

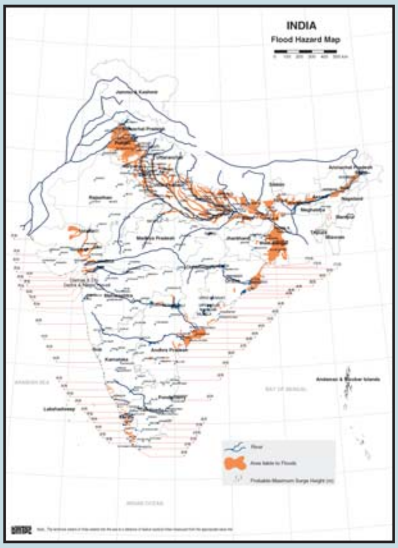




Guidelines

Improving Flood Resistance of Housing

2010



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

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Improving Flood Resistance of Housing

bmtpc

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Phone: +91-11-24638096, Fax: +91-11-24642849
E-Mail: bmtpc@del2.vsnl.net.in
Website: http://www.bmtpc.org

FOREWORD

Ever since the Kosi floods of 2008 inflicted damages and loss of lives in a colossal way, BMTPC thought of publishing the guidelines on improving flood resistance of housing which not only dwells upon the planning aspects of houses in flood prone areas but also on construction technologies to be adopted to make them safe in the event of inundation. I am happy to bring out the first ever comprehensive guidelines on flood resistance for the people of India who do not have any access to design, technologies and other paraphernalia. The guidelines are written in simple and easy to understand language and can easily be implemented at field. The publication is the updated version of BMTPC's earlier version of the guidelines which was drafted by Padamshree Prof. Anand S. Arya with the approval of expert group.

It is to be stressed here that India is a country where we have many natural hazards such as earthquakes, cyclones, floods, tsunamis etc. and it is high time that we build in safety culture in our construction practices. Also, there is need of greater outreach and advocacy amongst the masses regarding long lasting disastrous impact of these hazards.

I hope the information given in the guidelines would serve as a useful repository for all stakeholder involved in planning and rehabilitation of flood affected areas.

I place on record my deep and humble appreciation for Dr. Arya, Professor Emeritus, IIT, Roorkee who painstakingly prepared these guidelines.

10th Day of May 2010

Dr. Shailesh Kr. Agrawal
Executive Director, BMTPC

PREFACE

Flood damage to housing, infrastructure, and agriculture has been occurring in India since long times and the problem attracted great attention since independence. However, the causes and nature of damage to *housing* was not studied systematically, nor methods regarding flood safety of housing given due attention.

After the severe floods in Punjab, Haryana and Delhi in 1995, the opportunity of first hand study of building performance during these floods was utilized by commissioning a study by Building Materials and Technology Promotion Council. TARU for Development were assigned the task, who submitted their report titled “Flood Damage Assessment for the North-West Indian Flood of September, 1995” to BMTPC in March 1996. Using the observations, damage assessment and suggestions contained in the report, a preliminary set of guidelines were drafted by Dr. A.S. Arya and Shri S.K. Chaudhuri.

Since then floods have been occurring almost every year in Brahamputra & Barak valleys in Assam, the northern river plains in Bihar and Eastern river plains in Uttar Pradesh in which lakhs of poor man’s huts and homes have been destroyed. The worst floods were caused in five districts of Bihar in 2008 due to the bursting of embankment of River Kosi and diversion of the river flow into an old abandoned course. The safety of the flood impacted population will need reconstruction of houses which should not only be safe against flood damage to foundations *due to scouring and settlement*, and the walls of mud or bamboo, but will also be able to withstand the severe damage under future earthquakes.

These guidelines not only provide design and construction details of small houses but also include recommendations for specifying appropriate clauses in the Building Bylaws. The design of a simple, economical and safe house for construction in flood-cum-earthquake prone areas is presented with sufficient details for easy adoption by governments, NGOs and people themselves.

10th Day of May 2010

Dr. Anand S. Arya
Professor Emeritus, IIT Roorkee

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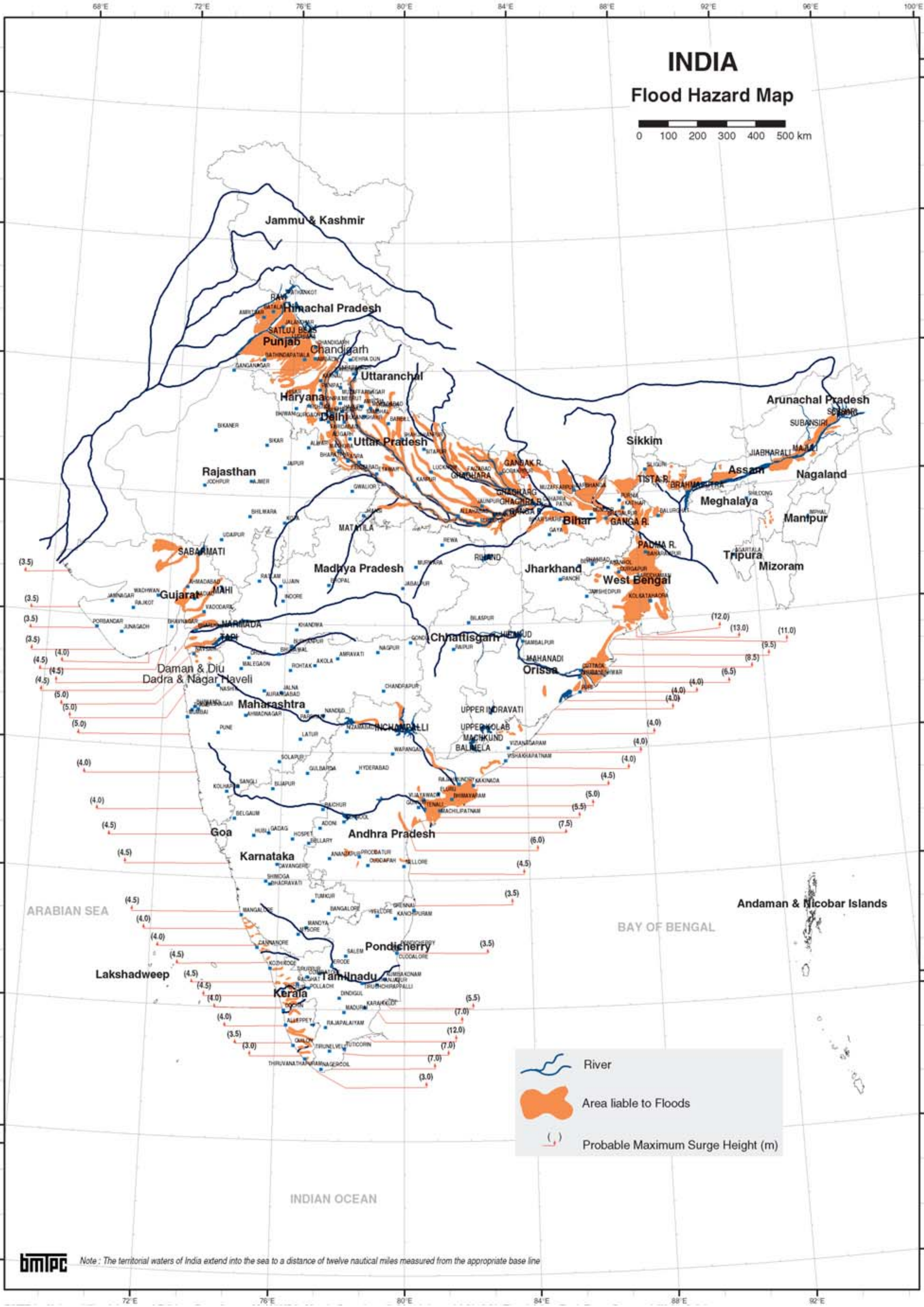


BMTPC : Vulnerability Atlas of India – 2nd Edition (2006); Peer Group, MoH&UPA; Map is based on digitised data of SOI, GOI; Flood Atlas, Task Force Report, C.W.C., GOI.

Fig. 1: Flood Hazard Map of India

IMPROVING FLOOD RESISTANCE OF BUILDINGS: GUIDELINES

1. THE PROBLEM OF FLOODS IN INDIA

1.1 Floods-A Natural Disaster

Floods have been recurrent natural phenomena in India from times immemorial. Almost every year in the summer monsoon season, floods of varying magnitude affect some parts of the country or the other. The country receives the maximum rainfall during the south-west (SW) monsoon for a period starting from the first week of June to the end of September.

1.2 Flood Prone Regions in India

The flood hazard prone areas in India can be seen from Flood Hazard Map of India as shown in Fig. 1. From the flood proneness consideration, the country can be broadly divided into the following four regions.

i. ***The Brahmaputra River Plains:***
This region consists of the rivers Brahmaputra and Barak and their tributaries, and covers the states of Assam, Arunachal Pradesh, Meghalaya, Mizoram, Manipur, Tripura, Nagaland, Sikkim and the northern parts of West Bengal.

ii. ***The Ganga River Plains:***
The river Ganga has many tributaries, the important ones being Yamuna, Sone, Ghaghra, Raphti, Gandak, Burhi Gandak, Bagmati, Kamla Balan, Adhwara group of rivers, Kosi and the Mahananda. It covers the states of Uttarakhand, Uttar Pradesh, Jharkhand, Bihar, south and central parts of West Bengal, parts of Punjab, Haryana, Himachal Pradesh, Rajasthan, Madhya Pradesh and Delhi. The flooding and erosion problem is serious in the states of Uttar Pradesh, Bihar and West Bengal.

iii. ***The North-West River Plains:***
The main rivers in this region are the Indus, Sutlej, Beas, Ravi, Chenab and Jhelum. This region covers the states of Jammu and Kashmir, Punjab and parts of Himachal Pradesh, Haryana and Rajasthan.

iv. ***The Central India and Deccan Region:***
Important rivers in this region are the Narmada, Tapi, Mahanadi, Godavari, Krishna and Cauvery. These rivers have mostly well defined and stable courses. They have adequate capacities within the natural banks to carry the flood discharge except in the delta areas. This region covers the states of Andhra Pradesh, Karnataka, Tamil Nadu, Kerala, Orissa, Maharashtra, Gujarat and parts of Madhya Pradesh. The region does not have serious flood problem except that some of the rivers in Orissa State namely Mahanadi, Brahmini, Baitarni, and Subarnarekha are prone to floods every year.

