World Housing Encyclopedia Report

Country: Nepal

Housing Type: Traditional oval-shaped rural stone house.

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1 General Information

1.1 Country
Nepal

1.3 Housing Type
Traditional oval-shaped rural stone house.

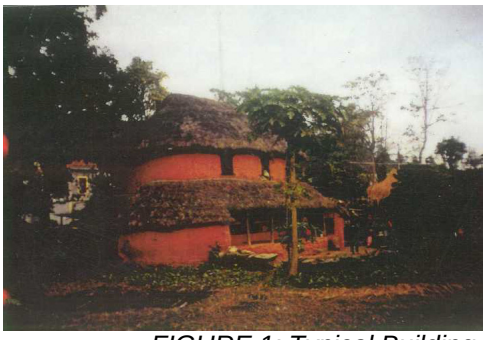

FIGURE 1: Typical Building

1.4 Summary
This is a typical rural construction concentrated in the central mid-mountains, particularly in Kaski, Syangja, Parbat, Baglung districts (the country is divided into 75 administrative districts). The basic function of these buildings is residential. These buildings are basically loose fit load bearing structures constructed of uncoursed rubble stone masonry walls and a timber structure for floor and roof. These buildings are owner-built and village artisans play a pivotal role. These buildings are expected to be extremely vulnerable in earthquake effects because of the loss of integrity during an event.

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
This building type is concentrated in Kaski, Syangja, Parbat, and Baglung districts of Central Mid Mountains of the Western Development Region of Nepal (Nepal is divided into five development regions and seventy five districts which are further subdivided into small political units (56 municipalities and some 4000 Village Development Committees). The percentage of this building type in the total stock as well as total population inhibiting this building type is unknown.

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	

Additional Comments: These buildings are being gradually replaced by more modern building types even in rural areas.

2 Architectural Features

2.1 Openings

Typically three to four openings are provided in each story, one for door and rest for windows in main building. Front façade has more openings than the back. Openings are limited in size. Openings constitute some 15-20% of total wall length. Spacing between openings is generally more than twice the length of opening.

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)	X	
Is it typical for buildings of this type to have common walls with adjacent buildings?		X

The typical separation distance between buildings is 10 meters

2.3 Building Configuration

Building plan is oval in shape.

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

Buildings of this type haven't additional door besides the main entry.

2.6 Modification of Buildings

There aren't modifications of bearing structures in these buildings usually.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

Single/ multiple families both live in a single house.

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	X	
5 to 10		X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 0
Number of Latrines: 0

Additional Comments: This building type does not comprise attached toilet or bathroom. In the past, there were no latrines or bathrooms available in this type of house. Presently, toilets are constructed but away from the houses and in isolation. Insert additional text if applicable

3.5 Economic Level of Inhabitants

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

Additional Comments: A pricing system does not exist because of informal housing production mechanism.

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	X
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

The load bearing walls carry the lateral loads. The masonry walls thus act as shear walls. The building has only a perimeter wall, which encloses the building space and also carries the loads. The roof and floor are loose fit timber structures, which act as flexible diaphragm and are not able to transfer the lateral load to wall piers according to their stiffness.

4.2 Gravity Load-Bearing Structure

The gravity loads of the main building are carried by load bearing walls. Floor and roof are constructed of timber, which transfers their loads to the walls (typical thickness 450 mm - 600 mm), which carries the load to the foundation. These walls are carried by a strip foundation of uncoursed rubble stone masonry. The veranda (annex to the main building) is a lean-to structure to main building, which is supported by timber posts at one end. These posts are generally supported by an above-ground stone pedestal (no anchorage between stone and post). No rigid connection is made between column and beam being supported.

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)	X
		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	
		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	
	Rubble stone (fieldstone) isolated footing	
	Rubble stone (fieldstone) strip footing	X
	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		X
	Wood single roof		X
	Wood planks or beams that support clay tiles		
	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	Wood planks (or fire wood) and joists covered with thick mud overlay	X	

Additional Comments: Floor and roof structures are loose-fit elements, as if one component is stacked over the other (without any nailing). These therefore behave as flexible diaphragm. In past earthquakes such floors were just scattered due to shaking.

4.6 Typical Plan Dimensions

Length: 10 - 10 meters
Width: 10 - 10 meters
Additional Comments: Length varies from 8 to 10 meters. Width varies from 6 to 8 meters.

