
World Housing Encyclopedia

*an Encyclopedia of Housing Construction in
Seismically Active Areas of the World*



an initiative of
Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

Unreinforced brick masonry walls in mud mortar with flat timber roof

Report #	20
Report Date	06-05-2002
Country	INDIA
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in mud/lime mortar
Author(s)	Amir Ali Khan, Khalid Moin
Reviewer(s)	Ravi Sinha

Important

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John A. Martin & Associates, Inc. or the participants' organizations.

Summary

This is a traditional construction practice prevalent both in the urban and rural areas of northern India, particularly in the western part of the Uttar Pradesh state. According to the 1991 Indian census, this construction constitutes about 17% of the total national housing

stock and about 31% of the U.P. housing stock. Typically, this is a single-story construction. The main load-bearing 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 on top of the tiles for the thermal protection and to prevent leakage. The main seismic deficiencies are heavy roofs and low-strength masonry walls, which render the building rather vulnerable to seismic effects.

1. General Information

Buildings of this construction type can be found in Northern India and particularly in western part of the Uttar Pradesh (U.P.) State. According 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. This type of housing construction is commonly found in both rural and urban areas.

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.

This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built.



Figure 1: Typical Building

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. Houses may be located closely without a link or with a distance of 5-10 m. When separated from adjacent buildings, the typical distance from a neighboring building is 5 meters.

2.2 Building Configuration

This type of buildings is rectangular shaped in general. Very few buildings are of L-shaped. This type of buildings have very few 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 openings are made in the outer room over the doors. These houses are usually constructed in the form of a cluster with wall-to-wall attachment and as such there are no opening spaces except the front portion of the buildings. In general, the openings are found above the middle door in the shape of small ventilators with some traditional shapes such as.

2.3 Functional Planning

The main function of this building typology is single-family house. 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 pukka/ semi pukka and one kutcha portion of buildings. Depending upon the growth of economic condition of the household the kutcha portion changed over to pukka 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. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. As such there are no special means of escape in these type of buildings. Most of the buildings are single story.

2.4 Modification to Building

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

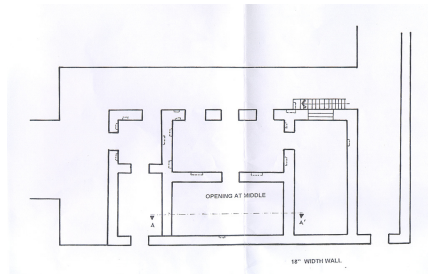


Figure 2: Plan of a Typical Building

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	<input type="checkbox"/>
		2	Dressed stone masonry (in lime/cement mortar)	<input type="checkbox"/>
	Adobe/ Earthen Walls	3	Mud walls	<input type="checkbox"/>
		4	Mud walls with horizontal wood elements	<input type="checkbox"/>
		5	Adobe block walls	<input type="checkbox"/>
		6	Rammed earth/Pise construction	<input type="checkbox"/>
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	<input checked="" type="checkbox"/>
		8	Brick masonry in mud/lime mortar with vertical posts	<input type="checkbox"/>
		9	Brick masonry in lime/cement mortar	<input type="checkbox"/>
		10	Concrete block masonry in cement mortar	<input type="checkbox"/>
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	<input type="checkbox"/>
		12	Clay brick masonry, with concrete posts/tie columns and beams	<input type="checkbox"/>
		13	Concrete blocks, tie columns and beams	<input type="checkbox"/>
			14	Stone masonry in cement mortar

	Reinforced masonry	15	Clay brick masonry in cement mortar	<input type="checkbox"/>
		16	Concrete block masonry in cement mortar	<input type="checkbox"/>
Structural concrete	Moment resisting frame	17	Flat slab structure	<input type="checkbox"/>
		18	Designed for gravity loads only, with URM infill walls	<input type="checkbox"/>
		19	Designed for seismic effects, with URM infill walls	<input type="checkbox"/>
		20	Designed for seismic effects, with structural infill walls	<input type="checkbox"/>
		21	Dual system – Frame with shear wall	<input type="checkbox"/>
	Structural wall	22	Moment frame with in-situ shear walls	<input type="checkbox"/>
		23	Moment frame with precast shear walls	<input type="checkbox"/>
		Precast concrete	24	Moment frame
	25		Prestressed moment frame with shear walls	<input type="checkbox"/>
	26		Large panel precast walls	<input type="checkbox"/>
27	Shear wall structure with walls cast-in-situ		<input type="checkbox"/>	
28	Shear wall structure with precast wall panel structure		<input type="checkbox"/>	
Steel	Moment-resisting frame	29	With brick masonry partitions	<input type="checkbox"/>
		30	With cast in-situ concrete walls	<input type="checkbox"/>
		31	With lightweight partitions	<input type="checkbox"/>
	Braced frame	32	Concentric connections in all panels	<input type="checkbox"/>
		33	Eccentric connections in a few panels	<input type="checkbox"/>
	Structural wall	34	Bolted plate	<input type="checkbox"/>
35		Welded plate	<input type="checkbox"/>	
Timber	Load-bearing timber frame	36	Thatch	<input type="checkbox"/>
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	<input type="checkbox"/>
		38	Masonry with horizontal beams/planks at intermediate levels	<input type="checkbox"/>
		39	Post and beam frame (no special connections)	<input type="checkbox"/>
		40	Wood frame (with special connections)	<input type="checkbox"/>
		41	Stud-wall frame with plywood/gypsum board sheathing	<input type="checkbox"/>
		42	Wooden panel walls	<input type="checkbox"/>
Other	Seismic protection systems	43	Building protected with base-isolation systems	<input type="checkbox"/>
		44	Building protected with seismic dampers	<input type="checkbox"/>
	Hybrid systems	45	other (described below)	<input type="checkbox"/>

