MARCH 10, 2015 - LOS SANTOS, SANTANDER EARTHQUAKE, COLOMBIA

Surveyed March 24-25, 2015
Report Released June 16, 2015

Build Change Post-Disaster Reconnaissance Report

BUILD CHANGE

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TABLE OF CONTENTS

Contents

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1. Background

On March 10th, 2015, at 3:55 local time, (2015-03-10 20:55 U.T.C. time), several regions of Northern Colombia were shaken by a magnitude 6.2 earthquake (M6.2 was reported by USGS and M6.4 reported by the Servicio Geológico Colombiano). The epicenter was located 178 km below the area known as Mesa de Los Santos.

The following information is summarized from the event report published by the Servicio Geológico Colombiano, “El Sismo De Los Santos, Santander Del 10 De Marzo De 2015, Aspectos Sismológicos y Movimiento Fuerte”:

The area of Mesa de Los Santos is located in the department of Santander at 6° 45′ 22″ N, 73° 6′ 8″ W with an area of 302 km^2 and populated by about 11,200 people. In the region several settlements suffered damages, mainly rural villages in the municipalities of Betulia and Matanza.

The town of Betulia is located in the department of Santander at 6° 54′ 0″ N, 73° 17′ 1″ W with an area of approximately 413 km^2 and populated by about 5,244 people. The town of Matanza is also located in Santander, at 7° 19′ 22″ N, 73° 0′ 56″ W with an area of 184 km^2 and populated by about 7,639 people.

The northwest of South America is a tectonically complex region, associated with the convergence between the South American plate, the Nazca plate and the Caribbean plate; the current configuration of the northwest edge of South America is the result of this interaction since the end of the Cretaceous period (Cortés & Angelier, 2005).* See Figure 1.

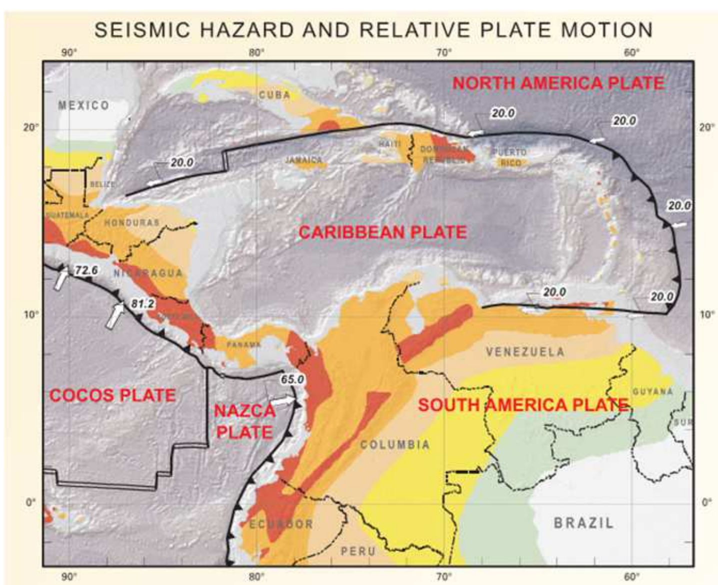


Figure 1. Tectonics in Northern Colombia (Source: USGS, 2011).

This interaction leads to the seismic activity around the area of Santander. Please refer to the Servicio Geológico Colombiano report for additional information.

On March 24th and 25th, a reconnaissance team of Build Change staff visited the earthquake-affected area. This report summarizes the observations of that visit.

1.1 Visit Objectives

1. Identify the main types of existing structures common in the affected areas, especially those that suffered damages.

2. Make a general evaluation of the most common damages and failure modes that appear in the building structures, to improve understanding of the seismic vulnerability of the common building types.

3. Gain an understanding of the distribution of damages throughout the affected region (concentrated or dispersed).

4. Meet with people in the affected towns and obtain contact information to allow follow-up communications in the future.

