World Housing Encyclopedia Report

Country: Indonesia

Housing Type: Unreinforced clay brick masonry house

Contributors:
Sugeng Wijanto

Primary Reviewer:
Ravi Sinha

Created on: 6/5/2002
Last Modified: 7/2/2003

This encyclopedia contains information contributed by various earthquake engineering professionals around the world. All opinions, findings, conclusions, and 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 A. Martin & Associates, Inc. or the participants' organizations.

Table of Contents

1 General Information

1.1 Country
Indonesia

1.3 Housing Type
Unreinforced clay brick masonry house

1.4 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.

FIGURE 1: Typical Building

1.5 Typical Period of Practice for Buildings of This Construction Type

How long has this construction been practiced	
< 25 years	
< 50 years	
< 75 years	X
< 100 years	
< 200 years	
> 200 years	

Is this construction still being practiced?	Yes	No
	X	

1.6 Region(s) Where Used
Unreinforced clay brick housing can be found in almost all rural areas in Indonesia.

1.7 Urban vs. Rural Construction

Where is this construction commonly found?	
In urban areas	
In rural areas	X
In suburban areas	
Both in rural and urban areas	

2 Architectural Features

2.1 Openings

Unreinforced clay brick housings are usually facilitated with openings like main door, room doors and windows.

2.2 Siting

	Yes	No
Is this type of construction typically found on flat terrain?	X	
Is this type of construction typically found on sloped terrain? (hilly areas)		X
Is it typical for buildings of this type to have common walls with adjacent buildings?		

The typical separation distance between buildings is meters. meters

2.3 Building Configuration

The configuration of the building is typically regular and rectangular in plan.

2.4 Building Function

What is the main function for buildings of this type?	
Single family house	X
Multiple housing units	X
Mixed use (commercial ground floor, residential above)	
Other (explain below)	

2.5 Means of Escape

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.

2.6 Modification of Buildings

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.

3 Socio-Economic Issues

3.1 Patterns of Occupancy

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

3.2 Number of Housing Units in a Building

1 units in each building.

3.3 Average Number of Inhabitants in a Building

How many inhabitants reside in a typical building of this construction type?	During the day / business hours	During the evening / night
< 5	X	
5 to 10		X
10-20		
> 20		
Other		

3.4 Number of Bathrooms or Latrines per Housing Unit

Number of Bathrooms: 1
Number of Latrines: 1

Additional Comments: 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.

3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor		/
Poor	X	30/1
Middle Class		/
Rich		/

3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	X
Personal Savings	X
Informal Network: friends and relatives	
Small lending institutions/microfinance institutions	
Commercial banks / mortages	
Investment pools	
Combination (explain)	
Government-owned housing	
Other	

3.7 Ownership

Type of Ownership/Occupancy	
Rent	X
Own outright	X
Own with Debt (mortgage or other)	
Units owned individually (condominium)	
Owned by group or pool	
Long-term lease	
Other	

4 Structural Features

4.1 Lateral Load-Resisting System

In order to resist lateral forces caused by earthquakes, UCB buildings relied on UCB walls which were interconnected at the corner of the walls.

4.2 Gravity Load-Bearing Structure

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.

