World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

Pillar walaghar (URM infilled RC frame buildings)

Report#	145
Last Updated	
Country	Nepal
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Important

General Information

Building Type:	Pillar walaghar (URM infilled RC frame buildings)
Country:	Nepal
Author(s):	Yukta Bilas Marhatta Jitendra K Bothara Meen Bahadur Magar Gopal Chapagain
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in many areas of Nepal. This type of housing construction is commonly found in both sub-urban and urban areas. This building type is perceived to be the safest and strongest in every respect compared to all the other building types in Nepal. It has allthe characteristics of a vernacular building only with the exception that few of theconstruction materials are not local. It is one of the most emerging building typologies in Nepal. This is mostly non-engineered building typology. However, in urban areas sometimescompetent structural engineers are also involved in the design. This technology was picked upafter its relatively better performance during 1988 Udaypur earthquake which recorded M6.4on Richter scale, that severely hit eastern Nepal. In this type of building a lightly reinforcedframe is constructed first and then infill walls are erected later between columns. Though notusual, sometimes walls are constructed first and columns and beams later. These buildingsserve multifunctional purposes such as residential, commercial, official, religious, educational,etc. These buildings are highly vulnerable to earthquake because of deficient detailing, inferiorconstruction materials and the inadequate technology employed. Despite the use of modernmaterials of construction there is an ever growing risk to life and property due to potentialearthquake attack. This building type, if designed and constructed properly, is suitable for lowrise buildings up to 3 to 4 stories high. It is necessary to disseminate simple techniques ofearthquake resistant measures for these buildings to the grass-root level.

Summary:	This building type is widely constructed in the urban and semi-urban area of Nepal.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwellingMixed residential/commercialOther
Typical number of stories:	2-4
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	Each building typically has 1 housing unit(s). However, a building could have multiple households as well, dependingon the buil

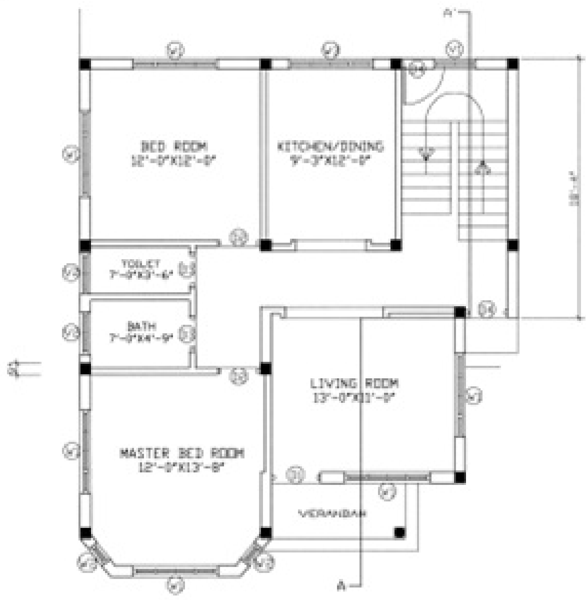
Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	Building configuration in general depends on where the building is located and its function. Usually these buildings are rectangular and regular in plan shape depending on the shape of land. Sometimes, these buildings have wings.
Typical plan length (meters)	10-20
Typical plan width (meters)	8-10
Typical story height (meters)	2.75-3.3
Type of Structural System	Structural Concrete: Moment Resisting Frame: Designed for gravity loads only, with URM infill walls
Additional comments on structural system	The vertical load-resisting system is reinforced concrete moment resisting frame. Vertical load resistance is primarily provided by a RC frame, though part of the load is carried by infill walls. The lateral load-resisting system is reinforced concrete moment resisting frame. Lateral loads on the buildings are resisted by the combined effect of RC Frames and the brick or block masonry infill walls.
	The most common practice is to construct the frame first and infill later. The most common infill is

