World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT

Adobe with sawn timber roof framing and corrugated iron sheeting

Report#	136
Last Updated	
Country	Guatemala
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Important

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General Information

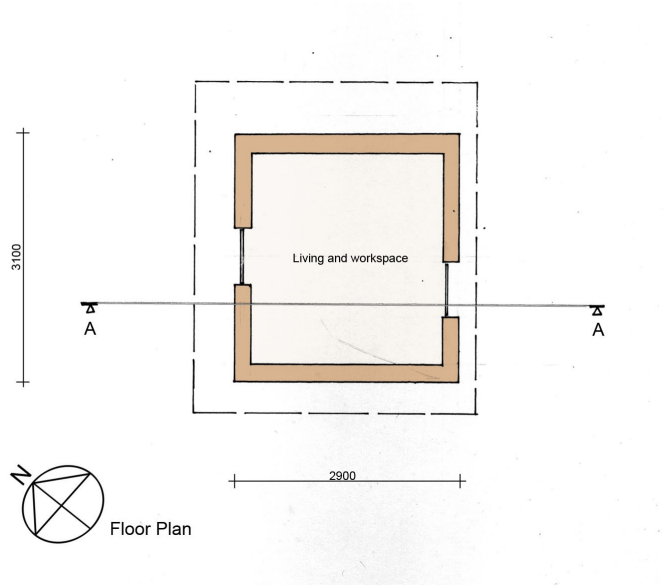
Building Type:	Adobe with sawn timber roof framing and corrugated iron sheeting
Country:	Guatemala
Author(s):	Matthew A. French
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in Guatemala, mostly in the highlands. The traditional construction is bajareque, which is similar to Wattle and Daube. Vertical and horizontal timber poles hold a core of stone and/or mud, and the outside is plastered with mud mix. Adobe use in urban areas is less prevalent than it has been historically. There are some historic towns, such as Antigua, which are almost completely composed of adobe dwellings relying on this romanticized past of adobe architecture to draw tourists. This type of housing construction is commonly found in both rural and urban areas. As noted, there is a large existing building stock of adobe in urban centres, but few new buildings. The exception to this is in Guatemala city, where 'satellite settlements' on the urban fringe use adobe for economic reasons. Thin reinforced concrete frames with red fired brick infill walls is the emerging preferred method in these urban centres.
Summary:	This very small building doubles as a home and workplace. The homeowner weaves products such as hats, clothes and mats for a living. The building functions as a showroom for her products by the day and as her house for rest at night. Three months before the site visit, the house was washed away by Hurricane Stan that hit the Central American region. Massive rainfall led to landslides in the Lago Antilian area, where the site is located. Her house was destroyed and this is the new one constructed. This case study is characteristic of new adobe construction in the Guatemala today. Timber dowels at the top brick course help to secure the ring beam or timber roof framing to the walls. For economic reasons, the roof is corrugated iron, but the long-term plan is to place clay tiles directly over

	top for their thermal and aesthetic properties. This case study is testament to the trying and tenuous living conditions which the occupants face. It demonstrates that even though un-reinforced adobe fails, many have no option but to replace it with structurally fragile adobe once more.
Length of time practiced:	More than 200 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Mixed residential/commercial
Typical number of stories:	1
Terrain-Flat:	Typically
Terrain-Sloped:	Off
Comments:	Currently, this type of construction is being built. In the Solola district, adobe is commonly used still, because the transport

