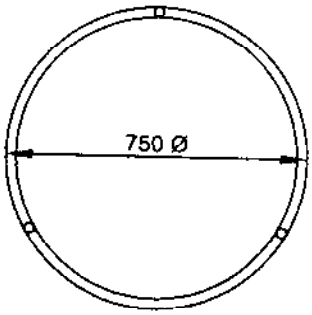
Some typical street furniture are given in Fig. 3.



ELEVATION



ELEVATION



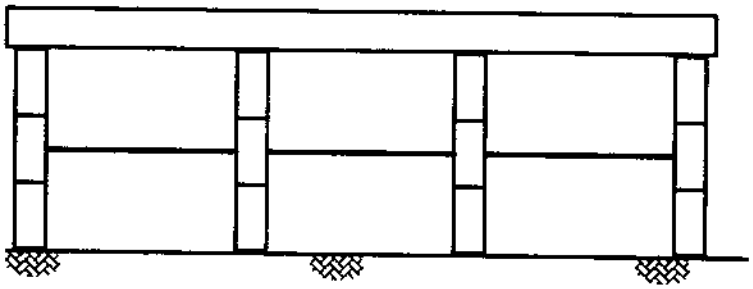
TREE GRILL

PLAN

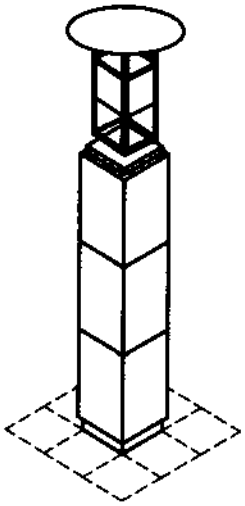
All dimensions in millimetres.

3A BARRIER — FENCE AND BOLLARD COMBINATION

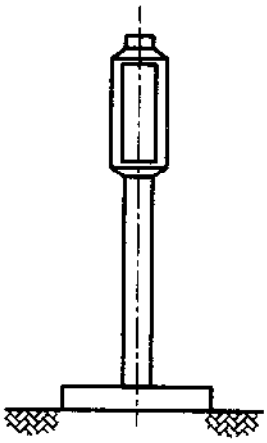
FIG. 3 TYPICAL STREET FURNITURE — *Continued*

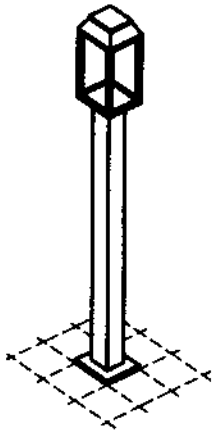


3B KIOSK

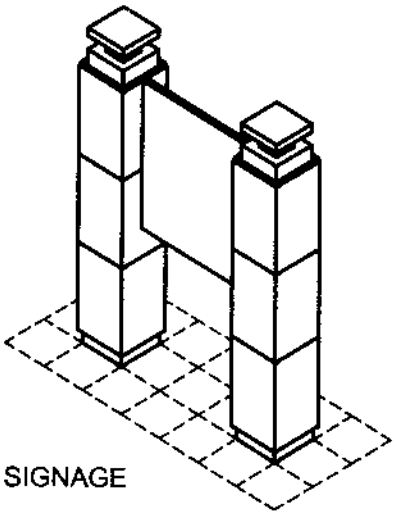


3C LIGHT POLE





3D PARK LIGHT



3E SIGNAGE

FIG. 3 TYPICAL STREET FURNITURE

NATIONAL BUILDING CODE OF INDIA

PART 10 LANDSCAPING, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 2 Signs and Outdoor Display Structures

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Section covers the requirements of signs and outdoor display structures with regard to public safety, structural safety and fire safety. With the growing industrialization followed by urbanization of large number of cities and towns, the advertising signs and its appurtenant structures had increased. In the absence of any definite rules, the display of advertising signs had proceeded unrestrained resulting in a city or town littered indiscriminately with hoardings and advertising signs of all types. Consideration of the aspects of urban aesthetics and public safety, pointed to the necessity for building regulations for the control of advertising signs and structures.

This Section was, therefore, published in 1970 as Part 10 of the Code and was subsequently revised in 1983. In the first revision, comments and suggestions received during its use were incorporated. As a result of experience gained in implementation of 1983 version of this Section and feedback received, a need to revise this Section was felt. In the existing version of the Code, Part 10 is titled as Signs and Outdoor Display Structures. Now, this Part has been enlarged to also cover Landscaping. This Part is therefore, being brought out in two sections, namely Section 1 Landscape Planning and Design and Section 2 Signs and Outdoor Display Structure. This revision as Section 2 Signs and Outdoor Display Structure has, therefore, been prepared to take care of the need to update the same. The significant changes incorporated in this revision include:

a) Few more terminologies related to signs have been added.
b) Few explanatory figures have been added.
c) Guidelines for signs in urban and rural areas have been introduced.
d) Guidelines for environmental graphics for the city scape have been introduced.

The provisions of this Section are without prejudice to the regulations already in vogue in areas requiring special controls in harmony with their historical monuments/environment.

For signs coming on highways, relevant IRC rules shall apply. In this connection reference is made to 'IRC 46 : 1972 A policy on road advertisements'.

All standards, cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

PART 10 LANDSCAPING, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 2 Signs and Outdoor Display Structures

1 SCOPE

This Section covers the requirements with regard to public safety, structural safety and fire safety of all signs and outdoor display structures.

2 TERMINOLOGY

2.0 For the purpose of this Section, the following definitions shall apply.

2.1 Signs

2.1.1 *Abandoned Sign* — A sign structure that has ceased to be used, and the owner intends no longer to use the same, for the display of sign copy, or as otherwise defined by state law.

2.1.2 *Advertising Sign* — Any surface or structure with characters, letters or illustrations applied thereto and displayed in any manner whatsoever out of doors for purposes of advertising or to give information regarding or to attract the public to any place, person, public performance, article or merchandise whatsoever, and which surface or structure is attached to, forms part of or is connected with any building, or is fixed to a tree or to the ground or to any pole, screen, fence or hoarding or displayed in space.

2.1.3 *Banner* — A flexible substrate on which copy or graphics may be displayed.

2.1.4 *Banner Sign* — A sign utilizing a banner as its display surface.

2.1.5 *Canopy Sign* — A sign affixed to the visible surface(s) of an attached or freestanding canopy.

2.1.6 *Closed Sign* — An advertising sign in which at least more than fifty percent of the area is solid or tightly enclosed or covered.

2.1.7 *Combination Sign* — A sign that is supported partly by a pole and partly by a building structure.

2.1.8 *Direction Sign* — Usually included with an arrow and used for indicating a change in route or confirmation to a correct direction.

2.1.9 *Electric Sign* — An advertising sign in which electric fittings, which are an integral part of the signs, are used.

2.1.10 *Exterior Sign* — Any sign placed outside a building.

2.1.11 *Freestanding Sign* — A sign principally supported by a structure affixed to the ground, and not supported by a building, including signs supported by one or more columns, poles or braces placed in or upon the ground.

2.1.12 *Ground Sign* — An advertising sign detached from a building, and erected or painted on the ground or on any pole, screen, fence or hoarding and visible to the public.

2.1.13 *Identification Sign* — A sign that gives specific location information, identifies specific items, for example, Parking Lot B, Building No. 5, First Aid, etc.

2.1.14 *Illuminated Sign* — An advertising sign, permanent or otherwise, the functioning of which depends upon its being illuminated by direct or indirect light, and other than an electric sign.

2.1.15 *Informational Sign* — Used for overall information for general organization of a series of elements that is, campus plan, bus route, building layout, shopping mall plan, etc.

2.1.16 *Mansard* — An inclined decorative roof-like projection that is attached to an exterior building façade.

2.1.17 *Marquee Sign* — An advertising sign attached to or hung from a marquee canopy or other covered structure projecting from and supported by the building and extending beyond the building wall, building line.

2.1.18 *Open Sign* — An advertising sign in which at least fifty percent of the enclosed area is uncovered or open to the transmission of wind.

2.1.19 *Parapet* — A low wall or railing built along the edge of a roof or floor.

2.1.20 *Portable Sign* — Any sign not permanently attached to the ground or to a building or building surface.

2.1.21 *Projecting Sign* — An advertising sign affixed to any building element and projecting more than 300 mm therefrom.

2.1.22 *Regulatory Sign* — Sign that gives operational requirements, restrictions or gives warnings, usually used for traffic delineation or control, for example 'Stop', 'No Parking', 'One Way', etc.

2.1.23 *Roof Sign* — An advertising sign erected or placed on or above the parapet or any portion of a roof

building.