Gravity load-bearing & lateral load-resisting systems	fired brick in cement mortar, though block or stone infills are also common. Infills constructed of stone in mud mortar have also been seen in remote areas. This building type does not work as moment resisting system.
Typical wall densities in direction 1	5-10%
Typical wall densities in direction 2	5-10%
Additional comments on typical wall densities	Wall density depends upon the function of the building. In mixed used buildings the bottom story could be open if used for commercial purpose. In commercial, institutional buildings, wall density is much lower than that of a residential building.
Wall Openings	A room has two windows and a door provided that there are no legal and other practical restrictions such as building on or near the property line. The openings are usually around 30-40% of the plinth area.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Both vertical and horizontal extensions of a building are common depending on the requirement of space and availability of funds. Vertical extension is more common in this type of building as this building type is perceived as strong enough to go as high as required. Change in room size by removing walls is quite common in the upper storeys depending on functional needs. This requires placing of partition walls away from the frame or walls in the storey below. Sometimes columns are also removed to make larger rooms.
Type of Foundation	Shallow Foundation: Reinforced concrete isolated footing
Additional comments on foundation	These isolated footings are not tied together at the foundation level though a plinth beam is provided at plinth level. Sometimes combined footings are also used. For large commercial buildings, raft foundations are also used. Pile foundations for buildings are not common in Nepal. In hilly terrain, foundation pads are placed at different levels.
Type of Floor System	Other floor system
Additional comments on	Structural concrete: Solid slabs (cast-in-place)

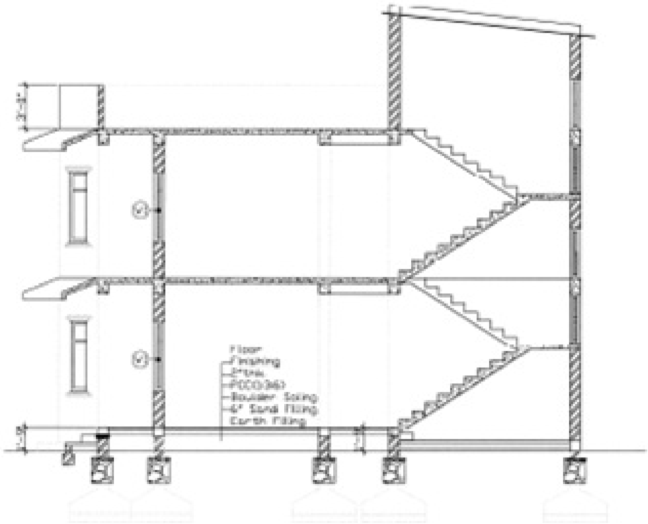
floor system	Structural concrete: Solid slabs (cast-in-place)
Type of Roof System	Roof system, other
Additional comments on roof system	Structural concrete: Solid slabs (cast-in-place)
Additional comments section 2	Usually there is no separation gap with adjoining buildings if a building is constructed along an urban strip, especially where the land is expensive and scarce. Hence, openings are provided only in the front and rear part of the building. However, in residential areas, they are usually free-standing buildings; hence the openings could be on all sides. In residential buildings, the storey height, number of columns and quantity of walls per story is usually similar. Walls are usually well distributed. However, in commercial buildings, the ground floor is usually open with a lot of walls in upper storey for partitions which are never tied to the frames. There are 3 to 5 rooms in each story in a typical residential building of this type. However, there could be many rooms per floor in a large apartment building.

Different height buildings along a street.



Plan of a typical RC frame residential house

Typical elevations of a RC frame residential house



Typical section of a residential building

A long narrow building

A stepped building

A building with increasing floor areas with height

A free standing building with large top story

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Bricks or blocks are commonly used construction materials for walls, how ever, sometimes stones are also used. Reinforced concrete is used in beams and column.	Wall: Strength of bricks varies between 40-120kg/cm2. Cement sand mortar is mixed in the proportion of 1:6-8 Brick size ranges from 20x10x10 to 50x50x20 cm. Wall thickness ranges from 12.5 to 23 cm. Strength, size and quality of materials of wall construction varies from place to place. Many times, bricks or blocks are of inferior quality such as low crushing strength, broken corners, etc. Frame: Strength of concrete varies

