MULTI HAZARD RESISTANT NEW CONSTRUCTION

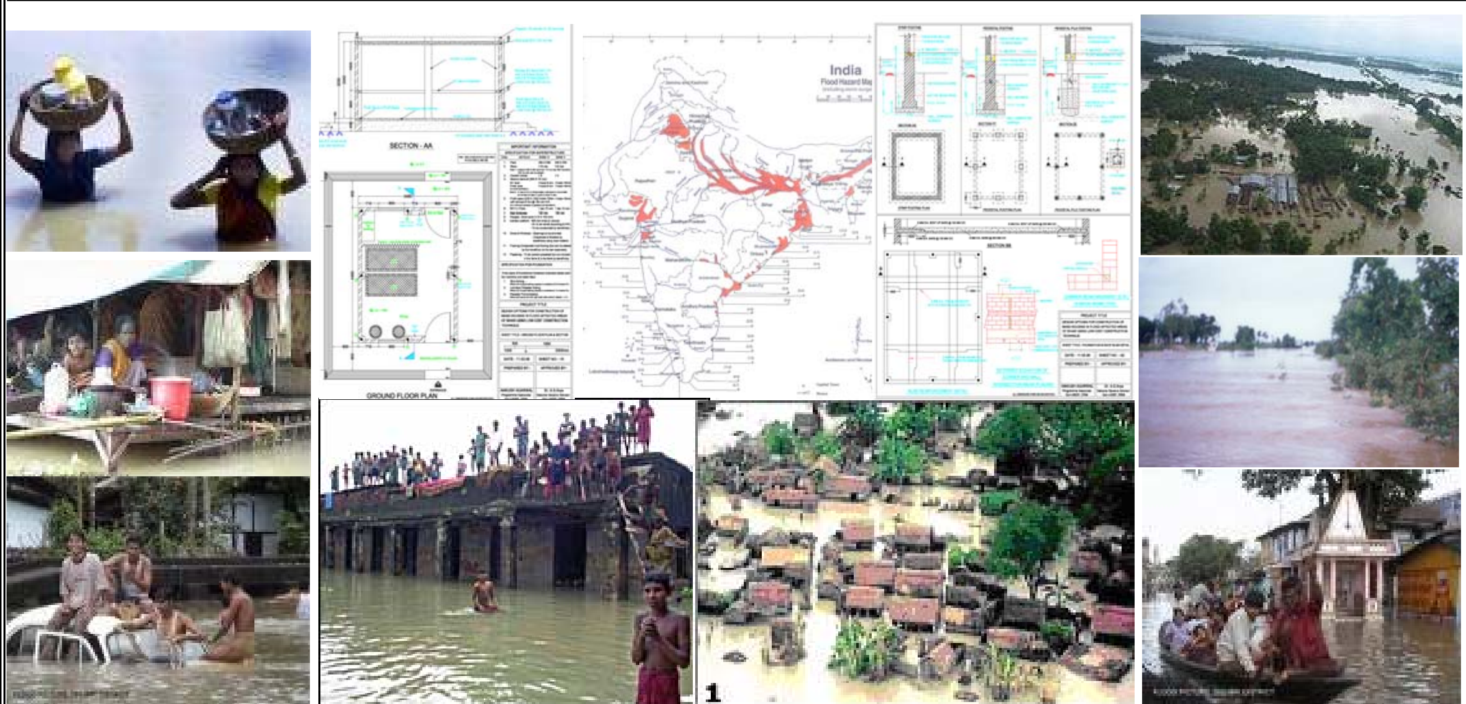
OR

RECONSTRUCTION

OF

BPL HOUSES IN FLOOD PRONE ALLUVIAL AREAS

(Bihar in particular and India in general)



Prepared Under

G o I – U N D P D I S A S T E R R I S K M A N A G E M E N T P R O G R A M M E

N E W D E L H I

Multi-Hazard Resistant New Construction or Reconstruction
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1. *THE FLOOD PROBLEM IN INDIA*

According to the estimates prepared by the Rashtriya Barh Ayog (National Commission on Floods), the area prone to floods in the country is of the order of 40 million hectares out of which about 80% can be provided with reasonable degree of protection through various measures. During such floods, the losses suffered by the people include: the damage to crops, damage to houses and loss of human and cattle lives. Besides, public utilities also get damaged on a large scale. According to the 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. The number of people who lost their lives during floods has been 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 which also results in the displacement of the people from their habitations for considerable length of time, putting a huge burden on the relief machinery of the States to take care of their temporary sheltering and feeding requirements.

2. *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 following house type figures which are prone to damage or destruction during floods:

Table 1. **Houses by Material of Wall in the Rural Areas of India**

S.No	Wall Material	1991 Census of Housing		2001 Census of Housing	
		No. of Houses	% of Total Houses	No. of Houses	% of Total Houses
1.	Mud & Unburnt Bricks	67,218,236	34.47	65,087,212	26.13
2.	Burned Brick	36,646,602	18.79	62,715,919	25.18
3	Stone	17,284,400	8.86	20,347,899	8.17
4.	GI Sheets and other Metal Sheets	251,910	0.13	876,677	0.35
5.	Grass, Leaves, Reeds, Bamboo or Other Materials	18,432,665	9.45	22,162,932	8.90
	Total number of Census of Houses (Rural + Urban)	**195,024,357**		**249,095,869**	

From Table 1, it is seen that first three wall materials are of heavy type and the last two materials are of the light weight type. 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 are usually constructed using mud mortar in the rural areas. The mud mortar also becomes soft under continuous wetting under water by which the walls lose their bearing strength and tend to collapse under their own weight or the weight of the roof. Also, if the water is flowing, they collapse more easily under the dynamic pressure of 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 ports are uprooted by the flowing water.

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 2 below:

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**
< 0.9 m (3 ft)	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.

From Table 2 it is inferred that if the inundation is less than 900 mm and if the water stays less than 24 hrs, it may be considered as very light intensity of Grade I. However, if the depth of the inundation is more than 2 m (6.56 ft) and water stays more than 72 hours, the inundation Intensity may be considered most severe, of Grade V. These inundation intensities will be most relevant to the safety of earthen walls or masonry walls using mud mortar.

The intensity of flow will depend upon the velocity of flow along with the depth of water and will be much more severe for the earthen walls as well as walls of lighter materials which could flow away with the velocity of water.

3. SITE SOIL CONDITIONS

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

(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) Siltation can take place around the buildings when the flood water recede away from the site.

(iv) The phenomena of *soil liquefaction* can take place during an earthquake of medium to high intensity if occurring during the flood seasons. It actually happened in large areas of north Bihar during August 1988 earthquake when the area was already under floods.

All the site effects can lead to severe damage to the housing units unless constructed using appropriate types of foundations, materials and technologies.

4. *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. Under the present construction types, namely lighter materials such as Metal sheets and bio-mass materials are not much affected during earthquakes, but can be blown away under the high winds. But those constructed using heavy materials will be totally destroyed under earthquake conditions endangering life and property.

Therefore, in all new constructions the choice of materials and technology will need to be based on prevailing multi-hazard conditions in the construction areas so that whatever is constructed should remain safe not only under floods but also under the other natural hazards if and when they strike the area.

