World Housing Encyclopedia

an Encyclopedia of Housing Construction in
Seismically Active Areas of the World

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Earthquake Engineering Research Institute (EERI) and
International Association for Earthquake Engineering (IAEE)

HOUSING REPORT
Traditional adobe house without seismic features

Report #	89
Report Date	07-03-2003
Country	ARGENTINA
Housing Type	Adobe / Earthen House
Housing Sub-Type	Adobe / Earthen House : Adobe block walls
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Summary

This construction type is used as a single-family house. It is a single-story, detached building, found in the rural and suburban areas of the province of San Juan. This traditional type of construction is built with adobe walls and no cornice. The traditional adobe house has a range of deficiencies: weak connections, heavy roofs, adobe blocks that deteriorate (especially at the base of the walls) due to prolonged exposure to humidity. This housing type is expected to

perform poorly in earthquakes.

1. General Information

Buildings of this construction type can be found in the province of San Juan since Colonial times, and it is still being built in the rural and suburban areas of San Juan. In Tulum Valley, where the population is about 85% of the population of the whole population of the whole province, almost 40% of the construction is of this type. This type of housing construction is commonly found in both rural and sub-urban areas. This construction type has been in practice for more than 200 years.

Currently, this type of construction is being built. .

Figure 1: Typical Building

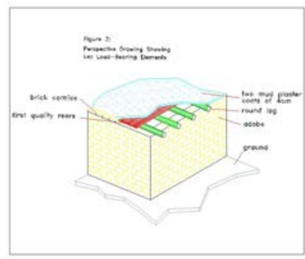

Figure 3: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. Typically, more than 100 meters separate each of these houses When separated from adjacent buildings, the typical distance from a neighboring building is 10 or more meters.

2.2 Building Configuration

The typical shape of a building plan for this housing type is irregular ("U"- form). This housing type has five windows and six doors. Four windows of $0.48m^2$ and one of $0.09m^2$, all of them placed in the middle of the wall. The six doors have variable areas: one of $1.60m^2$, one of $2.00m^2$, one of $2.40m^2$ and three of $1.80m^2$. Outside the house there is a toilet with a door of $1.40m^2$. Three doors are placed to one side of the wall, the other three in the middle of the wall, and the toilet door is also placed to one side of the wall. The total opening area is about 8.42% of the whole wall area.

2.3 Functional Planning

The main function of this building typology is single-family house. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. There is a main entrance door at the front of the house.

2.4 Modification to Building

Typically no modifications are made to these buildings.

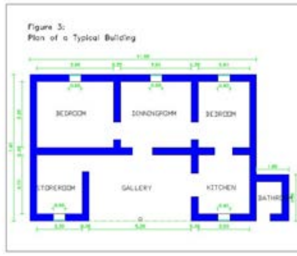

Figure 2: Plan of a Typical Building

3. Structural Details

3.1 Structural System

Material	Type of Load-Bearing Structure	#	Subtypes	Most appropriate type
Masonry	Stone Masonry Walls	1	Rubble stone (field stone) in mud/lime mortar or without mortar (usually with timber roof)	☐
		2	Dressed stone masonry (in lime/cement mortar)	☐
	Adobe/ Earthen Walls	3	Mud walls	☐
		4	Mud walls with horizontal wood elements	☐
		5	Adobe block walls	☑
		6	Rammed earth/Pise construction	☐
	Unreinforced masonry walls	7	Brick masonry in mud/lime mortar	☐
		8	Brick masonry in mud/lime mortar with vertical posts	☐
		9	Brick masonry in lime/cement mortar	☐
		10	Concrete block masonry in cement mortar	☐
	Confined masonry	11	Clay brick/tile masonry, with wooden posts and beams	☐
		12	Clay brick masonry, with concrete posts/tie columns and beams	☐
		13	Concrete blocks, tie columns and beams	☐
	Reinforced masonry	14	Stone masonry in cement mortar	☐
		15	Clay brick masonry in cement mortar	☐
		16	Concrete block masonry in cement mortar	☐
Structural concrete	Moment resisting frame	17	Flat slab structure	☐
		18	Designed for gravity loads only, with URM infill walls	☐
		19	Designed for seismic effects, with URM infill walls	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐
	Structural wall	22	Moment frame with in-situ shear walls	☐

