World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

Unreinforced brick masonry residential building

Report#	112
Last Updated	
Country	Pakistan
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Reviewers	Robin Spence,

Important

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General Information

Building Type:	Unreinforced brick masonry residential building
Country:	Pakistan
Author(s):	Qaisar Ali
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in all major cities of Pakistan except Karachi. 90% of residential buildings and 80% of all building stock consist of this type. Other types of buildings in urban areas include RC frame structures with concrete blocks or brick infill walls. In Karachi, the most populous city of Pakistan, with more than 10 million people, RC frame structures with infill walls of concrete blocks are most commonly used. Unreinforced brick masonry construction in Pakistan may constitute more than 50% of all buildings. In rural areas, unreinforced buildings in clay mortar and adobe construction were very common in the past and still exist in some areas, but now are being replaced by unreinforced brick masonry with cement sand mortar. In hilly areas, unreinforced stone masonry without mortar or with cement sand mortar are widely used. Those with financial resources opt for RC frame structures with stone infill or concrete block walls. This type of housing construction is commonly found in urban areas. Most often found in urban areas but sometimes in rural areas, where adobe houses can also be found.
Summary:	In Peshawar and adjoining areas (in northern Pakistan), the most popular residential construction is a single- or double-story unreinforced masonry building with 9-inch-thick, solid burnt-brick walls and a 5- to 6-inch reinforced-concrete roof slab. Sometimes, however, 4.5- inch solid brick walls are also used as load-bearing walls. The layout of these dwellings is usually regular, mostly rectangular, having horizontal dimensions in the range of 30 ft x 60 ft or 60 ft x 90 ft, etc. Building height rarely exceeds 35 ft. Wall connections at the corners are achieved through proper toothing. Lintels, approximately 6- to 9-inches deep, with a width equal to the wall thickness, are provided above openings. In a relatively engineered construction, however, the lintel beam runs throughout the perimeter. Similar residential buildings are also found in other cities of Pakistan, for example, in Islamabad and Lahore. In Karachi, Pakistan's largest city, concrete frame structures with concrete-block infill walls are most often used.

Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	1-3
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	Normally used as a single-family house but sometimes also used as multiple-housing units and mixed-use.

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	
Typical plan length (meters)	10-40
Typical plan width (meters)	5-20
Typical story height (meters)	3
Type of Structural System	Masonry: Unreinforced Masonry Walls: Brick masonry in lime/cement mortar
Additional comments on structural system	The vertical load-resisting system is un-reinforced masonry walls. The masonry walls also act as load-bearing walls. The roof slab rests directly on walls and transfers the load to walls, which, in turn, transfer it to the foundation. The lateral load-resisting system is un-reinforced masonry walls. The lateral load-resisting system consists only of masonry walls.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	15-20%
Typical wall densities in direction 2	15-20%
Additional comments on typical wall densities	The typical structural wall density is more than 20 %. 15-30 The wall density ranges from 0.15 to 0.30 meters.
	The houses typically have one door and one or two window openings in each wall. The openings are frequently close to the corners of rooms (< 0.3 m). The

Wall Openings	windows are generally 1.2 to 1.8 square meters and the doors are 2.2 to 2.5 square meters. The total length of the opening is 20-30% of the wall length. RCC lintel beams are commonly provided above the openings.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Building modification is not as common in urban areas but may occur in rural areas. A typical modification is the construction of additional rooms, both horizontally and vertically.
Type of Foundation	Shallow Foundation: Reinforced concrete strip footing
Additional comments on foundation	The foundation consists of plain cement concrete strip footing and several brick steps. The size of the foundation is normally 0.76 m. The thickness of the concrete strip is 150 mm.
Type of Floor System	Cast-in-place beamless reinforced concrete floor
Additional comments on floor system	
Type of Roof System	Cast-in-place beamless reinforced concrete roof
Additional comments on roof system	
Additional comments section 2	For small residential units (100 square meters), there is usually no separation distance; for larger units (280 to 900 square meters), there is separation in the range of 3 to 10 meters.

