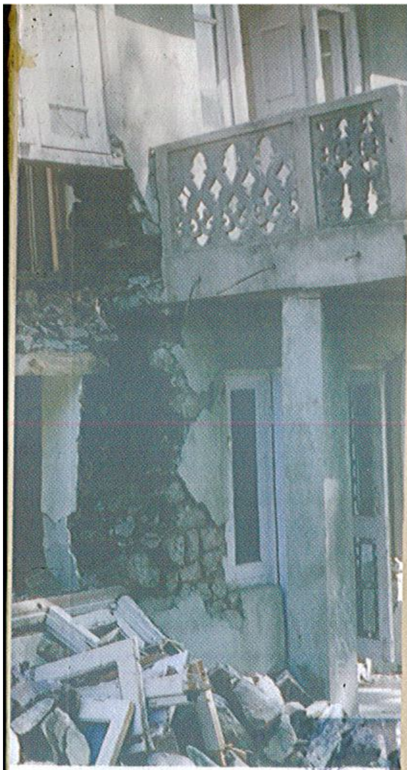
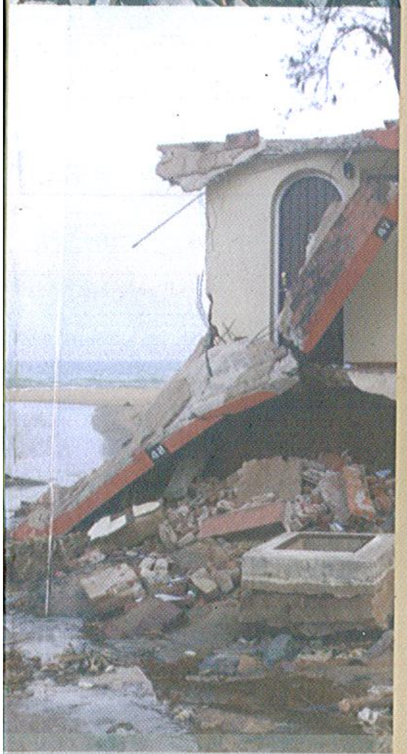
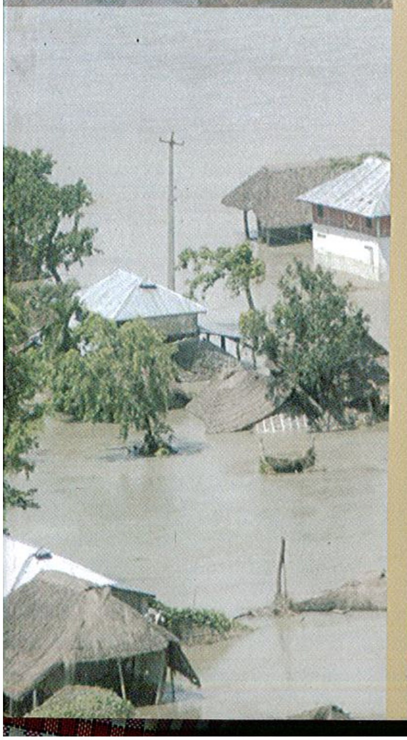

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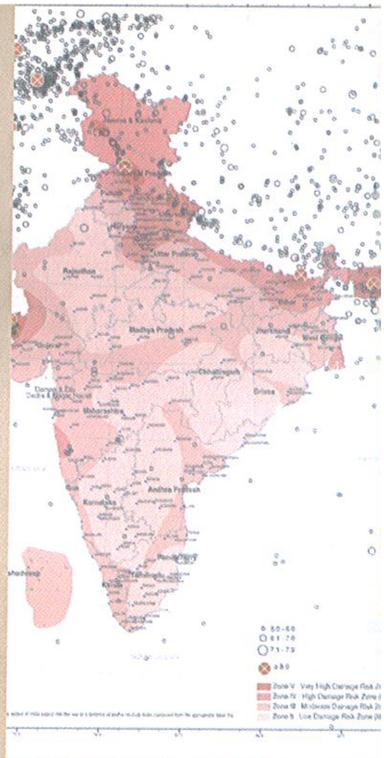
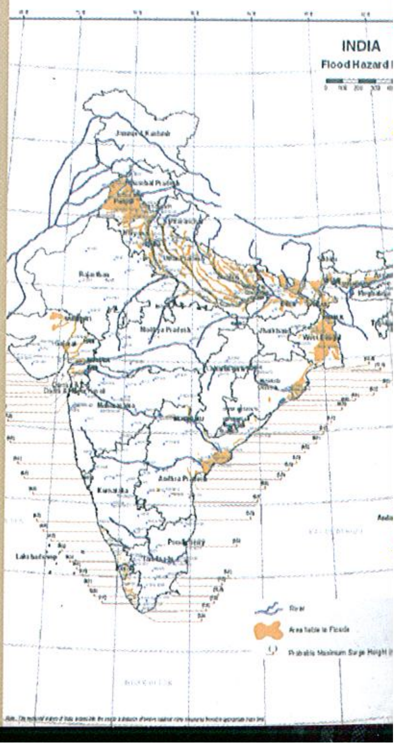
Multi-Hazard Resistant Construction of EWS Housing Projects





bmtpc

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India, New Delhi

Guidelines

Multi-Hazard Resistant Construction of EWS Housing Projects

Building Materials & Technology Promotion Council
Ministry of Housing & Urban Poverty Alleviation
Government of India
New Delhi

Prepared by Dr. Anand S. Arya, Professor Emeritus, IIT Roorkee

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FOREWORD

It is indeed an honour to present the guidelines on Multi Hazard Resistant construction of EWS Housing Projects for the benefit of all the professionals, govt. or non-govt., involved into slum renewal projects. It has been BMTPC's experience as an appraisal and monitoring agency for JNNURM that while preparing detailed project reports by the state agencies, the disaster resistant features often take a back seat or rather reduced to a mere certification by the competent authority that the design incorporates the various provisions given in Indian standards as regards earthquake and therefore, earthquake resistant. This kind of practice is not able to ensure earthquake resistant construction some times and therefore, a need was felt to develop a document which empowers the professionals through series of checklists, tables and forms, to look for hazard resistant features given in Indian standards and use them while designing and preparing the project report. Also, the document covers the various disaster resistant provisions for various types of buildings e.g. load bearing, RC framed structures and wooden houses in different chapters so that the user can get the first hand information on hazard resistant practices.

The document has been prepared by Padamshree Prof. A.S. Arya, Professor Emeritus, IIT, Roorkee and I place on record the deep appreciation and gratitude on behalf of BMTPC for doing a commendable work and producing the guidelines which would be of immense use to the engineers and architects involved into design and construction of EWS housing.

BMTPC in its pursuit to promote disaster resistant construction practices is committed to publish the guidelines, manuals, books which would not only help the common people of India but also the professionals to embrace disaster resistant features while conceiving the project. I am sure that the guidelines of this kind would facilitate the technical framework so as to create housing stock which can withstand the vagaries of nature's wrath without inflicting losses to life and property.

17th Day of August 2011
Place: New Delhi

Dr. Shailesh Kr. Agrawal
Executive Director, BMTPC

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Chapter - 1 : Preamble

1.1 STATEMENT OF THE PROBLEM (Impacts of Hazards on the Housing projects)

Historically, India is prone to the occurrence of damaging earthquakes, floods, cyclones and landslides resulting into damage or total loss of more than twelve lakh housing unit on an average every year. Given both the population explosion and increased need of developmental activities, the exposure, the scale and impact of natural hazards is increasing.

These events, coupled with underdevelopment and changing poverty profiles in most urban centres, lead to catastrophic situations for vulnerable sections of society and the housing stock, both in urban and rural settlements. Housing sector is the most commonly affected in any disaster be it earthquake, flood, cyclone, tsunami, or landslides. The main reason for "Housing Sector" to be most vulnerable is that majority of housing stock in India comprise of non-engineered category of construction with least capacity of the inhabitants to respond to disasters. High Vulnerability of housing settlements is also the result of ill-planned projects and policies which do not strictly prohibit occupation of flood prone areas and expansion of residential pockets (authorized and most often unauthorized) in other risk prone areas in the absence of clearly laid down land-use policies.

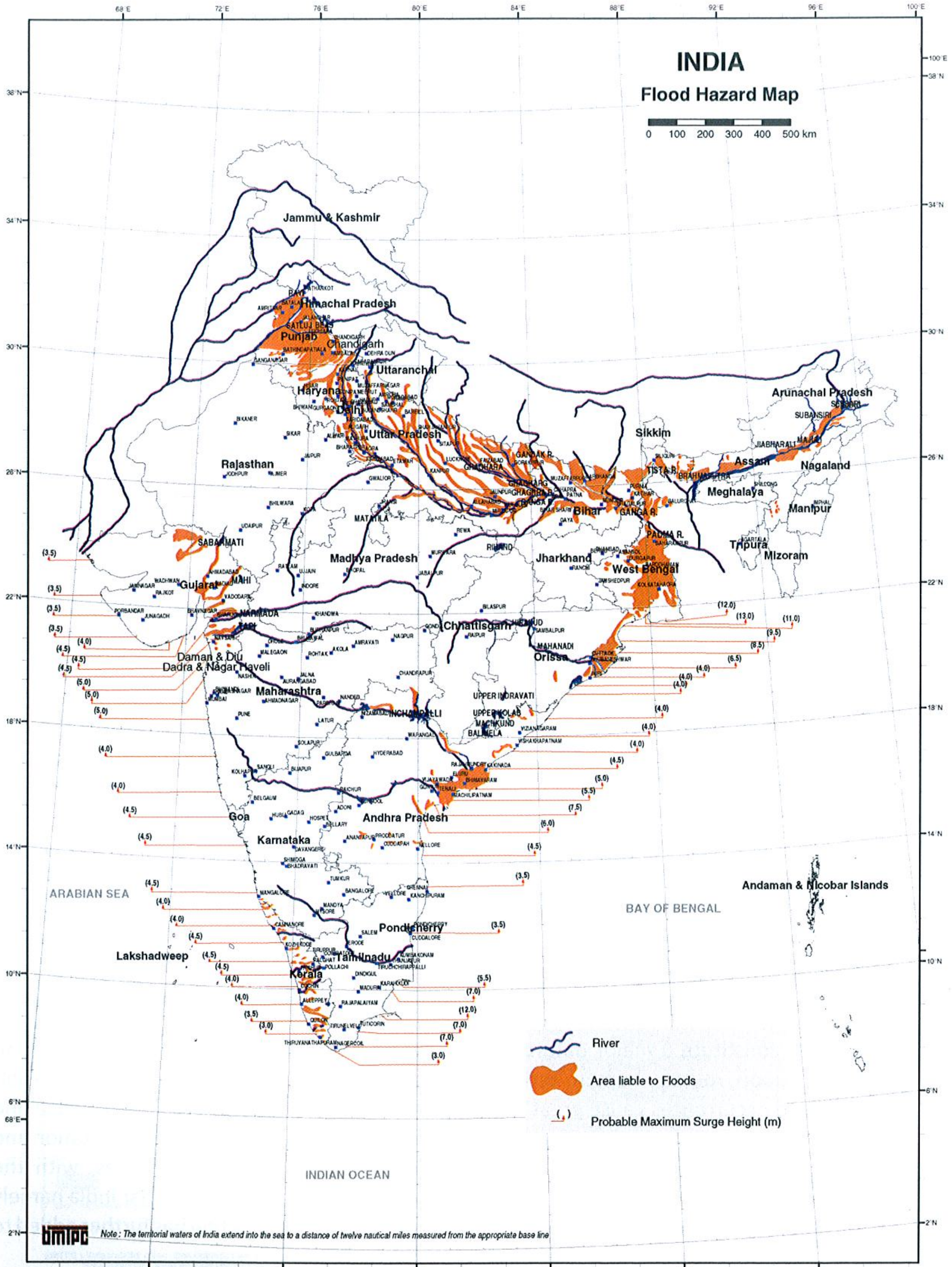
The hazard risk in India may be described briefly as follows:

1.1.1 Earthquake

India's high earthquake risk and vulnerability is clear from the fact that about 59 per cent of India's land area could face moderate to severe earthquakes in Seismic Zone III, VI and V. See Seismic Zone Map of India from Vulnerability Atlas of India 2006, BMTPC, in Fig. 1.1. During the period 1990 to 2006, more than 23,000 lives were lost in India due to 6 major earthquakes, which also caused enormous damage to buildings and public infrastructure. These earthquakes include the Uttarkashi earthquake of 1991, the Latur earthquake of 1993, the Jabalpur earthquake of 1997, and the Chamoli earthquake of 1999, followed by the Bhuj earthquake of 26 January 2001 and the Jammu & Kashmir earthquake of 8 October 2005. The occurrence of several devastating earthquakes even in Zone III area indicates that the built environment in the country is extremely fragile. All these major earthquakes established that the casualties were caused primarily due to the collapse of buildings. However, similar high intensity earthquakes in the United States, Japan, etc., do not lead to such enormous loss of lives, as the structures in these countries are built with earthquake resistant measures. This emphasizes the need for strict compliance of town planning bye-laws and earthquake-resistant building codes in India.

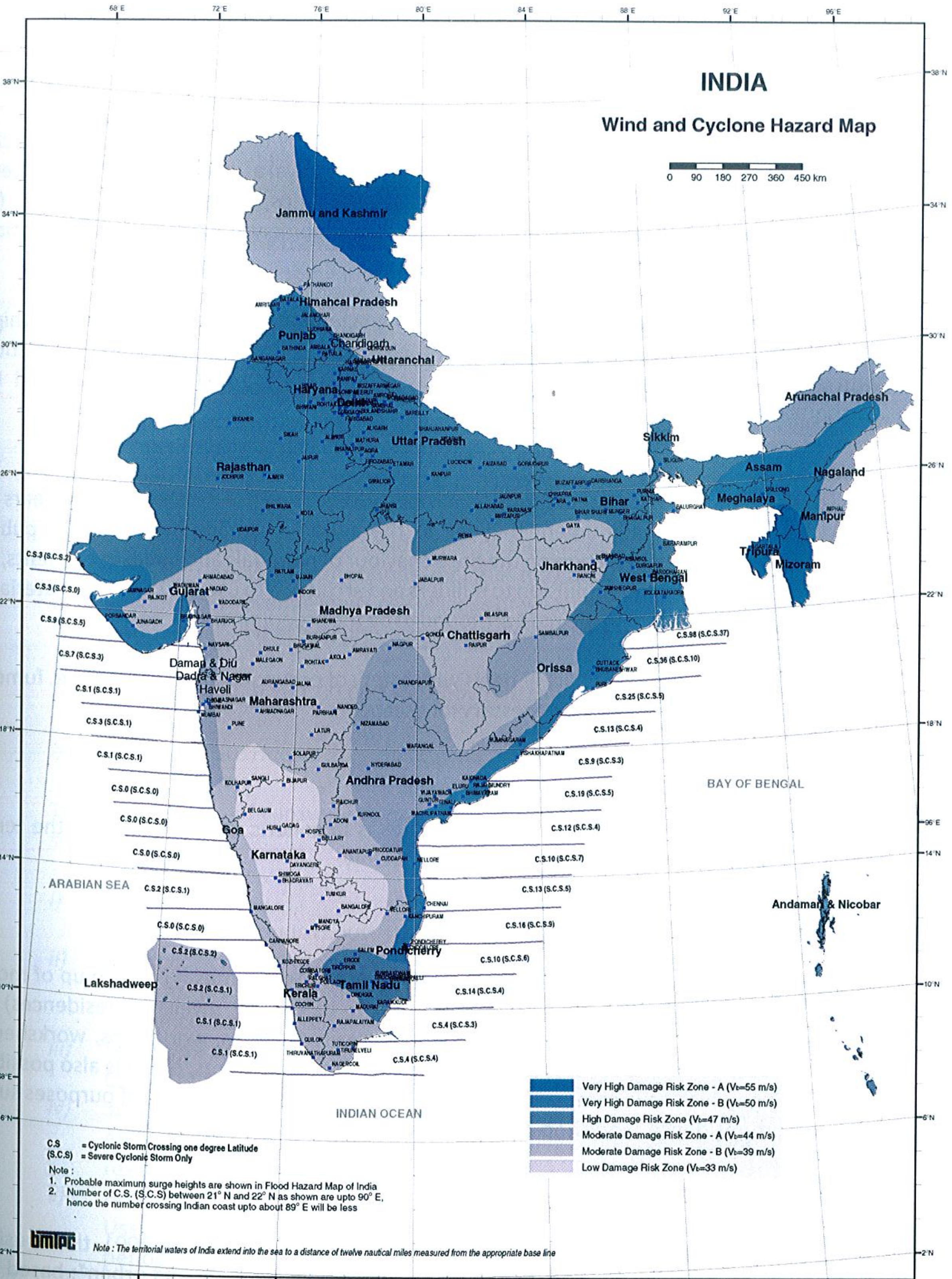
1.1.2 Flood

Floods have been a recurrent phenomenon in India and cause huge losses to lives, housing,



BMTPC : Vulnerability Atlas - 2nd Edition; Peer Group, MoH&UPA; Map is Based on digitised data of SOI, GOI; Flood Atlas, Task Force Report, C.W.C., G.O.I.

Fig. 1.2 : Flood Hazard Map of India (Including Storm - Surge Heights on the Sea Coasts)



BMTPC : Vulnerability Atlas - 2nd Edition; Peer Group, MoH&UPA; Map is Based on digitised data of SOI, GOI ; Basic Wind Speed Map, IS 875(3) - 1987; Cyclone Data, 1877-2005, IMD, GOI

Fig. 1.3 : Wind and Cyclone Hazard Map of India (Including Cyclone Crossing the Sea Coasts)

The Indian subcontinent, with diverse physiographic, seismotectonic and climatologic conditions is subjected to varying degrees of landslide hazards; the Himalayas including Northeastern mountain ranges being the worst affected, followed by a section of the Western Ghats, Eastern Ghats and the Vindhyas. Depiction and portrayal of various levels of these geo-hazards is a prerequisite for (a) projecting damage scenarios, (b) reliable risk analysis, (c) planning and execution of any environment friendly developmental activity and (d) mitigation of hazard-related miseries.

Large scale deforestation along with faulty management practices have led to high vulnerability to landslides in many regions of the country. These often occur in conjunction with severe precipitation on slopes, or in association with ground shaking caused by earthquakes.

1.1.5 Building Fires

India performs poorly in terms of fire costs, property losses and fire deaths. There appears to be no basic culture or any urgent thinking as the nation is already behind in the public awareness schedule, information on the fire behaviour of materials and building elements, in codal requirements, or in compulsion to builders and architects to use only fire safe materials. Kitchen fires and electric short-circuit are found to be the predominant causes.

National Building Code 2005, Part IV deals with safety of occupants from fire, smoke, fumes, and panic during the time period necessary for escape.

1.2 HOUSING

The term Housing considered in these guidelines is in generic form and akin to the term building as defined in Census 2001 as stated here below:

1.2.1 Building

A 'building' is generally a single structure on the ground. Sometimes it is made up of more than one component unit which are used or likely to be used as dwellings (residences) or establishments such as shops, business houses, offices, factories, workshops, worksheds, schools, places of entertainment, places of worship, godowns, stores, etc. It is also possible that buildings which have component units may be used for a combination of purposes such as shop-cum-residence, workshop-cum-residence, office-cum- residence, etc.

1.2.2 Housing Sector

We may consider Housing Sector comprising of all buildings as per Census 2001- the Housing Series, where buildings are classified in three different ways: "rural and urban"; based on "functional uses"; and as "permanent, semi-permanent or temporary". These are defined below:

a) Rural-Urban Areas

The unit of classification is 'town' for urban areas and 'village' for rural areas. The definition of urban area adopted is as follows:

i) All places with a municipality, corporation, cantonment board or notified town area, etc.

ii) A place satisfying the following three criteria simultaneously:
   - a minimum population of 5,000;
   - at least 75 per cent of male working population engaged in non-agricultural pursuits; and
   - a density of population of at least 400 per sq. km.

For identification of places, that would qualify to be classified as 'urban', all villages which, as per the 1991 Census, satisfied the above criteria were so chosen.

Apart from these, the outgrowths (OGs) of cities and towns have also been treated as urban under 'Urban Agglomerations': Examples of out-growths are railway colonies, university campuses, port areas, military camps, etc. that may have come up near a statutory town or city but within the revenue limits of a villages or villages contiguous to the town or city. Thus, the town level data, wherever presented, also includes the data for outgrowths of such towns.

Towns with population of 1,00,000 and above are called cities.

b) Uses of Census Houses

The different uses of census houses were standardized and grouped into ten categories, as shown below:

i) Residence:
This category includes houses that were used exclusively for residential purpose.

ii) Residence-cum-other use:
Such as residence-cum- grocery shop, residence-cum workshop (book binding), residence-cum-boarding house, etc.,

iii) Shop/Office:
Census houses exclusively used as shops, and offices were covered under this category.

iv) School/College, etc.:
All types of educational institutions and training centers without lodging facilities or any residential use.

v) Hotel/lodge/guest house, etc.:
Used exclusively for temporary stay or stay in transit and where no person living for a period of three months or more.

vi) Hospital/Dispensary, etc.:
Used as hospitals, dispensaries, nursing homes and such other health or medical institutes.

vii) *Factory/workshop/workshed, etc.:*
Exclusively used for running a factory or a workshop of manufacturing, production, processing, repairing or services, etc.

viii) *Place of worship:*
Such as temples, gurudwaras, mosques, churches, prayer halls, etc.

ix) *Other non-residential use:*
Used as places of entertainment and community gathering and all other non-residential miscellaneous uses not covered under any of the above categories; used as cattle-shed, godown, garage, petrol pump, power station, pump house, tube well room, cinema house, museum, stadium, etc.

x) *Vacant:*
Found vacant, under construction or not being used for any other non-residential purpose.

c) *Type of Census Houses*

These have been classified according to the types of material used in the construction of wall and roof of the house. The basis of their classification is described hereunder:

i) *Permanent Houses:*
Houses, the walls and roof of which are made of permanent materials. The material of walls can be any one from the following, namely galvanized iron sheets or other metal sheets, asbestos sheets, burnt bricks, stones or concrete. Roof may be made of from any one of the following materials, namely: tiles, slate, galvanized iron sheets, metal sheets, asbestos sheets, bricks, stones or concrete.

ii) *Temporary Houses:*
Houses in which both walls and roof are made of materials, which have to be replaced frequently. Walls may be made from any one of the following temporary materials, namely: grass, thatch, bamboo, plastic, polythene, mud, unburnt bricks or wood. Roof may be made from any one of the following temporary materials, namely, grass, thatch, bamboo, wood, mud, plastic or polythene.

iii) *Semi-permanent houses:*
Houses in which either the wall or the roof is made of permanent material and the other is made of temporary material.

iv) *Serviceable temporary houses:*
Temporary houses in which wall is made of mud, unburnt bricks or wood.

v) *Non-serviceable temporary houses:*
Temporary houses in which wall is made of grass, thatch, bamboo, etc., plastic or polythene.

1.3 RESISTANCE TO HAZARDS

To achieve safety under the impact of various hazards, the following actions need to be taken before the occurrence of the hazards:

Mitigation: Measures aimed at reducing the risk, impact or effects of a hazard or threatening disaster situation. It will include structural as well as non-structural measures.

Preparedness: The state of readiness to deal with a threatening disaster situation or disaster and the effects thereof.

The terms related to hazards resistance of buildings are defined below:

1. *Disaster :* A catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man made causes, or by accident or negligence which results in substantial loss of life or human suffering or damage to, and destruction of, property, or damage to, and degradation of, environment, and is of such a nature or magnitude as to be beyond the coping capacity of the community of the affected area.

2. *Disaster Risk Reduction:* The expression 'disaster risk reduction' is now widely used as a term that encompasses the two aspects of a disaster reduction strategy: Mitigation and Preparedness.

3. *Exposure (Element at Risk):* The buildings population, properties, infrastructures, life lines economic activities, including public services etc. in a given area which are exposed to the threat of the hazard occurrence.

4. *Hazards:* A threatening event or the probability of occurrence of a potentially damaging phenomenon (e.g., natural hazards namely an earthquake, a cyclonic storm or a large flood or a landslide) within a given time period and area or man-made hazard such as building fire.

5. *Local Authority:* It includes Panchayati Raj institutions, municipalities, a district board, cantonment board, town planning authority or Zilla Parishad or any other body or authority, by whatever name called, for the time being invested by law, for rendering essential services or, with the control & management of civic services, within a specified local area.

6. *Mitigation:* Measures aimed at reducing the risk, impact or effects of a disaster or threatening disaster situation.

7. *Non-Structural Measures:* Non-engineered measures to reduce or avoid possible impacts of hazards such as education, training, capacity development, public awareness, communication etc.

8. *Preparedness:* The state of readiness to deal with a threatening disaster situation or disaster and the effects thereof.

9. *Rapid Visual Screening:* Rapid Visual Screening is a procedure requiring visual evaluation to assess the vulnerability of buildings, by permitting vulnerability

assessment based on walking around the building by a trained assessor. (The evaluation procedure and system is compatible with GIS-based city database and also permits use of the collected building information for a variety of other planning and mitigation purposes)

10. *Resilience:* The capacity of a system to tolerate perturbation or disturbances without collapsing into a qualitatively different state, to withstand shock and rebuild when necessary.

11. *Risk:* It consists of the expected number of lives lost, persons injured, damage to buildings and other property, and disruption of economic activity due to a particular natural or man-made hazard.

12. *Risk Assessment:* The determination of the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability that could pose a potential threat or harm to people, property, livelihoods, and the environment

13. *Seismic Hazard:* Seismic hazard in the context of engineering design is defined as the predicted level of ground acceleration which would be exceeded with 10% probability at the site under construction due to occurrence of earthquake anywhere in the region, in the next 50 years.

14. *Seismic Retrofitting:* The structural modifications to upgrade the strength, ductility and energy dissipating ability of seismically deficient or earthquake-damaged structures.

15. *Structural Measures:* Any physical construction to reduce or avoid possible impacts of hazards, which include engineering measures and construction of hazard-resistant and protective structures and infrastructure.

16. *Vulnerability:* The degree of loss to an exposure element at risk or set of such elements resulting from the occurrence of a natural man-made hazard (or manmade) of a given magnitude or intensity. It is expressed on a scale from 0 (no damage) to 1(total loss).

