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
Popular, non-engineered urban housing on flat terrain

Report #	67
Report Date	05-06-2002
Country	VENEZUELA
Housing Type	RC Moment Frame Building
Housing Sub-Type	RC Moment Frame Building : Designed for gravity loads only, with URM infills
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Summary

This is an urban housing construction type found in the Andean states of Venezuela. In some cities, e.g., Mérida, this construction accounts for 40% of the total building stock. Typical buildings of this type are two to three stories high. Typically, there are two or three bays in the

longitudinal direction (spaced at 3 to 4 m) and four or five bays in the transverse direction (4 to 5 m apart). The main load-bearing system consists of reinforced concrete frame (columns and beams) with hollow clay tile, and masonry-infill walls. The roof structure consists of lightweight roofing (zinc and/or acclimatized galvanized sheets) supported by I-shaped steel beams. The building's roof level is used as a terrace with a one-meter-high masonry parapet, which serves as a guardrail on the slab perimeter. This is a non-engineered construction, i.e., these buildings are constructed by the owners. Because of the lack of adequate detailing in the longitudinal and transverse steel reinforcement bars, beam-column connections are inadequate and do not provide the continuity required for adequate seismic performance.

1. General Information

Buildings of this construction type can be found in Mérida, Táchira and Trujillo, comprising the Andean states in Venezuela. This housing covers almost 40% of the total building stock in the city of Mérida. This type of housing construction is commonly found in urban areas.

See Figure 1.

This construction type has been in practice for less than 50 years.

Currently, this type of construction is being built. .

Figure 1: Typical Building

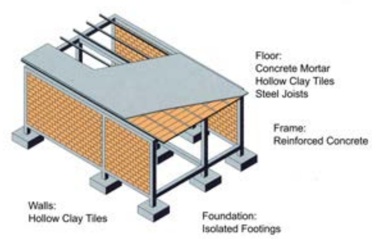

Figure 2: Key Load-Bearing Elements

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 0.03-0.05 meters.

2.2 Building Configuration

The typical shape of a building plan for this housing type is rectangular, with proportions (width/length) ranging from 1/3 to 1/4. Usually, openings are created at the front and the back of the building, with door and window openings on the first level and two windows on successive levels. The openings range from 5 to 10% of the overall wall area.

2.3 Functional Planning

The main function of this building typology is multi-family housing. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Consideration has not been given to the means of escape. Only one access door is available and it is protected with an external metallic door equipped with more than one lock (due to the high rate of criminality). Additional staircases in higher buildings are not practical because of the proximity of the buildings.

2.4 Modification to Building

Modifications respond to vertical growth: balconies, new windows, and staircases for separate access to upper levels. Usually, when a new level is constructed, an external staircase facing the façade is built to permit separate access to the upper levels. Windows and balconies are located in the façade and back walls. When possible, windows are built in lateral walls, due to the lateral proximity of the buildings.

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	☐
		22	Moment frame with in-situ shear walls	☐

Structural concrete	Structural wall			
		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)	☐

See Figure 2.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is reinforced concrete moment resisting frame. .

3.3 Lateral Load-Resisting System

The lateral load-resisting system is others (described below). Reinforced concrete frames generally provide acceptable lateral load resistance, depending upon quality adequacy and upon the detailing of structural elements (columns and beams). In this case, several of the items are inadequate: the detailing of the reinforced concrete columns and beams, e.g., excessive stirrup spacing (same distance of element's section base); the tie anchorage (angle of anchorage is 90º instead of 135º as recommended in seismic codes); and the location of the laps in longitudinal reinforcement for columns (laps are provided at the bottom of columns in successive stories). The roof structure consists of lightweight roofing (zinc and/or acclimatized galvanized sheets) supported by I-shaped steel beams.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 12 and 15 meters, and widths between 3 and 5 meters. The building has 2 to 3 storey(s). The typical span of the roofing/flooring system is 5.0 meters. Typical Span: Usually, the typical span ranges from 3 to 5 meters. The typical storey height in such buildings is 2.8 meters. The typical structural wall density is none. Two possibilities regarding wall density exist depending on the position of the building in the block; there are wall density values for inner and for corner buildings respectively. Wall Density for Inner Buildings: Floor Number Total Wall Area longitudinal direction Total Wall Area transverse direction Typical Wall Density long. Dir. Typical Wall Dens. Trans. Dir 1 114.24 56.96 1.28 0.64 2 119 64.72 1.33 0.62 Wall Density for Corner Buildings: Floor Number Total Wall Area longitudinal direction Total Wall Area transverse direction Typical Wall Density long. Dir. Typical Wall Dens. Trans. Dir 1 108.48 56.96 1.21 0.64 2 114.2 64.72 1.28 0.72.

