

# World Housing Encyclopedia

*A Resource on Construction in Earthquake Regions*



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

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## HOUSING REPORT

### Unreinforced clay brick masonry house

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<b>Report#</b>	24
<b>Last Updated</b>	
<b>Country</b>	Indonesia
<b>Author(s)</b>	Sugeng WIJANTO,
<b>Reviewers</b>	Ravi Sinha ,

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### Important

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions & recommendations expressed herein are those of the various participants, and do not necessarily reflect the views of the Earthquake Engineering Research Institute, the International Association for Earthquake Engineering, the Engineering Information Foundation, John

## **General Information**

<b>Building Type:</b>	Unreinforced clay brick masonry house
<b>Country:</b>	Indonesia
<b>Author(s):</b>	Sugeng WIJANTO
<b>Last Updated:</b>	
<b>Regions Where Found:</b>	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.
<b>Summary:</b>	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 loadbearing 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 behaviour of typical buildings in the surrounding area. Buildings of this type typically experience severe damage or collapse in the earthquakes in Indonesia.
<b>Length of time practiced:</b>	51-75 years
<b>Still Practiced:</b>	Yes
<b>In practice as of:</b>	
<b>Building Occupancy:</b>	Single dwelling
<b>Typical number of stories:</b>	1
<b>Terrain-Flat:</b>	Typically
<b>Terrain-Sloped:</b>	3
<b>Comments:</b>	

## **Features**

<b>Plan Shape</b>	Rectangular, solid
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<b>Additional comments on plan shape</b>	The configuration of the building is typically regular and rectangular in plan.
<b>Typical plan length (meters)</b>	8-20
<b>Typical plan width (meters)</b>	3-12
<b>Typical story height (meters)</b>	2.5-3
<b>Type of Structural System</b>	Masonry: Unreinforced Masonry Walls: Brick masonry in lime/cement mortar
<b>Additional comments on structural system</b>	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. In order to resist lateral forces caused by earthquakes, UCB buildings relied on UCB walls which were interconnected at the corner of the walls.
<b>Gravity load-bearing &amp; lateral load-resisting systems</b>	
<b>Typical wall densities in direction 1</b>	15-20%
<b>Typical wall densities in direction 2</b>	15-20%
<b>Additional comments on typical wall densities</b>	The typical storey height in such buildings is 3 meters. The typical structural wall density is up to 20%. Around 0.150.
<b>Wall Openings</b>	Unreinforced clay brick housings are usually facilitated with openings like main door, room doors and windows.
<b>Is it typical for buildings of this type to have common walls with adjacent buildings?</b>	No
<b>Modifications of buildings</b>	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.
<b>Type of Foundation</b>	Shallow Foundation: Rubble stone, fieldstone strip footing

## Additional comments on foundation

**Type of Floor System**

Other floor system

## Additional comments on floor system

**Type of Roof System**

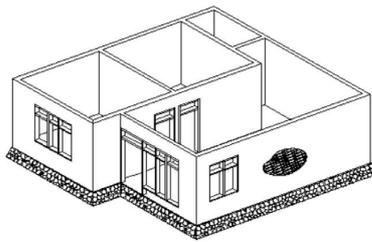
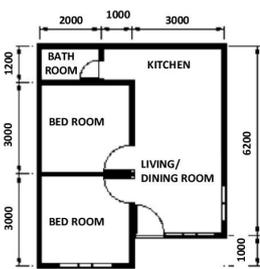
Roof system, other

