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

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

HOUSING REPORT
Clay brick/concrete block masonry walls with concrete floors (predating seismic codes or with a few seismic features)

Report #	12
Report Date	06-05-2002
Country	COLOMBIA
Housing Type	Unreinforced Masonry Building
Housing Sub-Type	Unreinforced Masonry Building : Brick masonry in lime/cement mortar
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Summary

Typical multi-family housing construction found in urban areas of Colombia. It is a modern

construction practice and represents approximately 50% of the housing stock for medium-rise (4- to 6-story high) buildings constructed in the last 25 years. This type of construction generally predates seismic codes; however, some buildings of this type were constructed after the first edition of the Colombian Seismic Code was issued in 1984. This type of construction can be found either on flat or on sloped terrain; vertical stiffness irregularity in the sloped terrain conditions may introduce additional unfavorable effects. Due to poor construction practices and poor detailing of the reinforcement, this construction is considered to be very vulnerable to earthquake effects.

1. General Information

Buildings of this construction type can be found in Colombia. It represents approximately 50% of the existing housing stock of medium rise buildings (4- to 6-story high). This type of housing construction is commonly found in urban areas.

Majority of buildings of this type found in rural areas are 1- and 2-story high.

This construction type has been in practice for less than 25 years.

Currently, this type of construction is being built. This is a modern construction for 4- to 6-story high buildings constructed in the last 25 years.

Figure 1: Typical Building

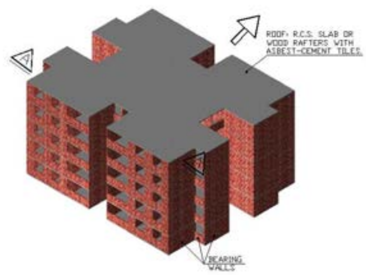

Figure 2A: Key Load-Bearing Elements

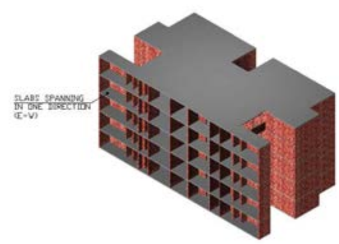

Figure 2B: Key Load-Bearing Elements

2. Architectural Aspects

2.1 Siting

These buildings are typically found in sloped and hilly terrain. They do not share common walls with adjacent buildings. This type of construction is found on flat terrain (in the coastal areas) and in the continental region (the Andean) on the sloped and occasionally very steep terrain When separated from adjacent buildings, the typical distance from a neighboring building is 10 meters.

2.2 Building Configuration

Typically, a square plan (4 flats per floor) or a rectangular plan (2 flats per floor). Information about the openings in a typical median building is summarized below: Number of openings Size (m²) Opening area/wall area Position of opening Doors Windows Facade 5 0 1.80 Between 0.5 and 1.0m from corners Interior 7 2.0 0. Total 30%.

2.3 Functional Planning

The main function of this building typology is multi-family housing. Many buildings of this type are of mixed use. In a typical building of this type, there are no elevators and 1-2 fire-protected exit staircases. Usually building does not have additional means of escape.

2.4 Modification to Building

There are no many modifications in this building type. The most typical modification pattern observed is demolition of interior walls.

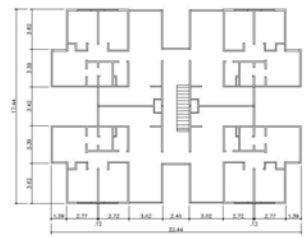

Figure 3: Plan of a Typical Building

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	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	frame			
		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)	☐

Most buildings of this construction are of types 9 and 11 per the above table; however, some buildings are of type 10 and other of type 12.

3.2 Gravity Load-Resisting System

The vertical load-resisting system is reinforced concrete structural walls (with frame). The walls carry both lateral and gravity loads down to the R.C. strip foundation. In poor soil conditions, pile foundations are used because of the great susceptibility to settlement of the bearing walls. It is important to mention that the slabs span normally in one direction so the walls in one direction sustain gravity and lateral loads and the walls in the cross direction carry lateral loads only.

