World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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

HOUSING REPORT

Popular, non-engineered urban housing on flat terrain

Report#	67
Last Updated	
Country	Venezuela
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Important

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General Information

Building Type:	Popular, non-engineered urban housing on flat terrain
Country:	Venezuela
Author(s):	Argimiro Castillo Gandica Francisco Lopez Almansa
Last Updated:	
Regions Where Found:	Buildings of this construction type can be found in Merida, Tachira and Trujillo, comprising the Andean states in Venezuela. This housing covers almost 40% of the total building stock in the city of M#rida. This type of housing construction is commonly found in urban areas.
Summary:	This is an urban housing construction type found in the Andean states of Venezuela. In some cities e.g. Merida 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 masonry infill walls. Roof structure consists of lightweight roofing (zinc and/or acclimatized galvanized sheets) supported by I-shaped steel beams. The roof level of a building is used as a terrace with an one meter high masonry parapet that serves as a guardrail on the slab perimeter. This is a nonengineered construction i.e. these buildings are constructed by the owners. Due to 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.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Other
Typical number of stories:	2-3
Terrain-Flat:	Typically
Terrain-Sloped:	Off

Comments:	0.03 up to 0.05 meters typical separation distance between buildings

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	Typical shape of a building plan for this housing type is rectangular, with proportions (width/length) ranging from 1/3 to 1/4.
Typical plan length (meters)	12-15
Typical plan width (meters)	3-5
Typical story height (meters)	2.8
Type of Structural System	Structural Concrete: Moment Resisting Frame: Designed for gravity loads only, with URM infill walls
Additional comments on structural system	The vertical load-resisting system is reinforced concrete moment resisting frame. 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 90# instead of 135# 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.
Gravity load-bearing & lateral load-resisting systems	See Figure 2.
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	Two possibilities regarding wall density exist depending on position of the building in the block; there are Inner and Corner buildings Wall Density 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
Wall Openings	Usually, openings are produced at the front and the back of the building, having door and window openings on the first level and two windows in successive levels. The openings range from 5 to 10% of the overall wall area.
Is it typical for buildings of this type to have common walls with adjacent buildings?	No
Modifications of buildings	Modifications respond to vertical growth, balconies, new windows, staircases for separate access to upper levels. Usually, when a new level is constructed, an external staircase facing the facade is built to permit separate access to upper levels. Windows and balconies are located in the facade and back walls. In lateral walls, windows are built when possible due to lateral proximity between buildings.
Type of Foundation	Shallow Foundation: Reinforced concrete isolated footing
Additional comments on foundation	See Figure 2
Type of Floor System	Other floor system
Additional comments on floor system	Composite hollow clay tiles and steel joists; Floors may be considered as rigid diaphragms. Special inspection must be performed on floor connection with beams, to guarantee transmission of lateral loads.
Type of Roof System	Roof system, other
Additional comments on roof system	Steel joists and metal sheathing (zinc/aluminum); 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 top of walls in roof level).
Additional comments section 2	When separated from adjacent buildings, the typical distance from a neighboring building is 0.03-0.05 meters.

Building Materials and Construction Process

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: Hollow Clay Tile, Cement Mortar Frame: Reinforced Concrete	Characteristic Strength: Cement mortar 3.0 MPa Mix Proportion/Dimensions: W/H/L (mm.)100/250/350120/250/350150/200/350200/200/350 N/A

Foundations	Reinforced Concrete	Mix Proportion/Dimensions: W/H/L (mm.)1000/400/1000
Floors	Clay tiles Steel joists	Characteristic Strength: N/A Structural Steel Mix Proportion/Dimensions: W/H/L (mm.)60/350/60060/350/800 IPN 80(h: 80mm)IPN100(h:100mm)
Roof	Steel Joists Ties Metal sheathing (zinc/aluminum)	Characteristic Strength: Steel Mild steel Mix Proportion/Dimensions: IPN 80 (h:80mm) 2x1 inches W/L (mm.)830/4000
Other		

Design Process

Who is involved with the design process?	Other
Roles of those involved in the design process	As an auto-constructed type, construction professionals (Architects and/or Engineers) are not involved in the design or in the construction process. Professional intervention is unaffordable for the inhabitants of these settlements.
Expertise of those involved in the design process	No professionals (Architects and/or Engineers) are involved in the design or construction process.