## Additional comments on roof system

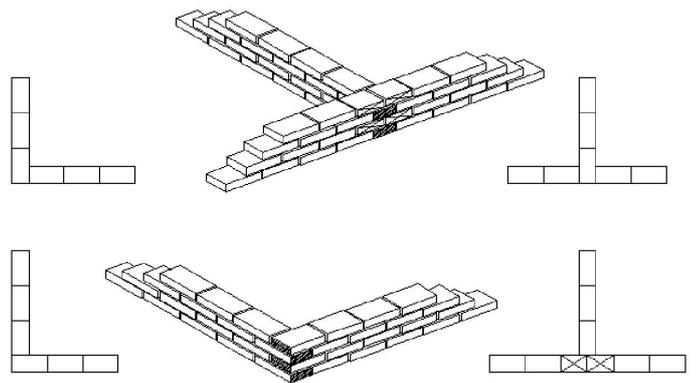
Wood planks or beams supporting naturalstones slates, Wood planks or beams that support slate,metal, asbestos-cement or plastic corrugatedsheets or tiles

## Additional comments section 2

Whenseparated from adjacent buildings, the typical distance from a neighboring building is several meters.



**Plan of a Typical Building**



**Key Load-Bearing Elements**

## Building Materials and Construction Process

### Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Clay bricks	2MPa - 6 MPa w x l x t = 90 mm x 190 mm x 42 mm1. very low compressive strength2. The quality of clay-brick varies depends on the local clay-soil material3. The clay-brick is very brittle and doesnt have any ductility

Foundations	Rubble stone, fieldstone in strip footing	around 3 MPa
Floors	Timber truss system without any special connection with the clay brick walls	low class <1.50 MPa
Roof	Timber truss system without any special connection with the clay brick walls	low class <1.50 MPa
Other		

## Design Process

<b>Who is involved with the design process?</b>	Other None of the above
<b>Roles of those involved in the design process</b>	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.
<b>Expertise of those involved in the design process</b>	

## Construction Process

<b>Who typically builds this construction type?</b>	Owner Builder Other
<b>Roles of those involved in the building process</b>	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.
<b>Expertise of those involved in building process</b>	Construction was usually done by local labour without any special engineer skills. The construction skills were obtained from local community habit or information passed from one generation to the other.

The construction process usually carried out by local semi-skilled labour. 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

## Construction process and phasing

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.

## Construction issues

## Building Codes and Standards

Is this construction type address by codes/standards?

No

Applicable codes or standards

Not any special code for this type of buildings.

Process for building code enforcement

## Building Permits and Development Control Rules

Are building permits required?

Yes

Is this typically informal construction?

Yes

Is this construction typically authorized as per development control rules?

No

Additional comments on building permits and development control rules

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 Maintenance and Condition

Typical problems associated with this type of construction

Who typically maintains buildings of this type?

Owner(s)

**Additional comments on maintenance and building condition**

Low income people only do the very necessary maintenance.

**Construction Economics**

**Unit construction cost**

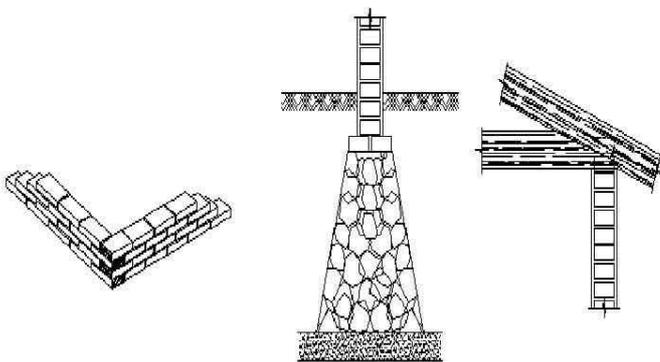
Unit construction cost per m<sup>2</sup> is approximate US\$ 60 to 75 (1 US\$ = Rp. 10.000,- in year 2001). The price include the standard architectural finishing and electricity.

