World Housing Encyclopedia Report

Country: India

Housing Type: Rural mud house with pitched roof

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1 General Information

1.1 Country
India

1.3 Housing Type
Rural mud house with pitched roof

FIGURE 1: Typical Building

1.4 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 load bearing 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.

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	
< 200 years	
> 200 years	X

Is this construction still being practiced?	Yes	No
	X	

1.6 Region(s) Where Used
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.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	
In rural areas	X

In suburban areas	
Both in rural and urban areas	

2 Architectural Features

2.1 Openings

Generally the owners and local unskilled masons construct this type of building. The craftsmanship of these buildings is very poor. The walls are often found to be out of plumb. 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.

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?		

The typical separation distance between buildings is 3 meters

2.3 Building Configuration

These buildings are rectangular in plan.

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)	

2.5 Means of Escape

Usually there is one door in the building.

2.6 Modification of Buildings

More typical modification is extensions to buildings.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

Generally a single family occupies a single dwelling.

3.2 Number of Housing Units in a Building

One or two 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	X	
5 to 10		X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 0

Additional Comments: Generally in rural India, the bathrooms and toilets are located away from the housing units. Houses belonging to poor families often do not have any toilet facilities, while the others may have a single toilet.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor	X	/
Poor	X	350/
Middle Class		/
Rich		/

Additional Comments: The price is expressed in US$.

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	X
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

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.

4.2 Gravity Load-Bearing Structure

The roof loads are directly supported by the walls/frames whose loads are supported by the wall/frame foundations.

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	X
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	X
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		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		

4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	X
	Rubble stone (fieldstone) isolated footing	X
	Rubble stone (fieldstone) strip footing	X
	Reinforced concrete isolated footing	
	Reinforced concrete strip footing	
	Mat foundation	
	No foundation	X
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		X
	Wood single roof		X
	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		X
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other			

4.6 Typical Plan Dimensions

Length: 8 - 8 meters
Width: 8 - 8 meters
Additional Comments: It is average. 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 1½:1, 2:1 or 2 ½:1.

4.7 Typical Number of Stories

1

4.8 Typical Story Height

3.5 meters

4.9 Typical Span

2.5 meters

Additional Comments: 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.

4.10 Typical Wall Density

The wall density of typical houses is approximately 40%.

4.11 General Applicability of Answers to Questions in Section 4

This contribution describes a generic 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				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	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	Provision of wooden columns at regular interval	Partially or complete collapse of wall wyth failure
Frame (columns, beams)	No proper connection between column and beam	Partially, it works as a frame structure.	Damage observed at weaker sections i.e. joint of column and beam
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		Collapse of roofing

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)
2000	Jabalpur	5.3	VI (MSK)
1997	Jabalpur	6.1	VII (MSK)

Additional Comments: 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, 1997, Part-1, Earthen Houses With Clay Tile Roofing Guidelines for Damage Assessment and Post-Earthquake Action).

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Stone	N/A	N/A	
Foundations	Mud	N/A	N/A	
Frame	Timber	N/A	N/A	
Roof and floors	Timber	N/A	N/A	

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

These buildings are typically self-owned wherein the owner is directly involved in the construction process, and may also contribute labor.

7.3 Construction Process

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 purlines 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.

7.4 Design/Construction Expertise

The buildings are constructed by local unskilled persons and villages with out any technical inputs.

7.5 Building Codes and Standards

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

Title of the code or standard: IS13828-1993 Improving Earthquake Resistance of Low Strength Masonry Buildings-Guidelines
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 or architects do not have a role in the design/construction of this housing type.

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

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: The building byelaws in rural areas are not yet enforced. It requires proper enforcement to the rural and urban areas.

7.9 Building Maintenance

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

7.10 Process for Building Code Enforcement

There is no proper building code enforcement in rural areas.

7.11 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 ageing.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

Rs. 440 per m² ($10 per m²)

8.2 Labor Requirements (estimate)

Labor requirement is approximately 85 man-days for the construction of 22.5 m² plan building.

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?

