World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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

HOUSING REPORT

Adobe / Earthen House : Mud walls

Report#	134
Last Updated	
Country	Honduras
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Important

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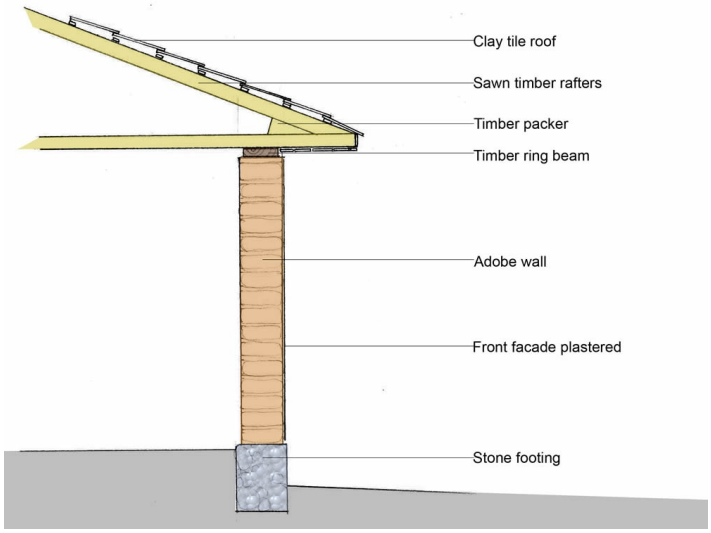
General Information

Building Type:	Adobe / Earthen House : Mud walls
Country:	Honduras
Author(s):	Matthew A. French
Last Updated:	
Regions Where Found:	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.
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.
Length of time practiced:	76-100 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	1
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	There are existing adobe buildings in urban areas, but few new constructions. Currently, this type of construction is being bu

Features

Plan Shape	Square, solid
Additional comments on plan shape	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.
Typical plan length (meters)	4-6
Typical plan width (meters)	3-4
Typical story height (meters)	2.0-2.7
Type of Structural System	Masonry: Earthen/Mud/Adobe/Rammed Earth Walls: Mud walls
Additional comments on structural system	Lateral load-resisting system: 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. Gravity load-bearing 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.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	Wall density is unknown.
Wall Openings	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.

Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	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.
Type of Foundation	Shallow Foundation: Rubble stone, fieldstone isolated footing
Additional comments on foundation	
Type of Floor System	Other floor system
Additional comments on floor system	Compacted earth.
Type of Roof System	Roof system, other
Additional comments on roof system	Sawn timber with clay tiles
Additional comments section 2	Typical separation distance between buildings: 1 meter



Wall section.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Adobe	Characteristic Strength- 3-4 MPa standard block strength. Stabilised blocks up to 8 MPa. Final block strength depends on mix. consistency when forming blocks. Mix Proportion/Dimensions- Clay 10%-30% Silt 0%-20% Sand 50%-70% Straw to bind The mix changes w ith site conditions, material availability and builder preference
Foundations	Stone and mortar	Mix Proportion/Dimensions: Field stones and mud Foundation types vary widely.
Floors	Compacted earth.	Mix Proportion/Dimensions: 5- 10% chopped straw to bind earth Re-laid/ re-levelled as required
Roof	Sawn timber with clay tiles	Mix Proportion/Dimensions: 120mm X 45mm sawn timber rafters with clay tile roof
Other		

Design Process

Who is involved with the design process?	Other
Roles of those involved in the design process	No formally trained people worked on site. Seldom is an engineer or architect involved in adobe construction.
Expertise of those involved in the design process	

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	The home was built by the occupants and this is typical
Expertise of those involved in building process	
Construction process 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.
Construction issues	Here, it was necessary to use concrete block as adobe performs poorly under exposure to water and moisture.

Building Codes and Standards

Is this construction type address by codes/standards?	No
Applicable codes or standards	
Process for building code enforcement	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.

Building Permits and Development Control Rules

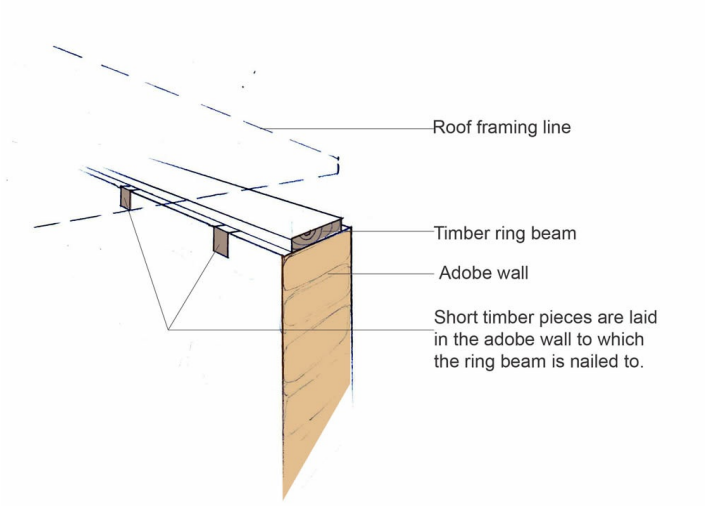
Are building permits required?	No
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	