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	☑	☑

Floor: composite hollow clay tiles and steel joists. Roof: steel joists and metal sheathing (zinc/aluminum). Floors may be considered as rigid diaphragms. Special inspection must be performed on floor connections with beams to guarantee transmission of lateral loads. The roof may not be considered as a rigid diaphragm, due to the reduced sections (at most IPN 80), the low connectivity between joists and the lack of connection with the rest of the structure (absence of a collar beam on the top of walls in the roof level). Floor: composite hollow clay tiles and steel joists. Roof: steel joists and metal sheathing (zinc/aluminum) Floors may be considered as rigid diaphragms. Special inspection must be performed on floor connections with beams to guarantee transmission of lateral loads. The roof may not be considered as a rigid diaphragm, due to the reduced sections (at most IPN 80), the low connectivity between joists and the lack of connection with the rest of the structure (absence of a collar beam on the top of walls in the roof level).

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	☐

See Figure 2.

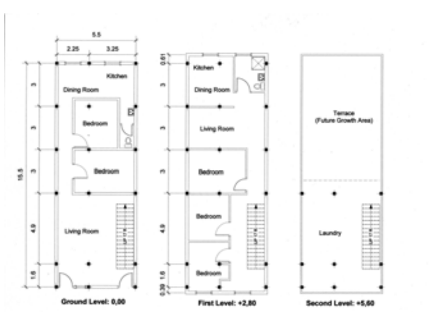

Figure 3: Plan of a Typical Building

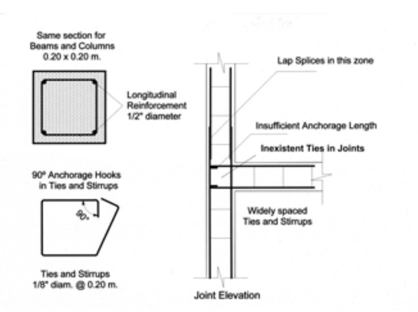

Figure 4: Critical Structural Details

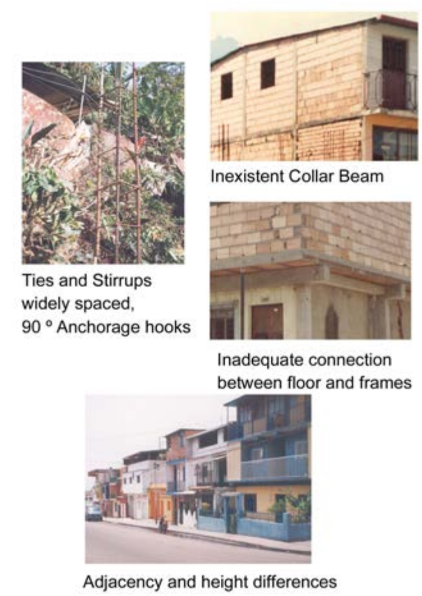

Figure 5: An Illustration of Key Seismic Features and/or Deficiencies

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 2 housing unit(s). This is an estimate of the average number of housing units per 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 11-20.

4.2 Patterns of Occupancy

The number of families depends mostly upon the number of levels (e.g., two levels, two families). An average occupancy pattern is two families (5.40 members/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)	☐

Annual income ranges from $2000-$3000 Currency: US $ Economic Level: For Poor Class the Housing Price Unit is 31000 and the Annual Income is 2500.

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 no bathroom(s) without toilet(s), no toilet(s) only and 1 bathroom(s) including toilet(s).

Each housing unit has a bathroom. If several housing units are present in a building (the average is two), there are as many bathrooms as housing units. .

4.4 Ownership

The type of ownership or occupancy is outright ownership.

