

World Housing Encyclopedia

A Resource on Construction in Earthquake Regions



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

HOUSING REPORT

Rural mud house with pitched roof

Report#	23
Last Updated	
Country	India
Author(s)	Amit Kumar,
Reviewers	Ravi Sinha,

Important

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General Information

Building Type:	Rural mud house with pitched roof
Country:	India
Author(s):	Amit Kumar
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in all parts of India. Variations of this type of construction are found all over India except where very high rainfall is experienced, such as in the Northeast states of India. Information on percentage of housing stock of this type is not available, but their number is expected to be substantial. This type of housing construction is commonly found in rural areas.
Summary:	This is a typical rural construction found throughout India, except in the high rainfall areas (northeastern part of the country). It is a single family house, mainly occupied by the poorer sections of the population. The main loadbearing system consists of mud walls which carry the roof load. In some cases wooden posts are provided at the wall corners and at intermediate locations. The wooden posts and walls are not structurally integrated, and therefore the loads are shared by the walls and the frame. There are very few openings (doors and windows) in these buildings; in rural areas there are usually no windows at all. In general, this type of construction is built by the owners and local unskilled masons and the craftsmanship is very poor. This building type is classified as grade-A (most vulnerable) as per the IAEE building classification and IS Code 1893:1984. This is a low-strength masonry construction and it is considered to be extremely vulnerable to seismic forces.
Length of time practiced:	More than 200 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling

Typical number of stories:	1
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	Generally the owners and local unskilled masons construct this type of building. The craftsmanship of these buildings is very poor.

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	It is difficult to state the actual length and width of a typical building. The length and width varies according to the requirements. The ratio of such length and width can be 1#:1, 2:1 or 2 #:1. Typical Span: The building size and typical span depends on the number of occupants. Generally wooden posts are provided at the distance of 2 - 2.5 m centre-to-centre longitudinally and transversely.
Typical plan length (meters)	8
Typical plan width (meters)	4
Typical story height (meters)	3.5
Type of Structural System	Masonry: Earthen/Mud/Adobe/Rammed Earth Walls: Mud walls
Additional comments on structural system	Lateral Load Resisting System: The mud walls take the load of the roofing and wall elements. Sometimes the walls are provided with wooden posts at the corners and at intermediate locations. These are generally provided at spacing not exceeding 2 m center to center. However, the wooden posts and walls are not structurally integrated, and the loads are partially shared by walls and partially taken by frame, with each behaving independently of the other. Gravity Load-Bearing System: The roof loads are directly supported by the walls/frames whose loads are supported by the wall/frame foundations.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in	

typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	The typical structural wall density is more than 20 %. The wall density of typical houses is approximately 40%.
Wall Openings	The door and windows openings of such buildings are very small. In rural India windows are generally not provided in such houses. Both gravity and lateral loads are resisted by the mud walls. The doors are typically of size 1.75 m X 0.75 m.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	More typical modification is extensions to buildings.
Type of Foundation	Shallow Foundation: Wall or column embedded in soil, without footing Shallow Foundation: Rubble stone, fieldstone isolated footing Shallow Foundation: Rubble stone, fieldstone strip footing Shallow Foundation: No foundation
Additional comments on foundation	
Type of Floor System	Other floor system
Additional comments on floor system	
Type of Roof System	Roof system, other
Additional comments on roof system	Thatched roof supported on wood purlins Wood shingle roof Wood planks or beams that support clay tiles Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 3 meters.



Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Stone/Timber	
Foundations	Mud	
Floors	Timber	
Roof	Timber	
Other		

Design Process

Who is involved with the design process?	None of the above
Roles of those involved in the design process	Engineers or architects do not have a role in the design/construction of this housing type.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	These buildings are typically self-owned wherein the owner is directly involved in the construction process, and may also contribute labour.
Expertise of those involved in building process	The buildings are constructed by local unskilled persons and villages with out any technical inputs.