4.3 Type of Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	
Masonry	Stone masonry walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	
		2	Massive stone masonry (in lime or cement mortar)	
	Earthen walls	3	Mud walls	
		4	Mud walls with horizontal wood elements	
		5	Adobe block or brick walls	
		6	Rammed earth/Pise construction	
	Unreinforced brick masonry walls	7	Unreinforced brick masonry in mud or lime mortar	
		8	Unreinforced brick masonry in mud or lime mortar with vertical posts	
		9	Unreinforced brick masonry in cement or lime mortar (various floor/roof systems)	X
	Confined masonry	10	Confined brick/block masonry with concrete posts/tie columns and beams	
	Concrete block masonry walls	11	Unreinforced in lime or cement mortar (various floor/roof systems)	
		12	Reinforced in cement mortar (various floor/roof systems)	
		13	Large concrete block walls with concrete floors and roofs	
Concrete	Moment resisting frame	14	Designed for gravity loads only (predating seismic codes i.e. no seismic features)	
		15	Designed with seismic features (various ages)	
		16	Frame with unreinforced masonry infill walls	
		17	Flat slab structure	
		18	Precast frame structure	
		19	Frame with concrete shear walls-dual system	
		20	Precast prestressed frame with shear walls	
	Shear wall structure	21	Walls cast in-situ	
		22	Precast wall panel structure	
Steel	Moment resisting frame	23	With brick masonry partitions	
		24	With cast in-situ concrete walls	
		25	With lightweight partitions	
	Braced frame	26	Concentric	
		27	Eccentric	
Timber	Load-bearing timber frame	28	Thatch	
		29	Post and beam frame	
		30	Walls with bamboo/reed mesh and post (wattle and daub)	
		31	Wooden frame (with or without infill)	
		32	Stud wall frame with plywood/gypsum board sheathing	
		33	Wooden panel or log construction	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
	Other	35	Unreinforced brick masonry in cement mortar with plaster screed floor and timber roof structure	X

4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	
	Rubble stone (fieldstone) isolated footing	
	Rubble stone (fieldstone) strip footing	X
	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	
	Wood piles	
	Steel skin friction piles	
	Cast in place concrete piers	
	Caissons	
Other		

4.5 Type of Floor/Roof System

Material	Description of floor/roof system	Floor	Roof
Masonry	Vaulted		
	Composite masonry and concrete joist		
Structural Concrete	Solid slabs (cast in place or precast)		
	Cast in place waffle slabs		
	Cast in place flat slabs		
	Precast joist system		
	Precast hollow core slabs		
	Precast beams with concrete topping		
	Post-tensioned slabs		
Steel	Composite steel deck with concrete slab		
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 single roof		
	Wood planks or beams that support clay tiles		
	Wood planks or beams that support slate, metal asbestos-cement or plastic corrugated sheets or tiles		X
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls		
Other			

4.6 Typical Plan Dimensions

Length: 8 - 20 meters
Width: 8 - 20 meters

4.7 Typical Number of Stories

1

4.8 Typical Story Height

3.0 meters

Additional Comments: Usually typical story height is 2.5-3 meters

4.9 Typical Span

4 meters

Additional Comments: The distance between the clay brick masonry walls are range from 3 m to 5 m

4.10 Typical Wall Density

Around 0.150

4.11 General Applicability of Answers to Questions in Section 4

This contribution describes is not based on the case study of a particular building.

5 Evaluation of Seismic Performance and Seismic Vulnerability

5.1 Structural and Architectural Features: Seismic Resistance

Structural/ Architectural Feature	Statement	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 form the building to the foundation.		X	
Building configuration	The building is regular with regards to both the plan and the elevation.	X		
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.		X	
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.			X
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.		X	
Wall and frame structures- redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	X		
Wall proportions	Height-to-thickness ratio of the shear walls at each floor level is: 1) Less than 25 (concrete walls); 2)Less than 30 (reinforced masonry walls); 3) Less than 13 (unreinforced masonry walls).		X	
Foundation- wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.			X
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.			X
Wall openings	The total width of door and window openings in a wall is: 1) for brick masonry construction in cement mortar: less than 1/2 of the distance between the adjacent cross walls; 2) for adobe masonry, stone masonry and brick masonry in mud mortar: less than 1/3 of the distance between the adjacent cross walls; 3) for precast concrete wall structures: less than 3/4 of the length of a perimeter wall.		X	
Quality of building materials	Quality of building materials is considered to be adequate per requirements of national codes and standards (an estimate).		X	
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).		X	
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).		X	
Other				

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.

Additional Comments: 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 Seismic Vulnerability Rating

Vulnerability						
	High (Very Poor Seismic Performance) A	B	Medium C	D	E	Low (Excellent Seismic Performace) F
Seismic Vulnerability Class	<	0	>			

0 - probable value
< - lower bound
> - upper bound

6 Earthquake Damage Patterns

6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
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

Additional Comments: 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.