5. *COST CONSIDERATION*

If ample funds are available to the owner from his own sources or through bank loans etc. one can always choose from such materials and technology options which will save his house from all types of natural hazards, for example one can use deep piles for the foundations with an appropriate plinth beam above the high flood level, use reinforced concrete or reinforced brickwork super-structure with flat RCC slab-beam roof approachable by an appropriate staircase. This will result into a very safe house. However, where the funds are limited such as for IAY houses, the choice of the construction materials will be much limited and will therefore require very deep consideration of the available choices. It is understood that under IAY Scheme it is expected that the beneficiary will also supplement the grant provided by the Government through his own means, in terms of labour and material, to complete the comforts in the house, hence the funds of the Government may be utilised to achieve a stable structural system for safety of life and property under the given natural hazard scenario of the area.

6. *DELIVERY MECHANISM*

In a housing scheme of large magnitude such as planned in the State of Bihar, namely construction of 5,00,000 houses at a cost of Rs. 25,000/- each, a scheme of owner driven construction may best be employed with overall technical guidance and delivery mechanism of the chosen construction materials. The best example in India of the construction of more than 2,00,000 houses under 'beneficiary driven' scheme was adopted in Gujarat after the Bhuj earthquake wherein, the following mechanism was used:

(i) The funding was given to the beneficiaries through bank accounts in the joint names of husband and wife in three stages, 40% advance, 40% when the construction was completed upto plinth /door lintel level and 20% when the construction was complete upto the eve level band.

(ii) Technical guidelines were made available for various types of construction and technology options, also permitting variation in the house plan to suit the beneficiary's requirement.

(iii) Enough Junior Engineers were trained in the construction technology to guide, supervise and monitor the construction as it proceeds upwards and verify the level of construction and the technology adoption for releasing the next installment.

(iv) Training of masons in the art of Disaster resistant construction through the trained Junior Engineers/Non-Governmental Organisations. Such Masons once trained will become an asset to the construction industry in the State.

(v) Material banks were created by the Government where cement and steel bars were made available at cheaper rates through waivers of the duties on such materials for strict use in the rehabilitation/reconstruction work.

(vi) Third party audit was adopted to check the quality of construction and proper use of technology by an independent organization appointed by the Government.

It may be mentioned that with all these measures, the constructions were assured of the required quality and safety of the houses under various natural hazards. It also had an added benefit that the knowledge base of ‘disaster resistance’ was expanded upto the village level.

7. __SCENARIO IN BIHAR__

7.1 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.

Table 3:- Houses by Material of Wall in the rural areas of Bihar

S. No.	**Material**	**2001 Census of Housing**	
		No. of Houses	**% of Total Houses**
1	Mud & unburnt bricks	3,555,951	21.8
2	Burnt bricks	5,576,724	34.2
3	Stone	19,473	0.1
4	Wood wall	81,917	0.5
5	Metal Sheets, Grass, leaves, Reeds, Bamboo or other materials	5,327,185	32.6
	Total number of Census Houses (Rural + Urban)	**16,316,527**	**100**

From table 3 it is seen that mud and unburnt brick wall, stone wall as well as burnt brick wall constructions are heavy weight. Out of these mud and unburnt brick walls when inundated under water will become soft loosing their dry strength to as low as 15% of the dry value. Such walls therefore, start collapsing when inundated for longer duration of time. Burnt brick and stone houses in the rural areas are usually constructed using mud mortar. The mud mortar unfortunately also becomes soft under continuous wetting due to which the walls lose their bearing strength and tend to collapse under their own weight and the weight of the roof. Under flowing water, such wetted walls collapse more easily under the dynamic pressure of the flowing water. The houses made from light weight material like wood or metal sheets or grass, reeds, bamboos etc. easily float away under flowing water as soon as their holding down posts are uprooted by erosion of soil.

As explained earlier, the intensity of damage will depend upon the Intensity of Inundation as given in Table 2 before and the velocity of the flow of water.

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.

7.2 Multi-hazard situation in the Districts of Bihar which are found to be flood prone

Table 4 gives a jist of the multi-hazard situation in the various flood prone districts of Bihar giving areas which are earthquake prone under Zone V, IV & III; wind velocities of 47 m/s (170 km/hr) and 44 m/s (160 km/hr). The flood prone areas of the districts are also indicated in table 4.

Table 4: **Multi-hazard Proneness of Flood-Prone Districts in Bihar**
[Source: Vulnerability Atlas of India (Revised) 2006]

	Percent Area of District lying under					
Name of District	**Seismic Zone**			**Wind Velocity**		**Flood Proneness in %**
	V	**IV**	**III**	**47 m/s**	**44 & 39 m/s**	
Predominantly Zone V						
Madhepura	53.2	46.8		100		25.7
Dharbanga	64.2	35.8		100		71.2
Sitamarhi	86.6	13.4		100		91.6
Madhubani	100			100		42.8
Supaul	100			100		81.6
Araria	85.1	14.9		100		41.2
Predominantly Zone IV						
Saharsa	44.6	55.4		100		78.9
Muzaffarpur	7.1	92.9		100		22.4
Kishanganj	9.2	90.8		100		91.9
Purnia	4.1	95.9		100		31.8
Katihar		100		100		26.4
Pashchim Champaran		100		100		33.7
Purba Champaran		100		100		23.9
Gopalganj		100		100		8.8
Siwan		98.8	1.2	100		13.9
Saran		100		100		22.1
Samastipur		100		100		31.6
Begusarai		100		100		33.4
Khagaria		100		100		66.8
Bhagalpur		100		100		68.6
Banka		91.7	8.3	87.6	12.4	3.1
Munger		100		100		7.0
Lakhisarai		100		100		54.6
Sheikhpura		100		52.5	47.5	53.9
Nalanda		98.2	1.8	85.0	15.0	36.7
Patna		88.1	11.9	100		55.1
Nawada		37.2	62.8		100	9.8
Jamui		73.7	26.3	3.0	97.0	2.1
Predominantly Zone III						
Buxar			100	100		5.1
Rohtas			100	58.1	41.9	10.1
Bhojpur		12.2	87.8	100		6.8
Jehanabad		19.3	80.1	95.7	4.3	13.6

It is therefore, quite clear that ***any reconstruction of houses must take into account the safety of the houses under the applicable Seismic Zone Intensity as well as the roofs must be stable under the high velocity winds as and when they occur***.

7.3 Damage Scenario observed in 1833 Bihar-Nepal earthquake

This is mentioned as a violent earthquake in Mallet's Earthquake Catalogue of the British Association. It had shaken the eastern India and Nepal between 5.30 to 8.00 PM on Aug. 26, 1833. The epicentre of the earthquake is stated as about 27½^{0}N 86.5^{0}E and Magnitude 7 ½ to 8 in the earthquake catalogue prepared by the India Meterology Department, Govt. of India. It will thus be at about 100 km north of India border inside Nepal. Widespread damage occurred in Nepal killing 414 persons. In India water was thrown out of tanks 1.2m deep at Muzaffarpur, a Chasm of considerable size was formed in the earth at Chapra and many houses were destroyed and damaged at Monghyr, Rangpur, Muzaffarpur and other places. No loss of life was reported in India.