Construction process and phasing

The building is constructed with the help of masons. Generally no technical and engineering input is used during the construction process. Foundation: Trench of about 2.5 feet is excavated along the walls. Stone blocks are rammed with mud into the trench to form consolidated foundation. Timber posts, if used, are erected during the ramming of stones. The load-bearing wall is erected above the ground level. The stone walls are sometimes constructed up to 2 feet above ground level, and the mud wall is extended above this level. Wall construction: The wall is made up of mixed mud with wheat husks and water (mud-polymer composite). Generally the wheat husk is mixed and kept for about a week to give it a homogenous texture. The mud mortar is placed and rammed to make it compacted. The wall is erected up to about 2.5 feet in each lift and allowed to dry for one or two days before the next lift. Roofing: Roof truss is either made up of bamboo, wood or built up steel section. The spacing between purlins and rafters are generally not regular. Generally old conventional typical house is covered with heavy clay tiles. The cladding material may not be firmly anchored to the trusses and wall. Openings : Generally mud wall buildings are provided with very few large openings. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. The building byelaws in rural areas are not yet enforced. It requires proper enforcement to the rural and urban areas.

Construction issues

Building Codes and Standards

Is this construction type address by codes/standards?

Yes

Applicable codes or standards

Code/Standard: IS13828-1993 Improving Earthquake Resistance of Low Strength Masonry Buildings-Guidelines, 1993 National Building Code, Material Codes, 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, 1993

Process for building code enforcement

There is no proper building code enforcement in rural areas.

Building Permits and Development Control Rules

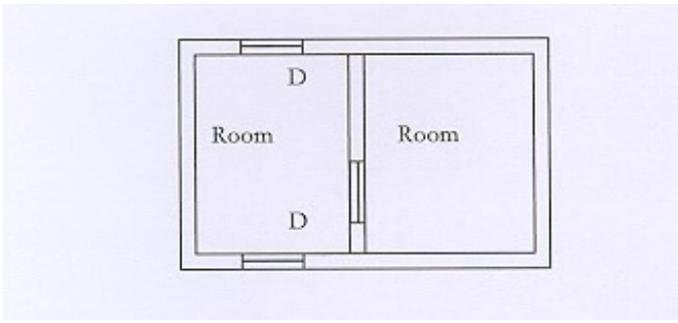
Are building permits required?	No
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	

Building Maintenance and Condition

Typical problems associated with this type of construction	The main problems with this building type are: (1) poor workmanship, (2) choice of low-strength building materials, (3) improper interlocking of different building components, (4) inadequate maintenance, and (5) rapid deterioration in strength due to aging.
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	Rs. 440 per sq m (\$10 per sq m).
Labor requirements	Labor requirement is approximately 85 man-days for the construction of 22.5 sq m plan building.
Additional comments section 3	



Plan of a Typical Building



Critical Structural Details: Wall Section (Source: Sudhir K. Jain)

Socio-Economic Issues

Patterns of occupancy	Generally a single family occupies a single dwelling. Each building typically has one or two units.
Number of inhabitants in a typical building of this construction type during the day	<5
Number of inhabitants in a typical building of this construction type during the evening/night	5-10
Additional comments on number of inhabitants	
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)
Additional comments on economic level of inhabitants	The price is expressed in US\$. For Poor Economic Level the Housing Price unit is 350. Ratio of housing unit price to annual income: 5:1 or worse
Typical Source of Financing	Owner financedPersonal savings
Additional comments on financing	
Type of Ownership	RentOwn outright

Additional comments on ownership

Is earthquake insurance for this construction type typically available?

No

What does earthquake insurance typically cover/cost

N/A

Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?

No

Additional comments on premium discounts

Additional comments section 4

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1997	Jabalpur
2000	Jabalpur

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Jabalpur earthquake of May 22, 1997 seriously affected the life and damaged properties in the epicentral area. It is estimated that about 33,000 buildings in the urban areas and 24,000 buildings in the rural areas were partially damaged or completely destroyed. A typical earthquake damage is shown on Figure 6 (Source: BMTPC Publication).
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1997, Part-1, Earthen Houses With Clay Tile Roofing Guidelines for Damage Assessment and Post-Earthquake Action)

Additional comments on earthquake damage patterns

Partially or complete collapse of wall with failure. Damage observed at weaker sections i.e. joint of column and beam. Collapse of roofing

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ 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.