		from 100 to 150 kg/cm2. Standard yield strength of steel, commonly used for longitudinal steel is 415 and 500 MPa. For stirrups 250 MPa plain bars are used. Cement:sand:aggregate is mixed in the proportion of 1:3:5 to 1:3:4 Mostly hand mixing and hand compaction is applied in concrete. However, in recent days there is a growing trend to use machines for mixing and compacting
Foundations	Reinforced concrete is used in the foundation	Strength of concrete varies from 100 to 150 kg/cm2. Standard yield strength of steel, commonly used for longitudinal steel is 415 and 500 MPa. Cement:sand:aggregate is mixed in the proportion of 1:3:5 to 1:3:4 Mostly hand mixing and hand compaction is applied to the concrete. Recently however, there is a growing tendency to use machines for mixing and compacting.
Floors	Reinforced concrete is used in roof and floors.	Strength of concrete varies from 100 to 150 kg/cm2. Standard yield strength of steel, commonly used for longitudinal steel is 415 and 500 MPa. Cement:sand:aggregate is mixed in the proportion of 1:3:5 to 1:3:4 Mostly hand mixing and hand compaction is applied in concrete. Recently however, there is a growing tendency to use machines for mixing and compacting
Roof	Reinforced concrete is used in roof and floors.	Strength of concrete varies from 100 to 150 kg/cm2. Standard yield strength of steel, commonly used for longitudinal steel is 415 and

		500 MPa. Cement:sand:aggregate is mixed in the proportion of 1:3:5 to 1:3:4 Mostly hand mixing and hand compaction is applied in concrete. Recently however, there is a growing tendency to use machines for mixing and compacting
Other		

Design Process

Who is involved with the design process?	EngineerOther
Roles of those involved in the design process	Design/ construction expertise exists in the country, particularly in urban areas. The irony is that these buildings behave very differently than that of the moment resisting frame. However, most engineers design them as moment resisting frame without considering the infill walls in the design. Most of this type of building is non-engineered although technicians are involved in the preparation of drawings for building permit in municipal areas. However, mostly it is mere official formality.
Expertise of those involved in the design process	Owners rely on masons who play a crucial role in building construction of this type. However, they are unaware of the National Building Code. Moreover, all masons are not equally competent in their profession. In most of the cases, the role of engineers is limited only in making drawings and building permit processes. In some cases, they are involved in structural design, construction monitoring, and quality control as well.

Construction Process

Who typically builds this construction type?	Owner
Roles of those involved in the building process	House owners themselves are involved in the construction right from the beginning to the end. This construction is mostly informal construction. Basically, the building owner himself manages the project and procures the materials.
Expertise of those involved in building process	The leader craftsman (Naike) plays a pivotal role in the building development process by helping the building owner in various ways such as quantity

process	estimates, time estimates, providing advice etc.
Construction process and phasing	It is basically owner-built construction. Locally known contractors cum masons (leader craftsmen) are invited and entrusted with the labor contract. Construction is carried out under the advice and consultation of the mason though sometimes engineers/ architects are also involved. Construction material is procured by the building owner. Column and wall foundations are packed with rubble stone and soil alternately in layers up to ground level. After constructing the plinth beam, about 2.5 m high columns are cast. Then formwork for beam and slab are laid. Beams and slab are cast together though it is not a norm in many parts of the country. Then masonry walls are erected in cement sand mortar. The tools used are hammer, trowel, concrete mixtures, concrete vibrator etc. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. As a vernacular building, it is also constructed over the years depending upon availability of funds and requirement of space. Vertical extension is the most common form of extension. Usually these buildings are constructed by convention rather than design.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	Nepal National Building Code, NBC 201, Mandatory Rules of Thumb, Reinforced Concrete Buildings with Masonry Infill.
Process for building code enforcement	

Building Permits and Development Control Rules

Are building permits required?	Yes
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control	Yes

rules?	
Additional comments on building permits and development control rules	A building permit is required in municipal/ urban areas only; no building permit is required in rural areas. This type of construction is most common in the urban area but it has been spreading to the rural area as well.