1.4 OBJECT OF THE GUIDELINES

The objectives of the guidelines are as follows:

To develop a document which will describe the hazard resistant construction practices to be followed by architects and engineers while initiating / undertaking any building project. The document to be useful to municipal engineers and other professionals involved in housing schemes such as JNNURM, slum upgradation projects under RAY and other social housing schemes of States. The document is intended to provide guidance to contractors, quality assurance agencies etc. procedures, practices and principles so as to achieve safety under various natural hazard occurrences.

1.5 SCOPE OF THE GUIDELINES

The guidelines include, based on the National Building Code – 2005 and other applicable Indian Standards, the high lights of the principles and procedures to be followed for hazard safe design and construction of buildings of various materials and construction technologies. The earthquake, flood and cyclone prone areas are mainly considered. Multi hazard safety consideration is also included.

Chapter - 2 : Review of Some Major Central Housing Schemes

2.1 HOUSING SCHEMES IN INDIA

Most development schemes of Government of India and those of the states include the Housing component and should provide a great opportunity in practicing safety against hazard through the construction of building projects at various sites. Some of the Central Government schemes are mentioned below:-

(i) Jawaharlal Nehru National Urban Renewal Mission (JNNURM)
(ii) Indira Awas Yojana (IAY)
(iii) Rajiv Awas Yojana (RAY)

Besides the central government schemes, number of state governments have also started housing schemes for the poor people living in those states such as the following:-

(i) Birsa Munda Awas Yojana, in Jharkhand
(ii) Atal Awas Yojana, in Chhattisgarh
(iii) Kashi Ram Ji Shahri Awas Yojana, in Uttar Pradesh
(iv) Sardar Patel Awas Lojana, in Gujarat
(v) Credit / Cum-subsidy Scheme for Rural Housing, in Bihar
(vi) Housing for BPL and Middle Class Families, in Andhra Pradesh

The Disaster Mitigation and Management Act, 2005 recognizes the need to consider Disaster Mitigation Measures and Strategies as an integral part of all development activities in the country, specifically the Act provides as follows :-

- Section 11 (3)(b) states that the National Plan shall include measures to be taken for the integration of mitigation measures in the development plans; and
- Section 23(4)(c) states that the State plan shall include the manner in which the mitigation measures shall be integrated with the development plans & projects..

In view of the occurrences of large scale natural hazards in India, it is necessary that all investment going for creation of physical infrastructure as a part of the development schemes take cognizance of the likely adverse impact of natural hazards on the assets proposed to be created in the disaster prone regions. The losses of life and property could thus be minimized in the future. The guidelines attached here are to be incorporated in all the stages of project formulation, sanction, implementation and monitoring.

A review of the three Central Government schemes is done here below from disaster safety view point under the various hazards.

2.2 JAWAHARLAL NEHRU NATIONAL URBAN RENEWAL MISSION (JNNURM)

The mission covers 65 cities consisting of 7 major cities, 28 million plus cities and 30 other identified cities with less than 1 million population. The Urban Renewal Mission, covering 65 cities, provides a great opportunity for improving safety of our cities with respect to natural hazards which often tend to become disasters as experienced in recent past. It needs to be considered that each project, when sanctioned particularly in disaster prone region should include a component for assessment of impact of natural hazards that may occur in the area.

2.2.1 Hazard Proneness of Cities Under JNNURM

(i) Earthquake Proneness

(a) From the earthquake hazard proneness point of view the following 8 cities fall in Seismic Zone V with very high damage risk, with the highest intensity considered MSK IX or higher. (example of such an earthquake in recent times is Kachchh earthquake of 26th January, 2001):

Guwahati, Itanagar, Imphal, Shillong, Aizwal, Kohima, Agartala & Srinagar (J&K)

(b) The following 14 cities are classified in Seismic Zone IV considered high damage risk zone with MSK Intensity VIII considered probable (recent example of such an earthquake is that occurred in Uttarkashi 1991 and Chamoli earthquake of 1999):

Delhi, Patna, Faridabad, Ludhiana, Amritsar, Meerut, Jammu, Shimla, Gangtok, Dehradun, Nainital, Chandigarh, Mathura and Haridwar.

(c) The following selected 28 cities fall in Seismic Zone III i.e. moderate damage risk zone with MSK Intensity VII considered probable (recent example of such an earthquake is that occurred in Jabalpur in 1997):

Greater Mumbai, Ahemdabad, Chennai, Kolkatta, Lucknow, Nashik, Pune, Cochin, Varanasi, Agra, Vadodara, Surat, Kanpur, Coimbatore, Jabalpur, Asansol, Vijaywada, Rajkot, Dhanbad, Indore, Panaji, Thiruvananthapuram, Bhubaneshwar, Puri, Porbander and Tirupati

(d) Other selected cities are in Seismic Zone II that is low damage risk zone with MSK Intensity VI considered probable.

(ii) Cyclone Proneness

(a) The following 9 coastal cities may be affected by very high cyclonic wind velocities causing severe damage to tall flexible & sheeted residential & industrial structures:

Chennai, Kolkata, Vishakapatnam, Bhubaneshwar, Agartala, Puri, Pondicherry, Porbandar and Tirupati.

(b) Other 5 cities which can also be affected by cyclonic winds are:

Greater Mumbai, Vadodara, Surat, Goa & Thiruvanathapuram.

(iii) Landslide Proneness

The following cities are located in severe to high landslide prone areas:

Coimbatore, Shimla, Imphal, Shillong, Aizwal, Kohima, Gangtok, Dehradun, Nainital & Srinagar (J&K).

From the foregoing discussion, it is seen that while most cities are prone to earthquake of varying intensities, some cities have multi-hazard proneness. The cities in hill areas are additionally liable to landslide damage which can be further intensified due to the earthquakes or severe monsoon rains. Low lying areas in all cities may be subjected to flooding during high 24 hour rainfall.

2.2.2 Comment

In order to ensure all new building projects under JNNURM are designed to achieve safety against natural hazards, it is necessary to include the suggested guidelines at the time of DPR (Detailed Project Report) preparation.

2.3 INDIRA AWAS YOJANA (IAY)

The genesis of the Indira Awas Yojana (IAY) can be traced to the programmes of rural employment, which began in the early 1980's. Construction of houses was one of the major activities under the National Rural Employment Programme (NREP), which began in 1980, and the Rural Landless Employment Guarantee Programme (RLEGP), which began in 1983. There was, however, no uniform policy for rural housing in the States. For instance, some States permitted only part of the construction cost to be borne from NREP/RLEGP funds and the balance was to be met by beneficiaries from their savings or loans obtained by them. On the other hand, others permitted the entire expenditure to be borne from NREP/RLEGP funds. Further, while some states allowed construction of only new dwellings, others permitted renovation of existing houses of beneficiaries. As per announcement made by the

Government of India in June 1985, a part of the RLEGP fund was earmarked for the construction of houses for SC/STs and freed bonded labourers. As a result, Indira Awas Yojana (IAY) was launched during 1985-86 as a sub-scheme of RLEGP. IAY, thereafter, continued as a sub-scheme of Jawahar Rozgar Yojana (JRY) since its launching in April, 1989. 6% of the total JRY funds were allocated for implementation of IAY. From the year 1993-94, the scope of IAY was extended to cover below the poverty line Non-Scheduled Castes/Scheduled Tribes families in the rural areas. Simultaneously, the allocation of funds for implementing the scheme was raised from 6% to 10% of the total resources available under JRY at the national level, subject to the condition that the benefits to Non-Scheduled Castes/Scheduled Tribes poor should not exceed 4% of the total JRY allocation. IAY was de-linked from JRY and made an independent scheme with effect from 1st January 1996.

Since 1999-2000, a number of initiatives have been taken to improve the Rural Housing (RH) programme by making provision for upgradation of unserviceable kutcha houses and by providing credit with subsidy for certain sections of the poor. Emphasis has also been laid on use of cost affective, disaster resistant and environment friendly technologies in rural housing.

2.3.1 Target Group

The target groups for houses under the IAY are 'below poverty line' (BPL) households living in the rural areas, belonging to Scheduled Castes/Scheduled Tribes, freed bonded laboures, minorities in the BPL category and non-SC/ST BPL rural households, widows and next-of-kin to defence personnel/paramilitary forces killed in action residing in rural areas (irrespective of their income criteria), ex-servicemen and retired members of paramilitary forces fulfilling the other conditions.

2.3.2 Strategy for the implementation of the programme

The programme is implemented through the Zilla parishads/DRDAs and houses are constructed by the beneficiaries themselves. The beneficiaries should be involved in the construction of the house. To this end, the beneficiaries may make their own arrangements for procurement of construction material, engage skilled workmen and also contribute family labour. The beneficiaries have complete freedom as to the manner of construction of the house. Zilla parishads/DRDAs can help the beneficiaries in acquiring raw material on control rates, if they so desire or request the Zilla parishads/DRDAs in this regard. This will result in economy in cost, ensure quality of construction, lead to greater satisfaction and acceptance of the houses by the beneficiary. The responsibility for the proper construction of the house will thus be on the beneficiaries themselves. A committee may be formed, if so desired, to coordinate the work. The Committee shall be sensitized to incorporate hazard-resistant features in the design of the houses.

2.3.3 *Unit Assistance for Construction of IAY Houses and Upgradation*

The ceiling on grant of assistance per unit cost under the Indira Awas Yojana for construction of a new house and upgradation of an unserviceable kutcha house is given as under:-

		Plain Areas	Hilly/Difficult Areas
a)	Construction of house including Sanitary latrine and smokeless Chulha	Rs. 45,000/-	Rs. 48,500/-
b)	Up gradation of unserviceable household	Rs. 15,000/-	Rs. 15,000/-

In addition to assistance provided under the IAY, an IAY beneficiary can avail a loan of upto Rs. 20,000/- per housing unit under differential rate of interest (DRI) scheme at an interest rate of 4% per annum.

2.3.4 *Location of Indira Awas Yojana Dwelling Units*

The Indira Awas Yojana dwelling units should normally be built on individual plots in the main habitation of the village. The houses can also be built in a cluster within a habitation, so as to facilitate the development of infrastructure such as internal roads, drainage, drinking water supply, sanitation etc. and other common facilities. Care should always be taken to see that the houses under the IAY are located close to the village and not far away, so as to ensure safety and security, nearness to work place and social communication. To the extent possible, the site should not be located in disaster prone areas for example frequently floodable areas.

2.3.5 *Appropriate Construction Technologies and Local Materials*

Effort should be made to utilize, to the maximum possible extent, local materials and cost effective disaster resistant and environment friendly technologies developed by various Institutions. Zilla parishads/DRDAs should contact various organization/institutions for seeking expertise information on innovative technologies, materials, designs and methods to help beneficiaries in the construction/upgradation of durable, cost effective houses and disaster resistant houses.

2.3.6 *House Design*

No type design should be prescribed for the IAY dwelling units, except that the plinth area of the houses should not be less than 20 sq.m. The layout, size and design of the IAY dwelling units should depend on the local conditions and the preference of the beneficiary, keeping in view the climatic conditions and the need to provide ample space, kitchen, ventilation, sanitary facilities, smokeless chulha, etc. and the community perceptions, preferences and

cultural attitudes. In areas frequented by natural calamities such as fire, flood, cyclones, earthquakes, etc., incorporation of disaster resistant features in design should be encouraged.

Life Insurance Corporation (LIC) of India has insurance policies called Janshree Bima for rural BPL families and Aam Aadmi Bima for the benefit of rural landless families. DRDAs will furnish the particulars of all the willing IAY beneficiaries every month to the respective Nodal Agency which is implementing the Janshree Bima and Aam Aadmi Bima in the district so that all willing IAY beneficiaries derive the benefits available under these insurance policies.

2.3.7 *Comments*

In its present guidelines of IAY, there is a requirement that the concerned DRDA/local committee and the beneficiary should consider hazard safety aspects in selecting the site and designing the buildings. However, there is a need to give specific guidelines as to what must be provided in the project design and implementation to achieve the stipulated safety from hazards.

2.4 RAJIV AWAS YOJANA (RAY)

Rajiv Awas Yojana (RAY) for the slum dwellers and the urban poor envisages a "Slum-free India' through encouraging State/Union Territories to tackle the problem of slums in a definitive manner. It calls for a multi-pronged approach focusing on:

- Bringing existing slums within the formal system and enabling them to avail the same level of basic amenities as the rest of the town:
- Redressing the failures of the formal system that lie behind the creation of slums: and
- Tracking the shortages of urban land and housing that keep shelter out of reach of the urban poor and force them to resort to extra-legal solutions in a bid to retain their sources of livelihood and employment.

2.4.1 *Comments*

To ensure natural hazard resistant construction, the suggested guidelines in this document shall have to be incorporated at the time of project preparation. This will ensure that the various building infrastructure projects to be undertaken with funding from the scheme should be made disaster resistant in the first instance by proper site selection, soil investigation, following the Bureau of Indian Standard (BIS) Codes in foundation design and structural design. There are number of cases where slums have come up in the path of natural drainage system or in low lying areas which are likely to be flooded. Under the scheme, these should be relocated to safer sites and this aspect to be examined at the time of preparing DPRs.

2.5 SUGGESTED SAFETY CHECKS IN HOUSING SCHEMES

In order to introduce safety checks in all present and future Housing Schemes framed by the Central and / or State Governments, the DPRs to be prepared for the various building construction projects should include guidelines for disaster safety requirements . A sample guideline is outlined in Table 2.1.

Table 2.1
Guideline for including Hazard Safety in DPR

1.	**General Information of the Project**
	a) Name of the Scheme
	b) Name of the Project:
	c) Address
	d) District:
	e) State:
2.	**Siting of the Building Project**
	- Location of Project Site
	- Latitude
	- Longitude
	- Height above mean sea level
3.	**Use of the Building**
	a. Residential,
	b. Educational,
	c. Hospital ,
	d. Office,
	e. Hotel,
	f. Religious,
	g. Workshop,
	h. Any other (describe) ....
4.	**Hazard Proneness of the project site**
	1) Earthquake Zone (Any known geological fault nearby may be listed) V, IV, III, II
	2) Flood Proneness & Vulnerability:
	a. Past history of floods in the area
	b. Observed Highest flood level
	c. Frequency of flooding
	d. Depth of flooding
	e. Duration of flooding
	f. Damage /loss (maximum, average, potential)
	3) Cyclone Proneness (If close to sea coast) & Vulnerability:
	a. Wind speed zone – {50},{47},{44},{39},{33} m/s
	b. Distance of site from sea coast
	c. Record of past storm surge / tsunami
	d. Frequency and Intensity
	4) Landslide Proneness:
	a. Location and angle of Hill slope
	b. Past history of landslides,
	c. Possibility of mud flows/rock falls/snow avalanches etc.
5.	**Hazards Risk to the project (if evaluated)**
	a. Probable maximum seismicity at site
	b. Probable Maximum storm surge
	c. Probable Maximum wind speed
	d. Probable Maximum precipitation
	e. Probable maximum flood level
	f. Probable occurrence of floods, earthquakes, land slides
	g. Soil liquefaction potential under probable earthquake intensity
6.	**Mitigation/Reduction of Risk: (relevant BIS codes and guidelines* have been complied with?)**
	a. National Building Code 2005.
	b. Earthquake Standards and Guidelines
	c. Wind Standard and Guidelines
	d. Flood Safety Guidelines
	e. Landslide Guidelines

*See Chapter 3.

undertaken. If the quick appraisal is not found satisfactory, more detailed assessment of the risks will have to be carried out or the site of the project to be shifted.

Phase 2: Project Preparation

In the stage of project preparation, disaster risk reduction measures are worked out and cost thereof estimated. The steps to be taken for reducing the risks are detailed and implemented as worked out in the plan. An evaluation also needs to be carried out to check if the measures are in the right direction.

Phase 3: Project Implementation

In this stage the project is taken up for implementation & execution. The resilience of the various project components under the stipulated hazard occurrences has to be checked continuously. It needs to be checked that no harmful aspects develop during the execution.

Phase 4: Project Evaluation

At the completion of the project, it needs to be evaluated if the targets of safety from impacts of various hazards have been met, and the project will not have any adverse disaster impacts nor it will have harmful impacts on the communities.

3.6 Capacity Building of Officials and Professionals

Understanding and application of hazard impact reduction is essential for all stakeholders of the housing sector. They need to be sensitized about potential importance of examining and integrating reduction of risk in their respective areas contributing to sustainable growth of housing activities. Such understanding is more critical on the part of decision makers and professionals who are dealing with planning, designing and implementing housing projects in varying situations.

Adequate capacities, institutional structures, empowerment for governance and enforcement of related regulatory framework have to be made available within the Municipal Corporations and Councils, Development Authorities, Nagar Panchayats and (rural) Zila Panchayats; and all Govt. Departments and Public Sector Undertakings for ensuring adherence to guidelines, regulations, codal provisions and sound construction practices for achieving disaster resistant housing construction and usage of land use zoning plans based on full information relating to locations/siting, soil conditions, liquefaction potential and characteristics like erosion, wave and wind action in coastal regions, slope stability history in hilly regions, etc. All implementing institutions and professionals should be adequately trained to take well informed decisions while undertaking their technical, administrative and regulatory roles for disaster resistant housing and related building construction which have considerable influence on the safety of total built environment in any urban or rural settlement, be in plain, hilly and coastal regions.

There is a need to develop syllabus for the training programmes for professionals and officials. number of organizations like IITs, NITs, NIDM, CIDC, IE(I), BMTPC, etc., have been engaged in running a number of Training and/or Executive Development Programmes on various subjects relating to safety aspects of buildings and other structures in response to impact of natural hazards. There is growing need that a group of experts may study the syllabus contents of these training programmes and through a participatory approach involving the faculty members of such ongoing programmes develop few implementable "modules" for short-term training courses ranging from three days to two to three weeks.

STRUCTURAL DESIGN BASIS REPORT CUM CHECK LIST : Part-I

Table 3.1 : General Building and Design Data

Sr. No.	Description of Items	Information given	Notes (Reference to BIS Standard)	Checking Information (see notes)
1.1	**Address of the building**			
	• Name of the building			
	• Plot number			
	• Subplot number			
	• TPS scheme			
	a. Name			
	b. Number			
	• Locality/Township			
	• District			
1.2	**Names, postal addresses and phones of persons**			
	• Owner			
	• Builder			
	• Architect /Design Engineer			
	• Structural engineer			
1.3	**The Building**			
	• Use of the building			
	• Number of total storeys above ground level (including those to be added later)			
	• Number of basements below ground level			
	• Overall Plan (LxB)			
	• Expansion /Separation joint			
1.4	**Type of building structure**			
	• Load bearing walls			
	• R.C.C frame			
	• R.C.C frame and Shear walls			
	• Steel frame			

Sr. No.	Description of Items	Information given	Notes (Reference to BIS Standard)	Checking Information (see notes)
1.5	**Soil data ***		IS:1498	
	• Type of soil			
	• Depth of water Table below GL after monsoon			
	▪ Liable to liquefaction under earthquake		IS:1893 Cl. 6.3.5.2	
	▪ Design safe bearing capacity recommended		IS: 1904	
	▪ Chemical analysis of ground water			
	▪ Chemical analysis of soil			
1.6	**Foundation data ***			
	▪ Recommended type and depth of foundation		IS: 1904	
	▪ Independent footings with foundation beams		IS: 4326 Cl. 4.5.3	
	▪ Independent footing with plinth beams		IS: 4326 Cl. 4.5.3	
	▪ Raft			
	▪ Piles with interconnected caps			
	▪ Recommended, type, length, diameter and load capacity of piles			
1.7	**Dead loads (unit weight adopted)**		IS: 875 Part 1	
	• Earth			
	• Water			
	• Brick masonry			
	• Plain cement concrete			
	• Reinforced cement concrete			
	• Floor finish			
	• Other fill materials, roof, toilets			
	• Piazza floor fill and landscape			

Sr. No.	Description of Items	Information given	Notes (Reference to BIS Standard)	Checking Information (see notes)
1.8	**Imposed (live) loads**		IS: 875 Part 2	
	• Piazza floor accessible to Fire Tender			
	• Piazza Floor not accessible to Fire Tender			
	▪ Floor loads			
	▪ Roof loads			
1.9	**Natural Hazards**		IS: 875 Part 3	
	i) Cyclone / Wind			
	• Speed			
	• Design pressure intensity			
	ii) Earthquake			
	▪ Seismic zone		IS:1893 (2002)	
	▪ Importance factor (I)		IS:1893 (2002) Table 6	
	▪ Seismic zone factor(Z)		IS:1893 Table 2	
	▪ Response reduction factor (R)		IS: 1893 Table-7	
	▪ Fundamental natural period - approximate,		IS: 1893 Cl. 7.6	
	▪ Design horizontal coefficient (Ah)*		IS: 1893 Cl. 6.4.2	
	iii) Flood			
	▪ Proneness to river (name)			
	▪ Proneness to heavy rains			
	• High Flood level above GL			
	▪ Plinth height above GL			
	iv) Land Slide			
	▪ Slide proneness			
	▪ Slope of hills, <30° or >30°			

1. Enclose small scale plans of each floor on A4 sheets, indicate expansion /separation joint.
2. Incase terrace garden is provided, indicate additional fill load and live load
3. Item marked with * may be informed to Local Body Authority before start of construction.
4. Checking information shall be given while submitting Building completion Report:-
   a) Giving any change from Structural Design Basis Report (SDBR) submission
   b) Conformity with BIS will be indicated by writing, 'compliant'.
   c) Non-conformity will be written as 'not complying' and reason for it explained.

STRUCTURAL DESIGN BASIS REPORT CUM CHECK LIST : Part-II

Table 3.2 : Load Bearing Masonry Buildings

Sr. No.	Description of Items	Information given	Notes (Reference to BIS Standard)	Checking Information (see notes)
2.1	**Building category** (tick one)	B C D E ☐ ☐ ☐ ☐	IS:4326 Cl. 7 read with IS: 1893 Zone / Bldg: II, III, IV, V Ordinary: B, C, D, E Important: C, D, E, E	
2.2	**Wall masonry** (see note 1)			
	• Ratio of wall height to thickness		IS:4326 Cl. 8.2.1	
	• Ratio of wall length between cross wall to thickness		IS: 4326 Cl. 8.2.3	
2.3	**Type and mix of Mortar**		IS:4326 Cl. 8.1.2	
2.4	**Size and position of openings** (See note No.1)		IS:4326 Table 4, Fig.7	
	• Minimum distance (b5)			
	• Ratio (b1+b2+b3)/l1 or (b6+b7)/l2			
	• Minimum pier width between			
	consecutive opening (b4)			
	• Vertical distance (h3)			
2.5	**Horizontal seismic band** (See note 2)	P TP NA		
	• at plinth level	☐ ☐ ☐	IS:4326 Cl. 8.4.6	
	• at window sill level	☐ ☐ ☐	IS:4326 Cl. 8.4.7	
	• at lintel level	☐ ☐ ☐	IS:4326 Cl. 8.4.2	
	• at ceiling level	☐ ☐ ☐	IS:4326 Cl. 8.4.3	
	• at eave level of sloping roof	☐ ☐ ☐	IS:4326 Cl. 8.4.3	
	• at top of gable walls	☐ ☐ ☐	IS:4326 Cl. 8.4.4	
	• at top of ridge walls	☐ ☐ ☐		

Sr. No.	Description of Items	Information given	Notes (Reference to BIS Standard)	Checking Information (see notes)
2.6	**Vertical reinforcing bar**			
	• at corners and T junction of walls	☐ ☐ ☐	IS:4326 Cl. 8.4.8	
	• at jambs of doors and window openings	☐ ☐ ☐	IS:4326 Cl. 8.4.9	
2.7	**Integration of prefab roofing/ flooring elements -** through reinforced concrete screed	☐ ☐ ☐	IS:4326 Cl. 9.2.3, 9.2.8	
2.8	**Horizontal bracings in pitched truss**			
	• in horizontal plane at the level of ties	☐ ☐ ☐		
	• in the slopes of pitched roofs	☐ ☐ ☐	IS: 13935 Cl. 7.1.3	

1. Specify wall masonry as burnt brick (BB), Fly Ash Brick (FB), Cement concrete block (CCB), Random Rubble (RRM) or any other to be described.
2. Information in item 2.4 should be given on separate A4 sized sheets for all walls with large number of openings.
3. P indicates **"Information Provided"** TP indicates **"Information to be Provided"**, NA indicates "Not Applicable". Tick mark one box as applicable.
4. Checking information shall be given while submitting Building completion Report:-
   a) Giving any change from Structural Design Basis Report (SDBR) submission
   b) Conformity with BIS will be indicated by writing, 'compliant'.
   c) Non-conformity will be written as 'not complying' and reason for it explained.

Sr. No.	Description of Items	Information given	Notes	Checking Information
	• Confining stirrups near ends of columns and in beam-column joints		IS: 13920 Cl. 7.4	
	a. Diameter		IS: 13920 Cl. 7.4.7	
	b. Spacing		IS: 13920 Cl. 7.4.6	
	• Ratio of shear capacity of columns to maximum seismic shear in the storey		IS: 13920 Cl. 7.3.4	

1. Submit framing plans of each floor
2. Incase of basements, indicate the system used to contain earth pressures
3. A certificate to the effect that design information in this report will be completed and submitted at least one month before commencement of Construction
4. Checking information shall be given while submitting Building completion Report:-
   a) Giving any change from Structural Design Basis Report (SDBR) submission
   b) Conformity with BIS will be indicated by writing, 'compliant'.
   c) Non-conformity will be written as 'not complying' and reason for it explained.