3.3 Lateral Load-Resisting System

The lateral load-resisting system is reinforced concrete structural walls (with frame). This is a bearing wall system, wherein the walls provide stiffness for in-plane lateral loading and stability to resist lateral loads (wind and seismic effects). Floor slabs are either 100 mm thick R.C. Slabs or different types of slab and joist floors; in some cases, slabs with concrete joists and tile blocks are used. The roof is normally made from rafters, sheathing roofing felt and asbestos-cement tile or R.C. slab. Floor slab can act as a rigid diaphragm; the same is not true for the wooden roof because a continuous R.C.beam (bond beam) atop the walls is often absent.

3.4 Building Dimensions

The typical plan dimensions of these buildings are: lengths between 17 and 17 meters, and widths between 17 and 17 meters. The building is 5 storey high. The typical span of the roofing/flooring system is 3.0 meters. Typical Plan Dimensions: Common plan dimensions: square plan buildings= 17.0 m x 17.0 m; Rectangular plan = 17.0 m x 8.0 m. The typical storey height in such buildings is 2.6 meters. The typical structural wall density is none. 6% to 8.5%.

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 floor is considered to be a rigid diaphragm that transfers the loads to the wall, although in many instances the floor-to-wall connections are deficient. The roof is considered to be a flexible structure.

3.6 Foundation

Type	Description	Most appropriate type
	Wall or column embedded in soil, without footing	☐
	Rubble stone, fieldstone	

Shallow foundation	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	☐

It consists of reinforced concrete end-bearing piles and reinforced concrete skin-friction piles. In some Colombian cities e.g. Bogotá, deep foundations are mandatory in a typical case. However, in other cities e.g. Medellín, R.C. strip footings are normally used.

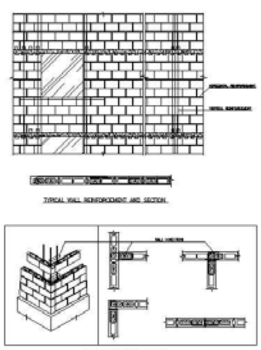
Figure 4A: Critical Structural Details - Typical Wall Reinforcement in New Buildings

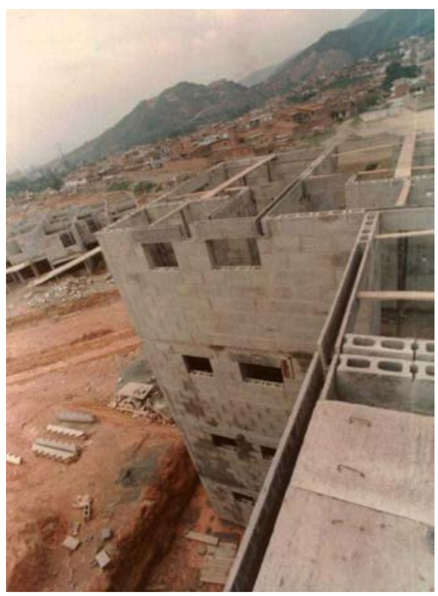
Figure 4B: Critical Structural Details - Modern buildings Built with Continuous R/C Bond Beams

Figure 5A: Key Seismic Deficiencies - Inadequate Reinforcement and Poor Grouting (note the reinforcement bar slippage)

Figure 5B: Seismic Deficiencies - Discontinuous R/C Bond Beams

Figure 5C: Poor construction practice - unreinforced masonry walls and the absence of cross walls (note that both clay bricks and concrete blocks were used for the wall construction)

Figure 5D: Vertical Stiffness Discontinuity - Walls Interrupted at the First Story and Replaced with Columns

Figure 5E: Seismic Deficiencies - An Example of a Building Collapse Caused by Gravity Loads Only (buildings with such weaknesses have very little chance to survive earthquake effects)

Figure 5F: Seismic Deficiencies - Poor Quality of Materials (mortar and grout); Inadequate Vertical and Horizontal Reinfocement

Figure 5G: A building weakened due to tilting induced by a pre-earthquake foundation settlement (separation between the two buildings was 100 mm at ground level but 0 mm at the top). Such buildings are likely to suffer more extensive earthquake damage