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	Approximately US$ 250/ m2.
Labor requirements	For construction of a one story average sized house (say 100 sqm), 4-6 persons work for about 9 months to a year. For upper stories it could be a little less, say 6 to 9 months. However, on the day of floor/ roof slab concreting 40-50 people work together as everything such as concrete mixing, placing, and compacting is done manually. Now manual mixing and compacting are being gradually replaced by machine mixing and compacting, which reduces the labor requirements from 40-50 to 30-40.
Additional comments section 3	Even in municipal areas most of the time engineers are involved in obtaining the building permit only. In theory, only buildings larger than a certain size require structural design, but most of the time this is a ritual rather than reality. Building permits are required to build this housing type.

Column starting from 5th storey

Missing columns in top storey

Missing beams

No anchorage of beam bars in column

Beam reinforcement hooking into column reinforcement. Also note inadequately large spacing of stirrups in the beam and column, and no stirrups in beam-column joint.

Column reinforcement left for splicing of upper story column reinforcement

Column reinforcement is far too short for the continuity of the column

Defective stirrups due to 90 degree bends

No stirrups in beam-column joint

Socio-Economic Issues

Patterns of occupancy	Houses of this type are occupied by a single family as well as multiple families depending on size of the building and number of stories. The number of households depends on size of building. Typically, one small building is occupied by one household unit.
Number of inhabitants in a typical building of this construction type during the day	<5
Number of inhabitants in a typical building of this construction type during the evening/night	5-10
Additional comments on number of inhabitants	The number of inhabitants in a building during the day or business hours is less than 5. On an average there are 2 to 5 occupants during day/business hours if the building is being used for a single household unit. During the day/business hours typically babies, very small children, mothers, sick people and grandparents would be at home. Children of school age and working men will typically be at school or work. School children will return earlier in the day than working adults. In the evenings and night time these buildings will have the largest number of inhabitants. As these buildings are mainly family homes, they will likely to have their highest occupancy level during school holidays. The number of inhabitants during the evening and night is 5-10. However, in institutional buildings (educational, day care centers, office, etc), the occupancy is much higher in day time. In schools, there could be 100s of children in one building during day time, but after school time none. Although this type of structure has many uses, the information supplied here addresses a typical residential building.
Economic level of inhabitants	Middle-income classHigh-income class (rich)
Additional comments on economic level of	Ratio of housing unit price to annual income: 5:1 or worse

inhabitants	worse
Typical Source of Financing	Owner financedPersonal savingsInformal network: friends or relatives
Additional comments on financing	These days, people can obtain a mortgage from a bank to buy an apartment or house, although it is not common.
Type of Ownership	Own outrightOwn with debt (mortgage or other)Units owned individually (condominium)
Additional comments on ownership	Most of the houses in Nepal are outright ownership. Ownership with mortgage is a relatively new concept in Nepal.
Is earthquake insurance for this construction type typically available?	Yes
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	Yes
Additional comments on premium discounts	
Additional comments section 4	Earthquake Insurance is not common in Nepal. However, insurance companies have started to offer insurance schemes and a few people procure it.

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1255	Data Not Available
1681	Data Not Available
1803	Data Not Available
1833	Data Not Available

1934	Sankhuwasabha, Nepal
1980	Bajang, Nepal
1988	Udayapur, Nepal
1993	Data Not Available
2003	Pokhara, Nepal

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Nepal has not suffered any major seismic event since the introduction of this building type.
Additional comments on earthquake damage patterns	(wall): 1 Out-of-plane toppling of infill walls. 2. Serious soft-storey and torsional problems. 3. Short column effect (frame): 2.1. Crushing of concrete, high brittleness of structural elements. 2.2 Splicing failure leading to severe damage and destruction of the building structure. 2.3 Anchorage failure of beam bars 2.4 Bursting of column due to lack of adequate confinement. 2.5 Relative movement between columns leading to column failure. (other): - Crushing of concrete, - Snapping of reinforcement.

