World Housing Encyclopedia

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

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

HOUSING REPORT
Solid brick masonry house with composite hollow clay tile and concrete joist roof slabs

Report #	70
Report Date	05-06-2002
Country	ARGENTINA
Housing Type	Confined Masonry Building
Housing Sub-Type	Confined Masonry Building : Clay brick masonry, with concrete tie-columns and beams
Author(s)	Virginia I. Rodriguez, Maria I. Yacante, Sergio Reiloba
Reviewer(s)	Argimiro C. Gandica

Summary

This housing type is found in the urban areas of San Juan province. It is a one-story, detached or semi-detached building, mainly used as a single-family house. The strength of this

construction type is due to its solid brick walls confined with concrete tie-beams and tie-columns. The roof slabs are of composite concrete and masonry hollow clay tile construction, which form a diaphragm tied to the walls. The deficiency of this type of construction is found in the slabs which suffer serious deterioration due to the effects of humidity. This housing type is expected to have good seismic behavior.

1. General Information

Buildings of this construction type can be found in Argentina. Nowadays, this housing type represents about 30% of all the houses built in the capital city of the province of San Juan, reaching 70% in certain neighborhoods. 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. .

Figure 1: Typical Building

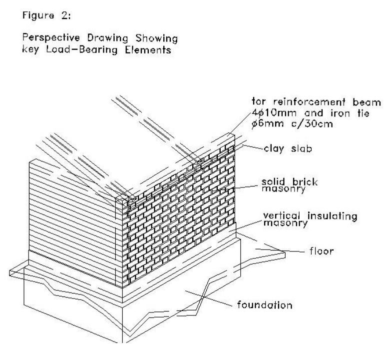

Figure 2: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in flat terrain. They do not share common walls with adjacent buildings. When separated from adjacent buildings, the typical distance from a neighboring building is 3.00 meters.

2.2 Building Configuration

The typical shape of a building plan for this housing type is rectangular. This housing type has five (5) windows and two (2) doors. It has a main window of about 3.5 m^2, other windows have an area that varies between 1 m^2, and 1.5 m^2.The area of the two doors varies between 1.70 m^2 and 2 m^2. All these openings are placed next to or very near the tie columns. 11.20% is the percentage for the overall window and door area as a fraction of the overall wall surface 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 an additional door on the side wall besides the main entry.

2.4 Modification to Building

A typical pattern of modification observed in this housing type is the extension of the dining room up to the building line and/or a garage. The most common final plan configuration is the "L" shape.

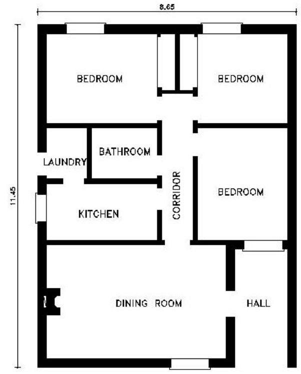

Figure 3: Plan of a Typical Building

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	☐
		20	Designed for seismic effects, with structural infill walls	☐
		21	Dual system – Frame with shear wall	☐

Structural concrete	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. Confined solid brick masonry with concrete tie columns and bond beams.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is confined masonry wall system. Confined solid brick masonry with concrete tie columns and bond beams.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 11.5 and 11.5 meters, and widths between 8.5 and 8.5 meters. The building is 1 storey high. The typical span of the roofing/flooring system is 4.00 meters. Typical Story Height: 2.80 meters in flat roof buildings and 4.30 meters in gable roof buildings. Sloping roof has 2.80 meters in perimeter walls and 4.30 meters in ridge. The typical storey height in such buildings is 2.80 meters. The typical structural wall density is up to 20 %. Total wall area/plan area: 0.15. Direction Y: 0.06 Direction X: 0.03.