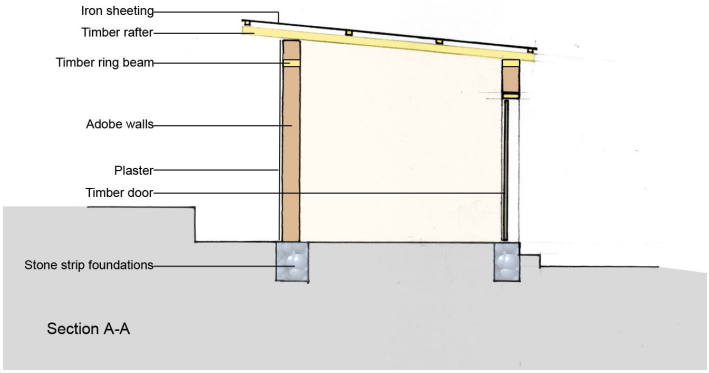
Features

Plan Shape	Square, solid
Additional comments on plan shape	The building is well configured with respect to its plan geometry and symmetry; it is simply one square room. The building has two doors, 700mmx1800mm. There are no windows.
Typical plan length (meters)	3.1-6
Typical plan width (meters)	2.9-6
Typical story height (meters)	2.2
Type of Structural System	Masonry: Earthen/Mud/Adobe/Rammed Earth Walls: Rammed earth/pile construction
Additional comments on structural system	Lateral load-resisting system: Adobe shear walls act as the lateral resisting structure in both directions. The blocks measure 200mm wide, 400mm long and 100mm deep. The timber framed roof is a flexible diaphragm, and hence will play minimal role in resisting or transferring lateral loads. Gravity load-bearing system: The adobe walls also act as the gravity load bearing structure. Gravity loads are

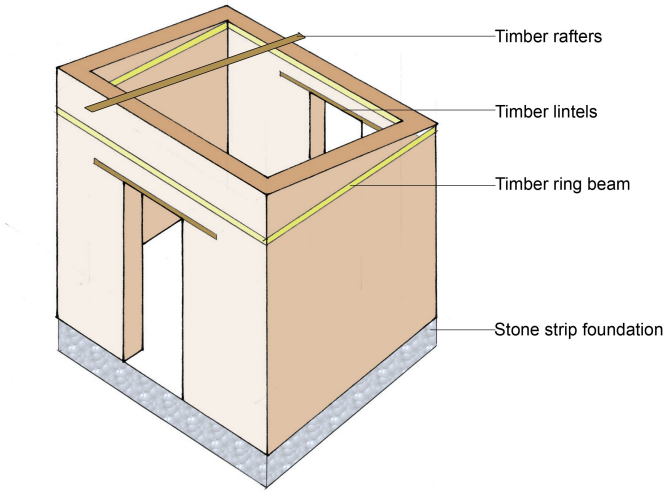
	transferred from the roof to the ring beam then to the wall and through to the ground.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	Wall density is unknown.
Wall Openings	The building has two doors, 700mmx1800mm. There are no windows.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	There are no structural modifications. The exterior plaster and clay roof tiles are added incrementally as funds permit. This will provide increased thermal comfort and aesthetic value. There are plans to build a timber addition on the east side.
Type of Foundation	Shallow Foundation: Rubble stone, fieldstone strip footing
Additional comments on foundation	
Type of Floor System	Metal beams, trusses, or joists supporting light flooring
Additional comments on floor system	Compacted earth and cement mix
Type of Roof System	Wooden roof, unknownRoof system, other
Additional comments on roof system	wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles
Additional comments section 2	Due to the limited availability of flat land in the area, the houses are constructed very close together. When separated from adjacent buildings, the typical distance from a neighboring building is 0.5 meters.



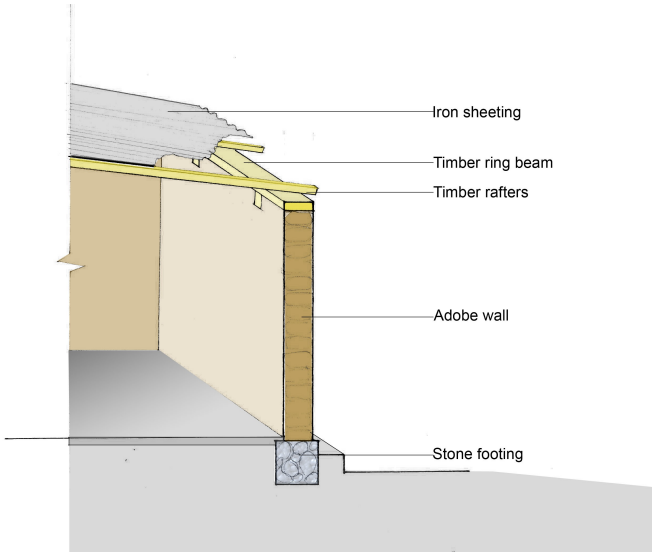
Floor Plan



Section A-A



Load bearing structure



Elements of the building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: Adobe blocks	Wall: Characteristic Strength- 3-4 MPa standard block strength. Stabilized blocks up to 8 MPa. Strength depends on mix consistency w hen forming blocks. Mix