Figure 5H: A building weakened due to tilting induced by a pre-earthquake foundation settlement (separation between the two buildings was 100 mm at ground level but 0 mm at the top). Such buildings are likely to suffer more extensively earthquake damage

Figure 6C: Typical Earthquake Damage - Lateral Movement of the Collapsed Building Relative to the Foundations

4. Socio-Economic Aspects

4.1 Number of Housing Units and Inhabitants

Each building typically has 5-10 housing unit(s). 5 units in each building. On the average, 5 floors per building; consequently, there are 20 units in buildings of a square plan (four apartments per floor), and 10 units in buildings of a rectangular plan (two apartments per floor). 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 more than 20.

4.2 Patterns of Occupancy

Normally one family occupies one 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)	☐

The above are average values. House price for middle class section ranges from US$ 30,000 to 50,000. The approximate economic distribution of population in Colombia is as follows: Economic status % Annual Income Very poor 35 <1000 Poor 35 1000 - 2000 Middle Class 25 2000 -10000 High Middle Class 4 10000 - 40000 Rich 1 >40000 Economic Status: For Poor Class the Housing Price unit is 10000 and the Annual Income is 1500. For Middle Class the Housing Price unit is 40000 and the Annual Income is 6000.

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)	☐

The main source of financing for the poor people is informal network (friends and relatives) and (sometimes) small lending institutions. For the middle class population, the main sources of financing are personal savings and commercial banks. In each housing unit, there are 2 bathroom(s) without toilet(s), 2 toilet(s) only and 2 bathroom(s) including toilet(s).

2 or 3 bathrooms per housing unit (apartment) .

4.4 Ownership

The type of ownership or occupancy is renting, outright ownership , ownership with debt (mortgage or other) and individual 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		
		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	Foundation Performance: Occasionally, there are buildings with induced weaknesses caused by foundation movements (please see Figure 5G and 5H). Wall-Roof connections: See Additional Comments in Section 4.5 "Type of floor/roof system".			

5.2 Seismic Features

Structural Element	Seismic Deficiency	Earthquake Resilient Features	Earthquake Damage Patterns
Wall	-Unreinforced or with insufficient vertical and horizontal reinforcement. - Stepped construction (offsets) for example half of the buildings with six stories and the other half with five due to the sloping terrain (resulting		

	in no uniform vertical stiffness distribution).		
Frame (columns, beams)			
Roof and floors	- Absence of continuous boundary members, chords and collectors. -Weak roof-wall and floor-wall connections.		
Other	-Poor quality of workmanship and materials. -Foundations designed only for vertical loads without considerations for overturning moments.		

For the illustration of seismic deficiencies please see Figures 5A, 5B, 5C, 5D, 5E, 5F, 5G, and 5H.

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
29182	4.8N, 76.2W, depth: 108 km (Mistrató)		VIII MMI (MANIZALES)
30406	2.46N, 76.69W, depth: 22 km (Popayán)		IX MMI (POPAYÁN)
34738	4.1N, 76.62W, depth: 73 km (Pereira)		VIII MMI (PEREIRA)
36185	4.46N, 75.72W, depth: 17 km (Armenia)		IX MMI (ARMENIA)

Typical earthquake damages are illustrated in Figures 6A, 6B, 6C, 6D, 6E, 6F, 6G, 6H, and 6I.

Figure 6A: Typical Earthquake Damage - Failure of Load bearing Masonry Walls

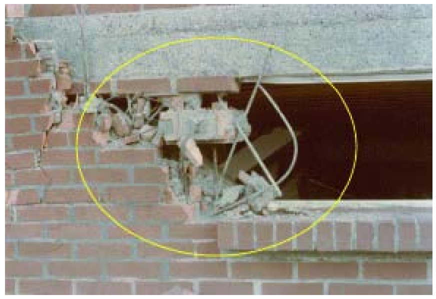

Figure 6B: Typical Earthquake Damage - Inadequate Reinforcement (Detail A shown on Figure 6)