7.4 Damage Scenario observed in 1934 Bihar-Nepal earthquake

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 26.6^{0}N Lat. 86.2^{0}E 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 including 50

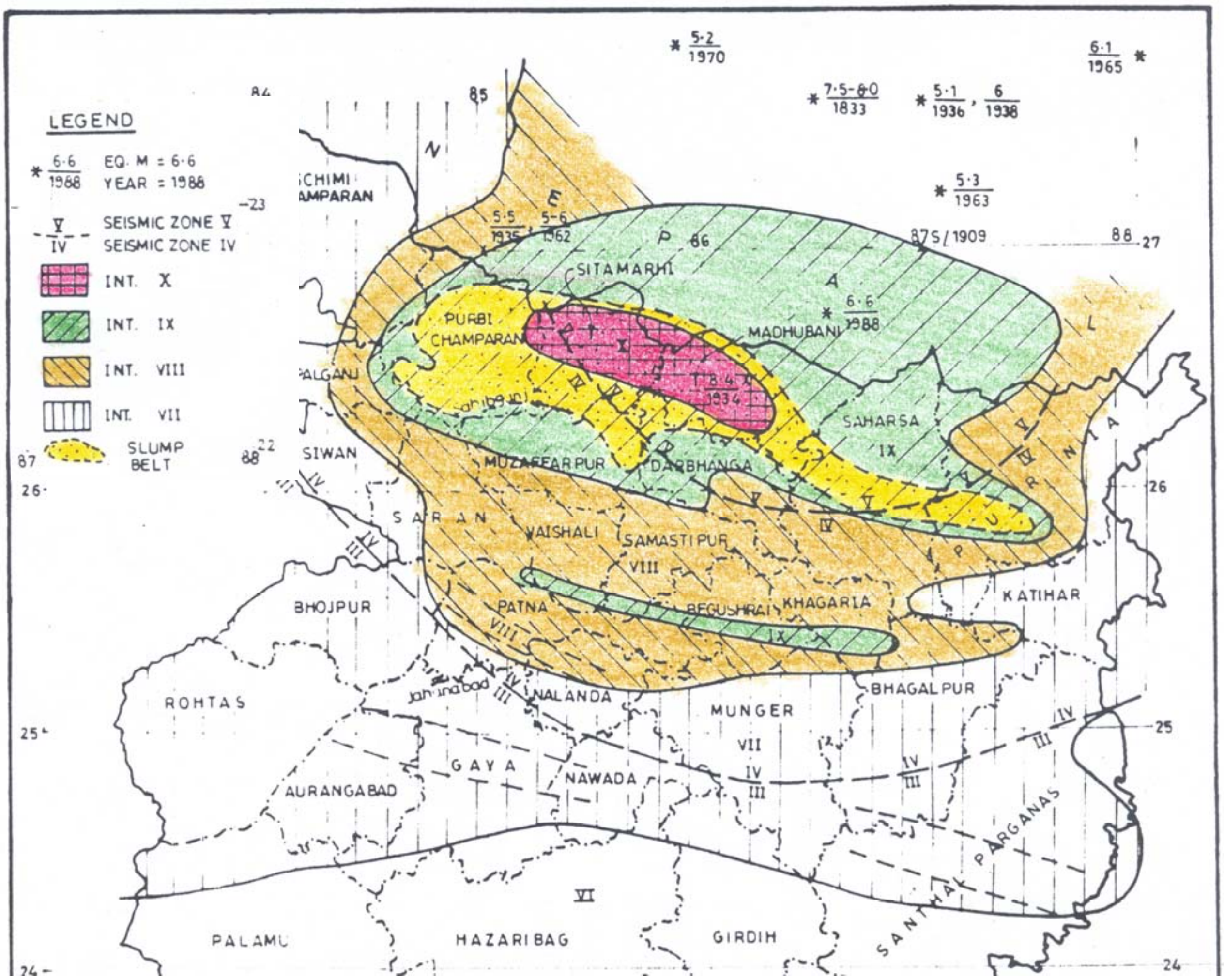


Fig.1:- Map of Bihar showing Districts, Epicentres, Seismic Zones and Isoseismals of 1934 earthquake

percent destroyed. Across the Ganga river also damage in towns of Patna, Barh and Jamalpur was severe including damage to roads. The following is the district wise life loss reported in India (Bihar): Champaran 499, Muzaffarpur 2539, Darbhanga 2149, Monghyr 1497, Saran 193, Bhagalpur 174, Patna 142, Goya 34, Purnia 24, Santhal Parganas 2. (The old districts of Muzaffarpur and Darbhanga include the present districts of Sitamarhi, Madhubani and Saharsa).

The effects of this earthquake expressed in modified Mercalli Scale and observed in terms of the slump belt are shown in the figure super imposed on the survey of India map of Bihar State published in 1974. The epicentres of the earthquakes having Magnitudes more than 5.0 are also plotted. The seismic zones as per IS:1893-2002 are superimposed on this map to show the current thinking about probable maximum intensity on MSK scale since seismic zone V indicates roughly areas of MSK IX and more and Zone IV areas of MSK VIII.

Thus some of the factors that controlled the intensity distribution in this earthquake can be summarized as follows:

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

ii. 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.

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

iv. Munghyr town situated more than 120 km from the epicentre suffered much more severe damage as compared with many towns in between due to a peculiar geologic-geotechnical set up. It is located on a thin shelf of alluvium abutting against Archaean quartzites. The discontinuity seems to play significant role in amplifying the ground motions greatly, due to which this town suffers damage from big as well as small earthquake motions arriving at it from any direction. This town was damaged again in the much smaller earthquake in Aug. 1988 described later and in the more distant earthquake of 1833 described here earlier.

It may be noted that isoseismal IX in this earthquake that is presently in Zone V had enclosed an area of about 36000 km^2 (with a length of about 300km).

7.5 *The 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^{0}45’18”N, Long. 86^{0}36’57.6”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. 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. The overall damage costs in private housing and government buildings structures and services, estimated by the various Government Departments 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 6.6earthquake 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.

8. CRITERIA TO BE ADOPTED IN THE DESIGN OF NEW HOUSES.

Based on the multi-hazard situation and prevailing alluvial soils with high water table conditions the following criteria may be adopted for designing the houses:-

8.1 Foundations

The foundations to be adopted should be resistant to erosion effect of flowing water, and also under the liquefaction effects which may be caused under earthquake intensities MSK VIII and higher likely to occur in Seismic Zone IV & V. Also it is know that rise of water table to the level of footings reduces the bearing capacity of the soil by 50%, hence, the bearing capacity to be considered in the design should be taken of a low value such as 5 – 6 ton/sq.m in the case of shallow foundations, otherwise deep foundations should be adopted.

8.2 Plinth

It will be appropriate to consider the plinth level of the house above the most common flood level in the area and naturally above the drain level in the village.
The plinth of the house must be made of non-erodeable material such as reinforced concrete, plain concrete, masonry constructed in cement mortar and the like.

8.3 Superstructure

The superstructure walls can be constructed using different materials like brick work, concrete block work, stabilized compressed earth block work or lighter materials such as wattle and daub, bamboo matting covered with mud plaster etc.. The requirement will be that the superstructure walls must be made stable under earthquake as well as high wind conditions. Also if the inundation level rises, the wall material should not become soft and dissolve under water. For heavy materials earthquake safety will require use of special reinforcing details for stability as per IS:4326-1993 or IS:13828-1993. If a steel frame is adopted for superstructure framework with different kind of paneeling, the steel work must be used with proper cross bracing to make it stable under earthquakes and wind conditions and pointing to make the construction corrosion-resistant.

