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 house

Report#	52
Last Updated	
Country	Peru
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Important

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General Information

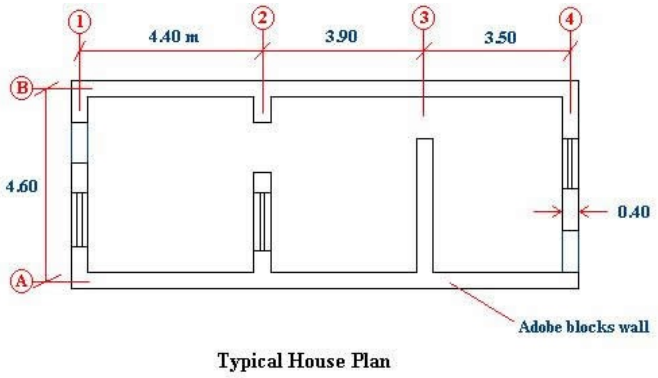
Building Type:	Adobe house
Country:	Peru
Author(s):	Cesar Loaiza Marcial Blondet Gianfranco Ottazzi
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in the Peruvian coastal and highland regions. This type of housing construction is commonly found in both rural and urban areas.
Summary:	This is a traditional construction practice followed for over 200 years. Houses of this type can be found both in urban and rural areas in the coastal and highlands regions of Peru. Walls are made of adobe blocks laid in mud mortar. The roof structure is made of wood; it usually consists of timber beams with timber planks covered with a mud mortar overlay or with clay tiles or metal sheets. Houses of this type are mainly occupied by poor people. Thisconstruction is considered to be very vulnerable to earthquake effects.
Length of time practiced:	More than 200 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Single dwelling
Typical number of stories:	1
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	

Features

Plan Shape	Square, solidRectangular, solid

Additional comments on plan shape	
Typical plan length (meters)	9
Typical plan width (meters)	8
Typical story height (meters)	4
Type of Structural System	Masonry: Earthen/Mud/Adobe/Rammed Earth Walls: Mud walls with horizontal wood elements
Additional comments on structural system	Adobe block walls carry gravity loads due to roof self-weight and transmit them to the foundations. Wood lintels assist in resisting the gravity loads at wall openings. Adobe block walls provide resistance to lateral loads. The wood roof structure is considered to be a flexible diaphragm in the analysis. Wall corners (junctions) are very vulnerable parts of the structure. Typical wall thickness varies from 300 to 800 mm.
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	The typical structural wall density is more than 20%. 20% - 40%.
Wall Openings	Typically one door or window opening per wall. It is estimated that the window and door widths constitute approximately 30 # 40% of the total wall length.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	In the coastal region it is common that owners build an additional floor with quincha. This material consists of wood planks filled with bamboo and covered with mud or gypsum.
Type of Foundation	Shallow Foundation: Wall or column embedded in soil, without footingShallow Foundation: Rubble

	stone, fieldstone strip footing
Additional comments on foundation	
Type of Floor System	Other floor system
Additional comments on floor system	Floor is not considered to be a rigid diaphragm in the analysis.
Type of Roof System	Roof system, other
Additional comments on roof system	Wood planks or beams supporting natural stones slates; Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles Roof is not considered to be a rigid diaphragm in the analysis.
Additional comments section 2	Typical Plan Dimensions: Length varies from 8 to 10 m. Width varies from 5 to 10 m. Typical Story Height: In the coastal region, the typical story height is 4.0 m; in the highland region the height is 3.0 m. Typical Span: Span varies from 3 to 6 m. The typical storey height in such buildings is 4.0 meters.



Typical House Plan

Plan of a Typical Building

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Adobe piles	-Compression 1.20 MPa -Shear 25 kPa Masonry mortar mix 1:5 cement/sand mortar Masonry brick dimensions:

		400mm x 18mm x 10 mm Mortar mix proportion changes significantly the resistance of a pile of adobe blocks
Foundations	Adobe piles	-Compression 1.20 MPa -Shear 25 kPa Masonry mortar mix 1:5 cement/sand mortar Masonry brick dimensions 400mm x 18mm x 10 mm
Floors	Wood	-Tension (parallel with the grain): 41 MPa -Compression (perpendicular to the grain): 4 MPa -Shear: 1.5 MPa
Roof	Wood	-Tension (parallel with the grain): 41 MPa -Compression (perpendicular to the grain): 4 MPa -Shear: 1.5 MPa
Other		

Design Process

Who is involved with the design process?	EngineerArchitectOther
Roles of those involved in the design process	It is not common that engineers and architects participate in the construction process, as this is typically an informal construction. However in big projects financed by the Peruvian Government or other institutions, engineers would be in charge of the construction process and the structural design, and architects would be in charge of the architectural design.
Expertise of those involved in the design process	Professional engineers do not have too much design experience related to this housing type. It is typically built by village artisans.

Construction Process

Who typically builds this construction type?	Mason
Roles of those involved in	Builders typically live in these houses, however

Roles of those involved in the building process	there are few houses built by professional construction companies.
Expertise of those involved in building process	
Construction process and phasing	Typically constructed by village artisans. Process starts with the selection of a good soil to make the adobe blocks. The soil needs to have an adequate proportion of clay. Subsequently, adobe blocks are prepared using wood molds and left to dry for minimum 15 days. A rubble stone strip footing is made, with a minimum depth of 0.40 m. After the wall height is reached, a wood beam is laid atop the adobe block wall with transverse timber planks laid over them. Finally, walls are covered with a cape of mud mortar. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
Applicable codes or standards	Peruvian Adobe Structures Code. The year the first code/standard addressing this type of construction issued was 1977. The most recent code/standard addressing this construction type issued was 1998.
Process for building code enforcement	There is no process for building code enforcement in rural areas. However, for construction in urban areas and for big projects it is necessary to obtain the approval of municipal authorities.

