World Housing Encyclopedia

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

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HOUSING REPORT
Confined Block Masonry House

Report #	1
Report Date	05-06-2002
Country	ARGENTINA
Housing Type	Confined Masonry Building
Housing Sub-Type	Confined Masonry Building with Concrete blocks, tie-columns and beams
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Summary

This is typically a one-or two-story residential building of detached or semi-detached construction, generally found in the urban areas of San Juan and Mendoza, and less frequently in the rural areas. The walls are made of concrete block masonry with reinforced concrete columns and beams that tie the walls together and provide strength for the building. One of the main structural deficiencies for this construction type lies in the widely different wall

densities in the two orthogonal directions. This deficiency may be eliminated with appropriate architectural design. This construction type is otherwise expected to demonstrate good seismic performance.

1. General Information

Buildings of this construction type can be found in San Juan Capital City and the surroundings. This type of housing construction is commonly found in urban areas. This construction type has been in practice for less than 50 years.

Currently, this type of construction is being built. This construction practice has been followed for 30 years.

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, each one with an average area of 2.50 m^2. The position of the openings differs from building to building, however generally there is a front door and a back or side door. There are windows in the family room, in every bedroom and the bathroom. The opening area is about 13% of the overall 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 is a front door and a back or side door in the building.

2.4 Modification to Building

This building type hasn't many modifications else.

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)	☐

3.2 Gravity Load-Resisting System

The vertical load-resisting system is confined masonry wall system. It consists of concrete block masonry walls with reinforced concrete beams and columns. In some cases, concrete beams and columns are provided without the masonry walls, in which case this system behaves as a frame; this depends on the architectural design.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is confined masonry wall system. It consists of concrete block masonry walls with reinforced concrete beams and columns.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 10 and 10 meters, and widths between 6.5 and 6.5 meters. The building has 1 to 2 storey(s). The typical span of the roofing/flooring system is 3 meters. The typical span between adjacent columns varies typically between 3.0 and 3.4 m. The typical storey height in such buildings is 3.3 meters. The typical structural wall density is up to 10 %. The total wall density is 0.116; it is 0.03 in the X-direction, and 0.08 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 flooring system is a nervure slab made of concrete with hollow clay blocks and fill-in elements. The roofing system is nervure slab made of concrete with hollow clay blocks and fill-in elements. It is considered to be a rigid diaphragm.

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	☐

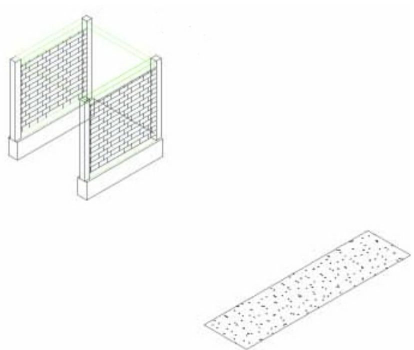
Figure 3: Key load-bearing elements

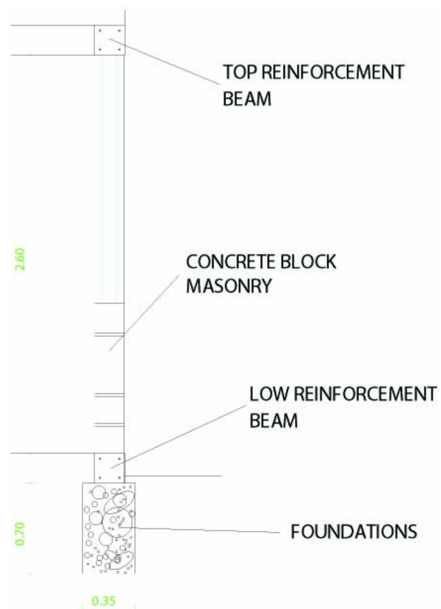

Figure 4: Critical structural details

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 1 housing unit(s). 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

A single family conducts its activities from each 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)	☐

Below are general guidelines related to the economic status of the inhabitants: Very Poor are lowest 10% of the population (per GDP), Poor from lowest 30% of the population, Middle Class from the lowest 30% up to the top 20% of the population, and Rich from top 20% of the population. For the Middle class, the price of the Housing Unit is 18,000 and their annual Income is 20,000.

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 no bathroom(s) including 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)	☐

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	In general, this type of building has no seismic deficiencies, except when the construction is not controlled by an official organization.		During the earthquake of 1977 in Caucete, in the capital city of San Juan, located about 100 km from the epicenter, the intensity was between VII and VIII. The buildings of this construction type sustained no serious damage
Frame (columns, beams)	Generally without seismic deficiencies		
Roof and floors	No seismic deficiencies		
Other			

5.3 Overall Seismic Vulnerability Rating

The overall rating of the seismic vulnerability of the housing type is *E: LOW VULNERABILITY (i.e., very good seismic performance)*, the lower bound (i.e., the worst possible) is D: MEDIUM-LOW VULNERABILITY (i.e., good seismic performance), and the upper bound (i.e., the best possible) is *F: VERY LOW VULNERABILITY (i.e., excellent 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	7.4	IX

In the Capital city of San Juan, located about 100 km from the epicenter, the intensity was between VII and VIII. The buildings of this construction type sustained the earthquake without serious damage.