Construction Process

Who typically builds this construction type?	Other
Roles of those involved in the building process	The builder lives in this construction type.
Expertise of those involved in building process	Builders mainly count on some experience in building construction. Semi-skilled level seems to suit adequately the expertise of the builders.
Construction process and phasing	Construction process is performed in vertical phases, i.e. a level at a time. Common practice is to build foundations and columns for the first level, leaving 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.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	No
Applicable codes or standards	
Process for building code enforcement	Official authorities have no process or strategy for building code enforcement.

Building Permits and Development Control Rules

Are building permits required?	No
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	No
Additional comments on building permits and development control rules	

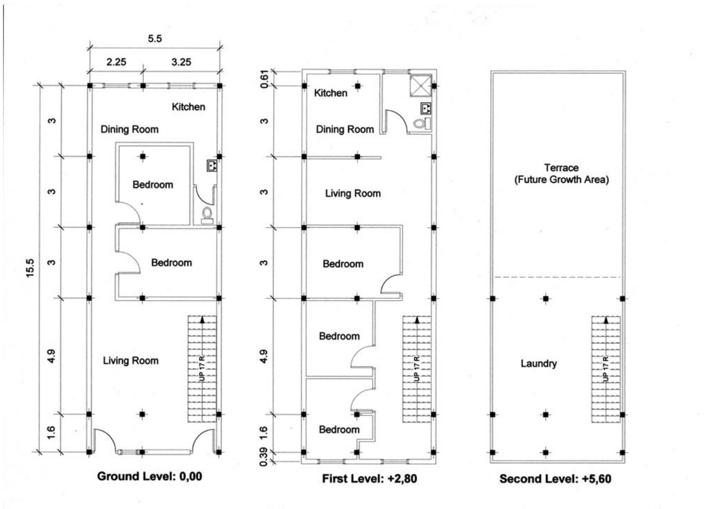
Building Maintenance and Condition

Typical problems associated with this type of construction	Inexistent seismic detailing features in reinforced concrete works. Connections between floors and structural frames do not guarantee lateral force transmission and may induce displacement of slabs with respect to the frames generating damage to columns. Parapets in uppermost levels represent a dangerous collapsible feature. The absence of collar beams and horizontal reinforcement in uppermost walls may produce out-of-plane inertial loads. Gap between adjacent buildings (not greater than 10.0 cm.) creates risk of pounding effect.
Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	

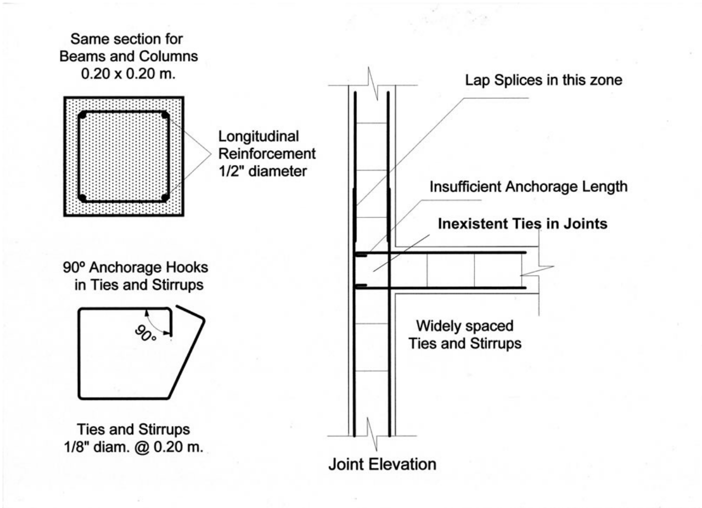
Construction Economics

Unit construction cost	Unit construction cost: 87000 Bs. (120 US$) per square

Unit construction cost	meter of built-up area.
Labor requirements	For each level, with a three worker team, 45 to 55 days are required to complete the construction.
Additional comments section 3	