		23	Moment frame with precast shear walls	☐
	Precast concrete	24	Moment frame	☐
		25	Prestressed moment frame with shear walls	☐
		26	Large panel precast walls	☐
		27	Shear wall structure with walls cast-in-situ	☐
		28	Shear wall structure with precast wall panel structure	☐
Steel	Moment-resisting frame	29	With brick masonry partitions	☐
		30	With cast in-situ concrete walls	☐
		31	With lightweight partitions	☐
	Braced frame	32	Concentric connections in all panels	☐
		33	Eccentric connections in a few panels	☐
	Structural wall	34	Bolted plate	☐
		35	Welded plate	☐
Timber	Load-bearing timber frame	36	Thatch	☐
		37	Walls with bamboo/reed mesh and post (Wattle and Daub)	☐
		38	Masonry with horizontal beams/planks at intermediate levels	☐
		39	Post and beam frame (no special connections)	☐
		40	Wood frame (with special connections)	☐
		41	Stud-wall frame with plywood/gypsum board sheathing	☐
		42	Wooden panel walls	☐
Other	Seismic protection systems	43	Building protected with base-isolation systems	☐
		44	Building protected with seismic dampers	☐
	Hybrid systems	45	other (described below)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is others (described below). Load-bearing adobe block masonry walls.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Load-bearing adobe block masonry walls.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 11.5 and 11.5 meters, and widths between 7.4 and 7.4 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 3.5 meters. Typical Span: The typical center-to-center distance between the walls is 3.35 - 3.7 meters. There are no columns. The typical storey height in such buildings is 3 meters. The typical structural wall density is none. 13% - 14% Total wall area: 0.25 direction y: 14% direction x: 13%.

3.5 Floor and Roof System

Material	Description of floor/roof system	Most appropriate floor	Most appropriate roof
Masonry	Vaulted	☐	☐
	Composite system of concrete joists and masonry panels	☐	☐
Structural concrete	Solid slabs (cast-in-place)	☐	☐
	Waffle slabs (cast-in-place)	☐	☐
	Flat slabs (cast-in-place)	☐	☐
	Precast joist system	☐	☐
	Hollow core slab (precast)	☐	☐
	Solid slabs (precast)	☐	☐
	Beams and planks (precast) with concrete topping (cast-in-situ)	☐	☐
	Slabs (post-tensioned)	☐	☐
Steel	Composite steel deck with concrete slab (cast-in-situ)	☐	☐
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 shingle roof	☐	☐
	Wood planks or beams that support clay tiles	☐	☐
	Wood planks or beams supporting natural stones slates	☐	☐
	Wood planks or beams that support slate, metal, asbestos-cement or plastic corrugated sheets or tiles	☐	☐
	Wood plank, plywood or manufactured wood panels on joists supported by beams or walls	☐	☐
Other	Described below	☐	☑

Flat cane roof with a mud coat supported by poplar logs.

3.6 Foundation

Type	Description	Most appropriate type
Shallow foundation	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone isolated footing	☐
	Rubble stone, fieldstone strip footing	☐
	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	☐
	Steel skin friction piles	☐
	Wood piles	☐

	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

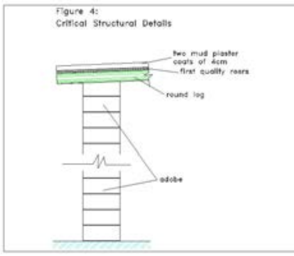

Figure 4: Critical Structural Details

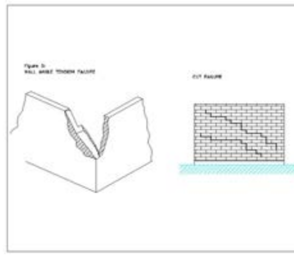

Figure 5: Key Seismic Deficiencies

Figure 6: Damage in the 1977 Caucete Earthquake

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 1 units in each building. The number of inhabitants in a building during the day or business hours is 5-10. The number of inhabitants during the evening and night is 5-10.

4.2 Patterns of Occupancy

In general, there is a single family in housing unit.

4.3 Economic Level of Inhabitants

Income class	Most appropriate type
a) very low-income class (very poor)	☑
b) low-income class (poor)	☑
c) middle-income class	☐
d) high-income class (rich)	☐

In the rural areas of Argentina, typically the economic status of the population falls in the following categories: rich people 1%, middle class 9%, poor people 30% and very poor people 60%.

Ratio of housing unit price to annual income	Most appropriate type
5:1 or worse	☐
4:1	☐
3:1	☐
1:1 or better	☑

What is a typical source of financing for buildings of this type?	Most appropriate type
Owner financed	☑

Personal savings	☑
Informal network: friends and relatives	☐
Small lending institutions / micro-finance institutions	☐
Commercial banks/mortgages	☐
Employers	☐
Investment pools	☐
Government-owned housing	☐
Combination (explain below)	☐
other (explain below)	☐

In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

4.4 Ownership

The type of ownership or occupancy is outright ownership and long-term lease.