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 slabs are made of concrete ribs and precast clay joists, with concrete topping cast in-situ. The floor/roof system 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	☐
	Reinforced-concrete bearing piles	☐

Deep foundation	Reinforced-concrete skin friction piles	☐
	Steel bearing piles	☐
	Steel skin friction piles	☐
	Wood piles	☐
	Cast-in-place concrete piers	☐
	Caissons	☐
Other	Described below	☐

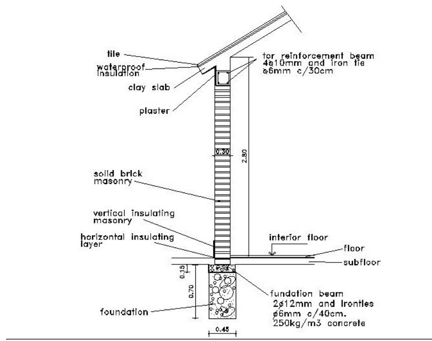

Figure 4: Critical Structural Details (e.g. wall section, foundations, roof-wall connections, etc.)

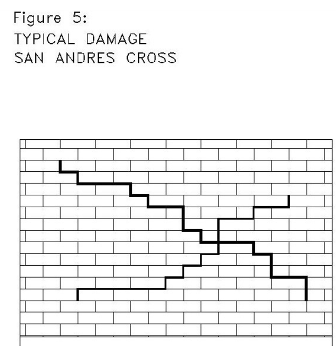

Figure 5: An Illustration of Key Seismic Features and/or Deficiencies

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

One family.

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)	☐

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 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		
		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.	☑	☐	☐
	The floor diaphragm(s) are considered to be rigid and it			

Floor construction	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	Both kinds of situations are present in this construction type because the slab deteriorates with humidity.			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Walls within frames of columns and beams	No deficiency	The required wall resistance necessary in the area is 0.02 in accordance with INPRES-CIRSOC 103. The common densities of this construction type in a normal direction at the front is 0.06; and in a parallel direction at the front 0.03. They generally offer a high resistance capacity, even under the present standards.	Diagonal shear cracks in buildings with poor construction quality.
Frame (columns, beams)			
Roof and floors	The structure is frequently rusted because the roof has deficient waterproof		

	insulation.		

5.3 Overall Seismic Vulnerability Rating

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

In the Capital city of San Juan Province, located 100 kilometers from the epicenter the intensity was between VI and VII per the MMI scale. Buildings of this construction type suffered minor damage.

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Solid clay brick	2.5 kg/cm² (1) 15 kg/cm² (2)	1:1:5 (cement/lime/sand) Dimensions: 6 X 13 X 27	(1) Resistance to shear strength (2) Resistance to compression
Foundation	Cyclopean concrete	130 kg/cm² (3)	1:3.50:4 (cement/sand/stone) Dimensions according to calculations. Minimum: wall width + 15 cm X 70 cm	(3) Typical resistance
Frames (beams & columns)	Reinforced concrete	170 kg/cm² (4) 4200 kg/cm² (5)	Columns 1:2.5:3.5 (cement/sand/stone) : 0.20 x 0.20 m 0.13 x 0.20 m 0.13 x 0.13 m Beams: 0.27 x 0.35 m 0.12 x 0.35 m	(4) Typical resistance of concrete (5) Typical resistance of steel
Roof and floor(s)	Clay joist slab	170 kg/cm² (6) 4200 kg/cm² (7)	1:2.5:3.5 (cement/sand/stone) Hollow brick	(6) Typical resistance of concrete (7) Typical resistance of steel

6.2 Builder

The builder usually does not live in this construction type. This type of building is designed and built by professionals.

6.3 Construction Process, Problems and Phasing

This construction type is built by a construction company. The construction process begins with the digging and filling of the foundations. Then the frame of low reinforcement concrete beam and the columns are placed, later the beams are filled; the masonry is erected and the columns are filled. Finally, the frames of the top reinforcement beams are placed and the slab is built to fill with concrete all the structure at once. This construction process does not need many tools. The tools and equipment typically used are: shovels, hoes, baskets, pliers, levels, cement mixers, etc. The construction of this type of housing takes place incrementally over time. Typically, the building is originally designed for its final constructed size. This construction type is designed for its final constructed size, but it is usually extended. The extensions are generally built without the participation of an architect or an engineer.

