World Housing Encyclopedia

A Resource on Construction in Earthquake Regions

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HOUSING REPORT
Confined masonry

Report#	199
Last Updated	16/08/16
Country	Colombia
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Important

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General Information

Building Type:	Confined masonry
Country:	Colombia
Author(s):	Ana Beatriz Acevedo Juan Diego Jaramillo Fernando Alexis Osorio
Last Updated:	16/08/16
Regions Where Found:	Confined masonry structures can be mainly found in the urban areas of Colombia, primarily in the big cities. An important percentage of the existing housing stock of Colombia consists of masonry buildings, which include confined masonry. Few available works on the Colombian housing stock specify the amount of confined masonry structures, as they are usually treated as masonry structures, or categorized along with reinforced masonry. The work of Salgado et al. (2013) states that 22 percent of the building stock of Medelln is of confined masonry structures. Figure 1 shows the distribution of this building typology depending on the number of stories based on the work of Salgado et al. (2013). Recent exposure models of residential buildings in the Colombian cities of Bogot, Medelln and Cali (https://sara.openquake.org/risk) indicate unreinforced masonry structures being the most common building class, followed by confined masonry structures. Confined masonry buildings represent 23%, 12% and 26% of the total number of buildings in Bogota, Medellin and Cali, respectively. None of the referenced works differentiates between engineered and non-engineered confined masonry structures.
	Confined masonry structures have been built in Colombia mainly without considering seismic design principles. Structures built before the year 1998 (when an update of the first seismic code was released) had up to five stories. After the release of the 1998 code, the maximum number of stories of this type of buildings was reduced to two, for both formal and informal (non-engineered) constructions.Before the release of the first seismic code (1984) there was no restriction on the use of

Summary:	confined masonry, and this typology was mainly used for mid-rise buildings without seismic design. Once the code was released, some confined masonry buildings with seismic design were built up to five stories approximately. With the release of the 1998 code confined masonry can only be used for regular structures and the building height is limited to: two stories for high seismic zones, 12 meters for medium seismic zones, and 18 meters for low seismic zones. Current seismic designed confined masonry buildings usually provide housing for the high-income class. Non-engineered confined masonry structures refer to buildings of this typology built without fully complying to the code, as those buildings shown in Figure 2. Many non-engineered confined masonry buildings are built by low-income class without any building permit. In many occasions the structure is built in different stages, even with different quality materials, as partly shown in Figure 2. After 1998, the common maximum number of stories for non-engineered confined masonry buildings is two, with one or two dwellings per building.
Length of time practiced:	25-60 years
Still Practiced:	Yes
In practice as of:	
Building Occupancy:	Residential, unknown type
Typical number of stories:	02-May
Terrain-Flat:	Typically
Terrain-Sloped:	Typically
Comments:	Confined masonry structures usually share common walls with adjacent buildings, mainly for buildings of one or two stories.

Features

Plan Shape	Rectangular, solid
Additional comments on plan shape	
Typical plan length (meters)	15m
Typical plan width	5m

(meters)	[illegible]m
Typical story height (meters)	3.5m
Type of Structural System	Masonry: Confined Masonry: Clay brick masonry with concrete posts/tie columns and beams
Additional comments on structural system	The gravity load-resisting system consists of confined masonry walls. As beams and columns are slender, they do not constitute rigid frames and the lateral load-resisting system is basically represented by the confined masonry walls.
Gravity load-bearing & lateral load-resisting systems	
Typical wall densities in direction 1	>20%
Typical wall densities in direction 2	>20%
Additional comments on typical wall densities	
Wall Openings	The typical shape of this type of building is rectangular. Openings are usually located in the facade as can be seen in Figure 2. Openings have typical dimension of 1.2 to 1.5 meters. As the building is usually non-engineered, openings may be placed irregularly. There are no local construction guidelines for this type of structures available. However, in some occasions the configuration of non-engineered confined masonry buildings is similar to the engineered ones. This is because the workers have previously acquired their experience during the construction of engineered confined masonry structures and later use these skills in constructing non-engineered buildings, often for their own family.
Is it typical for buildings of this type to have common walls with adjacent buildings?	Yes
Modifications of buildings	For non-engineered confined masonry structures, a typical modification is a vertical expansion (i.e. construction of additional stories). New stories may have a different structural system as shown in Figure 3.
	Shallow Foundation: Reinforced concrete isolated