In addition to the above regions on the main land, the Andaman and Nicobar Islands and the Lakshadweep islands have their own characteristics, which result in drainage congestion, flooding and erosion in their coastal areas.

Note: Flood prone Districts with more than or equal to 10 percent area under floods risk in various States are listed in Annexure-1.

1.3 Estimate of Flood Prone Area

According to the estimate of the Rashtriya Barh Ayog (National Commission on Floods) the area prone to floods in the country is of the order of 400 lakh hectares, out of which it is considered that 80 percent, that is 320 lakh hectares can be provided with a reasonable degree of protection by various types of structural measures.

1.4 Flash Floods

Flash floods are characterised by very fast rise and fall of water flow having high discharge, although the total volume may be small. It causes high damages because of its suddenness. The hilly areas, viz. Arunachal Pradesh, Assam, Himachal Pradesh, Uttarakhand, the Western Ghats in Maharastra and Kerala are more vulnerable to flash floods which are caused by cloud bursts. Sudden release of waters from upstream reservoirs, breaches in landslide dams and the embankments on the banks of rivers lead to disastrous flash floods.

1.5 Urban Flooding

Historically, towns have developed along river courses, and grown into larger cities faster on account of increase/influx of population. Owing to lack of land-use zoning regulation/control, there has been continuing encroachment of the flood plains. Damages have become serious as a result of inadequate capacity of storm water drainage system. The problem of urban flooding has increased seriously as evidenced by the recent floods in Mumbai and Surat, etc.

1.6 Damages and Losses Caused by Floods in India

Floods have been causing loss of human and cattle lives, damage to crops and habitations, displacement of large populations due to damage to housing and publics utilities, as well as huge economic loss year after year.

More than the loss of life and damage to property, the sense of insecurity and fear in the minds of people living in the flood plains is a cause of great concern. The after-effects of floods such as the agony of survivors, spread of epidemics, non-availability of drinking water, essential commodities and medicines, loss of the dwellings, etc. make floods among the most feared natural disasters faced by mankind.

Highlights of the flood damages in India from 1953 to 2005 are given in *Table 1*. As a consequence of the losses due to floods, large sums are spent yearly on rescue, relief and rehabilitation of flood affected population.

Table 1: Highlights of the flood damages in India (1953 to 2008)

Item of Damage/ Loss	Maximum during the year	Average 1953 to 2008
Area affected(in lakh hectares)	175 (1978)	73.75
Crop area affected(in lakh hectares)	151.8 (2005)	37.29
Population affected(in crores)	7.045 (1978)	3.273
Houses damaged(in lakhs)	35.1 (1978)	12.2
Cattle heads lost	618,248 (1979)	91,695
Human lives lost	11316 (1977)	1627
Value damage to crops (in Rs.crores)	4246.6 (2000)	704.58
Value of damage to houses (in Rs.crores)	1307.9 (1995)	282.30
Value of damage to public utilities (in Rs.crores)	5604.46 (2001)	817.8
Total damages (in Rs. crores)	8864.54 (2000)	1824.2

Source: Central Water Commission, Flood Management Planning Director (Communication dated 19.1.2010).

2. SCOPE OF THE GUIDELINES

2.1 The guidelines deal with the design and construction aspects for improving resistance of housing against flood and rain damage.

2.2 The provisions of these guidelines are applicable to all buildings used for housing in general and particularly to those with walls made from *clay mud* or those built with building units such as *clay blocks*, stones or burnt bricks laid in *mud* mortar.

3. CAUSES OF FLOODS

3.1 River flooding results from abnormally high precipitation rates, cloud bursts or rapid snow melt in catchment areas, bringing more water into the hydrological system which cannot be adequately drained within existing river channels, reservoir and canal systems. It is mostly caused due to inadequate capacity of the rivers to contain within their banks the high flows coming down from the upper catchment areas.

3.2. The sedimentation of river beds, deforestation of catchment areas and location of structures like barrages, bridges, spurs and embankments that cause flow concentrations can accentuate these conditions leading to floods. The tendency to carry out development works in the flood plains has been causing drainage congestion problem.

Notes:

1. *The 1995 floods in North-Western India were caused by excessive precipitation over a wide area that lead to overloading of the drainage system. In addition to this load, the coordination between water regulation agencies in adjoining states of Punjab, Haryana, Delhi and UP was less than adequate. This led to larger inundation of upstream areas as down-stream barrages were closed. In many areas natural drainage had been modified by the construction of canals, roads and railway lines, without adequate cross-drainage arrangements.*
2. *The 2008 flood in Bihar were caused by a breach in the Kosi River embankment due to which the flood flow took the route along the old abandoned course of the river causing large scale devastations of the habitations.*

3.3 Other factors contributing to increased flooding are silting of the river beds between the protection bunds, reduction in the carrying capacity of river channels, erosion of beds and banks leading to changes in river course, obstruction to flow due to landslides, synchronisation of floods in the main and tributary rivers and retardation due to tidal effects in the delta regions.

4. FLOOD MITIGATION MEASURES

The flood mitigation measures may be categorized in (i) Structural and (ii) Non-Structural Measures as described here below:

4.1 Structural Measures

These measures aim at prevention of flood from entering and impacting the habitations. These include the construction of embankments on the banks of the river channels; protection of towns; raising of villages above the high flood level; damming of rivers, etc. Since 1954 (upto March, 2006), 33928 km of new embankments and 38809 km of drainage channels have been constructed in the country. In addition, 2450 town protection works have been completed and 4721 villages have been raised above flood levels. Barring occasional breaches in embankments, these works have given reasonable protection to an area of about 182 lakh hectares.

4.2 Non-structural Measures

These measures will include: Flood forecasting, adoption and enforcement of flood plain zoning, land use zoning regulations in cities and towns, and consideration of adequate drainage of water in the master plans. Flood plain zoning is not only necessary in the case of floods by rivers but it is also useful in reducing the damage caused by drainage congestion particularly in urban areas where, on grounds of economy and other considerations, urban drainage is not designed for the worst conditions and presupposes some damage during storms whose magnitude frequently exceeds that for which the drainage system is designed. But there is hardly any programme towards such zoning measures in the country as yet.

4.3 Prior Action before construction of Buildings in Flood Prone Areas

For the construction of buildings in the flood prone areas, the following basic requirements are to be taken care of:

(i) Preparation of large-scale maps (1:10,000 or 1:15,000) of the area vulnerable to floods with contours at an interval of 0.3 m or 0.5 m;
(ii) Demarcation of areas liable to inundation by rains or floods of different frequencies, say once in two, five, ten or twenty years.
(iii) Marking of likely submersion areas for different flood stages or accumulation of rainwater on these maps.

Note: It will be extremely useful to mark the yearly highest flood levels on a permanent building or structure. In the absence of such a structure, the state may construct masonry or concrete pillars for marking of high flood levels.

4.4 Bye-laws for Buildings in Flood Prone Areas

The following provisions need be incorporated in the building bye-laws of Local Bodies for buildings in flood prone areas:

(a) Plinth levels of all buildings should be 0.6 m above the drainage/flood submersion levels under the mean annual flood.
(b) All the buildings should preferably be two or more storeys.
(c) In single storey buildings, a stairway must be provided to the roofs which could be used as temporary shelter for which roof should be made of flat type.
(d) The roof levels of the single storey buildings and the first floor level in double-storey buildings should be kept above 100-year flood levels.

5. FLOOD ZONING

5.1 A number of river basins are flood prone wherein some areas have already been protected by constructing *bunds, levees,* or raising of villages but there are others which are still liable to flooding without protection. Such zones are shown in statewise maps presented in the Vulnerability Atlas of India, 1996 and revised in digital format in 2006.

5.2 Land morphology is the main factor in determining how safe a site is against flood waters. Flood plains of rivers are typically broad, flat valleys containing a large or meandering river. Coastal flood plains can extend a long way inland from the sea itself, if the land is flat, without hills or ridges between it and the sea.

5.3 Sites below the level of nearby rivers or seas, for example below river banks, or in enclosed depressions are highly likely to suffer flooding at some time or another.

5.4 Sometimes when the floods are extremely severe or the maintenance of the *bunds* is poor, a *bund* may be breached, thereby releasing water which may cause havoc not only to agriculture but also to the villages situated behind the bund coming in the path of this fast flowing water. Therefore, the ‘protected areas’ will also need flood resistance precautions at least to a minimum extent. *See Fig. 2 and Fig. 3.*

5.5 The higher the elevation of a site above average river or sea levels, the less likely it is to be covered by flood waters.

6. RAIN ZONING

Sustained rains over few days or weeks tend to saturate the earthen roofs, the clay walls and those built with stone, Adobe or burnt bricks laid in clay mortar. Saturated clay loses its dry compressive strength even to the level of 15 to 20 percent only of its dry strength. Appropriate zoning based on ‘normal’ rain values, or Probable Maximum Precipitation values has still not been done. Guidance at District level is therefore to be taken from past history of damage to housing from rains alone as distinct from damage due to flooding.

Fig. 2: Breaching at the Embankment of Sutluj

Fig. 3: Plugging of Breach with Sand Bags

7. FLOOD INTENSITY

7.1. Flood intensity is currently measured by the water level of the river or canal above the danger mark at specific locations that is determined based on a “safe” peak discharge rate or inundation level. This is totally inadequate to assess vulnerability to both settlements and specific types of buildings within them.

7.2. An intensity scale that records the impact on buildings will have to take into account depth of inundation (e.g. short term inundation below plinth level may have limited impact), time period of inundation (as period of saturation of materials like earth is critical in determining their wet compressive strength) and rate of inundation (to understand the impact of hydro-dynamic forces). An inundation intensity scale for damage to houses on a broad basis is proposed in *Table 2.*

Table 2: Inundation Intensity Scale for Damage to Houses*

Depth of Inundation above plinth (mm)	Inundation Intensity Scale Period of Inundation in hours		
	24	**> 24 to 72**	**> 72**
- 900	I	II	III
900 - 2000	II	III	IV
> 2000	III	IV	V

* *Intensity may be assumed to increase linearly between the hours of inundation or depth of inundation stated in the table.*

8. ELEMENTS AT RISK OF FLOOD DAMAGE

8.1 Buildings with their material contents including cattle, fowl etc., the residents and the infrastructure sited in the flood plains of flood-prone rivers are the elements most at risk.