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

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). 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).

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). 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).

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 12 and 18 meters, and widths between 7 and 10 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 3 meters. Typical Story Height: 3-4 m. Typical Span: Wall span (between two adjacent cross walls) typically ranges from 3 to 4 meters. The typical storey height in such buildings is 3 meters. The typical structural wall density is none. 12 - 20%.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	<input type="checkbox"/>	<input type="checkbox"/>
	Composite system of concrete joists and masonry panels	<input type="checkbox"/>	<input type="checkbox"/>
Structural concrete	Solid slabs (cast-in-place)	<input type="checkbox"/>	<input type="checkbox"/>
	Waffle slabs (cast-in-place)	<input type="checkbox"/>	<input type="checkbox"/>
	Flat slabs (cast-in-place)	<input type="checkbox"/>	<input type="checkbox"/>
	Precast joist system	<input type="checkbox"/>	<input type="checkbox"/>
	Hollow core slab (precast)	<input type="checkbox"/>	<input type="checkbox"/>
	Solid slabs (precast)	<input type="checkbox"/>	<input type="checkbox"/>
	Beams and planks (precast) with concrete topping (cast-in-situ)	<input type="checkbox"/>	<input type="checkbox"/>
	Slabs (post-tensioned)	<input type="checkbox"/>	<input type="checkbox"/>
Steel	Composite steel deck with concrete slab (cast-in-situ)	<input type="checkbox"/>	<input type="checkbox"/>
Timber	Rammed earth with ballast and concrete or plaster finishing	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams with ballast and concrete or plaster finishing	<input type="checkbox"/>	<input type="checkbox"/>
	Thatched roof supported on wood purlins	<input type="checkbox"/>	<input type="checkbox"/>
	Wood shingle roof	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams that support clay tiles	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams supporting natural stones slates	<input type="checkbox"/>	<input type="checkbox"/>
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	<input type="checkbox"/>	<input type="checkbox"/>
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	<input type="checkbox"/>	<input type="checkbox"/>
Other	Described below	<input type="checkbox"/>	<input checked="" type="checkbox"/>

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.

3.6 Foundation

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Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	<input checked="" type="checkbox"/>
	Rubble stone, fieldstone isolated footing	<input type="checkbox"/>
	Rubble stone, fieldstone strip footing	<input type="checkbox"/>
	Reinforced-concrete isolated footing	<input type="checkbox"/>
	Reinforced-concrete strip footing	<input type="checkbox"/>
	Mat foundation	<input type="checkbox"/>
	No foundation	<input type="checkbox"/>
Deep foundation	Reinforced-concrete bearing piles	<input type="checkbox"/>
	Reinforced-concrete skin friction piles	<input type="checkbox"/>
	Steel bearing piles	<input type="checkbox"/>
	Steel skin friction piles	<input type="checkbox"/>
	Wood piles	<input type="checkbox"/>
	Cast-in-place concrete piers	<input type="checkbox"/>
	Caissons	<input type="checkbox"/>
Other	Described below	<input type="checkbox"/>

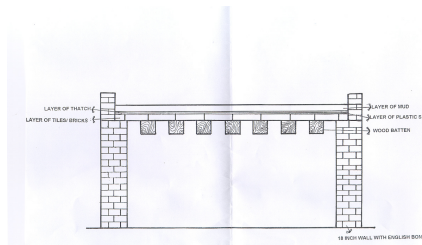


Figure 3: Critical Structural Details



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

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 1 units in each building. The number of inhabitants in a building during the day or business hours is 5-10. The number of inhabitants during the evening and night is 11-20.