Type of Foundation	footingShallow Foundation: Reinforced concrete strip footing
Additional comments on foundation	For one to two story buildings the foundation is usually a reinforced-concrete strip footing with a sectional area of 0.2 m x 0.2 m. The foundation longitudinal reinforcement is four steel bars with a diameter of 1/2 in (two on the top and two on the bottom); stirrups with a diameter of 3/8 in are placed every 0.20 m. For three to four story buildings the foundation is usually made of reinforced-concrete isolated footings located under the columns with an area of 1.20 m x 1.20 m. Tie beams that support masonry walls are 0.20 m x 0.20 m. Tie beams are common in sloped terrains in order to connect different footing levels and vertical elements. Figure 7 shows non-engineered confined masonry buildings supported by reinforced-concrete frame structures placed in sloped terrains. As these structures are non-engineered, the soil conditions are not considered in the definition of the foundation dimensions.
Type of Floor System	Other floor system
Additional comments on floor system	Structural Concrete: Waffle slabs (cast in place) Floor and roof are usually waffle slabs with 0.1 m thick clay bricks instead of voids as shown in Figure 6. The top slabs have a thickness of 0.05 m. The ribs usually are 0.10 m wide with a longitudinal reinforcement of one bar of 1/2 in diameter on the bottom of the central span and on top near the supports. When the span is greater than 4.0 m three ribs with cross sections of 0.2 m x 0.2 m are used, with four bars of 1/2 in diameter as longitudinal reinforcement and a transverse reinforcement of 3/8 in diameter every 0.20 m. Slabs of three to four stories buildings include a 0.20 m x 0.20 m confinement beams. The roof is usually a slab as it is common for these buildings to grow in height with time; hence, the slab of a future story will provisionally be the roof of the upper floor. Other types of roofs are lightweight roofs such as metal or asbestos-cement sheets, without confinement beams. In some buildings steel and timber structures to support the clay tiles can be found.
Type of Roof System	Roof system, other
Additional comments on roof system	Structural Concrete: Waffle slabs (cast in place) See Additional comments on floor system.
	The typical plan configuration of non-engineered

Additional comments section 2	confined masonry structures is rectangular, with plan dimensions of 15 m length and 5 m width. Buildings built before 1998 have up to five stories; after the year 1998 the maximum number of stories for typical non-engineered confined masonry structures was reduced to two. The typical span of buildings of one or two stories is 3.0 m; with a maximum of 3.5 m. Brick dimensions of the external walls are 0.40 m x 0.20 m x 0.15 m. Internal walls are made of bricks of dimensions 0.40 m x 0.22 m x 0.10 m. Internal and external walls use bricks with horizontal openings. The column transverse area depends on the brick dimensions; longitudinal reinforcement is two or four steel bars with 1/2 in diameter (see Figure 4) while transverse reinforcement is stirrups of 1/4 in diameter placed every 0.20 m.Columns of buildings of three and four stories are 0.20 m x 0.30 m, with reinforcement of four steel bars with 1/2 in diameter and stirrups of 3/8 in every 0.07 m near the supports (0.5 m) and 0.20 m in the middle section. As it can be seen in Figure 5a (and previous figures) beams are not common in non-engineered confined masonry as it is believed by the builders that the floor will act as a confining element. Nonetheless, when beams are present, the typical beam dimension is of 0.2 m depth with a width corresponding to the wall thickness, as show in Figure 5b. Beam reinforcement is similar to column reinforcement.