4.7 Typical Number of Stories

2

4.8 Typical Story Height

2.2 meters

Additional Comments: Typical story height is 2 - 2.2 meters.

4.9 Typical Span
1.7 meters

Additional Comments: Span between the supports of floor and walls ranges from 1.5 to 2 meters usually. The building is oval shaped and there does not exist any internal walls for separating internal space, so the concept of span is not applicable.

4.10 Typical Wall Density
Total wall density (total plan area of wall/ total plinth area) is around 25%.

4.11 General Applicability of Answers to Questions in Section 4
This is traditional structure of Nepal people.

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	- Binding material (mortar) for walling unit is too weak. - Walling units are irregular. - Absence of through stones.		
Frame (columns, beams)	- Inadequate beam-to-column connection and beam-to-wall connection. - No anchorage between timber posts and foundation.		
Roof and floors	- Flexible. - No interconnection between different structural elements. - No connection between walls and floor/ roof (in general). - Heavy floor		

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)

Additional Comments: No medium or major earthquakes observed in the area to date in known history (oral or written) so the performance of these buildings in a real earthquake is largely unknown. But buildings with similar construction materials and technology (but with different plan shape) have performed extremely poorly in past earthquakes.

7 Building Materials and Construction Process

7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Rubble stone	Not known/ Not relevant for strength	Irregular boulders (size 200-300mm or less)	Slates, lime stone, quartzite
Foundations	Mud	Very low compressive strength and no tensile strength		Used for mortar
Frame	Soft and hard wood	Not known	Depending on structural value of the member	Hard wood used for members of high structural value (e.g. Columns, principal beams) where as softwood used for members with relatively low structural value (e.g.. Joists, purlins)
Roof and floors	Timber/ bamboo	Not known		Difficult to define because of selected use of multiple species

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

Yes, builders/ owners live in this construction type (house owner himself is part of construction team).

7.3 Construction Process

The walls are constructed in a random uncoursed manner by using irregular stones bound with mud mortar. The stones are collected from quarries, riverbed or field, sometimes partially dressed. Space between interior and exterior wythes is filled with small stones and mud. The joists and rafters are just placed on walls without any anchorage or connection.
These buildings are owner-built where village artisans play pivotal role. Simple tools such as chisels, hammers, saw etc are used for construction.

7.4 Design/Construction Expertise

The artisans are without any formal training. The construction know-how is transferred from generation to generation or the people learn the process on site in a very informal way. The head mason is skilled but the level of know-how varies from person to person. No standard or minimum requirement exists for head or any other mason. The rest of the working team is composed of semi or unskilled personnel.

7.5 Building Codes and Standards

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

Title of the code or standard: NBC203 : Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry (Draft)

7.6 Role of Engineers and Architects

Engineers /architects / technicians are not involved in this construction 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

Additional Comments: The building by-laws, building permit process and building construction controlling monitoring mechanisms only exists in municipalities and not in Village Development Committee (local authority at village level- rural areas). This is basically a rural house type where the building permit process does not exist. If this type of housing were to be constructed in a municipality, it would have to pass through the formal process (but the process does not require approval of structural drawings for this size of building). Present bylaws or regulation do not prohibit the construction of this type of building in municipal areas.

7.8 Phasing of Construction

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

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 process for Building Code enforcement in rural areas (Village Development Committee areas) of Nepal.

7.11 Typical Problems Associated with this Type of Construction

Weak construction materials/ and construction technology, lack of quality control, lack of earthquake resistant features are the problems associated with this type of construction. Again this type of construction does not match the modern use pattern of user. So it is being phased out with time.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

Cash flow in such construction is very minimal so it is difficult to price the building cost.

8.2 Labor Requirements (estimate)

120 - 150 man-days (excluding effort required for collection of construction materials).

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?

Not applicable.

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (Strengthening)	Roof/ floor	Enhancement of integrity, anchorage with walls, bracing
	Walls	Insertion of bond stones, bandages at different levels, splint at critical sections
	Timber Frame	Bracing of frame (knee bracing, diagonal bracing) to strengthen beam-column connection, anchorage of column to foundation
New Construction	Roof/ floor	Enhancement of integrity, anchorage with walls, bracing
	Walls	Use of cement mortar, use of bond stones, bands at different levels , vertical bars at critical sections
	Timber frame	Knee or diagonal bracing of beam-column joints, connection of column to foundation

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

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

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

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

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

11 References

1994, Appendix-A: Prototype Building inventory; the Development of Alternative Building Materials and Technologies for Nepal, UNDP/UNCHS (Habitat) Sub-project Nep 88/054/21.03, His Majesty's Government of Nepal, Ministry of House and Physical Planning.

