World Housing Encyclopedia

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

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HOUSING REPORT
Traditional Adobe House with Reinforcement

Report #	2
Report Date	05-06-2002
Country	ARGENTINA
Housing Type	Adobe / Earthen House
Housing Sub-Type	Adobe / Earthen House : Mud walls with horizontal wood elements
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Summary

This construction type is a single-family house. In general, it is a single-storey building, an isolated construction found in the rural areas of San Juan and Mendoza. The traditional adobe block masonry walls are reinforced with foundations and plinth structure, which provide structural strength. A deficiency in this type of construction is that the adobe blocks deteriorate due to prolonged exposure to humidity.

1. General Information

Buildings of this construction type can be found in in the province of San Juan. This type of housing construction is commonly found in rural areas.

The building code allows this type of construction only in rural areas. However, as the city has grown, the current urban area now indudes adobe block constructions that were built in the past (when the area was rural).

This construction type has been in practice for less than 100 years.

Currently, this type of construction is being built. This is a traditional construction practice that has been practiced in San Juan for many years, but since 1948 it has been practiced following the seismic standards.

Figure 1: Typical building

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 5 meters.

2.2 Building Configuration

The typical shape of a building plan for this housing type is rectangular. The typical house has approximately seven openings, with an average area of 1.60 m². These openings are: 5 (five) windows, placed in the middle of the walls, and 2 (two) doors. The doors are placed to one side of the wall. The opening area is about 10.40% 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 no fire-protected exit staircases. Usually, there are 2 doors to one side in the building.

2.4 Modification to Building

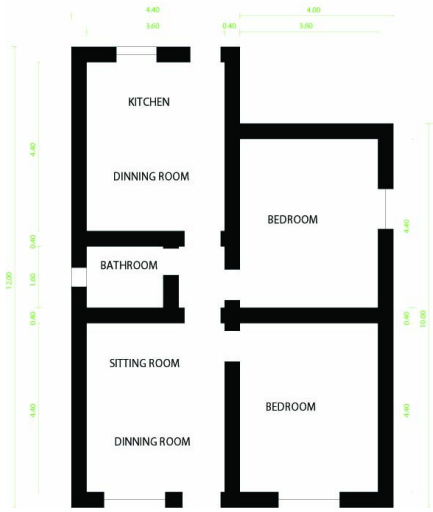

Figure 2: Plan of a typical building

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	☐
	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	☐

Structural concrete		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)	☐

40-cm-thick block walls joined using mud mortar.

3.2 Gravity Load-Resisting System

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

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). The earthquake-resistant system consists of adobe block walls of 40 cm thickness, which generally meet the quality standards and architectural requirements (small openings, heights shorter than 3 m). In general, the roofs are light (weight less than 150 kg/m^2). On the upper part of the wall, there is a reinforced concrete bond beam, and on the bottom there are foundations and plinth structure.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 12 and 12 meters, and widths between 8.4 and 8.4 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 4 meters. Typical Story Height: Variation of story height is 2.8 m - 3 m. The typical storey height in such buildings is 3.0 meters. The typical structural wall density is none. The total wall density is 0.215; it is 0.153 in the X-direction and 0.11 in the Y-direction.

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	☐	☑

. The roofing system consists of mud and cane roof with exterior finishing of day tiles supported by round logs. The roof is considered to be a flexible diaphragm with a maximum weight of 150 kg/m².

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	☐

Concrete, with a minimum cement of 180 kg/m³ and 30 % of stone. The top of the plinth is 30 cm above the ground level.