2.1.24 *Sky Sign* — An advertising sign displayed in space like:

a) a gas filled balloon anchored to a point on the ground and afloat in the air with or without a streamer of cloth, etc; or

b) sky-writing, that is, a sign or word traced in the atmosphere by smoke discharged from an aeroplane.

2.1.25 *Sign* — Any device visible from a public place that displays either commercial or non-commercial messages by means of graphic presentation of alphabetic or pictorial symbols or representations. Non-commercial flags or any flags displayed from flagpoles or staffs shall not be considered as signs.

2.1.26 *Sign Area* — The area of the smallest geometric figure, or the sum of the combination of regular geometric figures, which comprise the sign face. The area of any double-sided or 'V' shaped sign shall be the area of the largest single face only. The area of a sphere shall be computed as the area of a circle. The area of all other multiple-sided signs shall be computed as 50 percent of the sum of the area of all faces of the sign.

2.1.27 *Sign Copy* — Those letters, numerals, figures, symbols, logos and graphic elements comprising the content or message of a sign, exclusive of numerals identifying a street address only.

2.1.28 *Sign Face* — The surface upon, against or through which the sign copy is displayed or illustrated, not including structural supports, architectural features of a building or sign structure, non-structural or decorative trim, or any areas that are separated from the background surface upon which the sign copy is displayed by a distinct delineation, such as a reveal or border.

2.1.29 *Sign Structure* — Any structure supporting a sign.

2.1.30 *Temporary Sign* — An advertising sign, banner or other advertising device constructed of cloth, canvas, fabric or any other light material, with or without a structural frame, intended for a limited period of display; including decorative displays for holidays or public demonstrations.

2.1.31 *VERANDAH Sign* — An advertising sign attached to, posted on or hung from a *VERANDAH*.

2.1.32 *Wall Sign* — An advertising sign, other than a projecting sign, which is directly attached to or painted or pasted on the exterior surface of or structural element of any building.

of a window with its message intended to be visible to and readable from the public way or from adjacent property.

2.2 General

2.2.1 *Approved* — Approved by the Authority having jurisdiction.

2.2.2 *Area of Special Control* — Any area declared an area of special control by the Authority in respect of the display of advertising signs, where the requirements for such display are more restrictive than elsewhere in the area controlled by the Authority.

2.2.3 *Authority Having Jurisdiction* — The Authority which has been created by a statute and which for the purpose of administering the Code/Part, may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.2.4 *Building Line* — The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme.

2.2.5 *Combustible Material* — A material is combustible, if it burns or adds heat to a fire when tested for non-combustibility in accordance with good practice [10-2(1)].

2.2.6 *Owner* — Person or body having a legal interest in land and/or building thereon. This includes free holders, leaseholders or those holding a sub-lease which both bestows a legal right to occupation and gives rise to liabilities in respect of safety or building condition.

In case of lease or sublease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

2.2.7 *Street Line* — The line defining the side limits of a street.

3 PERMITS

3.1 Application

3.1.1 *Conditions for Grant of Permit*

No sign shall be erected, altered or maintained without first obtaining a permit for the same from the Authority and shall be subjected to the following conditions:

a) The written permission shall not be granted or renewed at any one time, for a period exceeding three years from the date of grant of such permission or renewal.

b) The written permission or the renewal granted by the Authority shall become void:

1) if any sign or the part thereof falls either through an accident or any other causes;
2) if any addition is made except for the purpose of making it secure under the direction of the Authority;
3) if any change is made in the sign or part thereof;
4) if any addition or alteration is made to the building or structure upon or over which the sign is erected and if such addition or alteration involves disturbance of the sign or any part thereof; and
5) if the building or structure upon or over which the sign is erected fixed or restrained becomes demolished or destroyed.

c) Light and ventilation of buildings, if any situated near the signs and hoardings shall not be obstructed in any way;
d) Advertisements displayed shall not be of any objectionable or obscene nature given in **3.3**;
e) In the public interest the Authority shall have the right to suspend the licence even before the expiry period, upon which the licencee shall remove the signs;
f) The licencee shall be responsible for the observance of all the rules and regulations laid down by the Authority;
g) The signs should not mar the aesthetic beauty of the locality;
h) The signs other than pertaining to building shall not be permitted to come in front of buildings such as hospitals, educational institutions, public offices, museums, buildings devoted to religious worship and buildings of national importance;
j) Maintenance and inspection of advertising signs and their supports shall be as given in **4**.
k) No hoarding sign on the highways shall be put without the permission of the Authority maintaining/incharge of flyovers, highways/ roads; and
m) In addition all signs shall conform to the general requirements given in **6**.
n) The signs shall not be nailed or tied to trees or any other woody vegetation.

3.1.2 *Application for Licence or Permit and Required Drawings*

Every person intending to erect, alter or display an advertising sign for which a permit or licence is required, shall make application to the Authority on the prescribed form containing such particulars as the Authority may require. Such a form (*see* Annex A) shall be signed by the applicant and by the owner of the site upon which such sign is or is to be situated and shall include the following information:

a) Full specifications showing the length, height and weight of the sign, the location where it is to be erected, the manufacturer's name and address and where applicable, the number of lights and electrical details of the same.
b) Such form shall be accompanied by a location plan indicating the position of the sign on the site drawn to a scale of 1:500 and by full detail drawing drawn to a scale of 1:20 or an exact multiple thereof in ink or on prints including, if required by the Authority, an elevation showing the sign in relation to the façade.
c) In the case of roof signs, projecting signs or ground signs in addition to the foregoing, the size of all members of supporting frameworks and anchorages, and, if required by the Authority, the necessary design calculations shall be furnished with the application.
d) Any other particulars as may be desired by the Authority covered in **6**.
e) In the case of sky signs, necessary information as desired by the Authority may be supplied.

3.1.3 The Authority may, on the receipt of an application for permit, either sanction or refuse such a permit or sanction with modifications as deemed necessary and shall communicate decision to the applicant. If within 30 days or receiving an application for a permit the Authority fails to intimate in writing to the applicant, the permit along with the plans shall be deemed as sanctioned.

3.1.4 When a sign has to be altered, information only on such plans and statements, as may be necessary, shall be included in the form. However, the changing of movable parts of an approved sign that is designed for such changes, shall not be deemed an alteration provided the conditions of the original approval and the requirements of this part are not violated.

3.1.5 *Existing Advertising Signs*

Advertising signs in existence at the date of promulgation of the Code and covered by a valid licence or permit issued by the Authority shall not require to be licensed under the Code until such licence or permit has expired, provided it is maintained in a good and safe condition.

3.1.6 For advertising signs application shall be submitted through a structural engineer along with

necessary drawings and structural calculations. The wind load taken in the design calculations shall be in accordance with Part 4 'Structural Design, Section 1 Loads, Forces and Effects'.

3.2 Exemptions

3.2.1 No permit shall be required for signs and outdoor display structures of the following types:

a) If the signs are exhibited within the window of any building provided it does not affect light and ventilation of the building.

b) If it relates to the trade or business carried on within the land or building upon which such advertisement is exhibited or to any sale, entertainment or meeting or lettering of such land or building or any effects therein; or to the trade or business carried on by the owner of any tramcar, omnibus or other vehicle upon which such advertisements is exhibited, *provided it is not more than* 1.2 m^2.

c) In addition no permission shall be required for the signs covered in **3.2.2** to **3.2.5**. Such exemptions, however shall not construed to relieve the owner of the sign from the responsibility of erection and maintenance in compliance with the Code.

3.2.2 *Wall Signs*

The wall signs listed in **3.2.2.1** to **3.2.2.3** shall not require a permit.

3.2.2.1 *Store signs*

Non-illuminated signs erected over a show window or over the door of a store or business establishment which announce the name of the proprietor and the nature of the business conducted therein; the sign shall not be more than 1 m in height and the width of the business establishment.

3.2.2.2 *Government building signs*

Signs erected on a municipal, state or central government building which announce the name, nature of the occupancy and information.

3.2.2.3 *Name plates*

Any wall sign erected on a building or structure indicating the name of the occupant of building, which is not more than 0.5 m^2 in area.

3.2.3 *Ground Signs*

3.2.3.1 *Transit directions*

The erection or maintenance of a sign designating the location of a transit line, a rail track, station or other public carrier when not more than 0.5 m^2 in area.

3.2.3.2 *Highway Signs*

In general, advertisements of the following classes are permissible without permission though these should reasonably conform to the principles set out in **3.5.1**:

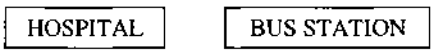
Class (1) Functional Advertisements:

a) Official warning signs, traffic directions, sign posting and notices or advertisements posted or displayed by or under the directions of any public or court officer in the performance of his official or directed duties.

