World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

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International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Traditional Nawari house in Kathmandu Valley

Report #	99
Report Date	29-08-2003
Country	NEPAL
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in mud/lime mortar, with vertical posts
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Summary

The traditional newari house is usually of rectangular plan shape and developed over three storeys. The depth of the plan is usually about six metres with façades of various widths but most commonly between 4 to 8 metres (see also Korn 1976, and NSET-Nepal 2000). The organisation of the house is usually vertical, over 3 storeys, with a spine wall running through

the height, creating front and back rooms. At the upper storey the spine wall is sometimes replaced by a timber frame system so as to create a larger continuous space. The staircase is usually a single flight to one side of the plan. The typical interstorey height is quite modest, between 2.20 and 2.50 m., including the floor structure. The bathroom, where present, is found at ground floor, while the kitchen is on the top floor, usually directly under the roof. The first floor is traditionally used as bedrooms, while the second floor is used as living room and for visitors' reception. There are essentially two types of clusters of houses, either in long arrays, or around a court or chauk . In some cases the two types of clusters are adjacent with some units in common. In the arrays each house has front and back façade free. The construction of each unit is usually independent so that the facades are not continuum over party walls but each unit forms a separate cell. In such cases connection between façades and sidewalls are usually very good. The most interesting characteristic of these buildings both from an architectural and seismic point of view is the presence of the timber frame. Usually at ground floor, on the facade, to provide an open space for workshops or shops. It is also found internally at the upper storeys. In some cases the masonry only forms the outer shell while the internal structure is all made of timber elements. In the better built example of this typology there are a number of construction details, usually made of timber, which, coupled with the brick masonry walls, substantially improve the seismic performance of the overall structure. These features are best preserved in older examples. Currently these buildings are substantially being altered by use of western materials and technology, typically adding concrete frames as upper storeys. This type of intervention highly increases the vulnerability of the existing buildings.

1. General Information

Buildings of this construction type can be found in Kathmandu Valley. This type of housing construction is commonly found in urban areas.

Mainly found in the royal cities of Kathmandu, Lalitpur and Bhaktapur, however some examples are also found in smaller towns and village of the Kathmandu Valley.

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

Currently, this type of construction is being built. Conservation Agencies are promoting the continued use and new construction of this type of buildings, although the building industry is oriented more towards concrete frame typologies.

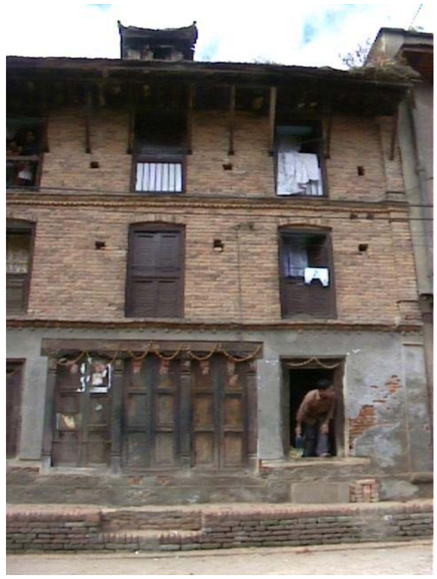

Figure 1: Typical urban house in array block with dalan at ground floor level.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. This building type forms part of an urban block of adjacent buildings, arranged either in rows or in square or rectangular blocks with an internal courtyard. In most case the perimeter walls of the building are independent from other, but in some cases, especially following inheritance divisions or reconstruction partywalls may be common to two buildings