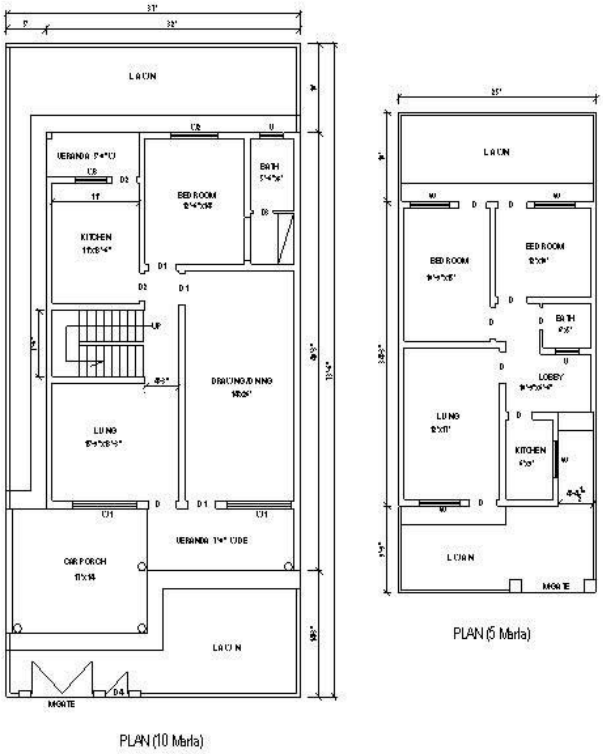

Fig 4.1: Typical plans of residential buildings in Peshawar region

Plans of typical buildings

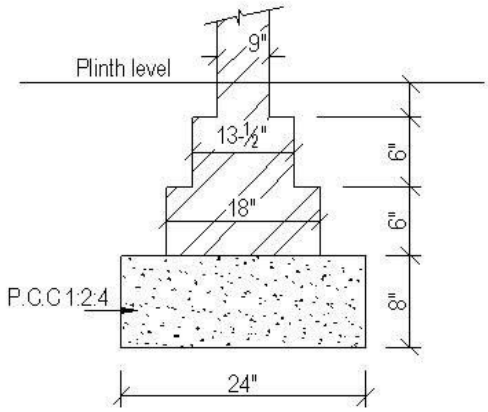

Fig 4.2: Typical Foundation

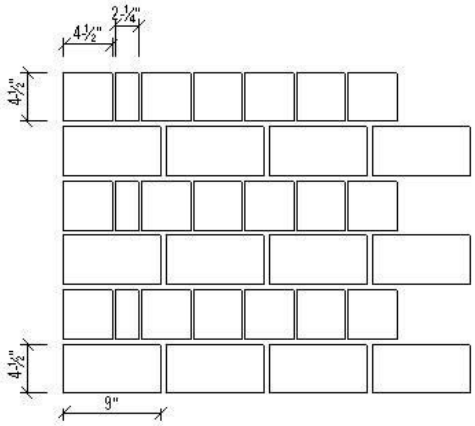

Fig 4.3: Bonding Arrangement and Toothing

Critical structural details

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Bricks and cement sand mortar.	Masonry compression strength varies from 2 to 5 Mpa. 1:8 cement sand or 1:4: 4 cement, sand and stone dust Brick size: 230 mm x 115 mm x 65 mm.
Foundations	Concrete	10 to 18 Mpa, compressive strength. Steel yield strength is 280 Mpa. 1:2:4
Floors	Concrete	10 to 18 Mpa, compressive strength. Steel yield strength is 280 Mpa. 1:2:4
Roof	Concrete	10 to 18 Mpa, compressive strength. Steel yield strength

		is 280 Mpa. 1:2:4
Other		

Design Process

Who is involved with the design process?	ArchitectOther
Roles of those involved in the design process	Almost no role for the engineer. There is, however, some involvement of architects in urban areas.
Expertise of those involved in the design process	Only rule of thumb. No engineering knowledge or involvement of engineers.

Construction Process

Who typically builds this construction type?	MasonContractorOther
Roles of those involved in the building process	
Expertise of those involved in building process	Only rule of thumb. No engineering knowledge or involvement of engineers.
Construction process and phasing	The construction is typically carried out by a contractor, who arranges for masons and laborers to carry out the work. The foundations are constructed from 1:2:4 concrete. The walls are constructed from brick masonry in cement sand or cement sandstone dust mortars. RCC roof slab is laid directly on the walls. The concrete mixing is either carried out manually or through machine-operated mixers. Both the mortars and concrete are prepared with very high water-tocement ratios and are used quite often for several hours after the addition of water. The construction of this type of housing takes place in a single phase. Typically, the building is originally not designed for its final constructed size.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	No
Applicable codes or standards	Currently Pakistan does not have any building code which covers construction of such type of buildings.
Process for building code enforcement	No such practice is ever carried out.

