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HOUSING REPORT
Brick masonry construction in Pakistan

Report #	173
Report Date	06-09-2013
Country	PAKISTAN
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in mud/lime mortar
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Summary

This report provides an overview of brick masonry housing construction, which constitutes 62.38% of the total built environment of Pakistan. Brick masonry construction ranges from typical one-storey houses which are common in rural areas up to three-storey buildings (common in urban areas). Buildings of this type are generally constructed without seeking any formal engineering input. Due to inherent weaknesses in the structural load carrying system and also to the usage of poor quality construction materials, this construction type has performed extremely poorly during recent earthquakes in Pakistan. Due to the lack of specific construction guidelines and the applicable building permit laws to regulate such construction techniques, an overwhelming percentage of existing as well as newer building stock is now under an increased seismic threat.

1. General Information

Buildings of this type are common in rural, sub-urban and urban areas and together they represent 62.38% of all construction in Pakistan [1]. The construction technique has been in practice for about 100 years and it still remains popular for construction of newer buildings in many areas of Pakistan.

The structural system is mainly gravity load-bearing brick masonry walls constructed using either sun-dried or fired bricks with mud or cement mortar. Due to the abundance of good quality clay within the plains of Punjab and interior Sindh, it is convenient to use brick as the primary building material. Local labor is quite skilled in the crafting of individual bricks, with a variety of sizes available (average size 4.5″ x 9″ x 3″) depending on the scale of construction. Manufacturing and transportation costs for towns within Punjab and interior Sindh, which are closer to the alluvial plains, are much less compared to a more arid urban center like Karachi, where brick is seldom used. This prompt supply of cheap building material means that brick is the material of choice for a range of economic classes within these towns. On the one hand, there are those who choose to pay for prefabricated, molded and fired bricks; on the other, those that cast their own adobe blocks which cost virtually nothing. Brick is also a natural selection for most people as it is a good insulator. In areas where temperatures can often soar above 38-40°C with harsh, dry gusts of air, the interiors of brick homes stay relatively cool and well-ventilated. Bricks trap heat during the daytime, and this heat they slowly dissipate at night as temperatures fall. Similarly, they also protect against extreme cold in areas where temperatures are lower. **Figure 1** shows a brick kiln in Punjab. Once erected, brick masonry buildings can be finished off with a number of external treatment options. It is not uncommon in villages or among economically less privileged users to leave the external wall surface unfinished, exposing the brick layers and mortar. This may make the joinery susceptible to natural agents like rainfall and wind. Where treatment does happen, it could be plaster, paint, or ornamental tile work. Brick houses are also found in parts of Baluchistan and Khyber Pakhtunkhwa (KPK), but with less frequency than in Punjab. KPK contains more stone masonry buildings due to the abundance of stone in the mountainous north and north-west. **Figure 2** illustrates the spatial distribution of brick masonry buildings in Pakistan.

Figure 1. Typical brick kiln to produce fired bricks in Punjab.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They share common walls with adjacent buildings, or are separated a typical distance of 2-5 meters. Brick construction is widespread throughout cities as well as the larger towns in Pakistan, with the exception of Karachi, where reinforced concrete slab (RCC) frame structures are more dominant. In villages where the population is more economically stable, structures are commonly built with fired brick rather than adobe. In lower income villages adobe is more common, but is more vulnerable to natural forces like wind and precipitation. Majority of these buildings comprise of single storey residential units and are generally distributed in clusters (*mohalla*).

2.2 Building Configuration

Unreinforced brick construction gives few planning options because of its limited strength and stability. Buildings must be configured in a careful manner to avoid susceptibility to damage over time. Brick houses are mostly rectangular in shape, with a length typically not exceeding three times the width. The main entrance is located centrally on the exterior wall. Off the main entrance is a foyer that connects to one or more rooms on either side. Openings on the exterior walls are kept to a minimum number and size, and are located at least 1-1.5 feet away from corners. Ideally, they should be at least 2 feet away from each corner.

2.3 Functional Planning

The main function of this building typology is mixed use (both commercial and residential). Unreinforced brick masonry is commonly employed for residential construction, or as storage sheds for animals, fodder, or precious belongings. In a typical family residence, there is a communal/public space marked as the main entrance lobby/foyer, to which other rooms constituting the private spaces are connected. This entrance lobby is commonly used as a socializing/dining space for the family. Inhabitants retreat to the more intimate private space at night. Planning is a bit different in two-storied houses, which are usually built on larger plots. Half of the plot area would be built upon, while the other half is left open as a *sehen* (courtyard). A main gate on one corner of the exterior wall grants entry to the *sehen*, from which one or more doors open into the interior spaces. A separate latrine or outhouse may be located in the *sehen* some distance away from the living space. An outdoor kitchenette may also be present for more efficient ventilation. From the *sehen*, a staircase (most often a wooden or steel ladder with a steep slope) leads to the upper story, which may have one or two rooms with the same footprint as the ground floor. **Figures 3** to **7** show views of various brick masonry buildings. In a typical building of this type, there are no elevators and no fire-protected exit staircases. Though there was some variety, these are general observed characteristics found amongst homes in the region.