2.2 Building Configuration

The typical configuration is a rectangular plan with staircase on one side and two or more room. However corner buildings might have different configuration, like the example shown which is L shaped. Openings vary in size depending on the period of construction. The older buildings have generally smaller squared windows with lintels extending well into the surrounding masonry. These also are usually built with a double frame, one within the external masonry leaf ,and one within the internal masonry leaf, slightly larger. The two frames are connected by timber elements embedded in the masonry. The size of the windows within a storey may vary depending on the use of the room. A feature of the older buildings is the San Jhya window, a richly decorated window that takes most of the façade at the third story level, with seating framed within it. Latter buildings have more homogeneous openings, usually taller and narrower of about 800 mm width and extending almost from floor to floor. In this typology spandrel above windows are very narrow. In more recent construction or alteration the concept of the San Jhya has been extended to each floor so that there is very little masonry left on the front façade of the house. In more modern construction window lintels are made of flat brickwork arches, and, in a minority of cases, by stone frames. Traditionally the openings are placed at a fair distance from the façade's edges, so leaving sufficient width for the lateral pier, constant throughout the height. This means that the pier can develop good structural behaviour, with substantial in-plane shear stiffness, and in turn most effective connection with lateral walls. In cases of building with shops or workshop, at ground floor the facade is completely open and the masonry is replaced by a timber frame called dalan. This is made of twin columns, surmounted by a capital on which sits a double beam, The two adjacent timber frames are usually connected only at the level of the beam. The dalan is most commonly found at the ground floor of the main façade of buildings in which the front room is used as shop or workshop. It is also common in upper storeys as an internal structure in place of the spine wall. The columns usually have a square cross section of about 100*100 mm minimum and 150*150 mm maximum and are pinned to the ground, 100 to 150 mm apart. The capital and the beam are also connected to the column by timber pins and the joists of the floor above sit directly on the beam, connected to this in some cases by timber pegs. Therefore the first floor joists directly support the façade of the upper storeys. The dalan usually takes most of the width of the building with only small masonry piers of about 200 mm width restraining it laterally and connecting it to the rest of the masonry box. In seismic terms the dalan can be compared with modern concrete soft storey structure and its associated failure mechanism, as all connections are simply pinned; the only lateral restraint, when present, is represented by the shear strength of the masonry piers at the edge of the façade.

2.3 Functional Planning

The main function of this building typology is mixed use (both commercial and residential use). Although traditionally this were single family houses with shops or workshops at ground floor, as buildable area have saturated and building plots increased in price, the original unit has been divided, usually vertically to host more than one family. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Usually there are two entrances on the ground floor per unit---one onto the main street and one onto the internal courtyard, or back street.

2.4 Modification to Building

The major modification consist of: updating of hygienic facilities, introduction of running water and toilets. replacement of traditional timber floor structure with concrete slab. vertical division of units. Vertical extension of units of one or more storeys with concrete frames above original masonry structure. Horizontal extension by means of lightweight structure jetties made of timber and corrugated metal sheets for one or two storeys.

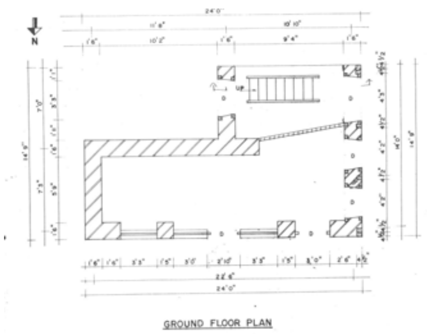

Figure 2: Typical floor layout of a house at the corner of a block.

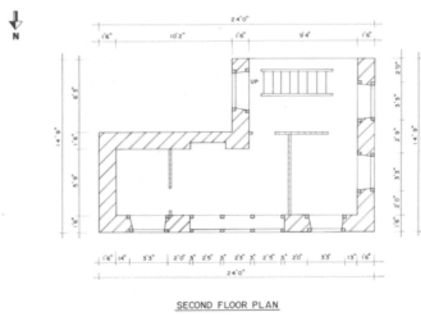

Figure 3: Second floor layout with large window

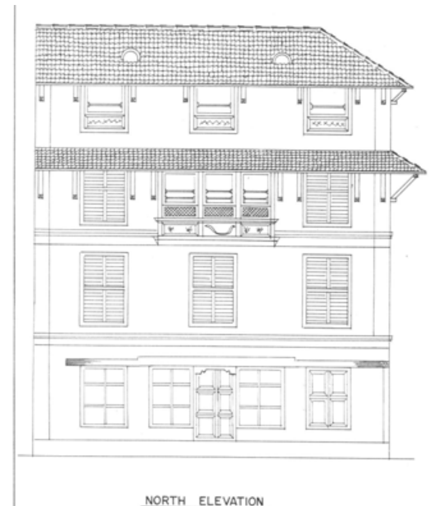

Figure 4: North elevation with shop windows at the ground floor and sajati window at the second floor.