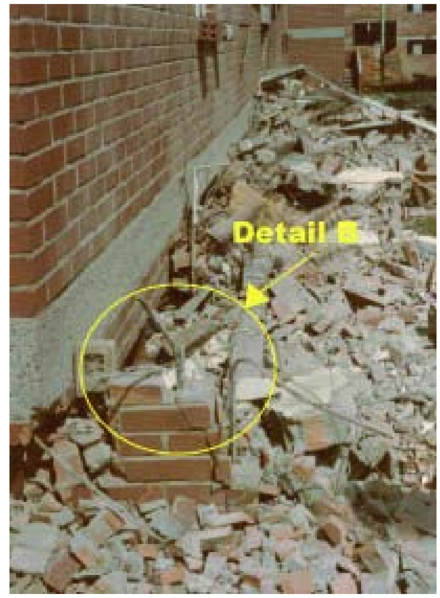

Figure 6D: Typical Earthquake Damage - Detail B Shown on Figure 6b

Figure 6E: Typical Earthquake Damage - Poor Workmanship and Inadequate Reinforcement (this is an enlarged detail B shown of Figure 6c)

Figure 6F: Typical Earthquake Damage Illustrating Two Similar Confined Masonry Buildings (note that the building on the right-hand side collapsed while te one on the left remained standing)

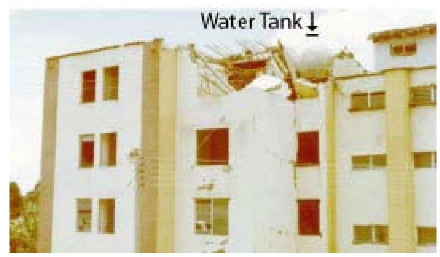

Figure 6G: Typical Earthquake Damage - Collapsed Roof; note the absence of continuous RC bond beam and the wall-roof connection; the water tank at the roof "walked off" and had contributed to the roof collapse

Figure 6H: Typical Earthquake Damage - Importance of the Details in Seismic Design : The "access bridge" to this building did not have adequate bearing length and had collapsed, thus leaving inhabitants without a means of escape

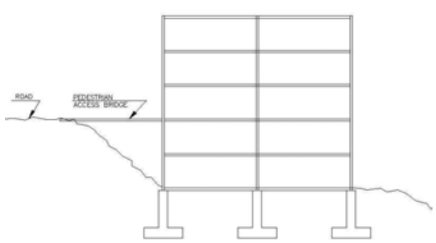

Figure 6I: Typical Earthquake Damage - Importance of the Details in Seismic Design : The "access bridge" to this building did not have adequate bearing length and had collapsed, thus leaving inhabitants without a means of escape

6. Construction

6.1 Building Materials

Structural element	Building material	Characteristic strength	Mix proportions/dimensions	Comments
Walls	Concrete block masonry walls Clay brick masonry walls Cement mortar Cement grout	f'm = 10.0 MPa f'm = 3-10.0 MPa 5.0 - 10.0 MPa 10.0 MPa	w / h / l 150 X 200 X 400 mm 120 X 200 X 400 mm 200 X 100 X 400 200 X 150 X 400 Cement : Sand 1:6 to 1:4 1:4	N/A 3 MPa for unreinforced or confined masonry and 10MPa for masonry with interior reinforcement Better strengths for buildings with vertical reinforcement, because they have some seismic features. For walls with vertical reinforcement
Foundation	Reinforced concrete	f'c = 20.0 MPa	1 : 2 : 3	Cement/sand/aggregates
Frames (beams & columns)				
Roof and floor(s)	Abarco (Cariniane piriformis)	9.0 MPa	50 x 100 mm	Whenever the roof is in R.C. properties are the same as floors.

6.2 Builder

Whenever engineered, this construction type is built for speculation purposes.

6.3 Construction Process, Problems and Phasing

This is a typical construction process: firstly, the terrace is formed, followed by the construction of strip foundation. Subsequently, walls, slabs and roof are built, and the masons are skilled or semi-skilled. No equipment is used except for the simple tools. Normally, buildings of this type are built by a developer (in some cases by the owner). The construction of this type of housing takes place in a single phase. Typically, the building is originally designed for its final constructed size. The above statements are true, except for the case of informal construction.