8.2 Buildings and infrastructure in zones protected by vulnerable flood protection works, such as *bunds* and embankments are also at considerable risk due to the probability of overtopping and/or breaching.

8.3 Earthen buildings or brick and stone masonry with mud mortar which is water soluble are highly risk prone.

8.4 Buildings with shallow foundations or with weak resistance to lateral hydro-dynamic loads caused by flowing water are also prone to risk due to their location at adverse topographical condition in the flood plain or behind the protection work.

8.5 Sewerage, power and water supply systems, industrial and communications equipment, and basements in buildings are also risk prone, besides food stocks, livestock and standing agricultural crops.

8.6 Though the proportion of building construction in traditional material is declining in various States since the last two decades, there is still a significant stock of the buildings which are constructed with earth based materials or using stone and brick in mud mortar. These are highly vulnerable to damage in heavy rains and/or floods. In addition, the occupation of sites within the flood plain of rivers has increased the vulnerability, especially in areas of high population concentration like towns.

9. MECHANISM OF DAMAGE TO BUILDINGS

9.1 The main mechanisms of flood damage to buildings are the following:

i. Foundation scouring & settlement and subsequent wall collapse under hydro-dynamic loads. *(Fig. 4)*

ii. Wall collapse, either due to inadequate bearing capacity caused by saturation under heavy rain or due to inundation (combined effect of saturation, buoyancy and mortar becoming mud), leading to collapse of roof along with. *(Fig. 5)*

iii. Roof floatation due to inundation, leading to wall damage also. *(Fig. 6)*

9.2 Other relatively less severe forms of damage are wall erosion, cracks and bulging, plaster delamination and floor settlement apart from damage to services like water supply, sanitation and electrical systems.

9.3 A major undocumented type of flood damage mechanism identified in Haryana is settlement in the core areas of *old mound settlements* due to soil saturation around during the flood even though many of the buildings damaged due to unequal settlement of soil were not inundated. *(Fig. 7)*

9.4 A graphic summary of causes of failure of earthen houses and those in burned brick or stones laid in mud mortar due to heavy rains or flood water is shown in *Fig. 8.*

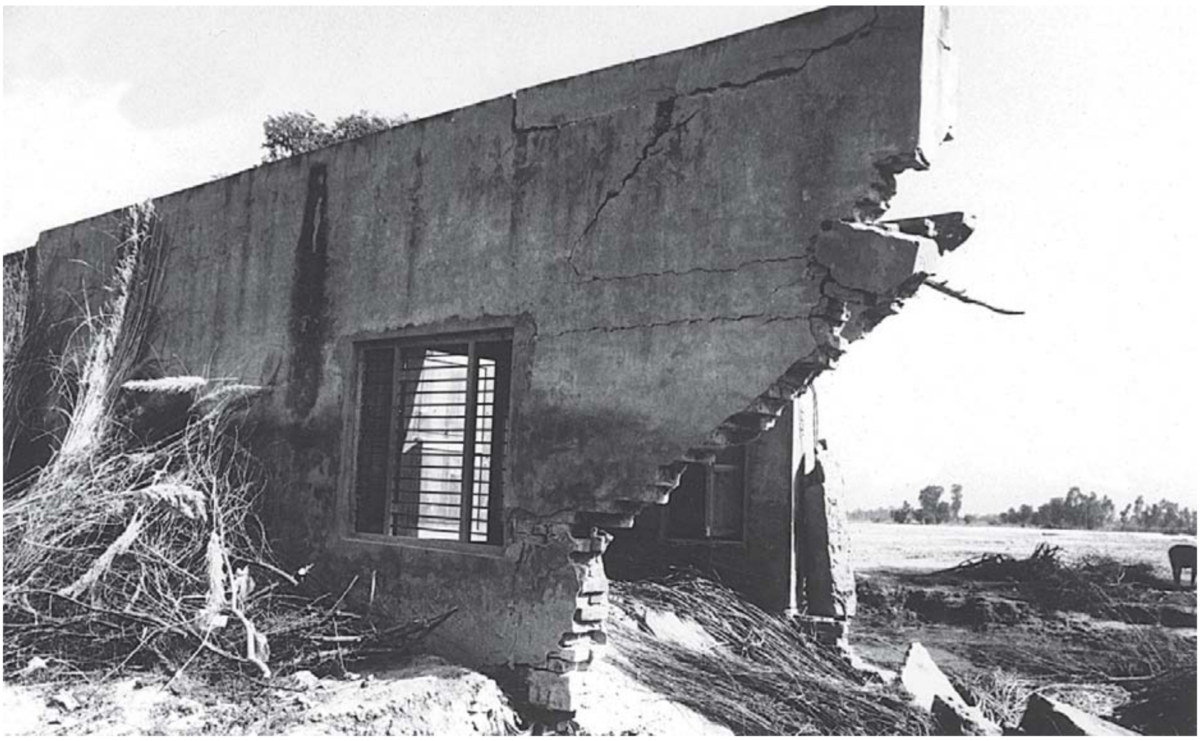


Fig. 4: High velocity of flood water leading to wall collapse due to under scouring

Fig.5: Collapse of earth roof building due to saturation

Fig.6: Collapse of tile roof building due to inundation

Fig. 7: Extensive cracking of the walls due to differential settlement

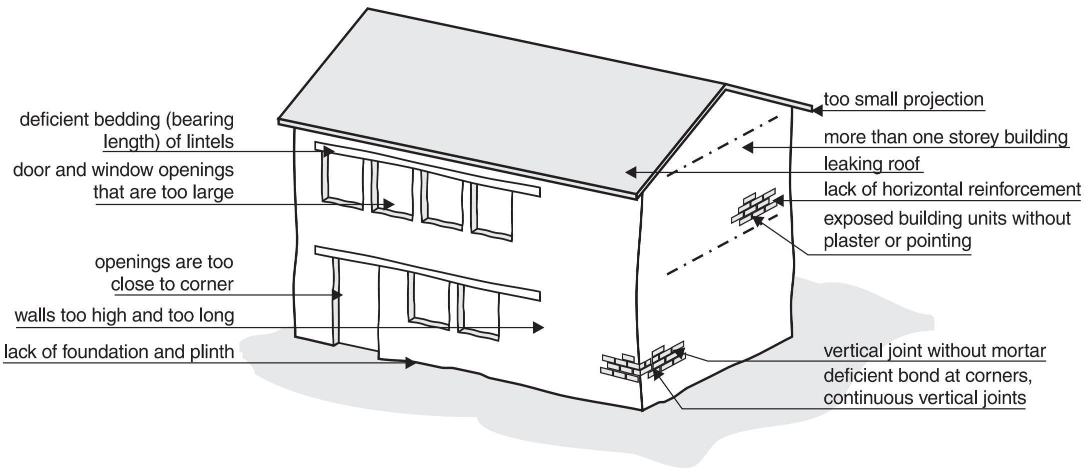


Fig. 8: Graphic summary of causes of failure of earthen houses or those in bricks or random stones laid in mud mortar due to heavy rain or flood

10. CATEGORIES OF DAMAGE TO HOUSING

The following five level categorisation of flood damage to housing was proposed in 1995 by the Export Group appointed by Ministry of Urban Development, Government of India:

G1: (Very low damage)
Fine cracks in plaster; fall of small pieces of plaster (say about 10% of wall area)

G2: (Low damage)
Fall of fairly large pieces of plaster (say upto 50% of wall area); small cracks in walls (say less that 6mm wide)

G3: (Moderate damage)
Large and deep cracks in walls; loss of belongings; damage of electrical fittings.

G4: (High damage)
Gaps in walls; parts of buildings may collapse; light roofs float away; erosion of foundation; sinking or tilting.

G5: (Very high damage)
Total damage including collapse of buildings; floating away of sheets, thatch, etc.; scouring of foundations, severe damage of lifeline structures and systems.
Note:The loss of value to the housing due to damage classified into the five categories may be taken as follows:
G1, less than 10%; G2, 10-25%; G3, 25-50%, G4, 50-75% and G5, more than 75% upto 100%.

11. PROTECTION FROM RAIN DAMAGE

Damage to housing from rain usually occurs in *kutcha* houses with walls of clay, and brick or stone walls laid in mud mortar, where rain water can soak into them either through seepage from the roof or by rain beating on the wall directly or by inundation in standing water. Pucca houses with brick or stone walls built using lime or cement mortars and slab or sheeted roofing are not damaged by rain.

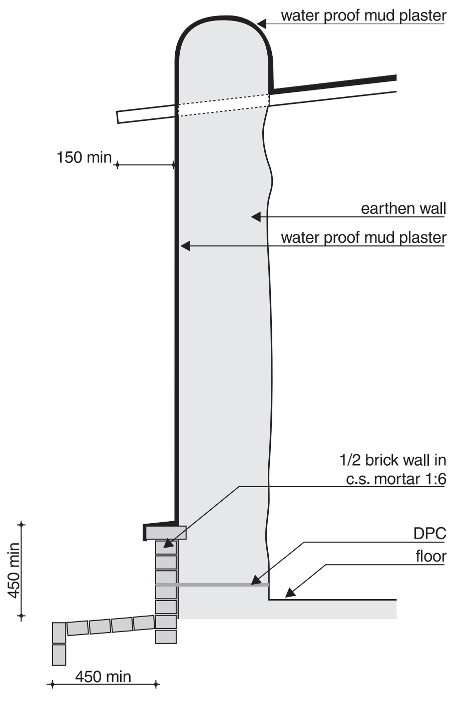


Fig. 9: Preventing rain / flood damage to earthen walls or stone / brick walls in mud mortar

11.1 Roof

1. For leak proofing of clay and thatch roofs, they may be plastered on the upper surface with water-proof mud plaster (see para 19). If applied on the underside of the thatch roof, the fire-resistance of the thatch will also improve greatly.
2. For the clay roof, alternatively, black polythene of heavy gauge sheets may be laid near mid-thickness or upper quarter thickness of the clay layer of about 150-200 mm thickness.
3. Drainage of clay roof should be ensured by using

adequate slope and *pucca* spouts projecting sufficiently beyond the walls. The areas of fall of water should be made *pucca* with protection to the lower portion of the adjacent wall, *Fig. 9*.

