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
Unreinforced clay brick masonry house

Report #	24
Report Date	06-05-2002
Country	INDONESIA
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in lime/cement mortar
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Summary

Unreinforced clay brick masonry (UCB) housing construction is still often found in rural areas of Indonesia. This is a single-story building and the main load-bearing structure in these buildings consists of brick masonry walls built in cement mortar and a timber roof structure. This is non-engineered construction built following the traditional construction practice, without any input by architects or building experts. Builders follow a pattern by observing the

behavior of typical buildings in the surrounding area. Buildings of this type typically experience severe damage or collapse in the earthquakes in Indonesia.

1. General Information

Buildings of this construction type can be found in almost all rural areas in Indonesia. This type of housing construction is commonly found in rural areas. This construction type has been in practice for less than 75 years.

Currently, this type of construction is being built. .

Figure 1: Typical Building

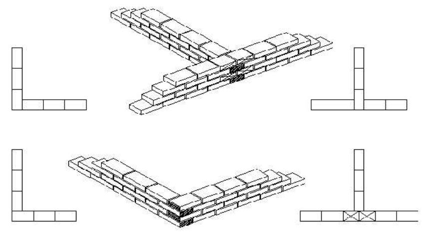

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

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

2.2 Building Configuration

The configuration of the building is typically regular and rectangular in plan. Unreinforced clay brick housings are usually facilitated with openings like main door, room doors and windows.

2.3 Functional Planning

Single family house and Multiple housing units. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. The building is usually single story and has a main entry door at the front building. Sometimes the main entry door is the only exit door in the building. Any additional door would be at the side or the rear of the building.

2.4 Modification to Building

Modification of the building often occurred in relation with the needs of additional rooms from the owner or the increased income of the owner. Additional rooms were done by extending to the side or the rear of the building.

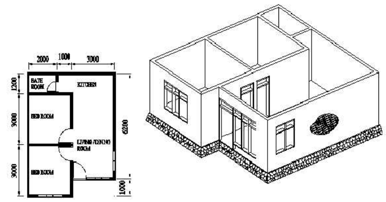

Figure 3: Plan of a Typical Building

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	☐
		24	Moment frame	☐

	Precast concrete	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. All clay brick walls are gravity load bearing structures. The timber roof rest directly on the walls without any special connection. All gravity load were transferred to the fieldstone strip footing.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is un-reinforced masonry walls. In order to resist lateral forces caused by earthquakes, UCB buildings relied on UCB walls which were interconnected at the corner of the walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 8 and 20 meters, and widths between 3 and 12 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 4 meters. Typical Story Height: Usually typical story height is 2.5-3 meters Typical Span: The distance between the clay brick masonry walls are range from 3 m to 5 m. The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 20 %. Around 0.150.

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	☐

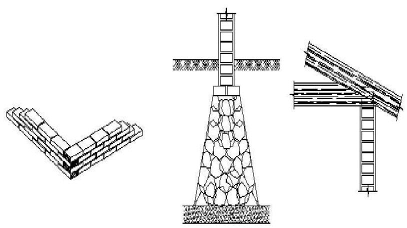

Figure 4: Critical Structural Details: wall section, foundations, and roof-wall connection

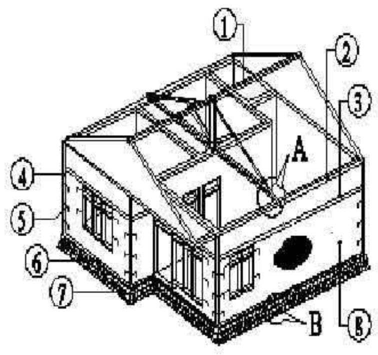

Figure 5A: Key Seismic Features (1 - light roof, 2 - roof band, 3 - lintel band, 4 - practical column in every corner (timber or reinforced concrete), 5 - connecting ties of steel, 6 - tie-beam, 7 - stable foundation); Sources: Boen and IAEE

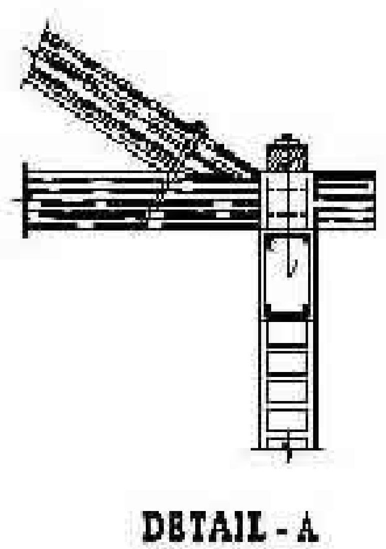

Figure 5B: The recommended connection between timber roof structure and roof band

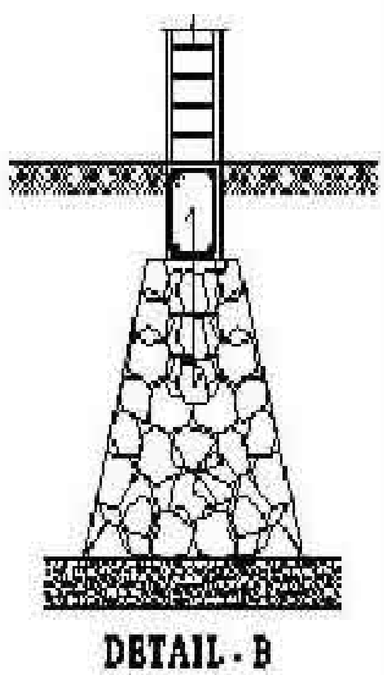

Figure 5C: The recommended connection between foundation and tie beam

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

Usually one house occupied by one family and sometime one big family grandfather until son and grandchildren.

