Multi-Hazard Resistant New Construction or Reconstruction of BPL Houses in Flood Prone Alluvial Areas
(Bihar in particular and India in general)

By:

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National Seismic Advisor (EVR) GoI-UNDP (DRM) New Delhi
Padmashree awarded by the President, 2002
FLOOD PROBLEM IN INDIA

According to the Rashtriya Barh Ayog (National Commission on Floods), the area prone to floods in the country was 40 million hectares out of which about 80% can be provided with reasonable degree of protection.

Losses suffered by the people:

- the damage to crops,
- damage to houses and
- loss of human and cattle lives.
FLOOD PROBLEM IN INDIA

Data published by NDMA in National Disaster Management Guidelines-Management of Floods, from the year 1953 to 2005 inclusive,

- 6,45,49,660 houses had been damaged by floods averaging about 12,18,000 houses lost per year, the maximum number of houses lost in one year (1978) was 35,07,540,

- number of people who lost their lives during floods; 84,207 with an average of 1588 persons per year, the maximum in any one year (1977) being 11,316.

Most of the lives lost were due to drowning of people due to the collapse of their shelters.
HOUSE TYPES USUALLY DAMAGED UNDER FLOODS

A study of the Vulnerability Atlas of India 1997 and that revised in 2006 based on Census of Houses in India 1991 and 2001 respectively, gives the house type which are prone to damage or destruction during floods:

Mud and Unburnt Brick walls when inundated under water become soft losing their dry strength by even as much as 85% of the dry value and therefore, start collapsing when inundated for longer duration of time.

Burnt Brick and Stone houses usually constructed using mud mortar in the rural areas. The mud mortar also becomes soft under continuous wetting under water.

The houses made from light weight materials like GI or other Metal sheets or Grass, Leaves, Reeds, Bamboo etc. easily float away as soon as their holding down posts are uprooted by the flowing water.
## HOUSE TYPES USUALLY DAMAGED UNDER FLOODS

### Houses by Material of Wall in the Rural Areas of India

<table>
<thead>
<tr>
<th>S.No</th>
<th>Wall Material</th>
<th>1991 Census of Housing</th>
<th>2001 Census of Housing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of Houses</td>
<td>% of Total Houses</td>
</tr>
<tr>
<td>1</td>
<td>Mud &amp; Unburnt Bricks</td>
<td>67,218,236</td>
<td>34.47</td>
</tr>
<tr>
<td>2</td>
<td>Burned Brick</td>
<td>36,646,602</td>
<td>18.79</td>
</tr>
<tr>
<td>3</td>
<td>Stone</td>
<td>17,284,400</td>
<td>8.86</td>
</tr>
<tr>
<td>4</td>
<td>GI Sheets and other Metal Sheets</td>
<td>251,910</td>
<td>0.13</td>
</tr>
<tr>
<td>5</td>
<td>Grass, Leaves, Reeds, Bamboo or Other Materials</td>
<td>18,432,665</td>
<td>9.45</td>
</tr>
<tr>
<td></td>
<td><strong>Total number of Census of Houses (Rural + Urban)</strong></td>
<td><strong>195,024,357</strong></td>
<td></td>
</tr>
</tbody>
</table>
The overall damage depends upon the intensity of flooding. Such an Intensity Scale was first defined by the Expert Group appointed by the Ministry of Urban Development for producing the Vulnerability Atlas of India as given in the Table.

<table>
<thead>
<tr>
<th>Depth of Inundation above plinth (mm)</th>
<th>Inundation Intensity scale Period of Inundation in hours</th>
<th>≤ 24</th>
<th>&gt;24 to 72</th>
<th>&gt;72</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.9 m (3 ft)</td>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>900 ≤ 2000</td>
<td></td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>&gt;2000</td>
<td></td>
<td>III</td>
<td>IV</td>
<td>V</td>
</tr>
</tbody>
</table>

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

Floods occurring in the alluvial plains of the rivers or the coastal deltas give rise to the following types of problems during floods:-

1. The bearing capacity of the soil gets reduced and buildings of heavy materials may sink and get damaged by differential settlements.
2. 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.
3. Siltation can take place around the buildings when the flood water recede away from the site.