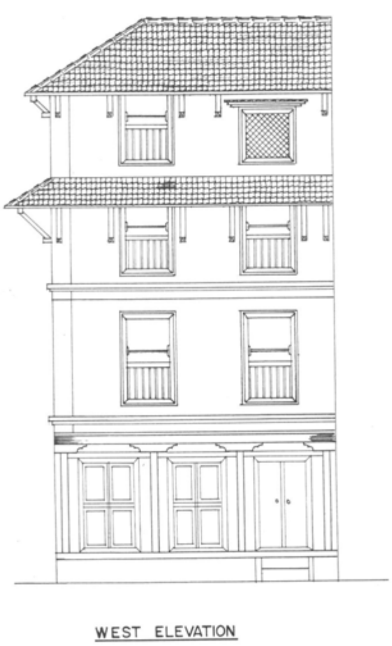

Figure 5: West elevation with dalan structure at ground floor.

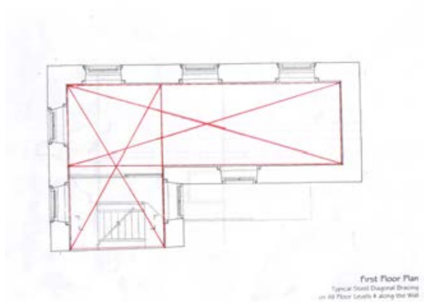

Figure 6: Proposed strengthening for stiffening of diaphragm and connection of bearing walls. (courtesy of Ing. Rohit K. Ranjiktar of the Kathmandu Valley Preservation Trust)

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	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		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	☐
	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐

Steel	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 un-reinforced masonry walls. Masonry walls and dalan frames.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced masonry walls. There is no distinction between the lateral load resisting system and the gravity load-bearing structure. The masonry external walls fulfill both roles. In some traditional buildings a number of construction details, of connections between masonry walls and timber floor structures are aimed at improving lateral load-resisting capacity. The presence of horizontal timber bands to brace the masonry is rare in the sample analysed in Lalitpur. However, the traditional openings have a double frame system one flush with the outer skin of the wall, one with the internal skin, and these are connected by transversal timber elements. Timber frame bracing with diagonal members has been observed only in very few cases and only in internal dalan structures.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 5 and 9 meters, and widths between 4 and 8 meters. The building has 3 to 5 storey(s). The typical span of the roofing/flooring system is 4.5 meters. The typical storey height in such buildings is 2.3 meters. The typical structural wall density is up to 20 %. 10% - 20% These are the minimum and maximum values at ground floor, where measurement were taken over a large sample. Values of minimum can be slightly higher at upper storey where there is no dalan. As buildings are usually arranged in arrays, the values refer to the observable facades, so mainly in the direction of the building along the street . In the direction normal to the street there is usually no openings, except for buildings on corners. Internal partitions in either directions have not been considered.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
	Vaulted	☐	☐

Masonry	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	☑	☑

Depending on level of alteration the traditional timber floor structures might be substituted by or found together with concrete slabs at different storey or at roof level.

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	☐

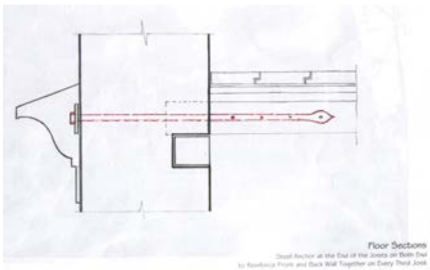

Figure 7: Detail of anchor key to be hidden behind floor band. (courtesy of Ing. Rohit K. Ranjiktar of Kathmandu Valley Preservation Trust)

Figure 8: Detail of timber post in the dalan structure.

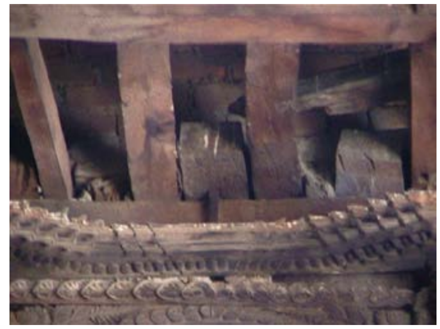

Figure 9: Detail of timber peg connecting joists to walls or transversal beam to limit lateral relative sliding.

