



# World Housing Encyclopedia Report

Country: Peru

Housing Type: Adobe house

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# 1 General Information

## 1.1 Country

Peru

## 1.3 Housing Type

Adobe house

## 1.4 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. This construction is considered to be very vulnerable to earthquake effects.



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	
< 100 years	
< 200 years	
> 200 years	X

Is this construction still being practiced?	Yes	No
	X	

*Additional Comments:* This is a traditional construction practice followed for over 200 years.

## 1.6 Region(s) Where Used

Peruvian coast and highland regions.

## 1.7 Urban vs. Rural Construction

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

## 2 Architectural Features

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### 2.1 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.

### 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?		X

The typical separation distance between buildings is meters. There is no separation between houses meters

### 2.3 Building Configuration

Building plan is typically of a regular shape, usually rectangular or square.

### 2.4 Building Function

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

### 2.5 Means of Escape

Usually there is one main door at the house façade and one auxiliary door at the rear part. Both doors can be used in case of emergency.

### 2.6 Modification 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.

### 3 Socio-Economic Issues

#### 3.1 Patterns of Occupancy

Typically occupied by extended families.

#### 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:* Typically one bathroom per house.

#### 3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor	X	1500/700
Poor	X	5000/1000
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 / mortgages	
Investment pools	
Combination (explain)	
Government-owned housing	X
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

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### **4.1 Lateral Load-Resisting System**

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.

### **4.2 Gravity Load-Bearing Structure**

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.

### 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	X
		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)	
	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	
		23	With brick masonry partitions	
Steel	Moment resisting frame	24	With cast in-situ concrete walls	
		25	With lightweight partitions	
		26	Concentric	
	Braced frame	27	Eccentric	
		28	Thatch	
Timber	Load-bearing timber frame	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	
		34	Building protected with base isolation devices or seismic dampers	
Various	Seismic protection systems	35		
	Other			

#### 4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	X
	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			

Additional Comments: Floor/roof is not considered to be a rigid diaphragm in the analysis.

#### 4.6 Typical Plan Dimensions

Length: 9 - 9 meters

Width: 9 - 9 meters

Additional Comments: Length varies from 8 to 10 m. Width varies from 5 to 10 m.

#### 4.7 Typical Number of Stories

1

#### 4.8 Typical Story Height

4.00 meters

Additional Comments: In the coastal region, the typical story height is 4.0 m; in the highland region the height is 3.0 m.

#### **4.9 Typical Span**

6 meters

*Additional Comments:* Span varies from 3 to 6 m.

#### **4.10 Typical Wall Density**

20% - 40%

#### **4.11 General Applicability of Answers to Questions in Section 4**

The information provided in this contribution refers to a typical house, the variation in the values given in this section could be on the order of 5%.

## 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 from 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	-Adobe block walls have poor tensile and shear resistance. -Wall corners are rather vulnerable. -Walls have low resistance to out-of- plane seismic forces.	-Steel mesh keeps walls working as a unit. -Wooden beams act as lintels	Wall shear cracking
Frame (columns, beams)			
Roof and floors	Roof behaves as a flexible diaphragm.		

### 5.3 Seismic Vulnerability Rating

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

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

## 6 Earthquake Damage Patterns

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### 6.1 Past Earthquakes Reported To Affect This Construction

Year	Earthquake Epicenter	Richter magnitude(M)	Maximum Intensity (Indicate Scale e.g. MMI, MSK)
1996	Nazca	7.3	VII (MMI)
1974	Lima	7.7	VIII (MMI)
1970	Chimbote	7.8	VI (MMI)

## 7 Building Materials and Construction Process

### 7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	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	
Roof and floors	Wood	- Tension (parallel with the grain): 41 MPa - Compression (perpendicular to the grain): 4 MPa - Shear: 1.5 MPa		

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

Builders typically live in these houses, however there are few houses built by professional construction companies.

### 7.3 Construction Process

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.

### 7.4 Design/Construction Expertise

Professional engineers do not have too much design experience related to this housing type. It is typically built by village artisans.

### 7.5 Building Codes and Standards

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

*Title of the code or standard:* Peruvian Adobe Structures Code

*Year the first code/standard addressing this type of construction issued:* 1977

*When was the most recent code/standard addressing this construction type issued?* 1998

### 7.6 Role of Engineers and Architects

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.

### 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:* 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.

### 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	X
Other	

### 7.10 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.

### 7.11 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.

## 8 Construction Economics

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### **8.1 Unit Construction Cost (estimate)**

This cost is variable, but an average value could be around \$US 20/m<sup>2</sup>. The unit cost can be lower than the value provided if the owners contribute with their own labor.

### **8.2 Labor Requirements (estimate)**

It will take approximately 1 month to complete the construction of a typical one-storey house.