Infill wall material

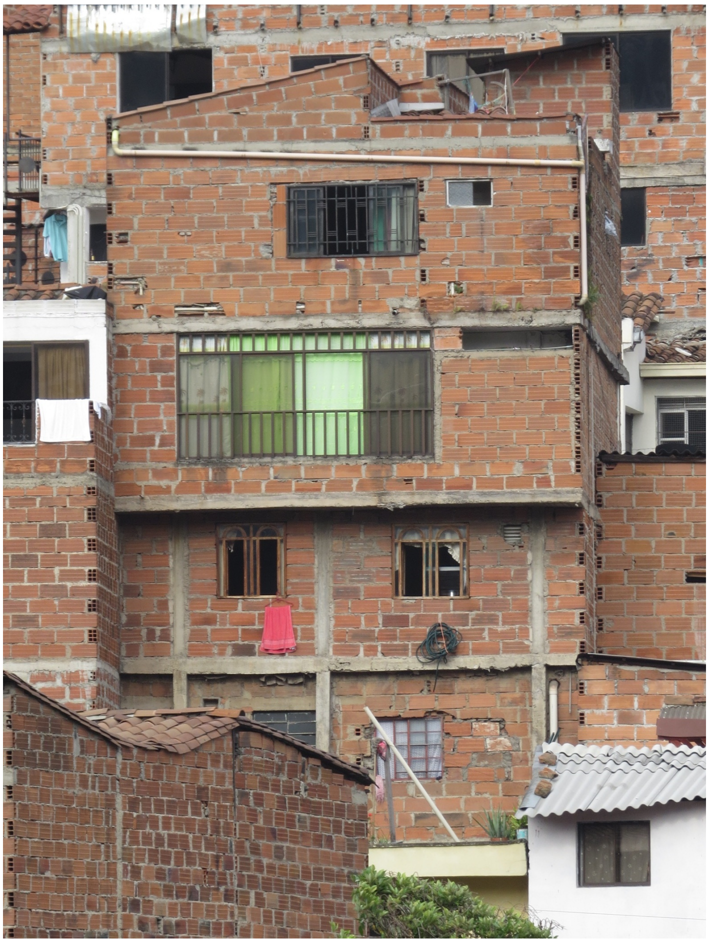

Figure 3. Building with vertical expansion.

