



# World Housing Encyclopedia Report

Country: El Salvador

Housing Type: Vivienda de Adobe (Adobe house)

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# 1 General Information

## 1.1 Country

El Salvador

## 1.3 Housing Type

Vivienda de Adobe (Adobe house)



FIGURE 1: Typical Building

## 1.4 Summary

This housing type can be found in rural and urban areas:

Rural: Adobe houses are generally small structures, 5 m X 6 m in plan, having load-resistant walls made of adobe bricks with thickness between 0.3 and 0.5 m. Usually, they are single family dwelling (5 people) houses. Wood planks that support metal sheets covered by tiles can constitute the roof. In some cases, the roof can be a thatched roof supported on wood purlins.

Urban: Adobe houses are much bigger in urban areas than in rural areas. Their plans are 15 m X 30 m or bigger. One floor structures. The wall thickness can easily reach 1 m and wall height can reach 3 m or more.

In both cases mentioned above, the adobe housing type has performed badly in earthquake; its heavy roof sometimes can be its biggest weakness; in addition, its unreinforced walls make this house vulnerable to earthquakes.

## 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 construction practice was, and still is, widely used in El Salvador although this region is highly seismic. El Salvador's earthquakes of 2001, and their aftershocks, mainly destroyed dwellings built with adobe; unfortunately, however, people are still using this construction type to rebuild their shelters.

## 1.6 Region(s) Where Used

This construction practice is widespread throughout the country. San Salvador, the capital of El Salvador, is perhaps the only area where this construction type does not exist. The San Salvador Metropolitan building and planning agency (OPAMSS) and the Vice Secretary of Housing (ViceMinisterio de Vivienda)

have prohibited the construction of adobe housing due to its poor seismic performance. The Vice Secretary allows adobe houses only in regions declared as ecological areas.

### 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

Additional Comments: This housing type is no longer permitted in urban areas.

## 2 Architectural Features

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### 2.1 Openings

Rural: Houses have four walls, two of which have openings. Openings are less than or equal to 30% of the wall area. The other two walls generally do not have openings.

Urban: There is a number of openings in these houses. The amount of openings can be as high as 50%.

### 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

### 2.3 Building Configuration

The typical shape of a building plan for this housing type is rectangular.

### 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)	

*Additional Comments:* Some houses also include commercial space, especially in towns in urban areas.

### 2.5 Means of Escape

Houses have a main entrance and have exits to an internal patio in urban areas. In rural areas, houses have two doors, each of which is located at opposite walls of the structure.

### 2.6 Modification of Buildings

There is no modification from the original structure.

### 3 Socio-Economic Issues

#### 3.1 Patterns of Occupancy

One family typically occupies one house.

#### 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:* 1 in urban areas; 1 or 0 in rural areas

#### 3.5 Economic Level of Inhabitants

Economic Status		House Price/Annual Income (Ratio)
Very poor	X	350/1000
Poor	X	700/2500
Middle Class	X	12000/20000
Rich		/

*Additional Comments:* The prices are expressed in US\$.

#### 3.6 Typical Sources of Financing

What is the typical source of financing for buildings of this type?	
Owner Financed	
Personal Savings	
Informal Network: friends and relatives	X
Small lending institutions/microfinance institutions	
Commercial banks / mortgages	
Investment pools	
Combination (explain)	
Government-owned housing	
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	X

*Additional Comments:* Urban: Typically own outright. Rural: The landowners give a space to peasants to build their houses and to work the land. The peasants give part of their harvest to the landowner as rent.

## 4 Structural Features

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

The adobe walls that act as shear walls providing the lateral stiffness. In urban areas, the thickness of the walls can be as much as 1 m. In rural areas, the thickness can be between 0.3 and 0.5 m. The roof can be considered as a flexible diaphragm and is supported directly on the walls.

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

Roof loads are directly transmitted to the shear walls by wood purlins or beams. The beams directly rest on the top of the walls. Walls take the entire gravity load. Walls transfer the load to the foundation.

### 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	
Various	Seismic protection systems	34	Building protected with base isolation devices or seismic dampers	
		35	Other	

#### 4.4 Type of Foundation

Type	Description	
Shallow Foundation	Wall or column embedded in soil, without footing	
	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		X
	Wood single roof		
	Wood planks or beams that support clay tiles		X
	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	Earth	X	

Additional Comments: Roof system can be considered as flexible diaphragm.