Example:

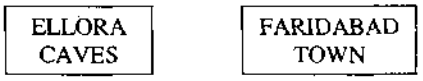
b) Direction signs to places of public amenity, such as petrol filling stations, hospitals, first-aid posts, police stations and fire stations.

Example:



c) Signs relating solely to any city, town, village or historic place, shrine, place of tourist interest:

Example:

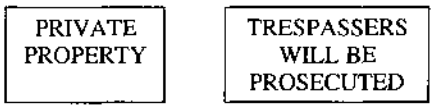


d) Signs, notices, etc, erected by the Defence Department for information of members of the armed forces or the public.

Example:

e) Signs restricting trespass of property, limited to 0.2 m^2 in area or less.

Example:



f) Signs or notices, 0.2 m^2 in area or less, placed so as to show direction to a residence and planted sufficiently away from the carriageway.

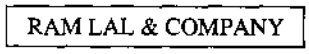
Class (2) Advertisements Relating to the Premises on which these are Displayed:

a) Advertisements for the purpose of identification, direction or warning with respect to the land or building on which they are displayed, provided not exceeding 0.2 m^2 in area in the case of any such advertisement.

Examples:

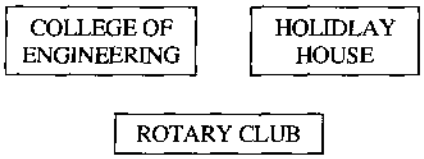
b) Advertisements relating to any person, partnership or company separately carrying on a profession, business trade at the premises where any such advertisement is displayed; limited to one advertisement not exceeding 0.3 m^2 in area in respect of each such person, partnership or company.

Example:



c) Advertisements relating to any institution of a religious, educational, cultural, recreational, medical or similar character or any hotel, public house, dark bungalow, block of flats, club, boarding house or hostel situated on the land on which any such advertisement is displayed; limited to one advertisement not exceeding 1.2 m^2 in area in respect of each such person, partnership or company.

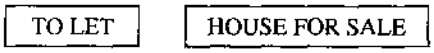
Examples:



Class (3) Advertisements of Temporary Nature

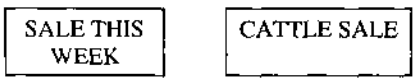
a) Advertisements relating to the sale or letting of the land on which they displayed; limited in respect of each such sale or letting to one advertisement not exceeding 2 m^2 in area.

Examples:



b) Advertisements announcing sale of goods or livestock, and displayed on the land where such goods or livestock are situated or where such sale is held, limited to one advertisement not exceeding 1.2 m^2 in area.

Examples:

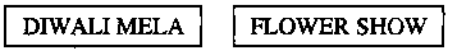


c) Advertisements relating to the carrying out of building or similar work on the land on which they displayed exceeding 2 m^2 in area.

Example:

d) Advertisements announcing any local event of a religious, educational, cultural, political, social or recreational character, not being an activity promoted or carried on for commercial purposes; limited to a display of advertisements occupying an area not exceeding 0.6 m^2 on any premises.

Examples:



3.2.4 *Temporary Signs*

3.2.4.1 *Construction site signs*

Construction signs, engineers' and architects' signs and other similar signs which may be authorized by the Authority in connection with construction operations (*see* Table 1).

3.2.4.2 *Special displays signs*

Special decorative displays used for holidays, public demonstrations or promotion of civic welfare or charitable purposes, on which there is no commercial advertising, provided that the Authority is not held responsible for any resulting damage (*see* **15.2.2**).

3.2.5 The qualitative requirements of signs given in Table 1 shall not require any permit.

3.3 Unsafe and Unlawful Signs

3.3.1 *Notice of Unsafe and Unlawful Signs*

When any sign becomes insecure, or in danger of falling, or otherwise unsafe, or if any sign shall be unlawfully installed, erected or maintained in violation of any of the provisions of the Code, the owner thereof, or the person or firm maintaining the same, shall upon written notice of the Authority, forthwith in the case of immediate danger and in any case within not more than three days, make such sign conform to the provisions of this part or shall remove it. If within three days the order is not complied with, the Authority may remove such sign at the expense of the owner.

3.3.1.1 Notwithstanding the above, it shall be the responsibility of the owner to ensure the safety of the advertising signs, even without a reference from the Authority. The owner shall also ensure to remove the remnant structures of the abandoned sign.

3.3.2 The following signs may not be permitted under any circumstances:

Any sign which in the opinion of the Authority is an

Table 1 Advertising Signs for Which No Permit or Licence is Required

(*Clause* 3.2.5)

Class (with Sample)		Area of Each Separate Sign (or Aggregate)	Maximum Height Above Ground Floor Level to Top of Sign	Illumination Provided	Description of Sign		Remarks
					Number Permitted	Maximum Dimension of Letters, Symbols, etc	
(1)		(2)	(3)	(4)	(5)	(6)	(7)
1) Functional signs of certain authorities statutory undertakings, public transport undertakings, and fire rigades, etc	BUS STATION	As may be reasonably required for the safe and efficient performance of the function	As stated in col 2	As stated in col 2	As stated in col 2	As stated in col 2	
2) Miscellaneous signs relating to premises on which they are displayed	X-RAY UNIT	Not more than 4 m^2	Not more than 5 m (in area of special control 4 m)	Only to indicate that medical or similar services or supplies are available on premises where advertisement is displayed*	Any number	Not more than 750 mm (in area of special control 300 mm)	
a) Identification, direction, or warning	MIND THE STEP						
b) Person partnership or company carrying profession business, or trade; name or private person	CHAWLA & CO. LTD. S. BOSE	Not more than 0.3 m^2 each	Not more than 5 m (in area of special control 4 m)	Only to indicate that medical or similar services or supplies are available on premises where advertisement is displayed*	One at each entrance	Not more than 750 mm (in area of special control 300 mm)	
c) Relating to any institution of a religious, educational, cultural, or medical character; name of building or premises	COLLEGE OF COMMERCE XYZ FLATS	Not more than 1.2 m^2 each	Not more than 5 m (in area of special control 4 m)	Only to indicate that medical or similar services or supplies are available on premises where advertisement is displayed*	One on each frontage	Not more than 750 mm (in area of special control 300 mm)	
3) Temporary signs (cloth banners)	HOUSE FOR SALE	Not more than 2.4 m^2 (ratio of width to depth 2:1) in aggregate area. No sign to project more than 1 m when displayed on a building (within the site)	Not more than 5 m (in area of special control 4 m)	None	Any number but aggregate area not to exceed that given in col 2	Not more than 750 mm (in area of special control 300 mm)	Shall not be displayed earlier than 28 days before the sale or other matter is due to start and shall be removed within 14 days after the conclusion of such sale or matter
a) Signs relating to the sale or letting off the land (within the site of the building) on which they are displayed							

Table 1 — *Concluded*

Class (with Sample)		Area of Each Separate Sign (or Aggregate)	Maximum Height Above Ground Floor Level to Top of Sign	Illumination Provided	Description of Sign		Remarks
					Number Permitted	Maximum Dimension of Letters, Symbols, etc	
(1)		(2)	(3)	(4)	(5)	(6)	(7)
b) Signs relating to the carrying out of building or similar operations on the land where sign is displayed	THIS FACTORY IS BEING ERECTED BY XYZ CONSTRUCTION CO. Building and Engineering Contractor	Not more than 4 m^2	Not more than 5 m (in area of special control 4 m)	None	One for each road frontage for each ontractor or sub-contractor	Not more than 750 mm (in area of special control 300 mm)	May be displayed only while such works are in progress
c) Signs announcing any local event in connection with an activity promoted for non-commercial purposes by various local organizations	DIWALI MELA	Not more than 1.5 m^2 (in aggregate area 4 m)	Not more than 5 m (in area of special control 4 m)	None	Any number but aggregate area not to exceed that given in col 2 on any premises	Not more than 750 mm (in area of special control 300 mm)	Shall not be displayed earlier than 28 days before the event is due to start and shall be removed within 14 days of its conclusion
d) Signs and business premises for areas of special control, signs on business premises with reference to the business, the goods sold, or the services provided, etc, in these premises and the name and qualifications of the person carrying on such activity	XYZQR BANK	Not to exceed one-twelfth of area of each face up to a height of 4 m	Not more than 4 m	Only to indicate that medical or similar services or supplies are available where advertisement is displayed*	Any number but aggregate area not to exceed that given in col 2	Not more than 300 mm	Area to be computed as if the advertisement were laid flat against the face of the building

* or where connected with danger.

obscene, repulsive, revolting, or objectionable character or prejudicial to the municipality or savouring political propaganda or of a nature calculated to produce pernicious or injurious effect on public or any particular class of persons, or is displayed in such a place, in such a manner or by any such means as, in the opinion of the Authority, could be likely to affect injuriously the amenities of, or to disfigure any neighbourhood.