1994, NBC 203 Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry, UNDP/UNCHS (Habitat) Sub-project Nep 88/054/21.03, His Majesty's Government of Nepal, Ministry of House and Physical Planning.

12 Contributors

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13 Figures

FIGURE 1: Typical Building

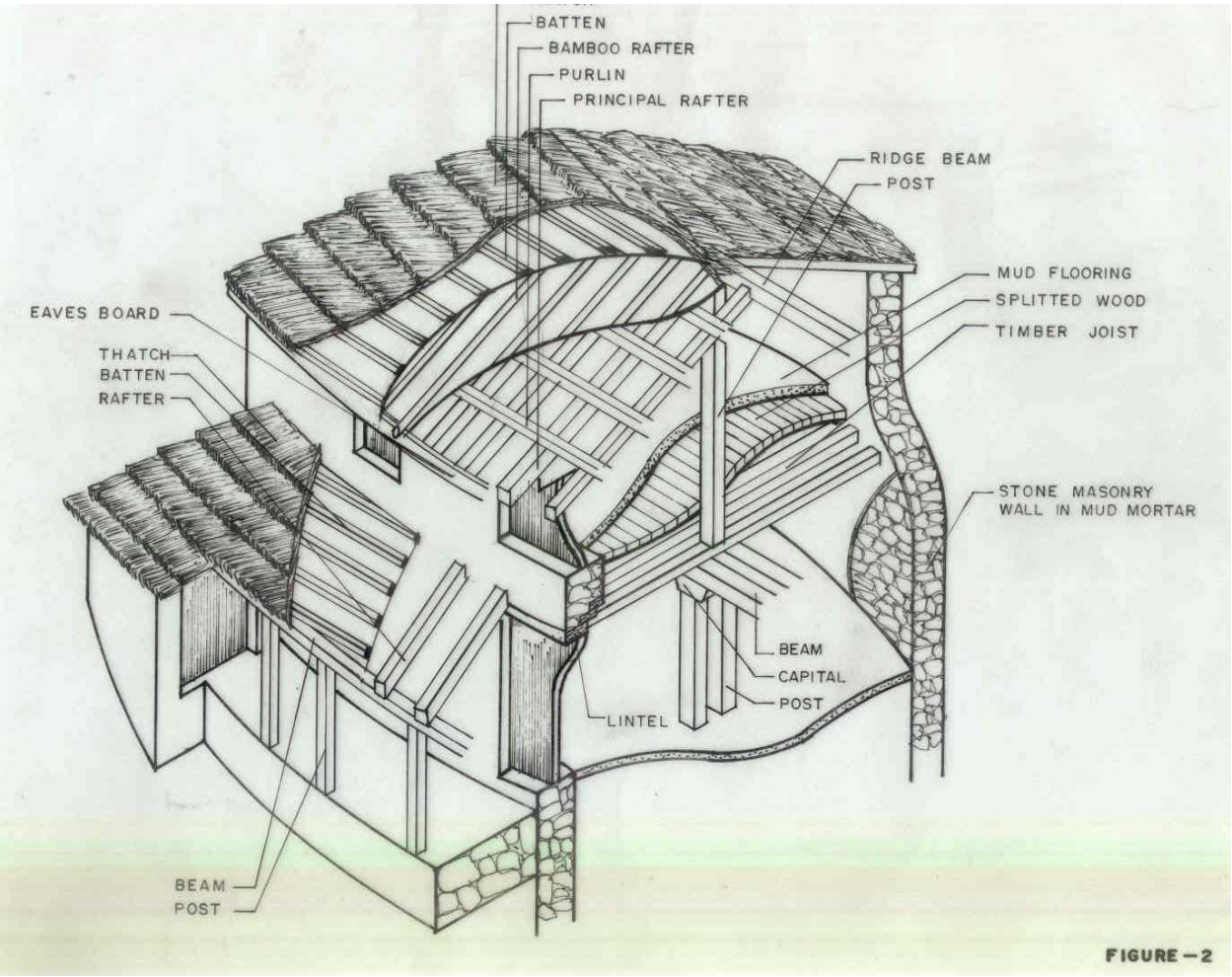
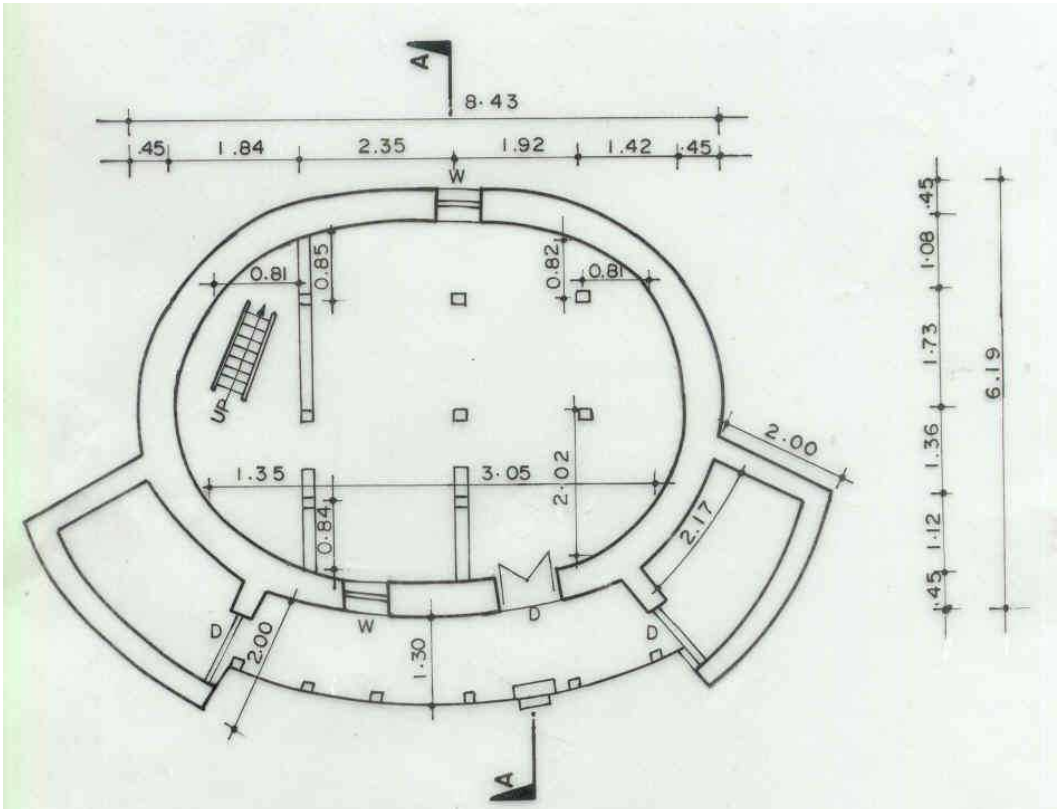
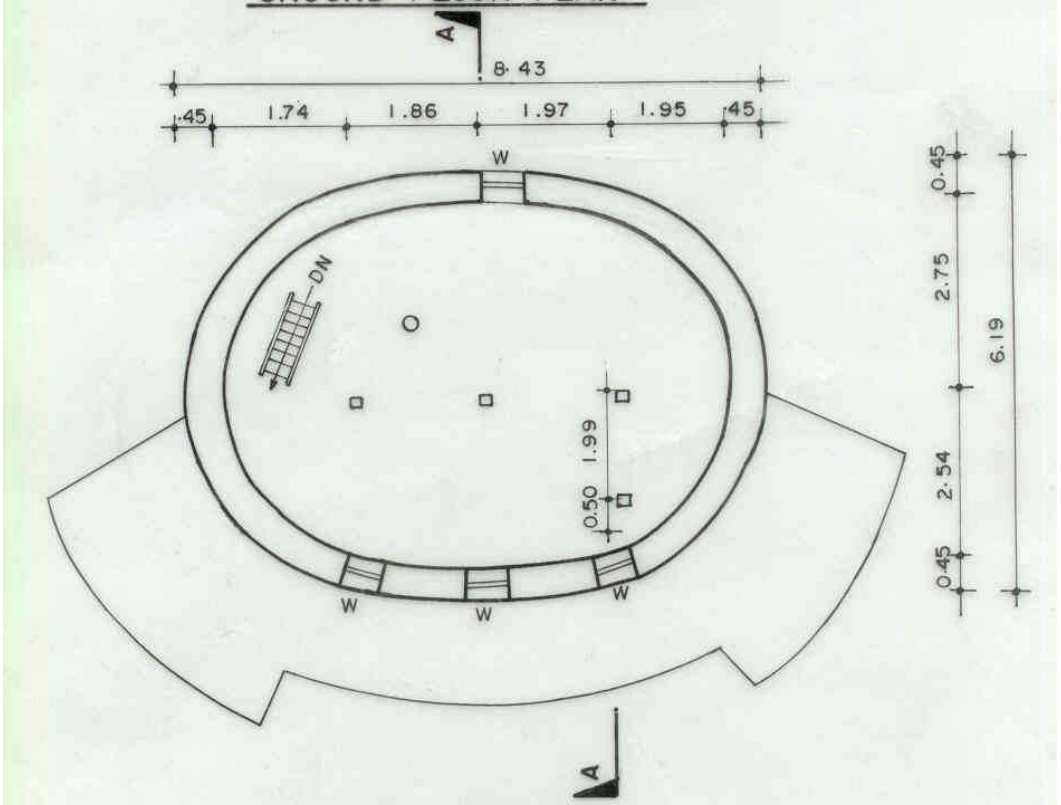