1.2 Survey Team

Build Change deployed the following team:

- Juan Caballero (Director of Programs and Partnerships, Latin America)
- Hector Andres Romero (Lead Engineer, Latin America)
- Adriana Duque (Construction Supervisor, Latin America)

1.3 The Earthquake

From USGS (http://earthquake-report.com/):
Magnitude: 6.2
Local Time (conversion only below land): 2015-03-10 15:55:44
GMT/UTC Time: 2015-03-10 20:55:44
Depth (Hypocenter): 178 km (This depth is relatively high in reference for this magnitude of seismic movement)

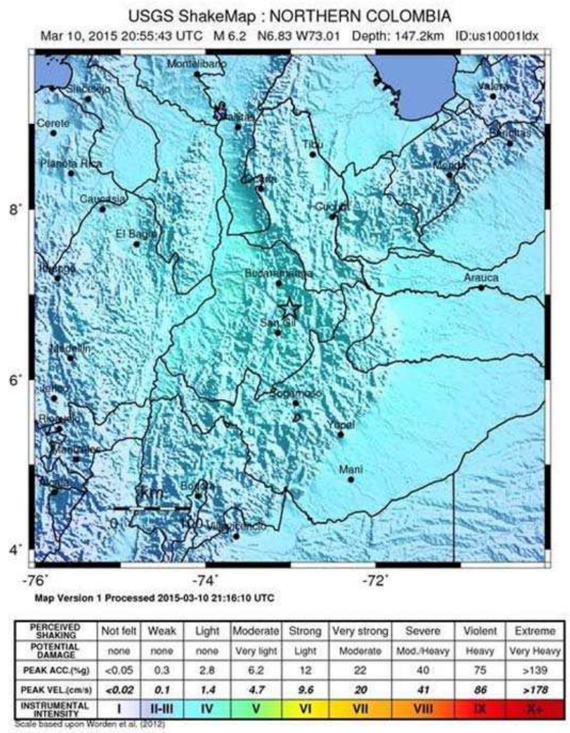


Figure 2. Localization of the epicenter (Source: USGS, 2015).

Another important comparison to make is between the Peak Ground Acceleration (PGA) that the stations close to the site of the earthquake recorded, and the Design Peak Ground Acceleration that the NSR-10 (the Colombian building code) proposes for this site. The affected areas fall in Region 5 of the seismicity maps for Colombia from NSR-10 (Figure 2b). This is considered a zone of high seismicity in Colombia and corresponds to an effective peak horizontal acceleration, Aa, of 0.25g for the design basis earthquake (that which has a probability of exceedance of 10% in 100 years).

- *PGA (Obtain from the Bucaramanga Station, the maximum acceleration observed): 0.0548g (Figure 2a)*

- *The design PGA for houses with typical soil conditions (Soil Type D) in this area would be 0.325g (Figure 2b)*

The PGA recorded is just under 20% of the design acceleration parameters. This likely one of the main reasons that relatively little damage was observed in the zone. It is also an illustration of the fragility of traditional building types, such as adobe and rammed earth, which were damaged.