STRUCTURAL DESIGN BASIS REPORT CUM CHECK LIST : Part-IV

Table 3.4 : Buildings in Structural Steel

Sr. No.	Description	Information	Notes	Checking Information
4.1	**Type of Building**			
	Regular frames			
	Regular frames with Shear walls			
	Irregular frames			
	Irregular frames with shear walls			
	Soft storey			
4.2	**Proposed material**			
	General weld-able		IS: 2062	
	High strength		IS: 8500	
	Cold formed		IS: 801, 811	
	Tubular		IS: 806	
4.3	**Floor Construction**			
	Composite			
	Non-composite			
	Boarded			
4.4	**Roof Construction**			
	Composite			
	Non-composite			
	Metal			
	Any other			
4.5	**Horizontal force resisting system**			
	Monsanto Resistant Frames			
	Braced frames			
	Frames & shear walls			
4.6	**Structural connections**			
	Rivets		IS: 800; Section-8	
	CT Bolts		IS: 1929,2155,1149	
	SHFG Bolts		IS: 6639, 1367	
	Black Bolts		IS: 3757, 4000	

Sr. No.	Description	Information	Notes	Checking Information
	Welding- Field Shop (Specify welding type proposed)		IS: 1363, 1367	
			IS: 816, 814, 1395,	
			7280, 3613, 6419, 6560, 813, 9595	
	Composite			
4.6	**Adopted method of Design**			
	Simple		IS: 800; Cl. 3.4.4	
	Semi-rigid		IS: 800; Cl. 3.4.5	
	Rigid		IS: 800; Cl. 3.4.6	
4.7	**Design based on**			
	Elastic analysis		IS: 800; Section-9	
	Plastic analysis		SP: 6 (6)	
4.8	**Slenderness ratios maintained**			
	Members defined in Table 3.1		IS: 800; Cl. 3.7	
4.9	**Member deflection limited to**			
	Beams, Rafters Crane Girders Purlins			
	Top of Columns		IS: 800; Cl. 3.13	
4.10	**Structural members**			
	Encased in Concrete		IS: 800; Section-10	
	Not encased			
4.11	**Minimum metal thickness for corrosion protection**			
	Hot rolled sections		IS: 800, Cl. 3.8	
	Cold formed sections		Cl. 3.8.1 to Cl. 3.8.4	
	Tubes		Cl. 3.8.5	
4.12	**Minimum Fire rating**			
	Rating ---------- hours		IS:1641,1642, 1643	
	Method proposed-			
	In tumescent Painting			
	Spraying			

Sr. No.	Description	Information	Notes	Checking Information
	Quilting			
	Fire retardant boarding			
Note : Seismic force as per IS: 1893-2002 would depend on frame system.				

1. Submit framing plans of each floor
2. Incase of basements, indicate the system used to contain earth pressures
3. A certificate to the effect that design information in this report will be completed and submitted at least one month before commencement of Construction
4. Checking information shall be given while submitting Building completion Report:-
   a) Giving any change from Structural Design Basis Report (SDBR) submission
   b) Conformity with BIS will be indicated by writing, 'compliant'.
   c) Non-conformity will be written as 'not complying' and reason for it explained.

Table 3.5 : List of Code / Guidelines for Safety of Building Structures from Natural Hazards*

Sr. No.	IS Code	Description
I	**For General Structural Safety**	
1	BIS:2005	National Building Code of India
2	IS: 456:2000	Code of Practice for Plain and Reinforced Concrete
3	IS: 800-2006	Code of Practice for General Construction in Steel
4	IS: 801-1975	Code of Practice for Use of Cold Formal Light Gauge Steel Structural Members in General Building Construction
5	IS 875 (Part 1) : 1987	Design loads (other than earthquake) for buildings and structures Part 1 unit weights of materials
6	IS 875 (Part 2) : 1987	Design loads (other than earthquake) for buildings and structures Part2 Imposed Loads
7	IS 875 (Part 3):1987	Design loads (other than earthquake) for buildings and structures Part 3 Wind Loads
8	IS 875 (Part 4):1987	Design loads (other than earthquake) for buildings and structures Part 4 Snow Loads
9	IS 875 (Part 5):1987	Design loads (other than earthquake) for buildings and structures Part 5 special loads and load combination
10	IS: 883:1966	Code of Practice for Design of Structural Timber in Building
11	IS: 1904:1987	Code of Practice for Structural Safety of Buildings: Foundation
12	IS: 1905:1987	Code of Practice for Structural Safety of Buildings: Masonry
13	IS 2911:1979 (Part 1)	Code of Practice for Design and Construction of Pile Foundation Section 1 ; Section 2 Cast-in-situ Piles; Section 3 Driven Precast Concrete Piles; Section 4 precast Concrete Piles.
14	IS 2911:1979 (Part 2)	Timber Piles
15	IS 2911:1979 (Part 3)	Under Reamed Piles
16	IS 2911:1979 (Part 4)	Load Test on Piles
II	**For Cyclone/Wind Storm Protection**	
17	IS 875 (3)-1987	Code of Practice for Design Loads (other than Earthquake) for Buildings and Structures, Part 3, Wind Loads
18	IS 15498: 2004	Improving cyclone resistance of low rise houses and other buildings
	BMTPC : 2010	Improving Wind / Cyclone Resistance of Housing – Guidelines
III	**For Earthquake Protection**	
19	IS: 1893-2002	Criteria for Earthquake Resistant Design of Structures (Fifth Revision)
20	IS: 13920-1993	Ductile Detailing of Reinforced Concrete Structures subjected to Seismic Forces - Code of Practice
21	IS: 4326-1993	Earthquake Resistant Design and Construction of Buildings - Code of Practice (Second Revision)
22	IS: 13828-1993	Improving Earthquake Resistance of Low Strength Masonry Buildings – Guidelines
23	IS: 13827-1993	Improving Earthquake Resistance of Earthen Buildings – Guidelines
24	IS: 13935-1993	Repair and Seismic Strengthening of Buildings - Guidelines
25	BMTPC : 2010	Improving Earthquake Resistance of Housing – Guidelines
IV	**For Protection of Landslide Hazard**	
26	IS 14458 (Part 1): 1998	Guidelines for retaining wall for hill area:
27	Part 1	Selection of type of wall
28	Part 2	Design of retaining/breast walls
29	Part 3	Construction of dry stone walls
30	IS 14496: 1998	Guidelines for preparation of landslide – Hazard zonation maps in mount ainous terrains
31	IS: 14680: 1999	Guidelines for land slide control
32	IS: 14804	Guidelines for Siting, Design and selection of materials for Residential Building in Hilly Areas
V	**For Protection of Flood Hazard**	
33	BMTPC : 2010	Improving Flood Resistance of Housing – Guidelines

*As these codes and guidelines are being updated from time to time by different Institutions/Organizations. Therefore, the latest updated version shall be referred at the time of conforming a project. A comprehensive list has been attempted, however, it may not be complete.

Table 3.6 : Model Proforma For Technical Audit Report

Sr. No.	Items	Comments
1.	**DESIGN**	
1.1	Design/Drawings available?	Y/N
1.2	Design category • Type design? • Specific design? If yes, design to be shown to technical auditor	 Y/N Y/N
1.3	Drawings prepared/checked by competent Authority?	Y/N
1.4	Design Drawings/details • Structural detailed included? • Earthquake/cyclone resistant features included?	 Y/N Y/N
1.5	Design verified/vetted by Dept./govt. approved agency/competent authority?	Y/N
1.6	Design changes approved by dept./govt. approved agency/competent authority?	Y/N
2.	**FOUNDATION**	
2.1	Foundation used	Existing/New
2.2	**If existing foundation used**	
2.2.1	Depth of foundation below ground	<50cm/50-70/>70cm
2.2.2	Type of masonry	Stone/Bricks/PCC Blocks
2.2.3	Thickness of masonry (above ground)	23cm/35/>35 cm
2.2.4	Mortar used	Cement-Sand/Lime/Mud
2.2.5	Mix of cement mortar	1:4/1:6/Leaner
2.2.6	Height up to Plinth	____________ cm
2.2.7	If stone masonry • Through Stones • Corner Stones	 Yes/No, if Yes Adequate/Inadequate Yes/No, if Yes Adequate/Inadequate
2.3	**If new foundation used**	
2.3.1	Depth of foundation below ground	_____<50/50-70/>70cm
2.3.2	Type of masonry blocks	stone/bricks/PCC
2.3.3	Thickness of Masonry above plinth	23 cm/35/>35cm
2.3.4	Mortar used	Cement – sand/lime/mud
2.3.5	Mix of cement mortar	1: 4/ 1:6/ Leaner
2.3.6	Height up to Plinth	<60/>60cm
2.3.7	If stone masonry • Through Stones • Corner Stones	 Yes/No, if Yes Adequate/Inadequate Yes/No, if Yes Adequate/Inadequate
2.4	Vertical reinforcement in foundation	Yes/No
3.	**WALLING**	
3.1	Type of masonry	Stone/Brick/PCC Blocks
3.2	Mortar used	Cement – Sand/Lime/Mud
3.3	Mix of cement mortar	1:4/1:6/Leaner
3.4	Thickness of wall	>23cm/23cm/<23cm
3.5	Mixing of mortar	OK/Not OK
3.6	Joint Properly filled	OK/NOT OK
3.7	Wetting of bricks	Good/ Medium/ Poor
3.8	If stone masonry • Through Stones • Corner Stones	 Yes/No Yes/No
3.9	Overall workmanship	Good / Medium / Poor

Sr. No.	Items	Comments
4.	**ROOFING**	
4.1	Type of roof	Flat/Sloping
4.2	If sloped	Morbi tiles/ A.C. sheet/ G.I. sheet
4.3	Purlins	Angle-Iron / Timber / other
4.4	Truss type	Steel / Timber / Other
4.5	Anchorage with wall	Adequate/ Inadequate
5.	**MATERIALS**	
5.1	**Cement**	
5.1.1	Source	Authorised Dealer/ Market
5.1.2	Type of cement	OPC/PPC/PSC
5.1.3	If OPC	Grade (33/ 43/ 53)
5.2	**Sand**	
5.2.1	Source	Quarry / Dealer
5.2.2	Type of sand	River sand / Stone dust
5.2.3	Presence of deleterious materials	Mild / Moderate/ High
5.3	**Coarse Aggregates**	
5.3.1	Source	Quarry / Dealer
5.2.2	Type of coarse Aggregates	Gravel/ Crushed Stone
5.3.3	Presence of deleterious material	Mild/ Moderate / High
5.4	**P.C.C. Blocks**	
5.4.1	Source	Onsite Maker/ Dealer
5.4.2	Type of P.C.C. Blocks	Solid blocks/Hollow blocks
5.4.3	Ratio of concrete in blocks	________________
5.4.4	Interlocking feature	Yes/No
5.4.5	Course aggregates used	Natural/ Crushed stone
5.5	**Bricks Blocks, Hewn Stone etc.**	
5.5.1	Source	
5.5.2	Strength (field assessment)	Low/Medium/High
5.2.3	Dimensional accuracy	Yes/No
5.6	**Concrete**	
5.6.1	Mix of concrete	(1:1½:3)/ (1:2:4)/Design Mix
5.6.2	Batching	Weigh batching/Volume batching
5.6.3	Compaction	Vibrators/Thappies and rods
5.6.4	Workability	Low / Medium / High
5.6.5	Availability of water	Sufficient / Insufficient
5.6.6	Curing	Satisfactory/Unsatisfactory.
5.7	**Reinforcing Steel**	
5.7.1	Type of Steel	Plain mild steel/HYSD bars
5.7.2	Source	Authorised Dealer/Market
5.7.3	Whether IS marked	Yes/No
5.7.4	Conditions of bars	Clean/Corroded / Cleaned
5.7.5	Fixing of reinforcement as per drawing	Yes/No
5.7.6	Suitable cover	Yes/No
5.7.7	Spacing of bars	Regular/Irregular
5.7.8	Overlaps as per specifications	Yes/ No
5.8	**Form Work**	
5.8.1	Type of Form Work	Timber / Plyboard/ Steel
5.8.2	Use of mould oil	Yes/No
5.8.3	Leakage of cement slurry	Observed/Not observed

Sr. No.	Items	Comments	
6.	**SEISMIC RESISTANCE FEATURES-MASONRY BUILDINGS**		
6.1	**Provision of Adequate bands at**		
6.1.1	Plinth level	Yes/No	
6.1.2	Sill level	Yes/No	
6.1.3	Lintel level	Yes/No	
6.1.4	Flat Roof level (if applicable)	Yes/No	
6.1.5	If sloped Roof		
	• Gable wall top	Yes/No	
	• Eaves level	Yes/No	
6.2	**Provision of adequate vertical steel at**		
6.2.1	Each corner	Yes/No	
6.2.2	Each T-junction	Yes/No	
6.2.3	Each door jamb	Yes/No	
6.2.4	Around each window	Yes/No	
6.3	**Openings**		
6.3.1	Total width of openings ratio to wall length (percent)	33/33-42/42-50/>50	
6.3.2	Clearance from corner	OK/Not OK	
6.3.3	Pier width between two openings	OK/Not OK	
7.	**SEISMIC RESISTANCE FEATURES RC FRAMES**		
7.1	Ductile detailing		
7.2	Spacing of stirrup	OK/Not OK	
7.3	Sizes of members	OK/Not OK	
7.4	End anchorage	OK/Not OK	
7.5	Lapping (length, location etc.)	OK/Not OK	
7.6	Angle of stirrup hook	90 / 135 degrees	
8.	**TESTING CARRIED OUT BY OWNER/ENGG. SUPERVISOR**	**TESTING DONE**	**TESTING RESULTS**
8.1	Water	Yes/No	OK/Not OK
8.2	Cement	Yes/No	OK/Not OK
8.3	Bricks/PCC blocks/Stones	Yes/No	OK/Not OK
8.4	Aggregate	Yes/No	OK/Not OK
8.5	Mortar	Yes/No	OK/Not OK
8.6	Concrete	Yes/No	OK/Not OK
8.7	Reinforcement	Yes/No	OK/Not OK

(Signature of Technical Auditor)

Chapter - 4 : National Building Code of India 2005

4.1 VARIOUS PARTS AND SECTIONS

Brief Details of the Coverage of various provisions under different parts and sections of the code are given below for ready reference to the required sections. Most Building Bylaws require compliance of the building plans and designs to the National Building Code (NBC) of India. Hence the following abstract information of NBC 2005 will be of immediate use to the architects and design engineers and same is reproduced here.

PART 1: ***DEFINITIONS***
It lists the terms appearing in all the Parts and Sections of the Code.

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.

PART 3: ***DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS***
It covers the development control rules and general building requirements for proper architectural planning and design at the layout and building level to ensure health safety, public safety and desired quality of life.

PART 4: ***FIRES AND LIFE SAFETY***
It covers the requirement 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.

PART 5: ***BUILDING MATERIALS***
It covers the requirements of building materials and components, and criteria for accepting new or alternative building materials and components.

PART 6: ***STRUCTURAL DESIGN***
This part through its seven sections described below 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.

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.

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.

Section 3: **Timber and Bamboo**

Section 3A: Timber: It covers the use of structural timber instructures or elements of structures connected together by various fasteners/ fastening techniques.

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, preservating treatment, design and joining techniques with bamboo which would facilitate scientific application and long term performance of structures.

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 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.

Section 5: **Concrete**

Section 5A Plain and Reinforced Concrete: It covers the general structural use of plain and reinforced concrete

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.

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.

Section 7: **Prefabrication, Systems Building and Mixed / Composite Construction**

Section 7A: Prefabricated Concrete :It covers recommendations regarding modular planning, components 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.

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.

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.

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 requirement in buildings.

Section 1: Lighting and Ventilation: It covers requirements and methods for lighting and ventilation of buildings.

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.

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.

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.

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.

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.

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.

Section 2: Gas Supply: It covers the requirements regarding the safety of persons and property for all piping uses and for all type's of gases used for fuel or lighting purposes in buildings.

PART 10: LANDSCAPING, SIGNS AND OUTDOOR DISPLAY STRUCTURES

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.

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.

4.2 MULTI-HAZARD RISK IN VARIOUS DISTRICTS OF INDIA

4.2.1 Multi-Hazard Risk Concept

The commonly encountered large-scale natural hazards are:

a) Earthquake
b) Cyclone and Wind Storm
c) Floods

A study of the earthquake, wind/cyclone, and flood hazard maps of India (see Chapter 1) 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 may not be economically viable to design all the buildings for multiple hazards. For 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.S.K. intensity in the case of earthquake; the duration and velocity of wind in the storms; and the severity of flooding in the flood prone areas; and
b) *The frequency* of occurrence of the severe hazards : All buildings must be designed using the relevant codes for loads. The designer may have to consider the loads due to any one of the hazards individually or in combination as appropriate.

4.2.2 *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 VII or more that is seismic zones III, IV and V of India and also flood prone 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 possibility of storm surge too.

c) *Earthquake, Cyclone and Flood Risk Prone:* Districts which have earthquake Zone of Intensity VII or more, cyclone prone as well as flood prone 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 VII 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 listed in Table 4.1.

4.2.3 *Use of the List of the District with Multi-hazard Risk*

The list provides some ready information for use of the authorities involved in formulating the housing schemes and projects. This information will be useful in establishing the need

for developing housing design to resist the multi-hazard situation.

It may be clarified that a district may be wholly in one severe hazard prone zone or having parts in different intensity zones. For example consider District Baleshwar in Orissa. It has seismic zones III and II in parts, cyclone wind in one whole zone and flood proneness in parts. The percent area covered by each part and its location can be found from Vulnerability Atlas of India 2006 (BMTPC) referring to the Hazard maps of Orissa and Risk Table No. OR-8, as follows:

Earthquake zone III	38.7% in north & zone II, 61.3% in south portion & zone III
Cyclone prone	100% one zone
Flood prone	46.3% in a strip from north to south

Reference to the State hazard maps of Orissa will only show the exact location of the hazard prone areas. The location of the project should be positioned on the hazard maps to take the appropriate design factors into account.

4.3 REFERENCE TO NBC - 2005

Every building project must satisfy the requirements of NBC – 2005 and the relevant standard codes of practice or design criteria specified in relevant Indian standards produced by BIS. For planning and designing a major project such as an important hospital building or a tall residential building complex, the involvement of the following specialized professionals will be needed:

Architects, geo-technical engineer, structural engineer, civil construction engineer, service engineers such as electrical services, water supply and sanitary services, air conditioning services and fire safety services, etc.

The National Building Code provides standard guidelines carrying out various building design and construction as well as specifications. All relevant health safety and structural and construction safety have to be ensured. Ensuring structural safety under dead and live vertical loads as well as lateral loads created by wind and earthquake must be taken care of. It will be desirable to have initial group of professionals identified and nominated for the job in consultation with the proprietor / user of the building so that all requirements of the National Building Code and other BIS standards are adhered to in letter and spirit including all evaluations, viz. test of materials, test of construction samples like concrete cubes and reinforcing steels are conducted and properly recorded for future reference.

It will be advisable to prepare Architectural and Structural Design Basis Reports for the project as a whole from foundation to the roof construction and mutually reviewed by all professionals involved in the project before adoption.

Chapter - 5 : Site Investigation, Soil and Foundations

5.1 SITE EXPLORED EARLIER

In those areas which have already been developed, the relevant information may be taken from the existing building projects' soil investigation reports as may be recently obtained from trial pits, bore holes, etc, 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 buildings of not more than two storeys. This information will also help in deciding scope of further soil investigation for larger structures.

5.2 SOIL EXPLORATION AT SITES

Soil exploration at the buildings site must be carried out at sufficient points and to sufficient depth so as to get the following data:

(a) Soil classification in various layers and the properties like grain size distribution, field density, angle of internal friction and cohesion, plastic and liquid limits, and coefficient of consolidation of cohesive sites.

(b) Position of water table just before and just after monsoon.

(c) SPT values and CPT values.

(d) The output results should include liquefaction potential, safe bearing capacity and the type of foundation to be adopted, viz. (i) individual column footing of given width, (ii) combined footing, (iii) Raft foundation or (iv) Pile foundations.

(e) Chemical analysis of soil to find if it has any harmful elements to the concrete. If so, precautions to be taken in making the foundations.

5.3 NUMBER OF TEST LOCATIONS

The number and disposition of various tests depends upon type of buildings and the soil strata variations in the area. The general guidelines are given below:

a) For a compact building site covering an area of about 0.4 hectare (4000 m^2), 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 many suffice.

c) For very large areas covering industrial and residential colonies, number of bore holes and/or trial pits should he decided considering importance of structure and type as well as uniformity of strata.

d) 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.

5.4 DEPTH OF EXPLORATION

The required depth of exploration 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. Normally, it should be one and a half times the width or length of the footing below foundation level. 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 half times the smaller dimension of the area. 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.

5.5 DEPTH OF FOUNDATION

The minimum depth which foundations should be carried, depends upon the following main factors:

a) The securing of adequate allowable bearing capacity.

b) In the case of clayey soils, penetration below the zone where shrinkage and swelling due to seasonal weather changes 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 due to flowing water during floods or tsunamis or storm surge, wherever relevant, should also be considered and the foundation should be located sufficiently below this depth.

e) Other factor such as possible liquefaction below water table due to earthquake shaking needs consideration.

f) Rise of water table to the base of foundation may reduce the bearing strength of soil by 50%. The depth of foundation should be fixed accordingly.

All foundations should 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, chiseled and stepped or otherwise, prepared so as to provide a suitable bearing and prevent sliding.

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 to place the foundation bearing at such a depth where the effects of seasonal changes are not important. A depth of about 1.8-2.0 m may usually suffice.

5.6 FOUNDATION AT SLOPING GROUND

Where the bottoms of the footings of a building 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 is subject to the limitations shown in Fig. 5.1 and 5.2.

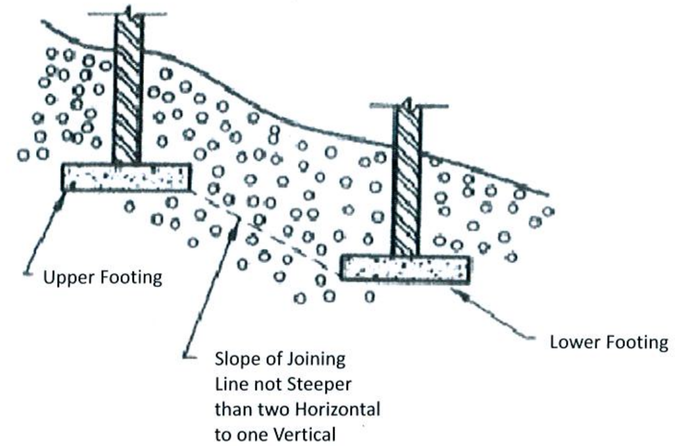


Fig. 5.1 : Footing in Granular Soil

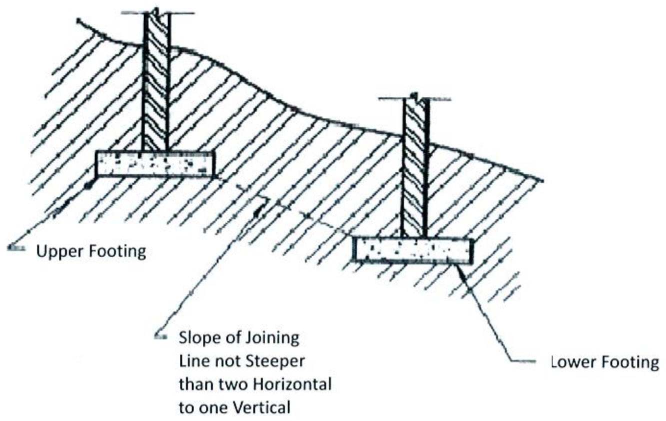


Fig. 5.2 : Footing in Clayey Soil

5.7 SITING OF SETTLEMENT AND BUILDINGS IN SEISMIC ZONES

5.7.1 Effect of Site Condition on Building Damage

Past earthquakes show that site condition significantly affects the building damage. Earthquake studies have almost invariably shown that the intensity of a shock is directly related to the type of soil layers supporting the building. Structures built on solid rock and firm soil frequently fare better than buildings on soft ground. In the 1976 Tangshan, China earthquakes, 50% of the buildings on thick soil sites were razed to the ground, while only 12% of the buildings on the rocky land near the mountain areas were totally collapsed. Rigid masonry buildings resting on rock may on the contrary show more severe damage than when built on soil during an earthquake as in Koyna (India) earthquake of 1967 and North Yemen earthquake of 1980. Buildings constructed in old river course in Philippines were destroyed in Bagio earthquake due to liquefaction.

Lessons learnt from recent earthquakes show that the topography of a building site can also have an effect on damage. Buildings built on sites with open and even topography are usually less damaged in an earthquake than buildings on strip-shaped hill ridges, separate high hills, and steep slopes.

5.7.2 Sitting of Settlements

i. Steep sites may have problems of landslides and rock falls and should either be avoided or effectively improved if adopted.
ii. Plain sites below normal yearly flood level or those with loose fine sands with high water table are liable to liquefaction and subsidence under earthquake intensities VII and higher. These sites (see IS: 1893 Table 1 Note 5) should be avoided, unless improved for building construction. Such areas should better be reserved for parks, play ground, etc.

5.7.3 Building Safety

Building safety starts by choosing a safe site. Such a choice is usually not available with many projects which may be constrained to build on whatever site be available. Unsafe sites such as those described in 5.7.2 above should be improved as follows for achieving safety of the building:

i. a steeply sloping site may be improved by terracing and constructing breast and retaining walls;
ii. a high plinth, higher than the high flood level should be provided.
iii. a site liable to liquefaction or subsidence may be improved by compaction, stabilization, or sand piling, etc.

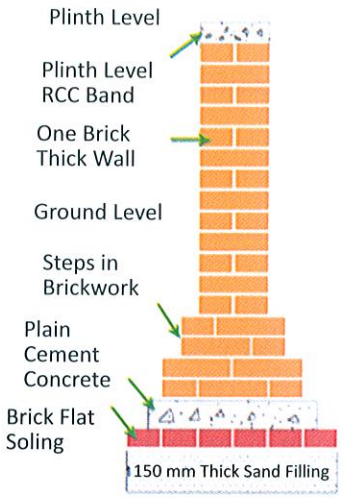
It may be mentioned that the improvement methods may usually involve large expense which should be carefully considered before hand.

5.8 TYPE OF FOUNDATION

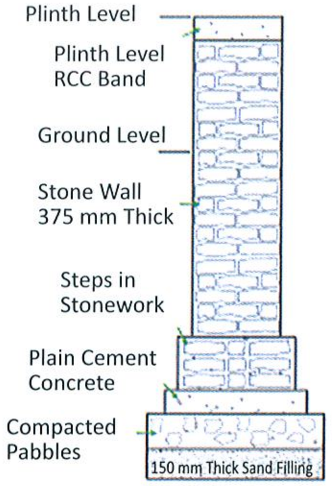
The type of foundation could be shallow or deep which is chosen based on type of available load bearing soil strata and the load of the building.

