World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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International Association for Earthquake Engineering (IAEE)

HOUSING REPORT

uncoarsed rubble stone masonry walls with timber floor and roof

Report#	74
Last Updated	
Country	Nepal
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Important

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General Information

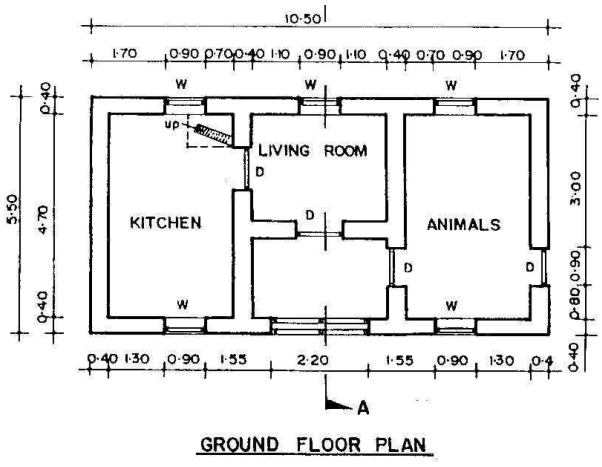
Building Type:	uncoarsed rubble stone masonry walls with timber floor and roof
Country:	Nepal
Author(s):	Yogeshwar Krishna Parajuli Jitendra Kumar Bothara Bijay Kumar Upadhyay
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in Nepal, most extensively constructed throughout the foothills, hills and mountains. The proportionate amount of this building type in the total housing stock and the percentage of the total population inhabiting these buildings of this type are unknown. This type of housing construction is commonly found in both rural and urban areas.
Summary:	This is a typical rural housing construction in the hills and mountains throughout Nepal. It is a traditional construction practice followed for over 200 years. These buildings are basically loose-fitting, load-bearing structures constructed of uncoursed rubble stone walls in mudmortar, with timber floors and roofs. They are expected to be extremely vulnerable to the effects of earthquakes due to their lack of structural integrity.
Length of time practiced:	More than 200 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwellingMixed residential/commercial
Typical number of stories:	2
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	

Features

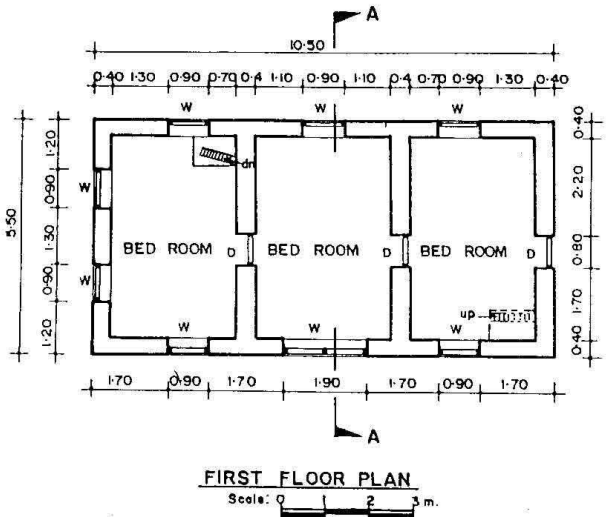
Plan Shape	Rectangular, solid
Additional comments on	

plan shape	
Typical plan length (meters)	6-10
Typical plan width (meters)	4-7
Typical story height (meters)	2.2
Type of Structural System	Masonry: Stone Masonry Walls: Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)
Additional comments on structural system	The gravity loads of main building are carried by loadbearing stone masonry walls (typical thickness 450 to 600 mm). Floor and roof are timber structures, which transfer the load to the walls down to the foundation (uncoursed rubble stone masonry strip footings). The verandah (annex to the main building), a lean-to structure to main building, is supported by timber posts. The posts generally rest above ground on stone pedestals without any anchorage. Beam-column connections at the verandah are not rigid. The loadbearing masonry walls carry the lateral load i.e. masonry walls act as shear walls.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	Total wall density (total plan area of wall/ total plinth area) is around 25%.
Wall Openings	Typically, three to four openings are provided in each story, one for a door and the rest for windows in main building. The front facade has more openings than the back. Openings are limited in size. Openings constitute some 15-20% or even less of the total wall length. Spacing between openings is generally more than twice the length of the opening.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	