7 Building Materials and Construction Process

7.1 Description of 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
Foundations	Rubble stone, fieldstone in strip footing	around 3 MPa		
Frame	Not available			
Roof and floors	Timber truss system without any special connection with the clay brick walls	low class <1.50 MPa		

Notes:
1. 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.

7.2 Does the builder typically live in this construction type, or is it more typically built by developers or for speculation?

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.

7.3 Construction Process

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.

7.4 Design/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.

7.5 Building Codes and Standards

	Yes	No
Is this construction type addressed by codes/standards?		X

7.6 Role of Engineers and Architects

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.

7.7 Building Permits and Development Control Rules

	Yes	No
Building permits are required	X	
Informal construction	X	
Construction authorized per development control rules		X

Additional Comments: 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.

7.8 Phasing of Construction

	Yes	No
Construction takes place over time (incrementally)	X	
Building originally designed for its final constructed size	X	

7.9 Building Maintenance

Who typically maintains buildings of this type?	
Builder	
Owner(s)	X
Renter(s)	
No one	
Other	

Additional Comments: Low income people only do the very necessary maintenance.

7.10 Process for Building Code Enforcement

Not any special code for this type of buildings.

7.11 Typical Problems Associated with this Type of Construction

The main problem is how to explain to the low income community in rural areas that it is important to maintain or perhaps strengthen the houses and becoming a earthquake resistant housing.

8 Construction Economics

8.1 Unit Construction Cost (estimate)

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

8.2 Labor Requirements (estimate)

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

9 Insurance

9.1 Insurance Issues

	Yes	No
Earthquake insurance for this construction type is typically available		X
Insurance premium discounts or higher coverages are available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features		X

9.2 If earthquake insurance is available, what does this insurance typically cover/cost?

10 Seismic Strengthening Technologies

10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used

Additional Comments: 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.

10.2 Has seismic strengthening described in the above table been performed in design practice, and if so, to what extent?

No.

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

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

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

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

11 References

Beca Carter Hollings and Ferner Ltd (1981), Indonesian Earthquake Study, Volume 7 : Masonry Testing

Boen, T. (1978), Manual of Earthquakes Resistant Building (Housing), In Indonesia, 105 p.

IAEE Committee (1986), Guidelines for Earthquakes Resistant Non-Engineered Construction, Gakujutsu Bunken Fukyu-kai, Japan, 158 p.

SII.0021-78 (1978), Quality and Testing Method of Solid Red Clay Brick, In Indonesia, Industrial Department.

Wijanto S. and Andriono T. (1999), Evaluation of The Seismic Performance of A 1907's L-shaped Three Storey Unreinforced Masonry Building in Indonesia, Proceeding of NZSEE Conference, Rotorua - New Zealand, pp. 103-110

Wijanto S., Andriono T. and Satyarno I. (2000), Strengthening of A 1907's L-shaped Three Storey Unreinforced Masonry Building in Indonesia, Proceeding 12th WCEE, Auckland 2000, paper number 1368.

Wijanto S., Wreksoatmodjo, S., Hardy, L. and Pendellah, A. (2001), Bengkulu Earthquake 4th June 2001, Journal of Civil Engineering Department, Trisakti University, Vol. 01, No. 1, Jakarta, 18 p (in progress).

12 Contributors

Name	Sugeng Wijanto
Title	Senior Lecturer
Affiliation	Civil Engineering Dept. Trisakti University
Address	Jalan Kyai Tapa No. 1
City	Jakarta Barat
Zipcode	11440
Country	Indonesia
Phone	+62(21)-5663232
Fax	+62(21)-5673001
Email	gistama@cbn.net.id
Webpage	

