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HOUSING REPORT
Concrete-block masonry construction in Pakistan

Report #	174
Report Date	17-12-2012
Country	PAKISTAN
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Concrete block masonry in cement mortar
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Summary

This report provides an overview of concrete block masonry housing construction, which is generally found in urban areas of Pakistan. Block masonry covers 3.3% of the total built environment of Pakistan. Block masonry construction is the most common type in less developed urban areas, where clay is not readily available, and ranges from one-storey houses to multi-storeyed buildings. The construction is generally carried out without any technical input. There are no guidelines and laws available to regulate it; therefore, it suffers from a number of weaknesses. This construction type is highly vulnerable to seismic forces.

1. General Information

Buildings of this construction type can be found in around 3.3% of all construction in Pakistan [1]. This type of construction is very popular in Karachi and its suburbs due to the ready availability of concrete blocks. Sand, gravel, aggregate, and cement, the necessary ingredients for casting concrete blocks, are conveniently available in Karachi. Cement is used as a binding agent, which gives the blocks their strength and durability (at the cost of adding substantial weight to the structure). In other parts of the country where sand and gravel are not available as easily it is more practicable to construct in brick, which is appropriate to those areas climatically as well as economically. Concrete block construction has also started to replace stone masonry in the northern areas of Pakistan because of its lower cost as compared to building in stone. In Karachi, concrete blocks are mass produced on a large scale and exported to the suburbs and outlying settlements bordering the central urbanized region. They have come to define the typical construction of Karachi. Concrete blocks are more commonly used as infill material within an RCC frame in most of the construction in Karachi. However, they can be used as load bearing members without reinforcement. Apart from being the main load bearing members in walls, concrete blocks are also used to make boundary walls (with regularly spaced buttresses for long walls) and interior partition walls, which may be made thinner than the main load bearing walls. Another advantage of building with concrete blocks is that they do not necessarily have to be plastered on the exterior. Their high durability gives one the leverage of leaving the exterior surfaces exposed, which offers considerable savings on plaster and paint cost. A major disadvantage of concrete block construction is their poor insulation capacity. An additional layer of insulation on walls is quite expensive, and is rarely applied during construction. This type of housing construction is commonly found in both sub-urban and urban areas.

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

Currently, this type of construction is being built.

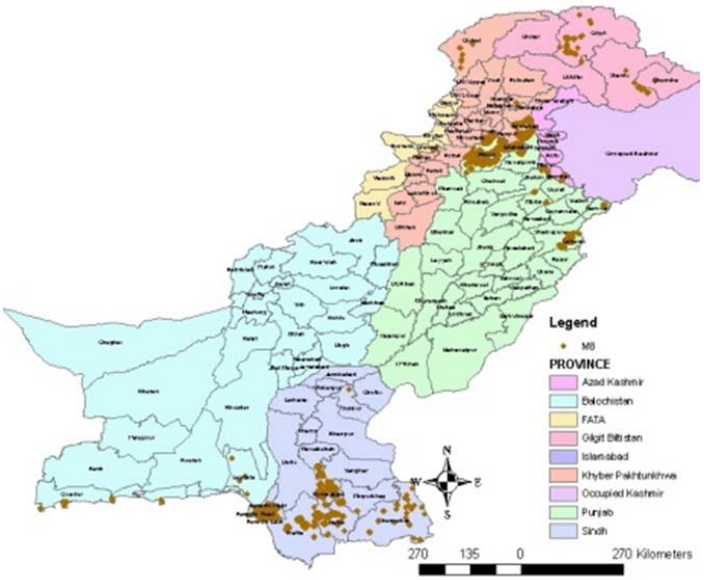

Figure 1. Spatial distribution of block masonry buildings in Pakistan [1].

Figure 2. Concrete block masonry house, Karachi.

Figure 3. Concrete block masonry house, Northern Areas.

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat, sloped and hilly terrain. They share common walls with adjacent buildings. These buildings can be found in the flattest of areas such as Karachi to quite rugged terrains such as the mountainous Gilgit and Hunza regions. The location of block masonry buildings depends more on the availability of suitable materials for construction than geographic features of the land. Another factor is the lack of availability of clay in the areas as they are located away from the river plains as shown in Figure 1. When separated from adjacent buildings, the typical distance from a neighboring building is 1-5 meters.

2.2 Building Configuration

As this type of construction is limited to urban or suburban regions where there are defined allotments of land rather than open parcels like in the countryside, buildings are strictly regular squares or rectangles in plan according to the plot size. Buildings contain basic living amenities. A main entrance door, which might not necessarily be located centrally on the external wall, opens into an interior lobby, from which one can access rooms or a staircase leading to an upper floor. Additional features like a wash basin, a water motor, and an underground tank may be located within this entrance lobby. Sometimes, the exterior door connects to an open veranda, and each interior room has its own door connected to the central veranda space. For other plots, shops may occupy the entire ground floor area, leaving just enough space for a minimal flight of stairs to the first floor where living facilities are provided.

