World Housing Encyclopedia Report

Country: India

Housing Type: Unreinforced brick masonry walls in mud mortar with flat timber roof

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1 General Information

1.1 Country
India

1.3 Housing Type
Unreinforced brick masonry walls in mud mortar with flat timber roof


FIGURE 1: Typical Building

1.4 Summary
This is a traditional construction practice prevalent both in urban and rural areas of the northern India, particularly in western part of the Uttar Pardesh State. According to the 1991 Census of India, this construction constutites about 17 % of the total national housing stock and about 31% of the U.P. housing stock. Typically, this is a single-storey construction and the main loadbearing elements are unreinforced brick masonry walls in mud mortar built without any seismic provisions. The roof structure consists of timber beams supported by the walls. Clay tiles or bricks are laid atop the beams; finally, mud overlay is placed atop the tiles for the thermal protection and to prevent leakage. The main seismic deficiencies of this construction are heavy roofs and low strength masonry walls, which render it rather vulnerable to seismic effects.

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	
< 50 years	
< 75 years	
< 100 years	X
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
	X	

1.6 Region(s) Where Used
This type of construction is prevalent throughout the North India and particularly in western part of the Uttar Pardesh (U.P.) State. Accoding to the 1991 Census of India, buildings of this type constitute around 17% of the total national housing stock and 31% of the housing stock in U.P.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	
In rural areas	
In suburban areas	
Both in rural and urban areas	X

Additional Comments: This type of building is found in both urban and rural areas. The only difference is in the use of mortar. Mud is used as mortar and overlaid on the roofs in rural areas while cement mortar is used instead of mud in urban areas.

2 Architectural Features

2.1 Openings

This type of buildings have very less openings, generally there are no openings except doors. The buildings are usually comprised of two rooms. The inner rooms do have only one door in the middle while outer rooms have 3 doors. There are usually no other openings. In some cases small opening are made in the outer room over the doors. These houses usually constructed in form of the cluster with wall to wall attachment and as such there are no opening spaces except front portion of the buildings.In general, the opening are found above the middle door in the shape of small ventilators with some traditional shapes such as

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)		
Is it typical for buildings of this type to have common walls with adjacent buildings?	X	

The typical separation distance between buildings is 5 meters

2.3 Building Configuration

This type of buildings is rectangular shaped in general. Very few buildings are of L-shaped.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	X
Multiple housing units	
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

Additional Comments: Traditionally a compound has two or more units of this type. The joint families do stay in this type of buildings. As the family extends and need for more space is felt, the extended families do construct different portion for their use in the same compound. Usually the house compound comprised of one pucka/ semi pucka and one kutcha portion of buildings. Depending upon the growth of economic condition of the household the kutcha portion changed over to pucka building over a period of time. Type of kutcha construction is very similar to pucca construction in terms of look and openings. The difference lies in the use of material. For kutcha house, mud walls or adobe walls are used instead of brick walls. Similar study for kutcha house (mud walls with flat roof housing types) is in progress to be included in the II stage of study.

2.5 Means of Escape

As such there are no special means of escape in these type of buildings. Most of the buildings are single story.

2.6 Modification of Buildings

As such there are no modifications in this type of buildings. The only modifications take place in terms if providing extensions by constructing one room in the over the terrace of the housing unit.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

As the joint family tradition is very strong in the rural parts of India, an extended family occupy the housing unit. Typically, the families comprise of a father and 3-4 sons, staying together in this type of house in the beginning. As the family further expands, the families of sons separate out and occupy the independent units.

3.2 Number of Housing Units in a Building

1 units in each building.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5		
5 to 10	X	
10-20		X
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 1

Additional Comments: The compound comprising of two or more such building units usually has one toilet and one bathroom common to both units. Very rarely, the households have the access to two toilets as well.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor		/
Middle Class	X	/
Rich	X	/

Additional Comments: The rich people do good quality finishing and good interiors. They usually do the cement plastering on the outer face of the wall and put cement plaster over the roof as well. This type of houses have brick paved surface for the courtyards and cement flooring in the rooms. The middle income household have no flooring and they use cement pitching on the outer face of the wall. They have the mud roofs. This type of houses do have mud flooring for the courtyards as well as in the rooms.