		Proportion/Dimensions- Clay 30%-50% Silt 0%-20% Sand 50%-70% Straw to bind. Mix changes with site conditions, material availability and builder.
Foundations	Stone and cement strip footing	
Floors	Compacted earth and concrete topping	Mix Proportion/Dimensions: 10% concrete, 90% earth. Straw to bind. It is not a 'concrete slab' floor, but around 10% cement was added to a earth mix.
Roof	Timber with corrugated iron	Mix Proportion/Dimensions: Sawn 80mm X 40mm rafters
Other		

Design Process

Who is involved with the design process?	Other
Roles of those involved in the design process	The NGO's working in the area and help that has come to 'clean up' may have had some trained building staff. The likelihood is that no practising architect or engineer was involved in this building.
Expertise of those involved in the design process	Traditional knowledge and methods generated the design and construction. These people are not involved.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	
Expertise of those involved in building process	
Construction process and phasing	The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size. With adobe construction a 'base' house is built as one complete project and over time other rooms (not always of

	adobe) are added as needed.
Construction issues	

Building Codes and Standards

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

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?	BuilderOwner(s)
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	US $ 35/ m2.
Labor requirements	The house took two people two months to build.

Additional comments section 3	

Connection of roof framing to wall incorporating a timber ring beam.

Socio-Economic Issues

Patterns of occupancy	The building is occupied by a mother and two children. It functions as a home and workshop.
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 The owner relies on sales of woven products to tourists, hence is economically very vulnerable to fluctuations in the tourist market.
Typical Source of Financing	Personal savingsInformal network: friends or relativesSmall lending institutions/microfinance institutions

Additional comments on financing	
Type of Ownership	Own outrightOwn with debt (mortgage or other)
Additional comments on ownership	Non-Governmental Organisations (NGOs) played a large role in providing relief to this community after Hurricane Stan struck. The actual figures are not known, but micro-finance and small loans along with volunteer help have enabled rebuilding to occur.
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
1976	15.320N, 89.100W
1988	13.881N, 90.450W
1991	14.646N, 90.986W

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	Wall - 45# shear cracking under in-plane lateral loads occurs. This cracking increases vulnerability for wall collapse under face loads. Roof and floors - The roof fails to hold the top of the walls in place. Wall displacement becomes too large and dislodges roof support, which in turn leads to roof collapse.
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 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 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.	TRUE
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	FALSE

	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).	TRUE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	TRUE

Building Irregularities

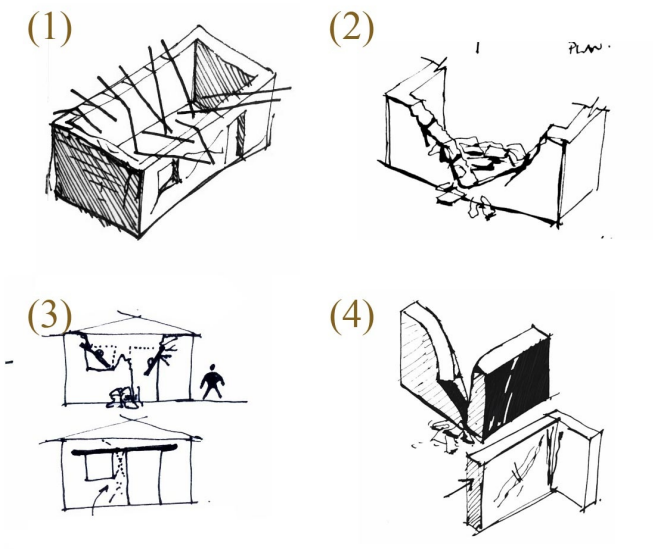
Additional comments on structural and architectural features for seismic resistance	This building is well maintained as it is new , but many others are not. The workmanship is very good. The blocks and mortar joints are even, course heights level and block mix consistent. This is to be commended.
Vertical irregularities typically found in this construction type	No irregularities
Horizontal irregularities typically found in this construction type	No irregularities
Seismic deficiency in walls	The adobe walls are too thin and brittle to resist lateral in plane and face loads. Adobe is strong in compression, but very weak in tension.
Earthquake-resilient features in walls	Lintels have suitable anchorage back into the walls.
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	The roof is too flexible and insufficiently connected to the walls to enable it to work as a rigid diaphragm
Earthquake resilient features in roof and	The roof is light- weight minimizing risk of injury