13 Figures

FIGURE 1: Typical Building

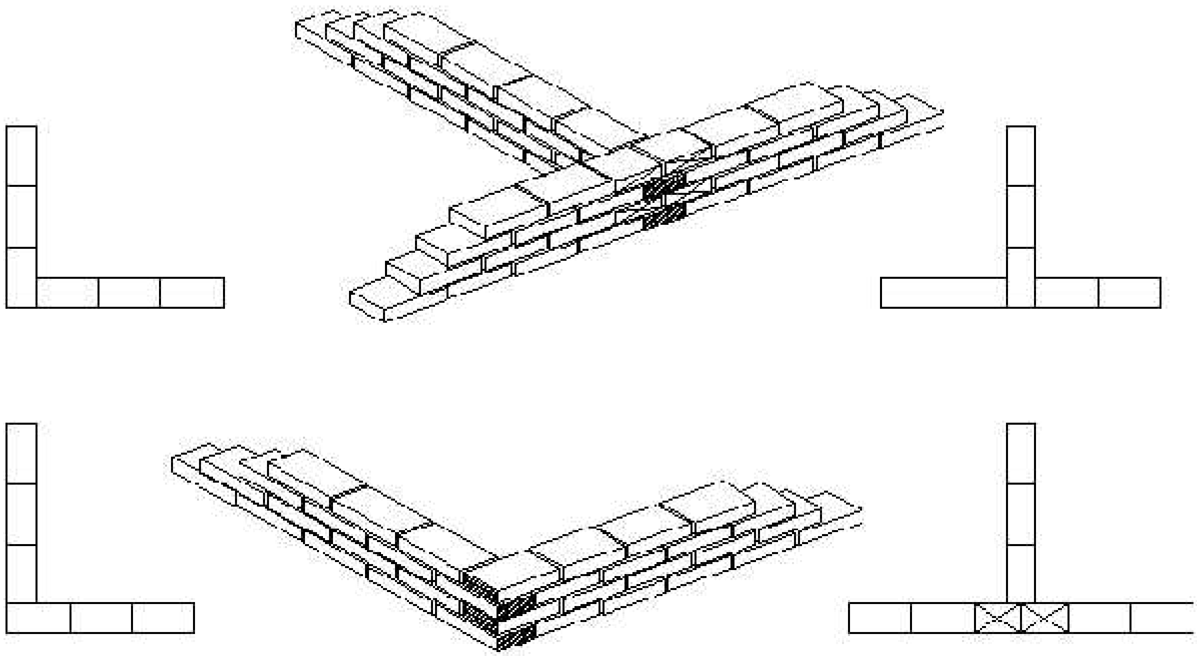

FIGURE 2: Key Load-Bearing Elements

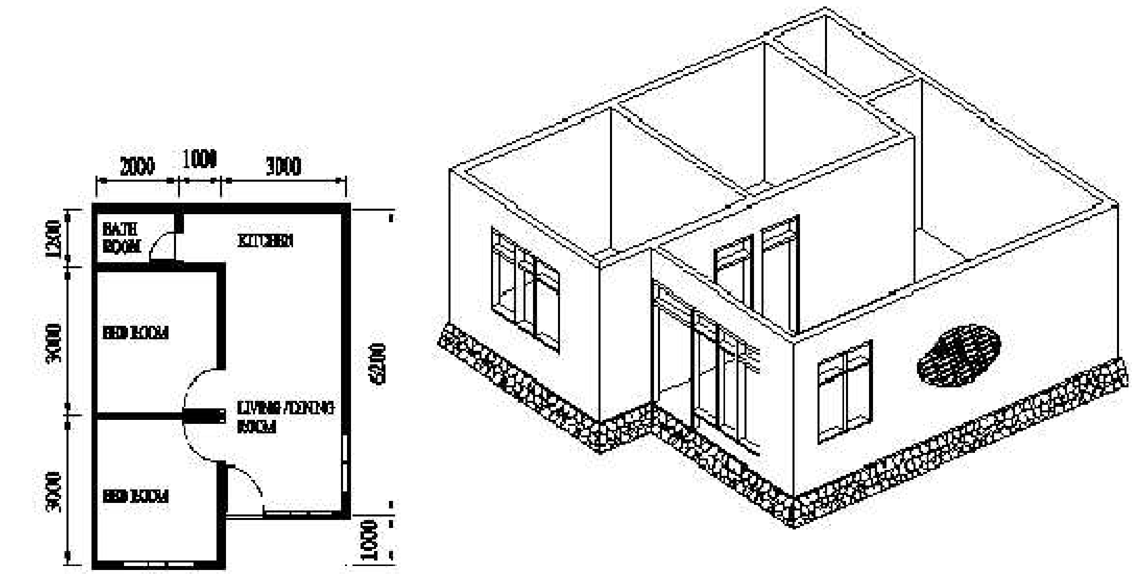

