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
Traditional oval-shaped rural stone house

Report #	47
Report Date	05-06-2002
Country	NEPAL
Housing Type	Stone Masonry House
Housing Sub-Type	Stone Masonry House : Rubble stone without/with mud/lime/cement mortar
Author(s)	Yogeshwar K. Parajuli, Jitendra K Bothara, Bijay K. Upadhyay
Reviewer(s)	Richard D. Sharpe

Summary

This is a typical rural construction concentrated in the central mid-mountain region, particularly in the Kaski, Syangja, Parbat, and Baglung districts. (The country is divided into 75 administrative districts.) These primarily residential buildings are basically loose-fitting, load-bearing structures, constructed of uncoursed rubble stone masonry walls and a timber structure for the floor and roof. Village artisans play a pivotal role in these owner-built

buildings. Because of the loss of integrity during an event, they are expected to be extremely vulnerable from the effects of an earthquake.

1. General Information

Buildings of this construction type can be found in 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.   This type of housing construction is commonly found in rural areas.

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

This construction type has been in practice for more than 200 years.

Currently, this type of construction is being built.   .

Figure 1: Typical Building

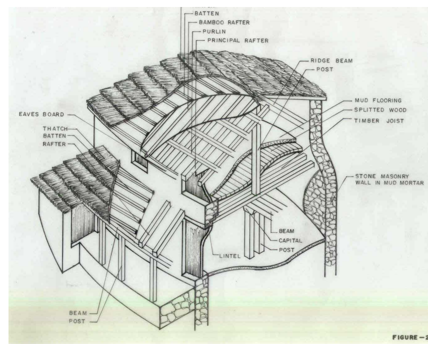

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain.   They do not share common walls with adjacent buildings.   It is minimum distance usually When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

Building plan is oval in shape.   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.

2.3 Functional Planning

The main function of this building typology is single-family house.   In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases.   Buildings of this type haven't additional door besides the main entry.

2.4 Modification to Building

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

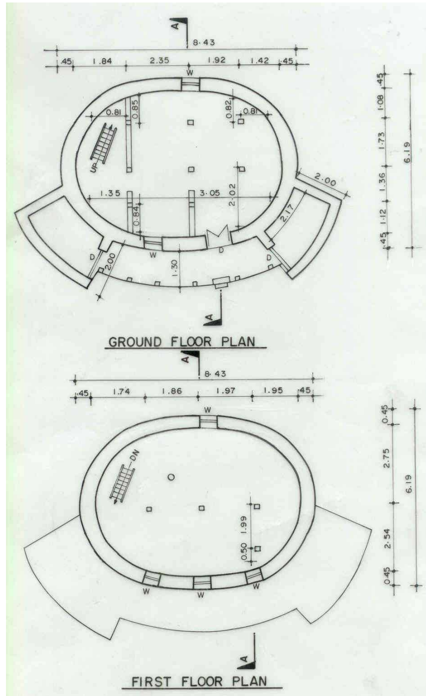

Figure 3: Plan of a Typical Building

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)	☑
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☐
		6	Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
		14	Stone masonry in cement mortar	☐

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

3.2 Gravity Load-Resisting System

The vertical load-resisting system is stone masonry walls. 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.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is stone masonry walls. 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.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 10 meters, and widths between 8 and 8 meters. The building is 2 storey high. The typical span of the roofing/flooring system is 1.7 meters. Typical Plan Dimensions: Length varies from 8 to 10 meters. Width varies from 6 to 8 meters. Typical Story Height: Typical story height is 2 - 2.2 meters. Typical Span: 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. The typical storey height in such buildings is 2.2 meters. The typical structural wall density is more than 20 %. Total wall density (total plan area of wall/ total plinth area) is around 25%.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☐	☐
	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
Timber	Rammed earth with ballast and concrete or plaster finishing	☐	☐
	Wood planks or beams with ballast and concrete or plaster finishing	☐	☐
	Thatched roof supported on wood purlins	☐	☑
	Wood shingle roof	☐	☑
	Wood planks or beams that support clay tiles	☐	☐
	Wood planks or beams supporting natural stones slates	☐	☐
	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	Described below	☑	☑

Wood planks (or fire wood) and joists covered with thick mud overlay. 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.