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-	The building is regular	TRUE

Vertical	with regards to the elevation. (Specify in 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.	TRUE
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.	TRUE
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.	N/A
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);	N/A
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to	TRUE

	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.	FALSE
Wall Openings		N/A
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
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).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	Many times severe structural deficiencies such as dislocation or abrupt interruption of columns can be seen. The other problem with these building types is reinforcement detailing such as deficient lapping of bars, deficient anchorage of beam bars in the column, open stirrups, etc. Further, due to lack of proper cover to reinforcement and porous concrete, severe corrosion of the reinforcement can be seen. It is also common to have areas where the load paths are indirect, and such configuration problems lead to soft-storeys in the case of commercial and residential occupancies.
Vertical irregularities	

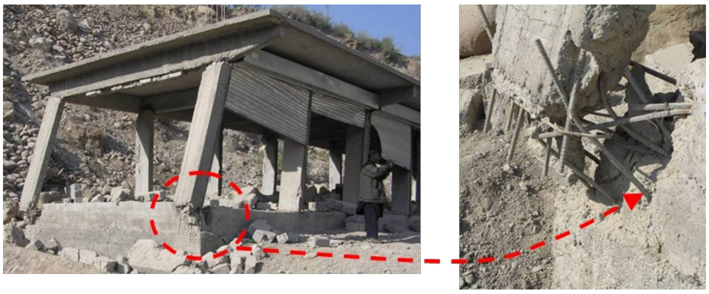
typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	1. Walls and frame are not integrated. The infills are not tied to the frames 2. Walls are placed without any judicious thought from a seismic point of view and so severe configuration problems such as soft-storeys can occur. 3. Provision of open ground floor for shops, parking, lobby etc that leads to a soft-story. 4. Trapped columns by partial-height confining walls.
Earthquake-resilient features in walls	The following features listed are recommended rather than existing features 1. Provide horizontal dowel bars in columns to tie infill walls to the frame. Provide lintel and sill level bands passing through columns. 2. Equal walls provided at extreme ends of the building in both the directions. 3. Continue some walls down to the foundation level to mitigate the soft storey effect. 4. Provide RC walls that continue from the foundation to the roof. The stiffness of the ground floor walls should be at least 70% of the upper storey. 5. Provide bracing to improve stiffness and strength of open story. 6. Isolate partial height walls from the frame to avoid the short- column effect. Provide closely spaced stirrups throughout the height of column where there is a possibility of a short column. Provide at least few full height shear walls in both the directions to reduce deflections that lead to short column effect damage.
Seismic deficiency in frames	1. Columns are deficient in terms of size, reinforcement and detailing. 2. Columns and beams suffer severely deficient detailing 2.1 Deficient reinforcement splicing, eg. length and location 2.2 Deficient anchorage for beam reinforcement in columns 2.3 Open stirrups at too widely spaced. 2.4. No foundation beam to tie column bases together.
Earthquake-resilient features in frame	2.1 Splice away from high action areas, longer splicing length to develop full strength of reinforcement 2.2 Enough length of anchorages with L-bends or hooks at the end of beam bars inside the column. 2.3 Closed stirrups with 135 degree hooks at close spacing. 2.4 Foundation beams at base of columns to tie column bases together.
Seismic deficiency in roof and floors	

Earthquake resilient features in roof and floors	Roof and floor slabs are strong and stiff enough to act as rigid diaphragms.
Seismic deficiency in foundation	
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	-|		



Deficient lap length, and very poor lap location leading to partial collapse of the building