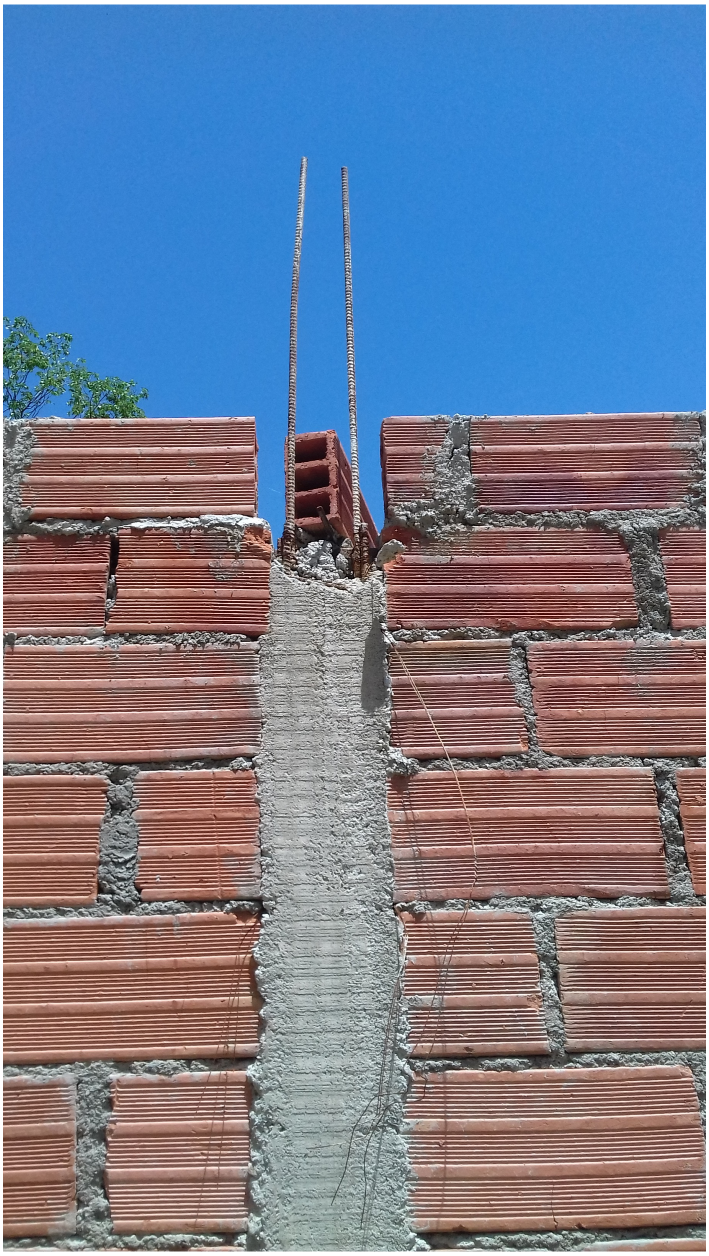

Figure 4a. Column details.

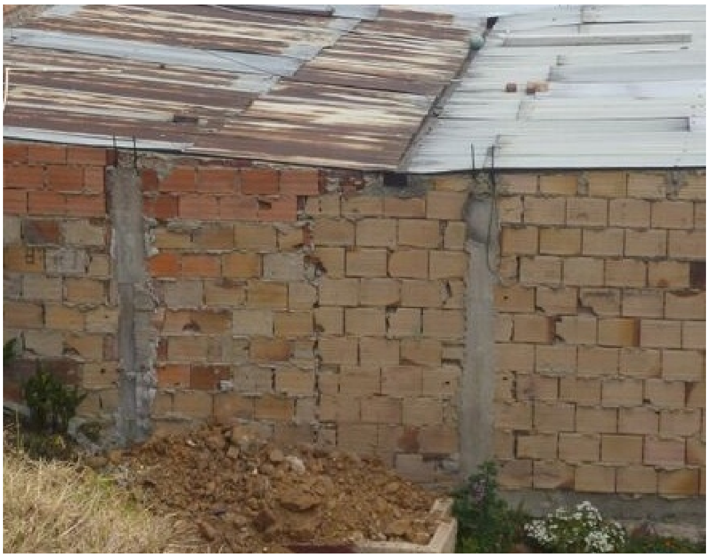

Figure 4b. Column details.

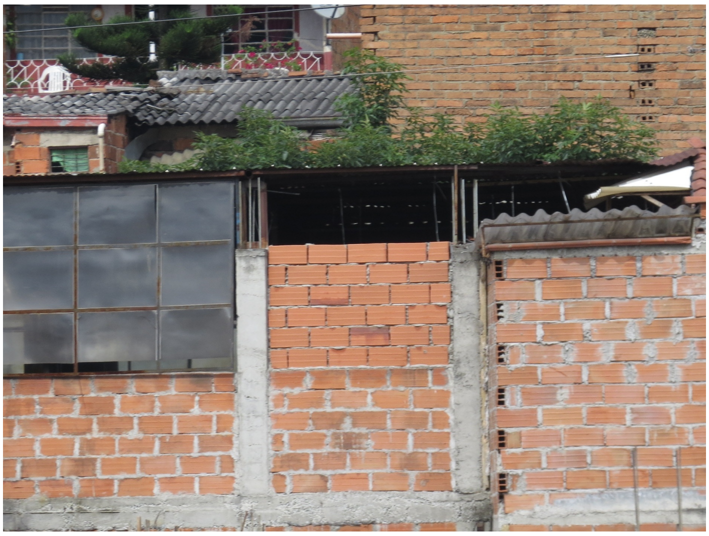

Figure 4c. Column details.