2.3 Functional Planning

The main function of this building typology is mixed use (both commercial and residential use). Residential buildings contain a simple circulation plan. Rooms are clustered together, with one room opening into another without any corridors or connecting spaces. Bathrooms may be located to the extreme rear of the house, to facilitate ventilation outwards. For non-residential block masonry buildings, such as restaurants and shops, a very rudimentary spatial configuration is adopted. Facilities like kitchen and service counters are docked to one side, whereas a larger portion of the interior space is used for seating or display of goods. Restaurants would have higher walls with vents to facilitate ventilation. In a typical building of this type, there are no elevators and no fire-protected exit staircases.

2.4 Modification to Building

Smaller block masonry units are usually open to incremental modification as funds become available. These modifications can be in the form of ad hoc appendages to an existing, finished construction (Figure 5), or the addition of a single block masonry room or floor on top of an already built RCC ground floor (Figure 6).

As block masonry construction is adopted by low and low-middle class residents, modifications to existing buildings are quite common, depending on when funds become available, and whether the owner decides to add more space to rent out to tenants as a source of additional income.

Figure 4. Typical block masonry settlement, Karachi.

Figure 5. Adhoc appendage to the building.

Figure 6. Vertical addition to existing house.

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)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is un-reinforced masonry walls. The loads from the roof are transferred to the walls and to the foundations.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced 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. Single storey construction is more common in settlements, whereas 2 to 3 storey buildings are commonly found in urban areas. The typical storey height in such buildings is 2.5 meters. The typical structural wall density is none.

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)	☐	☐

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
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 block masonry houses generally have a lighter roof made of steel girders with tiles or CGI sheets. Precast concrete beams and slab panels are also used in urban areas like Karachi. For block masonry buildings with 2 to 3 storeys, RC slab is also used. Single story block masonry houses generally have a lighter roof made of steel girders with tiles or CGI sheets. Precast concrete beams and slab panels are also used in urban areas like Karachi. For block masonry buildings with 2 to 3 storeys, RC slab is also 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 block masonry wall footings laid in cement sand mortar, typically 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(s). Block masonry houses are relatively small, single-family residences. A larger extended family resides where they cover two stories. Tenants may also be present if the resident family is small in size. 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

As block masonry houses are occupied by low to low-middle income households, they are left somewhat vacant during the daytime as men leave for work. Womenfolk from the surrounding houses may gather in one of the rooms to share gossip or do household chores together, like preparing meals. It is common for the elderly to bask in the sun during the early morning hours, and toddlers to play about in the street. This gives a block masonry settlement a lively morning ambience. Men return to the houses for afternoon meals, after which they might go off to work in the evening. It is not before night time that the entire family sits together for a while before retreating to the bedrooms.

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)	☐

Block masonry houses are ideal for low to low-income residents, who fall short of affording an RCC frame construction but still manage to pay for a durable form of construction.

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 no bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

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)	☐

Houses belong to the builder. Often after acquiring a plot and unable to start construction immediately, the owner may decide to erect a few temporary block masonry structures, such as a room or a number of shops, so that the plot is not encroached upon illegally by political or other vectors.

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 effects and shear
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 *(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
1668	Samawani Sindh	7.6	VIII to IX
1819	Allahbund Sindh	7.2	IX to X
1827	Lahore Punjab	7.8	VIII to IX
1852	Kahan Balochistan	8	IX
1935	Quetta Balochistan	7.5	VIII
1945	Pasni Makran	8.3	VII to VIII
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

The Indian plate upon which Pakistan, India and Nepal lie, is continuously moving northward and subducting under the Eurasian plate, thus triggering earthquakes in the process and forming the Himalayan mountains. Within the Suleiman, Hindu Kush and Karakoram mountain ranges, the Northern Areas, Chitral district in NWFP, Kashmir including Muzaffarabad, Quetta, Chaman, Sibi, Zhob, Khuzdar, Dalbandin, the Makran coast including Gwadar, and Pasni in Balochistan are located in high or very high risk areas. Cities of Islamabad, Karachi and Peshawar are located on the edges of high risk areas. Figure 7 shows the seismic zoning map of Pakistan, which was developed after 2005 Kashmir earthquake [2]. A large number of major earthquakes have hit Pakistan in 20th Century including: 1935 Quetta earthquake, 1945 Makran coast earthquake, 2001 Bhuj earthquake and 2005 Kashmir earthquake [3]. Figures 8 and 9 show the damage to block masonry houses in Kashmir 2005 earthquake.