Failure of column bar splicing

Failure of column bar splicing

Shear failure of first storey columns

Cold-joint problem

Onset of plastic hinging at top of columns

Onset of development of soft storey mechanism at 1st floor level

Failure of column due to shear imposed by infill wall

Short column due to partial height

Onset of out-of-plane collapse of infill wall

infill wall

Building being supported by infill walls after failure of column

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Plan irregularity	Provide additional walls, or bracing along open sides such as for a corner building
Soft storey effect	Continue most of the infill down to ground level in both orthogonal directions, increase the size of columns in bottom storey, or best of all, provide RC shear walls to resist lateral forces in both directions.
Short column effect	Provide full height walls to stiffen the frame thereby reducing the deflection, provide closely spaced stirrups in columns, isolate infill walls structurally from the columns.
Weak structure	Provide new RC shear walls in both directions, provide jacketing to the existing walls, increase the strength of the structure.
Out-of-plane toppling of walls	Provide a bandage at lintel level to integrate the walls with the frame.

	Anchorage failure of beam bars - Could consider providing a haunch to improve tying of the beam

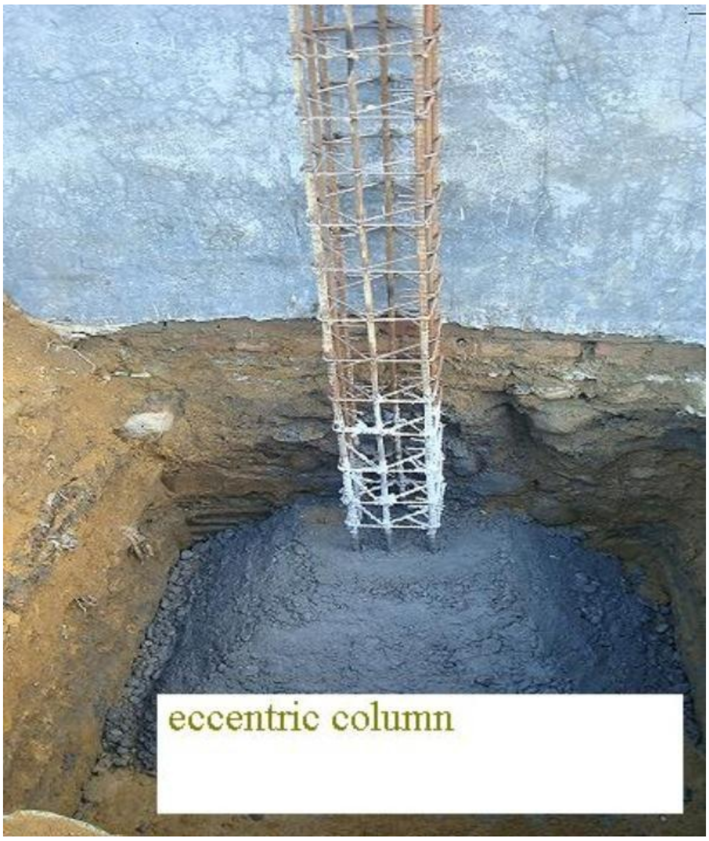
Additional comments on seismic strengthening provisions	with column but the best solution is to provide new lateral load resisting structure that relieves the poorly detailed frames from having to provide resistance. NEW CONSTRUCTION: Plan irregularity- Provide walls judiciously to avoid torsion and tie them into the frame. Vertical irregularity- Provide walls continuous from foundation to roof level uninterrupted. Weak structure- Provide solid masonry walls, or much better, RC walls in both the directions from foundation to roof. Short column effect- In the vicinity of the column provide a length of solid masonry so as a diagonal strut can form in the infill walls and not cause shear failure in the column. Provide solid walls in all the directions so the deflection can be reduced, provide closely spaced stirrups in the column (realizing that this will be insufficient on its own). Wall on two adjoining sides only (corner building) - Provide bracing infill walls along the open fronts. Deficient splicing length , open stirrups - Meet provisions for ductile detailing Beam-column joint failure - Provide stirrups in the beam column joint region. Anchorage failure of beam bars- Provide enough anchorage length of beam reinforcement in column with bend at the end of the reinforcement as well as other recommended measures
Has seismic strengthening described in the above table been performed?	Retrofitting is a completely new terminology even among practicing civil engineers. Retrofitting is practically non-existent but it is slowly emerging.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Such work is rare but a few retrofit projects have been accomplished. These are as part of a mitigation program.
Was the construction inspected in the same manner as new construction?	Yes.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Engineers are involved in the design of strengthening. The strengthening is implemented by contractors.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Not applicable. Nepal has not suffered any significant earthquake in recent history to test this work.