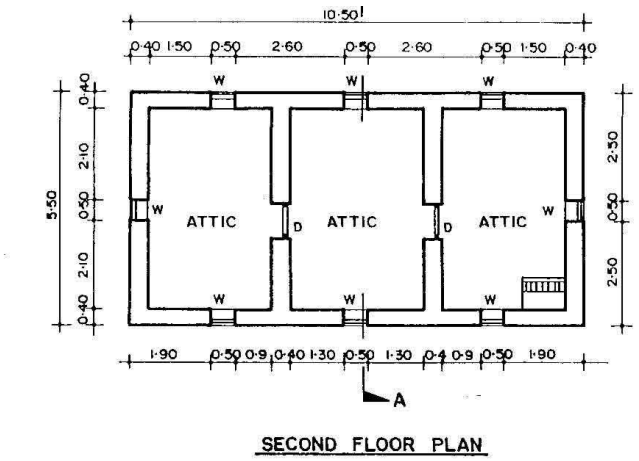
Type of Foundation	Shallow Foundation: Rubble stone, fieldstone strip footing
Additional comments on foundation	
Type of Floor System	Other floor system
Additional comments on floor system	Wood planks (or fire wood) and joists covered with thick mud overlay. Floors are loose fit structure, with one component stacked atop the other without any nailing, and should be considered as a flexible diaphragm. In past earthquakes such floors were scattered due to ground shaking.
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 supporting natural stones slates; Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles Floor and roof structures are loose fit structure, with one component stacked atop the other without any nailing, and should be considered as a flexible diaphragm.
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is several meters.



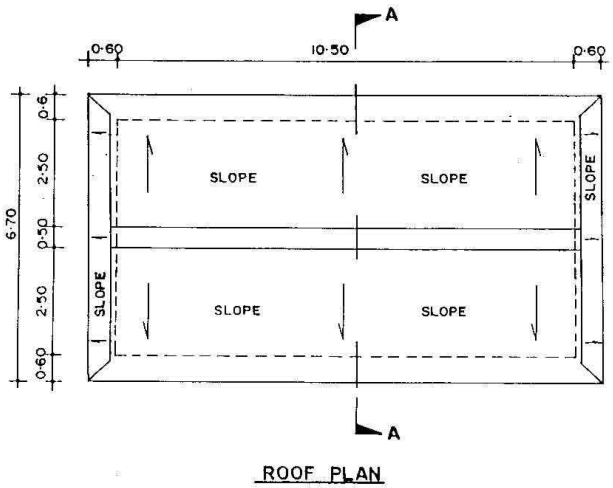
Ground Floor Plan



First Floor Plan



Second Floor Plan



Roof Plan

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Rubble stone	Strength unkown,. Irregular boulders (200-300mm) or less are used. Slates, limestone,quartzite.
Foundations	Mud	Very low compressive strength and no tensile strength. Used for mortar.
Floors	Timber/ bamboo	Difficult to define because of use of various wood species
Roof	Timber/ bamboo Thatch, shingle, slate, corrugated iron sheets	The choice of roofing material depends on availability of materials and cost Hard wood used for the main structural elements (e.g. columns main beams) whereas soft wood used for structural members of secondary importance (e.g. joists purlins).
Other	Timber frame: Soft wood and hard wood	Hard wood used for the main structural elements (e.g.,columns, main beams), whereas soft wood used for structural members of secondary importance (e.g., joists,

		purlins).

Design Process

Who is involved with the design process?	OtherNone of the above
Roles of those involved in the design process	Engineers, architects and technicians are not involved in this construction type unless the building is constructed by a government agency.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	OwnerMasonBuilder
Roles of those involved in the building process	Builders and owners live in this construction type. (The homeowner himself is a part of the construction team).
Expertise of those involved in building process	The artisans do not have any formal training. The construction know-how is transferred from generation to generation or the people learn the process on site in very informal way. The head mason is skilled but the level of know-how varies from person to person. There are no standard or minimum qualification requirements for head mason or other masons. Besides the head mason, the working team is composed of semi-skilled or unskilled personnel.
Construction process 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 stone rubble and mud. The joists and rafters are placed on walls without any anchorage or connection. This type of 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 incrementally over time. Typically, the building is originally not designed for its final constructed size.
Construction issues	There is a need for mass strengthening of buildings.

Building Codes and Standards

Is this construction type	

address by codes/standards?	Yes
Applicable codes or standards	NBC203 : Guidelines for Earthquake Resistant Building Construction: Low Strength Masonry (Draft)
Process for building code enforcement	A process for building code enforcement in rural areas (in Village Development Committee areas) does not exist.

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	The building bylaws, building permit process and building construction controlling monitoring mechanisms only exists in municipality areas and not in Village Development Committee (local authority at village units-rural areas). This type is basically a rural house type where building permit process does not exist. If this building type is constructed in a municipality area, it has to follow the formal process, however the approval of structural drawings for a building of this size is not required. Present building bylaws or regulations do not prohibit the construction of this type of building in municipal areas.