5.8.1 Pad or Spread and Strip Foundations

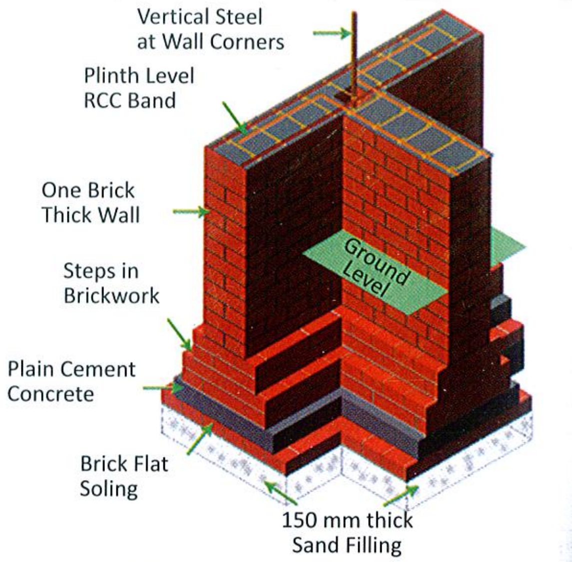
The plan dimensions of excavation for foundations should be wide enough to ensure safe and efficient working.



**OPEN FOUNDATION
BRICK WALL FOOTING**



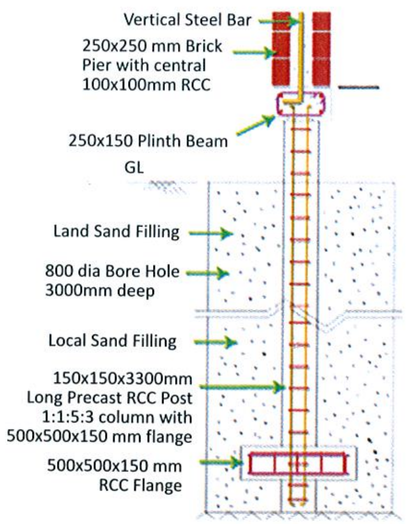
**OPEN FOUNDATION
STONE WALL FOOTING**



**OPEN FOUNDATION - WALL FOOTING
(Perspective)**

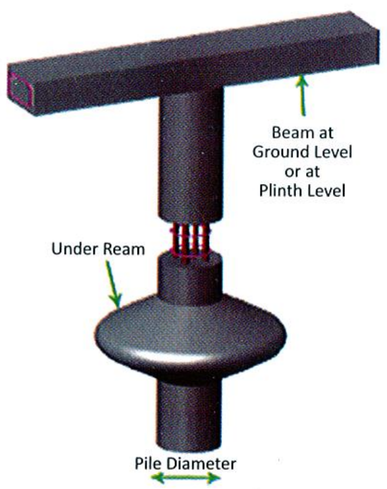
Fig. 5.4

iii) In conditions of non-cohesive, soft alluvial soils saturated during floods or having high-water table, where possibility of deeper scour or liquefaction during earthquake exists, pile foundations are recommended. A deep RC pile foundation with appropriate concrete bulb at the bottom may be used with the desired load capacity of the foundation. For very light building structures such as wooden and bamboo houses, a precast RC Pile shown in Fig. 5.5 with a depth of 3 m may be used. For heavy masonry buildings, under-reamed pile foundations of a depth of 3 to 8 m may be required based on liquefaction potential of the soil strata. See Fig. 5.6.

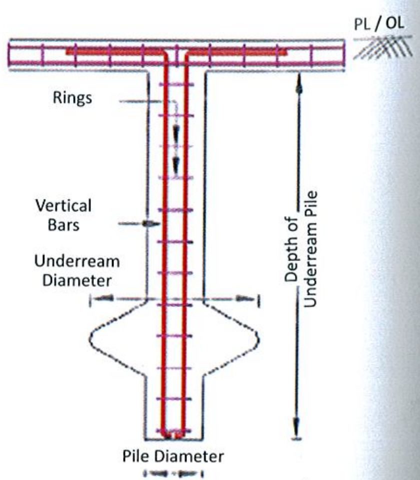


A Typical RCC Post Foundation
(For a typical single storey building)

Fig. 5.5



Under-Reamed Pile Foundation



Typical Dets of Under-Reamed Pile

Fig. 5.6

iv) Plinth beam to tie the piles / pedestals shall be designed based on superstructure loads and distance between piles or pedestals.

iv) Whenever tie beam connecting Pile/ Post /Pedestal foundations is provided at plinth level, a toe wall between the pedestal / post / piles may be constructed to hold the earth filling of the plinth. This toe wall may be constructed with lean cement mortar of *1:8* and be constructed above 23 cm below ground.

The foundation and the plinth masonry should be constructed using baked brick or concrete blocks. The pedestal foundation or the pile foundations will have to carry a reinforced concrete beam at the plinth level (or at ground level) to support the super structure. Reinforcement from the piles and pedestal shall be anchored into the plinth beam, as shown in Fig. 5.3 to 5.6.

Chapter - 6 : Hazard Safe Construction of Wooden and Bamboo Houses

6.1 WOODEN HOUSES

6.1.1 *Typical Characteristics of Wood*

Though wood has higher strength per unit weight than most other construction materials, it has the following peculiarities that are not seen in other building materials.

1. It is a non-homogeneous and anisotropic material showing different characteristics not only in different directions but also in tension and compression.
2. Shrinkage of wood on drying is relatively large. Particularly the joints slack easily by the contraction in the direction perpendicular to fibres. Therefore dry wood shall be used, and the moisture content should be less than 20%.
3. The elastic modulus is small. Consequently, members are apt to show large deformation.
4. A notable creep phenomenon is seen due to permanent vertical loads. This is important especially in snowy area.
5. Sinking occurs by compressive force in the direction perpendicular to fibers. This has a great influence to the amount of deformation of horizontal members and chord members of built-up members.
6. The defects and notches of wood influence greatly the strength and stiffness. Consequently, it is necessary to select and to arrange structural members considering their structural properties.
7. Wood is easily decayed by repeated changes of moisture. Therefore seasoned wood should be used in construction.
8. Preservative chemical treatment is necessary to avoid rotting and insect attack on timber so as to derive long life.
9. Wood is a combustible material. Therefore precautions must be taken to minimize the danger of fire.
10. Long lengths more than 3.5m and large size timbers are difficult to obtain, hence call for splicing through connectors or gluing.

In view of its lightness, very easy workability like cutting and nailing and safe transportability, timber makes an excellent material for post relief and rehabilitation construction.

6.1.2 *Typical Structural Properties*

There are large varieties of timbers in use in various areas of the country. It will, therefore, not be practicable to present the strength properties of various timbers here. But it will be pertinent to mention that these depend on a number of factors as given below:

1) Wood species
2) Direction of loading relative to grain of wood
3) Defects like knots, checks, cracks, splits, shakes and wanes
4) Moisture content or seasoning
5) Sapwood, pith, wood from dead trees and dried wood conditions
6) Location of use, viz. inside protected, outside, alternate wetting and drying.

The permissible stresses must be determined taking all these factors into account. Table 6.1 gives typical basic stresses for timbers placed in three groups A, B and C classified on the basis of their stiffness. It will be reasonable to increase the normal permissible stress by a factor of 1.33 to 1.5 when earthquake or wind stresses are superimposed.

Table 6.1: Basic permissible stresses for timber group*

	Types of stress	Location	Permissible Stress (MPa)		
			Group A	Group B	Group C
I)	Bending and tension along grain	Inside Outside Wet	18 15 12	12 10 8	8 7 6
ii)	Shear in beams Shear along grain	All All	1.2 1.7	0.9 1.3	0.6 0.9
iii)	Compression pararell to grain	Inside Outside Wet	12 11 9	7 6 6	6 6 5
iv)	Compression perpendicular to grain	Inside Outside Wet	6 5 4	2.2 1.8 1.5	2.2 1.7 1.4

* Based on Indian Standard IS:883

Note: Group A, B and C are classified according to Young's Modulus of elasticity as Group A for more than 12,600 MPa, Group B for more than 9,800 to 12,600 MPa and Group C for 5,600 to 9,800 MPa.

6.1.3 *Stud Wall Construction*

The stud-wall construction consists of timber studs and corner posts framed into sills, top plates and wall plates. Horizontal struts and diagonal braces are used to stiffen the frame against lateral loads due to earthquake and wind. The wall covering may consist of matting made from bamboo, reeds, and timber boarding or the like. Typical details of stud walls are shown in Fig.6.1.

1: Sill
2: Anchor bolt at joint of sill at maximum spacing of 2m
3: Stud
4: Blocking
5: Brace
6: Top plates
7: Metal strap
8: Window opening

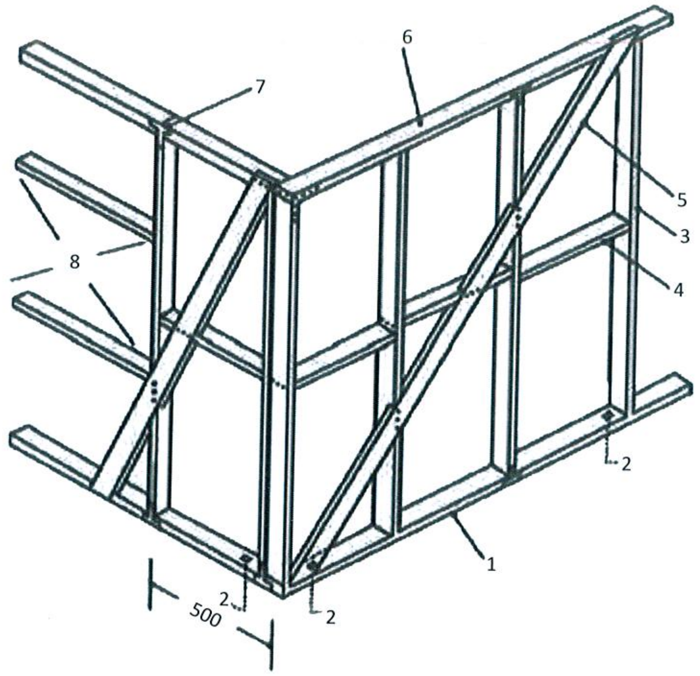


Fig. 6.1 : Stud-wall construction

If the sheathing boards are properly nailed to the timber frame, the diagonal bracing may be omitted. The diagonal bracing may be framed into the verticals, or nailed to the surface. Other details are given below:

a. Sill

The dimension of sill is kept 40 × 90 mm, 90 × 90mm or larger. The sill is connected to the foundation by anchor bolts whose minimum diameter is 12mm and length 300 mm. The anchor bolts are installed at both sides of joints of sills and at the maximum spacing of 2m.

b. Studs

The minimum nominal dimension of studs is 40 × 90 mm. The maximum spacings of these studs are shown in Table 6.2. If 90 × 90mm studs are used, the spacing may be doubled. Storey height should not be more than 2.7 m.

c. Top plates

The top of studs is connected to top plates whose dimension is not less than the dimension of the stud.

d. Bearing walls

Wall framing consisting of sills, studs and top plates should have diagonal braces, or sheathing boards so that the framings acts as bearing walls. In case, no sheathing boards are attached, all studs should be connected to the adjacent studs by horizontal blockings

at least every 1.5m in height. The maximum spacing of 40 × 90mm stud is shown in Table 6.2. The minimum size of braces is 20 x 60 mm in single storey or upper storey of two storeyed houses and 20 x 90 mm in lower storey of two storeyed houses. The brace is fastened at both ends and at middle portion by more than two nails whose minimum length is 50mm to the framing members. The sheathing board is connected to the framing members by nails whose minimum length is 50mm and maximum spacing is 150mm at the fringe of the board and 300mm at other parts.

Table 6.2: Maximum spacing (m) of 40x90 mm stud

Group of timber*	Single storeyed or upper floor of double storeyed building		Lower floor of double storeyed building	
	Exterior wall	Interior wall	Exterior wall	Interior wall
A	1.0		0.5	
B, C	1.0	0.8	0.5	

*Group of timber defined in Table 6.1

6.1.4 *Brick Nogged Timber Frame*

The brick nogged timber frame consists of studs, columns, sills, wall plates, horizontal nogging members framed into each other. Diagonal braces may also be framed with the studs or nailed or bolted on the faces. The space between framing members is filled with tight fitting brick or dressed stone masonry in stretcher bond. Typical details of brick nogged timber frame construction are shown in Fig.6.2. The studs in brick nogged bearing walls should have minimum finished sizes as specified in Table 6.3. The size of diagonal braces should be the same as in stud wall construction. The horizontal framing members in brick construction should be spaced not more than 1.0m apart. Their minimum sizes depend on spacing of studs: 25x100 mm for 0.5 m, 50x100 mm for 1.0 m and 70x100 mm for 1.5 m.

1: Sill
2: Brick nogging
3: Steel strap
4: Coner post
5: Horizontal strut
6: Diagonal brace
7: Stud
8: Horizontal brace at corner

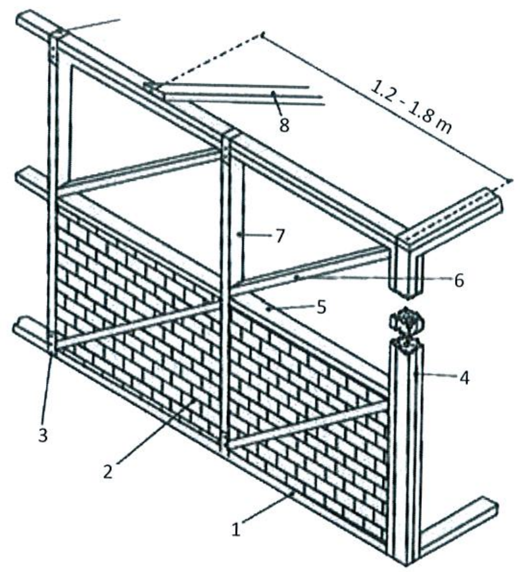


Fig. 6.2 : Brick Nogged timber frame

6.1.5 *Joints in Wood Frames*

The joints of structural members should be firmly connected by nails or bolts. The use of metal straps is strongly recommended at structurally important joints such as those of studs/columns with sill or wall plates and with horizontal nogging members.

Table 6.3: Maximum size (mm x mm) studs in brick nogged timber frame construction

Spacing	Group of timber*	Single storeyed or upper floor of double storeyed building		Lower floor of double storeyed building	
		Exterior wall	Interior wall	Exterior wall	Interior wall
1.0 m	A	50 x 100		50 x 100	70 x 100
	B, C	50 x 100		70 x 100	90 x 100
1.5 m	A	50 x 100	70 x 100	70 x 100	80 x 100
	B, C	70 x 100	80 x 100	80 x 100	100 x 100

*Group of timber defined in Table 6.1

6.1.6 *Foundations*

The superstructure should be supported by concrete or masonry footings as shown in Fig.6.3. Openings for ventilation need to be provided in continuous foundations (see Fig.6.3). Some reinforcement is preferable in very soft soil areas and in areas where liquefaction is expected. On hard or medium soil, isolated footings or boulders can also be used under the wood columns as shown in Fig. 6.3.

Details of (a), (b) and (c) are sometimes adopted in rural areas and superstructure found shifted during earthquakes & high winds, therefore detail (d) is recommended in these cases.

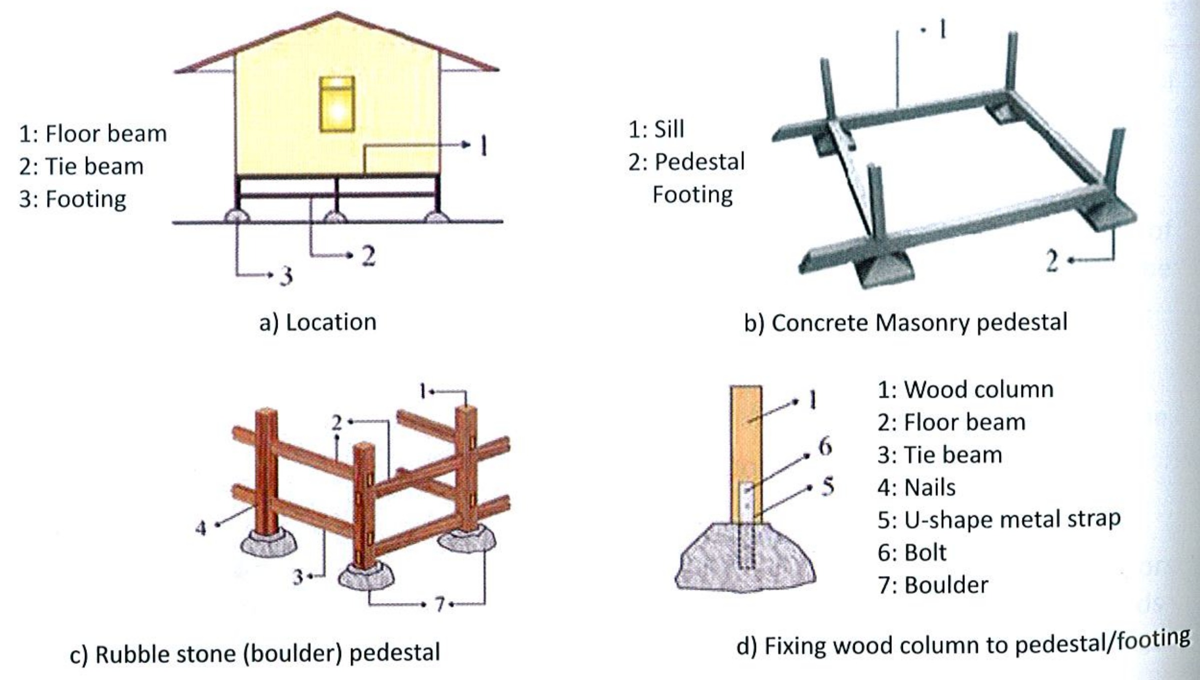


Figure 6.3: Wooden column footings

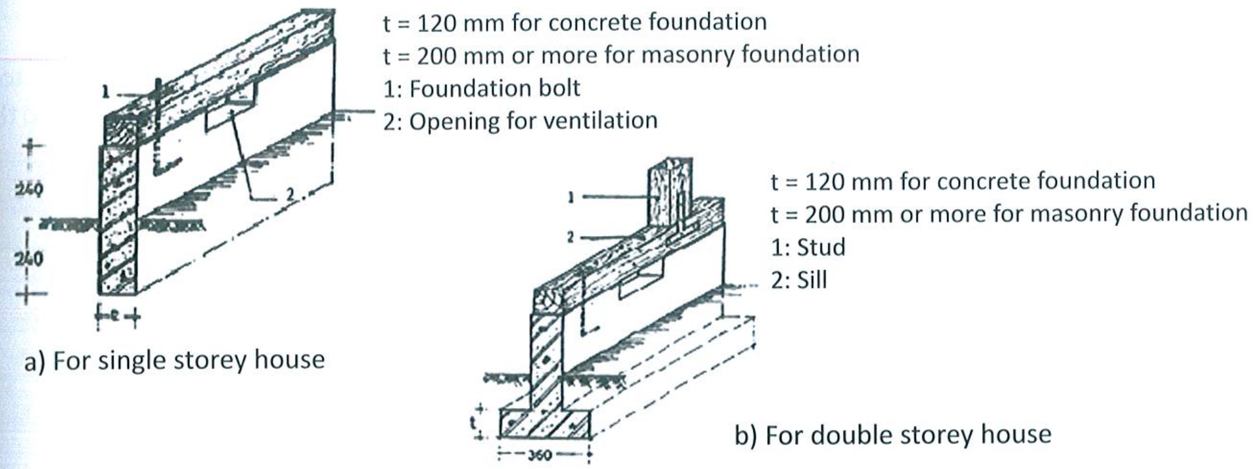


Figure 6.4: Strip footings under the wood silk beam

6.2 CONSTRUCTION OF BAMBOO HOUSES

The optimum design of bamboo houses shall be done for safety against flood and wind hazards as well as steps have to be taken for its long time durability. This construction shall also be earthquake resistant.

6.2.1 *For long time flood safety, raise the earthen plinth and finish with cement stabilized compacted soil*

Use the bamboo posts at every 1.5 to 1.8 m spacing to support the bamboo network wall panels as well s the sheeted roof (Fig. 6.5)

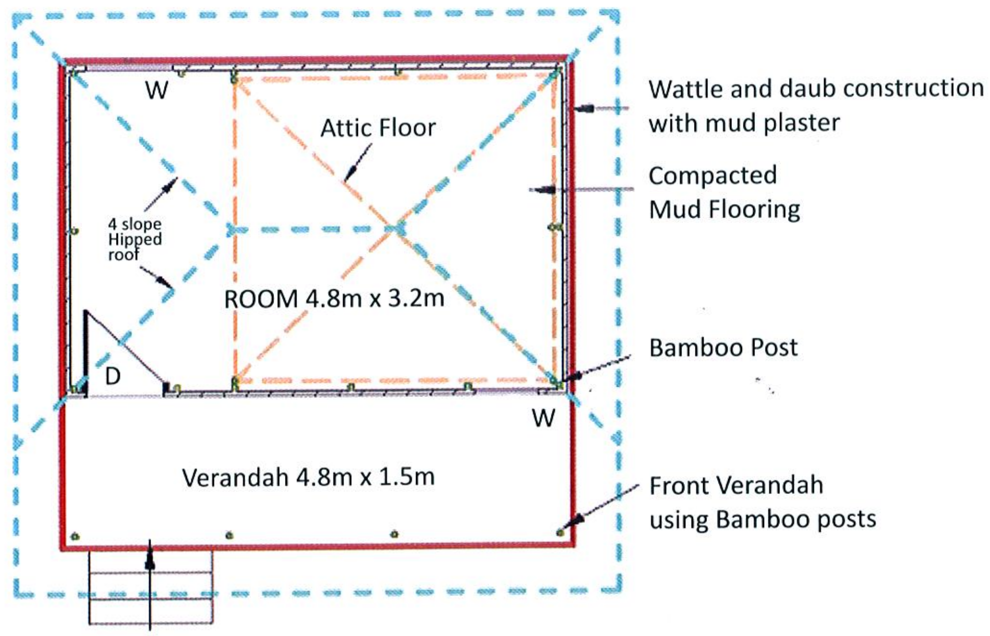


Fig. 6.5: Bamboo House: PLAN

6.2.2 Provide concrete stump (Fig. 6.6) under each bamboo post and clamp the bamboo post to it so that the bamboo ends are not taken into ground. It will be useful to paint the posts to the last maximum flood level.

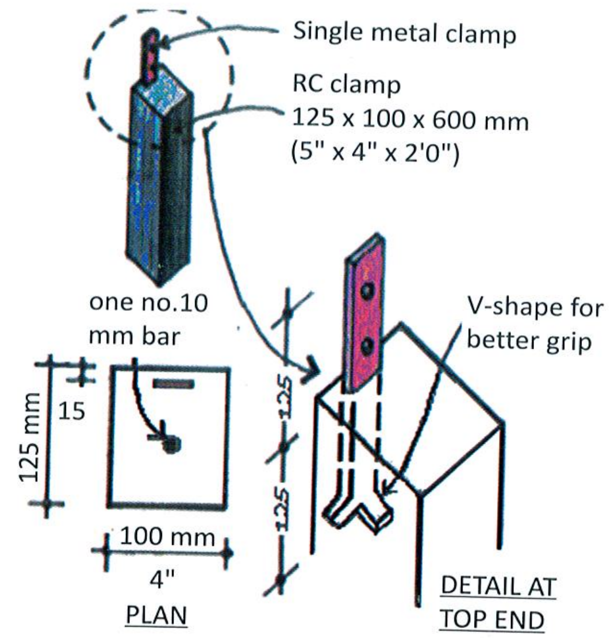


Figure 6.6: Concrete Stump (Source ADPC)

6.2.3 *Diagonal Braces*

Provide diagonal braces of half split bamboos (Fig. 6.7) in all bamboo wall panel as well as roof under-structure and provide an attic floor below the pitched roof (Fig. 6.8) as to strengthen the structure against lateral force of wind or earthquake.

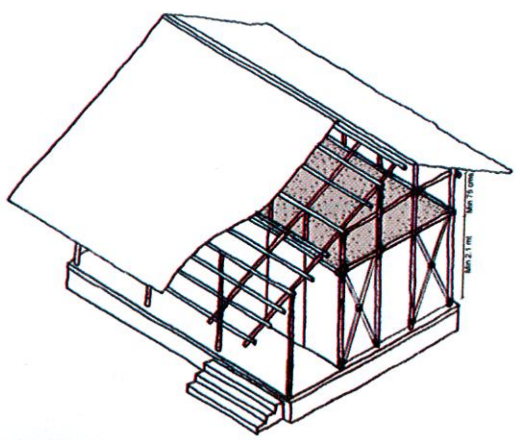


Figure 6.7: Bamboo house with Attic floor

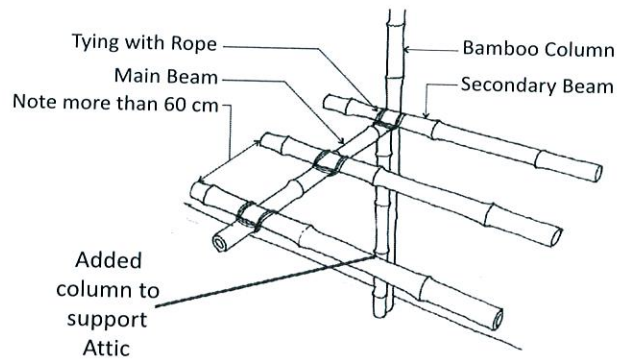


Figure 6.8: Attic column beam joint details

6.2.4 *Pitched Roof*

The pitched roof should be made of hipped shape (with four slopes) instead of gable shape (with two slopes) or lean-to (one slope only). The hipped roof is not only safe by itself against wind or earthquake but also stabilizes the overall structure of the house.

The roof sheets should be connected with purlins using J bolts with proper bitumen washers with steel washers and nuts (Fig. 6.9). This will hold the sheets against wind uplift and save them form tearing at the bolt holes.