FIGURE 3: Plan of a Typical Building

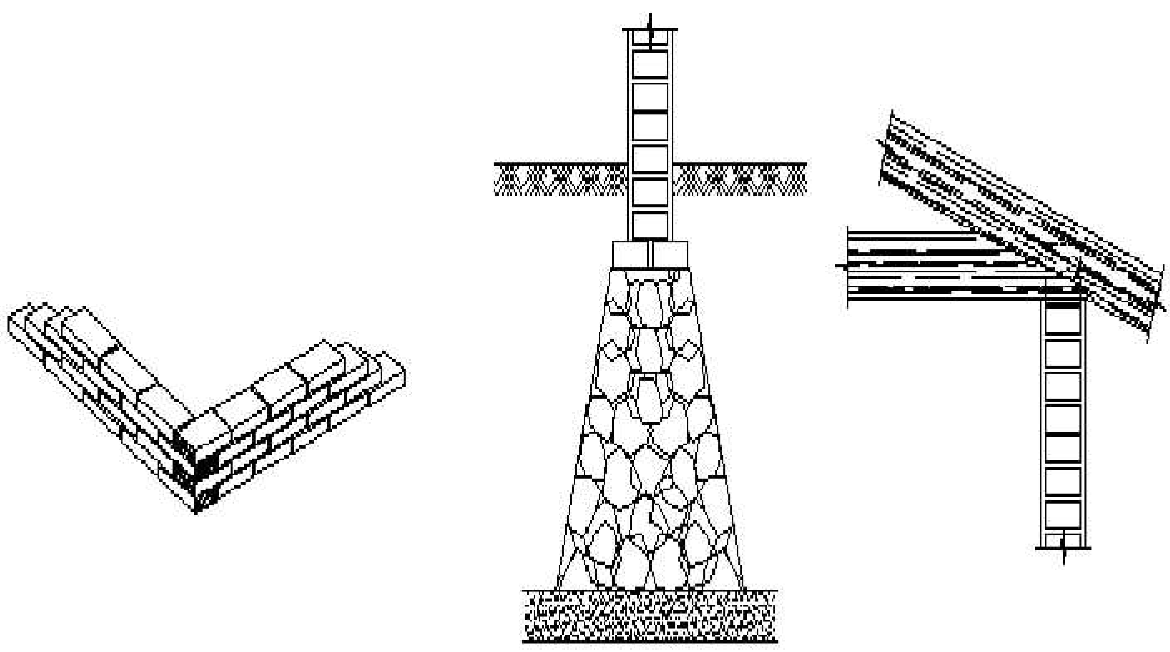

FIGURE 4: Critical Structural Details: wall section, foundations, and roof-wall connection