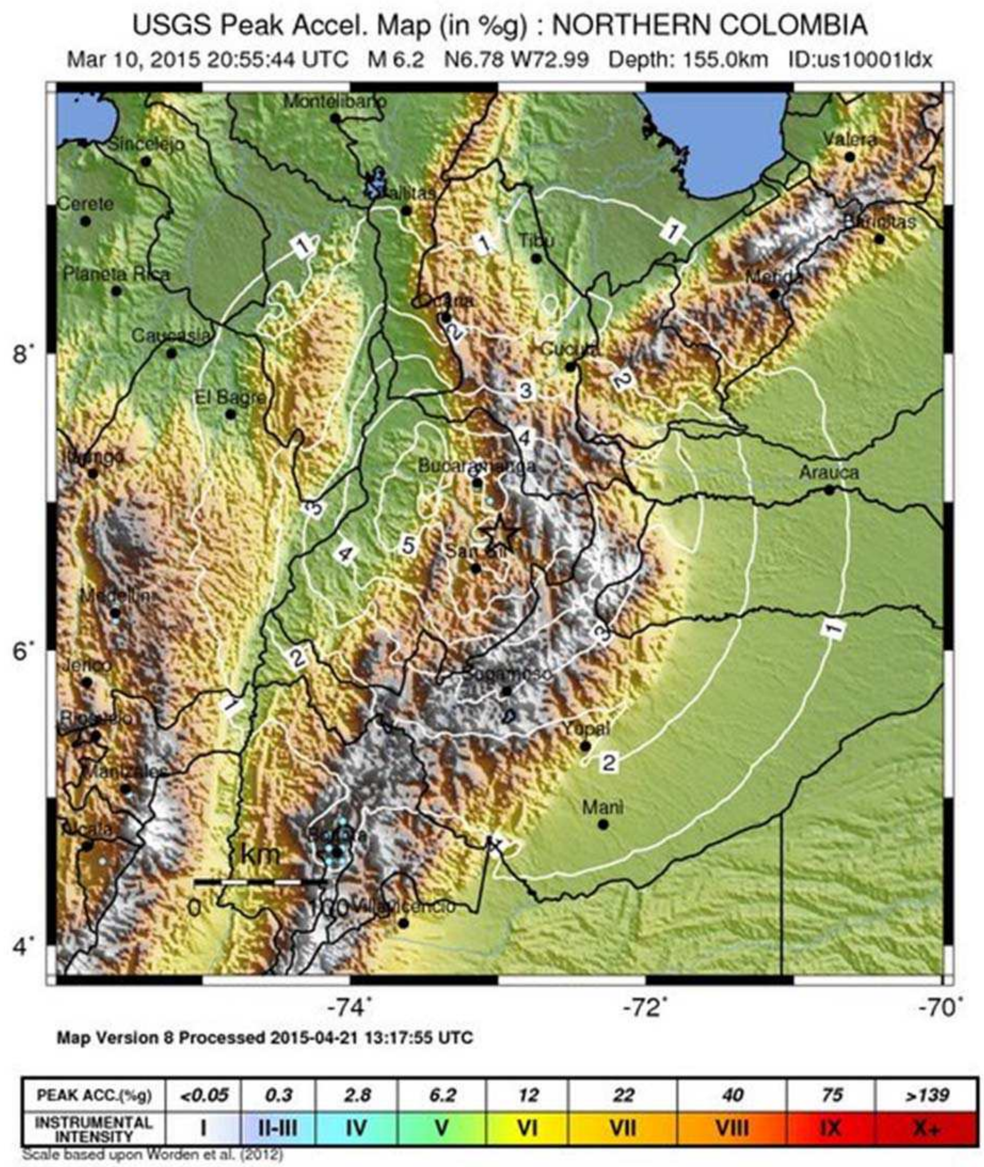


Figure 2a. Peak Ground Acceleration (Source: USGS, 2015).

