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

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HOUSING REPORT
Adobe with timber and clay tile roof

Report #	134
Report Date	26-05-2007
Country	HONDURAS
Housing Type	Adobe / Earthen House
Housing Sub-Type	Adobe / Earthen House : Mud walls
Author(s)	Matthew A. French
Reviewer(s)	Andrew W. Charleson

Summary

Adobe is commonly used in Honduras predominantly in rural areas in the western regions. The performance of adobe buildings in seismic events has been very poor, but for many rural poor in Honduras, there is no other option but to use this construction method. The building has a simple plan with three rooms of equal size. The roof is sawn timber with clay tiles.

1. General Information

Buildings of this construction type can be found in western, central and southern Honduras. Due to climatic conditions adobe is seldom used in the 'mosquito region' on the northern and eastern coast. As with other countries in the region, adobe is not used extensively in the urban centres. Red fired brick is commonly used today. This type of housing construction is commonly found in rural areas.

There are existing adobe buildings in urban areas, but few new constructions.

This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built. There is preference to use more 'modern' materials - reinforced concrete and concrete block masonry due to a perceived the 'cheap and rural' status of adobe.

Figure 1: Exterior view of house from the street.

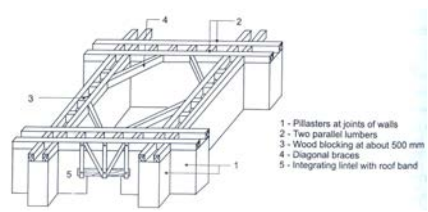

Figure 2: Recomended timber ring beam and lintel connection. IAEE Guidelines 2004, p72

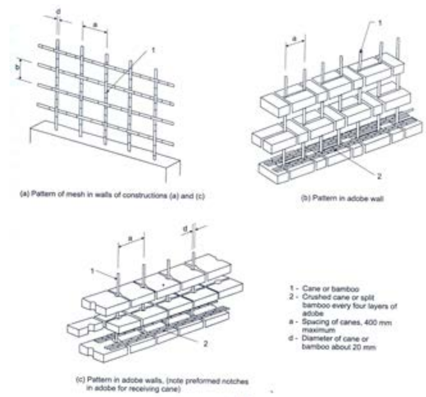

Figure 3: Reinforcement system utilising bamboo. IAEE Guidelines 2004, p.73.

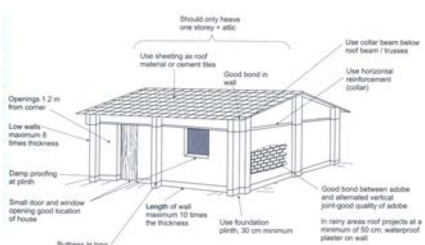

Figure 4: 'Improved Adobe' features which make adobe more earthquake resistant. IAEE Guidelines 2004, p.75.

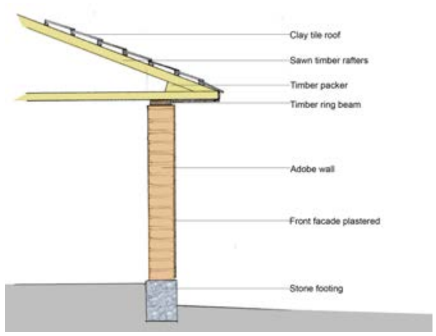

Figure 5: Wall section.

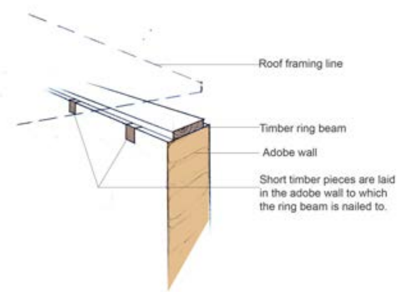

Figure 6: Timber ring beam connection to wall.