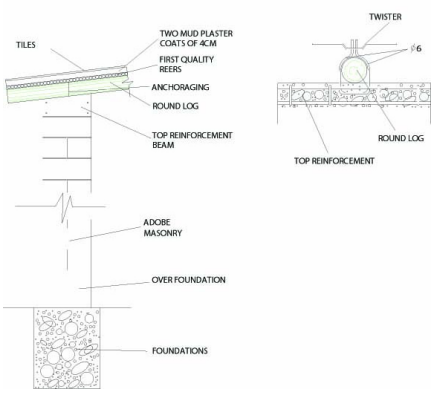

Figure 3: Critical structural details

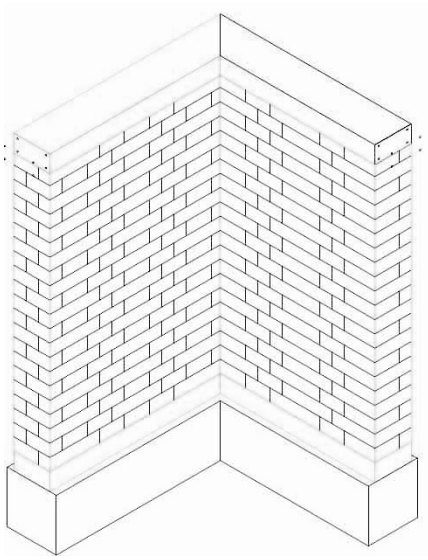
Figure 4: Key load-bearing elements

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

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

4.2 Patterns of Occupancy

In general, there is a single family in a 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)	☐

1. Below are the general guidelines related to the economic status of the inhabitants: Very Poor= lowest 10% of the population (per GDP), Poor= lowest 30% of the population, Middle Class= from the lowest 30% up to the top 20% of the population, Rich= top 20% of the population. Values are variable: the adobe blocks may be manufactured by the owner of the house and the masonry may also be made by the owner; canes grow on the banks of the water channels in the area. All this results in a notable reduction of the overall construction cost. Economic Level: For Poor Class the Housing Price Unit is 12,000 and the Annual Income is 7,200.

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 the '50s, a part of the cost was paid by the government, in the form of a non-repayable contribution or grant, and the rest of the money was financed by a bank. Nowadays, the construction is completely owner financed; the owners are doing the construction by themselves. In each housing unit, there are 1 bathroom(s) without toilet(s), no toilet(s) only and no bathroom(s) induding toilet(s).

4.4 Ownership

The type of ownership or occupancy is ownership with debt (mortgage or other).

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)	☐

The information in this chart reflects the period after the 1944 earthquake. After 1960, houses of this construction type

were built directly by the owners, without any kind of external financing.

5. Seismic Vulnerability

5.1 Structural and Architectural Features

Structural/ Architectural Feature	Statement	Most appropriate type		
		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.	☐	☑	☐
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	The resistance of adobe masonry in this construction type is weakened by the following factors: 1. The openings- due to the following factors: a) the big size of the two windows (1.60 m²) in the main face of the construction. b) The position of the doors in the angles formed by the meeting of walls. c) The great percentage of opening surface (31%) in the front and back walls. 2. The vulnerability of the adobe due to humidity		In general, during the 1977 earthquake, the adobe block construction built in Caucete using the standards of 1948, suffered moderate damage economically repairable); those built in the capital city of San Juan, under the same standards, were not damaged at all. Traditional adobe block houses, built without any kind of earthquake-resistant requirements, were seriously damaged during the same earthquake.
Frame (columns, beams)	No buttresses are provided at the wall intersections.		
Roof and floors	The roof is flexible.		

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *B: MEDIUM-HIGH VULNERABILITY (i.e., 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 *C: MEDIUM VULNERABILITY (i.e., moderate 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
1977	Caucete 100 km to the east of San Juan Capital City	7.4	IX MMI

In the Capital city of San Juan, located at approximately 100 km distance from the epicenter, the intensity was between VII MMI and VIII MMI. It is important to mention that a wide area of about 1000 km² experienced liquefaction.

Figure 5: Photograph illustrating typical earthquake damage

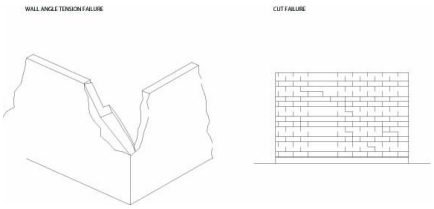

Figure 6: An illustration of key seismic features and/or deficiencies

Figure 7: Photograph illustrating typical earthquake damage

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Adobe blocks	3 kg/cm² - 10 kg/cm²	Clayey soil and thatch	Joined with mud: (1) resistance to compression, (2) resistance to flexion
Foundation	Concrete with stone	150 kg/cm²	1:3:5 and 3 (cement - sand - pebble and stone)	Minimum 180 kg/cm², 30% stone
Frames (beams & columns)	Reinforced concrete	200 kg/cm² 2400 kg/cm²	1:3:3 (cement-sand-gravel)	Top reinforced concrete beam is as wide as the wall. High resistance of concrete to compression, and of steel to tension.
Roof and floor(s)	Round logs with cane and mud roof		Round log d = 16 cm, every 60 cm	Roof maximum weight: 150 kg/m²