At the top level of the walls there will have to be a horizontal framework or use of an eave level band beam or all around integrated with the superstructure walls/frame to provide integrity to all the enclosing wall system. In case, RC slab roofs such a *band* or beam may not be necessary.

8.4 Roof

As per the recommendations given by NDMA in the *National Disaster Management Guidelines – Management of Floods* it is required that the houses in the flood prone areas should be made with *flat horizontal roofs* which could be used as the shelter by the family. This will become necessary when the flood water will rise above the waist level in the house. Therefore, the design criterion should be that the roof must be designed with capability of supporting the occupants of the house during high floods. Also either a permanent stair system will have to be devised, or a ladder will have to be kept by the occupants of the house to use it for going to the roof at the time of the need. For the same reason the roof must be provided with a parapet for providing security to the people when they are using the roof for temporary living.

9. ***TECHNOLOGY OPTIONS FOR CONSTRUCTION OF HOUSES***

9.1 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 are suggested the choice of which will be based on the soil conditions met at the site. These are

(i) Available stiff soil at a depth of about 60 cm below ground level which may not be eroded under flowing flood water nor subject to liquefaction in such a situation the strip foundation which is normally used by the people in the rural areas could be adopted.

(ii) 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 and

(iii) 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 upto 3 m may be adopted. Such piles will also have to carry a reinforced concrete beam at the plinth level to support the super structure.

It may be mentioned that the nature of foundation will be most critical to provide safety to the house under flood condition as well as under earthquake condition.

9.2 Treatment at Plinth Level

The plinth level must be chosen 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 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, which will serve as flooring inside as well as a sitting platform outside. The flooring inside the house is suggested to be kept compacted earthen floor with gobri lipping this could later on changed to a pucca floor by the house owner at his own cost.

9.3 Super Structure Walls

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. 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 200 thickness may also be adopted which will increase the weight of the foundation to some extent. The suggested wall system will provide full support to the roof slab without requiring any beams or the roof bands for seismic safety.

9.4 Safety from Earthquake

From the earthquake safety consideration following reinforcing arrangement has been suggested for strengthening the super structure.

a. Provision of sill level RC band in all the walls of 230 width and 75 mm thk. With 2 bars of 8 mm dia. longitudinally and 6 mm dia. links provided at 200 mm c/c.
b. Vertical reinforcing bars at the centre of the brick columns which will be anchored in the foundation masonry or in the reinforced concrete plinth beam at the bottom or into the roof slab at the top. Such a system will provide complete earthquake stability to the structure.

9.5 Roof

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.

9.6 Drawings of the proposed house

Taking into account the above technology options the drawings have been worked out for a single room house measuring 4.26 X 4.26 m plinth area. In sheet nos. 01 & 02, 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 columns with half brick thick panel walls constructed along with. However, one brick thick walls in rat-trap-bond can also be used on the same foundations. As a third alternative, flyash bricks of twenty centimeter thickness could also be used considering their economy and availability.

Three types of foundation namely

a) strip foundation under the walls, or
b) eight brick pedestals with RC plinth beam at top, or
c) precast RCC pile pedestal foundations at eight points along with a plinth beam at the top have been proposed. The type of foundation to be used will have to depend upon the soil condition at the site.

9.7 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

(i) Door/window chaukhat & shutters
(ii) Pucca floor in the house.
(iii) Plastering/pointing in the walls.
(iv) A high parapet on the roofs.
(v) A pucca staircase.
(vi) A pucca partition in the house

It is suggested that the beneficiary should initially provide the following facilities on its own:-

(i) Door/window chaukhat & shutters of what ever kind the beneficiary could afford.
(ii) The earth fill upto below the plinth level extending beyond the house to the extent he could achieve the land available to him.
(iii) A bamboo mat partition in the house to separate the cooking and living space.
(iv) A wooden/bamboo ladder to climb to the roof at the time of the need.
(v) A mat fence of appropriate height all round above the masonry parapet.

With all these cost additions, the beneficiary can make his house as comfortable as he could afford besides the full safety provided to the family from floods, winds as well as earthquakes.

10. ESTIMATED CONSTRUCTION COSTS

Using the drawings shown on sheet no. 01 & 02 and taking the current Schedule of Rates (24th March, 2008) for distt. Muzaffarpur, kindly supplied by Er. V.N.Sah, Subb. Engg. Services, Muzaffarpur, Bihar, detailed estimates of the various quantities and costs were worked out under the following variable conditions:-

a) Seismic Zones IV & V
b) Costs *including* 'all taxes and contractors profit' and costs *excluding* 'all taxes and contractor's profit'.
c) Providing earthquake resisting features and *without* earthquake resisting features.

The abstract of costs are shown here in tables 5,6 & 7 for the three types of foundation alternatives. Detailed abstract of costs giving the estimated costs of individual items for the three cases of the foundations are given in Annexure 1, 2 & 3 respectively.

TABLE 5:- COST OF THE PROPOSED BUILDING WITH 'STRIP' FOUNDATION

S.No.	Description	Cost in Zone IV		Cost in Zone V	
		Without Taxes & CP	With Taxes & CP	Without Taxes & CP	With Taxes & CP
1	Cost of super structure alone	20209.61	24145.41	20881.27	25640.52
2	Cost of foundation including plinth	13261.24	15829.73	13261.24	15829.73
3	Cost of Earthquake resisting elements	1338.17	1701.47	3314.49	4212.90
	TOTAL COST	**34809.02**	**41676.61**	**37456.99**	**45683.16**
	% COST OF EARTHQUAKE ELEMENTS TO THE TOTAL COST	**3.84**	**4.08**	**8.85**	**9.22**

TABLE 6:- COST OF THE PROPOSED BUILDING WITH 'PEDESTAL' FOUNDATION

S.No.	Description	Cost in Zone IV		Cost in Zone V	
		Without Taxes & CP	With Taxes & CP	Without Taxes & CP	With Taxes & CP
1	Cost of super structure alone	20209.61	24145.41	20881.27	25640.52
2	Cost of foundation including plinth	6534.39	8045.22	6534.39	8045.22
3	Cost of Earthquake resisting elements	1338.17	1701.47	3314.49	4212.90
	TOTAL COST	**28082.17**	**33892.11**	**30730.14**	**37898.65**
	% COST OF EARTHQUAKE ELEMENTS TO THE TOTAL COST	**4.77**	**5.02**	**10.79**	**11.12**

TABLE 6:- COST OF THE PROPOSED BUILDING WITH 'PILE PEDESTAL' FOUNDATION

S.No.	Description	Cost in Zone IV		Cost in Zone V	
		Without Taxes & CP	With Taxes & CP	Without Taxes & CP	With Taxes & CP
1	Cost of super structure alone	20209.61	24145.41	20881.27	25640.52
2	Cost of foundation including plinth	8469.58	10607.15	8469.58	10695.62
3	Cost fo Earthquake resisting elements	1338.17	1701.47	3314.49	4212.90
	TOTAL COST	**30017.36**	**36454.03**	**32665.34**	**40549.04**
	% COST OF EARTHQUAKE ELEMENTS TO THE TOTAL COST	**4.46**	**4.67**	**10.15**	**10.39**

Now referring to Tables 5, 6 & 7, the following observations could be made.

i) If the various taxes are waived by the govt. and materials are supplied to the beneficiaries through material banks and the beneficiaries are allowed to construct their own houses without involving contractor profit, the costs are considerably less namely by about Rs.6000/- to Rs.7000/- in Zone IV and by about Rs.7500/- to Rs.8500/- in seismic zone V which would be about 25% of the estimated costs.