11.2 Walls

1. To prevent the ingress of water in the walls from the top, the top of parapets should be plastered using water-proof mud or lime or cement plaster, *Fig 9*.
2. To protect the wall from saturation due to rain beating during monsoons, roof projection of about 500 mm, and/ or water proof mud plaster on external face of the walls exposed to such action needs to be used. Burnt brick or stone walls built in clay mortar should either be 'pointed' with 1:3 mix of lime or cement mortar, or, plastered using 1:3 lime-sand or 1:6 cement-sand mortar.
3. Another method will be to make the wall composite of 1½ brick thickness using burnt bricks on external face and sundried bricks on internal face, both using mud mortar and lime/cement pointing on external face, *Fig. 10*.
4. To prevent saturation of wall due to capillary action and rain splashes near the bottom of the wall, a minimum plinth height of 450 mm above general ground level should be adopted and a damp proof course (DPC) of 'water proof mud' or black polythene sheet should be laid at the plinth level in all the walls, *Fig. 10*.
5. A *pucca* apron of 600mm minimum width sloping away, and curtain wall of 75 to 114 mm thickness and 450mm minimum height using burnt bricks with external pointing, all around the house will protect the most critical part of the wall from direct rain damage, falling water from the spouts and low-depth water flow during high intensity rains of short duration. *See Fig. 9.*
6. A graphic summary of good features of flood resistant houses is shown in *Fig. 11*.

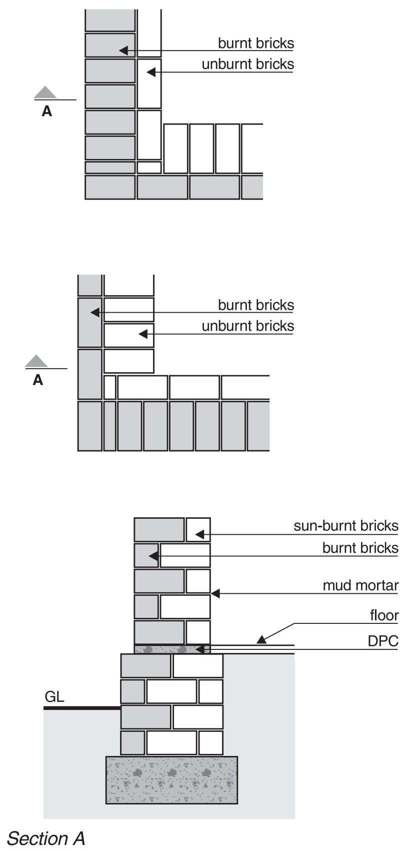


Fig. 10: Burnt brick and sun-dried brick mixed wall construction

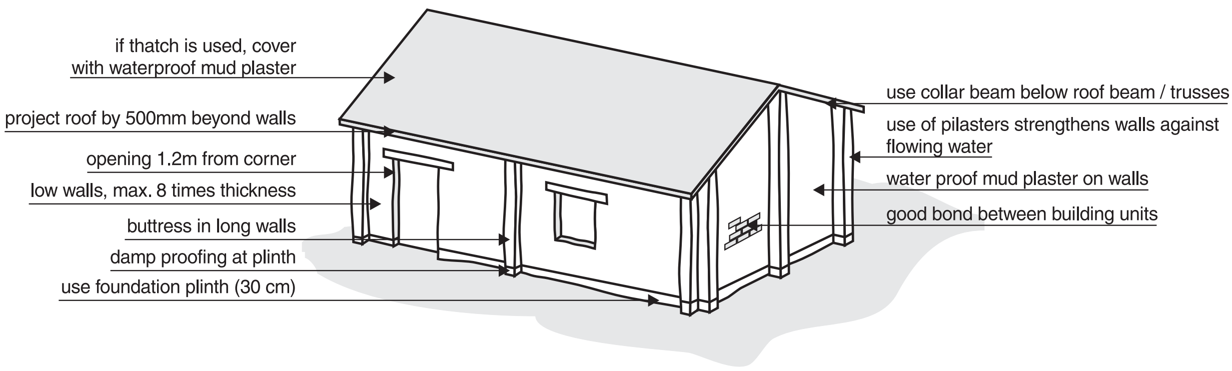


Fig. 11: Good features of flood resistant earthen construction

12. GENERAL PROTECTION OF HABITAT/BUILDINGS FROM FLOOD DAMAGE

12.1 The most effective preventive measures against flood risk are:

i. To avoid steep earth banks and slopes on river sides and the sides of gorges.
ii. To build at least 500 m away from the sea coast or at an elevation 3 m above the High Tide Level.
iii. The drainage system in all flood prone areas shall be suitably built up, so that the water can be drained off quickly to prevent accumulation.
iv. To construct the building with a plinth level higher than the known mean annual flood, or preferably the high flood level.
v. To construct the whole village or settlement on a raised platform higher than the high flood level.
vi. Where there is risk of swiftly moving flood flow also, the raised ground edges should be protected against erosion and scouring by pitching, vegetation growth, etc.

12.2 In high flood risk areas such as those liable to flash floods due to frequent embankment breaches, the following measures will be effective for disaster risk mitigation:

i. Ensure proper flood protection works through annual pre-monsoon inspection and repairs; as well as make contingency plans ready for emerging situation.
ii. Ensure adequate maintenance of drainage systems continuity and functioning.
iii. Arrange adequate prior warning of high discharge, either from the river flow or release from large reservoirs.
iv. Establish contingency plans for meeting emergency situation and ensure effective working of the system by training and annual drills.

12.3 Buildings may be constructed on raised ground with apron around (*Fig. 12a*). Stilts or columns with wall-free space at ground level (*Fig. 12b*) permitting free access to water whether inundation or flowing, will be safer in flood prone areas, provided that columns are circular, strong, and their foundation taken down to below deepest scour level. In dry weather condition, the ground area could be fenced and used for cattle, sheep, poultry farming, or storage etc.

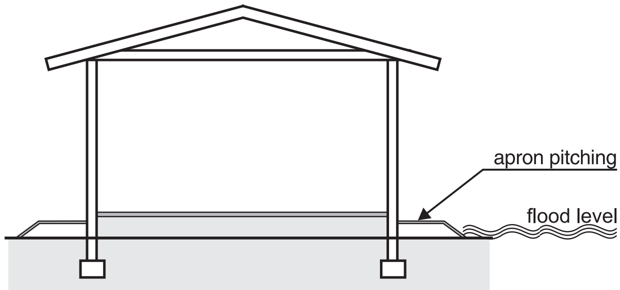


fig 12 a
Use of earth mound

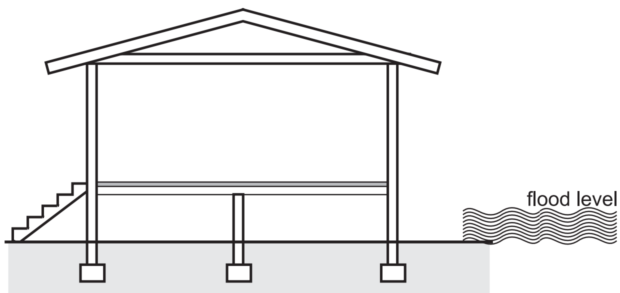


fig 12 b
Use of raised floor

Fig. 12: Raising the living above flood level

13. SPECIFIC PROTECTION OF HOUSES AGAINST INUNDATION EFFECTS

i. The depth and duration of inundation (see *Table 2*) determine the intensity of the inundation hazard. The lower portions of the walls upto the inundation level plus capillary rise are susceptible to damage except where constructed as *pucca* using burnt bricks/stones with cement-sand-mortar of 1:6 mix – or richer.

ii. The safest way will be to find the critical height, and build this portion along with the foundation in *pucca* masonry (that is, using burned brick or stone built using cement – sand mortar).

iii. Use of *semi-pucca masonry* in foundation and plinth and that of water proof mud in damp proof course as well as plastering in critical height of the wall on both faces should save the house if the inundation was less than 24 hours.

iv. For safety from roof collapse, it will be preferable to use lightweight water proof sheeted roof in flood Inundation intensities of III and more (*see Table 2*).

v. Walls of buildings liable to flood inundation intensity of III and above should be of *pucca* construction to achieve maintenance free long term safety.

14. SPECIFIC PROTECTION OF HOUSES AGAINST FLOWING WATER

The nature of protection from flowing water would depend on the velocity and depth of flowing water. It can cause erosion of soil around the buildings, scour the foundations and demolish or overturn the wall obstructing the flow.

i. Minimum safety requires that all external walls including foundations should be of *pucca* construction with cement-sand mortar pointing or plastering.

ii. High plinth all round in *pucca* construction as the walls in (i) above will be additional safety feature.

iii. Where flowing water depth is expected to be higher, the wall thickness may be made equal to one-third of the expected water depth.

15. RECOMMENDATION FOR CONSTRUCTION OF FLOOD RESISTANT HOUSES

15.1 Site Soil Conditions

Floods occurring in the alluvial plains of the rivers or the costal deltas give rise to the following effects on the foundation soils:

i. The bearing capacity of the soil gets reduced and buildings of heavy materials may sink and get damaged by differential settlements.

ii. The soil can be eroded under the action of flowing water and scouring can take place around and under the foundations resulting in the uprooting of the lighter posts or sinking and tilting of the heavier foundations.

iii. Silting can take place around the buildings when the flood water recede away from the site.

iv. The phenomenon of soil liquefaction can take place during an earthquake of medium to high intensity if occurring during the flood seasons.

Note: Liquefaction of soil actually happened in large areas of north Bihar during August 1988 earthquake when the area was already under floods.

15.2 Foundation

Taking into consideration the alluvial nature of the soil which normally has low bearing capacity, reduction in bearing capacity due to rising of water table and liquefaction potential of the water bearing soil under postulated earthquake intensity occurrences, three types of foundation designs may be considered, the choice of which will be based on the soil conditions met at the site. These are:

i. Where stiff soil is available at a depth of about 60-90 cm below ground level which may not be eroded under flowing flood water nor subject to liquefaction, the *strip foundation* which is normally used by the people could be adopted.
ii. If a stiff soil is available at a depth of upto 2.0 m, *brick pedestals* may be used at spacing of 1.5 to 2.0 m with a plinth level RCC beam at the top to support the superstructure walls.
iii. In the situation where soft alluvial soil is met to larger depths, a deeper *RC pile foundation* has to be used with an appropriate bulb at the foundation. In such a situation ordinarily a depth of 3 m may be adopted. Such piles will also have to carry a reinforced concrete beam at the plinth level to support the supper structure.