N/A

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (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 figure 7A)
	Wall	Filling of cracks with good fiber-reinforced mortar.
	Wall	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.
	Wall	Provide bamboo seismic bands at lintel and roof level.

Additional Comments: The suggested retrofit provisions are not complex and can be done by local masons and labor.

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

No.

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

Even small shocks may damage mud buildings to a greater extent. So, in general, after earthquake, delapitated dwellings are replaced with brick buildings.

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?

Owner

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

No evidence

11 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

12 Contributors

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13 Figures

FIGURE 1: Typical Building

FIGURE 1A: Typical Building (Source: Sudhir K. Jain, IIT Kanpur)

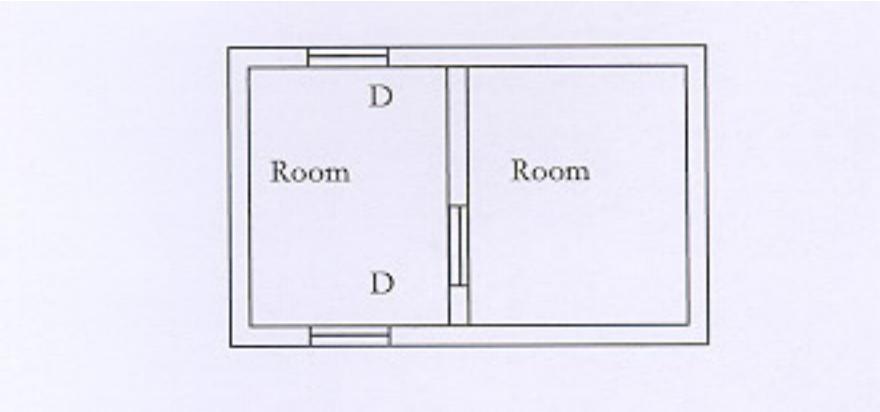

FIGURE 3: Plan of a Typical Building

FIGURE 4: Critical Structural Details - wall section (Source: Sudhir K. Jain, IIT Kanpur)

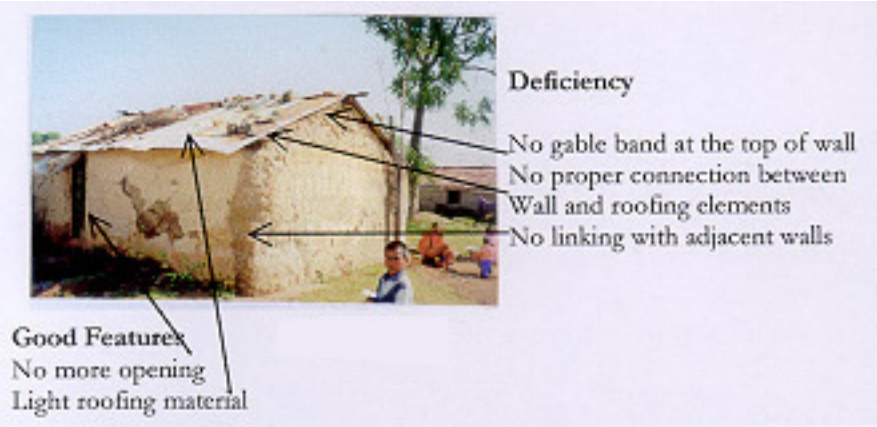

FIGURE 5: An Illustration of Key Seismic Features

FIGURE 6: Typical Earthquake Damage

FIGURE 6A: Typical Earthquake Damage - Cracking and Separation of Walls in the 1997 Jabalpur earthquake (Source: Sudhir K. Jain, IIT Kanpur)

FIGURE 6B: Typical Earthquake Damage - Building Collapse in the 1997 Jabalpur earthquake (Source: Sudhir K. Jain, IIT Kanpur)

FIGURE 6C: Typical Earthquake Damage - Crushing of Mud Walls in the 1997 Jabalpur earthquake (Source: Sudhir K. Jain, IIT Kanpur)