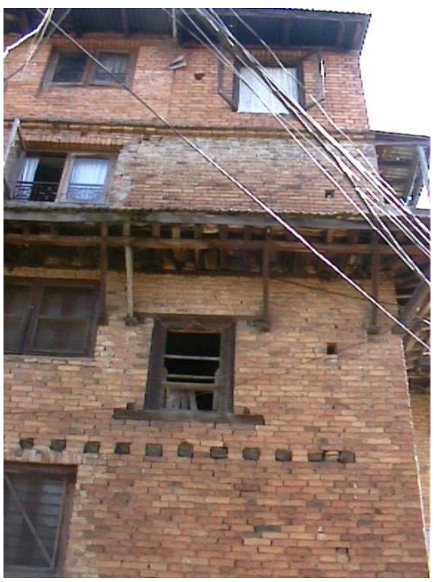

Figure 10: Typical elevation with joists coming through the wall, different window sizes, jetting at third floor level and overhanging of roof. This is sometimes supported by struts.

Figure 11: Alteration of original layout. Note vertical division of property, addition of one story and replacement of timber floors with concrete flat slab.

Figure 12: Typical floor structure.

Figure 13: Lean out of dalan structure after the earthquake in 1980.

Figure 14: Construction of 5-story concrete frame above a ground floor masonry building.

Figure 15: Photograph of a residential street in Lalitpur after the 1934 earthquake.

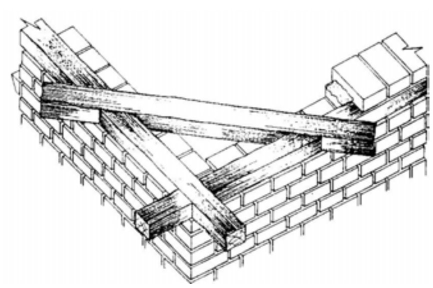

Figure 16: Example of single Band and diagonal element (Nepal National Building Code NBC 202 1994)

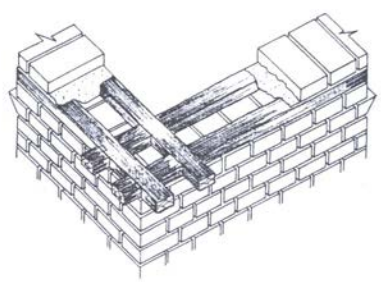

Figure 17: Collar band in wall at lintel level with rough cut timbers in parallel (NBC 202)

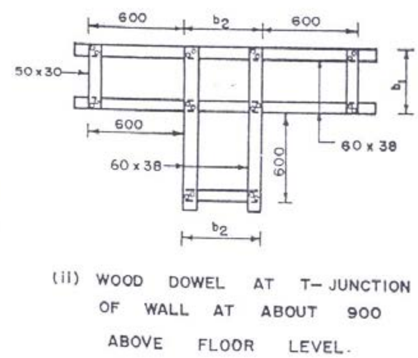

Figure 18: Detail of timber reinforcing at T junction (NBC 202)

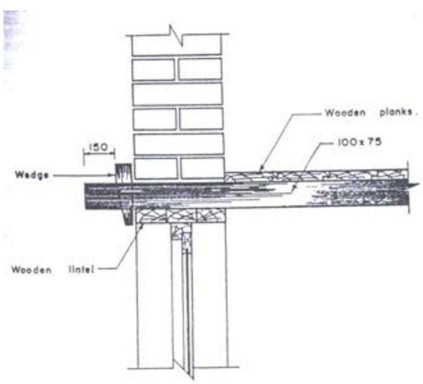

Figure 25.3 : Lintel and Floor Joint Detail

Figure 19: Example of use of wedge to anchor floor joist over lintel

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. Families are living together as joint family. The number of inhabitants in a building during the day or business hours is 5-10. The number of inhabitants during the evening and night is 11-20. Only child, retired elders and house wives spent most of time in house and male members go out of house for services, business and back home after their job and take dinner jointly.