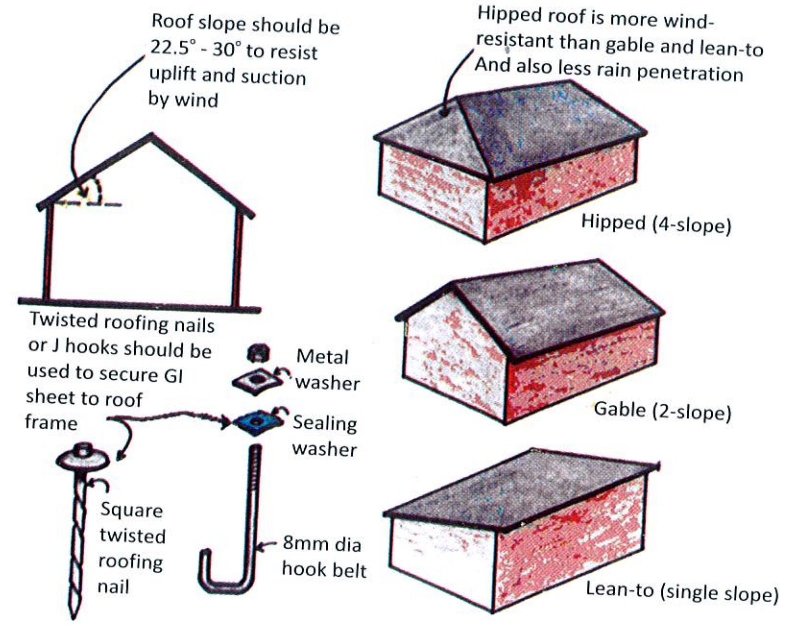


Figure 6.9: Basic features of wind-resistant roofing (Source ADPC)

6.2.5 *Connections*

h) All elements namely, bamboo posts, bamboo wall panels, and roofing rafters and purlins should be well tied with each other using nylon ropes or galvanized wire or bolting.

6.2.6 *Preservative Treatment*

i) Importantly, all bamboos used as posts, rafters and purlins and also the wall panels should be given chemical preservative treatment so as to increase their useful durable life from four years to thirty years. Figure 6.10 shows the use of a cycle air pump for pressure injection of boron in 4 bamboos simultaneously.

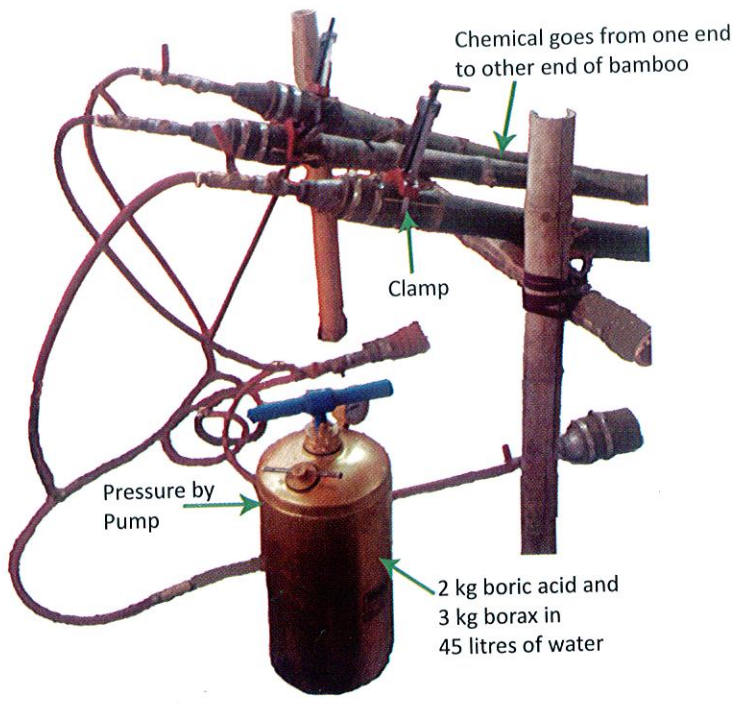


Figure 6.10: Pressure Impregnation of Boron in Bamboos

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6.1 National Building Code of India (second revision 2005) Part -6 Section 3A and 3B, BIS 2005
6.2 Arya A.S., Masonry and Timber Structures, N.C. Jain & Bros, Roorkee.
6.3 Arya A.S., Boen T. and Ishiyama Y. Guidelines for Earthquakes Resistant Non-Engineered Construction, IAEE, UNESCO and IISEE, Japan. 2011.
6.4 IS:4326 – 1993 Earthquake Resistant Design and Construction of Buildings- Code of Practice (Second Revision)" BIS 1993.
6.5 Arya A.S. Reconstruction of Multi hazard Resistant Houses for the 2008 Kosi, Flood affected District in Bihar (Part-II bamboo Houses), Govt. of Bihar 2009.

Chapter - 7 : Masonry Buildings Using Rectangular Building Units

7.1 RECTANGULAR BUILDING UNITS

The rectangular masonry units considered here are 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,
i. Gypsum partition blocks,
j. Autoclaved cellular concrete blocks, and
k. Concrete stone masonry blocks.

Any of these may be used with details as given in this chapter.

7.2 CAUSES OF DAMAGE

The main weaknesses in the materials and unreinforced masonry constructions and other reasons for the extensive damage of such buildings under earthquake shaking are described below:

a. Heavy weight and very stiff buildings, attracting large seismic inertia forces.
b. Very low tensile strength, particularly with poor mortars.
c. Low shear strength, particularly with poor mortars.
d. Brittle behaviour in tension as well as compression.
e. Weak connection between wall and wall.
f. Stress concentration at corners of windows and doors.
g. Overall unsymmetry in plan and elevation of building.
h. Unsymmetry due to imbalance in the sizes and positions of openings in the walls.
i. Defects in construction such as use of substandard materials, unfilled joints between bricks, not-plumb walls, improper bonding between walls at corners and T junctions, etc.

The damage under flood is caised by the reasons at (b), (c), (d), (e) and (i). Under high intensity winds of velocities of 33m/s (109 km/h) or higher, masonry walls such as boundary walls, parapets and external walls of houses may collapse or crack severely for reasons at (b), (c), (d), (e), (f) and (i). Poor quality of construction comes out as the main reason of damage of masonry walls besides poor mortar under various hazards.

7.3 TYPICAL STRENGTHS OF MASONRY

7.3.1 *Compressive Strength*

The crushing strength of masonry used in the walls depends on many factors such as the following:

1. Crushing strength of the masonry unit.
2. Mix of the mortar used and age at which tested.
3. The mortar used for different wall constructions varies in quality as well as strength. It is generally described on the basis of the main binding material such as cement or lime mortar, cement lime composite mortar, lime-pozzolana or hydraulic lime mortar. Clay mud mortar is also used particularly in rural areas.
4. Slenderness ratio of the wall, that is, the lesser of the ratio of effective height and effective length of the wall to its thickness higher is the strength. Larger is the slenderness ratio, smaller the strength.
5. Eccentricity of the vertical load on the wall. Larger the eccentricity, smaller the strength.
6. Percentage of openings in the wall. Larger the openings, smaller the strength.

The tensile and shearing strengths of masonry mainly depend upon the bond or adhesion at the contact surface between the masonry unit and the mortar and, in general, their values are only a small percentage of the crushing strength. Richer is a mortar in cement or lime content, higher is the percentage of tensile and shearing strength in relation to the crushing strength. Brick couplet tests under combined tension-shear and compression-shear stresses show that the shearing strength decreases when acting with tension and increases when acting with compression.

7.3.2 *Tensile Strength*

The tensile strength of masonry is not generally relied upon for design purposes under normal loads and the area subjected to tension is assumed cracked. Under seismic conditions, it is recommended that the permissible tensile and shear stresses on the area of horizontal mortar bed joint in masonry may be adopted as given in Table 7.1 (as default values where more precise values may not be available).

Table 7.1: Typical Permissible Stresses

Mortar mix or equivalent			Permissible Stresses		Compression for strength (MPa)* of unit			
Cement	Lime	Sand	Tension (Mpa)	Shear (Mpa)	3.5	7.0	10.5	14.0
1	-	6	0.05	0.08	0.35	0.55	0.85	1.00
1	1	6	0.13	0.20	0.35	0.70	1.00	1.10
1	-	3	0.13	0.20	0.35	0.70	1.05	1.25

* 1 Mpa = 1 N/mm^2 = 10.197 kgf/cm^2

7.3.3 *Modulus of Electricity*

The modulus of elasticity of masonry very much depends upon the density and stiffness of masonry unit, besides the mortar mix. For brickwork the values are of the order 2000MPa for cement-sand mortar in 1 : 6 proportion. The mass density of masonry mainly depends on the type of masonry unit. For example brickwork will have a mass density of about 1900 kg/m^3 and dressed stone masonry 2400 kg/m^3.

7.3.4 *Slenderness Ratio*

The slenderness ratio of the wall is taken as the lesser of h/t and l/t where h = effective height of the wall and l = its effective length. The allowable stresses in Table 7.1 must be modified for eccentricity of vertical loading due to its position and seismic moment and the slenderness ratio multiplying factors given. The effective height h may be taken as a factor times the actual height of wall between floors, the factor being 0.75 when floors are rigid diaphragms and 1.00 for flexible roofs; it will be 2.0 for parapets and boundary wall.

The effective length l will be a fraction of actual length between lateral supports, the factor being 0.8 for wall continuous with cross walls or buttresses at both ends, 1.0 for continuous at one end and supported on the other and 1.5 for continuous at one and free at the other.

7.4 GENERAL CONSTRUCTION ASPECTS

7.4.1 *Mortar*

Since tensile and shear strength are important for lateral resistance of masonry walls, use of mud or very lean mortars will be unsuitable. A mortar mix *cement : sand* equal to *1:6* by volume or equivalent in strength should be the minimum. Appropriate mixes for various categories of construction are recommended in Table 7.2. Use of a rich mortar in narrow piers between openings will be desirable even if a lean mix is used for walls in general.

Table 7.2: Recommended mortar mixes

Category*	Proportion of cement-sand or cement-lime-sand**
E	Cement-sand "1 : 4" or cement-lime-sand "1 : 0.5 : 4.5" or richer
D	Cement-sand "1 : 5" or cement-lime-sand "1 : 1 : 6" or richer
C	Cement-sand "1 : 6" or cement-lime-sand "1 : 2 : 9" or richer
B	Cement-sand "1 : 7" or cement-lime-sand "1 : 3 : 12" or richer

* Category of construction is defined in IS: 4326-1993.

** In this case some puzzolonic material like Surkhi (burnt brick fine powder) may be used with lime as per local practice.

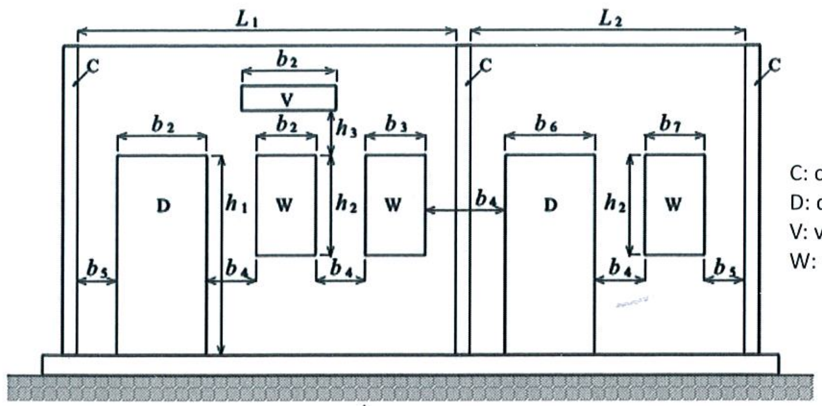
7.4.2 *Wall enclosure*

In load bearing wall construction, the wall thickness '*t*' should not be kept less than 190 mm, wall height not more than 20 *t* and wall length between cross-walls not more than 40 *t*. If longer rooms are required, either the wall thickness is to be increased, or buttresses of full height should be provided at 20 *t* or less apart. The minimum dimensions of the buttress shall be: thickness and top width equal to *t* and bottom width equal to one sixth the wall height.

7.4.3 *Openings in walls*

Studies carried out on the effect of openings on the strength of walls indicate that they should be small in size and centrally located. The following are the guidelines on the size and position of openings (see Fig.7.1):

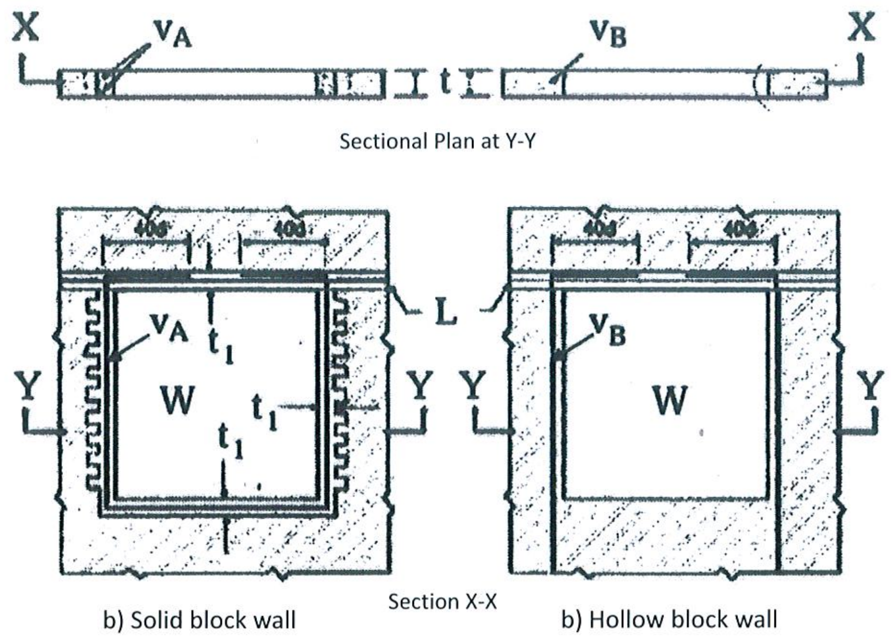
1. Openings to be located away from the inside corner of the room by a clear distance equal to at least 1/4 of the height of openings but not less than 0.45 m.
2. The total length of openings not to exceed 50% of the length of the wall between consecutive cross walls in single-storey construction, 42% in two-storey construction and 33% in three storey buildings.
3. The horizontal distance (pier width) between two openings to be not less than half the height of the shorter opening, but not less than 0.56 m.
4. The vertical distance from an opening to an opening directly above it not to be less than 0.6m nor less than 1/2 of the width of the smaller opening.
5. When the openings do not comply with requirements (1) to (4), they should either be boxed in reinforced concrete around or reinforcing bars provided at the jambs through the masonry (see Fig.7.2).



C: cross wall
D: door opening
V: ventilation
W: window opening

$b_1 + b_2 + b_3 \leqq 0.5L_1$ for one storey, 0.42 for two storey, 0.33 for three storey,
$b_6 + b_7 \leqq 0.5L_2$ for one storey, 0.42 for two storey, 0.33 for three storey,
$b_4 \geqq 0.5h_2$ but not less than 0.6 m, $b_5 \geqq 0.25h_1$ but not less than 0.6 m,
$h_3 \geqq$ 0.6m or $0.5b_2$ or b_6 whichever is more.

Figure 7.1: Recommendation regarding openings in bearing walls



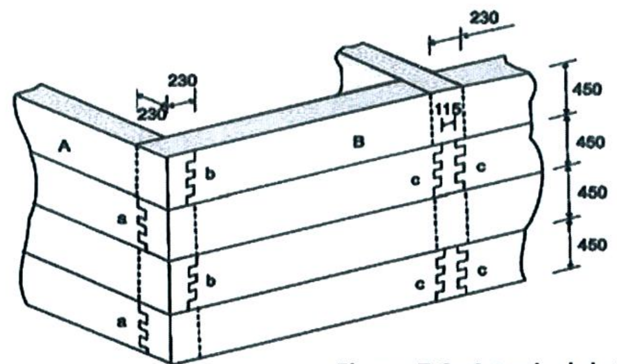
L: lintel band
W: window
t: thickness of wall min. one brick length
t_1: min. 75 mm
V_A: vertical and horizontal reinforcement, 2-∅d
V_B: vertical reinforcement 1-∅d
∅d: diameter of reinforcement

Figure 7.2: Strengthening of masonry walls around openings

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. The following deserves special mention.

Vertical joint between perpendicular walls:
For convenience of construction, builders prefer to make a toothed joint which is many times left hollow without mortar filling, hence weak. To obtain full bond it is necessary to make a sloping (stepped) joint by making the corners first to a height of 0.6m and then building the wall in between them. Otherwise, the toothed joint should be made in both the walls alternately in lifts of about 45 cm (see Fig. 7.3).



All dimensions are in mm

a, b, c: toothed joints in walls A, B, C

Alternating toothed joints in

Figure 7.3: A typical detail of masonry

7.5 HORIZONTAL REINFORCEMENT IN WALLS

Horizontal reinforcing of walls is required for imparting to them horizontal bending strength against plate action for out of plane inertia load and for tying the perpendicular walls together. In the partition walls, horizontal reinforcement helps preventing shrinkage and temperature cracks. The following reinforcing arrangements are necessary:

7.5.1 *Horizontal bands or ring beams*

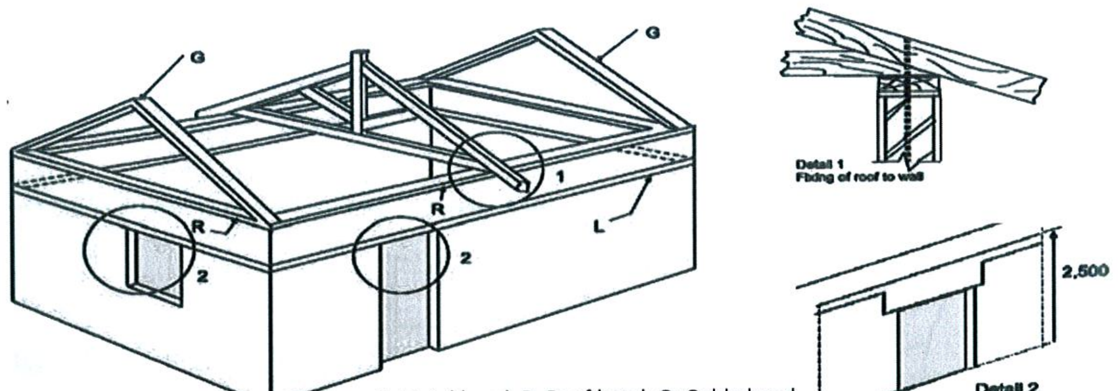
The most important horizontal reinforcing is through reinforced concrete bands provided continuously through all load bearing longitudinal and transverse walls at plinth, lintel, and roof/eave levels, also at top of gables according to requirements as stated hereunder:

1. ***Plinth band:*** This should be provided in those cases where the soil is soft or uneven in their properties as it usually happens in hill tracts. It will also serve as damp proof course. This band is not too critical for stiff soil condition under the foundations.

2. ***Lintel band:*** This is the most important band and will incorporate in itself all door and window lintels the reinforcement of which should be extra to the lintel band steel. It must be provided in all storeys in buildings.

3. ***Roof band:*** This band will be required at eave level of trussed roofs (see Fig. 7.4) and also below or in level with such floors, which consist of joists and covering prefabricated elements so as to properly integrate them at ends and fix into the walls.

4. ***Gable band:*** Masonry gable ends must have the triangular portion of masonry enclosed in a band, the horizontal part will be continuous with the eave level band provided on longitudinal walls (see Fig. 7.4).



L: Lintel band, R: Roof band, G: Gable band

Note: As an alternative to the gable masonry, a truss or open gable may be used and opening covered with light material like sheeting mat, etc.

Figure 7.4: Seismic Bands in House with Pitched Roof

7.5.2 *Section of bands or ring beams*

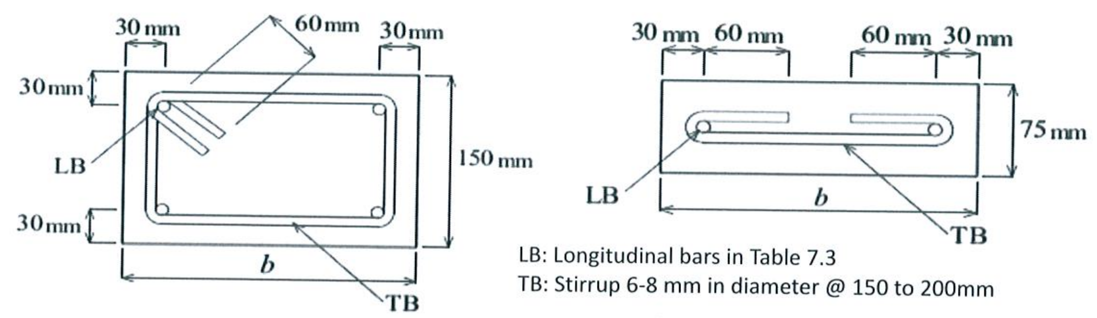
The reinforcement and dimensions of these bands may be kept as follows **"for wall spans upto 9m between the cross walls or buttresses"**. These dimensions cover most residential, offices and class-room sizes. **A band consists of two (or four) longitudinal steel bars with links or stirrups embedded in 75mm (or 50 mm) thick concrete (see Fig.7.5). The thickness of band may be made equal to or a multiple of masonry unit and its width should equal the thickness of wall. The steel bars are located close to the wall faces with 25mm cover and full continuity is provided at corners and junctions. The minimum size of band and amount of reinforcing will depend upon the unsupported length of wall between cross walls and the effective seismic coefficient based on seismic zone, importance of buildings, and storey of the building.**

Appropriate steel and concrete sizes are recommended for various buildings in Table 7.3. Such bands are to be located at critical levels of the building, namely plinth, lintel, roof and gables according to requirements. In Table 7.3, the following note will apply:

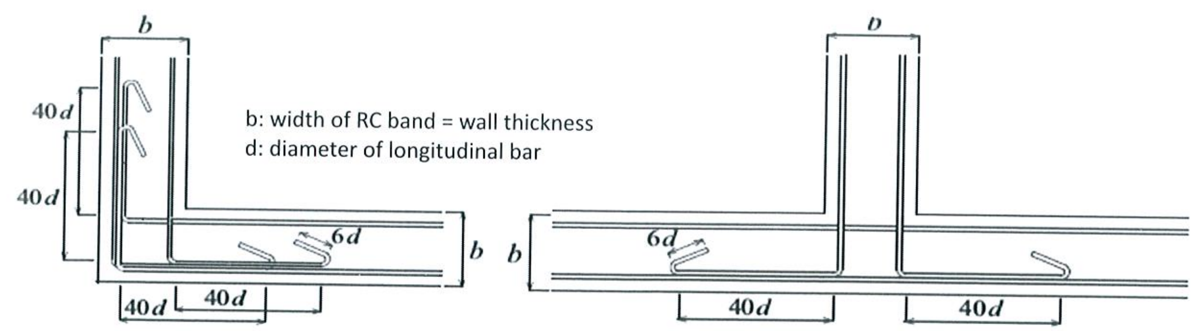
i) Width of the RC band is assumed to be the same as the thickness of wall. Wall thickness shall be 200mm minimum. A cover of 25mm from face of wall will be maintained. For thicker walls, the quantity of steel need not be increased.

ii) The vertical thickness of RC band may be kept minimum 75mm or 95mm where two longitudinal bars are specified and 150mm where four longitudinal bars are specified.

Placement of bars in bands



a) Cross section of RC band for two bars and four bars



b) RC band reinforcement details at corner and T junction

Figure 7.5: Reinforcement in RC Bands

iii) Concrete mix to be *1:2:4* by volume or having 15-20MPa cube crushing strength at 28 days.

iv) The longitudinal bars shall be held in position by steel links or stirrups 6mm diameter spaced at 150mm apart.

v) Bar diameters are for high strength deformed bars.

Table 7.3: Recommendation for Steel in RC Band

Span (m)	Longitudinal Steel in RC Band: Category E		Category D		Category C		Category B	
	No. of Bars	Dia of Bars (mm)	No. of Bars	Dia of Bars (mm)	No. of Bars	Dia of Bars (mm)	No. of Bars	Dia of Bars (mm)
5 or less	2	10	2	8	2	8	2	8
6	2	12	2	10	2	8	2	8
7	4	10	2	12	2	10	2	8
8	4	12	4	10	2	12	2	10
9	4	14	4	12	4	10	2	12

7.6 Vertical Reinforcement in Walls

The critical sections are the jambs of openings and the corners of rooms. The amount of vertical reinforcing steel will depend upon several factors like the number of storeys, storey heights, the effective seismic coefficient based on seismic zone and importance of building. Values based on rough estimates for building are given in Table 7.4 for ready use. The steel bars are to be installed at the critical sections, i.e., the corners of walls and jambs of doors right from the foundation concrete and covered with cement concrete in cavities made around them during masonry construction. This concrete mix should be kept *1:2:4* by volume or richer. Typical arrangements of placing the vertical steel in brick work are shown in Fig.7.6.

Table 7.4 Recommendation for vertical steel at critical sections

No. of Storeys	Storey	Diameter of mild steel single bar in mm at each critical section for Category*: Category E	Category D	Category C	Category B
One		12	10	Nil	Nil
Two	Top	12	10	Nil	Nil
	Bottom	16	12	Nil	Nil
Three	Top	12	10	10	Nil
	Middle	16	12	10	Nil
	Bottom	16	16	12	Nil
Four	Top		10	10	10
	Third		12	10	10
	Second	**	16	12	10

* Category of construction is defined in IS: 4326. Equivalent area of twisted grip bars or a number of mild steel bars could be used but the diameter should not be less than 10 mm.

** Four storeyed load bearing wall construction may not be used for E categories buildings.

The jamb steel was shown in Fig.7.2. The jamb steel of window openings will be easiest to provide in box form around it. The vertical steel of opening may be stopped by embedding it into the lintel band but the vertical steel at corners and junctions of walls must be taken into the floor and roof slabs.