FIGURE 6D: Typical Earthquake Damage - Roof Collapse in the 1997 Jabalpur earthquake (Source: Sudhir K. Jain, IIT Kanpur)

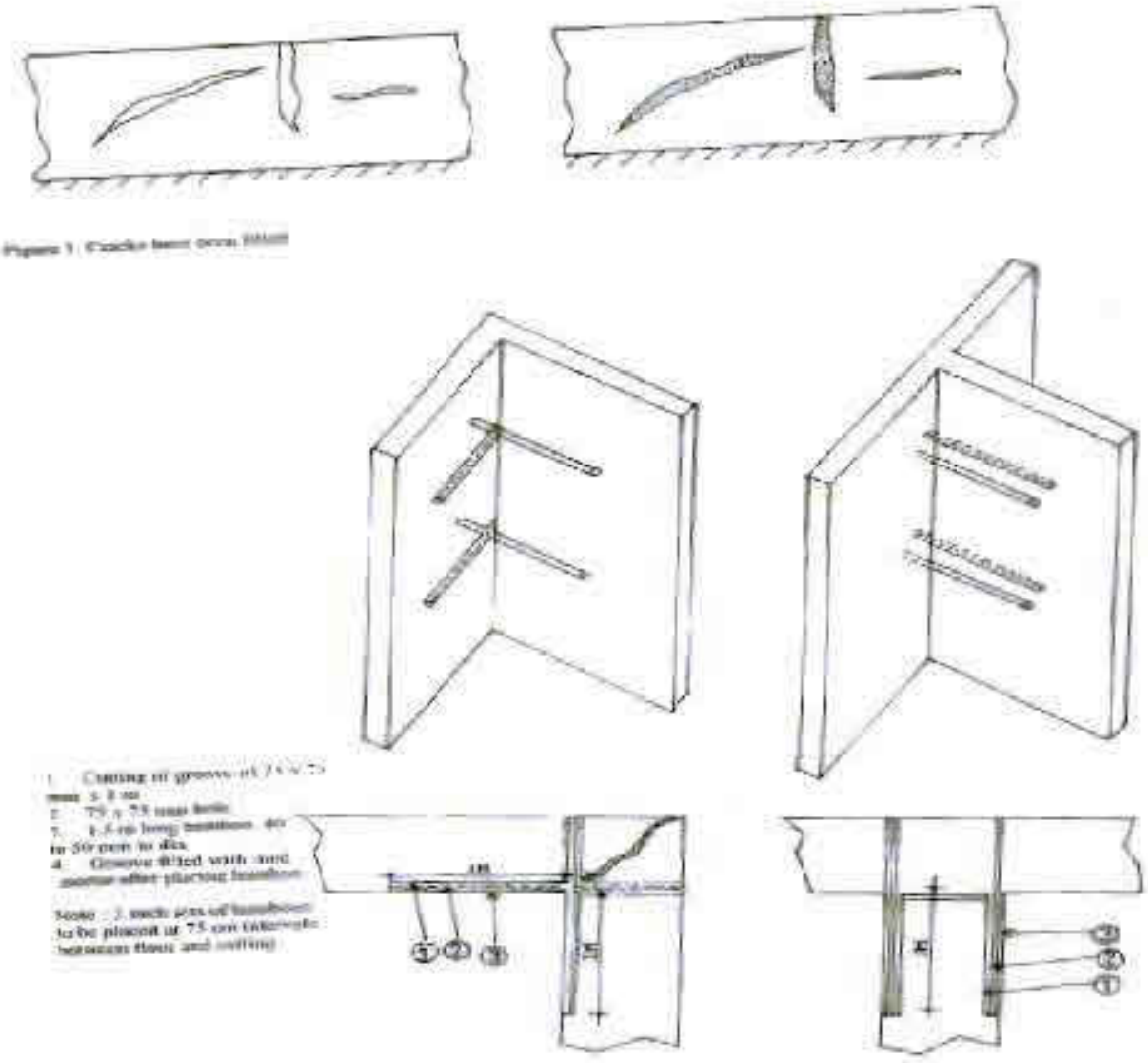