## 9 Insurance

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### 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?

N/A

# 10 Seismic Strengthening Technologies

## 10.1 Description of Seismic Strengthening Provisions

Type of intervention	Structural Deficiency	Description of seismic strengthening provision used
Retrofit (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 7C).
	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 7C).
	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 (see FIGURE 7B).

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

Yes, all of them had been performed.

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

The work was done in both cases.

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

Yes

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

Owners perform the construction, supervised by a structural engineer.

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

Very good performance; house collapse was avoided.

## 11 References

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Quiun, San Bartolomé, Torrealva, Zegarra, 1997, El Terremoto de Nasca del 12 de Noviembre de 1996, Pontificia Universidad Católica del Perú.

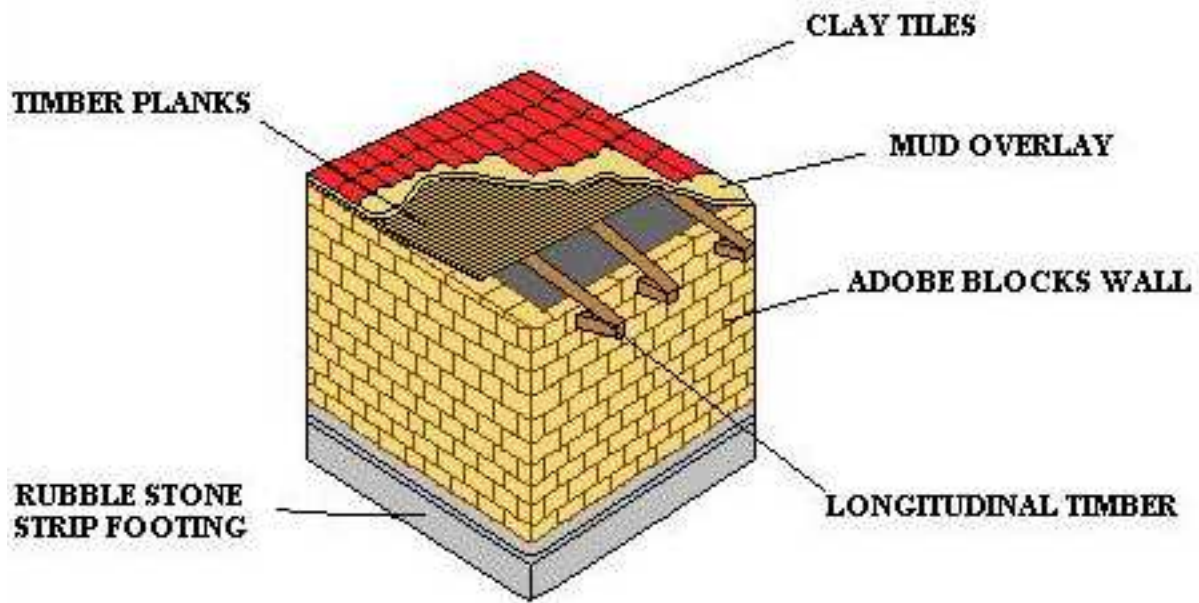
## 12 Contributors

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13 Figures

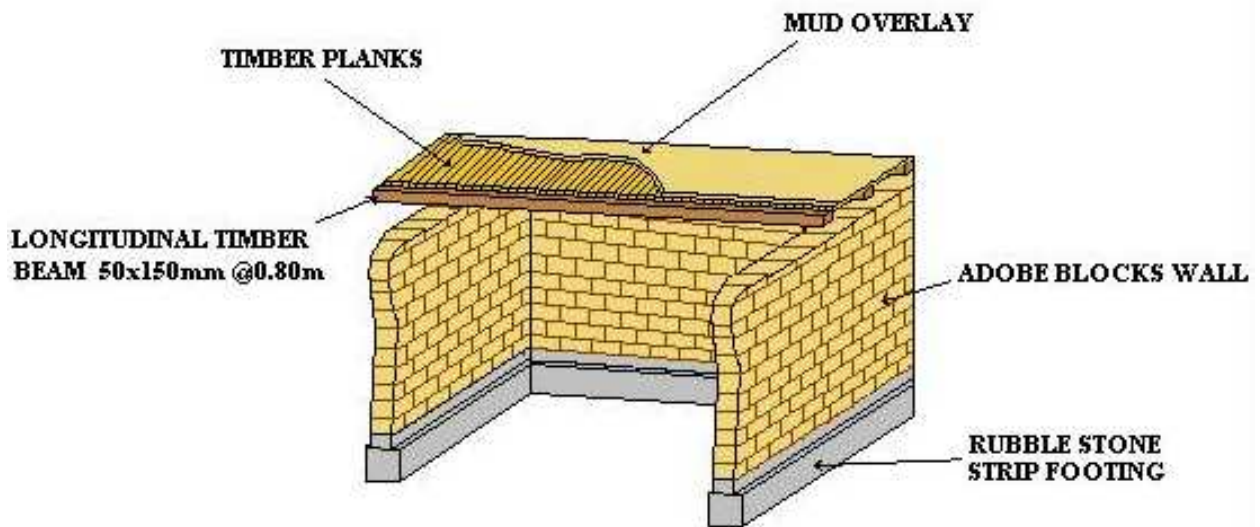


FIGURE 1: Typical Building



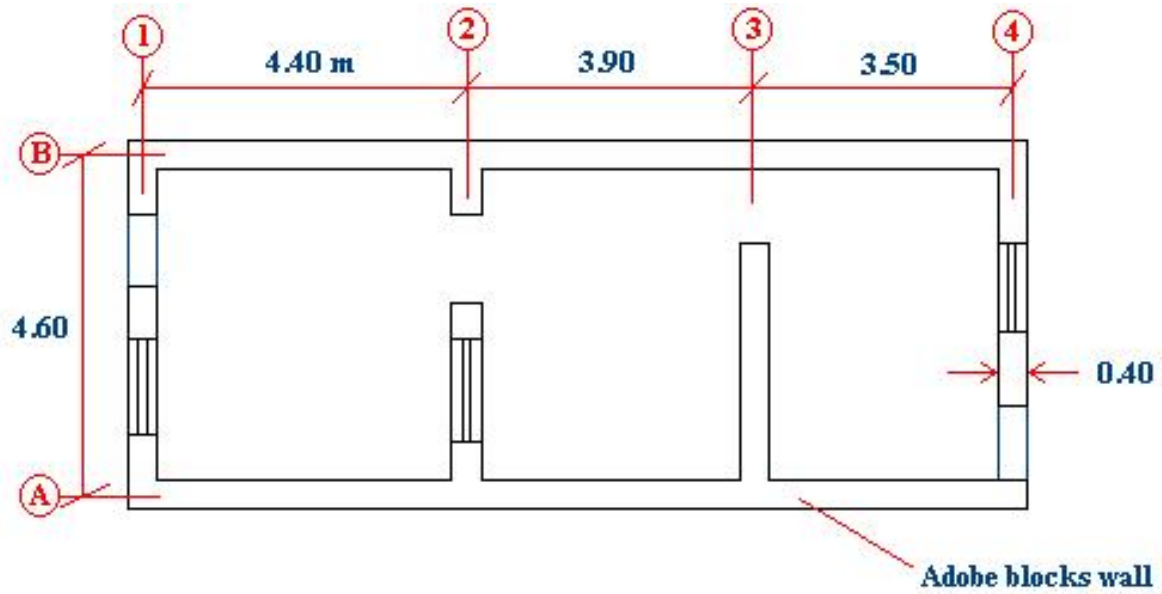
**FOR HOUSES AT THE HIGHLANDS REGION**

*FIGURE 2A: Key Load-Bearing Elements*



**FOR HOUSES AT THE COAST REGION**

*FIGURE 2B: Key Load-Bearing Elements for Houses in the Coastal Region*