3.4 Area of Special Control

3.4.1 Whenever in the opinion of the Authority it is likely that any advertising device otherwise permitted in terms of the Code may affect injuriously or disfigure any particular area within the jurisdiction of the Authority it may proclaim such area as an area of special control. Parks and land for public use may also be included as areas of special control.

3.4.2 Subject to the provisions of **3.4.1** within such area, the erection and display of any advertising sign shall be prohibited or restricted in any manner deemed necessary by the Authority. The Authority shall publish its intention of proclaiming such an area in one or more newspapers circulating in the area of jurisdiction of the Authority. Any owner of property within such area who may feel aggrieved by such proclamation may appeal within one month from such publication against proclamation of such an area to the Authority whose decision shall be final.

3.4.3 The wording on any *VERANDAH* sign, permitted by the Authority, in any area of special control, shall be restricted to the name of the proprietor or firm occupying the premises, the name of the building or institution, the general business or trade carried on, such as 'JEWELLER', 'CAFÉ', 'DANCING', or information regarding the location of the building entrance, box office or regarding the theatre programme or similar information. No *VERANDAH* sign in any area of special control shall advertise any particular article of merchandise nor shall any such sign refer to price or reduction in price.

3.4.3.1 Normally no other advertising sign shall, except as for **3.4.3**, be within a distance of 30 m from the area of special control.

3.5 Prohibition of Advertising Signs on Certain Sites

Where the Authority is of the opinion that any site is unsuitable for display of advertising signs by virtue of the general characteristics of the locality in regard to historic, architectural, cultural or similar interest, or by virtue of its position, the display of such signs is likely to affect in any way the safety of any form of transport, erection of advertising signs on such a site shall be prohibited.

3.5.1 *Highways and Roads*

In general the following advertisements should not be permitted:

a) At or within 100 m of any road junction, bridge or railway crossing or another crossing. In urban areas, this distance may be reduced to 50 m, provided there is no conflict with the requirements stated further on;

NOTE — The safe stopping distance for a vehicle travelling at a speed of 50 km/h is 60 m. This should be the 'uninfluenced distance' for a driver approaching a junction. Assuming that 3 seconds is the time during which the influence of an advertisement board persists, the distance travelled in this time will be about 40 m. The sign should, therefore, be more than 100 m away from the junction. Hence 100 m is suggested.

b) In such manner and at such places as to obstruct or interfere with the visibility of approaching, merging or intersecting traffic;

c) Within 10 m of the edge of a carriageway;

NOTE — A distance of 10 m may be taken as the normal minimum setback from the edge of the carriageway, the maximum area of the advertisement being 0.3 m^2 for every metre of setback.

d) Within 50 m along the road, of any sign board erected for the regulation of traffic under the orders of a Public Authority, such as a Traffic Authority, a Public Transport Authority, or a Local Authority;

e) In such a form as will obscure or hinder interpretation of any sign, signal or other device erected for traffic control by the Public Authorities. For instance, the advertisements should not imitate or resemble, in colour or shape, the standard legal traffic signs, or employ such words as 'STOP' in the same manner as used on traffic signs;

f) On boards, placards, cloth banners or sheets (except traffic signs) hung across a road as they distract the attention of driver and are, therefore, hazardous;

NOTE – Any advertisement allowed on the sides of a foot over bridge or flyover across the carriage-ways shall be restricted in size and shape such that no part of the advertisement board projects beyond the top, bottom and sides of the parapet of foot over bridge or flyover.

g) In such form as will obstruct the path of pedestrians and hinder their visibility at crossings;

h) Within right-of-way of the road; and

j) When these will affect local amenity.

3.5.2 Illuminated advertisements of the following description are objectionable from the angle or traffic safety and should not be allowed:

a) Advertisements which contain, include or are

illuminated by any flashing, intermittent or moving light or lights except those giving public service information, such as time, temperature, weather or date;

b) Illuminated advertisements of such intensity or brilliance as to cause glare or impair vision of the driver or pedestrians, or which otherwise interfere with any operations of driving; and

c) Advertisements illuminated in such a way as to obscure or diminish effectiveness of any official sign, device or signal.

4 MAINTENANCE AND INSPECTION

4.1 Maintenance

All signs for which a permit is required, together with all their supports, braces, guys and anchors shall be kept in good repair, both structurally and aesthetically, and when not galvanized or constructed of approved corrosion-resistive non-combustible materials, shall be painted when necessary to prevent corrosion.

4.2 Housekeeping

It shall be the duty and responsibility of the owner of every sign to maintain the immediate premises occupied by the sign, in a clean, sanitary and healthy condition.

4.3 Inspection

Every sign for which a permit has been issued and every existing sign for which a permit is required shall be inspected by the Authority at least once in every calendar year.

5 TYPES OF SIGNS

In this part, the following types of signs are covered [*see* also a few explanatory figures of general sign types (Fig. 1A), comparison of roof and wall or fascia sign (Fig. 1B) and sign area computation methodology (Fig. 1C and 1D)].

a) Electric and illuminated signs (*see* **7**);

b) Ground signs (*see* **8**);

c) Roof signs (*see* **9**);

d) *VERANDAH* signs (*see* **10**);

e) Wall signs (*see* **11**);

f) Projecting signs (*see* **12**);

g) Marquee signs (*see* **13**);

h) Sky signs (*see* **14**); and

j) Miscellaneous and temporary signs (*see* **15**).

6 GENERAL REQUIREMENTS FOR ALL SIGNS

6.1 Loads

Every advertising sign shall be designed so as to withstand safely the wind, dead, seismic and other loads as set out in Part 6 'Structural Design, Section 1 Loads, Forces and Effects'.

6.2 Illumination

No sign shall be illuminated by other than electrical means and electrical devices and wiring shall be installed in accordance with the requirements of Part 8 'Building Services, Section 2 Electrical and Allied Installations'. In no case, shall any open spark or flame be used for display purposes unless specifically approved by the Authority.

6.3 Design and Location of Advertising Signs

a) Sign should not obstruct any pedestrian movement, fire escape, door or window, opening used as a means for egress or fire fighting purposes.

b) No sign shall in any form or manner interfere with openings required for light and ventilation.

c) When possible signs should be gathered together into unified systems. Sign clutter should be avoided in the landscape.

d) Signs should be combined with lighting fixture to reduce unnecessary posts and for ease of illuminating the signs.

e) Information signs should be placed at natural gathering spots and included in the design of sight furniture.

f) Placement of sign should be avoided where they may conflict with pedestrian traffic.

g) Sign should be placed to allow safe pedestrian clearance vertically and latterly.

h) Braille strips may be placed along sign edges or raised letters may be used for readability for the blind and partially sighted.

j) No sign shall be attached in anyway to a tree or shrub.

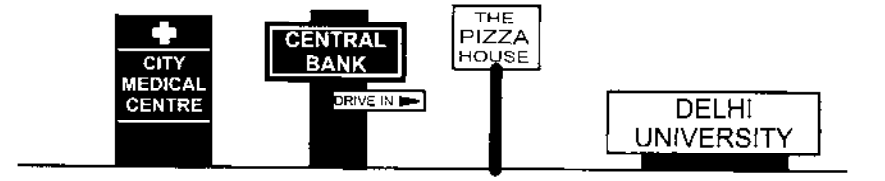
6.4 Use of Combustibles

6.4.1 *Ornamental Features*

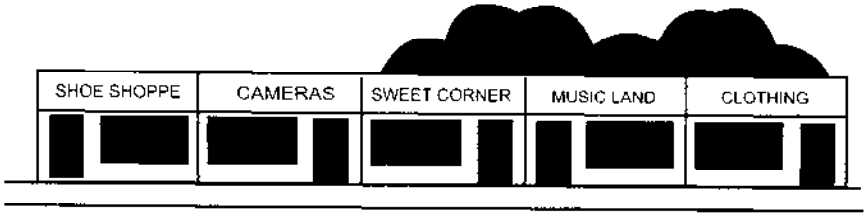
Wood or plastic or other materials of combustible characteristics similar to wood may be used for mouldings, cappings, nailing blocks, letters and latticing where permitted and for other purely ornamental features of signs.