#### 4.6 Typical Plan Dimensions

Length: 30 - 30 meters

Width: 30 - 30 meters

Additional Comments: It is for urban. For rural length is usually 6 and width 5

#### 4.7 Typical Number of Stories

1

#### 4.8 Typical Story Height

3 meters

Additional Comments: Height variation is 2.5 - 3 m.

#### 4.9 Typical Span

5 meters

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

Urban: 35%. Rural: 20%

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

Most of the adobe housing is very similar in the rural areas. In the case of urban areas the typical plan dimension may have a 20% variation from what has been specified above.

## 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	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				

*Additional Comments:* Wall openings are most true in the rural and may be false in urban.

### 5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake-Resilient Features	Earthquake Damage Patterns
Wall	There is a lack of dependable joints among walls, especially at the top of walls. This causes adjacent walls to open up during an earthquake.		Damages due flexural and shear effects.
Frame (columns, beams)			
Roof and floors	There is inadequate vertical and horizontal load transfer mechanism from roof to walls.		Total and partial collapse of the roof due to material degradation and loss of support from walls.

### 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)
1982	Pacific Ocean	7.2	(MMI) VII
1965	San Salvador	6	(MMI) VIII
1951	Jucuapa/ Chinameca	6	(MSK) VIII
1936	San Vicente	6.1	VII-VIII (SIEBERG)

*Additional Comments:* 1986, San Salvador, 5.4 (MMI), VIII El Salvador had two big earthquakes at the beginning of 2001. The first one was on 13 January 2001 with its epicenter located in the Pacific Ocean and with magnitude  $M_w = 7.7$ , with a maximum estimated intensity of VIII (MMI). The second one happened on 13 February 2001 with epicenter at San Juan Tepezontes and  $M_w = 6.5$ ; the estimated intensity was VIII in some places, however in many of the affected areas its intensity was VII (MMI). One of the most important features of these two EQ is that they destroyed adobe housing in many places throughout El Salvador.

## 7 Building Materials and Construction Process

### 7.1 Description of Building Materials

Structural Element	Building Material	Characteristic Strength	Mix Proportions/ Dimensions	Comments
Walls	Adobe Brick	0.25 kg/cm <sup>2</sup> (Shear)	13:4:3 (sand:lime:clay) 400 mm X 200 mm X 150mm	
Foundations	Mortar		1:2 (soil: straw)	
Roof and floors	Wood Tiles			

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

The builder typically lives in this construction type.

### 7.3 Construction Process

First of all, the builder hydrates the adobe mixture, composed of 65% sand, 20% lime and 15% clay. The water volume could be 1/3 of the whole mixture volume. Bricks are made by placing this mixture into molds measuring 40 cm X 20 cm X 15 cm. After 3 days, the bricks are removed from the molds and dried for four weeks. Meanwhile, the site where the structure will be erected is leveled. Once this step is complete, excavation for the foundation begins. The width of the excavation is one and a half times the width of the wall. Both stone and mortar are placed into the hole; this will be the foundation. After the foundation is finished, the walls begin to be erected up to 2.5 m. It has to be noted that maximum height per construction day must be 1 m to avoid crushing of the walls due to its own weight. When walls reach 2.5 m, approximately, the roof is built. Wood purlins are placed on top of walls spaced 20 cm between purlins. Later tiles or steel sheets are placed.

### 7.4 Design/Construction Expertise

There is some experience to build this construction type; however, the work force is not trained.

### 7.5 Building Codes and Standards

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

*Title of the code or standard:* Norma para la Construcción de Viviendas. An additional comment: Adobe housing is addressed by El Salvador's 1994 Building Code in an appendix; however, it gives recommendations about building better adobe housing without imposing enforcement.

*Year the first code/standard addressing this type of construction issued:* 1994

*When was the most recent code/standard addressing this construction type issued?* 1994

### 7.6 Role of Engineers and Architects

Generally, neither engineers nor architects have a role in the design, or construction of this housing type.

### 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

### 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

N/A

### 7.11 Typical Problems Associated with this Type of Construction

The biggest problem of this type of construction is water due to weathering. Adobe has be protected against water.

In addition, it has low resistance against seismic excitation, because of its very high mass-to-strength ratio.