2.4 Modification to Building

Smaller, individual brick buildings in villages are often built with materials taken on credit from local *thallas* or through loans acquired from relatives, and are therefore open to incremental modification as more funds become available. Additions to the buildings, generally carried out using the same materials, include an additional room or outhouse, a rudimentary boundary wall, or a storage shed. Larger units, like those in the city, can be subjected to additional rooms, horizontally as well as vertically. This depends on the expansion of the family size, or the decision by the homeowner to rent out some space to tenants as an additional source of income.

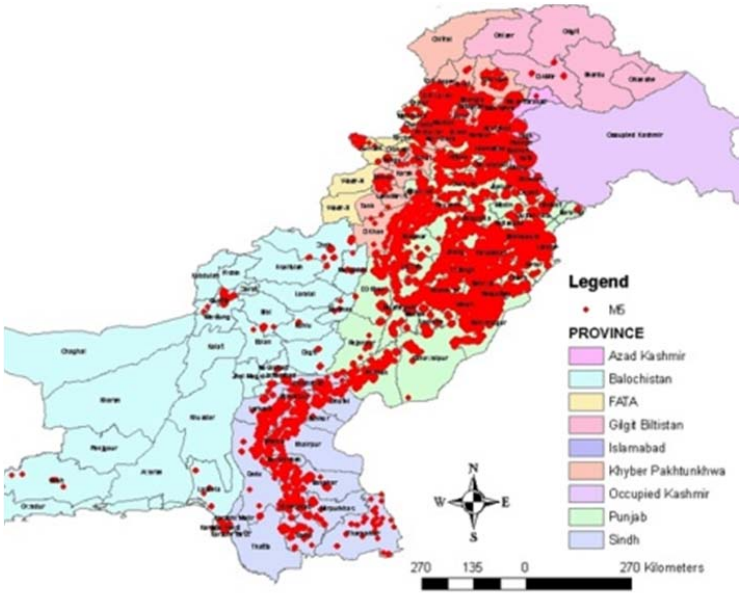

Figure 2. Spatial distribution of brick masonry buildings in Pakistan [1].

Figure 3. Rural brick houses – Mithi, Thar.

Figure 4. Khazana – a cultural center/library in Khairpur. Arcaded brick construction.

Figure 5. A small, one-room roadside brick mosque.

Figure 6. A brick house with attached verandah/semi-covered terrace space.

Figure 7. A relatively large brick house enclosed within a brick boundary wall, with detached outhouses.

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	☐

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
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)	☐

It may also contain lime/cement mortar.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is unreinforced masonry walls. The loads from the roof are transferred to the walls and to the foundations. Generally, there is no proper connection between the walls. No reinforcement or bands are used.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is unreinforced masonry walls. The walls have a very low resistance to out-of-plane forces. In most cases, there is no proper connection between the roof and the walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are lengths between 10 and 50 meters, and widths between 5 and 30 meters. The building has 1 to 3 storey(s). The typical span of the roofing/flooring system is 5-8 meters. The typical storey height in such buildings is 2.5 meters. There is no typical structural wall density.

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	☑	☑

Single story brick houses generally have a lighter roof made of timber, steel girders, bamboo/straw with a layer of mud, or corrugated galvanized iron (CGI) sheets. For brick masonry buildings with 2 to 3 storeys, reinforced concrete (RC) slabs are commonly used.

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 foundations are brick masonry wall footings laid in cement sand mortar, 1.5 to 2.5 feet deep, and 1.5 to 2.5 feet wide.

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit. Brick houses can range from small, one-unit, single-family residences in villages to substantially sized buildings in relatively urbanized towns. Residential buildings contain 1 or more units of housing for 1-2 families, or a larger extended family. The number of inhabitants in a building depends on the size of the family. As these buildings cater to rural households, the number of family members can be more than 6 – including at least one married couple, an elder grandparent or two, and a few children. 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

The house caters to one family, or two if the house contains another story. This is often the case in urban areas where space is limited and more expensive, and thus shared. Men generally leave the house for work and children for school, so homes are usually occupied by seniors, women and toddlers until mid-afternoon. In the evening, men return home for meals, after which they may go to other part-time jobs in the neighborhood. The house is fully occupied at night when the family goes to sleep. It is common in smaller towns for the brick house to be used for a home-based business or a cottage industry. This means the number of occupants during the day may increase, which leads to problems of adequate ventilation and limited space for interaction or work.