Structural/Architectural Feature	Statement	Seismic Resistance
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.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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.	FALSE
Floor Construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s)	FALSE

	will maintain its integrity during an earthquake of intensity expected in this area.	
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.	TRUE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
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);	TRUE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doveled into the foundation.	FALSE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		FALSE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
Quality of Workmanship	Quality of workmanship (based on visual	FALSE

	inspection of a few typical buildings) is considered to be good (per local construction standards).	
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	N/A

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Very poor lateral resistance No lintel band is present Opening proportion is not proper The distance between corner and opening is not according to IS code specifications.
Earthquake-resilient features in walls	Provision of wooden columns at regular interval.
Seismic deficiency in frames	No proper connection between column and beam.
Earthquake-resilient features in frame	Partially, it works as a frame structure.
Seismic deficiency in roof and floors	Roof: The roofing elements are not interconnected. The roofing truss is not fully anchored to the wall Poor maintenance makes the roof truss more vulnerable to damage Roof does not provide rigid-diaphragm action.
Earthquake resilient features in roof and floors	
Seismic deficiency in	

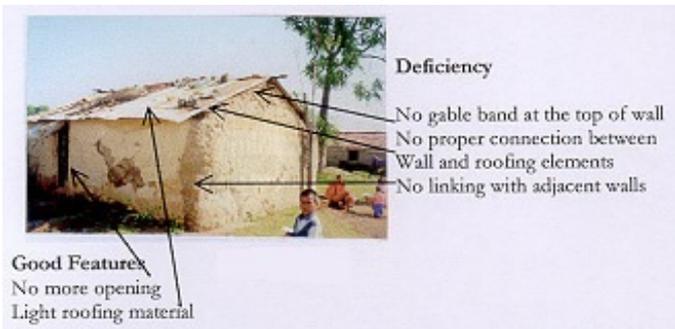
foundation

Earthquake-resilient features in foundation

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

	High vulnerability		Medium vulnerability		Low vulnerability	
	A	B	C	D	E	F
Seismic vulnerability class	0	-				



An Illustration of Key Seismic Features



Typical Earthquake Damage



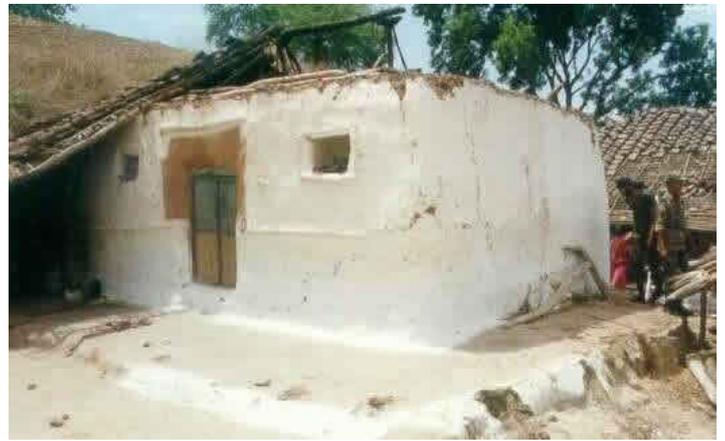
Typical Earthquake Damage - Cracking and Separation of Walls in the 1997 Jabalpur Earthquake (Source: Sudhir K. Jain, IIT Kanpur)



Typical Earthquake Damage - Collapse of roof in the 1997 Jabalpur Earthquake (Source: Sudhir K. Jain, IIT Kanpur)



Typical Earthquake Damage - Cracking and Separation of Walls in the 1997 Jabalpur Earthquake (Source: Sudhir K. Jain, IIT Kanpur)



Typical Earthquake Damage - Cracking of Walls in the 1997 Jabalpur Earthquake (Source: Sudhir K. Jain, IIT Kanpur)