## 8 Construction Economics

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

Rural: US\$ 15 /m<sup>2</sup>

Urban: US\$ 30 /m<sup>2</sup>

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

Rural: 1.5 months using two people (including time for the mixture to be hydrated).

## 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)	Walls: There is lack of dependable joints among walls, especially at the top of walls. This causes adjacent walls to open up during an earthquake.	Collar Beam or Lintel Band: This feature ties the walls together. Buttresses: This feature helps to retain the integral action of walls and facilitate the connection of collar beams with each other. Vertical and Horizontal Reinforcement using bamboo: This features tries to provide reinforcement similar to that for concrete structures. Adobe bricks have to be molded appropriately to use this kind of strengthening technique.
	Roof: Very heavy elements.	Sheets of metal: Use this feature instead of clay tiles

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

Yes, it has. However, It is not widely used. It has been done as a test in some rural communities.

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

It was done as a test.

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

No, it was not. These houses did have supervision.

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

An ONG.

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

Very good, nothing happened to them. However, they are located in an area that was not as affected by the recent earthquakes.

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13 Figures



FIGURE 1: Typical Building



FIGURE 2: Key Load Bearing Elements

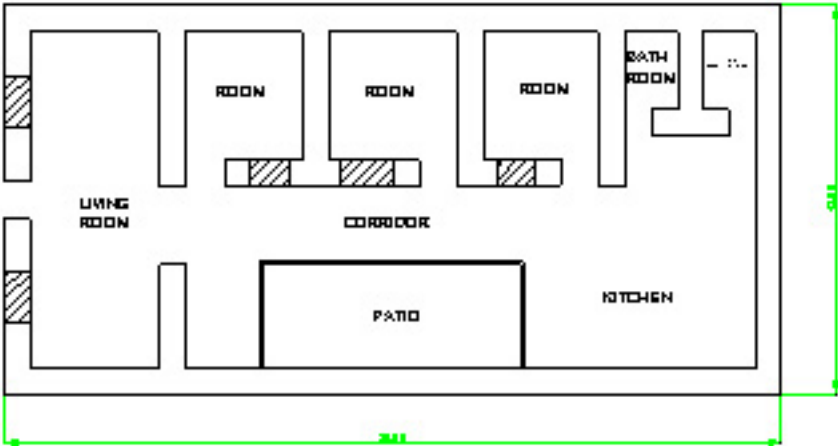


FIGURE 3A: Plan of a Typical Building

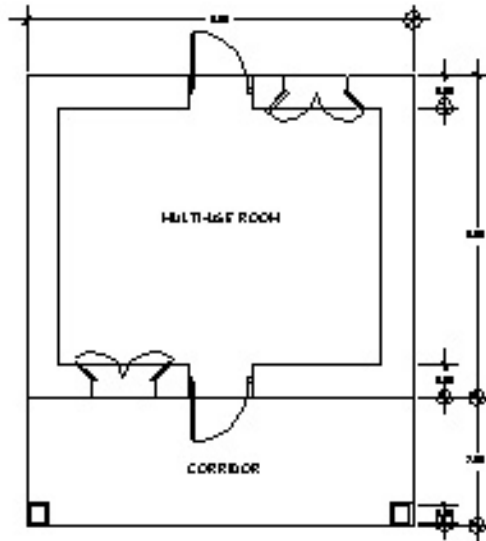


FIGURE 3B: Plan of a typical rural dwelling



FIGURE 4A: Critical Structural Details-An illustration of wood beams supporting clay tiles and roof-walls connections



