World Housing Encyclopedia

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

an initiative of
Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Single-storey brick masonry house (EMSB1)

Report #	91
Report Date	17-03-2003
Country	BANGLADESH
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in lime/cement mortar
Author(s)	Mehedi Ansary
Reviewer(s)	Alpa R. Sheth

Summary

This is a one-story brick masonry house of fired bricks with cement or lime mortar; roof is either GI sheet or another material. These houses can be seen throughout Bangladesh. During the 1918 Srimangal, 1930 Dhubri, and other recent earthquakes, this type of housing suffered heavy damage. Houses with a continuous lintel suffered less.

1. General Information

Buildings of this construction type can be found in all parts of Bangladesh. This type of housing construction is commonly found in both rural and urban areas. This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built. .

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. In the villages this type of housing may be located several 100 meters apart When separated from adjacent buildings, the typical distance from a neighboring building is 2 meters.

2.2 Building Configuration

Mostly L-shaped, sometimes rectangular. At least three for a single room (two windows and one door). The buildings generally comprise of two to three rooms. The inner and outer rooms have at least two doors. Opening per wall is around 20%. Doors and windows are located in the middle of the wall.

2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. No.

2.4 Modification to Building

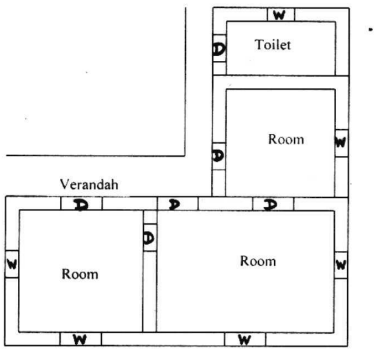

Figure 1: Typical plan

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
			Rubble stone (field stone) in mud/lime	

Masonry	Stone Masonry Walls	1	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	☐
		36	Thatch	☐

Timber	Load-bearing timber frame	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)	☐

Tie columns are not used.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is earthen walls. Traditionally, 10 inch wall is used as load bearing walls. But sometimes poor people use 5 inch wall. Poorer construction do not have any kind of plaster.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is earthen walls. Sometimes there is a continuous lintel, sometimes none. In earthquake prone areas like Chittagong, Sylhet etc. approximately 50% private housing units have continuous lintel. But on the government buildings, the percentage is much lower.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 3 and 5 meters, and widths between 2 and 4 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 3 meters. The typical storey height in such buildings is 2.8 meters. The typical structural wall density is up to 20 %. 15 - 20%.

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)	☐	☐
	Rammed earth with ballast and concrete or plaster finishing	☐	☐

Timber	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	☑	☑

GI roofs with purlins.

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	☐

Stepped brick foundations with cement mortars are used. Generally foundation bottom lies 2 to 3 ft below GL.

Figure 2: Typical Construction

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. 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 the joint family tradition is strong in the rural areas, an extended family occupy the housing unit. Typically, the families comprise of a father and two-three sons. As the family further expands, the sons families occupy independent units.

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)	☑

The middle dass housing unit roughly costs USD 1,000, on the other hand the rich housing unit costs USD 1,500 to 2,000.

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 1 bathroom(s) without toilet(s), 1 toilet(s) only and 1 bathroom(s) induding toilet(s).

4.4 Ownership

The type of ownership or occupancy is renting and outright 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	☐	☑	☐
	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;			

Wall openings	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	Weak from earthquake point of view; sometimes there are no plaster; lack of lintel bands; no measures to strengthen the corners.		
Frame (Columns, beams)			
Roof and floors			
Other	Lack of awareness about the earthquake resistant construction practices.		

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., 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 *C: MEDIUM VULNERABILITY (i.e., moderate 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
1885	Bogra-Sirajganj	7	VIII
1897	Assam	8	X
		7.6	

1918	Srimangal		VIII
1997	Bangladesh-India Border	5.6	VII

During the 1897 Assam earthquake, almost 90% of this type of structure suffered some kind of damage.