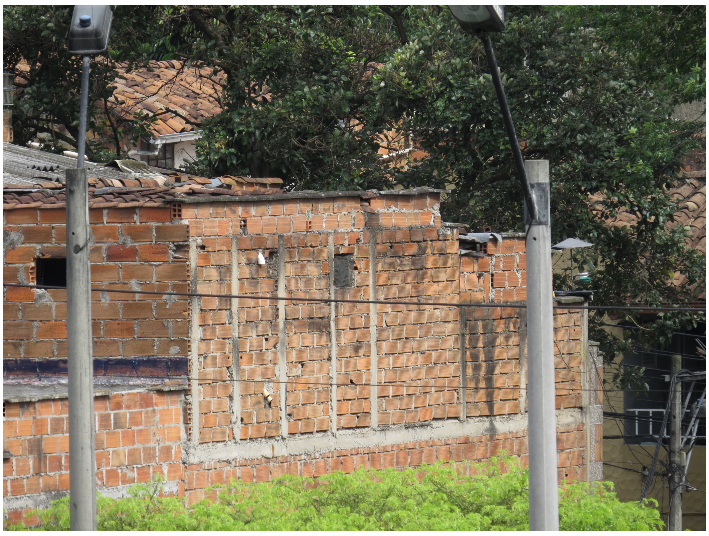

Figure 5a. Confinement beams

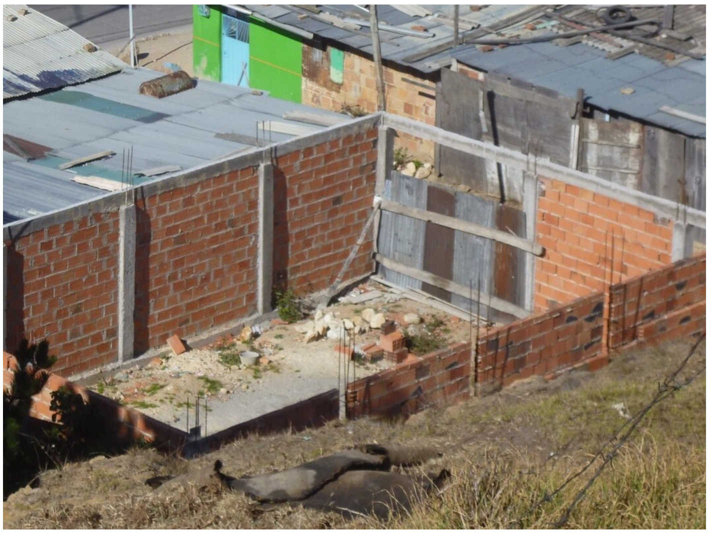

Figure 5b. Confinement beams

<u>Building Materials and Construction Process</u>

Description of Building Materials

Structural Element	Building Material (s)	Comment (s)
Wall/Frame	Wall: Unreinforced masonryFrames: Reinforced concrete	Clay units
Foundations	Reinforced concrete	1:3:2 Cement/sand/aggregates (in volume)
Floors	Reinforced concrete	1:3:2 Cement/sand/aggregates (in volume)
Roof	Reinforced concrete	1:3:2 Cement/sand/aggregates (in volume)
Other		

Design Process

Who is involved with the design process?	Owner
Roles of those involved in the design process	Non-engineered confined masonry buildings are built for residential occupancy. In general, only one floor is constructed, which is occupied by the owner; as time passes, new floors are added and those units are either sold or rented out.When the whole

	structure is built at once, there is usually an owner(s) that rents out the housing units.
Expertise of those involved in the design process	Non-engineered confined masonry structures generally have the same specifications on materials and element dimensions (foundation, tie-columns, tie-beams and slab). Typical dimensions are known to regular workers as they usually work in the construction of engineered structures of this building type. Even though this type of structure is non-engineered, the limitation on building height required by the code of 1998 to confined masonry buildings has also been applied to typical non-engineered structures.