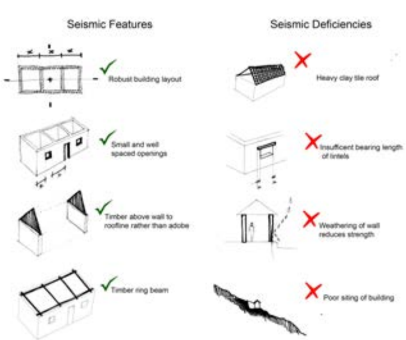

Figure 7: Key seismic features and deficiencies

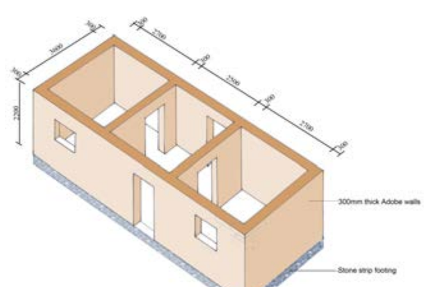

Figure 8: Loadbearing elements.

Figure 9: Roof framing and wall connection.


Figure 10: Lintel and wall connection.


Figure 11: Cooking area.


Figure 12: Side wall showing timber boards above wall and the weathering of the wall due to lack of plaster cover.

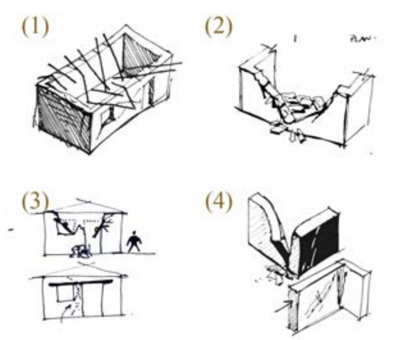

Figure 13: (1) Typically the roof collapses inwards due to reduced wall support and poor connections. The probability of this damage pattern occurring is increased when heavy roofing materials such as earth are used. (2) Wall collapse under face loads is a common earthquake damage pattern with adobe. This is especially true for long walls without mid-span buttresses. (3) Timber lintels above windows and doors typically fall due to insufficient wall support. When openings are too close together wall strength is compromised which increases the structures vulnerability to collapse by shear cracking. (4) Earthquake damage commonly occurs when building elements are not connected together adequately. Walls can separate at the corners due to poor bonding of the block courses in this area. Walls are also increasing vulnerable under seismic loads when rising moisture has eroded their base.

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 1 meters.

2.2 Building Configuration

The building is well configured. The rooms are square and symmetrically arranged around the central axis. The main house is composed of three rooms, one central living space and two bedrooms off either side of this. There are two small windows on the front elevation and an external door. Internally, there are three doors all opening from the central living space. In the cooking area to the rear of the house, the walls are not full height, and hence high openings are present there as well.

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 no fire-protected exit staircases. The front door is the only adequate means of escape. There are two very small front windows also.

2.4 Modification to Building

This case study demonstrates the way adobe is added to over time as the needs of the occupants grow. The rear of the house now contains a covered cooking area, formed by a large stone retaining wall and clay tile roof. This was added after the initial adobe hose was constructed. There is a wash area at the front of the dwelling, constructed from concrete block which was added at a later date. The timing of additions are predominantly financially dictated.

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	☐
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 earthen walls. The adobe walls act as the gravity load-bearing structure as well. The sawn timber roof rafters transfer loads to the sawn timber top plate. This in turn transfers to the walls, which take the load to the ground through compression.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). The 300 mm thick adobe walls act as shear walls in both longitudinal and transverse directions. The stone retaining wall at the rear acts in shear in the longitudinal direction. The roof is a flexible diaphragm, supported directly on the walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 4 and 6 meters, and widths between 3 and 4 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 4 meters. Typical Number of Stories: Adobe is seldom used to build more than one story in Honduras. Typical Story Height: Story height can vary between 2.0-2.7m. The typical storey height in such buildings is 2.2 meters. The typical structural wall density is none. Wall density is unknown.

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	☑	☑

Compacted earth.

3.6 Foundation

Type	Description	Most appropriate type
	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☑

Shallow foundation	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	☐

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 less than 5.

4.2 Patterns of Occupancy

One extended family lives in this house. During the day, only the women occupy the house, with full occupancy during the evening.

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)	☐

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 no bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is renting and ownership with debt (mortgage or other).