**Typical House Plan**

*FIGURE 3: Plan of a Typical Building*

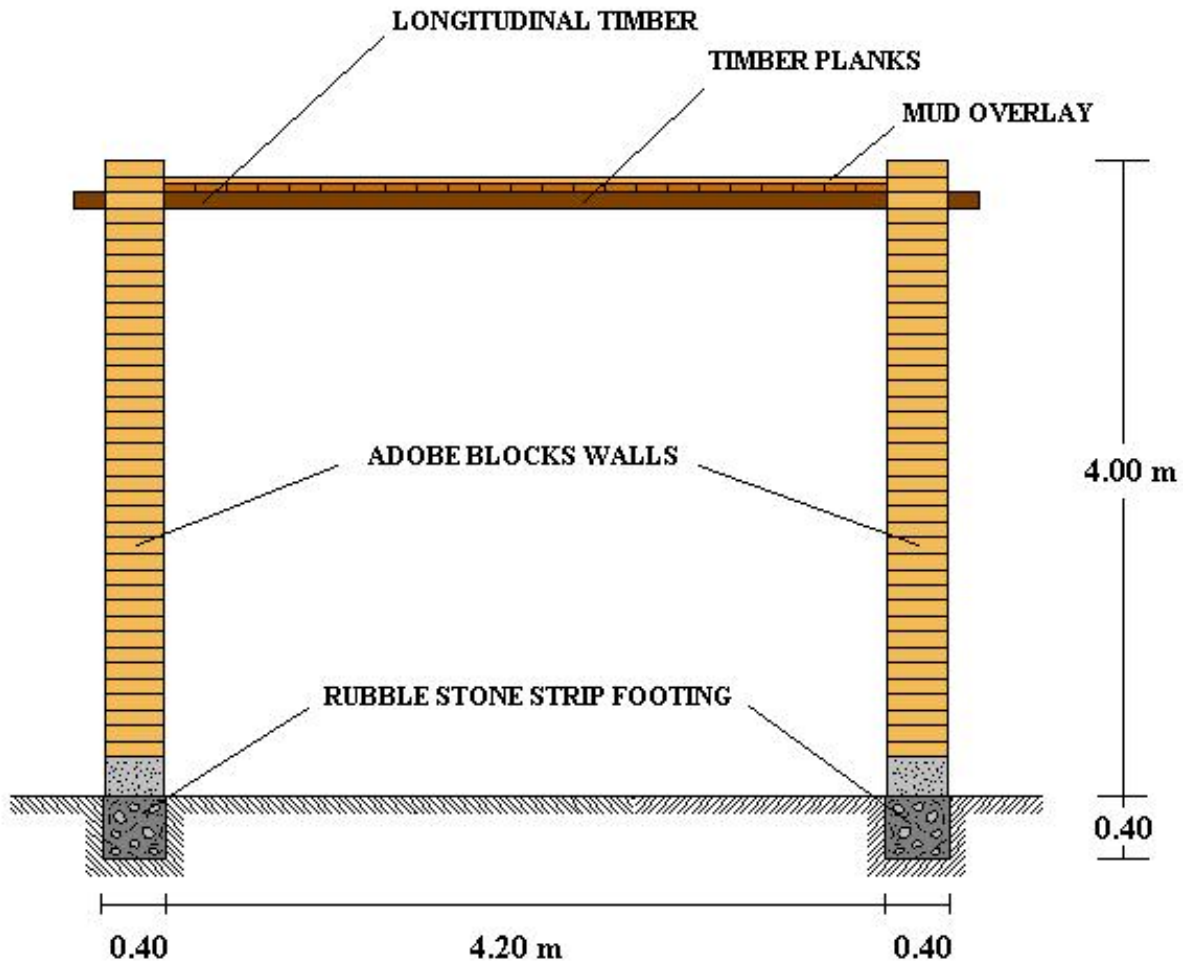


FIGURE 4: Critical Structural Details



FIGURE 5A: Key Seismic Deficiencies - Adobe Wall Failure Due to Out-of-Plane Seismic Forces



FIGURE 5B: Key Seismic Deficiencies - Wall Damage Due to Inadequate In-Plane Seismic Resistance



*FIGURE 6A: A Photograph Illustrating Typical Earthquake Damage (November 1996 Nasca Earthquake)*



FIGURE 6B: A Photograph Illustrating Typical Earthquake Damage (November 1996 Nasca Earthquake)

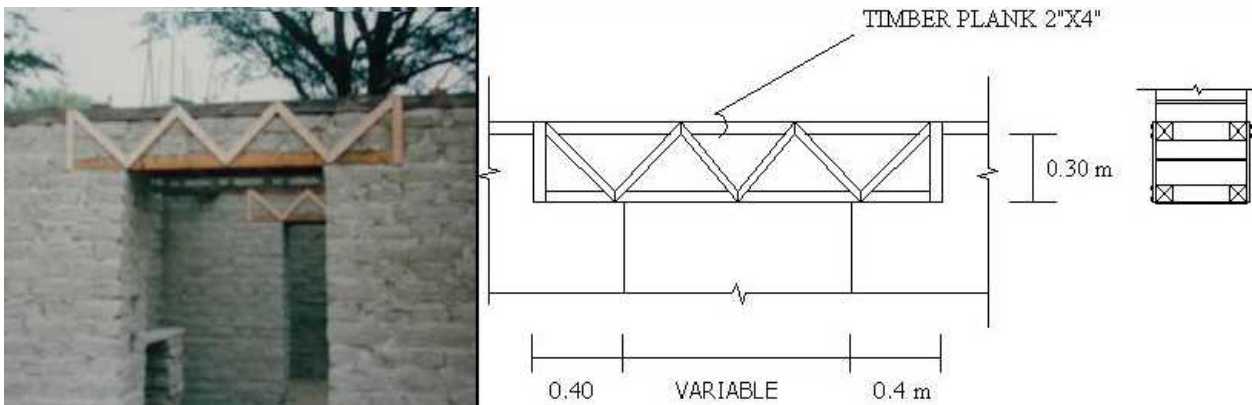


FIGURE 7A: Illustration of Seismic Strengthening Techniques



*FIGURE 7B: Seismic Strengthening- Cane Reinforcement for Adobe Walls*



*FIGURE 7C: Seismic Strengthening - Construction of Wooden Beams atop the Adobe Walls*