Note:

1. *It may be mentioned that the nature of foundation will be most critical to provide safety to the house under flood condition.*
2. *Estimates based on Schedule of Rates in Bihar districts show that the alternatives (ii) & (iii) are more cost effective and safer for prevailing soil conditions.*

15.3 Treatment at Plinth Level

The plinth level must be chosen at least 45 cm above the ground level, so as to provide security to the inmates under most frequent low flood conditions and above the drainage level in the village. In the case of the load bearing strip foundation, the foundation masonry must be raised upto plinth level on top of which a damp proof course must be provided.

In the case of brick pedestal or RC pile foundation, the pedestal and the piles will be raised sufficiently to provide a RC plinth beam on top. Such a beam will also serve as the damp proof course. The gap between the ground level and the plinth beam will have to be suitably filled with a curtain wall constructed using low strength brick, block, stone or plain concrete.

15.4 Super Structure Walls

There could be a number of options for wall construction such as solid brick walls (230 mm thk.), solid concrete block (200 mm thk.), stabilized compressed earth block (200 mm thk.) and hollow concrete blocks of 200 mm width etc. In consideration of reduction in cost and reduction of weight on the foundations, a system of 230 x 230 brick columns with 115 mm thk. brick wall built simultaneously with the columns may be used. In place of this arrangement, Rat-trap brick wall of 230 mm may also be adopted which will increase the weight on the foundation to some extent. These wall systems will provide full support to the roof slab without requiring any beams there.

15.5 Roof

The reinforced concrete slab or the filler type slab of 100 mm thickness with appropriate reinforcement is to be provided. This should serve as the shelter to the residents under high flood conditions. A low parapet of minimum 150 mm height is to be provided on the roof to give a sense of safety to the persons climbing to the roof. A fence of bamboo could be erected on top of the parpet where desired.

15.6 Drawing of a proposed house

Taking into account the above technology option, drawings have been worked out for;

i) A single masonry room house measuring 4.46 x 3.46, plinth area, with front and rear verandahs to be constructed with chemically preserved bamboo structure in sheet nos. 01 to 05 (*Annexure-2*), giving the plan and sections, the construction specifications, details of foundations and other reinforced concrete elements including the roof slab. The super-structure walls are suggested to consist of eight brick piers with half brick thick panel walls constructed alongwith the piers.

Two types of foundation are shown in sheet 5, namely:

i) Eight brick pedestals with RC plinth beam at top, or
ii) Precast RCC pile pedestal foundations at eight points along with a plinth beam at the top.

The type of foundation to be used will have to depend upon the soil condition at the site.

Sheet 06 shows details of rat-trap wall construction, if adopted alternatively.

Note: Reinforcing elements for earthquake protection, viz. horizontal RC Bands at window, sill and lintel levels and vertical steel bars at the corners of room and jambs of doors and windows have been provided, since the drawings given are developed for North Bihar area which falls in Seismic Zones IV and V.

16. PROTECTION OF EXISTING HOUSES FROM RAIN DAMAGE

It is easily feasible with low cost, to protect the existing houses from damage caused by rain, but not exposed to heavy inundation, as follows:

i. Earthen Houses: The treatment by water-proof mud plaster on all external surfaces as stated in Paras 11.1 and 11.2 may be applied. Laying of black polythene sheet on roof as per 11.1 will protect the clay roofs effectively.

ii. Burnt Brick or Stone Walls in Clay Mud Mortar: The external faces of walls may be pointed or plastered as stated in 11.2.

17. PROTECTION OF EXISTING HOUSING FROM INUNDATION DAMAGE

The damage resistance of existing houses to low intensity inundation say Intensities I and II *(Table 2)* can be achieved by making the lower portions of walls water proof upto the estimated level of saturation by inundation through application of water-proof mud plaster or pointing or plastering as appropriate in accordance with para 16. It will help a good deal if the adjacent area of floor inside the house and the ground outside could also be made water proof upto a width of about 900mm.

18. PROTECTION OF EXISTING HOUSES FROM FLOOD FLOW DAMAGE

This is the most difficult task. Planting closely spaced Eucalyptus or Jamoa trees around the house, keeping them of low heights of upto 3m by cutting the upper portions, will help in reducing the velocity of flow and minimizing soil erosion and scouring. Water proofing of walls and roof externally and that of walls internally also upto high flood level must be carried out in any case. In some cases, strengthening of the walls may be required by providing additional thickness.

19. PREPARATION OF WATER PROOF MUD AND APPLICATION

To prepare water proof mud plaster, the following procedure may be followed:

i. Cut-back should be prepared by mixing bitumen 80/100 grade and kerosene oil in the ratio 5:1. For 1.8 kg cut-back, 1.5 kg bitumen is melted and is poured in a container having 300 milliliters kerosene oil, with constant stirring, till complete mixing. This mixture can now be mixed with 30 liters of mud mortar to make it both, water repellent and fire resistant.
ii. The mud so prepared is to be used as plaster on the wall and roof as explained below:
The water proof plaster may be applied on top surfaces of the roof or thatch 20 to 25mm thick, and allowed to dry. It may then be coated twice with a wet mixture of cow dung and waterproof plaster in the ratio 1:1, and allowed to dry again. Walls are also to be plastered in similar way.
iii. The exterior of wall after plastering and thatch roof after treatment as explained) above may be suitably painted using a water-insoluble paint or washed with water solutions of lime or cement or gypsum.

20. REFERENCES

i. Vulnerability Atlas of India, 2006, Building Materials & Technology Promotion Council (BMTPC), Ministry of Housing & Urban Poverty Alleviation, Government of India.
ii. Natural Disaster Management Guidelines – Requirement of Flood, National Disaster Management Authority (NDMA), 2008.
iii. Arya, Anand S., Multihazard Resistant BPL Houses in Flood Prone Assures Area, prepared under Government of India – UNDP Disaster Risk Management Programme, 2008.

Annexure-1

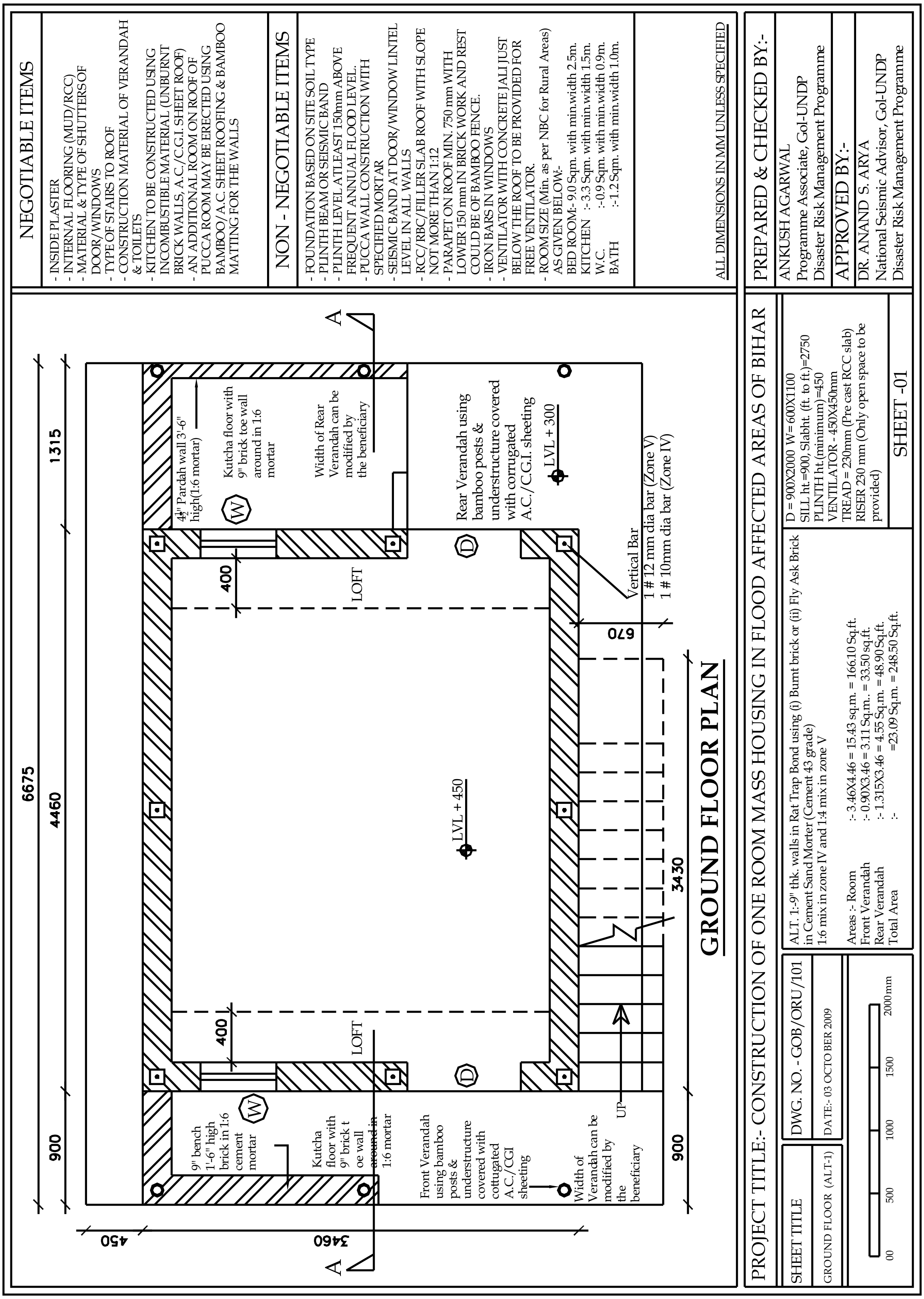
Flood prone Areas in States and Districts where more than 10 percent area is flood prone