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	The adobe walls have little tension resistance under seismic loads. The lintels above the doors and windows are not adequately connected back to the walls resulting in exit points being blocked by their fall, and leading to progressive roof collapse.		The walls will crack in shear from lateral in-plane loads, or will fall in due to face loads. In both cases roof collapse will follow due to loss of support.
Frame (Columns, beams)			
Roof and floors	Ther roof is poorly connected to the walls and these poor connections suggest that the roof cannot be counted on to act as a rigid diaphragm, but does act as a timber bond beam.		The roof collapses inwards due to lack of wall support and poor connections.
Other			

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
1951	13.000N, 87.800W	6.5	
1982	14.487N, 89.121W	5.1	

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Adobe	3-4 MPa standard block strength. Stabilised blocks up to 8 MPa. Final block strength depends on mix. consistency when forming blocks.	Clay 10%-30% Silt 0%-20% Sand 50%-70% Straw to bind	The mix changes with site conditions, material availability and builder preference.
Foundation	Stone and mortar		Field stones and mud	Foundation types vary widely.
Frames (beams & columns)				
Roof and floor(s)	Roof: Sawn timber with clay tiles Floor: Compacted earth.		Roof: 120mm X 45mm sawn timber rafters with clay tile roof Floor: 5-10% chopped straw to bind earth	Floor: Re-laid/ re-levelled as required

6.2 Builder

Yes, the home was built by the occupants and this is typical.

6.3 Construction Process, Problems and Phasing

The site is cleared. The mud brick ingredients (sand, clay and straw) are mixed and placed in a wet timber mould. This mix is compacted and turned out to dry. After four weeks, and several rotations of the drying block, the block is ready for final placement within the wall. While the blocks are drying, the site is further prepared. The wall is constructed by simply laying one block on another with mud mortar between each course until the desired height is reached. The timber roof framing is laid and the clay tiles applied. In this case study, as mentioned, the cooking and store area at the back were added after initial construction of the adobe house. The wall was constructed from locally available stones and cement mortar. The roof was added to connect up to the existing gutter. The wash area was added later. Here, it was necessary to use concrete block as adobe performs poorly under exposure to water and moisture. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. Typically an initial 'base house' is built and as the family grows or finances permit, additions take place.

6.4 Design and Construction Expertise

No formally trained people worked on site. Seldom is an engineer or architect involved in adobe construction.

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.

Rural adobe construction is a informal activity. In urban areas, adobe is not commonly used. 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

US$ 20 /m2. Typically, adobe dwellings take between 1-3 months to construct. The bricks alone must be left for 3-4 weeks to dry in the sun. As there are many people on site - family, friends & community helpers - adobe is a relatively quick and informal construction method.

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 New Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Walls: Adobe has limited tension resistance. Inadequate connections to return walls, poor lintel embedment, and lack of face load strength for long walls reduces strength.	1. Bamboo: Several researchers have been involved with using internal horizontal and vertical bamboo, in a similar fashion to reinforced concrete masonry walls. 2. Timber ring beam: This helps to hold the walls together and facilitate transfer of loads from the roof to the walls. 3. 'Improved Adobe' has long been promoted to make adobe buildings more robust under seismic activity. The 'system' does not utilise another material, but focuses on the design and planning of adobe buildings by limiting opening sizes, plan dimensions, wall lengths and heights, and roof weight.
Roof: Heavy clay tile roofs increase vulnerability	Galvanised sheet metal is now common and helps reduces high loads. For thermal and aesthetic reasons, however, clay tile continues to be used.

The bamboo strengthening scheme is not used in Honduras, but is presented in this report as an option for making Honduran buildings safer.

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?
Bamboo: Yes, it has been implemented in Peru with successful structural results but unsuccessful local adoption of the concept. Timber ring beam: These are common now but often limited finances ensure they are out of reach for many in Honduras. 'Improved Adobe': Some of the principles, such as small openings and walls, are used but others such as buttresses are not evident.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
No mitigation effort was undertaken in Honduras.

8.3 Construction and Performance of Seismic Strengthening

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
The bamboo system was not constructed in the same manner as new construction, with technical assitance by academics and students used in their implmentation. Timber ring beams are often used in new construction by owners.

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Author(s)

1. Matthew A. French, Architecture, Victoria University of Wellington
15 Landcross Street, Wellington 4001, NEW ZEALAND
Email:emailformatthew@hotmail.com

Reviewer(s)

1. Andrew W. Charleson
Associate Professor
School of Architecture, Victoria University of Wellington
Wellington 6001, NEW ZEALAND
Email:andrew.charleson@vuw.ac.nz