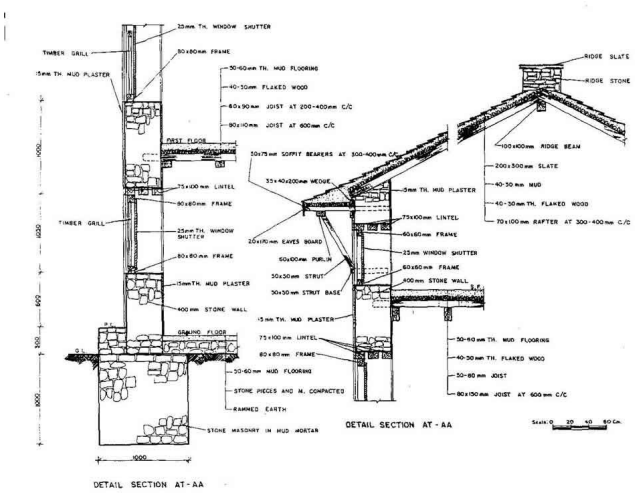
Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	Cash flow in such construction is very minimal so it is difficult to price the building cost. 20-150 man-days (excluding effort required for

Labor requirements	20-150 man-days (excluding effort required for collection of construction materials).
Additional comments section 3	



Critical Structural Details: Wall Section, Foundations, Roof-Wall Connections

Key Seismic Deficiencies: Lack of Connection Between the Wall Wythes (note loose stone rubble)

Seismic Deficiencies: Inadequate Wall-Roof Connections

Socio-Economic Issues

Patterns of occupancy	Single or multi-family housing. Each building typically has 1 housing unit(s).
Number of inhabitants in	

a typical building of this construction type during the day	5-10
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	Low-income class (poor)Middle-income classHigh-income class (rich)
Additional comments on economic level of inhabitants	It is hard to establish house price/annual income ratio due to the informal housing construction.
Typical Source of Financing	Owner financedPersonal savingsInformal network: friends or relatives
Additional comments on financing	
Type of Ownership	Own outright
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	Not applicable.
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

1988	Udaypur Earthquake
1999	Chamoli, India

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	This building type is among the most vulnerable to earthquake effects, as it suffers fatal damage in even minor shaking. Many building in Nepal suffered severe damage in the 1999 Chamoli Eartquake, although the epicentre was approximately 140 km away. The main source of damage is loss of integrity of building components, dislodging of rubble stones, delamination of walls etc.
Additional comments on earthquake damage patterns	-Separation of the walls at the junctions; In-plane and out-of-plane wall failure. -Total disintegration of roof/floor structure, separation of floor/roof structure from walls due to the absence of wall-floor anchorage (ties). -Because the superstructur

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.	TRUE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in	TRUE

	5.4.1)	
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) will maintain its integrity during an earthquake of intensity expected in this area.	FALSE
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 doweled 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		TRUE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	N/A
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	TRUE

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	-Binding material (mortar) for walling is too weak (mud mortar) or there is no binding material at all (dry stone masonry). -Stone units (boulders) are irregular; -Absence of header stones at wall junctions and corners. -Absence of through stones.
Earthquake-resilient features in walls	In some cases, bond stones or timber bands are provided.
Seismic deficiency in	

Seismic deficiency in frames	#NAME?
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	#NAME?
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	Inadequate foundation provided.
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	o	-|				

Typical Earthquake Damage: Roof Collapse Due to the Absence of Wall-Roof Connection

Typical Earthquake Damage - Delamination of Stone Walls Due to Absence of Bond Stones (through-stones)