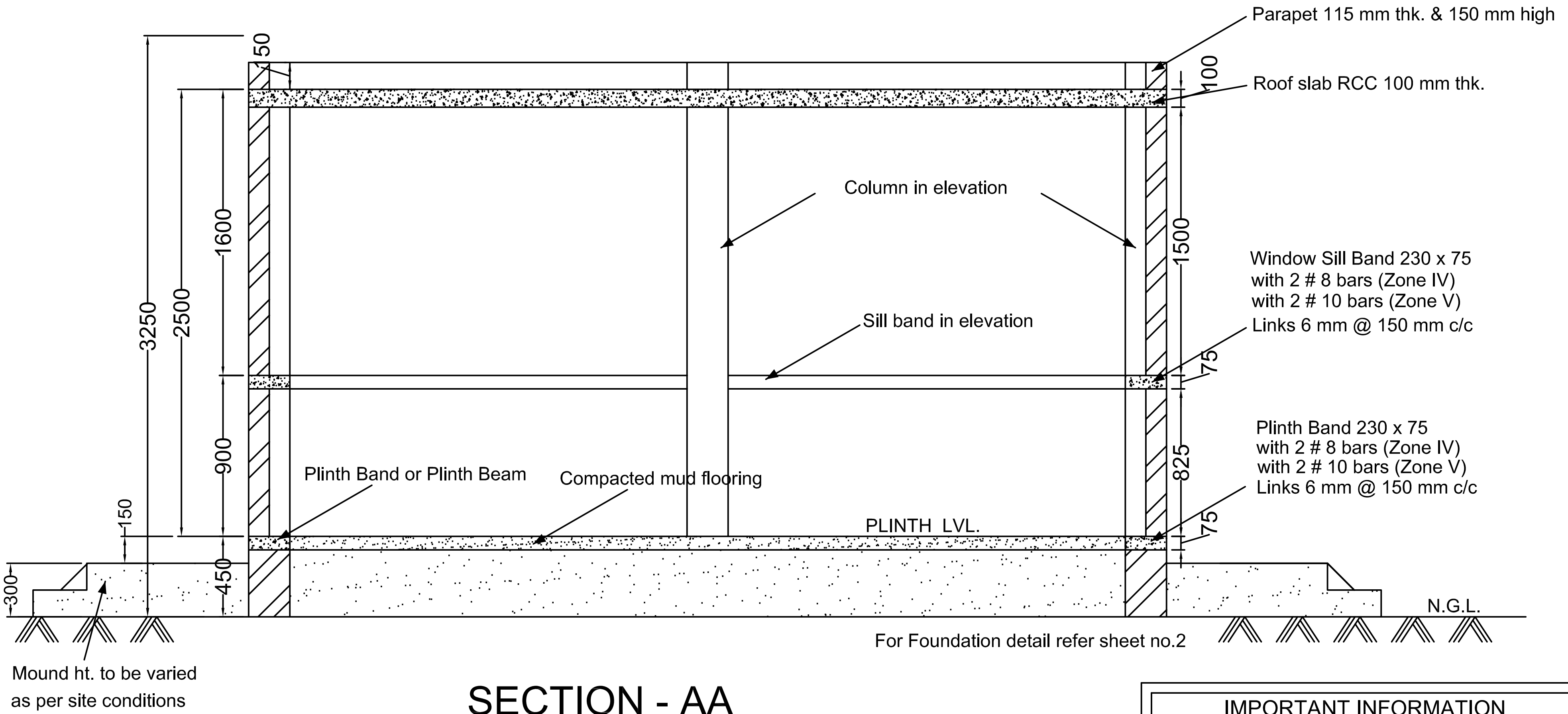
ii) Among the three types of foundation the brick pedestal foundation gives the most economical construction and could be adopted even where strip foundation is indicated by the soil stiffness. The RCC pile pedestal foundation also gives cheaper construction as compared with strip foundation case and may definitely be adopted where very soft soils are encountered to counter flood erosion and liquefaction effects.

iii) It is seen that the consideration of earthquake safety elements raises the cost by about 5% on an average in seismic zone IV and by about 10% on an average in seismic zone V. In view of the long term safety it will be desirable to adopt earthquake resisting designs in all cases.

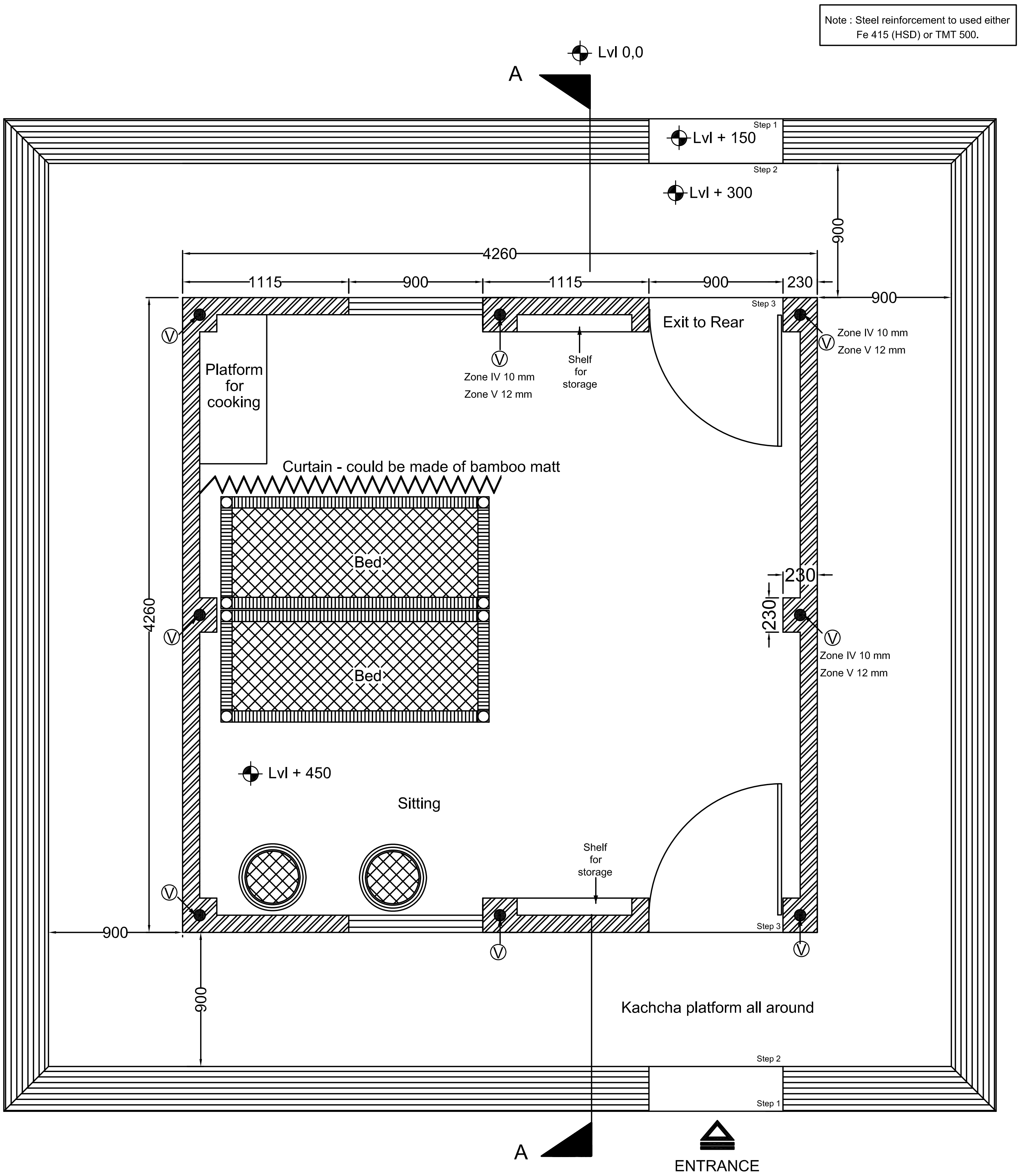
iv) So far as the costs are concerned, the minimum increase in costs in Seismic Zone IV that is where brick pedestal foundations are feasible will exceed the specified expenditure of Rs.25000/- by about Rs.9000/- only and by about Rs.13000/- in Zone V.