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 ea

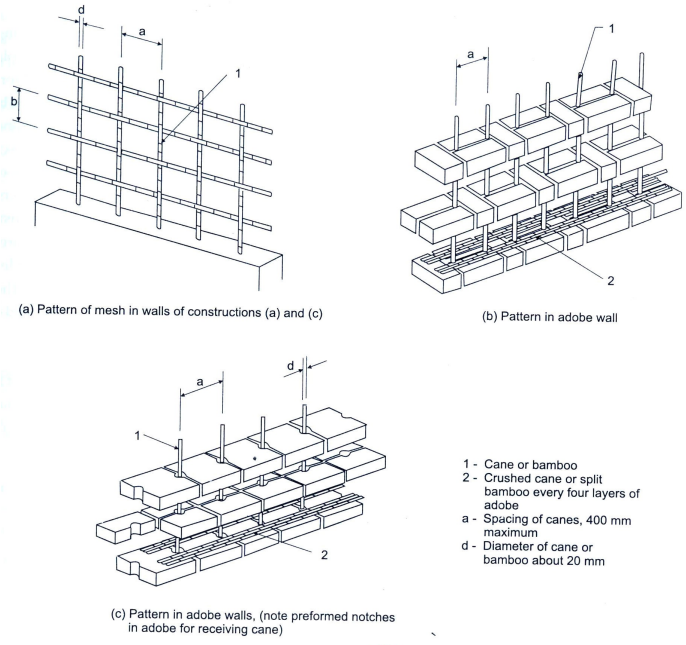
Retrofit Information

Description of Seismic Strengthening Provisions

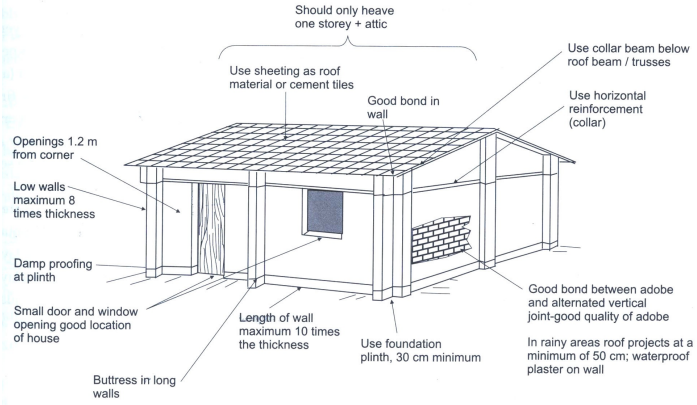
Structural Deficiency	Seismic Strengthening
Wall: Adobe as a material has limited tension strength. Inadequate connections to return walls and lack of face load strength for long walls reduces strength	1. Bamboo: Several researchers have been using internal horizontal and vertical bamboo, in a similar 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: The roof will not work as a diaphragm to help transfer lateral loads to the ground.	A timber ring beam helps to hold the walls together and prevent them falling inwards. Galvanized sheet metal as is used here reduced roof loads, which minimizes injury, if collapse occurs.