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.	☐	☑	☐
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	No reinforcement is visible throughout the walls (neither horizontal nor vertical). Poor quality mortar and cracked masonry units.		Cracks in walls, parts of walls collapse, great cracks in windows and around doors.
Frame (columns, beams)	Stirrup and tie spacing either in beams or in columns is not compliant with recommendations for less than d/2 spacing in beams and d/4 in columns. Spacing is regular throughout all members and is usually d or more. Anchorage hooks into the member cores are generally 90º, and do not comply with the recommendations for a minimum of 135º. Lap splices in longitudinal column bars are located at the bottom of tie-columns; no special spacing in ties is practiced, producing a potential plastic hinge formation region at the bottom of the column. Because sections and reinforcement detailing in beams and columns are identical, the Strong Column/Weak Beam recommendation is not complied with; this creates the possibility of column hinging and consequently leads to story mechanisms and concentration of inelastic activity at a single level.		Shear failure in connections between columns and beams, and between columns and foundations, excessive lateral displacements, cracking and spalling concrete columns due to inadequate confinement.
Roof and floors	The roof may not be considered as a rigid diaphragm due to the lack of adequate connectivity within its elements and within the walls (absence of a collar beam on top of walls at this level). Connections between floor and frames must be inspected to guarantee adequate linking and load transmission.		Roofs: great movement may be generated in roofs, total dismantlement and consequent collapse may occur. Floors: great movements may inflict damage in confinement and walls.
Other	Risk of pounding effect. Insufficient spacing between adjacent buildings - the distance is not greater than 10.0 cm.		Column failure at the level where slabs of neighboring construction pound.

See Figures 4 and 5.

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
1997	10.5N 5.3ºW Depth 9.4 km (Caríaco, Venezuela)	6.8	VIII (MMI)

See Figure 6.

Figure 6: A Photograph Illustrating Typical Damage (1997 Cariaco earthquake)

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Hollow Clay Tile Cement Mortar	Cement mortar 3.0 MPa	W/H/L (mm.) 100/250/350 120/250/350 150/200/350 200/200/350 N/A	
Foundation	Reinforced Concrete		W/H/L (mm.) 1000/400/1000	
Frames (beams & columns)	Reinforced Concrete		N/A	
Roof and floor(s)	Floors: Clay Tiles Steel Joists Roof: Steel Joists Ties Metal sheathing (zinc/aluminum)	Floor: N/A Structural Steel Roof: Structural Steel Mild Steel	Floor: W/H/L (mm.) 60/350/600 60/350/800 IPN 80 (h: 80 mm) IPN 100 (h:100 mm) Roof: IPN 80 (h:80 mm) 2 X 1 inches W/L (mm.) 830/4000	

6.2 Builder

The builder lives in this construction type.

6.3 Construction Process, Problems and Phasing

Construction process is performed in vertical phases, i.e., a level at a time. The common practice is to build foundations and columns for the first level, leaving the columns' longitudinal steel bars to be spliced. After concrete curing, the walls are built. Beams are built over walls, and afterwards the first slab (hollow clay tiles with steel joists) is constructed. The owner typically builds with no more than two helpers. The entire process is performed at the building site with ordinary building tools; no special machinery or equipment is used. The construction of this type of housing takes place incrementally over time. Typically, the building is originally not designed for its final constructed size. Construction phasing depends on the availability of money. These resources are obtained from savings and from the cooperation of other family members. Usually the inhabitants collaborate in the building process.

6.4 Design and Construction Expertise

No professionals (architects or engineers) are involved in the design and construction process. Builders depend mainly on some experience in building construction. "Semi-skilled" seems to most accurately describe the expertise of the builders. Construction professionals (architects or engineers) are not involved either in the design or in the construction process. Professional intervention is unaffordable for the inhabitants of these settlements.

6.5 Building Codes and Standards

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

Official authorities are not carrying out a process or strategy for enforcing building codes.

6.6 Building Permits and Development Control Rules

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

6.8 Construction Economics

Unit construction cost: 87000 Bs. (120 US$) per m² of built-up area. With a team of three workers, 45 to 55 days are required to complete each level of 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.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

For the moment, seismic strengthening provisions have not been performed, either in design or in retrofitting.

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.

8.3 Construction and Performance of Seismic Strengthening

Reference(s)

1. Basic Concepts of Seismic Codes, Vol.1, Part I, Non- Engineered Construction
   IAEE

2. Evaluaci
   FUNVISIS (Fundaci 1997

3. FEMA 310 Handbook for the Seismic Evaluation of Buildings: A Pre-standard
   Federal Emergency Management Agency, Washington, D.C. 1998

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