6.4.2 *Sign Facings*

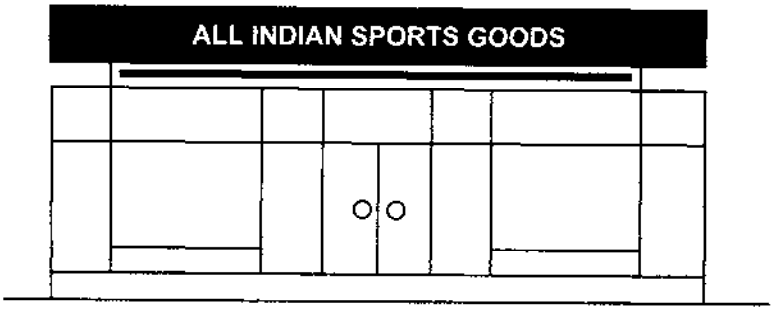
Sign facings may be made of approved combustible materials provided the area of each face is not more than 10 m^2 and the wiring for electric lighting is entirely enclosed in metal conduit and installed with a clearance of not less than 5 cm from the facing material.



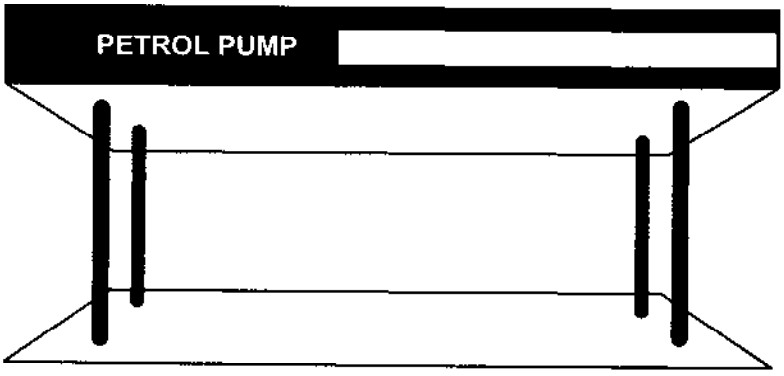
COMMON FREESTANDING SIGN TYPE



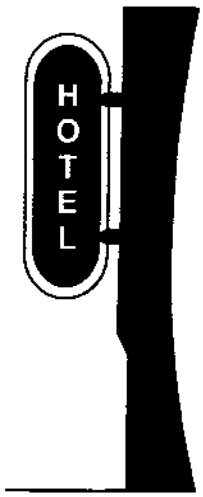
WALL OR FASCIA SIGNS ON STOREFRONTS



ROOF SIGN



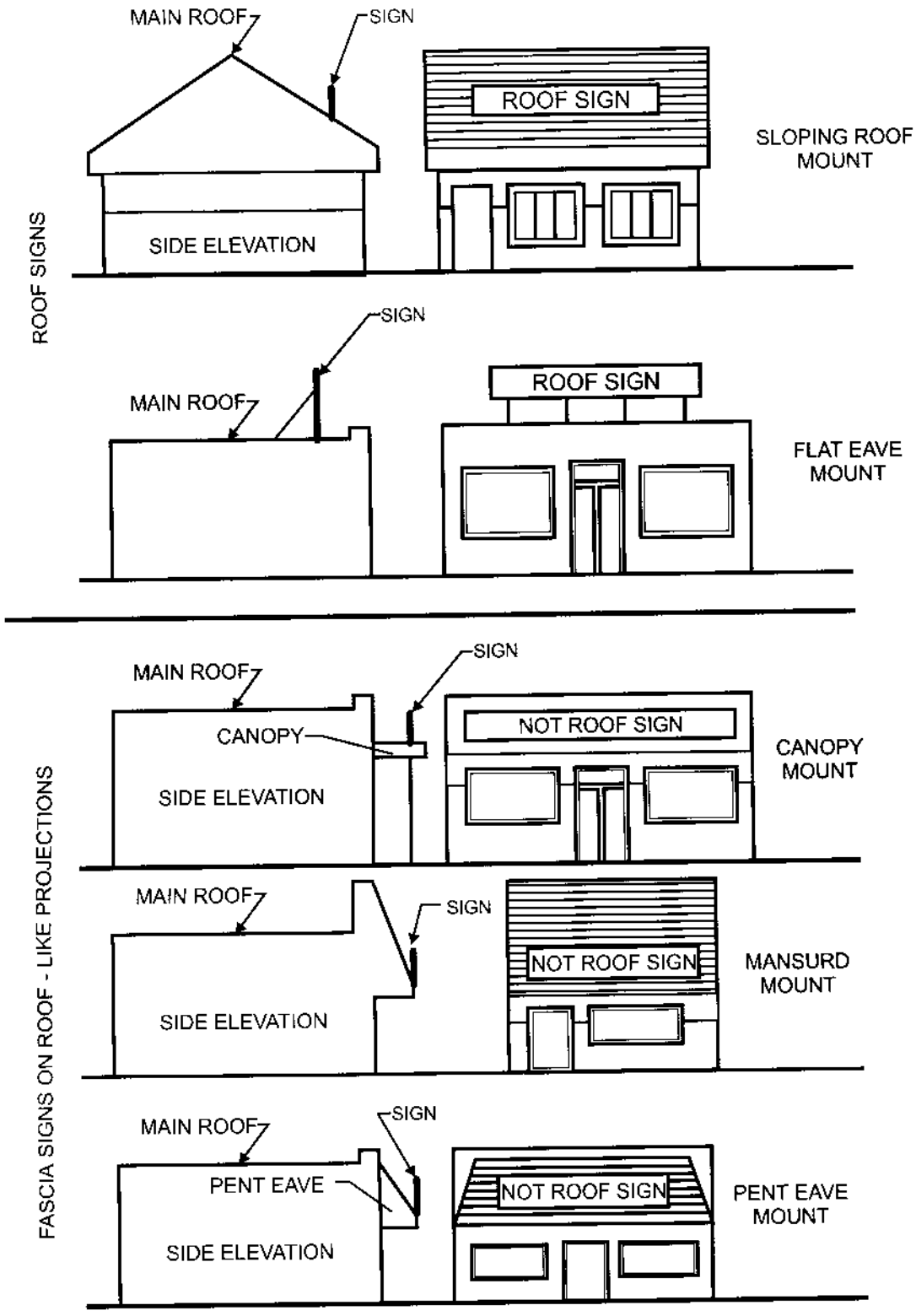
CANOPY SIGN ON FREESTANDING CANOPY



PROJECTING SIGN

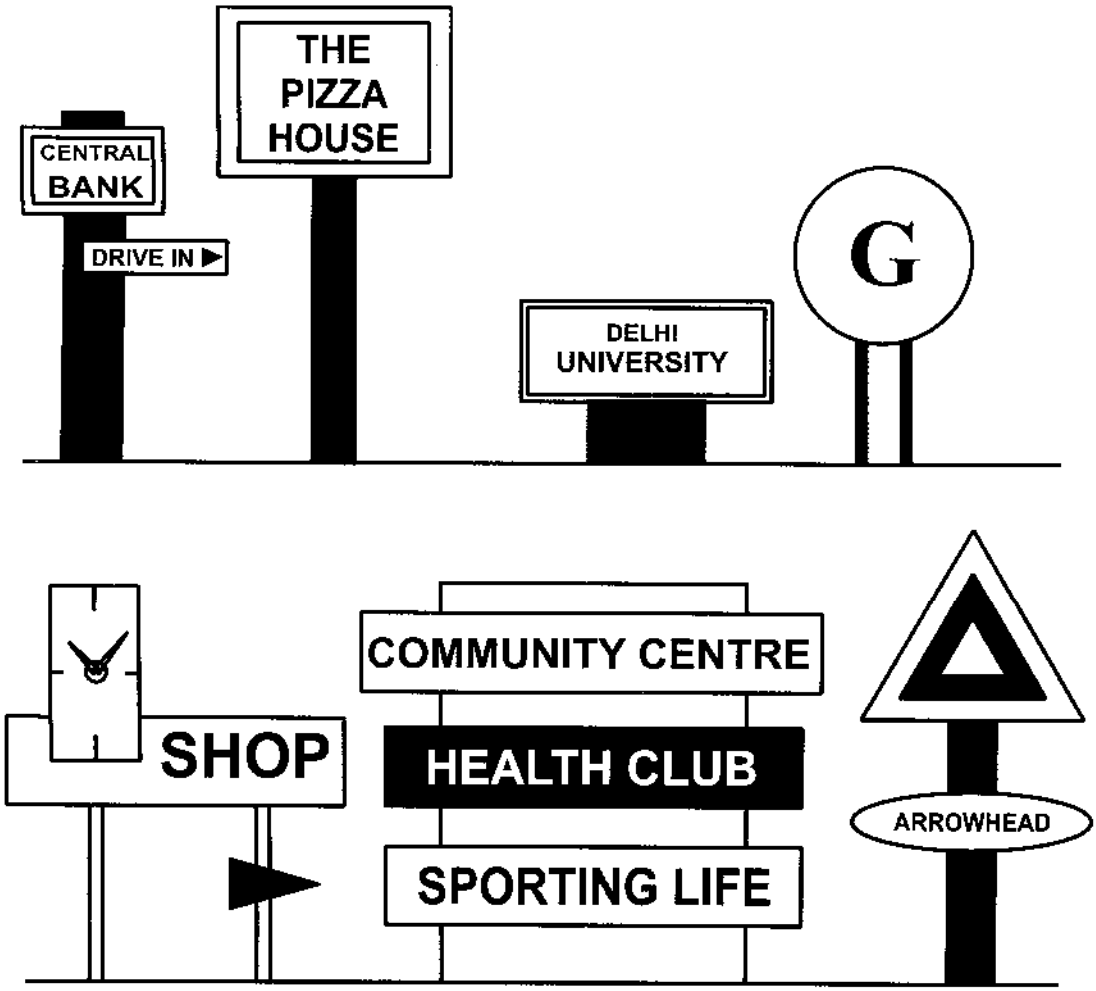
1A GENERAL SIGN TYPES

FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE — *Continued*

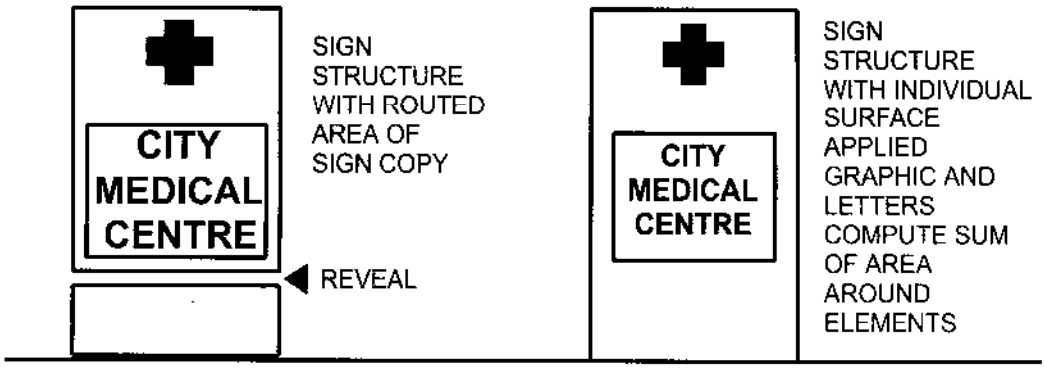


1B COMPARISON – ROOF AND WALL OR FASCIA SIGNS

FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE — *Continued*



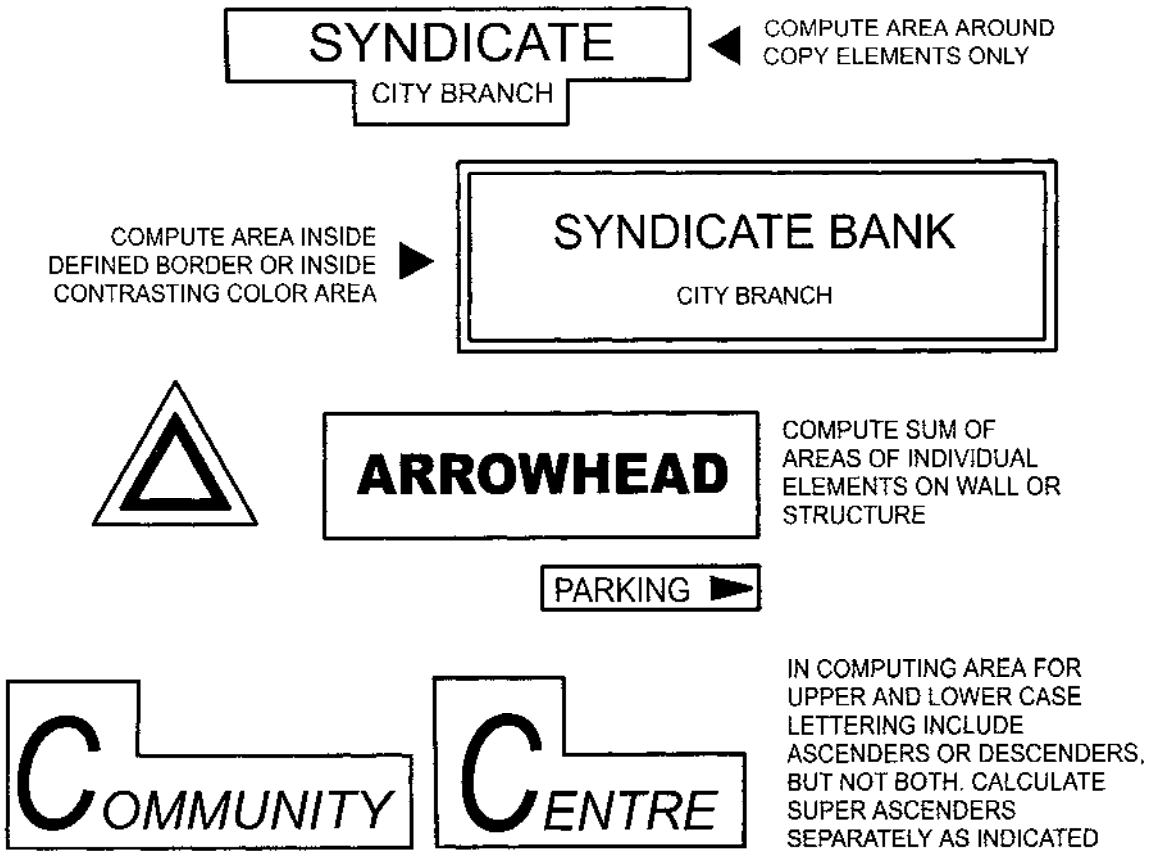
SIGN STRUCTURES



NOTE — Sum of shaded areas only represent sign area. Sign constructed with panels or cabinets.

1C SIGN AREA – COMPUTATION METHODOLOGY

FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE — *Continued*



NOTE Sum of shaded areas only represent sign area for compliance purposes. Signs consisting of individual letters, elements or logos placed on building walls or structures.

1D SIGN AREA – COMPUTATION METHODOLOGY

FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE

6.5 Damage or Defacement by Removal of Advertising Signs

Whenever any advertising sign is removed, whether in consequence of a notice or order under the Code or otherwise, any damage or defacement to the building or site on or from which such sign was displayed, shall be made good to the satisfaction of the Authority.

6.6 Alteration to Ground Level

Whenever any alteration is made to the ground level adjacent to any advertising sign, the owner of the site on which sign is erected, shall be responsible for the alteration of the height of such sign so as to conform to the requirements of this Section.

6.7 Traffic Control Interference

No advertising sign shall be erected or maintained which interferes with or is likely to interfere with any sign or signal for the control of traffic.

6.7.1 No advertising sign shall be placed particularly in bends and curves so as to obstruct the view of traffic at intersecting streets.

6.8 Draining of Signs