4.2 Patterns of Occupancy

Multiple families, 4 brothers families are living together as joint families.

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)	☐

The house price depends on the market and location of building. Economic Level: For Middle Class the Housing Unit Price is 5,000,000 and the Annual Income is 336,000.

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)	☐

The financing of the building is duty of owner. In very few cases of important building have got grant from donors and someone take loan from bank for building. In each housing unit, there are 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) including toilet(s).

Joint family members share their income for joint expenditures. .

4.4 Ownership

The type of ownership or occupancy is renting and ownership by a group or pool of persons.

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)	☐

Ownership of building hold by male members of one generation i.e. brothers of family. In the case of no brothers, the ownership goes to female members sister of family. On the separation of multiple ownership, the building would be divided into vertical ways mostly according to consideration of land division. One of the major problem in buildings structural damages due to vertical division of building as per ownership separation.

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	The applicability of some of the statements above is limited due to a construction philosophy completely different from the modern earthquake proof approach. For instance, although the floor structures are not rigid diaphragms, the closely spaced joists and their connection to the walls by timber pegs ensure uniform redistribution of lateral loads, 3D behavior and the continuity of load paths for lateral loads.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	-Level of bond in the geometric thickness of the multi-leaf walls.-Extent of connection between façade and party walls, depending on alteration and position of windows.-Level of bond between mortar and units depending on decay of original material and regular repointing.	Presence of pegs to anchor the wall to the floor joists-wall plates under the joist to redistribute vertical load homogeneously -timber bands along the walls and returns between the perpendicular walls to tie together both the leaves of the masonry and the walls	In cases of poor bonding between leaves, disintegration of the masonry fabric is the most common damage. In cases of poor connection between facades and party walls, an out-of-plane mechanism will take place resulting in partial or total collapse of one or more walls. In cases of good connections between orthogonal walls, an in-plane mechanism will take place resulting in diagonal cracking ("X" cracks).
Frame (Columns, beams)	Presence of dalan, without sufficient side piers at ground floors.		In case of presence of dalan lateral overturning.
Roof and floors	Original structures are flexible diaphragms. Excessive mass associated with mud layer. Substantial overhanging in some cases without supporting struts.	In some cases the main timber structure is laid out orthogonally at different floor levels to tie-in both sets of walls.	Partial or total collapse of floor or roof structure associated with partial or total collapse of load-bearing walls.
Other			

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is C: MEDIUM VULNERABILITY (i.e., moderate seismic performance), the lower bound (i.e., the worst possible) is B: MEDIUM-HIGH VULNERABILITY (i.e., poor seismic performance), and the upper bound (i.e., the best possible) is D: MEDIUM-LOW VULNERABILITY (i.e., good 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
1934	Bihar-Nepal earthquake	8	VIII-IX
1988	Udaypur Gahri earthquake	6.8	VIII

There was very limited damage to be observed in the field at the time of collection of the data. However, from historic photographs and the observed evidence it appears that the major deficiencies relate to the in-plane failure of facades with dalan and the out of plane failure of masonry facades. Traditionally floors and roof have a very thick ballast of mud above the joist and rafter and this clearly enhance the vulnerability and makes the horizontal structures prone to collapse.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Brick bonded with mud mortar forming ordinary masonry. Typically, two types of bricks: ordinary sun-dried bricks of dimensions 210 x 105 x 50 mm, and fired bricks, called "dachi aapa" with the same dimensions but in the shape of a trapezoidal cross section, so that the mud bed-joint is partially covered externally by the brick.	not available		
Foundation				
Frames (beams & columns)	The timber frame (dalan) is made of twin columns, surmounted by a capital upon which sits a double beam. Adjacent timber frames are usually connected only at the level of the beam. The columns usually have a square cross section (about 100 x 100 mm minimum and 150 x 150 mm maximum) and are pinned to the ground, 100 to 150 mm apart.	not available		
Roof and floor(s)	Timber joists (dimensions 100 x 70 mm) run from wall to wall at closely spaced intervals of 150 to 200 mm. Above the joists either planks or a bamboo chirpat are covered by compressed mud.	not available		

6.2 Builder

While in origin it might have been self built, this building type, in historic town centres, depending on the state of conservation is occupied by a diverse class and occupation population. Some might do self maintenance/repair but in the majority any work will be carried out by a building contractor.