11. <u>CONCLUDING RECOMMENDATION</u>

Considering the multi-hazard situation in the districts in North Bihar, it is strongly recommended that all houses under the proposed scheme of the Bihar Govt. should not only be of permanent nature capable of resisting the flood hazard but also should be made safe, in the first instance, against the earthquake hazard postulated in the seismic zoning map, of India. The houses should have a flat roof as recommended by NDMA, Flood Safety Guidelines, which could be used by the residents as temporary shelters. The designs proposed here satisfy all the safety requirements and have been so planned that it is feasible to construct such houses at very economical costs.



SECTION - AA



GROUND FLOOR PLAN

ALL DIMENSIONS IN MM UNLESS SPECIFIED

IMPORTANT INFORMATION

SPECIFICATION FOR SUPERSTRUCTURE

S.No.	DETAILS	ZONE IV	ZONE V
1.	Piers	230 X 230	230 X 230
2.	Walls	115 mm	115 mm
	Note 1: Instead of 230 X 230 piers with 115 mm wall, Rat Trap Bond 230 mm wall may be adopted.		
3.	Cement mortar	1:6	1:4
4.	Seismic band at (230 X 75 mm)		
	Sill level	2 bars-8 mm	2 bars-10mm
	Plinth level (On strip foundation)	2 bars-8 mm	2 bars-10mm
	Note 2:- In view of 2.4 m ceiling height, lintel band is not provided but window sill band in given in Zone IV also.		
5.	Plinth beam (230 X 150) with stirrups 6 mm @ 150 mm C/C. (On Individual pedestal or pedestal pile foundation)	4 bars-10mm	4 bars-10mm
6.	R/f V in Piers	1 bar-10 mm	1 bar-12 mm
7.	Slab thickness	100 mm	100 mm
8.	Parapet - Brick work (115 X 150 mm)		
9.	Earthen platform - 900 mm wide all around - Ht. to be varied according to HFL - To be constructed by beneficiary		
10.	Doors & Windows - Openings to be provided - Chaukhats & Shutters by beneficiary using local material		
11.	Flooring-Compacted mud flooring (but can be altered by the beneficiry on his own expenses).		
12.	Plastering - To be cement plastered but not included in the items & to be done by beneficiary		

SPECIFICATION FOR FOUNDATION

Three types of foundations havebeen proposed based upon Soil condition and water table.

1. Strip footing: -
   Where soil of good bearing capacity is available at 0.6 m below G.L.
2. Individual Pedestal footing
   Where soil of good bearing capacity is available at 1.5 m below G.L.
3. Pedestal Pile foundation
   Where soft sandy soil with high water table exists to depths > 2 m

PROJECT TITLE

DESIGN OPTIONS FOR CONSTRUCTION OF MASS HOUSING IN FLOOD AFFECTED AREAS OF BIHAR USING LOW COST CONSTRUCTION TECHNIQUE

SHEET TITLE:- GROUND FLOOR PLAN & SECTION

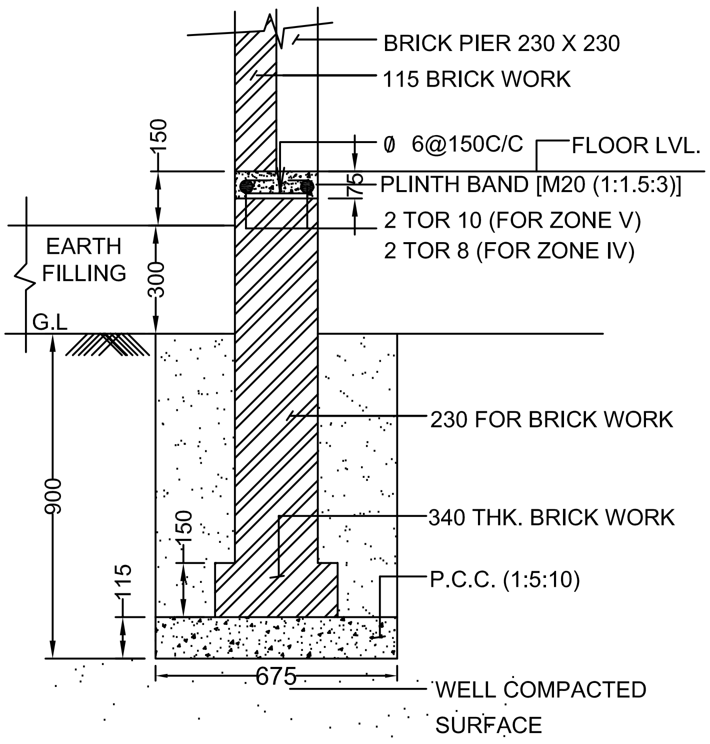
500 1000
1000 0 2000mm

DATE:- 11.03.08

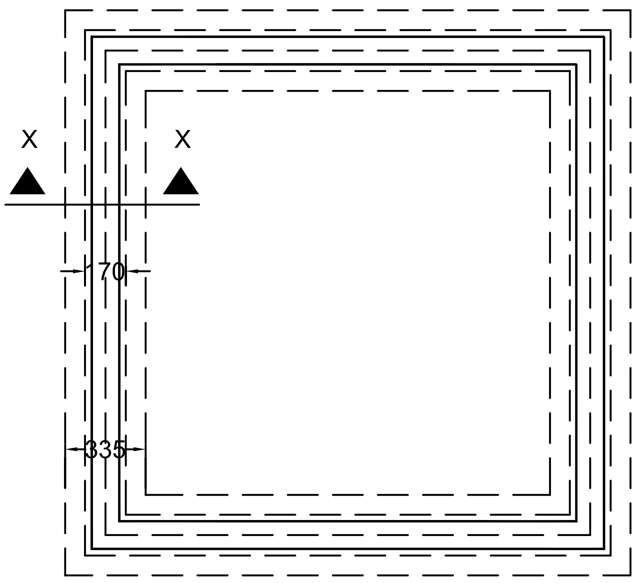
SHEET NO :- 01

PREPARED BY:-	APPROVED BY:-
ANKUSH AGARWAL Programme Associate GoI-UNDP, DRM	Dr. A.S.Arya National Seismic Advisor GoI-UNDP, DRM