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)	☐

4.4 Ownership

The types of ownership or occupancy are renting, full 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 ofpersons	☐
Long-term lease	☐
other (explain below)	☐

Brick houses are usually owned by the people who build them. Owners may decide to let one or two tenant families move in which provides an additional source of income for the owner. This also helps cover the costs of periodic maintenance and repairs on the house.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		True	False	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)	☐	☑	☐

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	Poor lateral resistance, weak in out of plane direction, no lintel band, Improper opening proportions, poor quality of construction	There are no earthquake resistant features.	Collapse of wall due to out-of-plane and in-plane effects.
Roof and floors	Heavy dead loads, no connection between roof elements and walls, lack of diaphragm action		Collapse of roof due to out-of- plane failure of walls.

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *A: High Vulnerability* (very poor seismic performance). Both the lower bound (i.e., the worst possible) and the upper bound (i.e., the best possible) are considered to fall into *Vulnerability Class A: High Vulnerability.*

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
1668	Samawani Sindh	7.6	VIII to IX
1931	Sharigh Valley Balochistan	7	VIII to IX
1931	Muchh Balochistan	7.4	VII
1935	Quetta Balochistan	7.5	VIII
1945	Pasni Makran	8.3	VII to VIII
1974	Pattan Swat	6.2	VII
2001	Bhuj Gujarat	7.6	VII
2005	Kashmir	7.6	X
2008	Ziarat Balochistan	6.4	VII
2011	Dalbandin Balochistan	7.2	IV to V

Pakistan, India and Nepal lie on the Indian plate, which is continuously moving northward and sub-ducting under the Eurasian plate, thus triggering earthquakes in the process of forming the Himalayan mountains. Within the Suleiman, Hindu Kush and Karakoram mountain ranges, the Northern Areas and Chitral district in NWFP, in Kashmir (including Muzaffarabad, Quetta, Chaman, Sibi, Zhob, Khuzdar, Dalbandin) and the Makran coast (including Gwadar and Pasni in Balochistan), are located in high or very high risk areas. The cities of Islamabad, Karachi and Peshawar are located on the edges of high risk areas. **Figure 8** shows the seismic zone map of Pakistan, which was developed after the 2005 Kashmir earthquake [2]. A large number of major earthquakes have hit Pakistan in 20th century including the 1935 Quetta earthquake, the 1945 Makran coast earthquake, the 2001 Bhuj earthquake and the 2005 Kashmir earthquake [3]. **Figures 9** and **10** show the damage to masonry houses in the 2005 Kashmir earthquake.

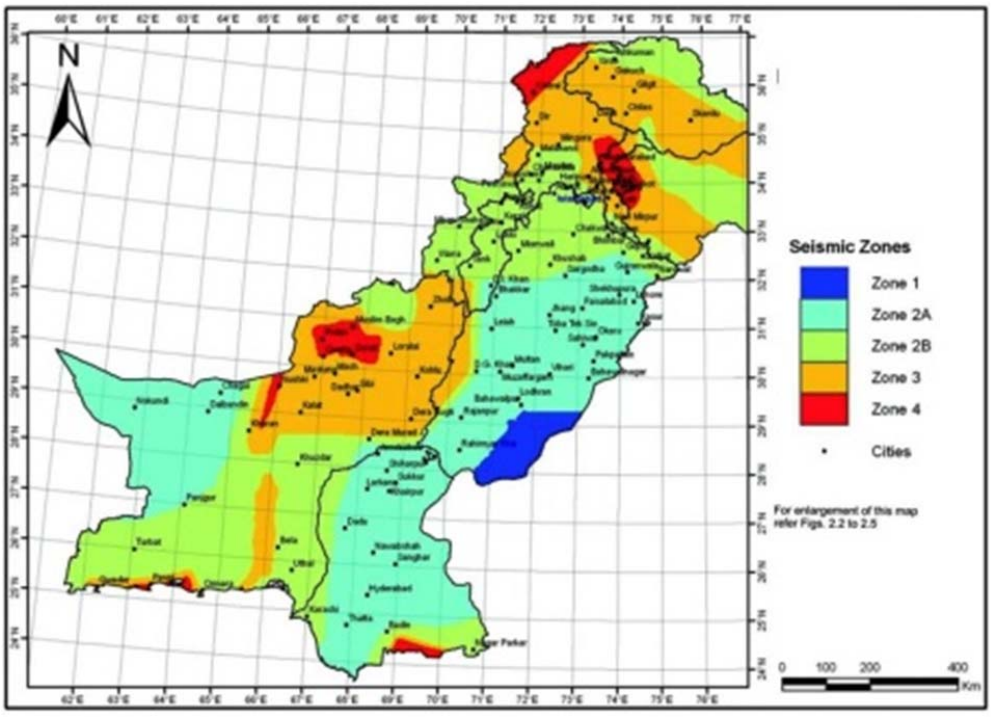

Figure 8. Seismic zone map of Pakistan [2].