FIGURE 7A: Illustration of Seismic Strengthening Techniques

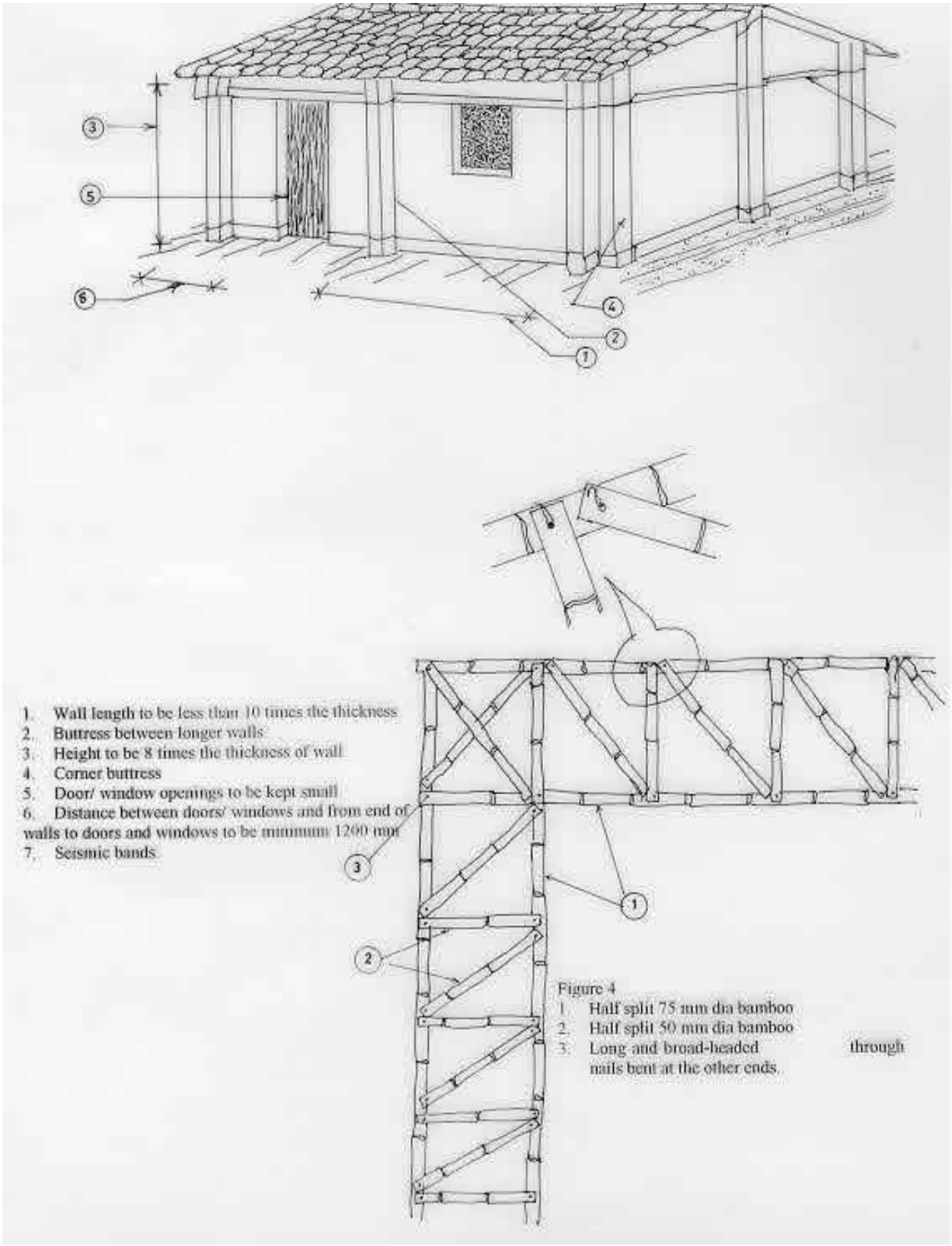

FIGURE 7B: Illustration of Seismic Strengthening Techniques-New Construction