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	X
Personal Savings	X
Informal Network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks / mortages	
Investment pools	
Combination (explain)	
Government-owned housing	
Other	

3.7 Ownership

Type of Ownership/Occupancy	
Rent	
Own outright	X
Own with Debt (mortgage or other)	
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	
Other	

4 Structural Features

4.1 Lateral Load-Resisting System

There is no special provision for the lateral load transfer; in general, these buildings are very weak against the earthquake loads. Mud mortar is often used as mortar; cement mortar is used much less often. Lime mortar was used in some older construction (more than 50 years old). The roof is laid over the wooden beams fixed in the slots in the walls (Fig. 4); bricks or tiles or redstones are laid over the beams. To seal the leakage and improve bonding, a 1 ft. thick mud overlay is placed atop the tiles; thickness of this overlay increases with time (as the owner add more and more mud each year before the rainy season).

4.2 Gravity Load-Bearing Structure

The gravity loads are transferred from the roof through the timber beams to the walls and then to the ground (there are typically no foundations in buildings of this type).

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	X
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35		

Additional Comments: Mud mortar is mainly used in rural areas and cement mortar is used in urban areas.

4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	X
	Rubble stone (fieldstone) isolated footing	
	Rubble stone (fieldstone) strip footing	
	Reinforced concrete isolated footing	
	Reinforced concrete strip footing	
	Mat foundation	
	No foundation	
Deep Foundation	Reinforced concrete bearing piles	
	Reinforced concrete skin friction piles	
	Steel bearing piles	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural Concrete	Solid slabs (cast in place or precast)		
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
Timber	Rammed earth with ballast and concrete or plaster finishing		
	Wood planks or beams with ballast and concrete or plaster finishing		
	Thatched roof supported on wood purlins		
	Wood single roof		
	Wood planks or beams that support clay tiles		X
	Wood planks or beams that support slate, metal asbestos-cement or plastic corrugated sheets or tiles		
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other			

Additional Comments: In this type of buildings timber beams are laid over the walls. Clay tiles cover these beams and are covered by a 1 ft. thick mud overlay.

4.6 Typical Plan Dimensions

Length: 12 - 18 meters
Width: 12 - 18 meters

4.7 Typical Number of Stories

1

4.8 Typical Story Height

3 meters

Additional Comments: Typical story height is 3-4 meters

4.9 Typical Span

3 meters

Additional Comments: Wall span (between two adjacent cross walls) typically ranges from 3 to 4 meters.

4.10 Typical Wall Density

12% - 20%

4.11 General Applicability of Answers to Questions in Section 4

This contribution describes a building type and it is not based on the case study of a particular building.

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	True	False	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces form the building to the foundation.		X	
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e.. shape and form, during an earthquake of intensity expected in this area.		X	
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity, during an earthquake of intensity expected in this area.			X
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.			X
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).		X	
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.		X	
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.		X	
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.		X	
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).			X
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).		X	
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).		X	
Other				

Additional Comments: In terms of wall openings - this condition is true in case of inner rooms, where opening are in the middle of the wall; it is not true in case of outer rooms, where three doors are provided.

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	-Very weak from earthquake point of view; -Use of mud mortar in rural areas; - RC bands at various levels are not provided - No measures to strengthen the corners - Internal cupboards openings -Loft erected from the wall in the inner rooms (could cause asymmetric displacement).		
Frame (columns, beams)			
Roof and floors	- No proper connection between the wall and roof -Heavy load of mud over the roof.		
Other	Complete lack of awareness about the earthquake resistant construction practices.		