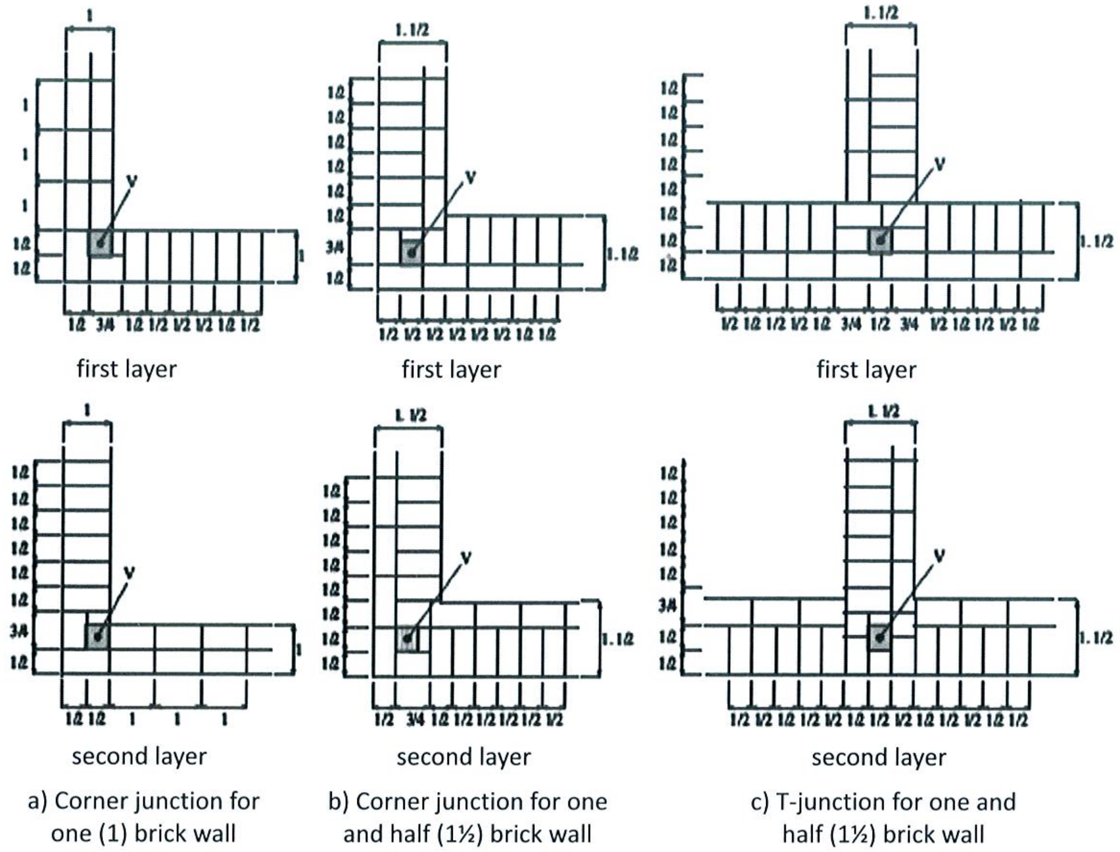
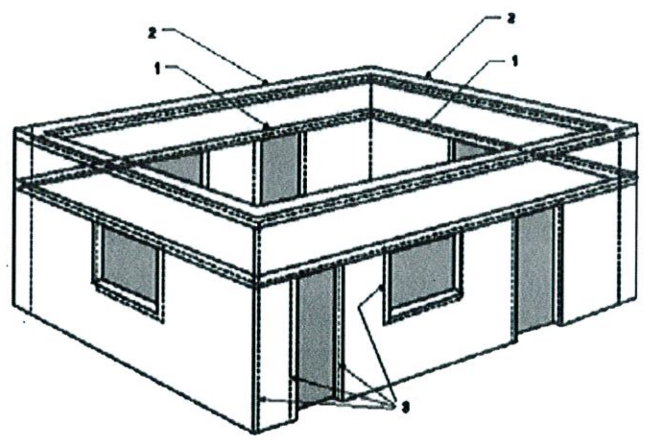


Figure 7.6: Vertical reinforcement (V) in walls



1: Lintel band
2: Roof band, only for pitched roofs and under flexible roof and floor
3: Vertical steel

Figure 7.7: Overall arrangement of reinforcing masonry buildings

The total arrangement of providing reinforcing steel in masonry wall construction with flat horizontal roof is schematically shown in Fig. 7.7.

7.7 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.

7.7.1 Horizontal band

U-shaped blocks may best be used for construction the horizontal bands at various levels of the storeys as per seismic requirements, as shown in Fig.7.8.

The amount of horizontal reinforcement may be taken 25% more than that given in Table 7.3 and provided by using four bars and 6mm diameter stirrups. Other continuity details shall be followed as was shown in Fig.7.5.

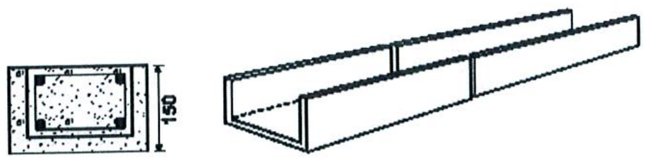


Figure 7.8: U-Blocks for horizontal bands

7.7.2 Vertical Reinforcement

The vertical bars as specified in Table 7.4 may conveniently be located inside the cavities of the hollow blocks, one bar in one cavity. 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.

A practical difficulty is faced in threading the bars through the hollow blocks since the bars have to be set in footings and have to be kept standing vertically while lifting the blocks through whole storey heights, and lowering it down to the bedding level. To avoid lifting of blocks too high, the bars are made shorter and overlapped with upper portions of bars. This wastes steel as well as the bond strength in small cavities remains doubtful. For solving this problem, two alternatives may be used: (a) use of three sides blocks as shown in Fig.7.9 /or (b) splicing of bars. But vertical bars should not preferably be spliced for single storey buildings. In taller buildings, the splicing of vertical bars where found necessary may be done by overlapping by a distance of 50 *d* and wrapped using binding wire shown in Fig. 7.9.

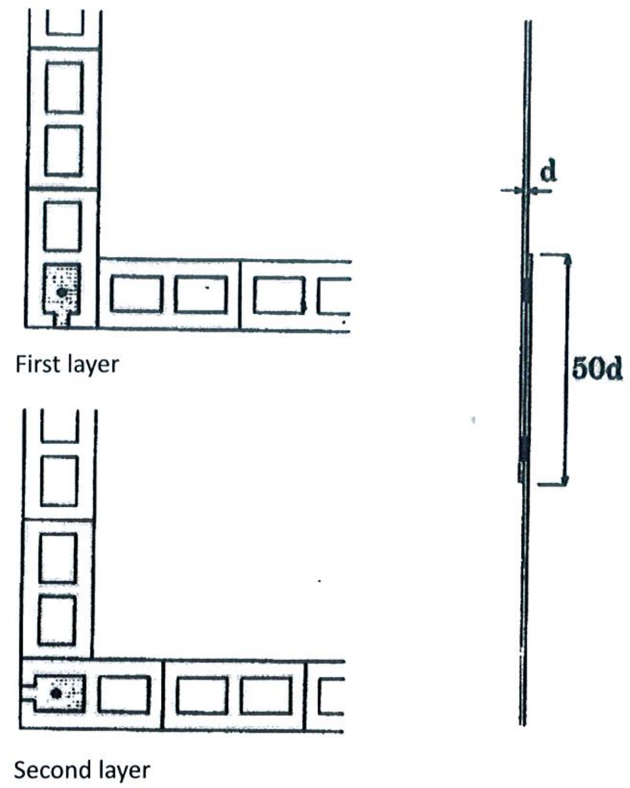


Figure 7.9: Blocks for Vertical Bars

References

7.1 National Building Code of India (second revision 2005) Part -6 Section 4, 3A and 3B, BIS 2005.

7.2 Arya A.S., Masonry and Timber Structures, N.C. Jain & Bros, Roorkee.

7.3 Arya A.S., Boen T. and Ishiyama Y. Guidelines for Earthquakes Resistant Non-Engineered Construction, IAEE, UNESCO and IISEE, Japan. 2011.

7.4 IS:4326 – 1993 Earthquake Resistant Design and Construction of Buildings- Code of Practice (Second Revision)" BIS 1993.

7.5 Arya A.S. Reconstruction of Multi hazard Resistant Houses for the 2008 Kosi, Flood affected District in Bihar (Part-I Masonry Buildings), Govt. of Bihar 2010.

Chapter - 8 : Earthquake Safe Design and Construction of Multi-storey RC Buildings

8.0 This chapter is based on a study of damages and deficiencies in design and construction observed in RC Buildings at Ahmedabad and Gandhidham in the Bhuj Earthquake of Jan. 26, 2001. The measures are suggestions to be adopted for achieving seismic safety in RC Buildings.

8.1 CAUSES OF THE COLLAPSE OF RC FRAME BUILDINGS AND RECOMMENDATIONS

8.1.1 Ignorance of the Architects and Structural Engineers.

It appears that there was no know how about the contents of the relevant earthquake resistant building codes and good quality of construction. It should be understood that the earthquake shakes the building in all three directions; longitudinal, transverse and vertical. If it is not accounted for in design, it may result in collapse in longitudinal direction.

Architect's and Structural engineer's design offices should have the current copies of the standards available in their offices and all their staff should be fully familiarized with contents of these codes (See Table 3.5 for list of Codes).

8.1.2 Softness of Base Soil

The foundation along with the soil plays critical role in amplifying the ground motion. Soil was not properly explored, nor considered in design. Also soil failures such as liquefaction and landslides caused by shaking may not have been considered in design and construction.

The soft soil on which most buildings in Ahmedabad were founded would have affected the response of the buildings in the following ways:

i. Amplification of the ground motion at the base of the building;
ii. Absence of foundation raft or piles;
iii. Relative displacement between the individual column foundations vertically and laterally, in the absence of either the foundation struts as per IS: 4326 or the plinth beams;
iv. Resonance or, semi-resonance of the whole building with the long period ground waves generated by long distance earthquake occurrences;
v. In the absence of the beam at plinth or, ground level, the length of ground storey columns gets increased, which increases the flexibility of the ground storey and if the columns become 'long', the buckling moments due to P- Δ effect will increase leading to cause collapse of the columns.
vi. Tilting, cracking and failure of superstructure may result from soil liquefaction and differential settlement of footings.

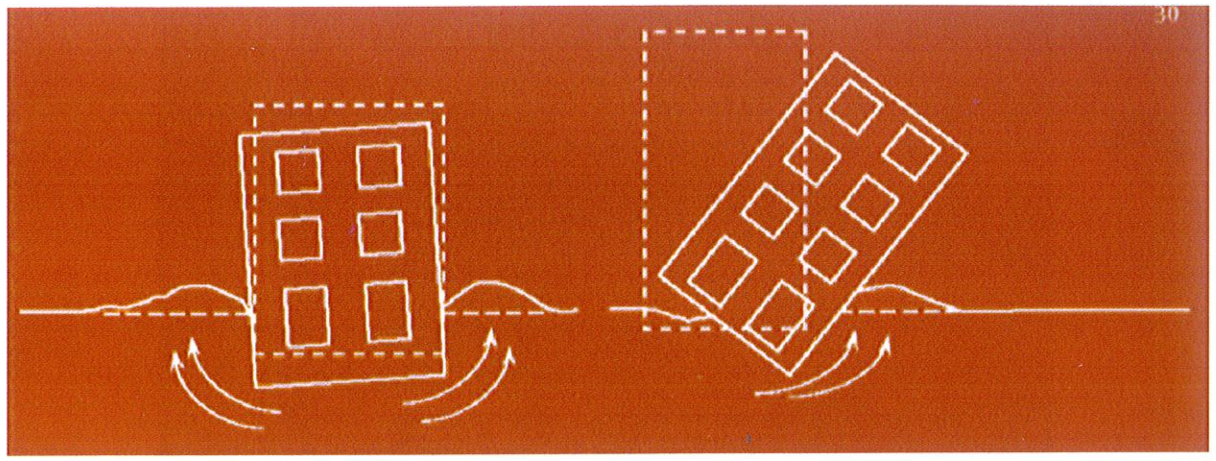


Figure 8.1: Tilting of Building due to Soil Liquefaction

Soil exploration at the buildings site must be carried out at sufficient points and to sufficient depth so as to get the following data:

i. Soil classification in various layers and the properties like grain size distribution, field density, angle of internal friction and cohesion, plastic and liquid limits and coefficient of consolidation of cohesive soils.
ii. Position of water table just before and just after monsoon.
iii. SPT values and CPT values.
iv. The output results should include liquefaction potential, safe bearing capacity and the type of foundation to be adopted.

8.1.3. Soft-first Storey:

Open ground storey (stilt floor) used in most severely damaged or, collapsed R.C. buildings, introduced 'severe irregularity of sudden change of stiffness' between the soft ground storey and stiff upper storeys since they had infilled brick walls which increase the lateral stiffness of the frame by a factor of three to four times. Such a building is called a building with 'soft' ground storey, in which the dynamic ductility demand during the probable earthquake gets concentrated in the soft storey and the upper storeys tend to remain elastic. Therefore, the columns of soft storey are damaged by the cyclic displacements between the moving soil and the upper part of the building.

In view of the functional requirements of parking space under the buildings, more and more tall buildings are being constructed with stilts. To safeguard the soft first storey from damage and collapse, clause 7.10 of IS: 1893-2002 (Part 1) provides two alternative design approaches:

I. The dynamic analysis of the building is to be carried out which should include the strength and stiffness effects of infills as well as the inelastic deformations under the

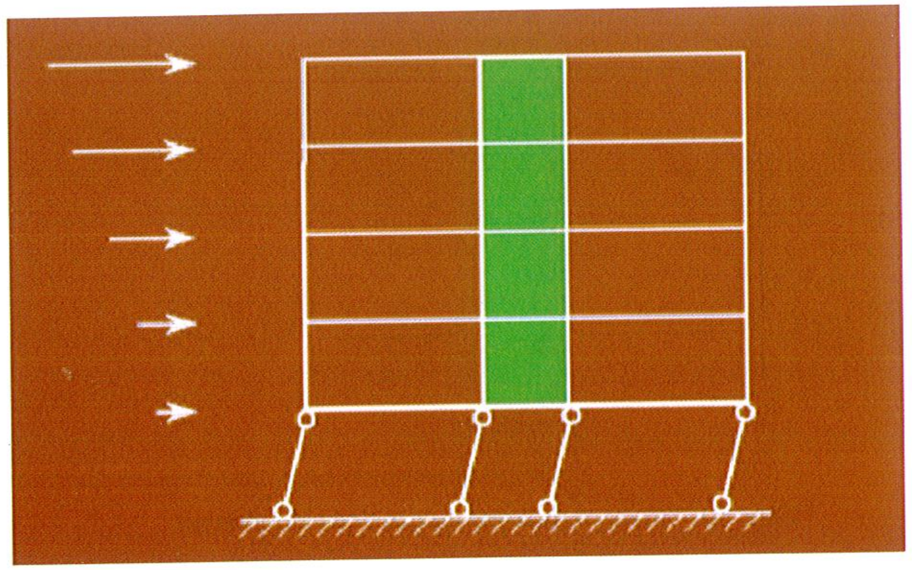


Figure 8.2: Building with soft ground storey (on Stilts)

design earthquake force disregarding the Reduction Factor R.

II. The building is analysed as a bare frame neglecting the effect of infills and, the dynamic forces so determined in columns and beams of the soft (stilt) storey are to be designed for 2.5 times the storey shears and moments: OR, the shear walls are introduced in the stilt storey in both directions of the building which should be designed for 1.5 times the calculated storey shear forces.

Figure 8.3 should help in choosing a safe system to be adopted for buildings with soft ground storey.

8.1.4 *Intermediate Soft Storey (Fig. 8.4)*

Some times a soft storey is created some where near mid-height of the multi-storey building, for using the space as restaurant or gathering purposes. For such a case also, the storey columns should be designed for the higher than calculated storey shear (forces) to 2.5 times, or a few shear walls or X-bracing system introduced to make up for the reduced stiffness of the storey.

8.2 BAD STRUCTURAL SYSTEMS

8.2.1 *Use of Floating Columns*

The structural system adopted using floating columns, for reasons of higher FSI is very undesirable in earthquake zones of moderate to high intensity as in Zone III, IV & V since it will induce large vertical earthquake forces even under horizontal earthquake ground

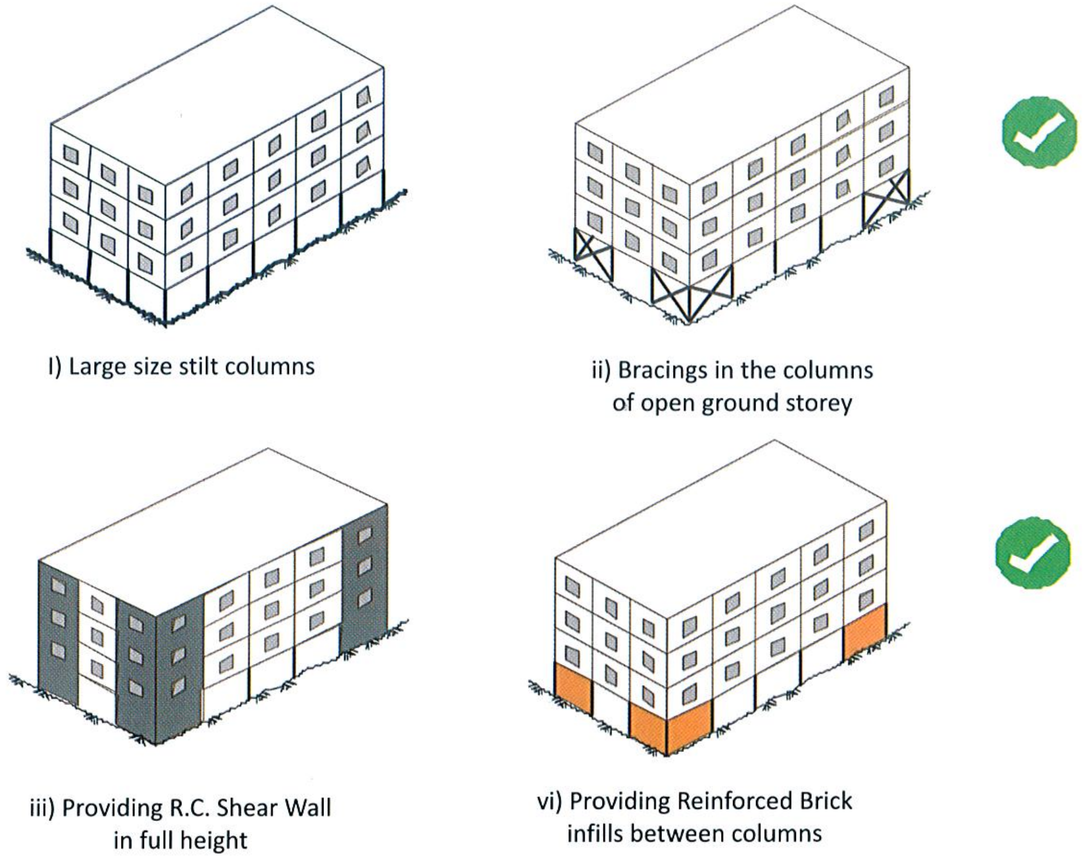


Figure 8.3: Seismic Safety of RC Building with Open Ground Floor

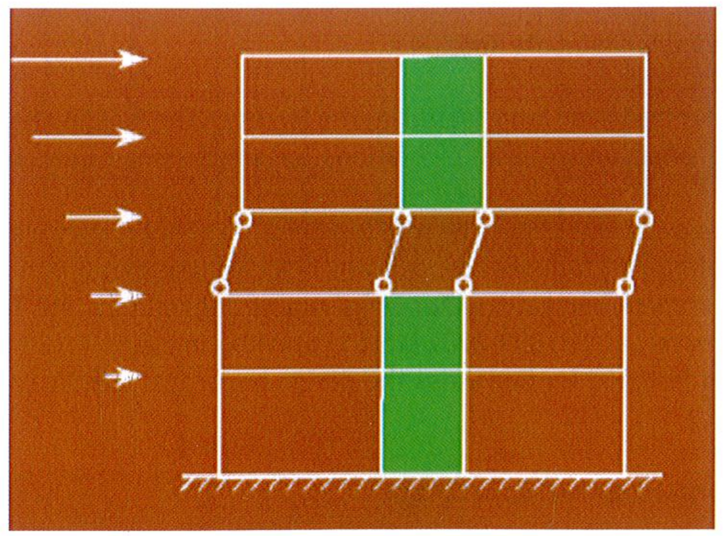


Figure 8.4: Intermediate Soft Storey

motions due to overturning effects.

The structural engineer should provide for the load path in the building from roof to the foundation. For example, a building with floating columns requires transfer of the floating column loads to horizontal cantilever beams through shear forces. The load path, therefore, is not vertical but changes from vertical to horizontal members before reaching the foundation.

It is important to note that any horizontal projections as the balconies or the cantilevers supporting floating columns, the cantilevers need to be designed for five times the design vertical seismic co-efficient as specified in clause 6.4.5 of IS: 1893-2002 (Part 1)

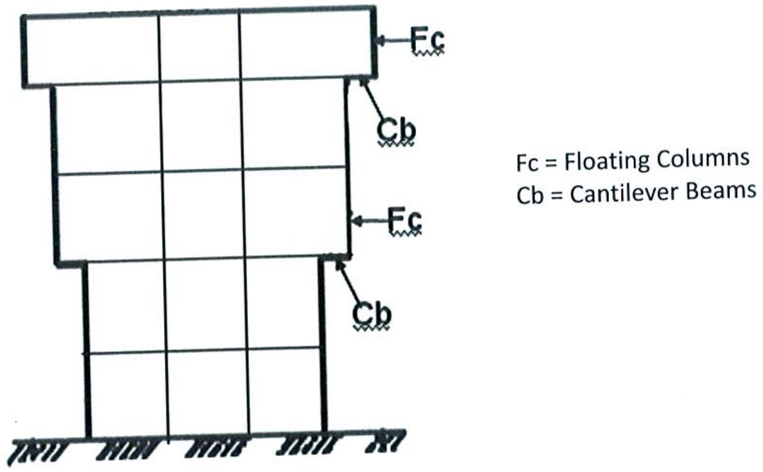


Figure 8.5: Floating Columns

8.2.2 Heavy Water Tanks on the Roof

Heavy water tanks add large lateral inertia forces on the building frames due to the so called 'whipping' effect under seismic vibrations, but which remain unaccounted for in the design.

All projected systems above the roof top behave like secondary elements subjected to *roof level horizontal earthquake motions* which act as base motions to such projecting systems namely, parapets, barsaatis, water tanks' supporting columns, etc. To account for such heavy earthquake forces, IS:1893-2002 (Part 1) provides in clause 7.12 that their support system should be designed for five times the design horizontal seismic co-efficient A_h specified in clause 6.4.2.

8.2.3 Lack of Earthquake Resistant Design

The buildings are not designed for the earthquake forces specified in IS: 1893, which was in existence from 1962, revised in 1970, 1976 and 1984. The applicable seismic zoning in

Gujarat had remained the same as adopted in 1970 version. It is the same even in 2002 version of IS: 1893 (Part I). Inspite of that, the structural designers ignored the seismic forces in design.

It must be emphasized that all buildings must be designed for earthquake forces as per IS: 1893 and 4326 and detailed as per IS: 13920-1993.

The design lateral forces specified in the standard {IS:1893 (Part 1)} have to be considered in each of the two orthogonal horizontal directions of the structure. To achieve safety along each axis of the building, the larges dimension of the columns or the shear walls need to be oriented along each axis. See Fig. 8.6.

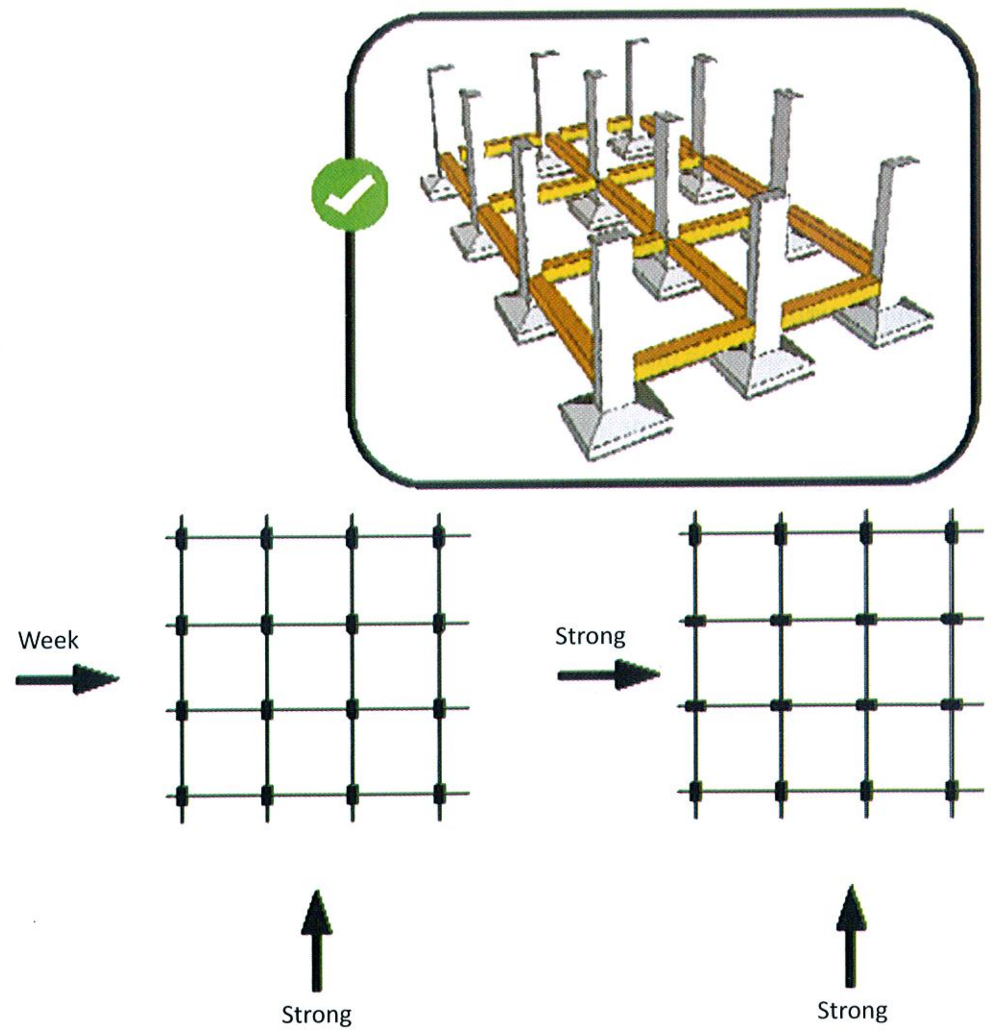


Figure 8.6: Orientation of columns for seismic resistance
(minimum column size to be 300mm)

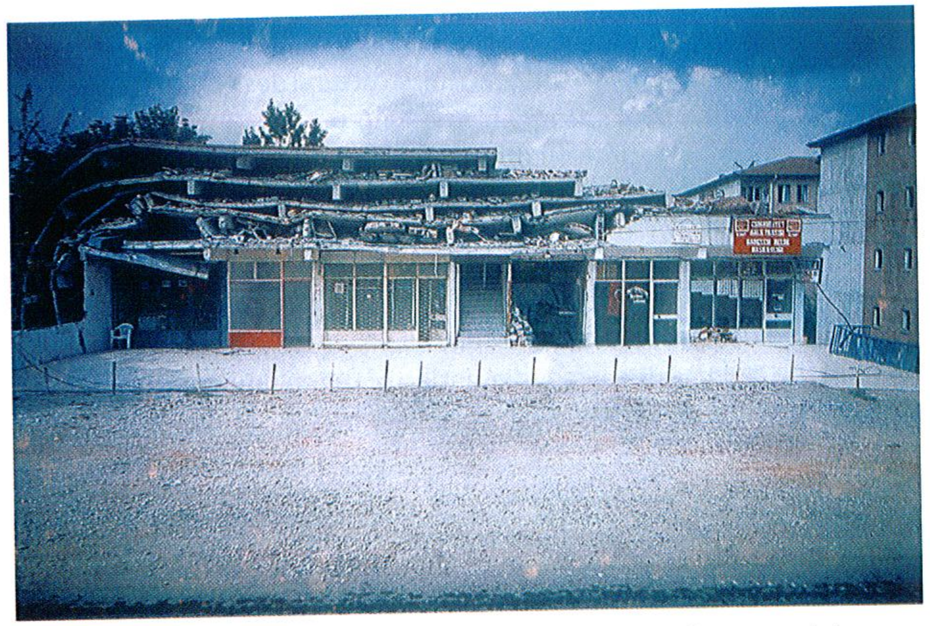


Figure 8.7: Building Collapse due to all the upper floors weak in long direction (Izmit, Turkey 1999)

8.3 IMPROPER DETAILING OF R.C. FRAMES

8.3.1 Improper Dimensioning of Beams & Columns

The structural dimensioning of beams and columns was inadequate in terms of provisions in IS: 13920-1993 and also for proper installation of reinforcements in Beam-Column joints as per IS: 456 and IS: 13920.