Construction Process

Who typically builds this construction type?	Owner
Roles of those involved in the building process	Same as above
Expertise of those involved in building process	Same as above
Construction process and phasing	The foundations are built first. The reinforcement bars of the first story tie-columns are assembled before pouring the foundation concrete. Then the walls of the ground floor are placed and once they reach their foreseen height the columns are casted. Tie-beams are constructed atop of the walls at each floor level. Special lintel beams are required in large wall openings. Floor or roof slabs are cast in-situ by concrete prepared on site and carried to the construction site in buckets.
Construction issues	

Building Codes and Standards

Is this construction type address by codes/standards?	Yes
	The first seismic code of Colombia dates from 1984. Previous to this date the majority of the structures were built without seismic design considerations; few engineers did seismic design mostly based on the SEAOC (1966), the ACI and the UBC codes.The first update of the 1984 code was done in 1998; an important change of the code of 1998 consisted in

Applicable codes or standards	more demanding drift requirements. The second and latest update of the code was done in 2010, without significant differences on seismic design from the code of 1998.Confined masonry was used mainly for mid-rise buildings without seismic design (before the code of 1984 was released). Once the first seismic code was released, some buildings of up to five stories were built based on seismic design principles. After 1998 (when a new version of the seismic code was released) engineered confined masonry has been mainly used for low-rise structures, especially for the high-income class.Non-engineered confined masonry buildings, which are the buildings addressed in this report, represent structures built without compliance of code regulations. People that built these buildings are usually workers that have participated in the construction of engineered confined masonry structures. Hence, some of the code regulations that apply to these engineered confined masonry structures apply to non-engineered buildings as well. Examples are the typical column dimensions and a maximum of two stories per building.
Process for building code enforcement	

Building Permits and Development Control Rules

Are building permits required?	Yes
Is this typically informal construction?	Yes
Is this construction typically authorized as per development control rules?	Off
Additional comments on building permits and development control rules	The current design code includes confined masonry and building permits are required. Nevertheless, many non-engineered confined masonry buildings are built by the low-income class without any building permits.

Building Maintenance and Condition

Typical problems associated with this type of construction	
Who typically maintains	

Who typically maintains buildings of this type?	Owner(s)
Additional comments on maintenance and building condition	The maintenance of this type of building is usually performed by the owner. Nevertheless, as the income of the inhabitants is low, maintenance is uncommon.

Construction Economics

Unit construction cost	The building cost is approximately USD 1,000 per square meter (200,000/m2 Colombian pesos). This cost varies if the owner requires building finishes.
Labor requirements	
Additional comments section 3	

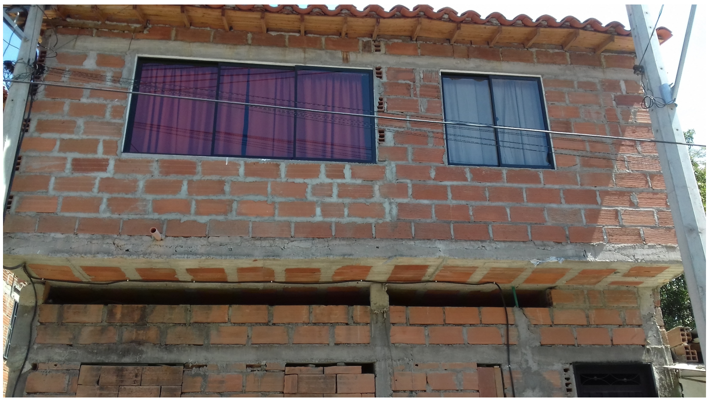

Figure 6a. Waffle slabs floors with clay bricks

Figure 6b. Waffle slabs floors with clay bricks

Figure 7a. Buildings settled in sloped terrain.