4. The phenomena of *soil liquefaction* can take place during an earthquake of medium to high intensity. It actually happened in large areas of north Bihar during August 1988 earthquake when the area was already under floods.
MULTI HAZARD SITUATION

Most flood prone areas in the country are also affected by other natural hazards, namely Earthquakes (such as Assam, Bihar, U.P., Punjab and Haryana); Cyclones in the coastal states along with storm surges; and high winds occurring in the coastal areas as well as the flood plains in the northern states.
TECHNOLOGICAL CONSIDERATION

If ample funds are available technology options:

• deep piles for the foundations
• appropriate plinth beam above the high flood level,
• use of reinforced concrete or reinforced brickwork super-structure
• flat RCC slab-beam roof
• an appropriate staircase.

Where the funds are limited such as for IAY houses, the choice of the construction materials will be much limited.
House Types in the Rural Areas of Bihar

With reference to the Vulnerability Atlas of India (Revised) 2006 gives the following data of houses by wall material in the rural areas of Bihar. This data is based on Census of Housing in 2001

Houses by Material of Wall in the rural areas of Bihar

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Material</th>
<th>2001 Census of Housing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No. of Houses</td>
</tr>
<tr>
<td>1</td>
<td>Mud &amp; unburnt bricks</td>
<td>3,555,951</td>
</tr>
<tr>
<td>2</td>
<td>Burnt bricks</td>
<td>5,576,724</td>
</tr>
<tr>
<td>3</td>
<td>Stone</td>
<td>19,473</td>
</tr>
<tr>
<td>4</td>
<td>Wood wall</td>
<td>81,917</td>
</tr>
<tr>
<td>5</td>
<td>Metal Sheets, Grass, leaves, Reeds, Bamboo or other materials</td>
<td>5,327,185</td>
</tr>
<tr>
<td></td>
<td><strong>Total number of Census Houses (Rural + Urban)</strong></td>
<td><strong>16,316,527</strong></td>
</tr>
</tbody>
</table>
SCENARIO IN BIHAR

The villages in Bihar are situated either near the river banks or between the *bunds* of the rivers and get subjected to various levels of inundation for even very long duration of time, therefore, mostly subjected to high Intensity floods. The design of new houses must take care of the prevailing situation of the flood prone areas in Bihar.
MULTI-HAZARD SITUATION IN THE DISTRICTS OF BIHAR WHICH ARE FOUND TO BE FLOOD PRONE
SEISMIC HAZARD MAP OF BIHAR

BIHAR
Earthquake Hazard Map (showing faults, thrusts and earthquakes of magnitude ≥5)
## Multi-hazard Proneness of Flood-Prone Districts in Bihar

[Source: Vulnerability Atlas of India (Revised) 2006]

<table>
<thead>
<tr>
<th>Name of District</th>
<th>Seismic Zone</th>
<th>Wind Velocity</th>
<th>Flood Proneness in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>IV</td>
<td>III</td>
</tr>
<tr>
<td>Predominantly Zone V</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Madhepura</td>
<td>53.2</td>
<td>46.8</td>
<td></td>
</tr>
<tr>
<td>Dharbanga</td>
<td>64.2</td>
<td>35.8</td>
<td></td>
</tr>
<tr>
<td>Sitamarhi</td>
<td>86.6</td>
<td>13.4</td>
<td></td>
</tr>
<tr>
<td>Madhubani</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supaul</td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Araria</td>
<td>85.1</td>
<td>14.9</td>
<td></td>
</tr>
</tbody>
</table>
Multi-hazard Proneness of Flood-Prone Districts in Bihar
[Source: Vulnerability Atlas of India (Revised) 2006]

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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>V</td>
<td>IV</td>
<td>III</td>
</tr>
<tr>
<td>Predominantly Zone IV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saharsa</td>
<td>44.6</td>
<td>55.4</td>
<td>100</td>
</tr>
<tr>
<td>Muzaffarpur</td>
<td>7.1</td>
<td>92.9</td>
<td>100</td>
</tr>
<tr>
<td>Kishanganj</td>
<td>9.2</td>
<td>90.8</td>
<td>100</td>
</tr>
<tr>
<td>Purnia</td>
<td>4.1</td>
<td>95.9</td>
<td>100</td>
</tr>
<tr>
<td>Katihar</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Pashchim Champaran</td>
<td>100</td>
<td>100</td>
<td>33.7</td>
</tr>
<tr>
<td>Purba Champaran</td>
<td>100</td>
<td>100</td>
<td>23.9</td>
</tr>
<tr>
<td>Siwan</td>
<td>98.8</td>
<td>1.2</td>
<td>100</td>
</tr>
<tr>
<td>Saran</td>
<td>100</td>
<td>100</td>
<td>22.1</td>
</tr>
</tbody>
</table>
## Multi-hazard Proneness of Flood-Prone Districts in Bihar