The relative dimensions of beams & columns become very important in tall buildings from the point of view of provision of longitudinal & transverse reinforcement in the members as well as the reinforcement passing through and anchored in the beam-column joints, permitting enough space for proper concreting and without involving any local kinking of the reinforcing bars. The practice of using small dimension columns like 200 or 230 mm and beams of equal width is totally unacceptable from the reinforcement detailing view point. The columns should have minimum dimension of 300 mm in all building with more than four storeys and width of beam lesser to facilitate the longitudinal bars to pass through the spaces between the column bars. See Fig. 8.8.

8.3.2. Detailing of Reinforcement

In detailing the stirrups in the columns, no conformity appeared to satisfy lateral shear requirements of the joint in the concrete as required under IS 4326- 1976 and IS: 13920-1993. The shape and spacing of stirrups seen in collapsed and severely damaged columns with buckled reinforcement was indicative of non-conformity even with the basic RCC Code IS: 456-2000.

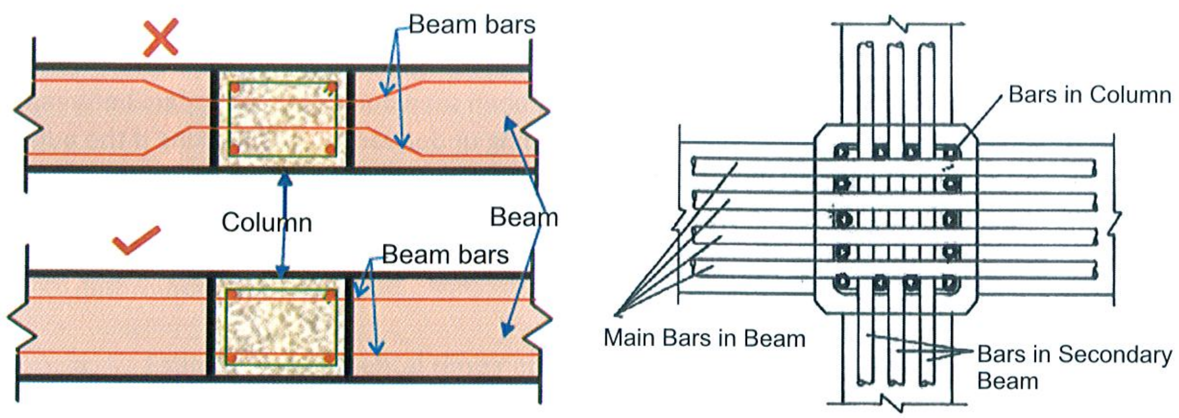


Figure 8.8: Reinforcement Pattern in Beam Column

In respect of proper detailing of reinforcement in beams, columns, beam-column joints as well as shear walls, all the provisions in IS:13920 have to be carefully understood and adopted in design. The philosophy is *over-design of beams in shear to force flexural hinge formation before shear failure.*

Confining of highly compressed concrete in columns is essential and the use of properly shaped stirrups with 135 degree hooks must be ensured. See Fig. 8.9. Those are some low-cost but extremely important provisions for overall safety of the frame. Design based on the concept of strong-column, weak-beam system should be adopted as far as practical.

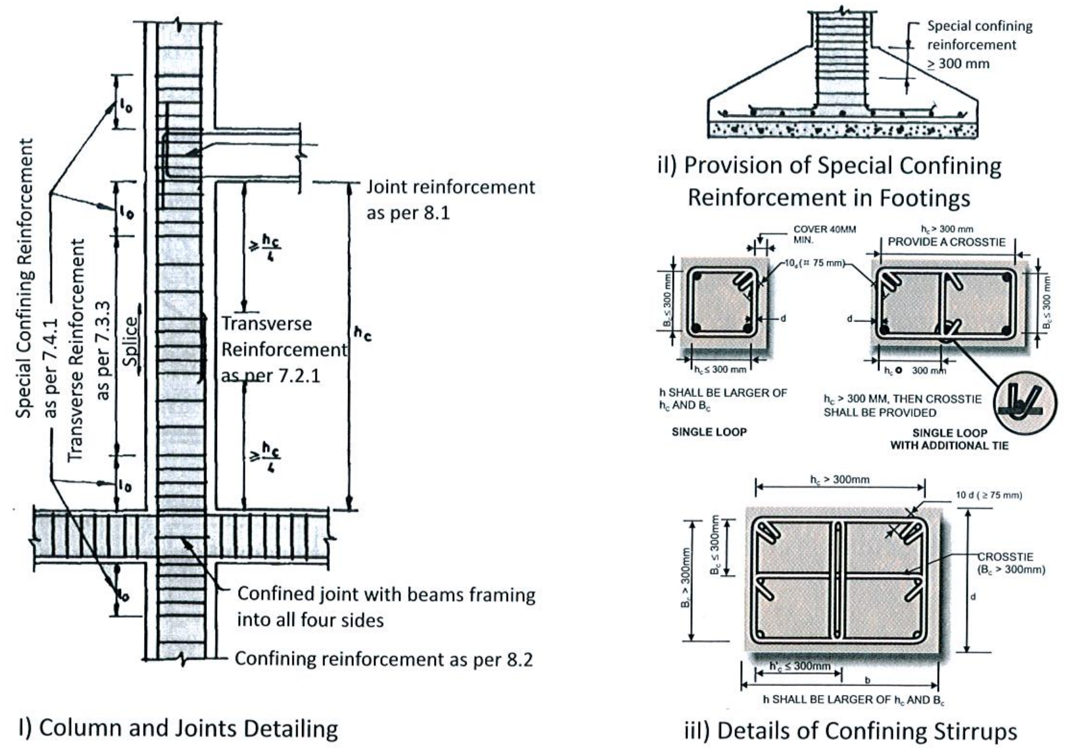


Figure 8.9: Reinforcement details in columns and joints

8.3.3 *Separation of Building Blocks*

Severe damage even leading to collapse have been seen due to severe impact between two adjacent buildings or blocks of the same building under earthquake shaking if the adjacent blocks or two adjacent buildings are of different heights with floors at different levels and with inadequate separation. Such buildings can vibrate out of phase with each other due to very different natural frequencies thus hitting each other quite severely. See IS: 4326-1993, Cl. 5.1.2 for guidance.

8.3.4 *Lack of Stability of Infill Walls*

In the observed RC Multi-storyed Buildings, the infill walls were not properly attached either to the column or the top beams for stability against out-of- plane bending under horizontal earthquake forces. Their cracking and falling was widespread.

8.4 POOR CONSTRUCTION QUALITY

The construction quality of the damaged R.C. buildings was found to be much below than what was desired, as seen by the cover to reinforcement in the damaged members and the bad quality of concrete in the columns in 150 to 300 mm length just below the floor beams and within the beam column joints.

It should be remembered that during earthquake shaking, all bad quality constructions will be revealed and nothing can be kept hidden. Needless to say that if the quality of construction is not commensurate with the quality of design, even a well planned and a well designed building can show extremely bad behavior under earthquake shaking.

Good quality of construction will include: proper mixing water, good quality sand and aggregates, designed quantity of cement in the mix, proper mixing of all the ingredients with control on water cement ratio, adequate compaction in the placement of concrete preferably by using vibrators, proper placement of steel with control on the cover to steel and adequate curing before striking of the form work.

The engineer incharge of the construction should personally be present at site to supervise all operations. He should have appropriate sampling and testing of materials carried out in a recognized laboratory, the results of test being kept in well maintained register for inspection by quality audit team. He should organize regular testing of sample of steel reinforcement & concrete cubes in adequate numbers at the specified age of testing.

8.5 SOME IMPORTANT CODAL PROVISIONS

8.5.1 *The Earthquake Load:*

For working out the earthquake loading on a building frame, the dead load and imposed load and weights are to be lumped at each column top on the basis of contributory areas. The imposed load is to be reduced as specified in IS: 1893 (Part1)-2002 for seismic load determination.

a. Estimate fundamental time period T_a using empirical expressions given in the Code IS: 1893-2002

$0.075\,h^{0.75}$, IS: 1893 Cl.7.6.1 for bare frame along each axis

$\frac{0.09h}{\sqrt{d}}$ along x-axis IS: 1893 Cl.7.6.2 for frame with substantial infills

$\frac{0.09h}{\sqrt{b}}$ along z-axis, IS: 1893 Cl.7.6.2 for frame with substantial infills

where h is the height of the building and d and b are the base dimensions of the building along x and z axis respectively.

Where the infill walls are thin and with openings as in tall residential buildings, some designers take the mean of these values in each principal axis x and z. Let these values be termed as T_x & T_z.

b. Calculate the design horizontal Seismic coefficient A_h

Now compute the fundamental time periods T_{1x} and T_{1z} for the bare frame along the two axes by dynamic analysis. These are generally found to be higher than T_x and T_z respectively. The design horizontal coefficient A_h is given by

$$A_h = \left(\frac{Z}{2}\right)\cdot\left(\frac{I}{R}\right)\cdot\left(\frac{S_a}{g}\right)$$

Take Z for the applicable seismic zone (IS: 1893 Cl.6.4.2);
Take I for the use importance of the building (IS: 1893 Table 2);
Take R for the lateral load resisting system adopted (IS: 1893 Table 7);
And take $\frac{S_a}{g}$ for the computed time period values T_{1x}, T_x, T_{1z} and T_z with 5% damping coefficient using the response spectra curves (IS: 1893 Fig 2 for the soil type observed).

Thus four values of Ah will be determined as follows

In x-direction A_{hx1} for T_{1x} & A_{hx} for T_x
In z-direction A_{hz1} for T_{1z} & A_{hz} for T_z

c. **Calculate the total horizontal shear (the base shear)**

The design value of base shear V_B

$V_B = A_h . W$

as per 1893 Cl.7.5.3, For design of the building and portions thereof, the base shear corresponding to higher of A_{hx} and A_{hx1}, similarly between A_{hz} and A_{hz1} will be taken as minimum design lateral force.

Note: Minimum Value of Design Base Shear: Currently, code IS:1893 (part 1)-2002 does not specify a minimum value of design base shear, but specifies a capping on the design time period in the form of empirical formulae as given above. This may result in very low Design Base Shear Coefficients in case of very high rise buildings. There is a need to provide such a minimum value. Clause 12.8.1.1 of ASCE-07 provides a base value of 1% of Design Base Shear. Until IS code takes a decision, we may adopt the following value for minimum Base Shear coefficient: Zone V: 2.4%; Zone IV: 1.6%; Zone III: 1.1% & Zone II: 0.7%.

d. **Seismic Moments and Forces in Frame Elements**

Calculate the seismic moments and axial forces in the columns, shears and moments in the beams by using the seismic weights on the floors/(column beam joints) through an appropriate computer software (having facility for using floors as rigid diaphragm and torsional effects as per IS: 1893:2002).

It may be performed by Response Spectrum or Time History analysis. The important point is that according to IS: 1893, Cl.7.8.2., the base shear computed by either of the dynamic method, say V_{1B} shall not be less than V_B calculated under Cl.7.5.3 using A_{hx} and A_{hz}. If so, all shears, moments, axial forces etc worked out under dynamic analysis will be increased proportionately, that is, in the ratio of V_B/V_{1B}.

8.5.2 *Strong Column-Weak Beam Design*

Presently this design approach is not provided in Code, IS:1893 (Part1)-2002. For reliable earthquake safety of the tall buildings, it will be necessary to adopt a provision as given below:

All beam-columns joints of frame buildings, the following conditions should be satisfied at each joint :

$$\sum MR_c \geq 1.2 \sum MR_b$$

where:

$\sum MR_c$ = Sum of design values of the moments of resistance of the columns framing into a joint. The minimum value of the column moments of resistance within the range of column axial forces produced by the seismic design situation should be used in this expression.

$\sum MR_b$ = Sum of design values of the moments of resistance of the beams framing into that joint.

8.6 SEISMIC DESIGN OF FLAT SLAB STRUCTURES

In such structural systems, the load is transferred to the column by thickening the slab near the column, using drop panels and/or by flaring the top of the column to form a column capital. The drop panel commonly extends about one sixth of the span each way from each column, giving extra strength in the column region while minimizing the amount of concrete at midspan. The flat-slab type of construction provides architectural flexibility, more clear space, less building height, easier formwork, and, consequently, shorter construction time.

In such cases, slab-column connections must undergo the lateral deformations of the primary lateral load-resisting structural elements without punching failure in order to sustain the gravity loads acting at the instance of earthquake occurrence in addition to unbalanced moments resulting from earthquake lateral forces. It has been suggested that the primary lateral load resisting structural elements, such as shear walls, should be combined with flat plates in seismic zones to keep the lateral drift ratio lower than 1.5%.

8.7 CONCLUDED REMARKS

It may be mentioned that the full ductility details as specified in IS: 13920 permit the use of the High Reduction Factor R=5 which would make the design not only safest but also economical. But if such ductility details are not adopted, the Reduction Factor is permitted as only 3.0, which means that the design force will become 1.67 times the cases when full ductile detailing is adopted, which may indeed turnout to be more expensive and at the same time brittle and relatively unsafe.

Chapter - 9 : Use of Prefabricated Units in Masonry Houses

9.1 INTRODUCTION

This chapter deals with NBC 2005 recommendations regarding modular planning, component sizes, joints, and erection of prefabricated elements for use in buildings. The earthquake resistance aspects in relation to various roofing elements are presented as per IS: 4326-1993.

9.2 PLANS AND SPECIFICATIONS

The detailed plans and specifications should cover the following for the prefabricated units:

a) The drawings should describe the elements of the structure and assembly including all required data of physical properties of component materials, materials specification, age of concrete for demoulding, casting / erection tolerance and type of curing to be adopted.

b) Details of connecting joints of prefabricates must be given to an enlarged scale.

c) Site or shop location of services, such as installation of piping, wiring or other accessories should be shown separately.

d) The drawings should also clearly indicate location of inserts and acceptable tolerances for supporting the prefabricate during erection, location 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, the sequence of erection with critical check points and measures to avoid stability failure during construction stage of the building.

9.3 MODULAR CO-ORDINATION

A basic module is to be adopted. Then further work is necessary to outline suitable range of modules with desired increments. A set of rules as detailed below would be adequate for meeting the requirement of conventional and prefabricated construction.

1. Take the basic module as M
2. The planning grid in both directions of the building plan be taken as 3M.
3. The centre lines of load bearing walls should preferably coincide with the gridlines.
4. The Planning module in the vertical direction be taken as 1M.
5. Preferred increments for sill heights, doors, windows and other fenestration shall be 1M.
6. In the case of internal columns, the grid lines shall coincide with the centre lines of columns.

7. In case of external columns and columns near the lift and stair wells, the grid lines shall coincide with centre lines of the columns in the topmost storey.

9.3.1 Components Dimensioning

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 in multiples of 0.5 M; and
   3. Overall Thickness – Overall thickness in multiples of 0.1 M.

b) Beams
   1. Length -Nominal length shall be in multiples of 1 M;
   2. Width -Nominal width in multiples of 0.1M; and
   3. Overall Depth -Overall depth of the floor zone (that is, from soffit of the beam to the top of in-situ decking) in multiples of 0.1M.

c) Columns
   1. Height- height for columns 1 M, and
   2. Lateral Dimensions – overall lateral dimension or diameter of columns to be in multiples of 0.1 M.

d) Walls
   1. Thickness - The nominal thickness of walls shall be in multiples of 0.1M.

e) Staircase
   1. Width - Nominal width shall be in multiples of 1 M.

9.3.2 Casting Tolerances of Precast Components

Product tolerances as specified in length and thickness of prefabricate in NBC 2005 - Section 7A should be used in casting the products.

9.4 PREFABRICATION SYSTEMS

The system of prefabricated construction depends on the extent of the use of prefab components, their materials sizes and the technique adopted for their manufacture and use in building.

9.4.1 Type of Prefabrication Components

The prefabricated concrete components such as those given below may be prepared using plains, reinforced or prestressed concrete.

1. Channel units
2. Slabs unit
3. Beams
4. Columns
5. Hollow core slab
6. Waffle slab / shells
7. Wall elements
8. Hollow / solid blocks and battens
9. Precast planks and joists for flooring and roofing
10. Precast joists and trussed girders
11. Light weight / cellular concrete slabs
12. Precast lintel and chajjas
13. Roof purlins
14. L-panel unit
15. Prefabricated sandwich concrete panel

There may be other types of components.

9.4.2 *Categories of Open Prefab System*

There are two categories of open prefab system:

a) *Partial Prefab System*
This system basically emphasizes the use of precast roofing and flooring components and other minor elements like lintels, chajjas, and kitchen sills in conventional building construction.

b) *Full Prefab Open System*
In this system almost all the structural components are prefabricated.

c) Large Panel Prefab 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.

9.5 DESIGN CONSIDERATIONS

9.5.1 *Analysis*

The precast structure should be analyzed as a monolithic one and the joints in them are designed to take the forces of an equivalent discrete system. Resistance to horizontal loading is provided by placing shear walls (in diaphragm braced frame type of construction) in two directions at right angles. 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 should be designed, taking into consideration the appropriate end conditions and loads at various

stages of construction. In addition, members should be designed for handling, erection and impact loads that might be expected during handling and erection.

9.5.2 *Buttressing*

Adequate buttressing of external wall panels is important since these elements are not fully restrained on both sides by floor panels. Experience shows that the external wall panel connections are the weakest points of a precast panel building.

9.5.3 *Restraints*

It is 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.

It is 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.

9.5.4 *Bearing for Precast Units*

Precast units shall have a bearing at least of 100 mm on masonry supports and 75 mm at least on steel or concrete. Steel angle shelf bearings shall have a 100 mm horizontal leg to allow for a 50mm 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, should be taken into consideration.

9.6 JOINTS

9.6.1 *Requirements of an ideal structural joint:*

a) to be capable to transfer the imposed load and moments with a known margin of safety;
b) to be provided at logical locations in the structure and at points which may be most readily analysed and easily reinforced;
c) to support the loads without marked displacement or rotation and avoid high local stresses;
d) to accommodate tolerances in elements;
e) to require little temporary support, permit adjustment and demand only a few distinct operations;
f) to permit effective inspection and rectification;
g) to be reliable in service with other parts of the building;
h) to also enable the structure to absorb sufficient energy during earthquakes so as to avoid sudden failure of the structure.

Precast structures may have continuous or hinged connections capable to providing sufficient rigidity to withstand vertical loads as well as horizontal loading.

9.6.2 Joining techniques/ materials

The following are usually adopted:

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) Use of shear connector 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.

9.7 FLOORS / ROOFS WITH SMALL PRECAST COMPONENTS

Earthquake resistance measures for floors in roofs with small precast units are dealt with in IS: 4326-1993. The basic issues of safety of such roofs and floors constructed using these components are:

a. Integration as a slab.
b. Achieving leak proof roof.
c. Strengthening the action of the roof or floor as rigid diaphragm.

The various details are explained in the following paragraphs, as outlined in IS:4326-1993.

9.7.1 Types of Precast Flooring /Roofing Units

The various units considered in IS: 4326 are:

a. Precast reinforced concrete channel unit.
b. Precast reinforced concrete cored / slab unit.
c. Precast reinforced concrete plank and joists scheme.
d. Prefabricated brick panel unit.
e. Precast reinforced concrete waffle unit.

The construction of floor / roof slab using above units are described below:

a) Precast Reinforced Concrete Unit Roof/Floor (Fig 9.1)

The unit is a precast reinforced concrete channel (inverted trough) shaped in section. The nominal width of the unit varies from 300 to 600 mm, its height from 150 to 200 mm and a minimum flange thickness of 30 mm. Length of unit shall vary according to room dimensions, but the maximum length is restricted to 4.2 m from stiffness considerations. Horizontal corrugations are provided on the two longitudinal faces of the units so that the structural roof/floor acts monolithic after concrete grouted in the joints between the units attains strength.

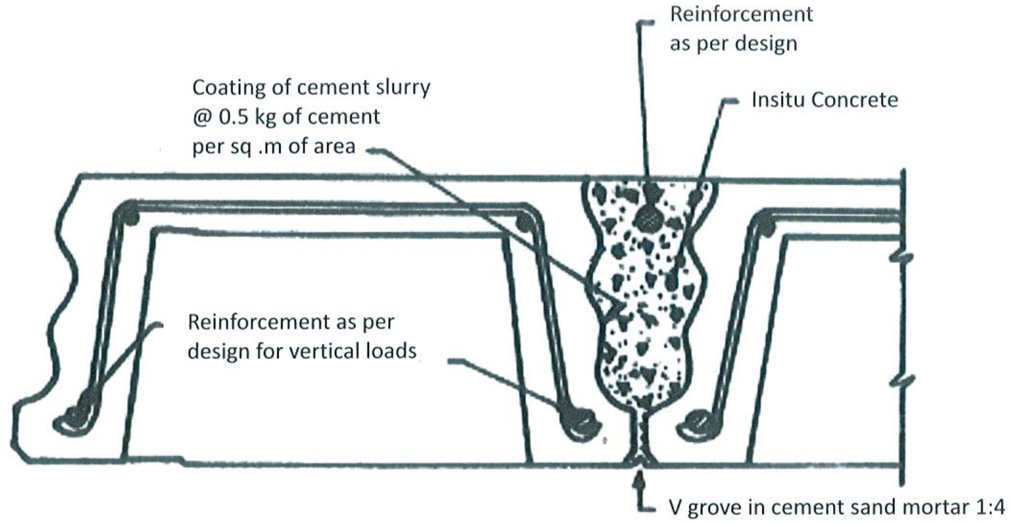


Figure 9.1: Channel Unit Floor

b) Precast Reinforced Concrete Cored Unit Roof/Floor (Fig. 9.2)

The unit is a reinforced concrete component having a nominal width of 300 to 600 mm and thickness of 130 to 150 mm having two circular hollows 90 mm diameter, throughout the length of the unit. The minimum flange/web thickness of the unit shall be 20 mm. Length of unit varies according to room dimensions, but the maximum length restricted to 4.2 m from stiffness considerations.

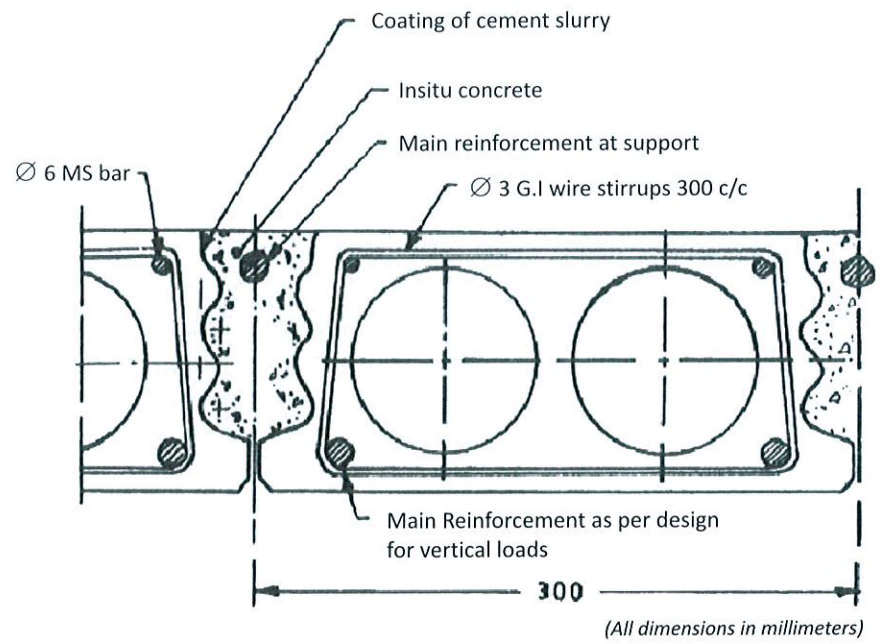


Figure 9.2: Cored Unit Floor

c) Precast Reinforced Concrete Plank and Joist Scheme for Roof/Floor (Fig. 9.3)

The scheme consists of precast reinforced concrete planks supported on partially precast reinforced concrete joists. The reinforced concrete planks are 300 mm wide and the length varies according to the spacing of the joists, but it shall not exceed 1.5 m. To provide monoliths to the roof/floor and to have T-beam effect with the joists, the planks shall be made partially 30 mm thick and the partially 60 mm thick and in-situ concrete shall be filled in the depressed portions to complete the roof/floor structurally.