6.2 Builder

When this construction was first used, the builder did not live in this construction type. However, later on it was built by the owners themselves; in general, owners of this type of construction are people without any chances of building their houses with other building materials (due to their high cost).

6.3 Construction Process, Problems and Phasing

The owner of the house usually carries out the construction. It begins with the manufacturing of adobe, the filling in of foundations and plinth construction. After that, the adobe block masonry is built, caring that the blocks are perfectly joined. Then, the frame of the top reinforcement concrete beam is made, and the iron bars are placed to fasten the round logs of the roof. The frame is filled in with concrete. The round logs are placed and fastened every 60 cm. After that a 5cm-wide coat of cane and mud is placed. This coat is later made waterproof with asphalt, finishing the process with the placement of Spanish tiles. The tools and equipment typically used are: wheelbarrows, grub hoe, and matrix for the manufacturing of adobe blocks; spatulas, shovels, hoes, baskets, saws, pliers, levels, cement mixers, etc., are used in the whole process. The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size. This type of construction is generally designed for its final constructed size, but the owner also builds additional parts, generally without any professional input.

6.4 Design and Construction Expertise

This construction began to be practiced after the 1944 earthquake, as an alternative to improve the seismic behavior of the traditional adobe block construction. The design of adobe construction was largely based on the local building experience related to this kind of construction. This experience and the new information gained after the earthquake helped in improving the adobe construction practice. This construction proved to be an economic solution as the local material and skills were used and the traditional construction practice was followed. In the beginning, this type of construction was designed and built by engineers and general builders, but later the same construction began to be made by the owners.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. 1951 Building Code of the Province of San Juan, Earthquake-proof Norms Concar 70, Argentinean Earthquake-proof Norms 80 and 1990 INPRES CIRSOC Norms. 1951 Building Code of the Province of San Juan, Earthquake-proof Norms Concar 70, Argentinean Earthquake-proof Norms 80 and 1990 INPRES CIRSOC Norms.

The construction process is controlled by the corresponding state authorities.

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 is subject to regulations and the approval of plans. Building permits are required to build this housing type.

6.7 Building Maintenance

Typically, the building of this housing type is maintained by Owner(s). Usually, it is the owner who maintains the building, but given the low economic levels of the owners there is generally little or no maintenance and over time the construction deteriorates.

6.8 Construction Economics

Unit construction cost per m^2 of built-up area is approximately US$ 137. The typical amount and skill-level of labour employed in the construction of a typical building of this type of housing is 380 man-days (assuming 8 working hours/day). Experience is required in the selection of the land. Knowledge is necessary about the adequate mix proportions to manufacture the adobe blocks, and about foundations, plinth structure, top reinforcement beam, and round log. The tools needed in this construction type are not many: shovels, baskets, hoes, pliers, spatulas, etc.

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. Insurance policies for buildings make explicit that disasters are not covered. Not available.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

This type of construction has emerged as a proposal to strengthen the traditional adobe block construction which had an unsatisfactory performance during the 1944 earthquake. This construction has been built in San Juan under the Adobe Construction Regulations of 1948, however it is only allowed in rural areas. During the 1977 Caucete earthquake, this construction has a satisfactory performance so no seismic strengthening has been done since that time. It should be noted that some traditional adobe construction (not following the 1948 Regulations) is still being practiced in rural areas.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

Reference(s)

1. Adobe Construction Regulations
2. The 1951 Building Code of the Province of San Juan
3. Adobe Block Housing in Dry Areas
   Hugo Giuliani and Jose Herrera Cano
4. 1991 National Survey on Population and Housing (INDEC) N
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