Figure 9. Typical scissor type cracks in a two story brick masonry house at Muzaffarabad, Kashmir [4].

Figure 10. Severely damaged unreinforced brick masonry wall in Muzaffarabad during the Kashmir Earthquake of 2005 [5].

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	The building materials used are bricks with mud mortar or cement sand mortar.	There is a large variation of the strength of the walls ranging from 2 to 6 MPa.	The mix proportions are 1:10:1 (Sand, Clay, Straw) or 1:8 cement sand and a brick size of 225 x 113 x 75 mm.	On average, load-bearing walls are 13.5 inches thick. Load-bearing walls may also be thinner, around 9 inches, especially if a light roof is employed. Cement sand mortar is commonly used to bond the bricks together. The height of walls varies from around 9 to 12 feet – generally higher in warmer climatic zones with ventilators at the top to ease ventilation, and lower in colder zones to keep the internal heat trapped. For houses that have an additional story, walls must be thicker to support the load of the roof (usually RCC slab) as well as other loads from the upper floor. Perpendicular walls should meet with appropriately joined teething. RCC or steel lintels are common above door and window openings on brick walls. **Figure 11** shows a typical building with view of masonry walls.
Foundation	The foundation is typically made of brick masonry with cement sand mortar.	The strength of the foundation is 2 to 6 MPa.	The mix proportions are 1:10:1 (Sand, Clay, Straw) or 1:8 cement sand and a brick size of 225 x 113 x 75 mm.	Foundations for brick houses are usually 1.5 to 2.5 feet deep, and 2 to 2.5 feet wide. They may be deeper and wider for buildings with more stories. It is common to provide a continuous strip foundation beneath the load-bearing walls to enhance the load transfer path. The plinth is kept at least 2 feet from the ground level, to prevent against rising dampness or stagnant water after a downpour or flood.
Roof and floor(s)	The roof and floors are timber or bamboo with a layer of mud, steel girder with clay tiles and mud, and RCC slab.	The strength of the RC slab is between 10 to 17 MPa.	For the RC slab the mix ratio is 1:2:4.	Single story brick houses have a lighter roof made of locally available material such as wood-soil, steel purlins, bamboo/straw coated with a 6 inches layer of mud, or corrugated galvanized iron (CGI) sheets held down by weights. CGI sheets are preferred in areas that receive high annual precipitation. For buildings with lighter roofs such as these, the walls may be constructed less thick than for a building with multiple stories. Also, mud mortar could be employed in the walls of buildings that have light roofs. For brick buildings that vertically exceed the ground floor, an RCC slab is commonly used to act as the load-bearing horizontal member for the first floor, and a comparatively lighter roof is used on the topmost floor.

6.2 Builder

Builders are usually the owners of the plot of land, and they employ local masons they know by reference in the community. Professional guilds may exist in larger villages and small towns that provide a somewhat standardized 'version' of craftsmen for daily wages.

6.3 Construction Process, Problems and Phasing

Brick masonry construction is usually carried out by local masons and laborers who rely on their experience. The foundations are generally constructed using brick masonry with cement sand mortar and are wider than the walls. From plinth level, the walls are constructed either of mud mortar or cement sand mortar. Various types of roofing materials are used and are directly resting on the walls without any connections. 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

There are no design or construction guidelines available for this type of construction. Local masons rely on their past experience and the engineers or architects are not generally involved.

6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country.

6.6 Building Permits and Development Control Rules

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

6.7 Building Maintenance

Typically, these types of buildings are maintained by the owners. Building repairs are periodically carried out on the external surfaces of walls when plaster or mortar cracks and falls off due to weather effects. In severe cases roofs may be heavily damaged, especially those made of lighter materials, and would need to be replaced. Stagnant water is also known to damage building foundations, so proper waterproofing must be applied to the foundation prior to construction. Depending on the quality of the original construction, the level of maintenance varies. If poorly constructed, the level of maintenance is generally very low.

6.8 Construction Economics

The cost of construction is roughly Rs. 7,500 to Rs. 10,000 per m^2. The construction of a typical housing unit takes approximately 4 to 6 months to complete.

Figure 11. Brick masonry walls.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating features which are resilient to seismic forces, an insurance premium discount or more complete coverage is unavailable.

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