Plan of a Typical Building



Critical Structural Details

Ties and Stirrups widely spaced, 90 º Anchorage hooks

Inexistent Collar Beam

Inadequate connection between floor and frames

Adjacency and height differences

An Illustration of Key Seismic Features

and/or Deficiencies

Socio-Economic Issues

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). Each building typically has 2 housing unit(s). This is an estimate of the average number of housing units per building.
Number of inhabitants in a typical building of this construction type during the day	<5
Number of inhabitants in a typical building of this construction type during the evening/night	10-20
Additional comments on number of inhabitants	
Economic level of inhabitants	Low-income class (poor)
Additional comments on economic level of inhabitants	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: 5:1 or worse
Typical Source of Financing	Owner financedPersonal savings
Additional comments on financing	
Type of Ownership	Own outright
Additional comments on ownership	
Is earthquake insurance for this construction type typically available?	No
What does earthquake insurance typically cover/cost	
Are premium discounts or higher coverages available for seismically strengthened buildings or new buildings built to incorporate seismically resistant	No

features?	
Additional comments on premium discounts	
Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
1997	10.5N 5.3#W Depth 9.4 km(Car#aco, Venezuela)

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	See Figure 6.
Additional comments on earthquake damage patterns	Wall: Cracks in walls, parts of walls collapse, great cracks in windows and around doors. Frame: 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/Floors: Roof- great movements may be generated in roofs, total dismantlement and consequent collapse may occur. Floors- great movements may inflict damage in confinement and walls. Other: Column failure at level where slabs of neighboring construction pounds.

Structural and Architectural Features for Seismic Resistance

The main reference publication used in developing the statements used in this table is FEMA 310 “Handbook for the Seismic Evaluation of Buildings-A Pre-standard”, Federal Emergency Management Agency, Washington, D.C., 1998.

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.

Structural/Architectural Feature	Statement	Seismic Resistance
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.	FALSE
Building Configuration-Vertical	The building is regular with regards to the elevation. (Specify in 5.4.1)	TRUE
Building Configuration-Horizontal	The building is regular with regards to the plan. (Specify in 5.4.2)	TRUE
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.	FALSE
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.	FALSE
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.	TRUE
Wall and Frame Structures-Redundancy	The number of lines of walls or frames in each principal direction is greater than or equal to 2.	TRUE
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	FALSE

	walls);	
Foundation-Wall Connection	Vertical load-bearing elements (columns, walls) are attached to the foundations; concrete columns and walls are doweled into the foundation.	TRUE
Wall-Roof Connections	Exterior walls are anchored for out-of-plane seismic effects at each diaphragm level with metal anchors or straps.	FALSE
Wall Openings		FALSE
Quality of Building Materials	Quality of building materials is considered to be adequate per the requirements of national codes and standards (an estimate).	FALSE
Quality of Workmanship	Quality of workmanship (based on visual inspection of a few typical buildings) is considered to be good (per local construction standards).	FALSE
Maintenance	Buildings of this type are generally well maintained and there are no visible signs of deterioration of building elements (concrete, steel, timber).	FALSE

Building Irregularities

Additional comments on structural and architectural features for seismic resistance	
Vertical irregularities typically found in this construction type	Other
Horizontal irregularities typically found in this construction type	Other
Seismic deficiency in walls	No reinforcement is visible throughout the walls (neither horizontal nor vertical). Poor quality mortar and cracked

	masonry units.
Earthquake-resilient features in walls	
Seismic deficiency in frames	-Stirrup and tie spacing is not compliant to recommendations of less than d/2 spacing in beams and d/4 in columns, neither in beams nor in columns. Spacing is regular throughout all members and is usually d or more. Anchorage hooks into member cores are g
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Roof may not be considered as a rigid diaphragm due to the lack of adequate connectivity within its elements and with 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.
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	
Earthquake-resilient features in foundation	

Seismic Vulnerability Rating

For information about how seismic vulnerability ratings were selected see the Seismic Vulnerability Guidelines

	High vulnerability		**Medium vulnerability**		**Low vulnerability**	
	A	B	C	D	E	F
Seismic vulnerability class	|-	o	-|			

A Photograph Illustrating Typical Damage (1997 Cariaco earthquake)

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening

Additional comments on seismic strengthening provisions	For the moment, seismic strengthening provisions have not been performed, either in design or in retrofitting.
Has seismic strengthening described in the above table been performed?	No
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	
Was the construction inspected in the same manner as new construction?	
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	
What has been the performance of retrofitted	

buildings of this type in subsequent earthquakes?	
Additional comments section 6	

References

"Basic Concepts of Seismic Codes, Vol.1, Part I, Non- Engineered Construction", IAEE, 1980.

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

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