6.4 Design and Construction Expertise

The masons involved in the construction are usually skilled and semi-skilled. Architects and engineers participate in the design of buildings of this type built for inhabitants belonging to the middle economic class. However, architects and engineers are not involved in the informal construction developed in areas inhabited by poorer sections of the society. Often engineers and architects participate in the design phase of the project especially when the buildings are built for the middle class. If engineers and architects are involved in the construction, there is a "resident" (architect or engineer) on the site during the construction. Unfortunately, he/she is concerned mainly with the project cost aspects (rather than with the construction quality). Engineers and architects do not play any role in informal projects developed for poor people.

6.5 Building Codes and Standards

This construction type is addressed by the codes/standards of the country. 1984: Colombian code for earthquake resistant buildings CCCSR-84. 1998: Colombian code for earthquake resistant design and construction of buildings NSR-98 Prior to 1984, the ACI and UBC codes were widely used. The year the first code/standard addressing this type of construction issued was 1984. The most recent code/standard addressing this construction type issued was 1998. Title of the code or standard: 1984: Colombian code for earthquake resistant buildings CCCSR-84. 1998: Colombian code for earthquake resistant design and construction of buildings NSR-98 Prior to 1984, the ACI and UBC codes were widely used. Year the first code/standard addressing this type of construction issued: 1984 When was the most recent code/standard addressing this construction type issued? 1998.

After an earthquake, the authorities enforce the use of building codes, however shortly thereafter these regulations are not enforced with an adequate effort.

6.6 Building Permits and Development Control Rules

This type of construction is an engineered, and authorized as per development control rules.

Some of these buildings, especially those of unreinforced masonry construction (types 9 and 11, Table 4.3) or confined masonry (type 10, Table 4.3) are informal construction. 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).

6.8 Construction Economics

On the average $300,000 Colombian pesos/ m² ($US 150 /m²). It is possible to construct one floor per month on the average (when the building is designed for its final size and engineers/architects participate in the construction).

7. Insurance

Earthquake insurance for this construction type is typically available. For seismically strengthened existing buildings or new buildings incorporating seismically resilient features, an insurance premium discount or more complete coverage is unavailable. Earthquake insurance is available only for engineered buildings. At the present time, premium discounts are not available for seismically strengthened buildings, however the insurance companies are dealing with this matter. Although there are many unclear aspects in this matter, in general the insurance covers the previously fixed value of the building. The insurance cost varies from 0.1 to 0.15% of the building value.

8. Strengthening

8.1 Description of Seismic Strengthening Provisions

Strengthening of Existing Construction :

Seismic Deficiency	Description of Seismic Strengthening provisions used
Walls # Unreinforced or with insufficient vertical and horizontal reinforcement # Stepped construction (offsets) for example half of the buildings with six stories and the other half with five due to the sloping terrain (resulting in non-uniform vertical stiffness distribution)	See Additional Comments
Roof and floors: # Absence of continuous boundary members, chords and collectors. # Weak roof-wall and floor-wall connections.	See Additional Comments
Other : # Poor quality of workmanship and materials. # Foundations designed only for vertical loads without considerations for overturning moments.	See Additional Comments

Due to the fact that this construction type in general belongs to poor or middle class population, the costs of seismic strengthening is so prohibitive and unaffordable; this is a major reason for a very limited experience in this area. For the above reason, only scarce efforts have been made in the area of seismic strengthening. As illustrated in Figures 7A and 7B, an appropriate seismic strengthening technique includes the installation of new end confining members in the selected walls. An alternative seismic strengthening technique that would be appropriate for buildings of this type (using the Fiber Reinforced Polymers) is very expensive.

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.

Figure 7A: Seismic Strengthening Techniques-Installation of New Conrete Tie Columns

Figure 7B: Seismic Strengthening Techniques - Installation of New Concrete Tie Column

Reference(s)

1. Normas Colombianas de Dise

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