Type of ownership or occupancy?	Most appropriate type
Renting	☐
outright ownership	☑
Ownership with debt (mortgage or other)	☐
Individual ownership	☐
Ownership by a group or pool of persons	☐
Long-term lease	☑
other (explain below)	☐

This construction type is built by poor people following the system of self-construction. In some cases, the house-owners own the land.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		Yes	No	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.	☐	☑	☐
Building Configuration	The building is regular with regards to both the plan and the elevation.	☐	☑	☐
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.	☐	☑	☐
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.	☐	☑	☐
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.			
Wall and frame structures-redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	☐	☑	☐
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);	☑	☐	☐
Foundation-wall connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	☐	☑	☐
Wall-roof connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps	☐	☑	☐
Wall openings	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.	☐	☑	☐
Quality of building materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	☐	☑	☐
Quality of workmanship	Quality of workmanship (based on visual inspection of few typical buildings) is considered to be good (per local construction standards).	☑	☐	☐
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber)	☐	☑	☐
Additional Comments				

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	-Lack of connection between walls -Adobe block masonry simply laid on the ground without any foundation or overfoundation. -Openings placed next to wall intersections. -Walls with openings greater than the 30% of the total wall area.		-Collapse of interior walls. -Collapse of walls. -Falling down of pieces and parts of adobe blocks from the middle of the face of the wall. -Collapse of walls which are weakened on their base due to the erosive action of water. -General cracking of walls. -Damage on the upper corners of the openings.-Falling of lintels.-Loosening of plastering due to the lack of sticking.
Frame (Columns, beams)			
Roof and floors	-Excessive weight of the roof. -Simply laid.		Total and partial collapse of the roof towards the inside of the rooms. -Displacing of logs.
Other			

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is A: HIGH VULNERABILITY (i.e., very poor seismic performance), the lower bound (i.e., the worst possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance), and the upper bound (i.e., the best possible) is A: HIGH VULNERABILITY (i.e., very poor seismic performance).

Vulnerability	high	medium-high	medium	medium-low	low	very low
	very poor	poor	moderate	good	very good	excellent
Vulnerability Class	A	B	C	D	E	F
	☑	☐	☐	☐	☐	☐

5.4 History of Past Earthquakes

Date	Epicenter, region	Magnitude	Max. Intensity
1944	La Laja (Albardon District)	7.8	IX
1952	La Rinconada (Pocito District)	7	VIII
1977	Pie de Palo (Caucete District)	7.4	IX
1984	Del Tigre Fault (Iglesia District)	8.2	X

The first earthquake known in the area was in 1894, it was called "The Argentinean Earthquake." All the buildings at that time were of this construction type. 100% of this construction type collapsed in the most affected area, while in the areas which were far from the epicenter, cracks on walls and the total or partial collapse of cornices were observed. During the 1944 earthquake, 90% of the buildings of this construction type collapsed completely or suffered severe damage. The same happened with this adobe house without seismic provisions during the earthquakes of 1952 and 1977.

Figure 7: Damage in the 1977 Caucete Earthquake

Figure 8: Damage in the 1977 Caucete Earthquake

Figure 9: Damage in the 1977 Caucete Earthquake

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Adobe	Contact compression 2.20 kg/cm2. Shear strength 1.8 kg/cm2. Horizontal cut 0.1 kg/cm2.	Traditional adobe dimensions: 20x35x50 very clayey soil	Adobe blocks laid with mud from the level of the floor.
Foundation				
Frames (beams & columns)				
Roof and floor(s)	Cane and mud on poplar logs.			Logs: 8 or 10 cm diameter every 60 cm.

6.2 Builder

The builder / owner usually lives in this housing type.

6.3 Construction Process, Problems and Phasing

This construction type is typically built by the owner himself. The construction process starts with the making of the mixture for the manufacturing of adobe and the drying of the blocks. Then the masonry is built binding one line of blocks with another and laying the adobe blocks with mud. Finally, when the masonry is dried, the roof is built placing the logs properly to lay the canes and a mud coat on them. The tools and equipment typically used are: shovels, hoes, baskets, level, plumb line, etc. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. The owner modifies this housing type according to his own needs.

6.4 Design and Construction Expertise

There is a high level of expertise in this traditional construction type in the province of San Juan. This kind of construction is the result of the socio-economic conditions and it reflects not only the cultural and technological development of the region, but also the availability of natural material in the area. Architects and engineers have no role in the design, calculation or construction of this housing type. All of the construction process is carried out by the owner (self construction).

6.5 Building Codes and Standards

This construction type is not addressed by the codes/standards of the country.

This construction type without any seismic provisions does not follow any building code.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and not authorized as per development control rules.

This construction type is not authorized by any of the present regulations, that is the reason why no plans are presented and there are no permits or inspections. Building permits are not required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s). There is rare or minimal maintenance due to the economic situation of the owner.

6.8 Construction Economics

\$100 per m^2 (350 \$US/m^2). The main requirement in this construction type is the people's expertise to choose the proper soil, the manufacturing and drying of the adobe blocks and the making of the walls and roof. This housing type is generally built in summer and the required time to complete the construction is two or three months.

7. Insurance

Earthquake insurance for this construction type is typically unavailable. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. This construction type has no approved plans and no inspections so it has no insurance coverage either. Anyway, insurance companies do not have a coverage for earthquakes and they make it explicit that they do not cover catastrophes.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

There are no seismic strengthening provisions available for this construction type.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

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