6.4 Design and Construction Expertise

This construction type was most prevalent between 1950 and 1970. Nowadays it is rarely built. Architects and engineers involved in the design and construction process acquired a good level of expertise since the reconstruction of the city of San Juan after the earthquake of 1944. Architects are in charge of the architectural design and they are sometimes responsible for the construction process of this housing type. Engineers work in structural design and sometimes in the construction process too.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. "Código de la Edificación de la Provincia de San Juan". The year the first code/standard addressing this type of construction issued was 1951. "Normas Argentinas para Construcciones Sismorresistentes" (INPRES-CIRSOC 103 Rules - 1983). The seismic code: "Normas Argentinas para Construcciones Sismorresistentes" (Reglamento INPRES-CIRSOC 103) first issued in November 1983, and nowadays in current use, allows the construction of ribbing slabs. The most recent code/standard addressing this construction type issued was 1983. Title of the code or standard: "Código de la Edificación de la Provincia de San Juan" Year the first code/standard addressing this type of construction issued: 1951 National building code, material codes and seismic codes/standards: "Normas Argentinas para Construcciones Sismorresistentes" (INPRES-CIRSOC 103 Rules - 1983). The seismic code: "Normas Argentinas para Construcciones Sismorresistentes" (Reglamento INPRES-CIRSOC 103) first issued in November 1983, and nowadays in current use, allows the construction of ribbing slabs. When was the most recent code/standard addressing this construction type issued? 1983.

The process of application of the Building Code is -in general- appropriate. In the province of San Juan there is an official entity called Dirección de Planeamiento y Desarrollo Urbano (Planning and Urban Development Secretary) which examines and approves the projects (the functional design and the structural calculations). This office also examines the foundations and the structure (plinth, columns, beams, slabs) that must be in accordance with the previously approved project.

6.6 Building Permits and Development Control Rules

This type of construction is an 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). There is no careful maintenance of the building.

6.8 Construction Economics

450 $US/m. This construction type requires the approval of the architectural plans, the structural plans, and the sanitary installations plans by the provincial authorities; it also needs the electrical installation plans and the building permit given by the municipal authority. Nowadays, the gas installation plans are examined and approved by a private entity. This type of construction needs about 3 or 4 months to complete the construction.

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 does not cover earthquakes, and in fact they make explicit that there is no coverage for catastrophes.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

8.2 Seismic Strengthening Adopted

Has seismic strengthening described in the above table been performed in design and construction practice, and if so, to what extent?
No.

Was the work done as a mitigation effort on an undamaged building, or as repair following an earthquake?
N/A.

8.3 Construction and Performance of Seismic Strengthening

Was the construction inspected in the same manner as the new construction?
N/A.

Who performed the construction seismic retrofit measures: a contractor, or owner/user? Was an architect or engineer involved?
N/A.

What was the performance of retrofitted buildings of this type in subsequent earthquakes?
N/A.

Reference(s)

1. Interrelations Between Architectural Design and Structural Design in High Seismic Risk Areas
   Unversidad Nacional de San Juan, San Juan, Argentina 1989

2. Interrelations Between Architectural Design and Urban Design in High Seismic Risk Areas
   Universidad Nacional se San Juan, Argentina 1994

3. The 1951 Building Code of the Province of San Juan

4. Argentinean Standards for Earthquake Resistant Constructions (INPRES-CIRSOC 103 Rules) 1993

Author(s)

1. Virginia I. Rodriguez
   Architect/Professor
   #B UDAP III M.EM Block 1 Piso #1, San Juan 5425, ARGENTINA
   Email:deskjet@impsat1.com.ar FAX: 54-264-4342556

2. Maria I. Yacante
   Architect/Professor
   Av. Libertador 1068 (s), San Juan 5400, ARGENTINA

3. Sergio Reiloba
   Architect
   Napole, San Juan 5400, ARGENTINA
   Email:cereiloba@mixmail.com

Reviewer(s)

1. Argimiro C. Gandica
   Professor
   , University of the Andes
   Merida 5101, VENEZUELA
   Email:argimirocastillo@icnet.com.ve FAX: (58-414) 745 7626

Save page as