5.3 Seismic Vulnerability Rating

	Vulnerability					
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class	<	0	>			

0 - probable value
< - lower bound
> - upper bound

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
0	Bulandshahar (Uttar Pradesh)	6.7	VIII (MSK)
1993	Killari (Maharashtra)	6.4	VIII (MSK)
1997	Jabalpur (MP)	6.1	VII (MSK)
2001	Bhuj (Gujarat)	7.6	X (MSK)

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	BrickMud MortaCement Mortar (urban)	3.5 N/mm² N/A 7.5 N/mm²	228 X 114 X 76 mm³ N/A 1:4 (cement:sand) Standard size	
Foundations	Mud Mortar			
Roof and floors	Timber (good quality) Clay Tiles	N/A 3.5 N/m²	150 X 150 X L mm³ NA	

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

Local mason do the construction of this type of buildings. He may also built his house in the similar fashion.

7.3 Construction Process

o erect the wall, a trench is excavated 1-1.5 m deep. The first layer (~150 mm thick) is laid using broken brick aggregate and the wall is constructed over it.
After the completion of the walls the timber beams are placed over the wall slots and tiles are placed over them. The top tiles surface is covered using thatch / plastic sheets etc. and mud is overlaid.
Openings are made during the walls construction process.

7.4 Design/Construction Expertise

There is no formal training for the masons. The person constructing the house learnt the art of construction over a period of time. The person starts working with the local mason as laborer and learn the art of construction just by observing the head mason. After a period of time he himself starts working as the assistant mason and later on take over as the head mason.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?	X	

Title of the code or standard: Improving Earthquake Resistance of Low Strength Masonry Buildings - Guidelines IS 13828:1993 by Bureau of Indian Standards
Year the first code/standard addressing this type of construction issued: 1993
National building code, material codes and seismic codes/standards: IS 4326-1993 Indian Standard Code of Practice for Earthquake Resistant Design and Construction of Buildings IS 1893-1984 Indian Standard Recommendations for Earthquake Resistant Design of Structures
When was the most recent code/standard addressing this construction type issued? 1993

7.6 Role of Engineers and Architects

Engineers and architects do not play any role in construction of this type. In the rural parts of India the professionally trained architects and engineers do not play any role in the construction of the private buildings. The same practice prevails in the construction of this housing type even if built in semi-urban areas.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required		X
Informal construction	X	
Construction authorized per development control rules		X

Additional Comments: There are no building control and/ or guidelines in the rural parts of India. Even no

approval of any authority is required prior to construction of houses / buildings.

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)		X
Building originally designed for its final constructed size		X

Additional Comments: In certain cases construction of single room over the roof may take place on a later date to adjust the extended joint family.

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	
Owner(s)	X
Renter(s)	
No one	
Other	

Additional Comments: The owners do the maintenance themselves. It is customary to lay mud / mud plaster over the roof prior to the rainy season. The whitewashing etc. are done on regular basis on the occasion of festivals and other special occasions.

7.10 Process for Building Code Enforcement

There is no enforcement of building codes in India for the rural / semi urban construction.

7.11 Typical Problems Associated with this Type of Construction

No technical know-how about earthquake resistant construction practices.
Poor brick quality.
Poor workmanship if a less experienced masons is employed.
Number of buildings do develop the cracks due to different reasons (such as back to back joints with different types of construction).
The occupants of the building have no knowledge and usually do not worry for the repair etc.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

The unit cost of construction of this type of houses is about Rs. 2000/-(US$ 42) per m². This cost may increase depending upon the quantity of cement used for mortar, flooring and plastering etc. The overall cost may also reduced based on the contribution of the household towards labor.

8.2 Labor Requirements (estimate)

The labor requirement for a typical house of about 80-100 m² are about 60-80 man days.

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available		X
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features		X

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (Strengthening)	Heavy roof due to extensive mud overlay	Removal of mud from the roof top will help in overall weight reduction of the building
	Inadequate wall resistance due to the absence of seismic provisions	i) Covering the wall with 2 ft. wide seismic belt (steel wire mesh and cement mortar) at lintel level on both sides of the wall; Seismic belt extended by 1 ft. above slab level covering parapets is proposed to enhance the box action i.e. integrity of the roof and wall).
New Construction	Foundation	Provision of strip foundation (currently, many buildings of this type do not have foundations at all)
	Wall	- Provision of RC ring beams ar plinth, lintel and roof levels - Provision of vertical steel reinforcement bars at the wall corners and intersections
	Roof	- Placing the timber beams used for roofing over a long beam/plank for uniform load transfer of the roof load. - Reduce mud overlay atop the roof

10.2 Has seismic strengthening described in the above table been performed in design practice, and if so, to what extent?