Building Maintenance and Condition

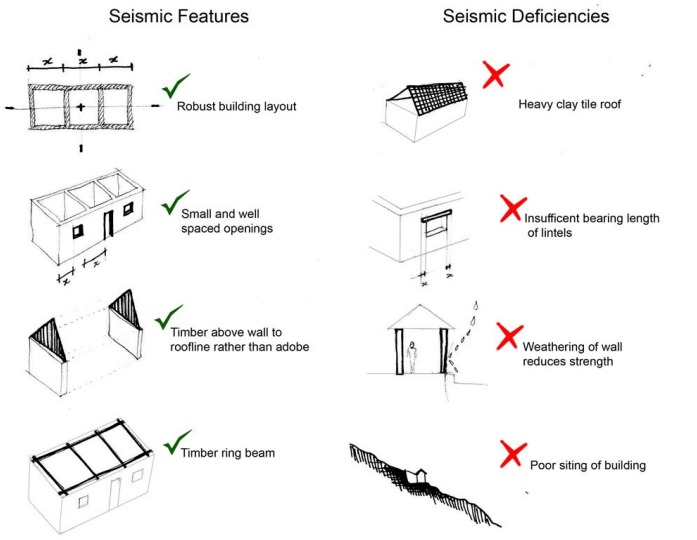
Typical problems associated with this type of construction	
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	

Construction Economics

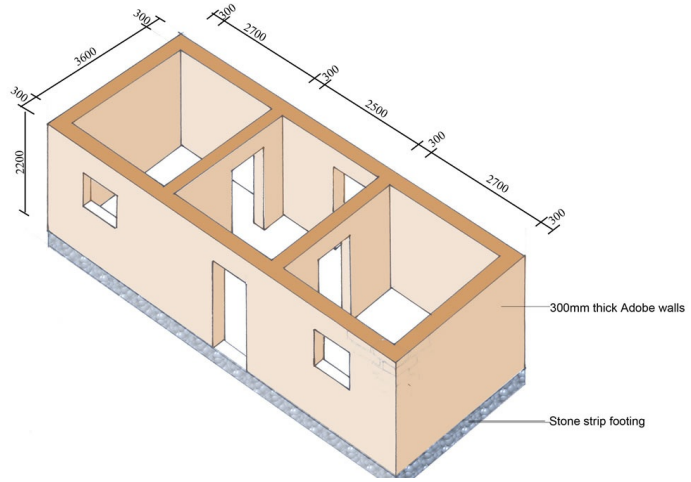
Unit construction cost	US$ 20 /m2.
Labor requirements	Typically, adobe dwellings take between 1-3 months to construct. The bricks alone must be left for 3-4 weeks to dry in the sun. As there are many people on site - family, friends & community helpers - adobe is a relatively quick and informal construction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



Timber ring beam connection to wall.



Key seismic features and deficiencies



Loadbearing elements.

Roof framing and wall connection.

Lintel and wall connection.

Socio-Economic Issues

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.
Number of inhabitants in a typical building of this construction type during the day	<5
Number of inhabitants in a typical building of this construction type during the evening/night	<5
Additional comments on number of inhabitants	
Economic level of inhabitants	Very low-income class (very poor)
Additional comments on economic level of inhabitants	House Price/Annual Income (Ratio) 1:1 or better
Typical Source of Financing	Personal savingsInformal network: friends or relatives
Additional comments on financing	
Type of Ownership	RentOwn with debt (mortgage or other)
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant features?	No
Additional comments on premium discounts	

Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1951	13.000N, 87.800W
1982	14.487N, 89.121W

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	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. The roof collapses inwards due to lack of wall support and poor connections.
Additional comments on earthquake damage patterns	

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 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.

Structural/Architectural Feature	Statement	Seismic Resistance
Lateral load path	The structure contains a complete load path for seismic force effects from any horizontal direction that serves to	FALSE

	transfer inertial forces from the building to the foundation.	
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 area.	FALSE
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);	TRUE

Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	FALSE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		TRUE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
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