4.2 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.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	<input type="checkbox"/>
b) low-income class (poor)	<input type="checkbox"/>
c) middle-income class	<input checked="" type="checkbox"/>
d) high-income class (rich)	<input checked="" type="checkbox"/>

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.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	<input type="checkbox"/>
4:1	<input type="checkbox"/>
3:1	<input type="checkbox"/>
1:1 or better	<input checked="" type="checkbox"/>

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	<input checked="" type="checkbox"/>
Personal savings	<input checked="" type="checkbox"/>
Informal network: friends and relatives	<input type="checkbox"/>
Small lending institutions / micro-finance institutions	<input type="checkbox"/>
Commercial banks/mortgages	<input type="checkbox"/>
Employers	<input type="checkbox"/>
Investment pools	<input type="checkbox"/>
Government-owned housing	<input type="checkbox"/>
Combination (explain below)	<input type="checkbox"/>
other (explain below)	<input type="checkbox"/>

In each housing unit, there are 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) including toilet(s).

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.

4.4 Ownership

The type of ownership or occupancy is outright ownership.

Type of ownership or occupancy?	Most appropriate type
Renting	<input type="checkbox"/>
outright ownership	<input checked="" type="checkbox"/>
Ownership with debt (mortgage or other)	<input type="checkbox"/>
Individual ownership	<input type="checkbox"/>
Ownership by a group or pool of persons	<input type="checkbox"/>
Long-term lease	<input type="checkbox"/>
other (explain below)	<input type="checkbox"/>

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		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 from the building to the foundation.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Building Configuration	The building is regular with regards to both the plan and the elevation.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
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.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
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.	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
	The total width of door and window openings in a wall is:			

Wall openings	For brick masonry construction in cement mortar : less than 1/2 of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
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 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance)*, the lower bound (i.e., the worst possible) is *A: HIGH VULNERABILITY (i.e., very poor seismic performance)*, and the upper bound (i.e., the best possible) is *C: MEDIUM VULNERABILITY (i.e., moderate seismic performance)*.

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
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)



Figure 6: Typical Earthquake Damage in the 2001 Bhuj Earthquake
Damage in the 2001 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)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Brick Mud Mortar Cement Mortar (urban)	3.5 N/mm ² N/A 7.5 N/mm ²	228 X 114 X 76 mm ³ N/A 1:4 (cement:sand) Standard size	
Foundation	Mud Mortar.			
Frames (beams & columns)				
Roof and floor(s)	Timber (good quality) Clay Tiles	N/A 3.5 N/m ² .	150 X 150 X L mm ³ NA	

6.2 Builder

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

6.3 Construction Process, Problems and Phasing

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. The construction of this type of housing takes place in a single phase. Typically, the building is originally not designed for its final constructed size. In certain cases construction of single room over the roof may take place on a later date to adjust the extended joint family.

6.4 Design and Construction Expertise

There is no formal training for the masons. The person constructing the house learned 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. 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.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Improving Earthquake Resistance of Low Strength Masonry Buildings - Guidelines IS 13828:1993 by Bureau of Indian Standards. The year the first code/standard addressing this type of construction issued was 1993. 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. The most recent code/standard addressing this construction type issued was 1993. 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.

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

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and not authorized as per development control rules.

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. Building permits are not required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s). 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.

6.8 Construction Economics

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

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
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).

Strengthening of New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Foundation	Provision of strip foundation (currently, many buildings of this type do not have foundations at all)
Wall	- Provision of RC ring beams at 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

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). Foundation Provision of strip foundation (currently, many buildings of this type do not have foundations at all) Wall - Provision of RC ring beams at 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.

8.2 Seismic Strengthening Adopted

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

No (very rarely).

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

N/A.

8.3 Construction and Performance of Seismic Strengthening

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

N/A.

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

N/A.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

N/A.

Reference(s)

1. IS:13828-1993 Indian Standard Guidelines - Improving Earthquake Resistance of Low Strength Masonry Buildings
Bureau of Indian Standards, New Delhi
2. IS: 13935-1993 Indian Standard Guidelines - Repair and Seismic Strengthening of Buildings
Bureau of Indian Standards, New Delhi
3. Vulnerability Atlas of India
BMTPC, New Delhi 1997
4. Manual of Earthquake Resistant Non- Engineered Construction
IAEE
ISET, Roorkee
5. Improving Earthquake Resistance of Housing - Guidelines
BMTPC, New Delhi.

Author(s)

1. Amir Ali Khan
Assistant Professor, Geo Hazard Group, National Institute of Disaster Management
5B Indra Prastha Estate, IIPA Campus, Ring Road, New Delhi 110002, INDIA
Email:alikhanamir@gmail.com FAX: (91-11) 23702446/42
2. Khalid Moin
Reader, Dept. of Civil Engineering & Technology, Jamia Millia Islamia Jamia Nagar, New Delhi 110025, INDIA
Email:Kmoin_ci@hotmail.com

Reviewer(s)

1. Ravi Sinha
Professor
Civil Engineering Department, Indian Institute of Technology Bombay
Mumbai 400 076, INDIA
Email:rsinha@civil.iitb.ac.in FAX: (91-22) 2572-3480, 2576-7302

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