**Labor requirements**

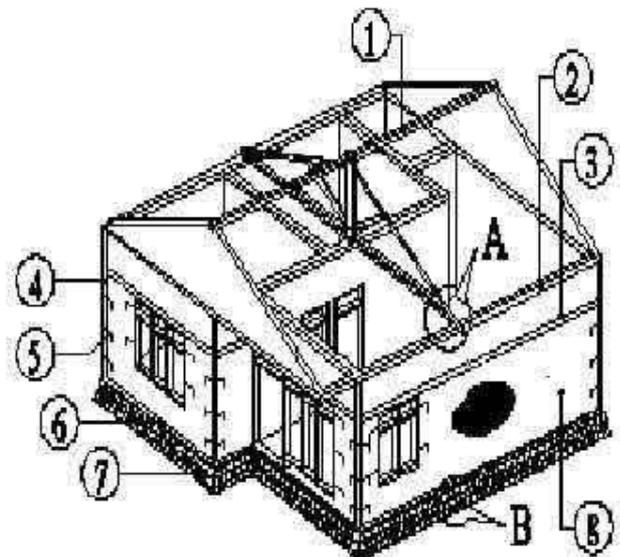
About 10-15 people are involved in constructing this typical building. It takes about 3-4 months to construct the UCB housing.

**Additional comments section 3**

Clay bricks are produced as mass production in every rural area in Indonesia and without any explicit standard. The quality of the clay bricks are varied depending on the local clay-soil condition used as the main ingredients. Nowadays common size of a brick is relatively small (length 190 mm, width 90 mm, thickness 42 mm) compare to the old bricks (Dutch colonial time, length 260 mm, width 120 mm, thickness 55 mm). Mix proportion for cement mortar is 1 cement : 5 to 7 sand. 2. 3. Tension/compression/shear strength (e.g. concrete compression strength, steel yield strength, masonry compressive/shear strength)

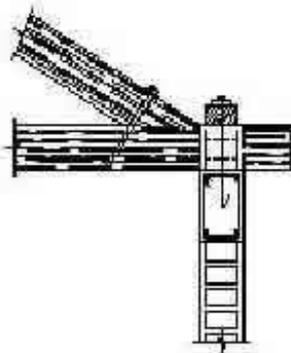


**Critical Structural Details: wall section, foundations, and roof-wall connection**



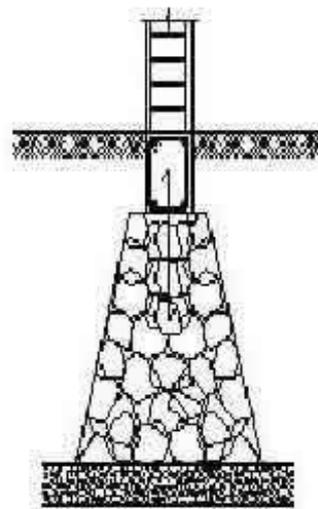
**Key Seismic Features (1 - light roof, 2 - roof band, 3 - lintel band, 4 - practical column in every corner)**

*(timber or reinforced concrete), 5 - connecting ties of steel, 6 - tie-beam, 7 - stable foundation); Sources: Boen and IAEE*



**DETAIL - A**

*The recommended connection between timber roof structure and roof band*



**DETAIL - B**

*The recommended connection between foundation and tie beam*

## Socio-Economic Issues

<b>Patterns of occupancy</b>	Usually one house occupied by one family and sometime one big family grandfather until son and grandchildren.
<b>Number of inhabitants in a typical building of this construction type during the day</b>	<5
<b>Number of inhabitants in a typical building of this construction type during the evening/night</b>	5-10
<b>Additional comments on number of inhabitants</b>	
<b>Economic level of inhabitants</b>	Low-income class (poor)
<b>Additional comments on economic level of inhabitants</b>	Ratio of housing unit price to annual income: 5:1 or worse
<b>Typical Source of</b>	

<b>Typical source of Financing</b>	Owner financed Personal savings
<b>Additional comments on financing</b>	
<b>Type of Ownership</b>	Rent Own outright
<b>Additional comments on ownership</b>	
<b>Is earthquake insurance for this construction type typically available?</b>	No
<b>What does earthquake insurance typically cover/cost</b>	
<b>Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?</b>	No
<b>Additional comments on premium discounts</b>	
<b>Additional comments section 4</b>	