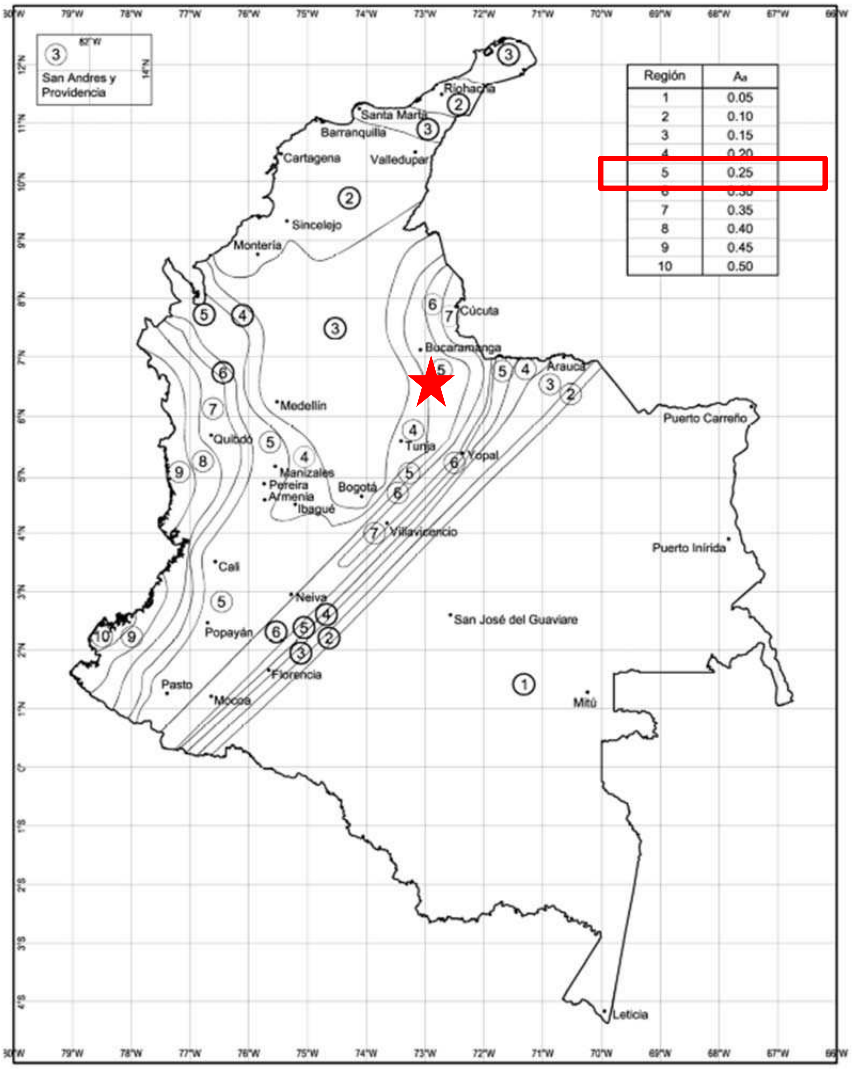


Figura A.2.3-2 — Mapa de valores de A_a

Figure 2b. Acceleration Parameters in Colombia (Source: NSR-10).

2. Observations

2.1 General Overview of the Region

Two areas were visited by the team: the municipal jurisdictions of Matanza and Betulia (Figure 2).

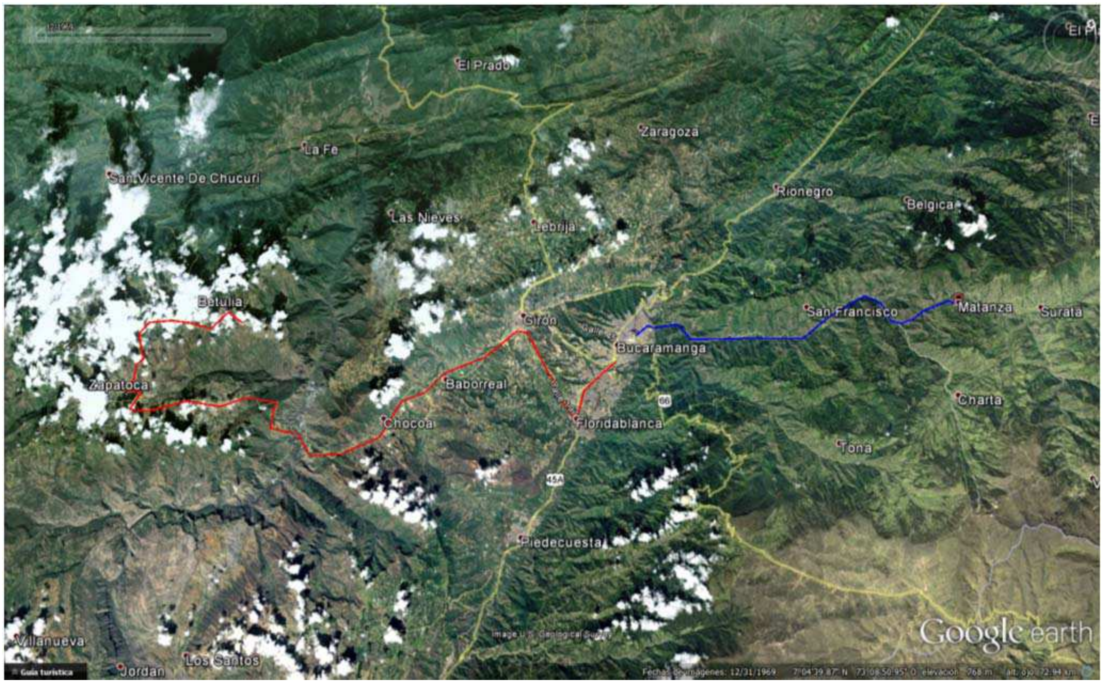


Figure 2. ----- *Path of field visit to Matanza an La Capilla on March 24, 2015.*

----- *Path of field visit to Betulia on March 25, 2015.*

Widespread total collapse of structures in both rural and urban areas was not observed. Occasionally, buildings were observed in which the damage was significant and which therefore suffered collapse.