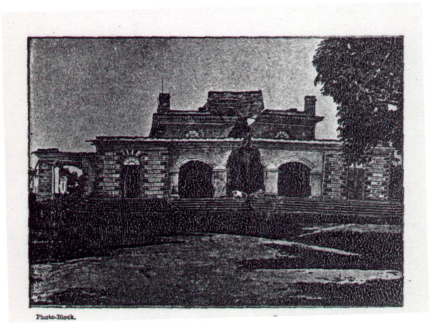

Figure 3: Damage at Rangpur, 1897 earthquake

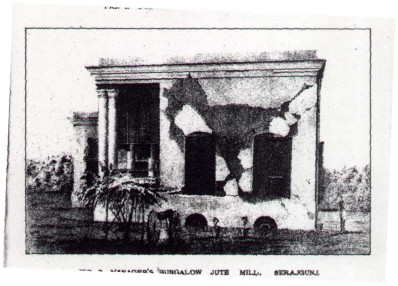

Figure 4: Damage at Sirajganj, 1897 Earthquake

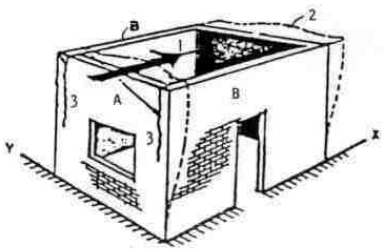

Figure 5: elevation of typical building

Figure 6: Damage due to 2003 Rangamati Earhquake

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Brick, cement mortar		1:4 (cement: sand)	
Foundation	Brick, cement mortar		1:4 (cement: sand)	
Frames (beams & columns)				
Roof and floor(s)				

6.2 Builder

The house owners hire masons to build these houses. Sometimes masons live in similar houses.

6.3 Construction Process, Problems and Phasing

- trench line is planned - excavate 2 to 3 ft deep trench - 6 inch thick sand layer - lay brick and use cement mortar to join them. 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. Sometimes new rooms are constructed for the extended family.

6.4 Design and Construction Expertise

No formal training. Masons are trained by their seniors. Owners are the architect and masons are the engineer for this

type of housing. They do not have a large role, but masons can be trained by the engineers according to the code guideline for construction.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. Bangladesh National Building Code. The year the first code/standard addressing this type of construction issued was 1993. BNBC 1993. Title of the code or standard: Bangladesh National Building Code. Year the first code/standard addressing this type of construction issued: 1993 National building code, material codes and seismic codes/standards: BNBC 1993.

There is no enforcement of building codes for this type of construction.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and not authorized as per development control rules.

There are no guidelines for this type of housing. No prior approval is required. 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

Total project: US Dollar 50/sq m. The labor requirements for a typical house of about 30 to 50 sq.m are about 100 to 120 man-days.

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

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Inadequate wall resistance due to the absence of seismic provisions	Covering the wall with 1 ft wide seismic belt (steel wire mesh with cement mortar) at lintel level on both sides of the wall.

Strengthening of New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Foundations	Provision of strip foundation
Walls	Provision of RC ring beams at plinth, lintel etc. levels. Provision of vertical steel reinforcement bars at the wall corners and intersections.

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?

Proposed for the damaged buildings of 2003 Rangamati earthquake.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?

N/A.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?

N/A.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?

N/A.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?

N/A.

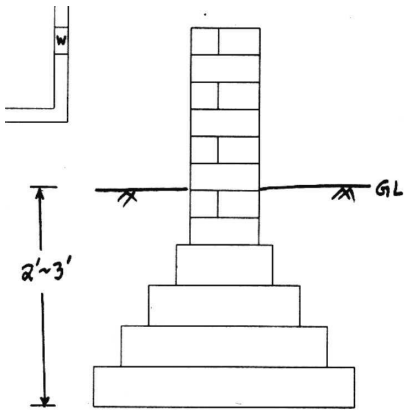

Figure 7: Typical foundation

Reference(s)

1. Seismic Risk of Five Selected Cities of Bangladesh
   Ansary,M.A.
   CARE-Bangladesh, BUET. February 2003

2. Bangladesh National Building Code, 1993

3. Guidelines for Earthquake Resistant Non-engineered Construction
IAEE

Author(s)

1. Mehedi Ansary
Doctor, Department of Civil Engineering, Bangladesh University of Engineering & Technology
Department of Civil Engineering, Bangladesh University of Engineering & Technology, Dhaka 1000, BANGLADESH
Email:ansaryma@yahoo.com FAX: 8802-8613026

Reviewer(s)

1. Alpa R. Sheth
Partner
, Vakil Mehta Sheth Consulting Engineers
Mumbai 400023, INDIA
Email:alpa_sheth@vsnl.com FAX: (91-22) 2284 3735