FIGURE 2: Key Load-Bearing Elements



GROUND FLOOR PLAN



FIRST FLOOR PLAN

FIGURE 3: Plan of a Typical Building

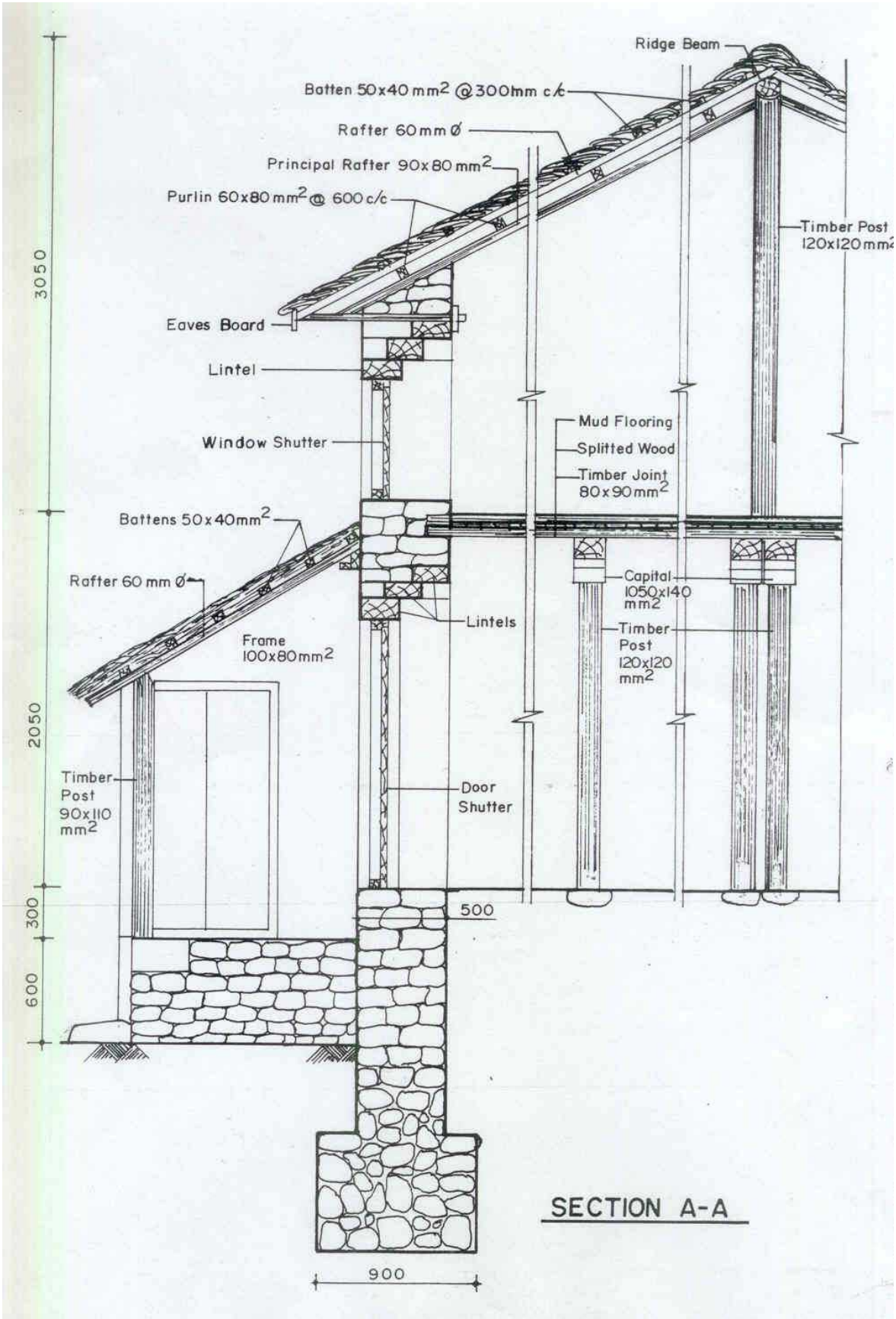
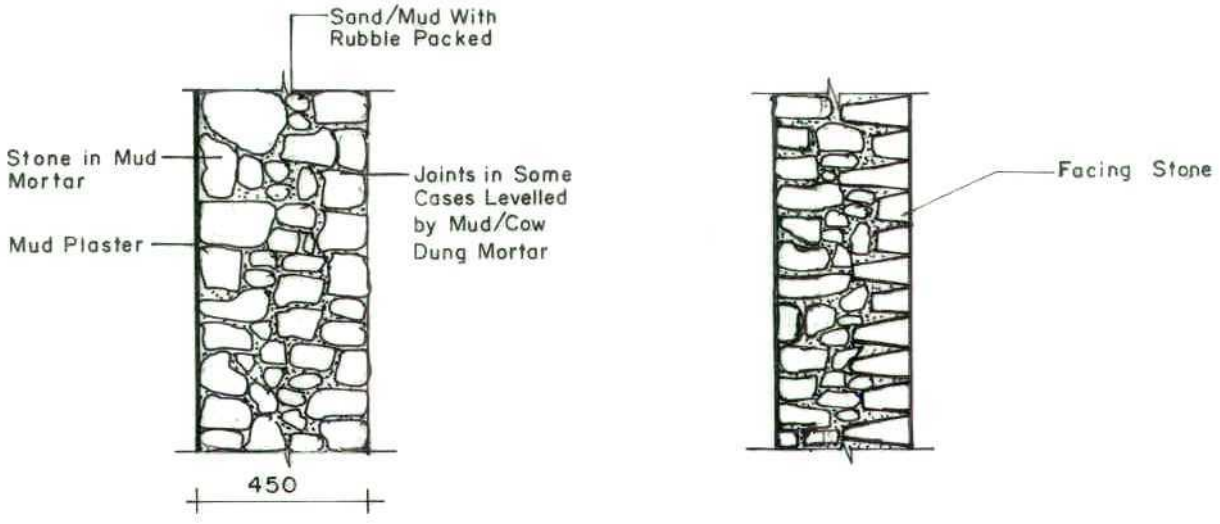