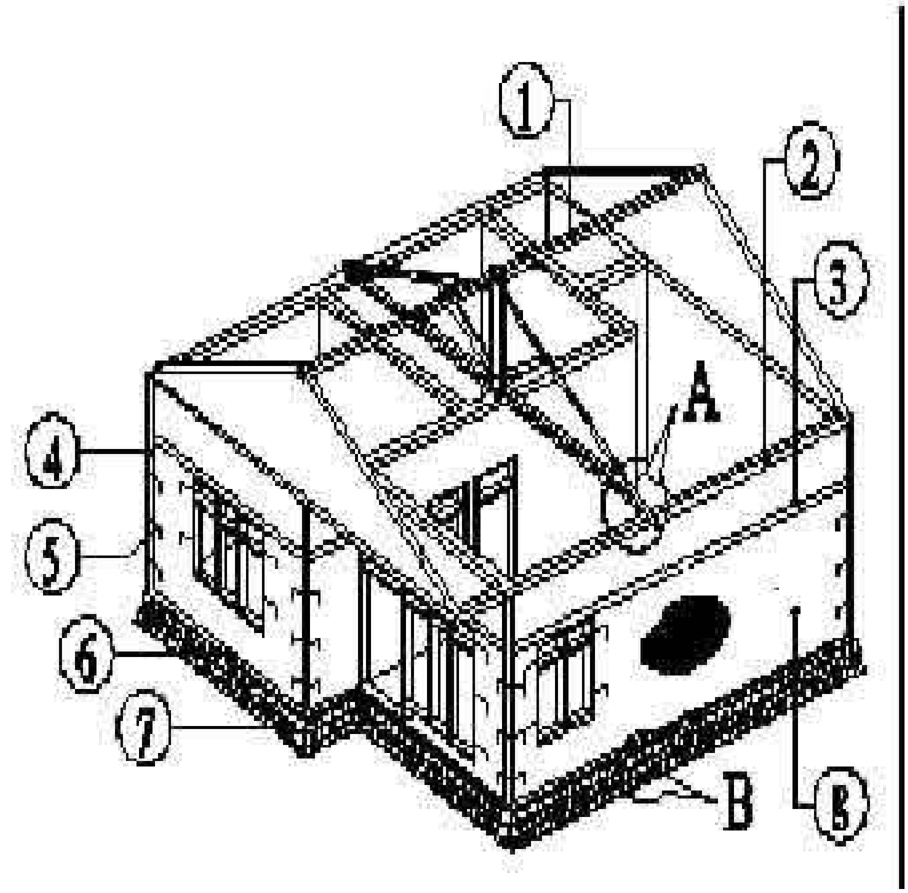

FIGURE 5A: Key Seismic Features (1 - light roof , 2 - roof band , 3 - lintel band , 4 - practical column in every corner (timber or reinforced concrete), 5 - connecting ties of steel , 6 - tie-beam, 7 - stable foundation); Sources: Boen and IAEE

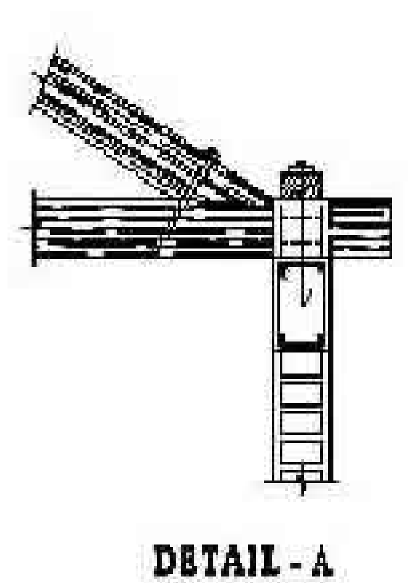

FIGURE 5B: The recommended connection between timber roof structure and roof band

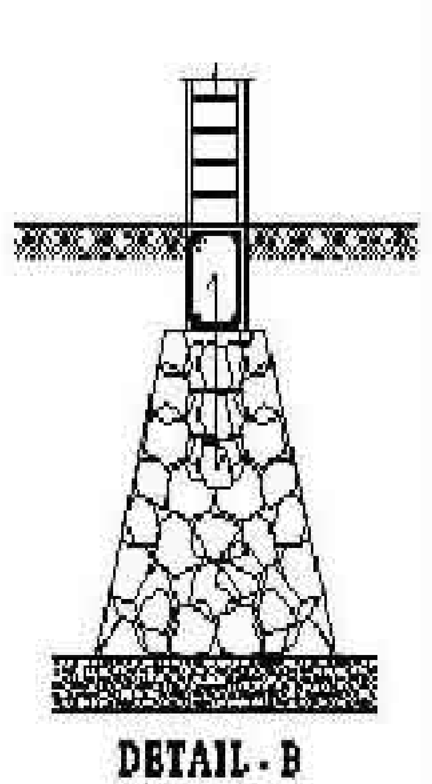

FIGURE 5C: The recommended connection between foundation and tie beam

FIGURE 6A: A Photograph Illustrating Typical Earthquake Damage (June 4, 2000 Bengkulu Earthquake)

FIGURE 6B: Typical Earthquake Damage (June 4, 2000 Bengkulu Earthquake)

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