Figure 5: Photograph illustrating typical earthquake damage

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Hollow concrete blocks.	Compressive strength of the blocks varies from 2-50 kg/cm².	The mix proportion used in making the mortars is 1:1:5 (cement-lime-sand). Wall thickness varies from 0.20 to 0.40 m.	The walls have good resistance to compression and shear strength.
Foundation	Concrete.	Compressive strength of the concrete used is 210 kg/cm².	The mix proportion used in making the concrete is 1:3:5 (cement-sand- pebble). The foundation under columns is of size 0.60 m x 0.25 m.	The foundation has average resistance to compression.
Frames (beams & columns)	Beams and columns used for confining the masonry walls are made of reinforced concrete.	The compressive strength of the concrete used is 210 - 420 kg/cm².	The mix proportion used in making the concrete is 1:2:4 (cement-sand-pebble). The size of columns is 0.20 m x 0.20 m and that of beams is 0.20 m x 0.15 m.	
Roof and floor(s)	The roof is made of reinforced concrete hollow clay blocks.	The compressive strength of the concrete used is 210 - 420 kg/cm².	The mix proportion used in making the concrete is 1:2:4 (cement-sand-pebble).	

6.2 Builder

The builder usually does not live in this construction type. It is designed and built by professionals and used in housing plans developed and financed by the state.

6.3 Construction Process, Problems and Phasing

The construction process is usually carried out by a construction company. It begins with the filling in of foundations, the assembling of the bottom reinforced concrete beams and columns and the casting of these beams. Then the block masonry walls are being built and the concrete columns are being cast. Subsequently, the top reinforced concrete beams are assembled and the slab concrete is poured. The tools and equipment typically used are: spatulas, shovels, hoes, baskets, saws, pliers, levels, cement mixers. The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size. This type of construction is generally designed for its final constructed size, but usually the final size is fulfilled in a later stage, as an extension of the original construction. Sometimes the owner also builds additional parts, generally without any professional input.

6.4 Design and Construction Expertise

The professionals involved in the design and construction process -architects and engineers- have a good level of expertise and great experience in this type of construction, typical in San Juan. Architects are in charge of the architectural design of the building and sometimes, the construction process. Engineers are in charge of the structural design and of the construction process in general.

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. The relevant national codes and standards are: 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 provincial authorities approve the design and control the construction process. To start the process of construction it is necessary to have the approval of the general and structure plans, the electrical wiring plans, plumbing, and gas plans. This approval is provided by the Provincial Authorities. A construction license provided by the Municipal Authorities is also required.

6.6 Building Permits and Development Control Rules

This type of construction is a non-engineered, and authorized as per development control rules. 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 little or no maintenance is done.

6.8 Construction Economics

The unit construction cost per m² of built-up area is approximately US$ 250. This price includes the entire needs of the construction. To start the process of construction, it is necessary to have the approval of the general and structure plans, the electrical wiring plans, plumbing, and gas plans. This approval is provided by the Provincial Authorities. A construction license provided by the Municipal Authorities is also required. This type of building will need approximately 4 months to complete the construction. Workmen must satisfy minimum requirements like some expertise in the making of concrete, bond-beams, tie-columns, slabs cement mortars, and joists as well as in the construction of block masonry walls.

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.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Wall	Increase the width of some walls. This has a low increase in the construction cost and a high likelihood of enhancing seismic stability. It is relatively simple to perform.

8.2 Seismic Strengthening Adopted

8.3 Construction and Performance of Seismic Strengthening

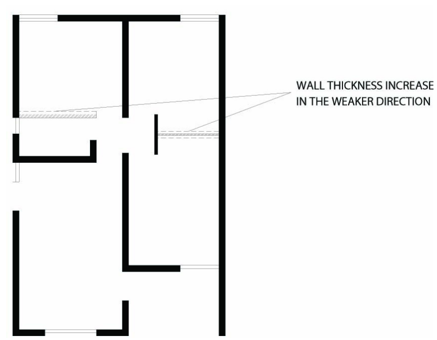

Figure 6: Illustration of seismic strengthening techniques

Reference(s)

1. The 1951 Building Code of the Province of San Juan
2. Inter-relations between Architectural Design and Structural Design in High Seismic Risk Areas : Building Level - San Juan
   San Juan, Argentina 1989
3. Earthquake-proof Norms Concar 70

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