3.6 Foundation

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

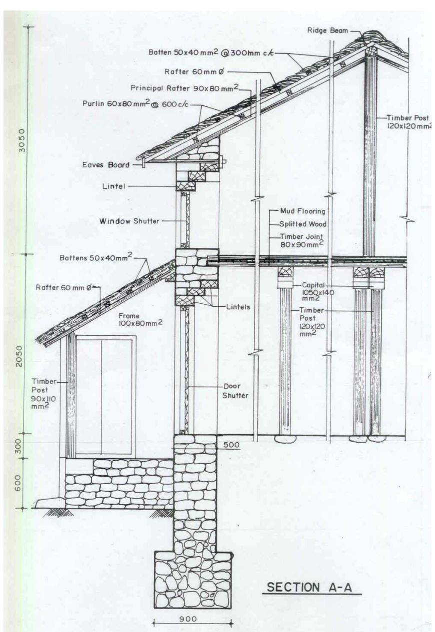

Figure 4: Critical Structural Details

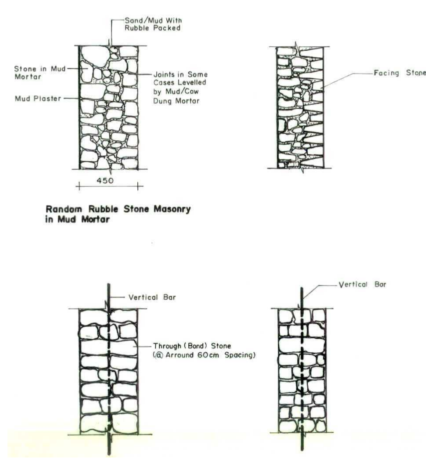

Figure 5: An Illustration of Key Seismic Features and/or Deficiencies

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 less than 5. The number of inhabitants during the evening and night is 5-10.

4.2 Patterns of Occupancy

Single/ multiple families both live in a single house.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☐
b) low-income class (poor)	☑
c) middle-income class	☑
d) high-income class (rich)	☐

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

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☐
4:1	☐
3:1	☐
1:1 or better	☑

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

In each housing unit, there are no bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) including toilet(s).

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. .

4.4 Ownership

The type of ownership or occupancy is outright ownership.

Type of ownership or occupancy?	Most appropriate type
Renting	☐
outright ownership	☑
Ownership with debt (mortgage or other)	☐
Individual ownership	☐
Ownership by a group or pool of persons	☐
Long-term lease	☐
other (explain below)	☐

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	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.	☑	☐	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐
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.	☐	☑	☐
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.	☐	☑	☐
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.	☑	☐	☐
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☑	☐	☐
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);	☑	☐	☐
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☐	☑	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	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.			
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☐	☑	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of 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)	☑	☐	☐
Additional Comments				

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 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *A: HIGH VULNERABILITY (i.e., very 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 *B: MEDIUM-HIGH VULNERABILITY (i.e., poor 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
	☑	☑	☐	☐	☐	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity

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.

6. Construction

6.1 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.
Foundation	Mud.	Very low compressive strength and no tensile strength.		Used for mortar.
Frames (beams & columns)	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 floor(s)	Timber/ bamboo.	Not known		Difficult to define because of selected use of multiple species.

6.2 Builder

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

6.3 Construction Process, Problems and Phasing

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. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size.

6.4 Design and 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 s 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. Engineers /architects / technicians are not involved in this construction type.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. NBC203 : Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry (Draft). Title of the code or standard: NBC203 : Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry (Draft).

There is no process for Building Code enforcement in rural areas (Village Development Committee areas) of Nepal.

6.6 Building Permits and Development Control Rules

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

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. 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).

6.8 Construction Economics

Cash flow in such construction is very minimal so it is difficult to price the building cost. 120 - 150 man-days (exluding effort required for collection of construction materials).

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. Not applicable.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
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

Strengthening of New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
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

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 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.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

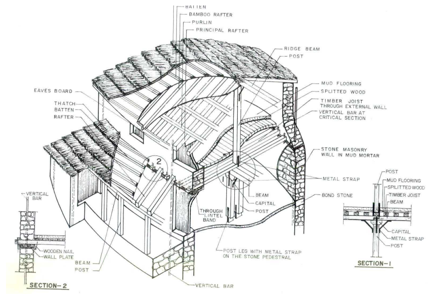

Figure 6: Illustration of Seismic Strengthening Techniques

Reference(s)

1. 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

2. 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 1994

Author(s)

1. Yogeshwar K. Parajuli
   Architect/National Team Leader, Nepal National Building Code Development Project
   C/O TAEC Consult P. Ltd., Shankhamul Kathmandu , NEPAL
   Email:taec@mos.com.np FAX: -497471

2. Jitendra K Bothara
   Senior Seismic Engineer, Beca Carter Hollings & Ferner
   77 Thorndon Quay, Wellington, , NEW ZEALAND
   Email:jitendra.bothara@gmail.com FAX: 64-4-496 2536

3. Bijay K. Upadhyay
   Building Technologist/Team Member, C/O TAEC Consult P. Ltd., Nepal National Building Code Development Project
   Shankhamul, Kathmandu , NEPAL
   Email:taec@mos.com.np

Reviewer(s)

1. Richard D. Sharpe
   Director of Earthquake Engineering
   , Beca International Consultants Ltd.
   Wellington , NEW ZEALAND
   Email:rsharpe@beca.co.nz FAX: 64-4-473-7911