6.3 Construction Process, Problems and Phasing

Not relevant, as at the moment very limited construction of this type of building occurs. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size.

6.4 Design and Construction Expertise

The building type is being studied by building industry professional with interest in conservation of the historic environment. Expertise relates mainly to rehabilitation and strengthening work, especially for seismic upgrading, although this is still a very limited activity. Traditionally, this type of house was self-built. Now, in some cases architects or engineers are employed if alteration or strengthening work is undertaken.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Nepal National Building Code NBC 105: 1994 Seismic design of buildings in Nepal, HMG of Nepal Ministry of Housing and Physical Planning, Department of Buildings, 1995. Nepal National Building Code NBC 202: 1994, Mandatory rules of thumb for load-bearing masonry, HMG of Nepal Ministry of Housing and Physical Planning, Department of Buildings, 1995. Nepal National Building Code NBC 203: 1994 Guidelines for earthquake resistant building construction: low strength masonry, HMG of Nepal Ministry of Housing and Physical Planning, Department of Buildings, 1995. The year the first code/standard addressing this type of construction issued was 1995. Title of the code or standard: Nepal National Building Code NBC 105: 1994 Seismic design of buildings in Nepal, HMG of Nepal Ministry of Housing and Physical Planning, Department of Buildings, 1995. Nepal National Building Code NBC 202: 1994, Mandatory rules of thumb for load-bearing masonry, HMG of Nepal Ministry of Housing and Physical Planning, Department of Buildings, 1995. Nepal National Building Code NBC 203: 1994 Guidelines for earthquake resistant building construction: low strength masonry, HMG of Nepal Ministry of Housing and Physical Planning, Department of Buildings, 1995. Year the first code/standard addressing this type of construction issued: 1995.

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 type is already in existence, and in some cases, it would appear evident from the level of alteration that no building permit was required. Building permits are not required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Builder and Owner(s).

6.8 Construction Economics

not applicable. not applicable.

Figure 20: Khokana VDC Office building- New construction with traditional technology - Pilot project for the "Urban Management and economic diversification project (UMEDP)". Genral view of construction in progress. Note horizontal bands at 1/3 and 2/3 of wall's height and presence of vertical pins in transversal joists.

Figure 21: Khokana VDC Office. Detail of positioning of the internal dalan columns. Vertical pins connect the columns to the lower and upper beam. (courtesy of UMEDP)

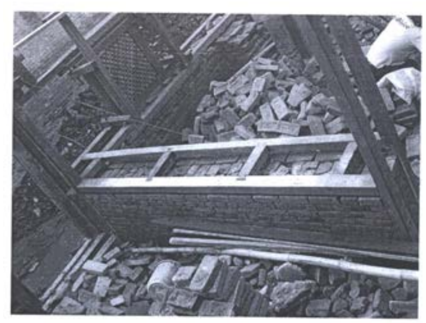

Figure 22: Detail of strengthening timber band. Note the dove-tailing connection rather than the use of pins. (courtesy UMEDP)

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.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Connection between walls	Use of steel ties at floor levels to connect front and back walls has been proposed.
Flexible diaphragm	Inclusion of diagonal ties within the interior floor structure to stiffen the floor structure and create a more rigid diaphragm has been proposed.

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?
This is a project proposal. Strengthening has been carried out to monumental buildings such as the royal palaces in Lalitpur and Kathmandu. In figures 16-19 examples of "Rule of thumbs for construction of load bearing masonry buildings" recommendations for the Kathmandu valley area are shown. Furthermore examples of application of these rules to a pilot building designed and built within the "Urban Management and Economic Diversification Project (UMEDP)" in the Village of Khokana is shown in figures 20-22.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
This is proposed as repair to a building which showed damage following the 1988 earthquake, specifically in plane distortion following the failure of the dalan (see figure).

8.3 Construction and Performance of Seismic Strengthening

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
Architect and engineer where involved in the development of the strengthening.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
not available.

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