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)	☐

Economic Level: For Poor Class the Housing Unit Price is 30 and the Annual Income is 1.

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) including toilet(s).

Generally each house is equipped with one bathroom facility. Sometimes in high density population area , several houses has a common area for bath and wash purposes equipped with well and bathrooms. .

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	☐	☐	☑
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	1. Clay-brick with very low compressive strength 2. The quality of clay-brick varies depends on the local clay-soil material 3. The clay-brick material is very brittle and doesn't have any ductility.		Shear crack, flexure crack or combination of both in clay brick walls.
Frame (columns, beams)			
Roof and floors	Timber truss system for roofing without any special connection with the clay brick walls.		The roof sliding off from the clay brick walls.

Typical damage features on non-engineered buildings : 1. Failure on corners of the walls and the openings like doors and windows. 2. Roof structure was usually sliding off from its base 3. Diagonal cracks on the clay-brick walls 4. Fail in connection between: - foundation and walls, - walls and walls, - walls and roof structure. 5. low construction quality (the quality of building material and labor).

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**
2000	Hypocenter 4.7 degree South line and 102.05 degree East line with 33 km depth and 100 km from Bengkulu city	7.3	V-VI MMI

Indonesia lies on seismic prone area, since March 1997, there were several earthquakes happened in Indonesia such as : - On March 17, 1997, a 6.0 Richter Scale earthquake struck west part area in Java Island. The epicenter (7.47 South latitude dan 104.66 East longitudinal) was about 300 km in South-West direction from Jakarta capital city, the exact location was at 33 km depth in Hindia Ocean. - On December 21, 1999 at 21:14:59 (Indonesian Time), a 6.0 Richter Scale earthquake struck west part area in Java Island. The epicenter (7.21 South latitude dan 105.64 East longitudinal) was about 200 km in South-West direction from Jakarta the capital city, the exact location was at Hindia Ocean. - On June 4, 2000 at 23:28:24.4 (Indonesian Time) or 16:28:24 GMT, a 7.3 Richter Scale earthquake struck Bengkulu Province in Sumatera Island of Indonesia. The epicenter (4,70 South latitude dan 102,00 East longitudinal) was in Hindia Ocean about 100 km from Bengkulu city. This is a big earthquake in early year 2000, with following after shock above 5.6 Ms in several days. The earthquake has caused material damage of about 250 - 300 billion Rupiahs, 103 deaths and up to 2,600 injured people. This earthquake has demolished the transportation system and public services building. Majority of damages occurred in resident housing area (UCB-housing). - On July 12, 2000 at 08:30 (Indonesian Time) , a 5.1 Richter Scale earthquake Sukabumi areas - West Java.

Figure 6A: A photograph Illustrating Typical Earthquake Damage (June 4, 2000 Bengkulu Earthquake)

Figure 6B: Typcial Earthquake Damage (June 4, 2000 Bengkulu Earthquake)

Figure 6C: Unreinforced Brick Masonry Building totally collapsed in the June 4, 2000 Bengkulu Earthquake)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Clay bricks.	2MPa - 6 MPa	w x l x t = 90 mm X 190 mm X 42 mm	1. Very low compressive strength 2. The quality of clay-brick varies depends on the local clay-soil material 3. The clay-brick is very brittle and doesn't have any ductility
Foundation	Rubble stone, fieldstone in strip footing.	around 3 MPa		
Frames (beams & columns)	Not available			
Roof and floor(s)	Timber truss system without any special connection with the clay brick walls.	low class <1.50 MPa.		

6.2 Builder

Generally housings in rural area were constructed by local builder or the owner himself helped by the community. The community house was built for their own purpose and no speculation involved.

6.3 Construction Process, Problems and Phasing

The construction process usually carried out by local semi-skilled labor. Foundation digging was done manually using hoe and material field-stone can be found from surrounding river area if any. Stone foundation was constructed using cement mortar. Clay brick was taken from local community production and the quality was varied. Half-Clay brick laying walls (Figure 2) stacked with cement mortar and usually the walls were covered by cement plaster as well. Timber roof structure was done manually at site area and covered by local roof-tile, corrugated roof metal or palm fiber roof. The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size.

6.4 Design and Construction Expertise

Construction was usually done by local labor without any special engineer skills. The construction skills were obtained from local community habit or information passed from one generation to the other. No supervision from architects or engineers had any roles towards the buildings. Occasionally final year university students organize a training on how to design and built Earthquake resistance housing using local material to the local community in rural areas.

6.5 Building Codes and Standards

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

Not any special code for this type of buildings.

6.6 Building Permits and Development Control Rules

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

Indonesia like other development countries experiences the fast cities development and lack of planning and even uncontrollable. A fast uncontrollable development and low level economic condition usually creates "informal" residence area which are beyond existing rules and laws and the interrelated institution have difficulties to control and have their eyes closed. These residence areas are actually prohibited or have no permits and vulnerable to earthquake. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s). Low income people only do the very necessary maintenance.

6.8 Construction Economics

Unit construction cost per m² is approximate US$ 60 to 75 (1 US$ = Rp. 10.000,- in year 2001). The price include the standard architectural finishing and electricity. About 10 - 15 people are involved in constructing this typical building. It takes about 3 - 4 months to construct the UCB housing.

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

It is rather difficult to convince the community to do seismic strengthening on the existing undamaged houses to the local community. One of the best ways is by disseminating recommended earthquake resistant construction to the local community under supervised an engineer by applying local material condition which are easy to obtain in the neighborhood. Recommended seismic strengthening provisions for the new construction of this type are illustrated in Figures 5A, 5B and 5C.

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.

8.3 Construction and Performance of Seismic Strengthening

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