No (very rarely).

10.3 Was the work done as a mitigation effort on an undamaged building, or as repair following earthquake damage?

N/A

10.4 Was the construction inspected in the same manner as new construction?

N/A

10.5 Who performed the construction: a contractor, or owner/user? Was an architect or engineer involved?

N/A

10.6 What has been the performance of retrofitted buildings of this type in subsequent earthquakes?

N/A

11 References

Improving Earthquake Resistance of Low Strength Masonry Buildings - Guidelines IS:13828-1993

Repair and Seismic Strengthening of Buildings - Guidelines IS: 13935-1993

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A Manual of Earthquake Resistant Non- Engineered Construction; ISET, Roorkee

Improving Earthquake Resistance of Housing- Guidelines; BMTPC, New Delhi.

12 Contributors

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13 Figures

FIGURE 1: Typical Building

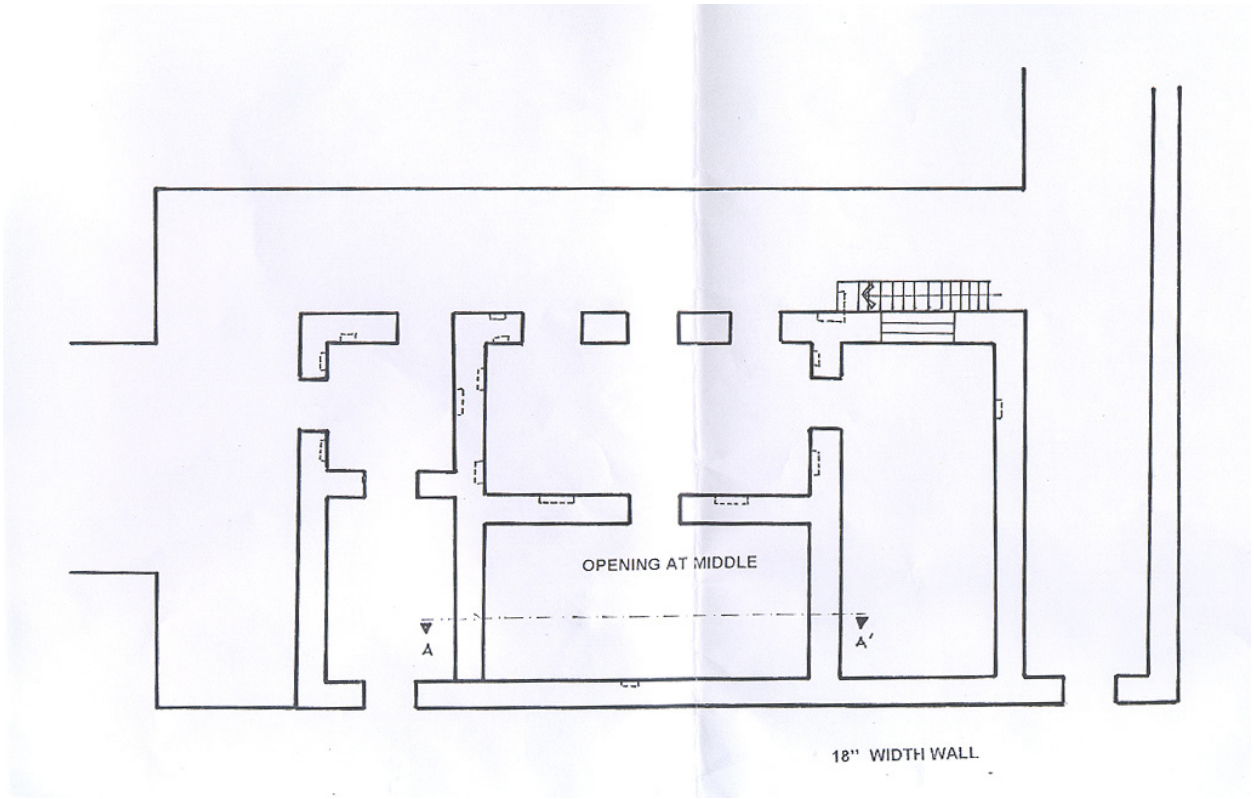

FIGURE 3: Plan of a Typical Building

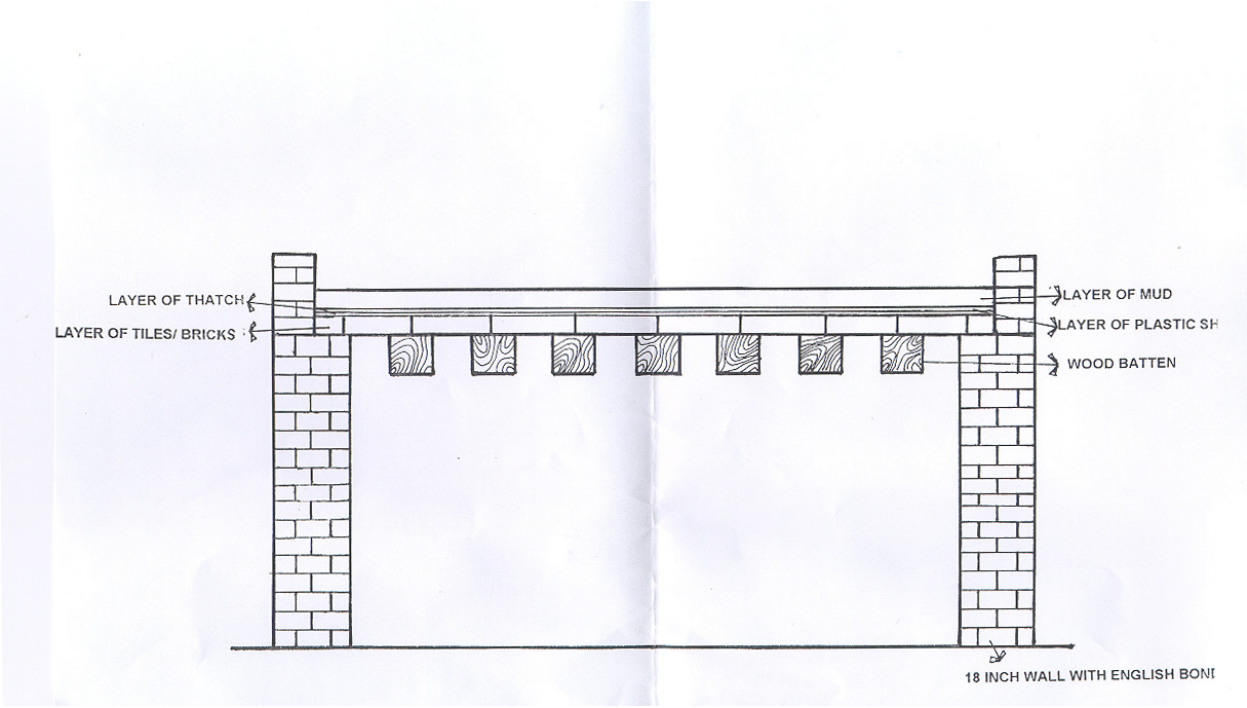

FIGURE 4: Critical Structural Details

FIGURE 4A: Critical Structural Details - Roof Structure (Source: Sudhir K. Jain, IIT Kanpur)

FIGURE 4B: Critical Structural Details - Unreinforced Brick Masonry Wall in Mud Mortar (1993 Killari Earthquake), Source: Sudhir K. Jain, IIT Kanpur

FIGURE 5: Key Seismic Deficiencies - Heavy Roof

FIGURE 6: Typical Earthquake Damage in the 2001 Bhuj earthquake (Source: Sudhir K. Jain, IIT Kanpur)

FIGURE 6A: Typical Earthquake Damage - Failure of Unreinforced Masonry Walls in the 1997 Jabalpur Earthquake (Source: Sudhir K. Jain, IIT Kanpur)