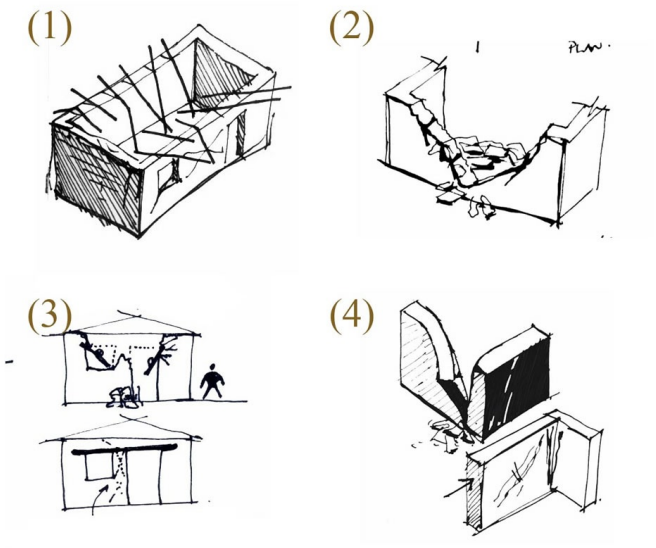
Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	No irregularities
Horizontal irregularities typically found in this	No irregularities

construction type	
Seismic deficiency in walls	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.
Earthquake-resilient features in walls	
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	The 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.
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

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					



(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 e

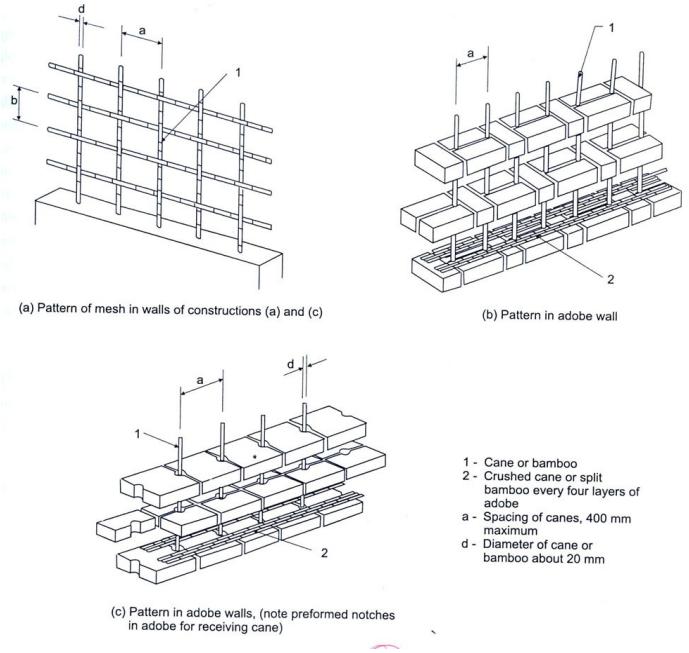
Retrofit Information

Description of Seismic Strengthening Provisions

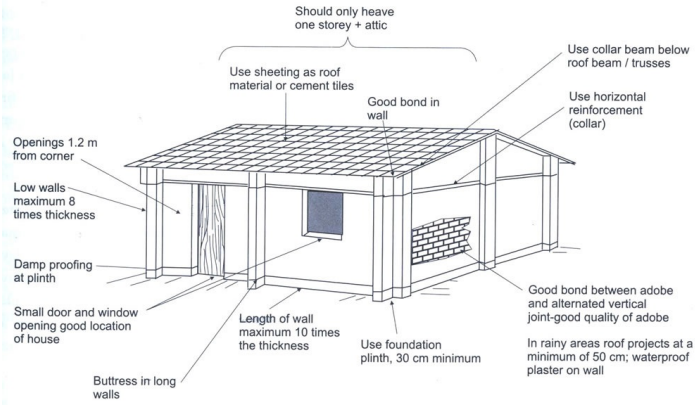
Structural Deficiency	Seismic Strengthening
Walls: Adobe has limited tension resistance. Inadequate connections to return walls, poor lintel embedment, and lack of face load strength for long walls reduces strength.	1. Bamboo: Several researchers have been involved with using internal horizontal and 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.

Additional comments on seismic strengthening provisions	The bamboo strengthening scheme is not used in Honduras, but is presented in this report as an option for making Honduran buildings safer.
Has seismic strengthening described in the above table been performed?	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 a repair following earthquake damages?	No mitigation effort was undertaken in Honduras.
Was the construction inspected in the same manner as new construction?	
Who performed the construction: 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 assistance by academics and students used in their implementation. Timber ring beams are often used in new construction by owners.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	
Additional comments section 6	



Reinforcement system utilising bamboo. IAEE Guidelines 2004, p.73.



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

References

Guidelines for earthquake resistant non-engineered construction IAEE National Information Center of Earthquake Engineering, IIT Kanpur, India 2004

Earthquake database search, www.ngdc.noaa.gov National Geophysical Data Centre, Date accessed: 15/3/2006

Adobe and rammed earth buildings: design and construction McHenry,P. John Wiley and Sons, Canada 1984

Building with earth: a handbook Norton,J. Intermediate Technology Group, Warw ickshire, UK 1986

An improved means of reinforcing adobe walls- external vertical reinforcementDow ling,D., Samali,B. & Jianchun,L. Sismo Adobe, Lima, Peru 2005

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