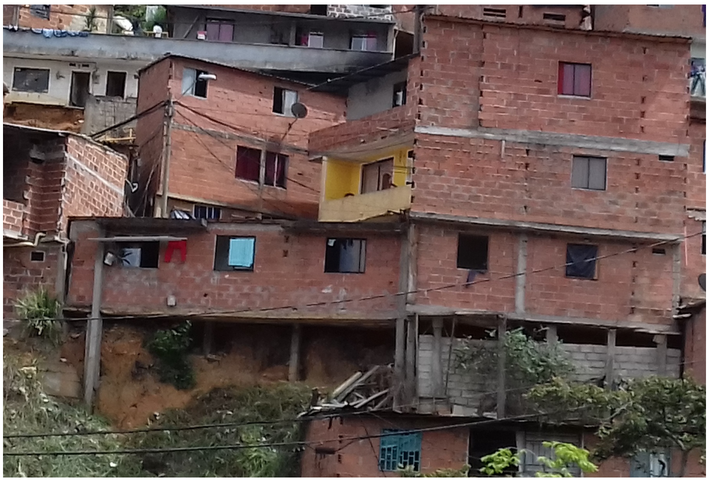

Figure 7b. Buildings settled in sloped terrain.

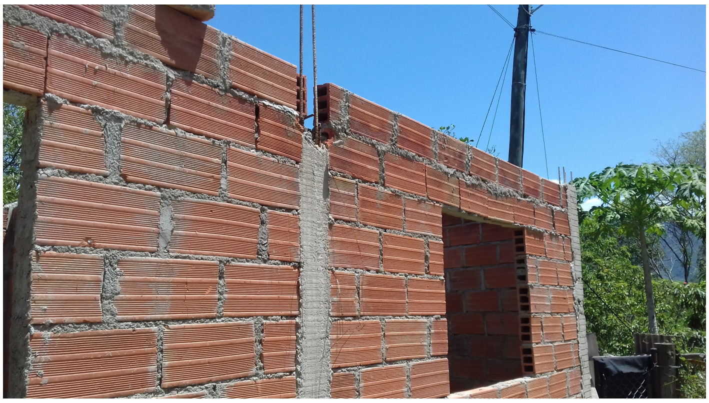

Figure 8a. Detailing during the construction phase.

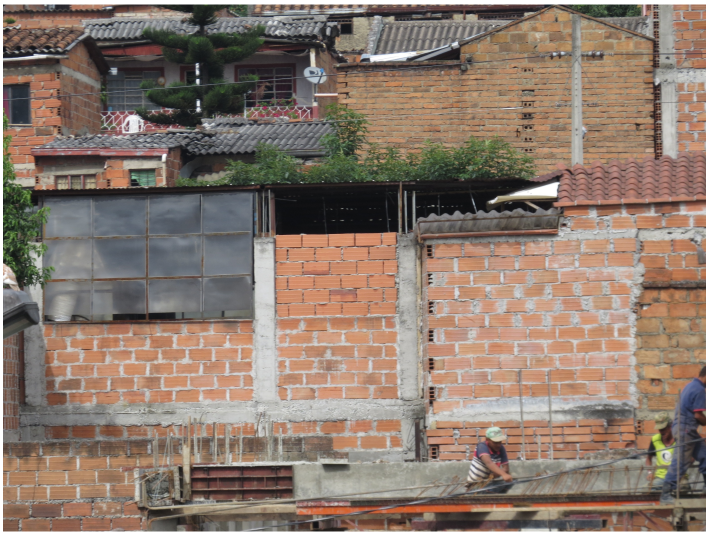

Figure 8b. Detailing during the construction phase.

Socio-Economic Issues

Patterns of occupancy	A housing unit of this type of building is usually occupied by a single family. Two to three low-income level families may occupy one single unit.