## Earthquakes

### Past Earthquakes in the country which affected buildings of this type

<b>Year</b>	<b>Earthquake Epicenter</b>
2000	Hypocentre 4.7 degree South line and 102.05 degree East line with 33 km depth and 100 km from Bengkulu city
2006	Yogyakarta
2009	Tasikmalaya
2009	Padang

## Past Earthquakes

### Damage patterns observed in past earthquakes for this construction type

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. Failure in connection between: - foundation and walls, - walls and walls, - walls and roof structure. 5. low construction quality (the quality of building material and labor).

On May 27, 2006 at 5:54 am local time, a Mw 6.3 earthquake struck the island of Java, Indonesia, about 20 km from Yogyakarta. According to the U.S. Geological Survey, the epicenter of the earthquake was on-shore at latitude 7.962 and longitude 110.458, with a fairly shallow focal depth ( 10 km). The affected area is a densely populated mix of urban and rural communities on the southern slope of Mount Merapi, an active volcano. The latest casualty figures stand at 5,176 killed and over 40,000 injured. The total amount of damage and loss caused by this earthquake is estimated at US \$3.1 billion (CGI 2006). Most heavily damaged are single storey houses, which were built using unreinforced clay bricks as their bearing walls.

On Wednesday, September 2, 2009, at 2:55:00 pm (07:55:00 am UTC), a tectonic earthquake with a magnitude of 7.3 on the Richter Scale struck the south part of West Java. Based on the report of the Indonesia Meteorology & Geophysics Agency, the epicenter of the earthquake was at 142 km South-West of Tasikmalaya (8.24°E, 107.32°E) and its focus was found at a depth of 30 km below the sea level. The quake happened at the intersection between the Eurasian and Australian tectonic plates. It was followed by some smaller aftershocks. Nearer to the epicentrum, the residents of four districts in the south part of West Java, namely Tasikmalaya, Garut, Cianjur, and Cilacap were terrified by the shocks, which reached the intensity of V to VI MMI Scale. The inhabitants went out right away from their dwellings. More than 67,000 houses were reported as badly damaged while about 150,000 of dwelling units experienced light to medium impairment. Based on the latest report, there were 80 people died, 47 missing villagers, and 1142 injured inhabitants. Single storey houses, which were built using unreinforced clay bricks as their bearing walls, suffered severe damages.

On Wednesday September 30, 2009, at 5:16 p.m. local time (10:16:10 UTC), an Mw 7.6 earthquake at 0.7250S, 99.8560E struck the west coast of

Sumatra, depth 87 kilometers epicenter. It was affecting an area with a population of about 1.2M people, including 900,000 in Padang and 80,000 in Pariaman. Padang is the capital of West Sumatra, situated on the coast of the Indian Ocean between the Sumatra fault and the Sunda Trench fault. Single storey houses, which were built using unreinforced clay bricks as their bearing walls, suffered severe damages.

**Additional comments on earthquake damage patterns**

Shear crack, flexure crack or combination of both in clay brick walls. The roof sliding off from the clay brick walls.

**Structural and Architectural Features for Seismic Resistance**

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

The total width of door and window openings in a wall is: For brick masonry construction in cement mortar : less than 1/2 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.

<b>Structural/Architectural Feature</b>	<b>Statement</b>	<b>Seismic Resistance</b>
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.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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	FALSE

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.	N/A
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.	FALSE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
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);	FALSE
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doveled into the foundation.	N/A
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	N/A
Wall Openings		FALSE
Quality of Building Materials	Quality of building materials is considered to be adequate per the	FALSE

requirements of national codes and standards (an estimate).

Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	FALSE

## Building Irregularities

<b>Additional comments on structural and architectural features for seismic resistance</b>	
<b>Vertical irregularities typically found in this construction type</b>	Other
<b>Horizontal irregularities typically found in this construction type</b>	Other
<b>Seismic deficiency in walls</b>	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 doesnt have any ductility
<b>Earthquake-resilient features in walls</b>	
<b>Seismic deficiency in frames</b>	
<b>Earthquake-resilient features in frame</b>	
<b>Seismic deficiency in roof and floors</b>	Timber truss system for roofing without any special connection with the clay brick walls.
<b>Earthquake resilient features in roof and</b>	

<b>floors</b>	
<b>Seismic deficiency in foundation</b>	
<b>Earthquake-resilient features in foundation</b>	

### Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the [Seismic Vulnerability Guidelines](#)

	High vulnerability		Medium vulnerability		Low vulnerability	
	A	B	C	D	E	F
Seismic vulnerability class	-	o	-			



***A photograph illustrating Typical Earthquake Damage (June 4, 2000 Bengkulu Earthquake)***



***Typical Earthquake Damage (June 4, 2000 Bengkulu Earthquake)***



***Unreinforced Brick Masonry Building totally collapsed in the June 4, 2000 Bengkulu Earthquake)***



***Unreinforced brick masonry house with both in-plane and out of plane wall failures\_Padang Earthquake.***



***Unreinforced brick masonry house with both in-plane and out of plane wall failures\_Padang Earthquake.***



***Unreinforced brick masonry house with both in-plane and out of plane wall failures\_Tasikmalaya Earthquake.***



***Unreinforced brick masonry house with both in-plane and out of plane wall failures\_Tasikmalaya Earthquake.***



***Unreinforced brick masonry house with both in-plane and out of plane wall failures\_Yogyakarta Earthquake.***



***Unreinforced brick masonry house with both in-plane and out of plane wall failures\_Yogyakarta Earthquake.***

## **Retrofit Information**

### **Description of Seismic Strengthening Provisions**

<b>Structural Deficiency</b>	<b>Seismic Strengthening</b>

<p><b>Additional comments on seismic strengthening provisions</b></p>	<p>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 neighbourhood. Recommended seismic strengthening provisions for the new construction of this type are illustrated in Figures 5, 6 and 7.</p>
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<p><b>Has seismic strengthening described in the above table been performed?</b></p>	<p>No.</p>
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<p><b>Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?</b></p>	<p> </p>
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<p><b>Was the construction</b></p>	<p> </p>
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**inspected in the same manner as new construction?**

**Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?**

**What has been the performance of retrofitted buildings of this type in subsequent earthquakes?**

**Additional comments section 6**

## **References**

- Indonesian Earthquake Study, Volume 7 : Masonry Testing Beca Carter Hollings and Ferner Ltd 1981
- Manual of Earthquakes Resistant Building (Housing) In Indonesia Boen, T.105 p. 1978
- Guidelines for Earthquakes Resistant Non-Engineered Construction IAAE Committee Gakujutsu Bunken Fukyu-kai, Japan, 158 p 1986
- Guidelines for Earthquakes Resistant Non-Engineered Construction IAAE Committee Gakujutsu Bunken Fukyu-kai, Japan, 158 p 1986
- Evaluation of The Seismic Performance of A 1907's L-shaped Three Storey Unreinforced Masonry Building in Indonesia Wijanto, S. and Andriono, T. Proceeding of NZSEE Conference, Rotorua - New Zealand, pp. 103-110 1999
- Strengthening of A 1907's L-shaped Three Storey Unreinforced Masonry Building in Indonesia Wijanto, S., Andriono, T. and Satyarno, I. Proceeding 12th WCEE, Auckland 2000, Paper Number 1368 2000
- Bengkulu Earthquake 4th June 2001 Wijanto, S., Wreksoatmodjo, S., Hardy, L. and Pendellah, A. Journal of Civil Engineering Department, Trisakti University, Vol. 01, No. 1, Jakarta, 18 p (in progress) 2001

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