Additional comments section 6	The national code provides rules of thumb for buildings up to three storey high. However, it does not discuss the retrofitting of such buildings.

Pits for isolated footings

Pits for combined foundation

Isolated footings under construction



Eccentric footing along property line

A corner eccentric footing

Constructing toe wall for tie (at plinth level) beam in stone masonry

Toe wall below tie beam in mud mortar

Plinth/ tie beam construction

RC frame under construction (note anchor bars at lintel and sill level for respective bands to tie the infill walls)

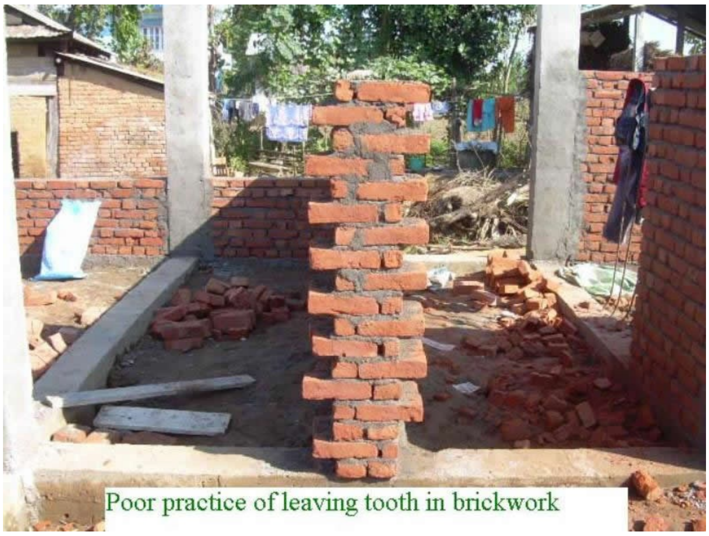
RC frame ready to receive infill walls. Note that there are no horizontal ties protruding from the columns to prevent the infills from

falling out of the frame.