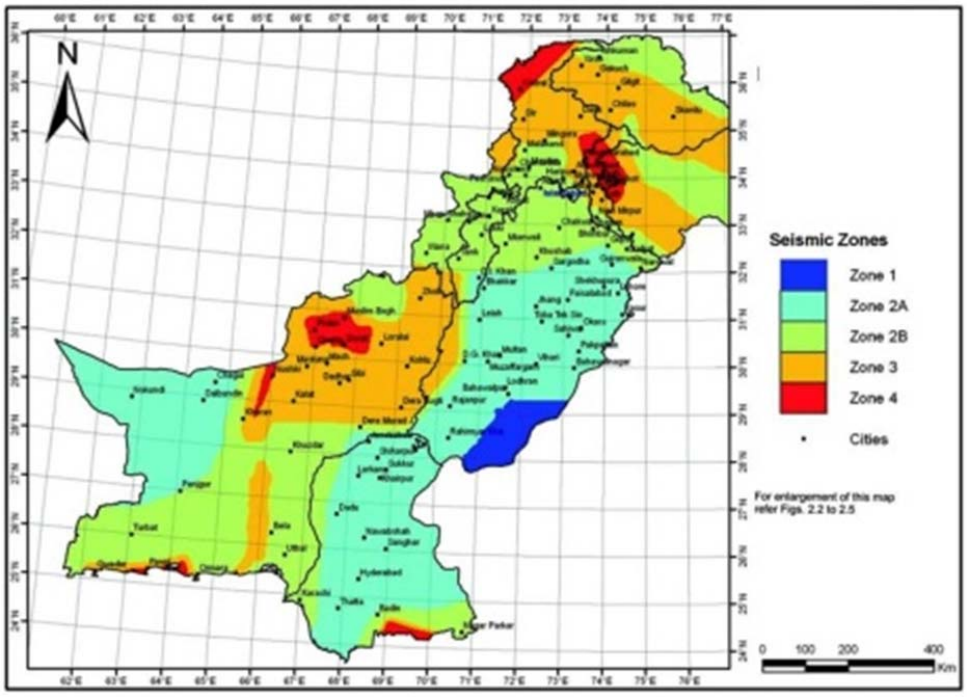

Figure 7. Seismic zone map of Pakistan [2].

Figure 8. Out of plane flexural failure of load bearing wall constructed with block masonry in Kashmir Earthquake of 2005 [4].

Figure 9. Collapse of unreinforced concrete block masonry houses in Kamsar near Muzaffarabad [5].

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Solid concrete blocks with cement sand mortar.	There is a large variation of strengthens, ranging from 2 to 6 MPa.	The mix proportions of the concrete blocks are 1:6 cement and sand. The dimensions of the blocks are 150 x 200 x 300 mm.	Walls of block masonry houses are approximately 10 feet high or more. The thickness is up to 6 inches, the same as the width of a single block. As most block masonry houses are single story structures, the total height of the structure rarely exceeds 12 feet. Where an additional story has been constructed, building heights can go up to 24 feet.
Foundation	Concrete blocks and cement sand mortar.	The strength of the foundation ranges from 2 to 6 MPa.	The mix proportions and the dimensions of the blocks are same as the walls.	Strip foundation is commonly provided, the depth of the foundation being at least 3 feet. The depth is larger in areas where the load bearing capacity of the soil is less. The foundation can be either of concrete blocks or stone masonry (Figure 10). The thickness of the stone masonry foundation is usually between 12 to 15 inches, and in some cases might be as high as 18 inches. Where stone is not available, concrete blocks are used in the foundation, with the foundation wall 12inches thick. The plinth is provided at around 2 feet from the ground level. The plinth wall has a thickness equal to that of the foundation. Both the internal and the external faces of the plinth are plastered.
Roof and floor(s)	Steel girders with clay tiles or precast slab panels.			Roofs of block masonry structures are constructed using lightweight material, as unreinforced blocks have a limited load bearing strength. In relatively urban settlements, the roofs are flat and may be of corrugated galvanized iron sheets held down by blocks or of concrete I-beams with concrete tile roofs where residents can afford them. Otherwise, light wooden or bamboo beams protected with a plastic sheet for waterproofing are covered with mud and soil. Wooden or bamboo rafters run along the shorter directions placed at a centre to centre distance of 18 inches or more. Wooden planks are laid perpendicular to these rafters. A 6 inch layer of soil is laid at the top of the plastic sheet. This practice is more common in the northern parts of the country where wood is abundant, and where the colder temperature requires a well-insulated rood layer.

6.2 Builder

The builder is usually the owner of the house who decides whether to live in it or rent out portions as residential or commercial space.

6.3 Construction Process, Problems and Phasing

Block masonry construction is usually carried out by local masons and labourers who rely on their experience. The foundations are generally constructed using block masonry with cement sand mortar and are wider than the walls. From plinth level, the walls are constructed in cement sand mortar. Various types of roofing materials are used which are generally directly resting on the walls without proper 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 a 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, the building of this housing type is maintained by Owner(s). Repairs consist largely of plaster peeling or blocks falling out of walls, which is not that common.

6.8 Construction Economics

The cost of construction is roughly Rs. 7,500 to Rs. 10,000 per m2. The construction of a typical housing unit takes approximately 4 to 6 months to complete.

Figure 10. Stone plinth and foundation underneath block masonry.

Figure 11. Block masonry with CGI sheet roof held down by a plastered parapet of blocks.

Figure 12. Block masonry with concrete girder roof and concrete tiles.

7. Insurance

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

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

There are no specific set of provisions available for seismic strengthening and retrofitting of block masonry houses.

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