STRIP FOOTING

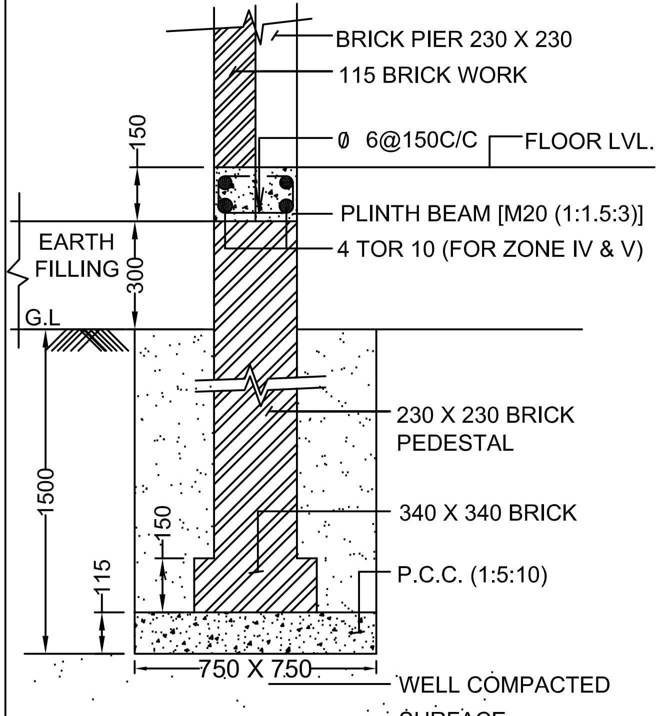


SECTION XX

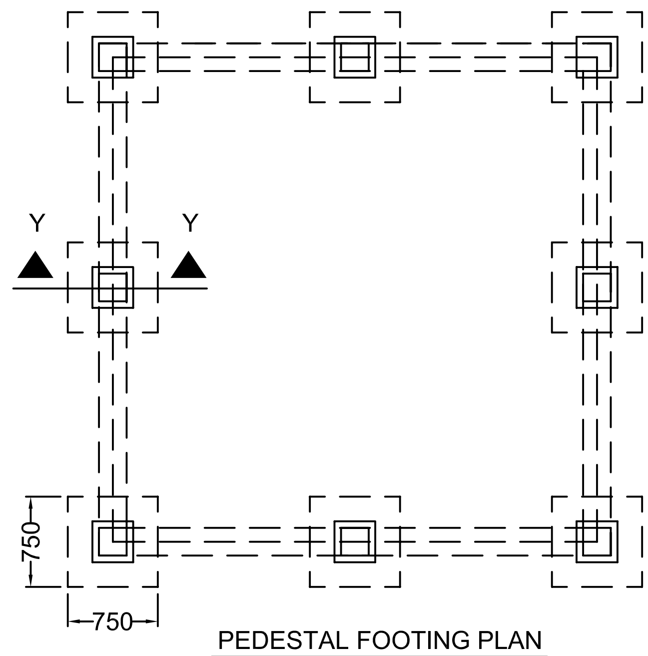


STRIP FOOTING PLAN

PEDESTAL FOOTING

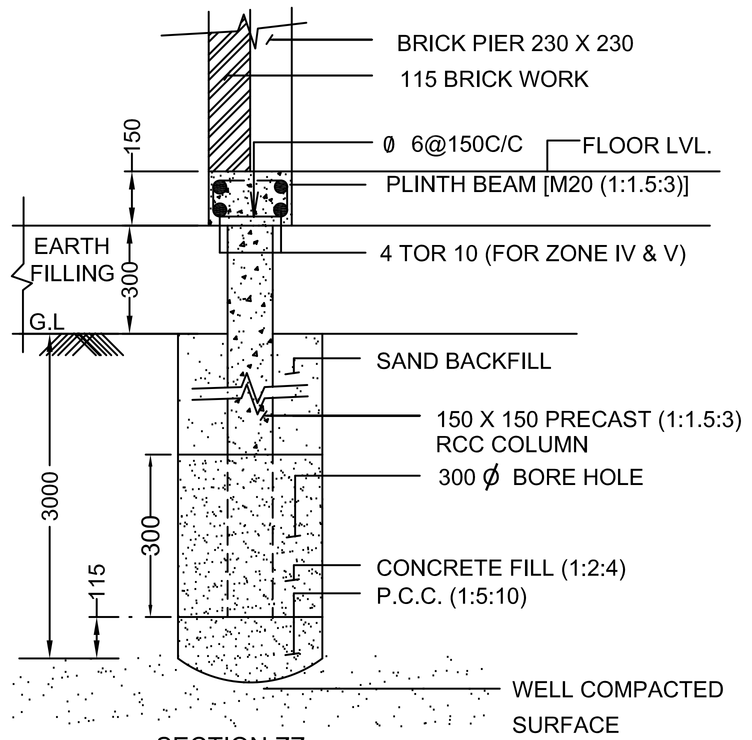


SECTION YY

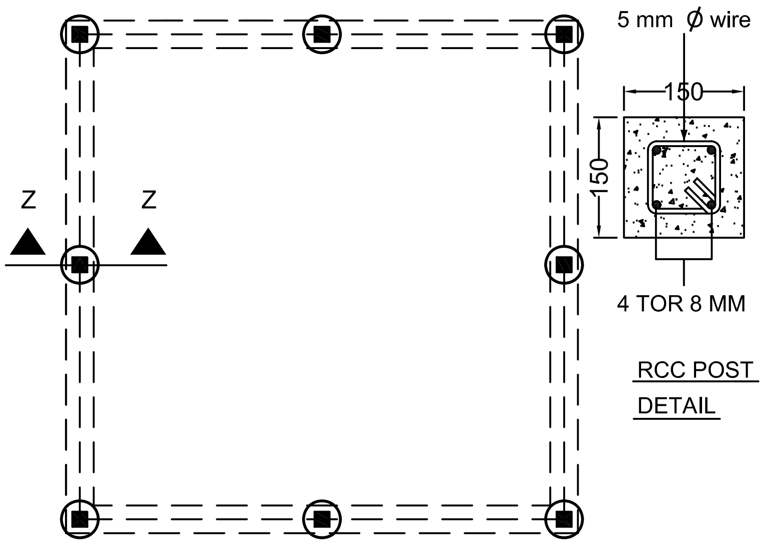


PEDESTAL FOOTING PLAN

PEDESTAL PILE FOOTING

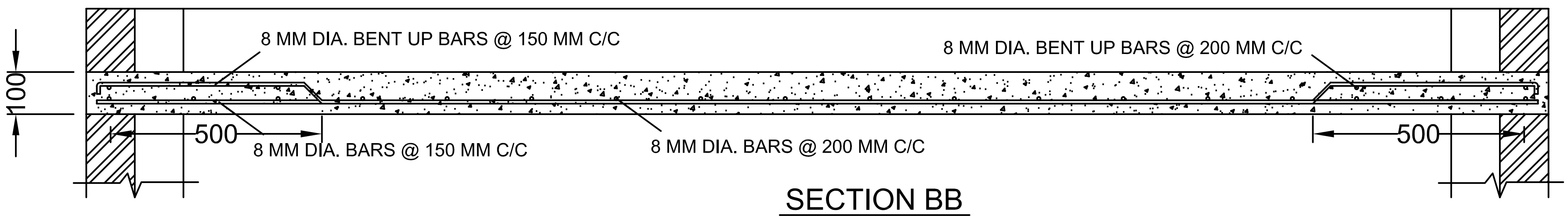


SECTION ZZ

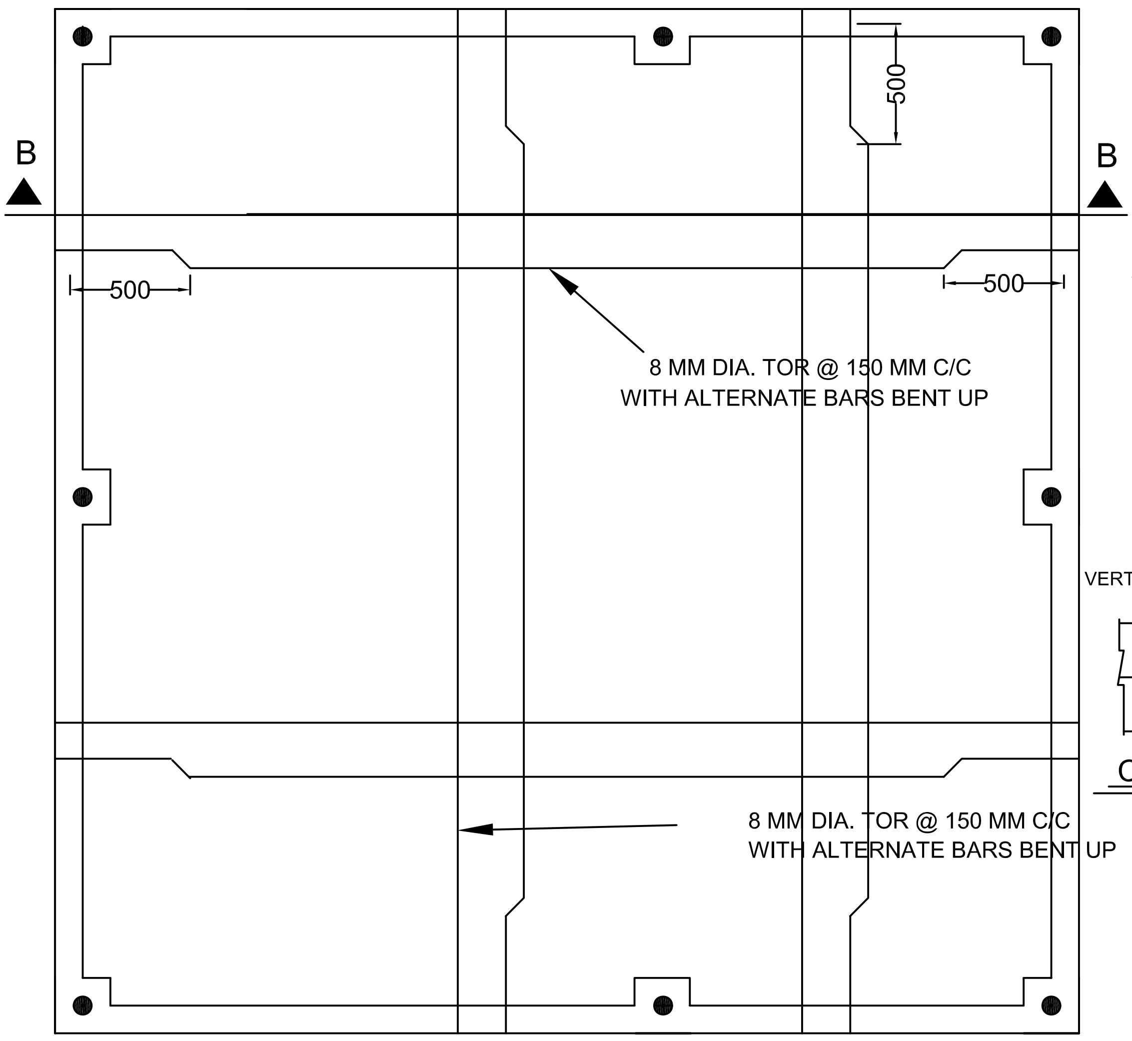


RCC POST DETAIL

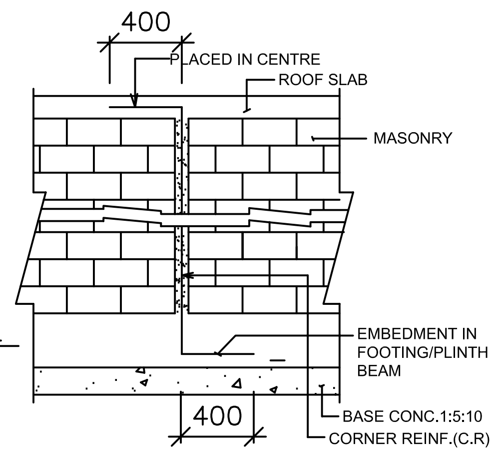
PEDESTAL PILE FOOTING PLAN



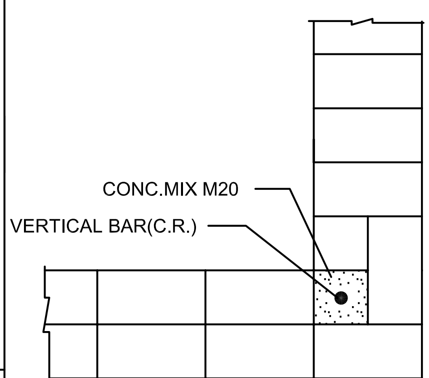
SECTION BB



SLAB REINFORCEMENT DETAIL



EXTENDED ELEVATION OF CORNER AND WALL INTERSECTION REINF.PLACING



CORNER REINFORCEMENT IN BRICK WORK (TYP)

ALL DIMENSIONS IN MM UNLESS SPECIFIED

PROJECT TITLE	
DESIGN OPTIONS FOR CONSTRUCTION OF MASS HOUSING IN FLOOD AFFECTED AREAS OF BIHAR USING LOW COST CONSTRUCTION TECHNIQUE	
SHEET TITLE:- FOUNDATION & ROOF SLAB DETAIL	
DATE:- 11.03.08	SHEET NO :- 02
PREPARED BY:-	APPROVED BY:-
ANKUSH AGARWAL Programme Associate GoI-UNDP, DRM	Dr. A.S.Arya National Seismic Advisor GoI-UNDP, DRM

Prepared by:

Professor Anand S. Arya and Ankush Agarwal

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