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?	Yes

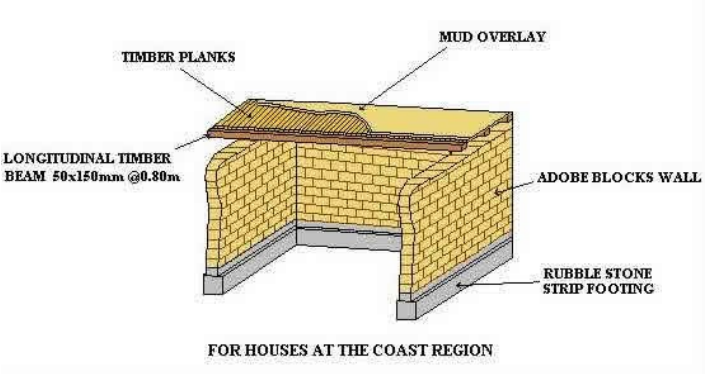
Additional comments on building permits and development control rules	In urban areas, building permits are required for this construction type, however in rural areas this construction is typically informal and consequently building permits are not required.

Building Maintenance and Condition

Typical problems associated with this type of construction	A typical problem is related to drying the adobe blocks on rainy days. These blocks are made using local soils, which is not good in some areas. Adobe blocks need to dry for at least 15 days, and during rainy weather the bricks take longer to dry and a special cover is required to protect the adobe blocks.
Who typically maintains buildings of this type?	Owner(s)No one
Additional comments on maintenance and building condition	

Construction Economics

Unit construction cost	This cost is variable, but an average value could be around $US 20/sq m. The unit cost can be lower than the value provided if the owners contribute with their own labor.
Labor requirements	It will take approximately 1 month to complete the construction of a typical one-storey house.
Additional comments section 3	



Critical Structural Details

Key Seismic Deficiencies - Adobe Wall Failure Due to Out-of-Plane

Seismic Forces

Key Seismic Deficiencies - Wall Damage Due to Inadequate In-Plane Seismic Resistance

Socio-Economic Issues

Patterns of occupancy	Typically occupied by extended families.
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	5-10
Additional comments on number of inhabitants	
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)
Additional comments on economic level of inhabitants	Economic Level: For Very Poor Class the Housing Unit Price is 1,500 and the Annual Income is 700. For Poor Class the Housing Unit Price is 5,000 and the Annual Income is 1,000. Ratio of housing unit price to annual income: 5:1 or worse
Typical Source of Financing	Owner financedPersonal savingsGovernment-owned housing
Additional comments on financing	

Type of Ownership	RentOwn outright
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
1970	Chimbote
1974	Lima
1996	Nazca

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	

Additional comments on earthquake damage patterns	Wall shear cracking

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.	TRUE
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		FALSE
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	FALSE

	standards).	
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	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	#NAME?
Earthquake-resilient features in walls	#NAME?
Seismic deficiency in frames	
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Roof behaves as a flexible diaphragm.
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	-|				

A Photograph Illustrating Typical Earthquake Damage (November 1996 Nasca Earthquake)

A Photograph Illustrating Typical Earthquake Damage (November 1996 Nasca Earthquake)

Retrofit Information

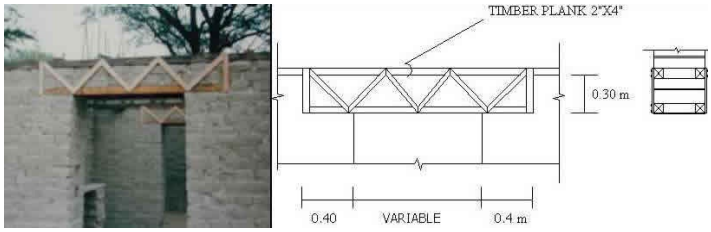
Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Adobe walls- Lack of confinement	Adobe walls are confined with reinforced concrete tie columns and beams. Concrete columns are cast against the serrated endings of adobe walls. This is a very good seismic strengthening system, however it could be expensive for owners.
Lack of integrity- adobe walls	A wood beam is cast atop the walls, keeping them united during an earthquake. It is an

	inexpensive system. (see Figure 10)
Adobe walls-poor in-plane and out-of-plane resistance	A steel mesh fixed with metal plates is installed to strengthen the adobe walls. The mesh is applied on both wall surfaces and at the wall corners. This is a very effective and inexpensive strengthening system, developed at the Catholic University of Lima.
(New Construction): Improved integrity of adobe walls	A wooden beam is cast atop the walls, keeping them united during an earthquake. Rectangular wood beams are used as lintels. (see Figure 10)
(New Construction):Reinforcing of walls with bamboo cane reinforcement	Bamboo cane is used in adobe walls to provide ductility and improve tensile resistance. This is a very effective and inexpensive strengthening system. Cane does not increase significantly the lateral resistance, however lateral drifts are reduced.

Additional comments on seismic strengthening provisions	
Has seismic strengthening described in the above table been performed?	Yes, all of them had been performed.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	The work was done in both cases.
Was the construction inspected in the same manner as new construction?	Yes
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	Owners perform the construction, supervised by a structural engineer.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	Very good performance; house collapse was avoided.

Additional comments section 6	



Seismic Strengthening - Cane Reinforcement of Adobe Walls

Seismic Strengthening - Construction of Wooden Beams atop the Adobe Walls

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3. Quiun, San Bartolome, Torrealva, Zegarra, 1997, El Terremoto de Nasca del 12 de Noviembre de 1996,Pontificia Universidad Catolica del Peru.

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