Number of inhabitants in a typical building of this construction type during the day	Oct-20
Number of inhabitants in a typical building of this construction type during the evening/night	>20
Additional comments on number of inhabitants	Non-engineered confined masonry buildings typically have 3 to 6 housing units. The number of inhabitants in a building during the day or business hours is approximately 10. At night the number of inhabitants increases to about 30.
Economic level of inhabitants	Very low-income class (very poor)Low-income class (poor)
Additional comments on economic level of inhabitants	Ratio of housing unit price to annual income is 4:1, 5:1 or worse
Typical Source of Financing	Personal savingsInformal network: friends or relativesSmall lending institutions/microfinance institutions
Additional comments on financing	
Type of Ownership	RentOwn outrightOwn with debt (mortgage or other)
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 features?	No
Additional comments on premium discounts	

Additional comments section 4	

Earthquakes

Past Earthquakes in the country which affected buildings of this type

Year	Earthquake Epicenter
13/08/2013(1)	5.75N, 78.25E. Pacific ocean, west coast.
09/02/2013(1)	1.11N, 77.56E. Narino, South-west region.
30/09/2012(1)	1.97N, 76.55E. Cauca, South-west region.
12/09/2009(1)	10.72N, 67.95E. Carabobo (Venezuela)
24/05/2008(1)	4.41N, 73.81E. Quetame. Andean region.
10/09/2007(1)	2.93N, 78.21E. Pacific ocean, west coast.
01/23/2006(1)	6.95N, 77.90E. Pacific ocean, west coast.
01/01/2006(1)	11.92N, 71.42E. Guajira. North-east region.
15/11/2004(1)	4.81N, 77.70E. Pizarro. Pacific region, west coast.
26/02/2000(1)	9.36N, 78.31E. Panama

Past Earthquakes

Damage patterns observed in past earthquakes for this construction type	
Additional comments on earthquake damage patterns	In walls, diagonal cracks are expected for medium seismic events. Walls falling out of the frames may take place.

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.	TRUE
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 walls);	FALSE
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		TRUE
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	Poor quality of materials and workmanship are common, which diminishes the lateral capacity of the structure. In some occasions walls are not properly tied to the confined elements.
Earthquake-resilient features in walls	
Seismic deficiency in frames	In some occasions columns and/or beams are discontinuous.
Earthquake-resilient features in frame	
Seismic deficiency in roof and floors	Weak roof-wall and floor-wall connections.
Earthquake resilient features in roof and floors	
Seismic deficiency in foundation	Sometimes foundations are not placed on good soil types.
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		|-	-|			

Retrofit Information

Description of Seismic Strengthening Provisions

Structural Deficiency	Seismic Strengthening
Lack of confinement	Construction of new tie-columns
Discontinuity or non-existence of the tie-beam	Construction of tie-beam
Low wall density	Construction of additional walls
Structural irregularity	Construction of tie-beams and tie-columns
Poor material or workmanship quality	Covering of the walls with reinforced concrete or composite fibers

Additional comments on seismic strengthening provisions	For openings without confinement: construction of confining columns and beams
Has seismic strengthening described in the above table been performed?	Not often. Normally this type of buildings does not have seismic strengthening. Occasionally, a new owner modifies an existing structure. The main retrofit consists of construction of new tie-beams and tie-columns in order to achieve structural confinement.
Was the work done as a mitigation effort on an undamaged building or as a repair following earthquake damages?	Both. After a seismic event it is common to repair the building as described above.
Was the construction inspected in the same manner as new construction?	If the owner of the building is from a high-income class the repair is usually done by an expert in retrofitting and sometimes the owner hires a company to inspect the repair work. When the owner is from a medium or low-income class, the repair is done by a construction worker without any inspection.
Who performed the construction: a contractor or owner/user? Was an architect or engineer involved?	For high-income class the seismic retrofit measures are usually performed by a contractor. An engineer or architect working for the contractor or the owner is involved. For low-income class the retrofit is done by a construction worker.
What has been the performance of retrofitted buildings of this type in subsequent earthquakes?	There has not been an important seismic event that has tested the retrofitted buildings yet.
Additional comments section 6	

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