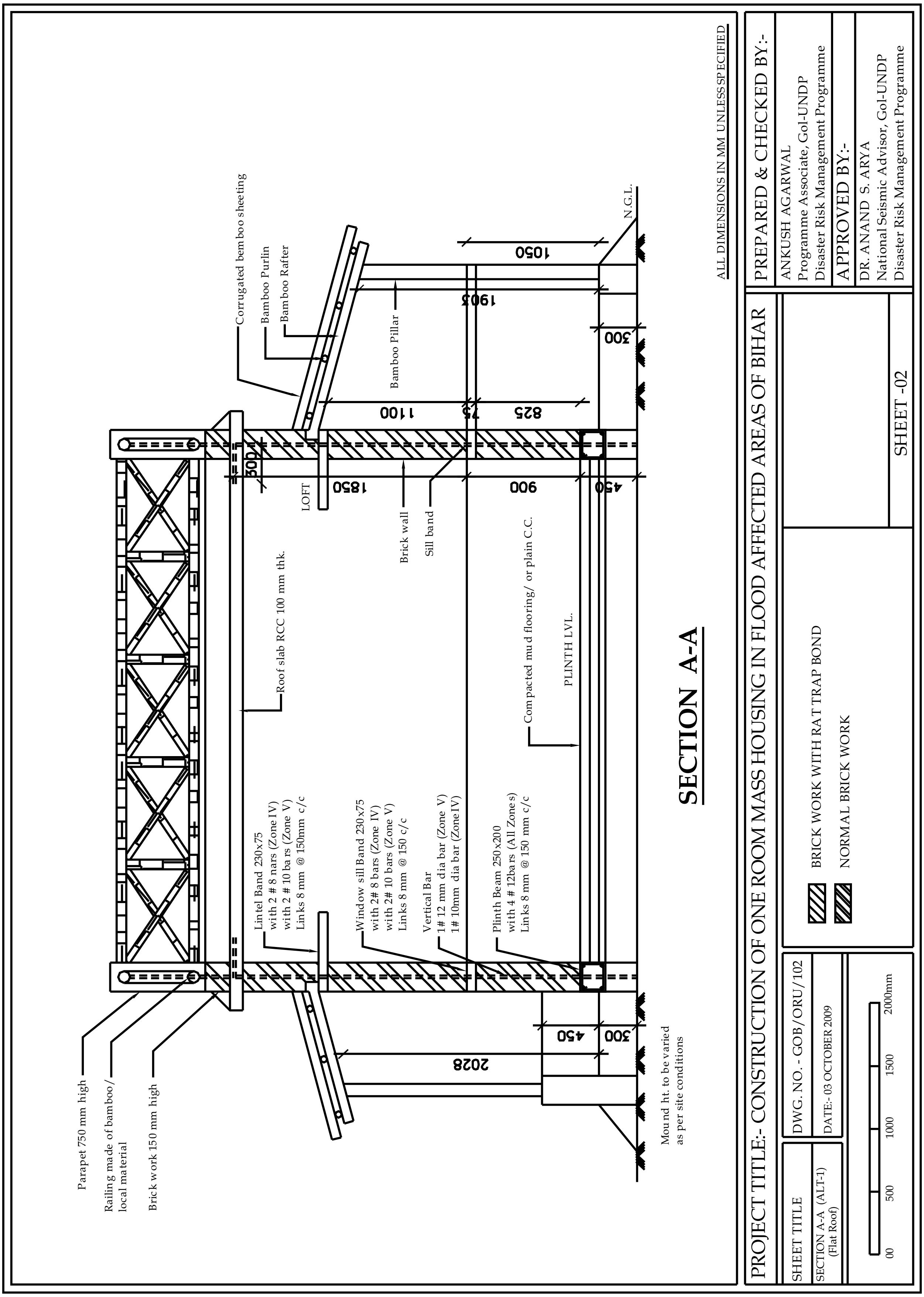
(Data sourced from Vulnerability Atlas of India, BMTPC 2006)

State	District	Flood Prone Area in (%)
ANDHRA PRADESH	East Godavari	38.2
Flood prone	Guntur	21.9
area 9.1%	Krishna	55.9
	West Godavari	42.6
ASSAM	Barpeta	46.9
Flood prone	Dhemaji	48.2
area 16.7%	Dhubri	44.3
	Dibrugarh	29.4
	Golaghat	36.4
	Jorhat	12.5
	Kamrup	18.7
	Lakhimpur	49.2
	Nagaon	18.3
	Nalbari	28.8
	Sonitpur	22.8
BIHAR	Araria	41.2
Flood prone	Begusarai	33.4
area 31.5%	Bhagalpur	68.6
	Darbhanga	71.2
	Jehanabad	13.6
	Katihar	26.4
	Khagaria	66.8
	Kishanganj	91.9
	Lakhisarai	54.6
	Madhepura	25.7
	Madhubani	42.8
	Muzaffarpur	22.4
	Nalanda	36.7
	Pashchim Champaran	33.7
	Patna	55.1
	Purba Champaran	23.9
	Purnia	31.8
	Rohtas	10.1
	Saharsa	78.9
	Samastipur	31.6
	Saran	22.1
	Sheikhpura	53.9
	Sitamarhi	91.6
	Siwan	13.9
	Supaul	81.6
Gujarat	Ahmadabad	21
Flood prone	Anand	34.6
area 21%	Banas Kantha	33.6
	Bharuch	27.6
	Gandhinagar	11.4
	Kheda	11
	Patan	38.7
	Sabar Kantha	18
	Surat	28.7
	Vadodara	16.3
Haryana	Ambala	83.2
Flood prone	Faridabad	56.8
area 30.6%	Fatehabad	44.2
	Gurgaon	18.3
	Hisar	22.3
	Jhajjar	31.8
	Jind	39.6
	Kaithal	21.2
	Karnal	48.6
	Kurukshetra	37.4
	Panchkula	62.3
	Panipat	22.8
	Rohtak	18.2
	Sonipat	27
	Yamunanagar	37.5
Kerala	Alappuzha	38.1
Flood prone	Ernakulam	22.8
area 18.7%	Kannur	16.1
	Kasaragod	27.6
	Kollam	26.7
	Malappuram	22.6
	Palakkad	19.5
	Pathanamthitta	27.1
	Thiruvananthapuram	29.9
	Thrissur	14.8
Orissa	Baleshwar	46.3
Flood prone	Bhadrak	35.9
area 13.5%	Cuttack	30
	Jagatsinghapur	100
	Kendrapara	35.5
	Puri	100
Punjab	Amritsar	88.3
Flood prone	Bathinda	19.5
area 74.6%	Faridkot	93.6
	Fatehgarh Sahib	100
	Firozpur	61.9
	Gurdaspur	69.4
	Hoshiarpur	79.1

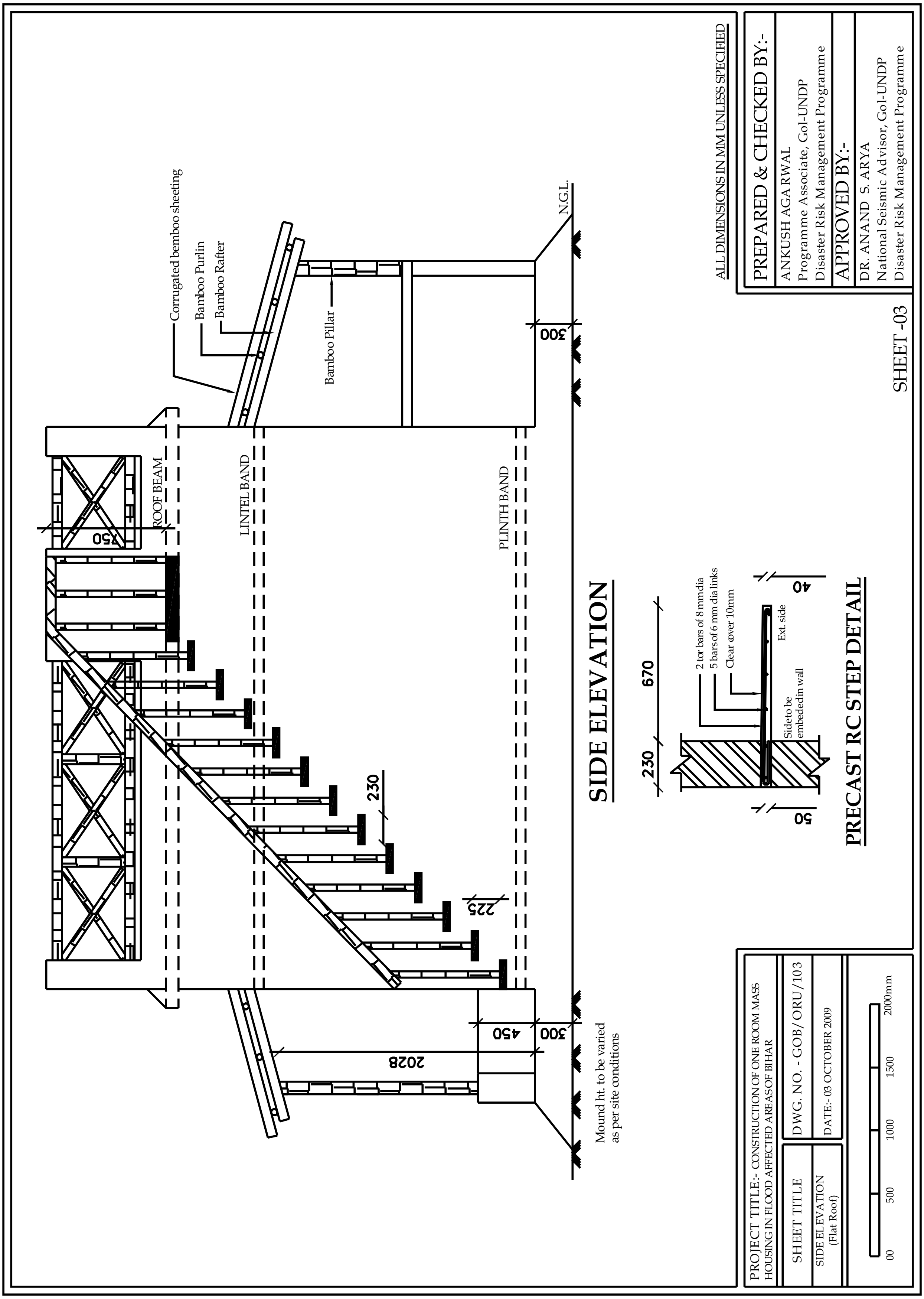
State	District	Flood Prone Area in (%)
	Jalandhar	95.5
	Kapurthala	73.2
	Ludhiana	86.6
	Mansa	33.9
	Moga	97.3
	Muktsar	37.1
	Nawanshahr	92
	Patiala	82.4
	Rupnagar	69.8
	Sangrur	89.4
Uttarakhand Flood prone area 1.9%	Nainital	11.3
Uttar Pradesh Flood prone area 27.5%	Agra	43.8
	Aligarh	12.8
	Allahabad	19.4
	Ambedkar Nagar	27.9
	Auraiya	8.9
	Azamgarh	18.1
	Baghpat	66.4
	Bahraich	51.1
	Ballia	53.1
	Balrampur	39.6
	Banda	24.9
	Barabanki	11.6
	Bareilly	36.4
	Basti	23.4
	Bijnor	22.1
	Budaun	33.1
	Bulandshahr	11.7
	Chandauli	31.8
	Deoria	66.5
	Faizabad	12.3
	Farrukhabad	43.5
	Gautam Buddha Nagar	56.2
	Ghaziabad	28.9
	Ghazipur	34.3
	Gonda	55.5
	Gorakhpur	53.4
	Hamirpur	22.5
	Hardoi	26.5
	Hathras	20.7
	Jalaun	10.3
	Jaunpur	63.4
	Jyotiba Phule Nagar	26.5
	Kannauj	26.3
	Kaushambi	27.6
	Kheri	28.6
	Kushinagar	32.8
	Lucknow	24.6
	Maharajganj	54.6
	Mathura	66.6
	Mau	46.8
	Meerut	12.3
	Mirzapur	14.2
	Muzaffarnagar	21.4
	Pilibhit	22.1
	Pratapgarh	18.9
	Rae Bareli	25.3
	Rampur	19.7
	Saharanpur	14.6
	Sant Kabir Nagar	18.6
	Sant Ravidas Nagar	60.3
	Shahjahanpur	46.4
	Shrawasti	22.7
	Siddharthnagar	51.1
	Sitapur	27.3
	Sultanpur	20.1
	Unnao	23.6
	Varanasi	77.3
West Bengal Flood prone area 55.8%	Barddhaman	61.8
	Birbhum	64.2
	Dakshin Dinajpur	33.4
	Haora	100
	Hugli	96.4
	Jalpaiguri	36
	Koch Bihar	42.8
	Kolkata	63
	Maldah	80.1
	Medinipur	46.3
	Murshidabad	87.4
	North 24 Parganas	84.12
	South 24 Parganas	48.2
	Uttar Dinajpur	46.7