Adequate provision for drainage shall be made in every advertising sign, where the possibility of collection of moisture exists.

6.9 Glass in Signs

All glass used in advertising signs, other than glass tubing used in gas discharge or similar signs, shall be of safety glass conforming to accepted standards [10-2(2)] at least 3 mm thick. Glass panels in advertising signs shall not exceed 6 m^2 in area, each panel being securely fixed in the body of the sign independently of all other panels. Glass signs shall be properly protected from the possibility of damage by falling objects by the provisions of suitable protecting metal canopies, or by other approved means. Use of

glass may be discouraged or avoided wherever possible for signs placed overhead.

6.10 Interference to Fire Hydrants

Advertising signs shall be so placed as not to obstruct the use of the hydrants or other fire fighting appliances.

6.11 Serving Devices

Ladders, platforms, hooks, rings and all other devices for the use of servicing personnel shall have safety devices and suitable design loadings (reference may also be made to Part 7 'Constructional Practices and Safety').

6.12 Animated Devices

Signs which contain moving section or ornaments shall have fail-safe provisions to prevent the section or ornaments from releasing and falling or shifting its centre of gravity more than 450 mm. The fail-safe device shall be in addition to the mechanism and its housing which operate the movable section or ornament. The fail-safe device shall be capable of supporting the full dead weight of the section or ornament when moving mechanism releases.

7 ELECTRIC SIGNS AND ILLUMINATED SIGNS

7.1 Material for Electric Signs

Every electric sign shall be constructed of non-combustible material except where the sign is purely a flood-lit sign.

7.2 Installation of Electric Signs and Illuminated Signs

Every electric sign and illuminated sign shall be installed in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations'.

7.3 No illuminated sign in red, amber or green colour shall be erected or maintained within a horizontal distance of 10 m of any illuminated traffic sign.

7.4 All advertising signs illuminated by light other than a white light at height of less than two storeys or 6 m above the footpath, whichever be the greater height, shall be suitably screened so as to satisfactorily prevent any interference with any sign or signal for the control of traffic.

