World Housing Encyclopedia

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

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HOUSING REPORT
Unreinforced brick masonry residential building

Report #	112
Report Date	01-11-2006
Country	PAKISTAN
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in lime/cement mortar
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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.

1. General Information

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.

This construction type has been in practice for less than 50 years.

Currently, this type of construction is being built.   .


Figure 1: A typical house of the construction type


Figure 2: Key load-bearing elements

Figure 3: Plans of typical buildings

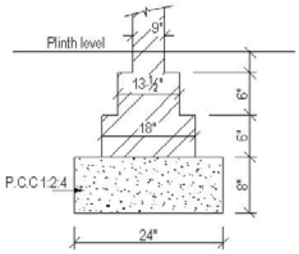

Fig 4.2: Typical Foundation

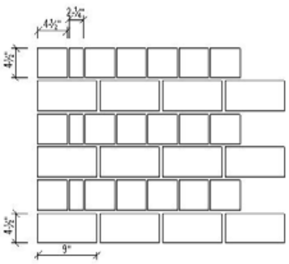

Fig 4.3: Bonding Arrangement and Toothing

Figure 4: Critical structural details

Figure 5: Discontinuity of lintel beams

Figure 6: Large openings in walls

Figure 7: Poor quality of RC work in roof slab (A large number of bricks are placed in RC work to save cement concrete)

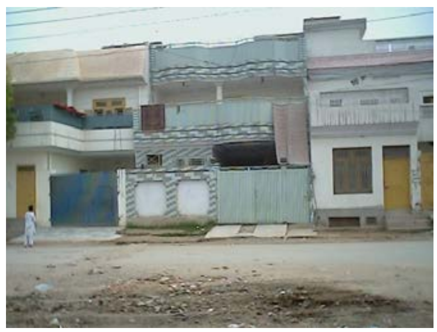

Figure 8: No seismic gap between buildings

Figure 9: Corner failure in in a two story brick masonry house at Muzaffarabad, Kashmir, (from Kashmir earthquake Oct 08, 2005)

Figure 10: 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 Figure 11: lintel in a 4.5 inch (125 mm) thick wall in a partition wall in a house at Muzaffarabad, Kashmir, (from Kashmir earthquake Oct 08, 2005)

Figure 12: Typical cracks in pier: Manserhra Hospital NWFP Pakistan (from Kashmir earthquake Oct 08, 2005)

Figure 13: DHQ Garhi Habibullah (NWFP, Pakistan): collapsed buildings constructed with

Figure 14: Shinkiari (NWFP Pakistan): out of plane flexural failure of load bearing wall constructed with block masonry. Note 6ft high

Figure 15: GHS School Garhi Habibullah (NWFP

stone Masonry. Note a stone masonry building in the back ground having a bond beam at roof level is still standing

parapet wall constructed with brick masonry is still standing in spite of higher inertial forces experienced as an appen

Pakistan): 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

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. 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 When separated from adjacent buildings, the typical distance from a neighboring building is 0 meters.

2.2 Building Configuration

The building type is normally rectangular. 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 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.

2.3 Functional Planning

The main function of this building typology is single-family house. Normally used as a single-family house but sometimes also used as multiple-housing units and mixed-use. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Normally, the main door is the only entry.

2.4 Modification to Building

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.

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	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☐
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is 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.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced masonry walls. The lateral load-resisting system consists only of masonry walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 40 meters, and widths between 5 and 20 meters. The building has 1 to 3 storey(s). The typical span of the roofing/flooring system is 5 meters. Typical Number of Stories: 1-3 Mostly two stories, although occasionally 3 stories are also found. Single-story buildings are also used but they are not as common as 2 story, although more common than 3 story. Typical Span: Center-to-center distance between the walls is 5-7 meters. The typical storey height in such buildings is 3 meters. The typical structural wall density is more than 20 %. 15-30 The wall density ranges from 0.15 to 0.30 meters.

3.5 Floor and Roof System

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

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	☐

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.

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. Normally one housing unit per building. The number of inhabitants in a building during the day or business hours is less than 5. The number of inhabitants during the evening and night is 5-10.

4.2 Patterns of Occupancy

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.

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)	☑

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

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

In each housing unit, there are 4 bathroom(s) without toilet(s), 4 toilet(s) only and 4 bathroom(s) including toilet(s).

The number widely varies from 1 to 6. In urban areas the number of bathrooms and latrines is more than 3, but in rural areas it may be 1 or none. .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership , ownership with debt (mortgage or other) and individual ownership.

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

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	N/A
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.	☑	☐	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☑	☐	☐
Roof construction	The roof diaphragm is considered to be rigid and it is expected that the roof structure will maintain its integrity, i.e. shape and form, during an earthquake of intensity expected in this area.	☑	☐	☐
Floor construction	The floor diaphragm(s) are considered to be rigid and it is expected that the floor structure(s) will maintain its integrity during an earthquake of intensity expected in this area.	☑	☐	☐
Foundation performance	There is no evidence of excessive foundation movement (e.g. settlement) that would affect the integrity or performance of the structure in an earthquake.	☑	☐	☐
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☑	☐	☐
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: Less than 25 (concrete walls); Less than 30 (reinforced masonry walls); Less than 13 (unreinforced masonry walls);	☐	☑	☐
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☐	☑	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than ½ of the distance between the adjacent cross walls; For adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; For precast concrete wall structures: less than 3/4 of the length of a perimeter wall.	☐	☑	☐
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☐	☑	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☐	☑	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☐	☑	☐
Additional Comments				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	Inadequate materials used. Poor quality of mortar, excessively thick bedding joints. Poor quality of construction.		Mainly, diagonal shear cracks. Separation of roof slab from walls.
Frame (columns, beams)			
Roof and floors		The RC roof helps to integrate the walls, and the structure essentially acts like a box-type structure.	
Other			

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is A: HIGH VULNERABILITY (i.e., very poor seismic performance), the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☑	☐	☐	☐	☐	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1994	Hindu Kush	6.5	V
2002	Hindu Kush	6.3	V
2005	Kashmir	7.6	VI-VIII

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.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	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.	
Foundation	Concrete	10 to 18 Mpa, compressive strength. Steel yield strength is 280 Mpa.	1:2:4	
Frames (beams & columns)				
Roof and floor(s)	Concrete	10 to 18 Mpa, compressive strength. Steel yield strength is 280 Mpa.	1:2:4	

6.2 Builder

Builders do not typically live in this building type.

6.3 Construction Process, Problems 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-to-cement 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.

6.4 Design and Construction Expertise

Only rule of thumb. No engineering knowledge or involvement of engineers. Almost no role for the engineer. There is, however, some involvement of architects in urban areas.

6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country. Currently Pakistan does not have any building code which covers construction of such type of buildings.

No such practice is ever carried out.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules. Building permits are not required to build this housing type.

6.7 Building Maintenance

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

6.8 Construction Economics

USD 180 to 200 per square meter. 10-15 persons working 8 hours a day can complete an approximately 280-square-meter building in four months.

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. No earthquake insurance is available.

8. Strengthening

8.1 Description of 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).

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?

No strengthening has been observed after earthquakes.

8.3 Construction and Performance of Seismic Strengthening

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