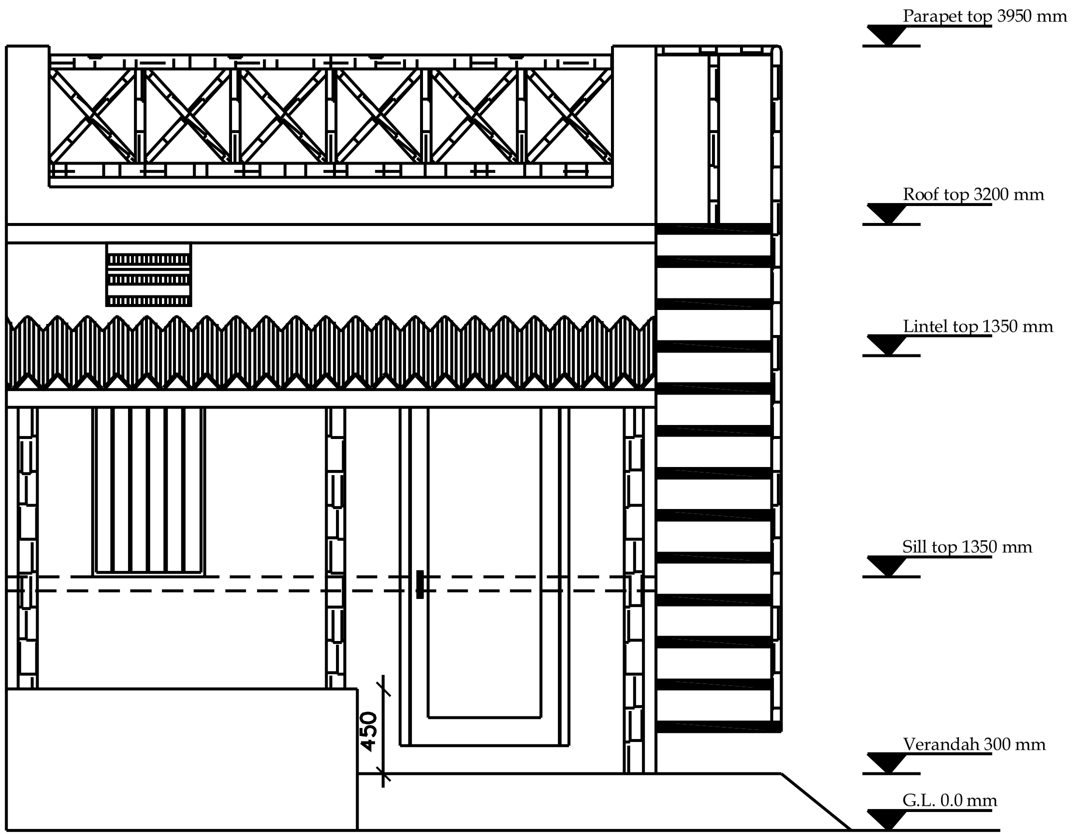
Model Design Detailing for Construction of One Room Mass Housing in Flood Affected Areas of Bihar





SECTION A-A
ALL DIMENSIONS IN MM UNLESS SPECIFIED
Corrugated bamboo sheeting
Bamboo Purlin
Bamboo Rafter
Bamboo Pillar
N.G.L.
1050
1905
300
1100
75
825
300
1850
900
450
LOFT
Brick wall
Sill band
Roof slab RCC 100 mm thk.
Compacted mud flooring/ or plain C.C.
PLINTH LVL.
Lintel Band 230x75
with 2 # 8 nars (Zone IV)
with 2 # 10 bars (Zone V)
Links 8 mm @ 150mm c/c
Window sill Band 230x75
with 2# 8 bars (Zone IV)
with 2# 10 bars (Zone V)
Links 8 mm @ 150 c/c
Vertical Bar
1# 12 mm dia bar (Zone V)
1# 10mm dia bar (Zone IV)
Plinth Beam 250x200
with 4 # 12bars (All Zones)
Links 8 mm @ 150 mm c/c
Parapet 750 mm high
Railing made of bamboo/ local material
Brick work 150 mm high
450
300
2028
Mound ht. to be varied as per site conditions
PROJECT TITLE:- CONSTRUCTION OF ONE ROOM MASS HOUSING IN FLOOD AFFECTED AREAS OF BIHAR
PREPARED & CHECKED BY:-
ANKUSH AGARWAL
Programme Associate, GoI-UNDP
Disaster Risk Management Programme
APPROVED BY:-
DR. ANAND S. ARYA
National Seismic Advisor, GoI-UNDP
Disaster Risk Management Programme
BRICK WORK WITH RAT TRAP BOND
NORMAL BRICK WORK
SHEET -02
SHEET TITLE
SECTION A-A (ALT-1) (Flat Roof)
DWG. NO. - GOB/ORU/102
DATE:- 03 OCTOBER 2009
00 500 1000 1500 2000mm


Corrugated bemboo sheeting
Bamboo Purlin
Bamboo Rafter
Bamboo Pillar
N.G.L.
300
ROOF BEAM
LINTEL BAND
PLINTH BAND
750
230
225
450
300
2028
Mound ht. to be varied as per site conditions
SIDE ELEVATION
230
670
2 tor bars of 8 mm dia
5 bars of 6 mm dia links
Clear cover 10mm
Ext. side
Side to be embeded in wall
40
50
PRECAST RC STEP DETAIL
ALL DIMENSIONS IN MM UNLESS SPECIFIED
PREPARED & CHECKED BY:-
ANKUSH AGARWAL
Programme Associate, GoI-UNDP
Disaster Risk Management Programme
APPROVED BY:-
DR. ANAND S. ARYA
National Seismic Advisor, GoI-UNDP
Disaster Risk Management Programme
SHEET -03
PROJECT TITLE:- CONSTRUCTION OF ONE ROOM MASS HOUSING IN FLOOD AFFECTED AREAS OF BIHAR
SHEET TITLE
SIDE ELEVATION (Flat Roof)
DWG. NO. - GOB/ORU/103
DATE:- 03 OCTOBER 2009
00
500
1000
1500
2000mm