[Source: Vulnerability Atlas of India (Revised) 2006]

<table>
<thead>
<tr>
<th>Name of District</th>
<th>Percent Area of District lying under</th>
<th>Seismic Zone</th>
<th>Wind Velocity</th>
<th>Flood Proneness in %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>V</td>
<td>IV</td>
<td>III</td>
</tr>
<tr>
<td><strong>Predominantly Zone IV</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Samastipur</td>
<td></td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Begusarai</td>
<td></td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Khagaria</td>
<td></td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Bhagalpur</td>
<td></td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Lakhisarai</td>
<td></td>
<td>100</td>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Sheikhpura</td>
<td></td>
<td>100</td>
<td></td>
<td>52.5</td>
</tr>
<tr>
<td>Nalanda</td>
<td></td>
<td>98.2</td>
<td>1.8</td>
<td>85.0</td>
</tr>
<tr>
<td>Patna</td>
<td></td>
<td>88.1</td>
<td>11.9</td>
<td>100</td>
</tr>
</tbody>
</table>
This earthquake of Magnitude estimated between 8.3 and 8.6 (assigned 8.4) had occurred on 15th January 1934 with origin time and location assigned as 14 h 13 min 25 sec Indian Standard time at 26.60N Lat. 86.20E long. It is one of the few most violent earthquakes experienced in India and Nepal so far wherein 7153 lives were lost in India and about 8519 in Nepal. In this earthquake the towns of Monghyr in India and Bhatgaon in Nepal were completely in ruins, so were large parts of the cities of Motihari, Muzaffarpur and Darbhanga in India and, Patan and Kathmandu in Nepal, not mentioning the numerous villages razed to the ground in both countries.
Large tracts in the districts of east Champaran, Sitamarhi, Madhubani, Saharsa and Purnia in a length of about 300 km and average width of about 50 km slumped due to liquefaction of sands and at many places sand foundations and sand-boils had occurred on a large scale. In Sitamarhi, Madhubani and Purnia houses had greatly tilted and sunk into the ground. In Purnia 95 percent houses became uninhabitable.
DAMAGE SCENARIO OBSERVED IN 1934 BIHAR-NEPAL EARTHQUAKE

Map of Bihar showing Districts, Epicentres, Seismic Zones and Isoseismals of 1934 earthquake
Thus some of the factors that controlled the intensity distribution in this earthquake can be summarized as follows:

1. Isoseismal X covered the epicentral region at the centre of the large slump belt and intensity dropped away from this area.

2. Damage was seen to be severe along river banks and low lying water logged areas near river banks (unconsolidated sandy beds). It was seen to be less on thick clay beds.

3. Damage in the slump belt was due to soil sinking effects.

4. Outside this belt collapse of buildings occurred on account of direct shock, which was more pronounced in earthen or earthen-brick composite houses and less in fired-brick houses. Also huts made from bamboo with mud plaster suffered much less damage.
1988 BIHAR - NEPAL EARTHQUAKE

This earthquake of M 6.6 on Richter scale according to U.S. Geological Survey occurred in India-Nepal border region at Lat 26°045’18”N, Long. 86°036’57.6”e on Aug. 21, 1988 at 4h 39m 10.3s Indian Standard Time, that is, in the early morning hours of a day in the monsoon season when the areas in north Bihar were under floods. As a result 282 persons died and 3766 were injured in Bihar. The figures are surprisingly low in view of the fact that 149334 houses were damaged in Bihar, (Pucca private houses: collapsed 11335, major damage 19141, minor damage 34142; Kutcha houses: collapsed 13758, major damage 27258 and minor damage 43700). Most of the damaged houses were of Unburnt or burnt brick masonry in Bihar constructed using mud mortar.
The worst affected Districts in Bihar were again Darbhanga, Madhubani, and Saharsa close to the border and Munger town due its special geologic and geotechnical set-up. As in the 1934 earthquake, large scale liquefaction of soil took place but to a much smaller extent than that in 1934. Loss of buildings structures and services, estimated by the various Government Deptts. were Rupees 108.9 crores for houses and Rs. 79.9 crores for government buildings and facilities.