FIGURE 6B: Typical Earthquake Damage - Failure of Masonry Walls in the 1997 Jabalpur Earthquake (Source: Sudhir K. Jain, IIT Kanpur)

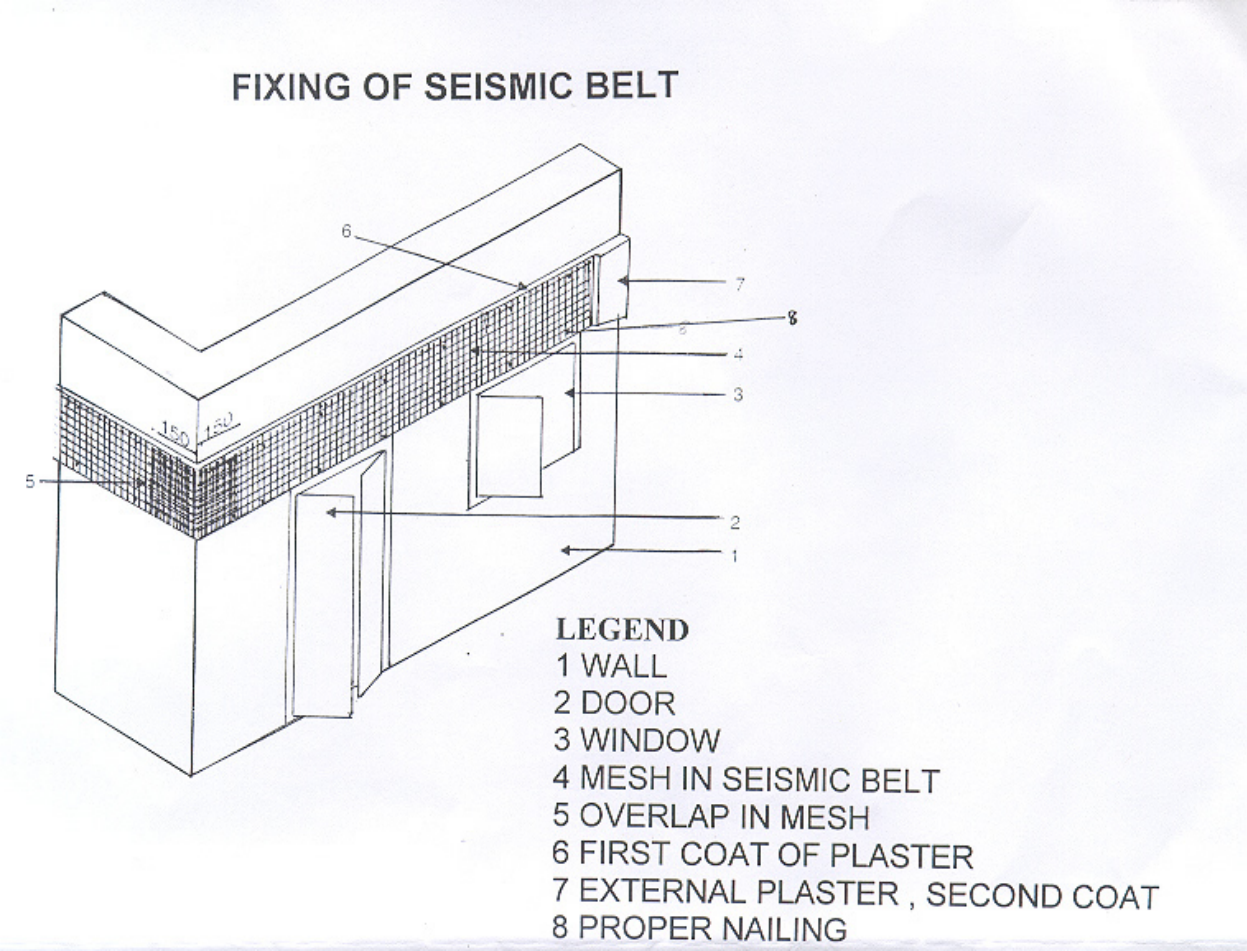

FIGURE 7: Illustration of Seismic Strengthening Techniques