7.5 Intense Illumination

No person shall erect any sign which is of such intense illumination as to disturb the residents in adjacent or nearby residential buildings. Notwithstanding any permission given for such erection, any such sign which after erection is, in the opinion of the Authority, of such intense illumination as to disturb the occupants of adjacent or nearby buildings shall, on the order of the Authority, be suitably altered or removed by the owner of the site concerned within such reasonable period as the Authority may specify.

7.6 Hours of Operation

No electric sign, other than those necessary in the opinion of the Authority in the interest of public amenity, health and safety, shall be operated between midnight and sunrise.

7.7 Flashing, Occulting and Animated

No flashing, occulting or animated advertising signs, the periodicity of which exceeds 30 flashes to the minute, shall be erected so that the lowest point of such signs is less than 9 m above the ground level.

7.8 For illuminated signs in the vicinity of airports, the Directorate General of Civil Aviation should be consulted.

8 GROUND SIGNS

8.1 Material

Every ground sign exceeding 6 m in height together with frames, supports and braces shall be constructed of non-combustible material except as in **6.4**.

8.2 Dimensions

No ground sign shall be erected to a height exceeding 9 m above the ground. Lighting reflectors may extend beyond the top or face of the sign.

8.3 Supports and Anchorage

Every ground sign shall be firmly supported and acnchored to the ground. Supports and anchors shall be of treated timber in accordance with good practice [10-2(3)], or metal treated for corrosion resistance or masonry or concrete.

8.4 Site Cleaning

The owner of any site on which a ground sign is erected shall be responsible for keeping such part of the site as is visible from the street, clean, sanitary, unoffensive and free of all obnoxious substances and unsightly conditions to the approval of the Authority.

8.5 Obstruction to Traffic

No ground sign shall be erected so as to obstruct free access to or egress from any building.

8.6 Set Back

No ground sign shall be set nearer to the street line than the established building line.

8.7 Bottom Clearance

The bottom line of all ground signs shall be at least 0.6 m above the ground, but the intervening space may be filled with open lattice work or platform decorative trim.

8.8 Ground painted signs shall conform to the requirements of **6** and **7** where applicable.

9 ROOF SIGNS

9.1 Material

Every roof sign together with its frames, supports and braces, shall be constructed of non-combustible material, except as in **6.4**. Provision shall be made for electric grounding of all metallic parts; and where combustible materials are permitted in letters or other ornamental features, all wiring and tubing shall be kept free and insulated therefrom.

9.2 Dimensions

No roof sign shall exceed the following heights on buildings of heights:

	Height of Building	*Height of Sign, Max*
a)	Not exceeding four storeys or 18 m	2 m
b)	Five to eight storeys or exceeding 18 m but not exceeding 36 m	3 m
c)	Exceeding eight storeys or 36 m, provided that in calculating the height of such signs, signs placed one above the other, or on planes at different levels of the same building shall be deemed to be one sign, whether or not such signs belong to different owners	5 m

9.3 Location

a) No roof sign shall be so placed on the roof of any building as to prevent free passage from one part of the roof to another.

b) No roof sign shall be placed on or over the roof of any building unless the entire roof construction is of non-combustible material.

9.4 Projection

No roof sign shall project beyond the existing building line of the building of which it is erected or shall extend beyond the roof in any direction.

9.5 Supports and Anchorage

Every roof sign shall be thoroughly secured and anchored to the building on or over which it is erected. All loads shall be safely distributed to the structural members of the building.

9.6 For roof signs near the airports the Directorate General of Civil Aviation should be consulted.

9.7 Painted roof signs shall conform to the requirements of **6** and **7**, where applicable.

10 *VERANDAH* SIGNS

10.1 Material

Every verandah sign shall be constructed entirely of non-combustible material except as in **6.4**.

10.2 Dimensions

No *VERANDAH* sign exceed 1 m in height. No *VERANDAH* sign hanging from a *VERANDAH* shall exceed 2.5 m in length and 50 mm in thickness, except that *VERANDAH* box signs measuring not more than 200 mm in thickness, measured between the principal faces of the sign and constructed entirely of metal wired glass may be erected.

10.3 Alignment

Every *VERANDAH* sign shall be set parallel to the building line, except that any such sign hanging from a *VERANDAH* shall be set at right angles to the building line.

10.4 Location

VERANDAH signs, other than hanging signs only, shall be placed in the following locations:

a) Immediately above the eaves of the *VERANDAH* roof in such a manner as not to project beyond the rear of the roof gutter;

b) Against but not above or below the *VERANDAH* parapet or balustrade provided such parapet or balustrade is solid and the sign does not project more than 20 cm from the outside face of such parapet or balustrade; or

c) On the *VERANDAH* beams or parapets in the case of painted signs.

10.5 Height of Hanging *VERANDAH* Signs

Every *VERANDAH* sign hanging from a *VERANDAH* shall be fixed in such a manner that the lowest point of such sign is not less than 2.5 m above the pavement.

10.6 Projection

Except as provided for in **10.4**, no *VERANDAH* sign shall extend outside the line of the *VERANDAH* to which it is attached.

11 WALL SIGNS

11.1 Material

Every wall sign exceeding 4 m^2 in area shall be constructed of non-combustible material except as in **6.4**.

11.2 Dimensions

a) The total area of any wall sign shall not exceed 20 m^2 for every 15 m of building frontage to the street to which such sign faces; except that in the case of a wall sign, consisting only of the name of a theatre or cinema, the total area of such sign shall not exceed 200 m^2.

b) No wall sign which exceeds 30 m^2 in area shall be located on any wall not directly facing the road; provided that any such sign or signs shall not exceed 25 percent of the side wall area visible from the street.

11.3 Projection

No wall sign shall extend above the top of the wall or beyond the ends of the wall to which it is attached. At any place where pedestrians may pass along a wall, any wall sign attached thereto shall not project more than 7.5 cm therefrom within a height of 2.5 m measured from the level of such place.

11.4 Supports and Attachment

Every wall sign attached to walls shall be securely attached. Wooden blocks or anchorage with wood used in connection with screws, staples or nails shall not be considered proper anchorage, except in the case of wall signs attached to walls of wood.

12 PROJECTING SIGNS

12.1 Material

Every projecting sign and its support and framework shall be constructed entirely of non-combustible material.

12.2 Projection and Height

No projecting sign or any part of its supports or frame work shall project more than 2 m beyond the building; however it shall not project beyond the plot line facing the street; when it projects into the street it shall be at clear height of 2.5 m from the road (*see* Part 3 'Development Control Rules and General Building Requirements'):

a) The axes of all projecting signs shall be at right angles to the main face of the building. Where a V-construction is employed for the faces, the base of the sign against the building shall not exceed the amount of the overall projection.

b) No projecting signs shall extend above the eaves of a roof or above the part of the building face to which it is attached.

c) The maximum height of a projecting sign shall be related to the height of the building to which it is attached in the following manners:

Sl No.	*Height of Building*	*Height of Sign, Max*
i)	Not exceeding four storeys or 18 m	9 m
ii)	Five to eight storeys or not exceeding 36 m	12 m
iii)	Exceeding eight storeys or 36 m	15 m

12.3 Supports and Attachment

Every projecting sign shall be securely attached to a building so that movement in any direction is prevented by corrosion-resistant metal brackets, rods, anchors, supports, chains or wire ropes so designed and arranged that half the number of such fixing devices may safely support the sign under all circumstances.

12.3.1 Staples or nails shall not be used to secure any projecting sign to any building.

12.4 Additional Loads

Projecting sign structures which could be used to support an individual on a ladder or other servicing device whether or not specifically designed for the servicing device shall be capable of supporting the anticipated additional load but in no case less than 500 kg concentrated horizontal load and 1 500 kg vertical concentrated load applied at the point of assumed loading or point of most eccentric loading. The building component to which the projecting sign is attached shall also be designed to support the additional loads.

13 MARQUEE SIGNS

13.1 Materials

Marquee signs shall be constructed entirely of metal or other approved non-combustible materials.

13.2 Height

Such sign shall not exceed 2 m in height nor shall they project below the fascia of the marquee nor lower than 2.5 m above the footpath.

13.3 Length

Marquee signs may extend the full length but in no case shall they project beyond the ends of the marquee.