**Note:** It may be mentioned that the earthquake of Magnitude 8.4 in 1934 would be about 750 times in the energy release in 6.6-earthquake Magnitude in 1988. The repeat of 1934 in future will indeed be catastrophic in view the increased population and the vulnerable assets. What ever is built now must be earthquake resistant.
TECHNOLOGY OPTIONS FOR CONSTRUCTION OF HOUSES
1. If a stiff soil is available at a depth of less than 1.5 m brick pedestal piles may be used with a plinth level RCC beam at top to support the superstructure.

2. The situation where soft alluvial soil is met to larger depths, here a deep RC pile foundation has been suggested with appropriate RC bulb at the foundation. In such a situation a depth of about 3 m may be adopted. Such piles will also have to carry a reinforced concrete beam at the plinth level to support the superstructure.

3. The pedestals may be kept upto 2.2 m apart c/c
PLAN

GROUND FLOOR PLAN

ALL DIMENSIONS IN MM UNLESS SPECIFIED
FOUNDATION PLAN

PEDESTAL FOOTING PLAN

Y

Y

750

750
PEDESTAL FOOTING

230 BRICK WORK
12 mm DIA. VERTICAL R/F
Ø6@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

1500

230 X 230 BRICK PEDESTAL
12 mm DIA. VERTICAL R/F
340 X 340 BRICK
P.C.C. (1:5:10)

750 X 750

WELL COMPACTED SURFACE

SECTION YY
ALTERNATIVE PLAN

VERANDAH

MULTIPURPOSE ROOM
3000x3000

Nahani
1.2x0.95

WC
0.95x0.95

Cooking Space
1.2x1.05

Dimensions:
- 3000
- 3400
- 600
- 900
- 1200
- 5610
- 1050
1. 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.

2. Gap between the ground level and the plinth beam will have to be suitably filled with a curtain wall constructed using brick, block, stone or plain concrete. However, to save funds it is suggested that this gap should be filled by raising the earth in the form of a platform going around the house properly compacted.
PLINTH BEAM/BAND

230 BRICK WORK
12 mm DIA. VERTICAL R/F
Ø6@150C/C FLOOR LVL.
300 mm LAP LENGTH IN PLINTH
PLINTH BEAM [M20 (1:1.5:3)]
4 TOR 10 (FOR ZONE IV & V)
SUPER STRUCTURE WALLS

1. There could be large number of options for wall construction such as solid brick walls (230 mm thk.), solid concrete block (200 mm thk.), compressed earth block (200 mm thk.) and hollow concrete blocks of 200 mm width etc.

2. However, 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 has been suggested. In place of this arrangement Rat-trap brick wall of 230 thickness may also be adopted
From the earthquake safety consideration following reinforcing arrangement has been suggested for strengthening the building.

1. **SILL BAND**: Two bars of 8 mm dia in Zone IV and two bars of 8 mm dia. in Zone V
2. One bar in each brick pedestal fixed in plinth beam
3. Vertical reinforcing bars at the centre of the brick columns which will be anchored in the reinforced concrete plinth beam at the bottom and into the roof slab at the top. Such a system will provide complete earthquake stability to the structure.
Parapet 115 mm thk. & 150 mm high

Roof slab RCC 100 mm thk.

Window Sill Band 230 x 75 with 2 # 8 bars (Zone IV) with 2 # 10 bars (Zone V)
Links 6 mm @ 150 mm c/c

Plinth Band 230 x 75 with 2 # 8 bars (Zone IV) with 2 # 10 bars (Zone V)
Links 6 mm @ 150 mm c/c
The reinforced concrete slab of 100 mm thickness with appropriate reinforcement to serve as shelter to the residence under high flood conditions. A low parapet of 150 mm height is provided on the roof to give a sense of safety to the persons climbing to the roof.
ROOF DETAIL

SECTION BB

SLAB REINFORCEMENT DETAIL

8 MM DIA. BENT UP BARS @ 150 MM C/C
8 MM DIA. BENT UP BARS @ 200 MM C/C
8 MM DIA. BARS @ 150 MM C/C
8 MM DIA. BARS @ 200 MM C/C
8 MM DIA. TOR @ 150 MM C/C
WITH ALTERNATE BARS BENT UP
OVER ALL REMARKS

This system of construction will provide adequate protection to the residents against floods, high winds as well as earthquakes both in seismic zones IV & V intensities. To cut the initial costs the following items are not included in the design:

• Door/window chaukhat & shutters
• Pucca floor in the house.
• Plastering/pointing in the walls.
• A high parapet on the roofs.
• A pucca staircase.
• A pucca partition in the house
Thank You