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?	Yes
Additional comments on building permits and development control rules	

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	USD 180 to 200 per square meter.
Labor requirements	10-15 persons working 8 hours a day can complete an approximately 280-squaremeter building in four months.
Additional comments section 3	

Socio-Economic Issues

Patterns of occupancy	In urban areas one family normally occupies the buildings, but in some cases there may be two or even three families residing in one building. In rural areas the house is typically occupied by one family, with the number of inhabitants frequently exceeding six.
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	
Economic level of inhabitants	Low-income class (poor)Middle-income classHigh-income class (rich)
Additional comments on economic level of inhabitants	
Typical Source of Financing	Owner financedPersonal savingsInformal network: friends or relativesCommercial banks/mortgagesGovernment-owned housing
Additional comments on financing	
Type of Ownership	RentOwn outrightOwn with debt (mortgage or other)Units owned individually (condominium)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
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?	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
1994	Hindu Kush
2002	Hindu Kush
2005	Kashmir

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Many far field earthquakes originating from the Hindu Kush region, varying from 6 to 7.5 and even up to 8 in some cases, have hit the northern part of Pakistan. The distance from the epicenter to Peshawar is in the range of 250 kilometers. Some low-level seismic activity also occurs near the city. According to MSK, Peshawar may be placed in VI or at most in VII, Islamabad in VI, and Lahore in V. A major earthquake in October, 2005, killed over 85,000 people and collapsed many buildings throughout Kashmir and NWFP. See photos for typical unreinforced masonry damage.
Additional comments on earthquake damage patterns	Mainly, diagonal shear cracks. Separation of roof slab from walls.

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 5.4.1)	TRUE
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	TRUE

	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.	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.	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);	FALSE
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		FALSE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an	FALSE

	estimate).	
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	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	Inadequate materials used. Poor quality of mortar, excessively thick bedding joints. Poor quality of construction.
Earthquake-resilient features in walls	
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	
Earthquake resilient features in roof and floors	The RC roof helps to integrate the walls, and the structure essentially acts like a box-type structure.
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					

Discontinuity of lintel beams

Large openings in walls

Poor quality of RC work in roof slab (A large number of bricks are placed in RC work to save cement concrete)

No seismic gap between buildings

Corner failure in in a two story brick masonry house at Muzaffarabad, Kashmir, (from Kashmir earthquake Oct 08, 2005)

Typical Scissor type cracks in a two story brick masonry house at Muzaffarabad, Kashmir (from Kashmir earthquake Oct 08, 2005)

Cracks above door opening and along lintel in a 4.5 inch (125 mm) thick wall in a partition w all in a house at Muzaffarabad, Kashmir, (from Kashmir earthquake Oct 08, 2005)

Typical cracks in pier: Manserhra Hospital NWFP Pakistan (from Kashmir earthquake Oct 08, 2005)

Shinkiari (NWFP Pakistan): out of plane flexural failure of load bearing wall

DHQ Garhi Habibullah (NWFP, Pakistan): collapsed buildings constructed with stone Masonry. Note a stone masonry building in the back ground having a bond beam at roof level is still standing

constructed with block masonry. Note 6ft high parapet wall constructed with brick masonry is still standing in spite of higher inertial forces experienced as an appen

GHS School Garhi Habibullah (NWFPPakistan): Half of the wall was constructed with stone and rest with brick masonry. Part of wall constructed with stone masonry was collapsed due to lack of cohesion with cement sand mortar

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening

Additional comments on seismic strengthening provisions	In the past 25 years there have been several earthquakes striking various cities of Pakistan. However, there is no documentation of the damage, especially to this type of structure. Therefore, no record of earthquake damage to such buildings is currently available. Neither are there records of retrofitting or strengthening. Major deficiencies of such buildings include low-quality mortar and lack of integrity (box-type action).
Has seismic strengthening described in the above table been performed?	No strengthening has been observed after earthquakes.

Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	
Was the construction inspected in the same manner as new construction?	
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	
Additional comments section 6	

References

A critical review of the seismic risk zoning Ali,Q. and Naeem,A. World Conference on Earthquake Engineering, Vancouver, BC, Canada, Paper #50 2004

Seismic performance study of brick masonry buildin Ali,Q. Doctoral Thesis, Civil Engineering Department, University of Engineering and Technology, Peshaw ar 2004

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