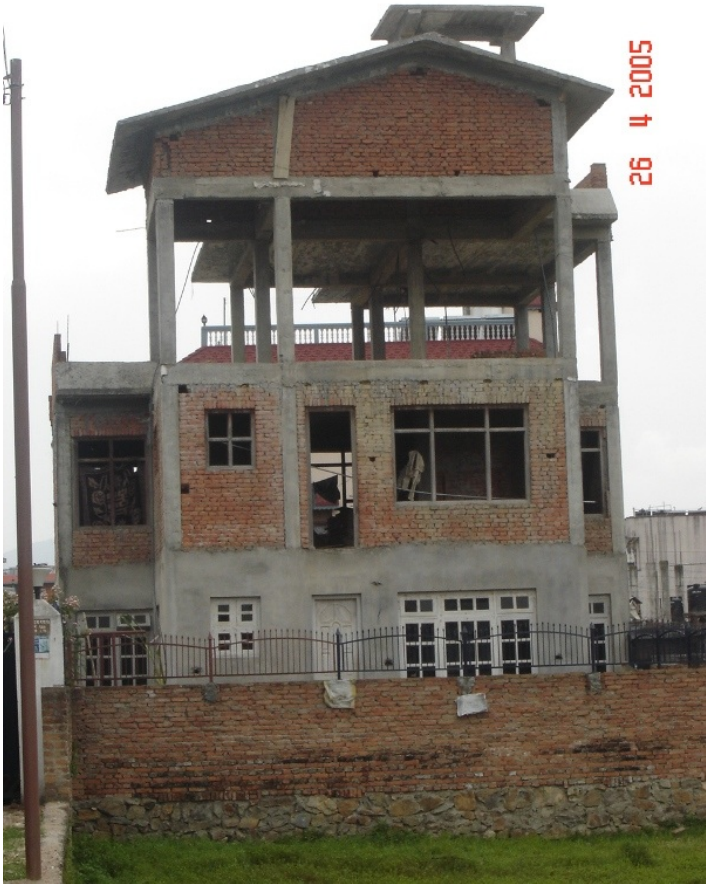
Infill wall under construction

Infill wall in stone masonry

Infill wall erected before concreting column

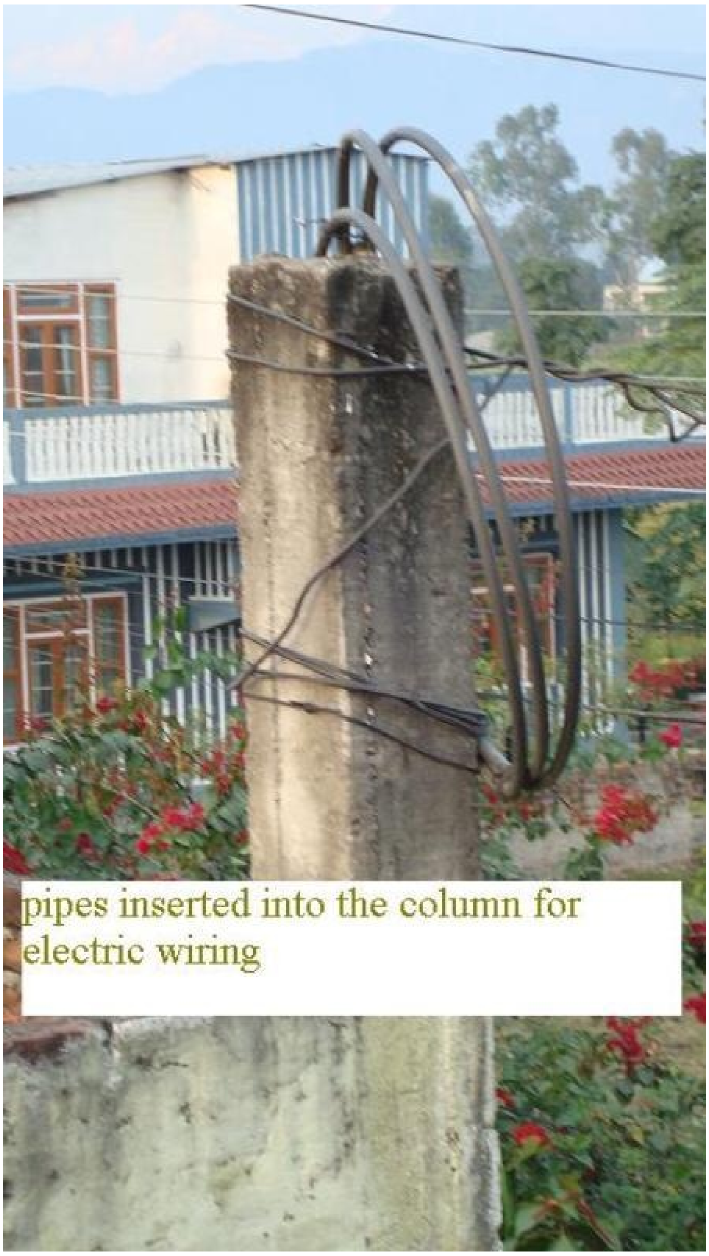


Toothing in brick work for extension of walls



Building with bottom storey ineffectively infilled because there are no solid bracing panels. The top storey is infilled and all the storeys below are very weak and vulnerable.

Construction of floor slab



Reinforcement left for future extension

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