Retrofit Information

Description of Seismic Strengthening Provisions

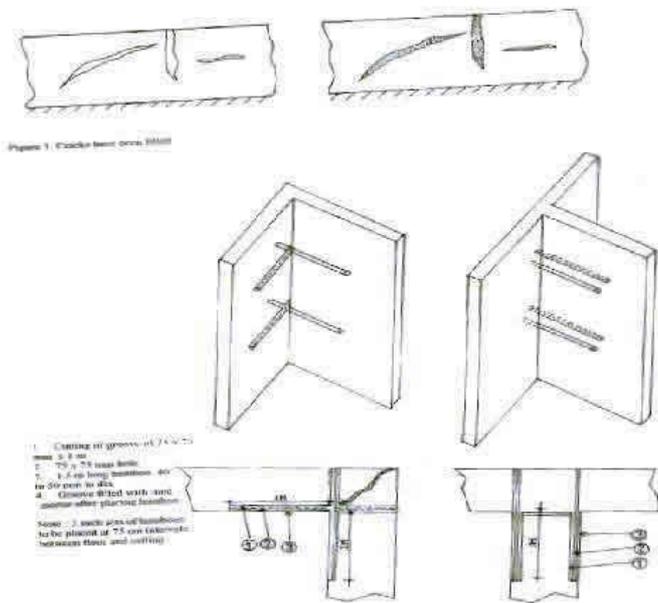
Structural Deficiency	Seismic Strengthening
No connection between adjacent walls	Provision of wooden bracing at regular interval in walls
Poor connection between roofing elements	Strengthening of roofing elements through bracings Securely tying of rafters to roof truss after removal of all tiles and purlins at the roof level
Large Opening	Reducing the openings and provide additional strength to openings(Refer Figures 11 and 12)
Wall	Filling of cracks with good fibre-reinforced mortar; Stitching of corner cracks with bamboo ties at 75 cm c/c
New Construction	Wall Span:Provide additional support if span exceeds 5 m Planning: Place roof truss and rafters in a symmetric or regular arrangement Wall: Reduce height of wall to ensure height/thickness ratio less than 8; Provide bamboo seismic bands at lintel and roof level

Additional comments on seismic strengthening provisions

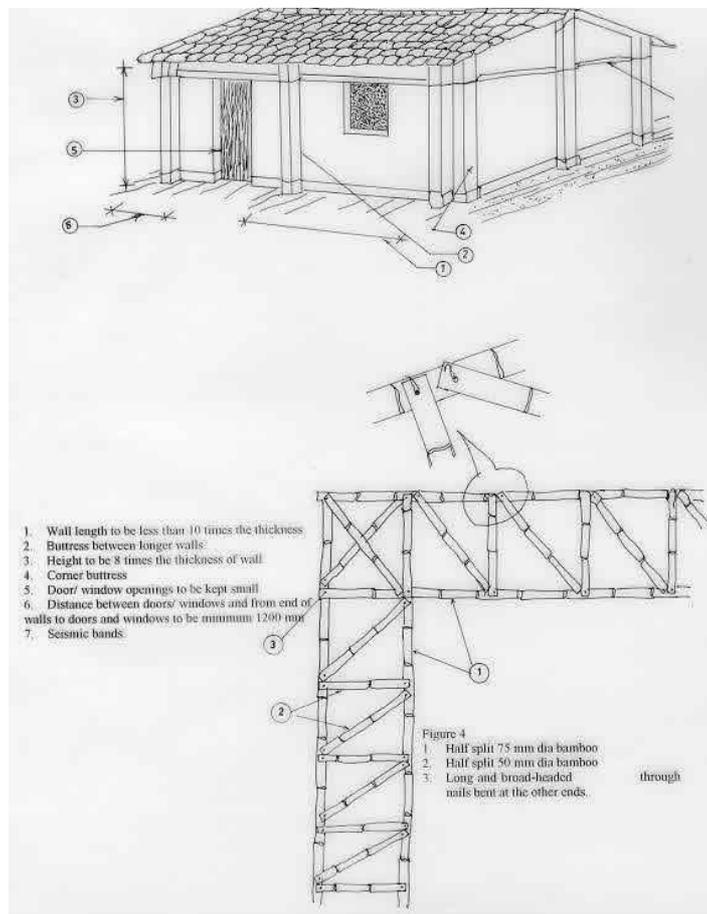
The suggested retrofit provisions are not complex and can be done by local masons and labour.

Has seismic

strengthening described in the above table been performed?	No
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Even small shocks may damage mud buildings to a greater extent. so, in general, after earthquake, dilapidated dwellings are replaced with brick buildings.
Was the construction inspected in the same manner as new construction?	N/A
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Owner
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	No evidence.
Additional comments section 6	



Strengthening measures suggested in IAEE Manual



Strengthening measures suggested in IAEE Manual

References

Guidelines for damage assessment and post earthquake action part-2, Building Materials Technology Promotion Council, Ministry of Urban Affairs, Government of India.

Vulnerability Atlas of India, Ministry of Agriculture, Government of India

Manorama Year Book, 1999.

A Manual of Earthquake Resistant Non Engineered Construction, Indian Society of Earthquake Technology, 1999.

Indian Standard Code IS 4326-1893

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