Typical Earthquake Damage to Stone Masonry Buildings

Complete Collapse of a Stone Building in an Earthquake

Typical Earthquake Damage: Out-of-plane Wall Collapse Due to Lack of Anchorage

Typical Earthquake Damage: Wall Bulging Due to Delamination

Typical Earthquake Damage: In-plane Failure of a Stone Masonry Wall

Retrofit Information

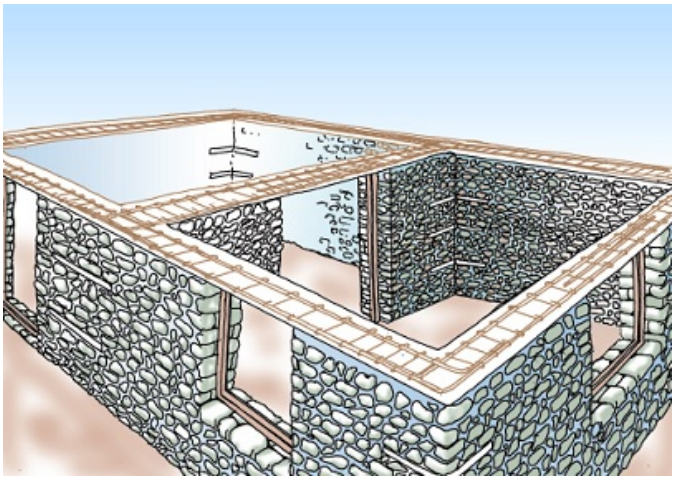
Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Delamination of walls	Introduction of bond (through) stones
Separation of walls at junctions	Introduction of stitches
Out-of-plane collapse of walls	Introduction of bandage (reinforced concrete, timber, steel) at different levels, or bolting the oppostie walls
Vertical tension (unstability)	Introduction of splints (reinforced concrete, steel, timber)
Lack of integrity at floor/ roof level	Nailing/ straping of different floor/ roof elements together and anchoring floor joists/ roof rafter with walls

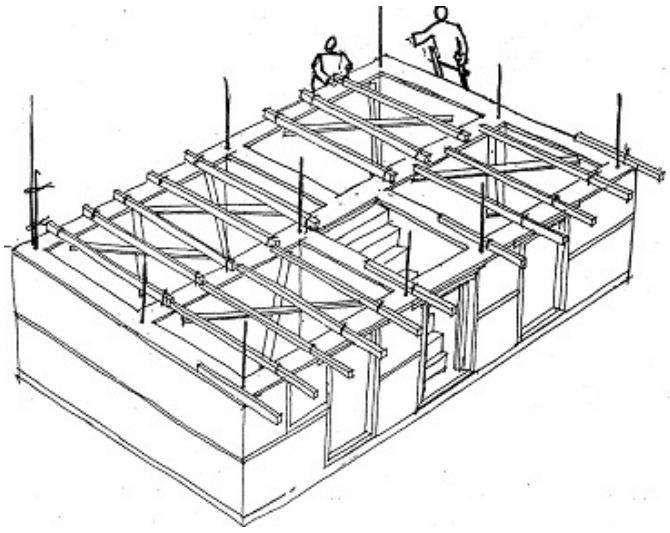
Additional comments on seismic strengthening	Floor/ roof flexibility ----> Introduction of floor/ roof

seismic strengthening provisions	bracing
Has seismic strengthening described in the above table been performed?	The seismic strengthening described above will significantly increase seismic safety of the building to sustain an earthquake of moderate intensity. However, as the wall construction is rather weak, it is expected that even the strengthened buildings would not be able to sustain a major earthquake.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Not applicable.
Was the construction inspected in the same manner as new construction?	Not very often.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	These are mostly owner-built buildings. Sometimes engineers/architects are involved, if the construction is formal (government-funded or if funding is provided by international organizations) and if constructed in remote areas.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	There have been no reported major earthquakes after the construction was performed.
Additional comments section 6	

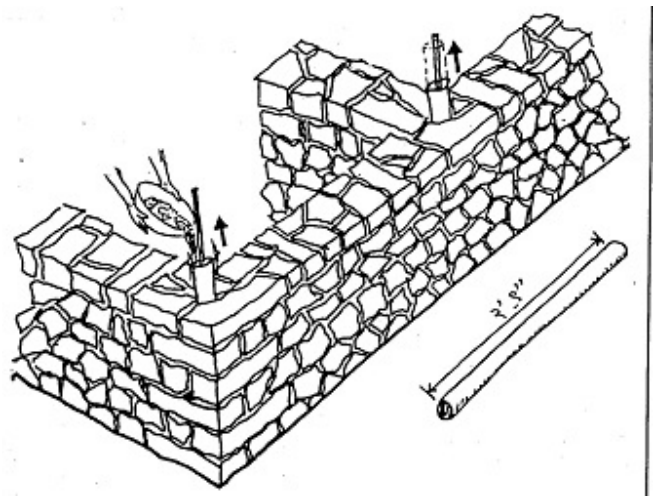
Illustration of Seismic Strengthening Techniques



Seismic Strengthening Techniques: Stone Masonry Walls Strengthened with Wall Corner Stitches and Bands (bond beams)



Seismic Strengthening: Floor Horizontal Bracing and Vertical Reinforcement Bars



Seismic Strengthening: Installation of Vertical Bars at Wall Corners

References

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 1994

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