Additional comments on seismic strengthening provisions	The bamboo strengthening scheme is not used in Guatemala, but is presented in this report as an option for making adobe buildings safer generally.
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. The system is not used in Guatemala. Timber ring beam: These are common now, but often limited finances ensure they are out of reach for many in Guatemala. '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?	All work was done as part of mitigation efforts.
Was the construction inspected in the same manner as new construction?	

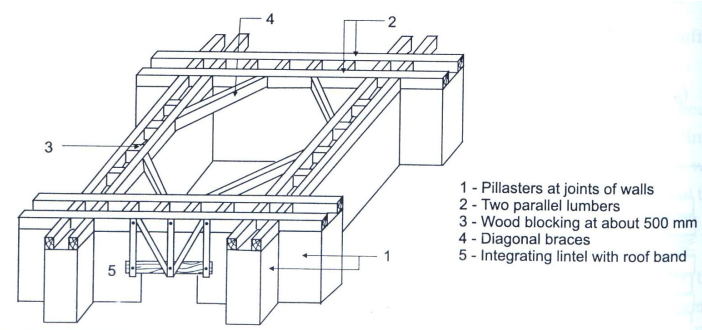
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Bamboo: The performance of buildings has been successful with only slight cracking and full collapse averted. Timber ring beams: These have been successful in reducing full collapse of the structure.
Additional comments section 6	



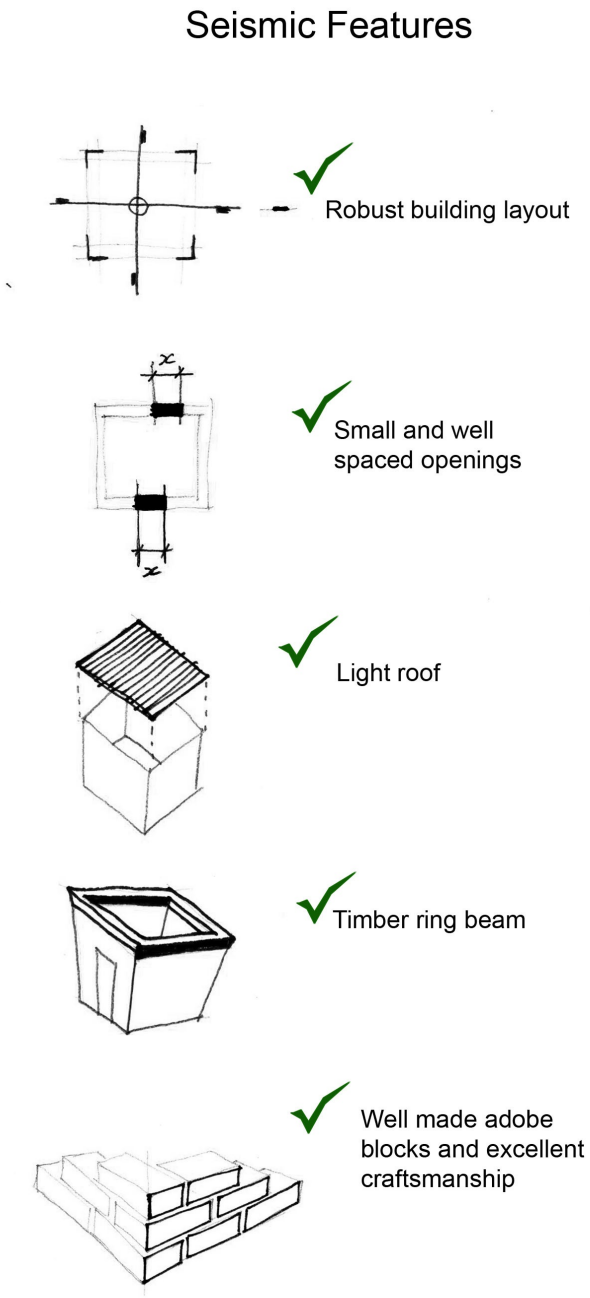
Bamboo reinforcing system. IAEE Guidelines, 2004, p.73.



'Improved Adobe' principles. IAEE Guidelines, 2004, p.75.



Timber ring beam and lintel connection. IAEE Guidelines, 2004, p.72.



Seismic features of this building.

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