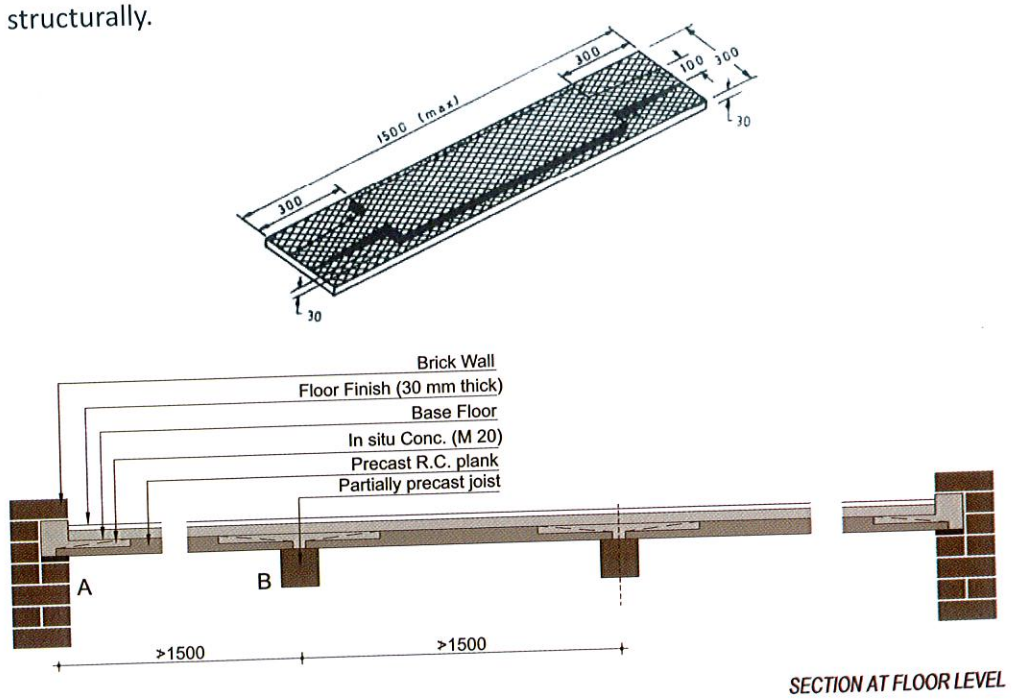


Figure 9.3: Precast Reinforced Concrete Plank Floor

d) Prefabricated Brick Panel System for Roof/Floor (Fig. 9.4)

It consists of prefabricated reinforced brick panels supported on precast reinforced concrete joists with nominal reinforced 35 mm thick structural deck concrete over the brick panels and joists. The width of the brick panels shall be 530 mm for panels made of bricks of conventional size and 450 mm for panels made of bricks of modular size. The thickness of the panels shall be 75 mm or 90 mm respectively depending upon whether conventional or modular bricks are used. The length of the panels shall vary depending upon the spacing of the joists, but the maximum length shall not exceed 1.2 m.

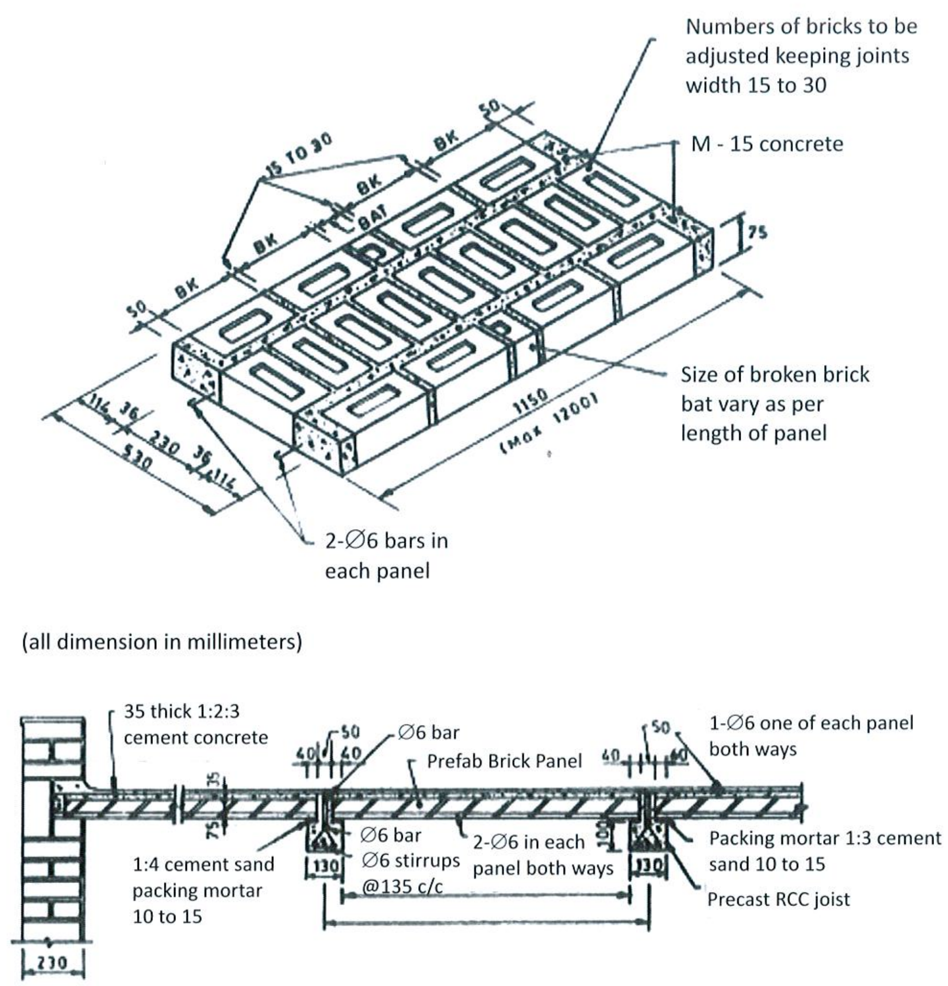
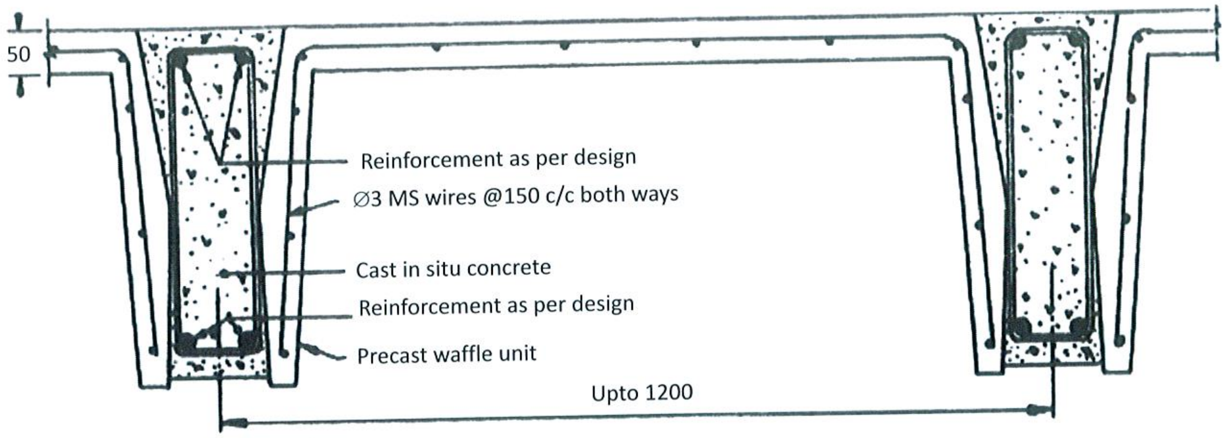


Figure 9.4: Brick Panel Floor

e) Precast Reinforced Concrete Waffle Unit Roof/Floor (Fig. 9.5)

Waffle units are of the shape of inverted troughs, square or rectangular in plan, having lateral dimensions up to 1.2 m and depth depending upon the span of the roof/floor to be covered. The minimum thickness of flange/web shall be 35 mm. Horizontal projections may be provided on all the four external faces of the unit and the unit shall be so shaped that it shall act monolithic with in-situ concrete to ensure load transfer. Vertical castallations, called shear keys, shall be provided on all the four external faces of the precast units to enable them to transfer horizontal shear force from one unit to adjacent unit through in-situ concrete filled in the joints between the units. The waffle units shall be laid in a grid pattern with gaps between two adjacent units, and reinforcement, as per design, and structural concrete shall be provided in the gaps between the units in both the directions. The scheme is suitable for two way spanning roofs and floors of buildings having large spans.



(all dimension in millimeters)

Figure 9.5: Waffle Unit Floor

9.7.2 *Seismic Resistance Measures*

All floors and roofs to be constructed with small precast components shall be strengthened as specified for various categories of buildings. The strengthening measures are detailed below.

i) *Vertical castellation,* called shear keys are provided on the longitudinal faces of the channel, cored and waffle units to enable them to transfer horizontal shear force from one unit to the adjacent unit through the in-situ concrete filled in the joints between the units.

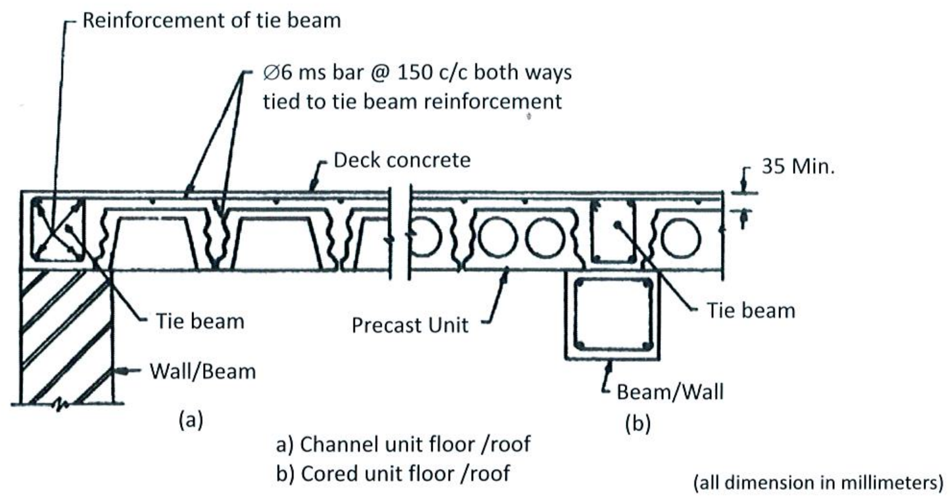
ii) *Tie beam* is a beam provided all round the floor or roof to bind together all the precast components to make it a diaphragm. The beams shall be to the full width of the supporting wall or beam less the bearing of the precast components. The depth of the beam shall be equal to the depth of the precast components plus the thickness of structural deck concrete, used over the components. The beam shall be made of cement concrete of grade not leaner than M15 and shall be reinforced as was detailed in Table 7.3 for the seismic bands. If depth of tie beam is more than 75 mm, equivalent reinforcement should be provided with one bar of minimum diameter 8 mm at each corner. Tie beams shall be provided on all longitudinal and cross walls.

Top reinforcement in the channel or cored units shall be projected out at both the ends for full anchorage length and tied to tie beam reinforcement.

iii) *Deck Concrete* is used in all cases of such roofs / floors so as to integrate their structural strength as a rigid horizontal diaphragm as well as to make them leak proof. Structural deck concrete of grade not leaner than M15 is provided over precast components to act monolithic with them. Wherever, deck concrete is provided, the top surface of the components is finished rough. Cement slurry with 0.5 kg of cement per sq.m of the

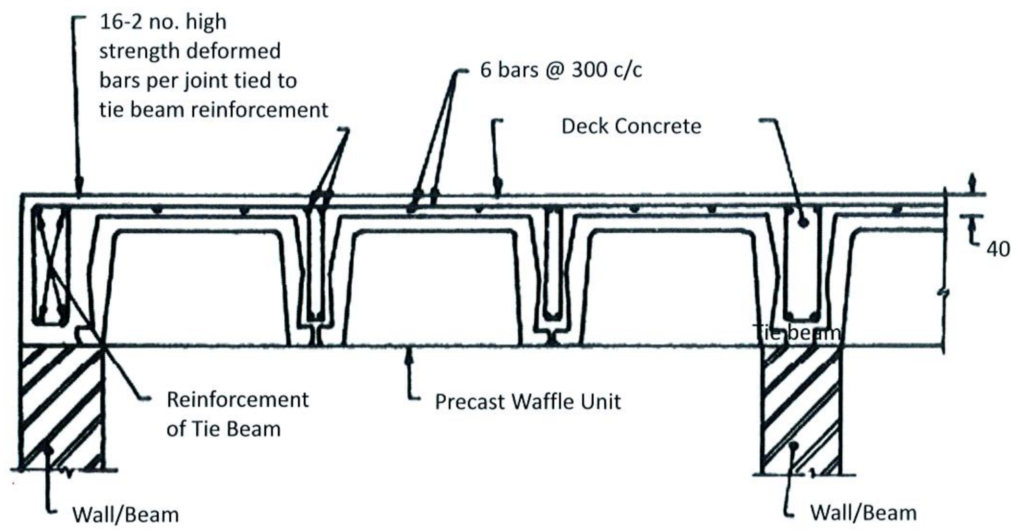
surface area is applied over the components immediately before laying the deck concrete and the concrete is compacted using plate vibrators. The minimum thickness of deck concrete shall be 35 or 40 mm reinforced with 6 mm dia bars @ 150 mm apart both ways and anchored into the tie beam placed all round.

Typical details of the beams and desk concrete are shown in Fig. 9.6 & Fig.9.7 for various precast units.



(all dimension in millimeters)

Figure 9.6: Connection of Channel/Cored Unit Floor/Roof (with Deck Concrete) with Tie Beam



(all dimension in millimeters)

Figure 9.7: Connection of Precast Waffle Unit Floor/Roof (with Deck Concrete) with Tie Beam

Chapter - 10 : Non Structural Building Elements

10.1 STRUCTURAL & NON-STRUCTURAL ELEMENTS

The "structure" is the part of the building that is designed to carry the weight of the building (dead load), its contents and people (live load), and the impact of wind and ground- shaking (dynamic load). The structural elements differ in each type of building, but generally they include the foundation, columns, slab, beams, and load-bearing walls. The biggest danger is from those buildings that have not been designed, constructed, or maintained to withstand expected imposed loads and earthquake shaking. Another dangerous issue is weak foundations and those resting on soft strata with high ground water table.

The non-structural building elements include the stairways, windows, chimneys, balconies, chhajjas parapets, wall cladding and partitions. When a building is totally damaged and collapsed, everything in the building is crushed and lost. But some of the deaths, many or most of the injuries, a large proportion of economic damage, destruction and disruption associated with earthquakes are caused by non-structural building elements and loss of building contents. extreme wind velocities higher than 30 m/s or 100 km/h can cause failure of parapets, external wall claddings and boundary walls if not properly designed. Occurrence of floods may lead to collapse of boundary walls and those built using mud or weak lime sand mortar. The safe design aspects of such building elements are dealt in this chapter.

10.2 VERTICAL CANTILEVER ELEMENTS

The elements that fall in this category are parapets, water tanks, smoke chimneys and light weight barsatis, projecting above the roof and attached to the building. These elements and their connections with the roof structure have to be designed for the imposed load, the wind loading as per IS: 875 (Part-3) -1987 and the earthquake loading as per IS: 1893 (Part 1)-2002.

10.2.1 Imposed Horizontal Load on Parapets (NBC 2005, Part 6 Section 1-3.5.1)

Parapets, parapet walls and balustrades, together with the members which give them structural support, shall be designed for the minimum loads given in Table 10.1. These are expressed as horizontal forces acting at handrail or coping level. These loads should be considered to act vertically also but not simultaneously with the horizontal forces. The values given in Table 10.1 are minimum values and where values for actual loadings are available, they may be used instead.

Table 10.1 Imposed Loads on Parapets

Sl. No.	Usage Area	Intensity of Horizontal Load kN/m run
1.	Light access stairs, gangways and like, not more than 600 mm wide	0.25
2.	Light access stairs, gangways and like, more than 600 mm wide, stairways, landings, balconies and parapet walls (private part of dwellings)	0.35
3.	All other stairways, landing and balconies and all parapets and handrails to roofs (except those subject to overcrowding covered under Sr.No.4)	0.75
4.	Parapets and balustrades in places of assembly, such as theaters, cinemas, temples and churches, schools, places of entertainment, sports buildings likely to be overcrowded.	2.25

10.2.2 Horizontal Wind Pressure on individual elements (NBC 2005 Part 6, Section 1-4.4.4)

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 wind pressure difference between opposite faces of such elements. It is, therefore, necessary to know the pressure on windward and leeward faces. Then the wind load acting in a direction normal to the individual element is:

$$F = (C_{pe} - C_{pi}) A P_d$$

where

C_{pe} = windward, and
C_{pi} = leeward pressure coefficient
A = Surface area of structural element in m^2; and
P_d = design wind pressure in N/m^2

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. The 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:

i) 1.25, if the overhanging slopes; downwards;
ii) 1.0, if the overhanging is horizontal; and
iii) 0.75, if the overhanging slope upwards, looking like parapet.

For overhanging portions (parapets) on sides other than windward side, the average pressure coefficients on the adjoining walls may be used.

10.2.3 Horizontal Earthquake Load (IS: 1893 (Part 1) -2002 - 7.12.2.1)

The vertical cantilever projections attached to buildings and projecting above the roof, water tanks, barsatis etc. (viz. parapets, smoke chimneys) shall be designed and checked for stability for *five times* the design horizontal seismic coefficient A_h specified for the building. In the analysis of the building, the weight of these projecting elements shall be lumped with the roof weight.

The increased design forces specified in IS: 1893 (Part 1)-2002 - 7.12.2.1 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.

10.2.4 Compound Boundary Walls

Compound walls shall be designed for the wind pressures at ground level and design horizontal seismic coefficient A_h with importance factor I =1.0 without any increase, taken separately. Where rain water can be collected to a certain height on one side of the wall, the hydrostatic water pressure should be included along with wind or earthquake force which ever found more severe.

10.2.5 Force Application for design

In applying the horizontal force for the design of cantilever elements like parapets, the imposed lateral load as per 10.2.1 will act on the top of the parapet towards the outside of the building. The same live load will also be assumed to act vertically downwards as if the people are sitting on top of the parapet.

The horizontal wind load or the earthquake load will be assumed to occur from inside to outside and from outside to inside, i.e. the loads may be considered reversible in direction.

The parapet wall and the balustrades will be reinforced on both faces of the wall and anchored into the reinforced concrete floor or roof slab. The moments created at the base of the parapet shall be transferred to the slab for which the slab should be designed with reinforcement on top and bottom faces of the slab.

10.3 HORIZONTAL CANTILEVER ELEMENTS

10.3.1 Imposed Load

The elements in this category will include balconies and cornices etc. subjected to imposed floor loads, parapet load effects, and the earthquake load. The imposed load should be taken as follows (NBC 2005, Part 6, Section 1, Table 1).

For residential buildings	3 kN/m^2 on area of the balcony along with 1.5 kN/m concentrated line load on outer edge.
For educational, office, hospital, hotel, etc.	Same as rooms to which they give access but with a minimum of 4.0 kN/m^2 along with a concentrated line load of 1.5 kN/m on the outer edge.

10.3.2 Earthquake Load

According to IS: 1893 (Part-I)-2002, the horizontal cantilever projections like balconies should be designed for seismic coefficient of *five time* the design vertical coefficient which is taken as 2/3 of horizontal seismic coefficient A_h. Thus the design vertical coefficient for the balcony will become 10/3 A_h.

10.3.3 Design of Cantilever Balconies

It is important to note that the stability of the balcony, if anchored in a wall, should be checked by taking the seismic force downwards and the stabilizing weight should be assumed to have the seismic force upward. If the balcony slab is made continuous with the floor/roof slab, the reinforcement of the balcony should be anchored in the slab for sufficient length to engage the appropriate weight of the slab.

10.3.4 Masonry Partition Walls

In India, masonry walls are used as infill walls in both the interior and exterior RC frames as partitions and cladding walls respectively. The material of the masonry infill is the main variant, ranging from cut natural stones (e.g granite, sandstone or laterite) to manmade bricks and blocks (e.g. burnt clay bricks, solid and hollow concrete blocks and hollow tiles).

Performance of such buildings in past earthquakes has revealed that the presence of masonry infill walls is somewhat detrimental for the seismic performance of the building frame. Masonry infill walls should not be used unless they are specifically designed by an engineer to work in conjunction with the frame to resist the lateral loads, or to remain isolated from the frame.

Some designers and builders believe that the presence of masonry infill in the frame panels improves earthquake performance to some extent. It can only be true if the building has been carefully designed by an engineer so the infill walls provide the bracing effect without failing the frame or themselves. A bare frame (without infills) must be designed to resist the full earthquake effects. Infill walls should be uniformly distributed in the building. Masonry infills should not be discontinued at any intermediate story or the ground storey level; this would have an undesirable effect i.e. causing soft storey effects.

Infill walls act as diagonal struts and increase the stiffness of RC frame building. The increase in the stiffness depends on the wall thickness and the number of frame panels with infills, and can be quite significant in some cases. The increased stiffness of the building due to the presence of infills reduces the ability of the frame to bend and deform. In ductile RC frames, masonry infills may prevent the primary frame elements (i.e., columns and beams) from responding in ductile manner. Instead, such structures may show a non-ductile (brittle) performance.

When ductile RC frames are designed to withstand large displacements without collapse, masonry infills should be isolated from the frame by a sufficient gap. In this manner, masonry infill walls do not affect the frame performance and frame displacements are not restrained. Another advantage of the isolated masonry infill is that the walls remain undamaged, thereby reducing post-earthquake repair costs. However, from the point of view of controlling weather and acoustic conditions inside the building, the gaps need to be sealed with an elastic material. These provisions may be expensive and require good construction details to be executed with precision.

Unreinforced brick partitions that are only half or one brick thick can crack and fall into rooms or outward to the ground outside, as the building moves back and forth in an earthquake. Large portions of the wall, or even the whole wall can topple, if the wall is not anchored to the concrete beams and columns in some way.

The issue in isolating masonry infill walls from RC frames is that such walls become susceptible to collapse in the out of plane direction, i.e., in the direction perpendicular to the wall surface. This is particularly pronounced when the storey height is large or when the column spacing is large. Once masonry walls crack, continued shaking can easily cause collapse in the heavy infill blocks and pose a serious life safety threat to building inhabitants, particularly in hospital wards.

10.3.5 Design of partition walls

The masonry partition walls in the form of infills in the internal frames are subjected to their self weight and lateral seismic force acting transverse to the wall at the floor level of the building. The design force for partition walls at various floors of the buildings will vary from the ground floor to the top floor, increasing towards the top. The design of the walls between the columns and beams must consider such forces based on its self mass. Also

supporting elements where used to save the wall from toppling over, shall be designed for these lateral forces. The following design options are suggested.

i) To anchor the brick partition walls using steel angles or channels connected to floor and ceiling at a spacing of about 1.5 m.
ii) To provide a fiber-reinforced polymer or micro-concrete (with woven wire mesh reinforcement) overlay on the wall and connected to the beam.
iii) Full-height partitions can also be detached from the columns, and a steel angel used to connect the top of the wall to the ceiling to prevent toppling.
iv) A simpler method will be to provide a thin RC seismic band at door lintel level connected with the RC columns.

10.3.6 Design of Cladding Walls

External cladding walls of the buildings are subjected to wind pressures on their face acting from outside and suction pressures on the inside face. The stability of the cladding walls whether constructed using masonry or glass plates must be checked for safety under such wind pressures and suctions. Like the inner partition walls, the cladding walls will also be subjected to seismic forces perpendicular to their face which will be increasing from storey to storey in the building upwards. The walls as well as their supports, if any, will have to be designed for such seismic forces.

10.4 SEISMIC DESIGN OF STAIRCASES

Referring to IS: 4326-1993, the interconnection of the stairs with the adjacent floor should be appropriately treated by providing sliding joints so as to eliminate their rigid connections which would create bracing effect on the floor of the building. Experience in past earthquakes shows that the forces generated due to bracing effect on stair flights has led to severe cracking and damage at the connection of flights with landings at one end and the slabs at the other end.

There are three staircase connection specified in the IS Code which are:

i) Separated Stair Case from the building frame by providing a separation joints between stair hall and the frame.
ii) Built in stair case boxed in a rigid wall system which is separated from the building frame.
iii) Stair case with sliding joints in which the flights have sliding joints on a reinforced concrete beam of the building frame at every floor level.

The details of the above systems are provided in the IS 4326-1993.

ABOUT BMTPC

Building Materials & Technology Promotion Council under the aegis of the Ministry of Housing & Urban Poverty Alleviation is an autonomous organization dedicated to promote and popularize cost effective, eco-friendly and energy efficient building materials and disaster resistant construction technology. BMTPC works as a Technology Transfer Council and helps various stakeholders involved in the construction industry for technology development, production, mechanization, implementation, standardization, certification & evaluation, training & capacity building and entrepreneur development. Over the last two decades, BMTPC has expanded its activities and made commendable efforts in the area of disaster mitigation and management.

Ever since 1991 Uttarkashi earthquake, BMTPC has been pro-actively involved not only in seismic rehabilitation but also in the area of prevention, mitigation & preparedness as regards earthquake safety is concerned. The much acclaimed publication of BMTPC entitled 'Vulnerability Atlas of India' is one of its kind which depicts the vulnerability of various man made constructions in different districts of India not only from earthquake hazards but also from Wind/Cyclone and Flood hazards. Efforts of BMTPC were applauded well and in the process UN Habitat selected the same as one of the Best Practices. It is being BMTPC's endeavour to constantly publish guidelines, brochures, pamphlets on natural hazards so as to educate the common man and create capacities within India. Some of the recently published documents of BMTPC on disaster are:-

1. Guidelines : Improving Earthquake Resistance of Housing
2. Guidelines : Improving Flood Resistance of Housing
3. Guidelines : Improving Wind/Cyclone Resistance of Housing
4. Manual on Basics of Ductile Detailing
5. Building a Hazard Resistant House, a Common Man's Guide
6. Manual for Restoration and Retrofitting of Buildings in Uttarakhand & Himachal Pradesh.

These documents are important tools for safety against natural hazards for various stakeholders involved in disaster mitigation and management. Apart from publications, the Council is also involved in construction of disaster resistant model houses and retrofitting of existing life line buildings such as Schools/Hospitals to showcase different disaster resistant technologies and also spread awareness amongst artisans and professionals regarding retrofitting and disaster resistant construction.

BMTPC joined hands with the Ministry of Home Affairs to draft Model Building Bye-laws incorporating disaster resistance features so that State/UT Governments incorporate them into their municipal regulations and prepare themselves against natural hazards. One of the very basic publications of BMTPC with IIT, Kanpur has been 'Earthquake Tips' which was specially designed and published to spread awareness regarding earthquake amongst citizens of India in a simple, easy to comprehend language. The Tips are being published in other languages also so that there is greater advocacy and public out reach regarding earthquake safety.

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