14 SKY SIGNS

14.1 In the case of the sky signs, the regulations laid down by the Authority concerned shall apply.

15 TEMPORARY ADVERTISING SIGNS, TRAVELLING CIRCUS SIGNS, FAIR SIGNS AND DECORATIONS DURING PUBLIC REJOICING

15.1 Types

None of the following advertising signs shall be erected or maintained, other than as temporary signs erected in accordance with **15.2**:

a) Any advertising sign which is painted on or fixed on to or between the columns of a *VERANDAH*;

b) Any advertising sign which projects above or below any fascia, bearer, beam or balustrade of a *VERANDAH* or balcony;

c) Any advertising sign which is luminous or illuminated and which is fixed to any fascia bearer, beam or balustrade of any splayed or rounded corner of a *VERANDAH* or balcony;

d) Any streamer sign erected across a road;

e) Any sign not securely fixed so as to prevent the sign swinging from side to side;

f) Any advertising sign made of cloth, paper mache, or similar or like material but excluding licensed paper signs on hoardings or fences;

g) Any advertising sign on a plot used or intended to be used exclusively for residential purposes, other than a brass plate or board preferably not exceeding 600 mm x 450 mm in size, affixed to the fence or entrance door or gate of a dwelling, and in the case of a block of flats, affixed to the wall of the entrance hall or entrance door of any flat; and

h) Any sign on trees, rocks, hillsides and similar natural features.

15.2 Requirements for Temporary Signs

15.2.1 All temporary advertising, travelling circus and fair signs and decorations during public rejoicing shall be subject to the approval of the Authority and shall be subjected to the approval of the Authority and shall be erected so as not to obstruct any opening and to minimize fire risk.

15.2.2 The advertisement contained on any such sign shall pertain only to the business, industry or other pursuit conducted on or within the premises on which such sign is erected or maintained. Temporary advertising signs shall be removed as soon as torn or damaged and in any case within 14 days after erection unless extended.

15.2.3 The Authority shall be empowered to order the immediate removal of any temporary advertising sign or decoration, where, in its opinion such action is necessary in the interests of public amenity and safety.

15.2.4 *Pole Signs*

Pole signs shall be constructed entirely of non-combustible materials and shall conform to the requirements for ground or roof signs as the case may be (*see* **8** and **9**). Such signs may extend beyond the street line if they comply with the provisions for projecting signs (*see* **12**).

15.2.5 *Banner and Cloth Signs*

Temporary signs and banners attached to or suspended from a building, constructed of cloth or other combustible material shall be strongly constructed and shall be securely attached to their supports. They shall be removed as soon as torn or damaged, and in no case later than 14 days after erection; except, that permits for temporary signs suspended from or attached to a canopy or marquee shall be limited to a period of 10 days.

15.2.6 *Maximum Size*

Temporary signs shall not exceed 10 m^2 in area.

15.2.7 *Projection*

Temporary signs of cloth and similar combustible construction shall not extend more than 300 mm over or into a street or other public space except that such signs when constructed without a frame may be supported flat against the face of a canopy or marquee or may be suspended from the lower fascia thereof but shall not extend closer to the footpath than 2.5 m.

15.2.8 *Special Permits*

All temporary banners suspended from building or hung on poles, which extend across streets or other public spaces shall be subject to special approval of the Authority.

15.2.9 Bill boards set up by the Authority shall be used for temporary signs, symbols, bills for entertainment, etc, so that other walls of the city are not defaced.

15.2.9.1 Bills for entertainment and other functions shall not be affixed on to building walls other than the bill boards (*see* **15.2.9**). The organization responsible for such bills and posters shall be held responsible for any such defacement and non-removal of signs.

16 ADDITIONAL GUIDELINES FOR SIGNS IN URBAN AND RURAL AREAS

16.1 Erecting maintaining and owning signs in rural areas shall be encouraged so as to boost the information and economic status of the rural population.

16.2 The tolerance criteria for the permission granted towards putting up any signs for any urban area shall be as given in **16.2.1** to **16.2.4**.

16.2.1 *Small Towns*

The traffic hazards in small towns are few and the defacement due to excessive advertising signs has not occurred. Therefore, orderly development of signs may enliven the town environment and boost the economy. The tolerance here may be high. The following guidelines may be followed for signage:

a) *Advertising Sign* — Electric sign, ground sign, building sign, illuminated sign, sky sign and temporary sign are permissible.

b) *Directional Sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

c) *Informational Sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

d) *Identification Sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory Sign* — Electric sign, ground sign, illuminated sign and temporary sign are permissible while building sign and sky sign are not permissible.

16.2.2 *Medium Towns*

The traffic hazards in medium towns are few and the defacement due to excessive advertising signs has not occurred. Proper design, erection and maintenance of the signs shall be encouraged. The following guidelines may be followed for signage:

a) *Advertising Sign* — Electric sign, ground sign, building sign, illuminated sign, sky sign and temporary sign are permissible.

b) *Directional Sign* — Electric sign, ground sign, illuminated sign are permissible while building sign, sky sign and temporary sign are not permissible.

c) *Informational Sign* — Electric sign, ground sign, illuminated sign, and temporary sign are permissible while building sign and sky sign are not permissible.

d) *Identification Sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory Sign* — Electric sign, ground sign, illuminated sign and temporary sign are permissible while building sign and sky sign are not permissible.

16.2.3 *Large Cities*

The traffic is high and hazards of accidents are many in large cities. Defacement of buildings, roads and the urban spaces due to advertisements has to be checked. Therefore, the permissivity and tolerance for erecting signs is very low. The following guidelines may be followed for signage:

a) *Advertising Sign* — Electric sign, ground sign, illuminated sign and sky sign are permissible while building sign and temporary sign are not permissible.

b) *Directional Sign* — Ground sign, illuminated sign are permissible while electric sign, building sign, sky sign and temporary sign are not permissible.

c) *Informational Sign* — Ground sign, illuminated sign, building sign and temporary sign are permissible while electric sign and sky sign are not permissible.

d) *Identification Sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory Sign* — Ground sign, illuminated sign and temporary sign are permissible while electric sign, building sign and sky sign are not permissible.

16.2.4 *Mega and Metro Cities*

The traffic hazards in mega and metro cities are many and the defacement due to excessive advertising signs has marred the urban environment. The density of population is very high and the danger of greater loss of life due to disasters is self evident. Therefore, the permissivity for erecting signs is very low and no tolerance exists for law breakers. The following guidelines may be followed for signage:

a) *Advertising Sign* — Electric sign, ground sign, illuminated sign and sky sign are permissible while building sign and temporary sign are not permissible.

b) *Directional Sign* — Ground sign, illuminated sign are permissible while electric sign, building sign, sky sign and temporary sign are not permissible.

c) *Informational Sign* — Ground sign, illuminated sign and temporary sign are permissible while electric sign, building sign and sky sign are not permissible.

d) *Identification Sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory Sign* — Ground sign, illuminated sign and temporary sign are permissible while electric sign, building sign and sky sign are not permissible.

17 ENVIRONMENTAL GRAPHICS FOR CITY SCAPE

17.1 The urban environment may be susceptible to confusion and chaos due to improper graphics, hoardings and advertisements. Therefore, the signage should be installed following requisite guidelines laid down keeping the functional, safety and aesthetic aspects in view.

The scale of the project should also be considered for implementing signage design. In urban design/planning projects and landscape projects on a large scale, the following criteria should be followed for signs and outdoor display structures:

a) The aesthetic and harmonious development of the visual environment.

b) Signage for the handicapped at all grade changes, entry points to buildings and public conveniences and facilities. Braille strips used should be displayed not above 1.5 m height for the benefit of the visually impaired at all important nodes, entrances and routes. Ramps for the people on wheelchair should be highlighted with the appropriate international sign of the wheelchair. These need to be lighted adequately even for night time.

c) Environmental graphics should be creatively designed to cater to the basic function of information, identity and way finding, with the objective of improvement of urban scape.

d) Safety aspects.

e) Protection of trees and other vegetation from harm due to signs.

ANNEX A

(*Clause* 3.1.2)

SPECIMEN FORM FOR APPLICATION FOR PERMIT TO ERECT, RE-ERECT OR ALTER ADVERTISING SIGN

1. Type of sign .....
2. *Location: .....
   a) Building/premises .....
   b) Location of building/premises with respect to neighbouring streets .....
   .....
3. *Dimensions and details of the sign .....
4. Materials used for different parts .....
5. *Electrical and lighting details .....
6. *Structural details showing also supporting framework and anchorages .....
   .....
7. Mode of operation .....

* Plans as desired in **3.1.2**(b) are enclosed.

Name and address of the applicant	Name and address of the owner of the building/premises
.....	.....
.....	.....
.....	.....
Signature	Signature .....
Date	Date .....

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of this Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

	IS No.	*Title*
(1)	3808 : 1979	Method of test for non-combustibility of building materials (*first revision*)
(2)	2553	Specification for safety glass:
	(Part 1) : 1990	General purpose (*third revision*)
	(Part 2) : 1992	For road transport
(3)	401 : 2001	Code of practice for preservation of timber (*fourth revision*)

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