Ridge Beam
Batten 50x40 mm2 @300mm c/c
Rafter 60mm Ø
Principal Rafter 90x80 mm2
Purlin 60x80 mm2 @ 600 c/c
Timber Post 120x120mm2
Eaves Board
Lintel
Mud Flooring
Splitted Wood
Timber Joint 80x90mm2
Window Shutter
Battens 50x40mm2
Rafter 60 mm Ø
Capital 1050x140 mm2
Lintels
Timber Post 120x120 mm2
Frame 100x80mm2
Timber Post 90x110 mm2
Door Shutter
500
3050
2050
300
600
900
SECTION A-A

FIGURE 4: Critical Structural Details



Random Rubble Stone Masonry in Mud Mortar

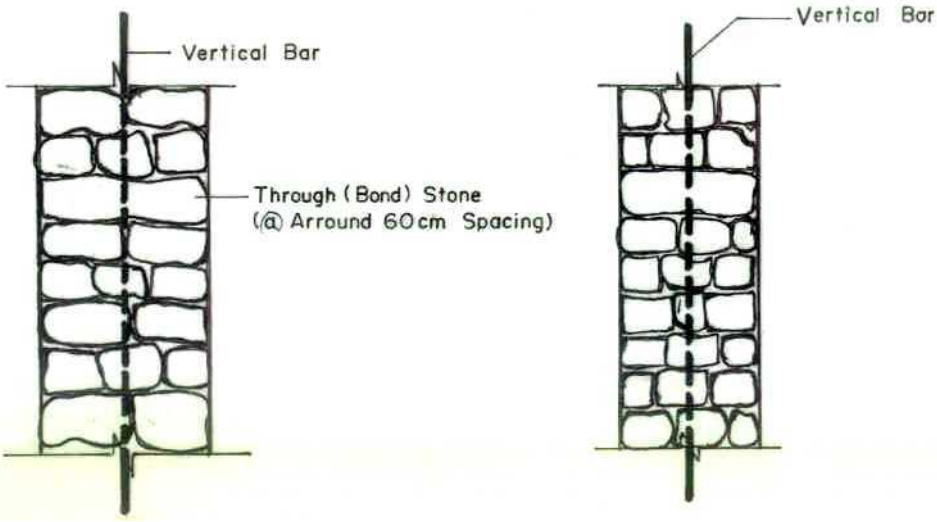


FIGURE 5: An Illustration of Key Seismic Features and/or Deficiencies

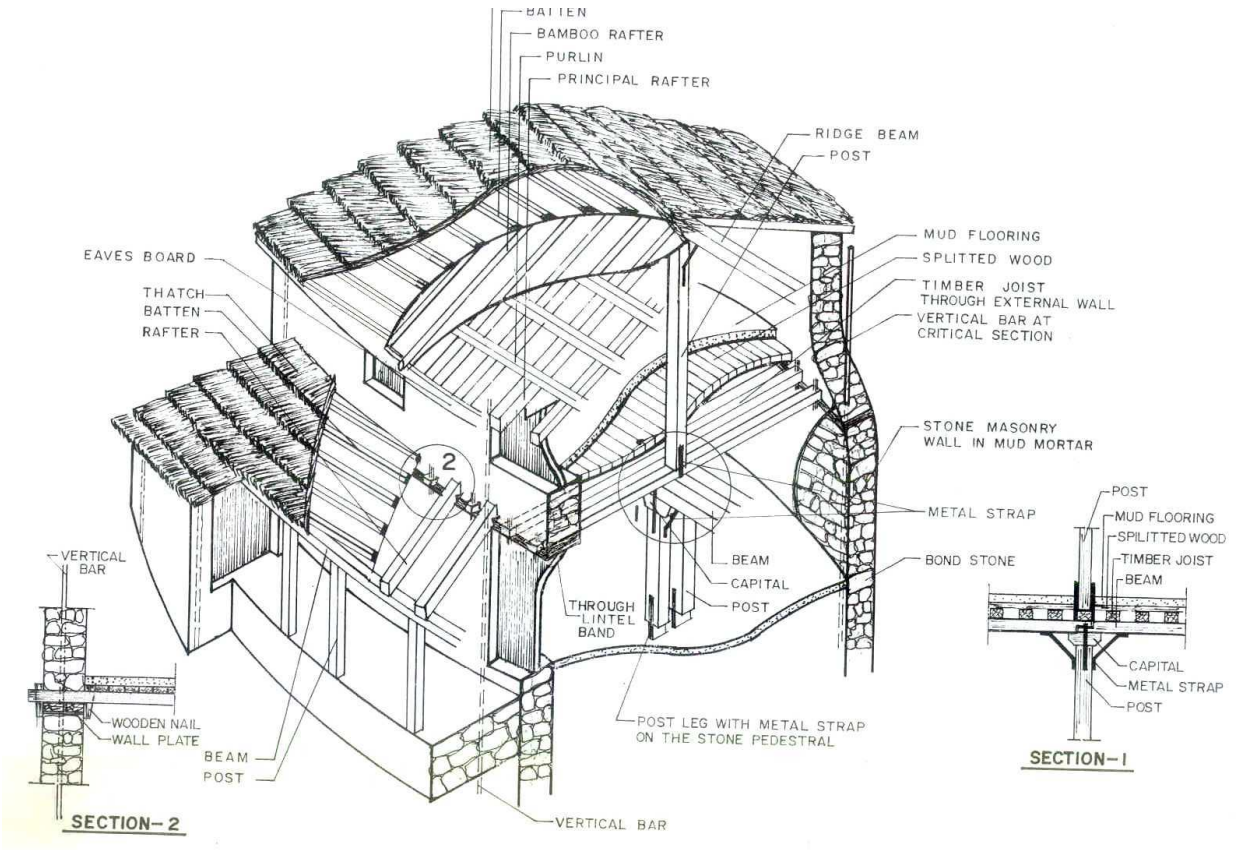


FIGURE 6: Illustration of Seismic Strengthening Techniques