FRONT ELEVATION

ALL DIMENSIONS IN MM UNLESS SPECIFIED

PROJECT TITLE:- CONSTRUCTION OF ONE ROOM MASS HOUSING IN FLOOD AFFECTED AREAS OF BIHAR

SHEET TITLE	DWG. NO. - GOB/ORU/104	
FRONT ELEVATION (Flat Roof)	DATE:- 03 OCTOBER 2009	SHEET -04

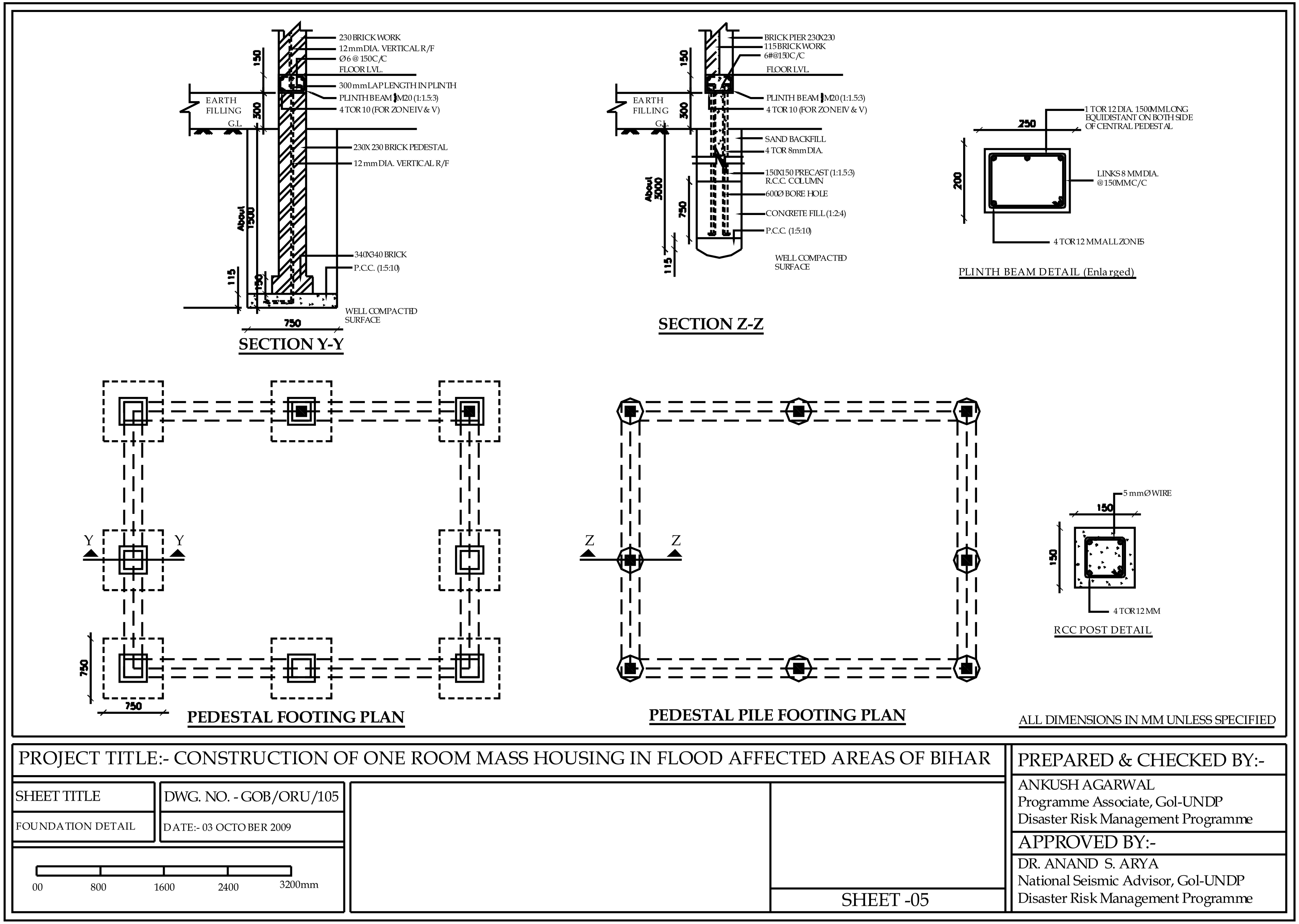
00 500 1000 1500 2000mm

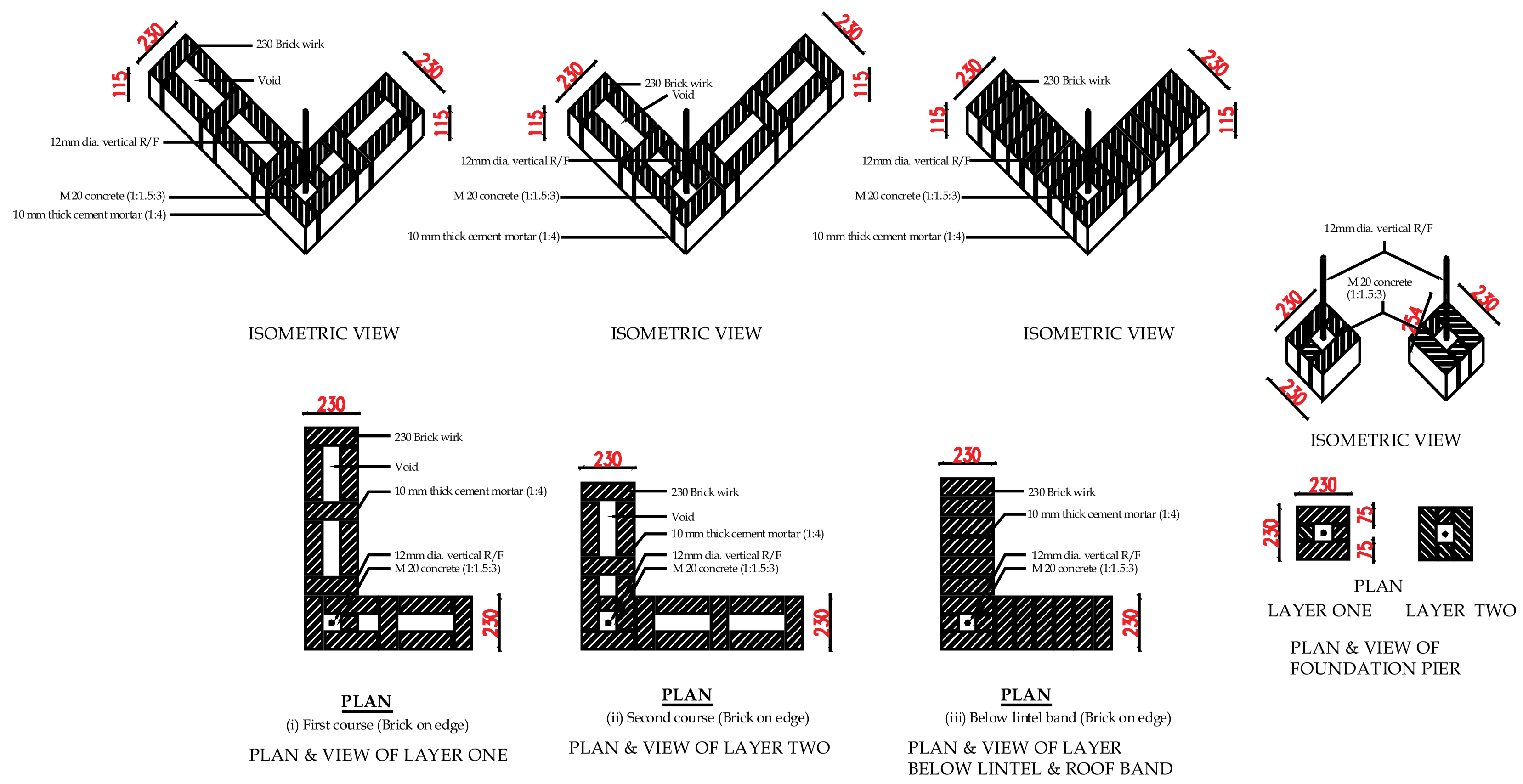
PREPARED & CHECKED BY:-

ANKUSH AGARWAL
Programme Associate, GoI-UNDP
Disaster Risk Management Programme

APPROVED BY:-

DR. ANAND S. ARYA
National Seismic Advisor, GoI-UNDP
Disaster Risk Management Programme


230 BRICK WORK
12 mm DIA. VERTICAL R/F
Ø 6 @ 150C/C
FLOOR LVL.
300 mm LAP LENGTH IN PLINTH
PLINTH BEAM M20 (1:1.5:3)
4 TOR 10 (FOR ZONE IV & V)
EARTH FILLING
G.L.
230X 230 BRICK PEDESTAL
12 mm DIA. VERTICAL R/F
340X340 BRICK
P.C.C. (1:5:10)
WELL COMPACTED SURFACE
150
300
About 1500
115
750
SECTION Y-Y
BRICK PIER 230X230
115 BRICK WORK
6#@150C/C
FLOOR LVL.
PLINTH BEAM M20 (1:1.5:3)
4 TOR 10 (FOR ZONE IV & V)
SAND BACKFILL
4 TOR 8mm DIA.
150X150 PRECAST (1:1.5:3) R.C.C. COLUMN
600Ø BORE HOLE
CONCRETE FILL (1:2:4)
P.C.C. (1:5:10)
WELL COMPACTED SURFACE
About 3000
SECTION Z-Z
1 TOR 12 DIA. 1500MM LONG EQUIDISTANT ON BOTH SIDE OF CENTRAL PEDESTAL
LINKS 8 MM DIA. @150MMC/C
4 TOR 12 MM ALL ZONES
250
200
PLINTH BEAM DETAIL (Enlarged)
5 mm Ø WIRE
4 TOR 12 MM
RCC POST DETAIL
Y
Z
PEDESTAL FOOTING PLAN
PEDESTAL PILE FOOTING PLAN
ALL DIMENSIONS IN MM UNLESS SPECIFIED
PROJECT TITLE:- CONSTRUCTION OF ONE ROOM MASS HOUSING IN FLOOD AFFECTED AREAS OF BIHAR
SHEET TITLE
FOUNDATION DETAIL
DWG. NO. - GOB/ORU/105
DATE:- 03 OCTOBER 2009
00 800 1600 2400 3200mm
SHEET -05
PREPARED & CHECKED BY:-
ANKUSH AGARWAL
Programme Associate, GoI-UNDP
Disaster Risk Management Programme
APPROVED BY:-
DR. ANAND S. ARYA
National Seismic Advisor, GoI-UNDP
Disaster Risk Management Programme



construction of wall using rat trap bond

ALL DIMENSIONS IN MM UNLESS SPECIFIED

PROJECT TITLE:- CONSTRUCTION OF ONE ROOM MASS HOUSING IN FLOOD AFFECTED AREAS OF BIHAR

SHEET TITLE	DWG. NO. - GOB/ORU/106
WALL DETAIL	DATE:- 03 OCTOBER 2009

00 300 600 900 1200mm

SHEET -06

PREPARED & CHECKED BY:-

ANKUSH AGARWAL
Programme Associate, GoI-UNDP
Disaster Risk Management Programme

APPROVED BY:-

DR. ANAND S. ARYA
National Seismic Advisor, GoI-UNDP
Disaster Risk Management Programme

ABOUT BMTPC

Building Materials & Technology Promotion Council under the auspices of 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 stake holders involved in the construction industry for technology development, production, mechanization, implementation, standardization, certification & evaluation, training & capacity building, certification 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 widely popularized 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 the Council in the process received UN Habit Award for the same. 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 to handle any disaster. BMTPC has recently published the following documents:-

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

These documents are important tools for safety against natural hazards for various stake holders involved in disaster 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 Ministry of Home Affairs to draft Building Bye-laws incorporating disaster resistance features so that State/UT Governments prepare themselves against natural hazards. One of the very basic publications of BMTPC with IIT, Kanpur has been 'Earthquake Tips' which were 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.

For further information, please contact:

Executive Director
Building Materials & Technology Promotion Council,
Ministry of Housing & Urban Poverty Alleviation,
Government of India, New Delhi
Phone: +91-11-24638096, Fax: +91-11-24642849
E-Mail: bmtpc@del2.vsnl.net.in; info@bmtpc.org
Website: http://www.bmtpc.org