FIGURE 4B: Wall connections

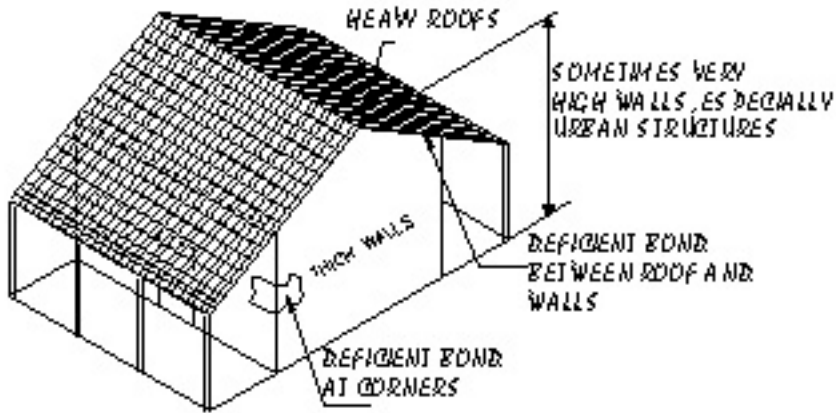


FIGURE 5A: An Illustration of Key Seismic Features and/or Deficiencies



FIGURE 5B: Deficient bedding of lintels



*FIGURE 6A: Damage to an adobe house in the 1936 San Vicente earthquake*



*FIGURE 6B: Damage to adobe houses in the 1936 San Vicente earthquake*



*FIGURE 6C: Damage to an adobe church in the 1999 Apastepeque earthquake*



*FIGURE 6D: Wall damage (corner separation) in the 1999 Apastepeque earthquake*



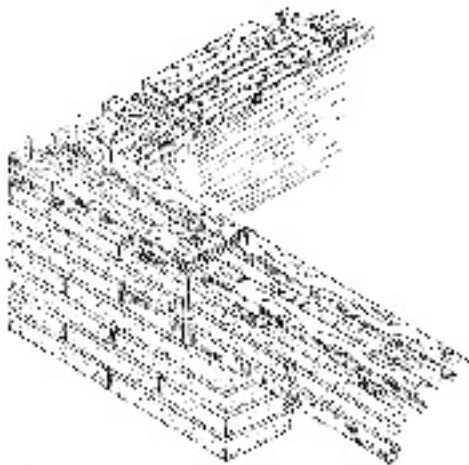
*FIGURE 6E: Damages in the town of Juayua due to the January 13, 2001 earthquake*



*FIGURE 6F: Damages in the city of Cojutepeque due to the February 13, 2001 earthquake*



*FIGURE 6G: The San Jose church, Cojutepeque, damaged in the 13 February 2001 earthquake*



*FIGURE 7A: Illustration of Seismic Strengthening Techniques*

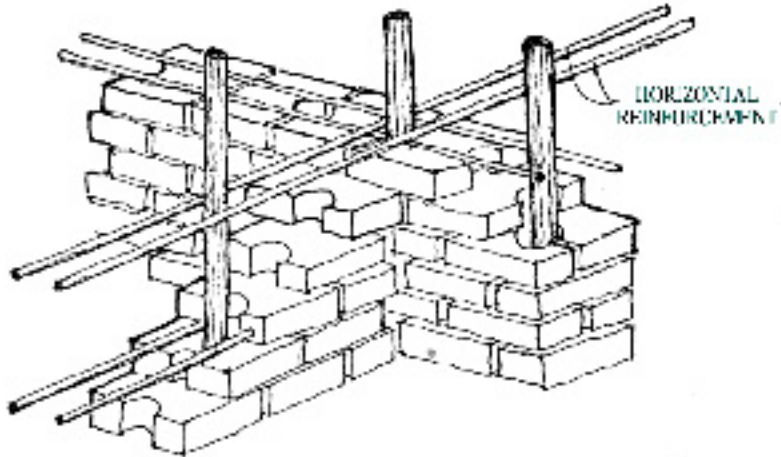


FIGURE 7B: Seismic Strengthening: Vertical and Horizontal Reinforcement

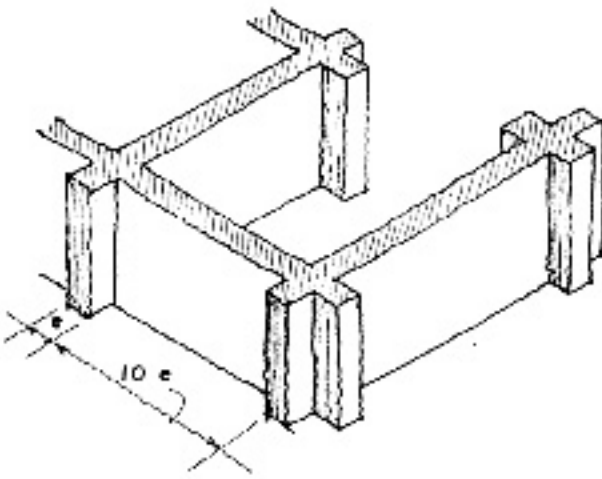


FIGURE 7C: Seismic Strengthening : Wall Buttresses