Most of the buildings that were found to have sustained severe damage were constructed of rammed earth or adobe masonry. These building types are less expensive to build than modern confined masonry and are common in the region, although less frequent in new construction.

Rammed earth or adobe masonry walls are relatively rigid and typically have a lower load resistance than modern wall systems common in newer house construction, such as clay masonry block walls. The occurrence of damage in buildings in the region was mainly found in earth-based wall systems; the general damage observed was the separation between walls because of the lack of competent connections between them (Picture 1).

Picture 1. House in the rural area of Betulia, Combination between Brick and Adobe Unreinforced Masonry.

Damage was also observed, although in lesser quantities, on isolated unreinforced hollow clay tile wall systems (HCT), especially on longer walls, such as in public buildings (schools and health care facilities), and residential lot enclosures with little or no transversal walls (Picture 2).

Picture 2. House in the urban area of Betulia, lot enclosure perimeter wall next to a house (undamaged).

2.2 Visit to Matanza

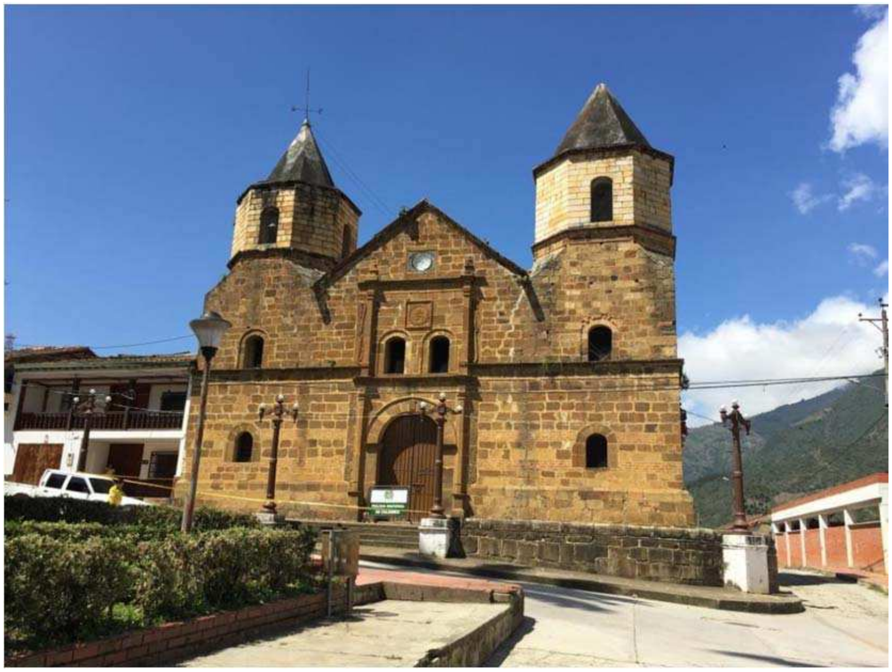
The team visited Matanza, including the villages of La Capilla and Santa Cruz de la Colina. In Matanza and La Colina, extensive damage was not observed. However, in the small village of La Capilla, roughly two-thirds of the structures were significantly damaged, including a school and daycare center of adobe construction. By the time the team arrived in La Capilla, the community center and school had already been demolished (Pictures 3 and 4).

Well-configured and one-story confined masonry buildings appeared to have performed relatively well, with limited wall cracking, which is consistent for the low level of ground accelerations experienced. These damaged buildings would, however, be susceptible to increased damage in future earthquakes if they are not properly repaired and strengthened.

Picture 3. Plot where the school previously sat, image of the demolition.

Picture 4. Lot where the school previously sat, image of the demolition.

In the town of Matanza, residential damage was not very significant, except for isolated cracking of walls. The largest building, the church, did suffer more damage and has been closed off. The building shows many older and previously repaired cracks on the walls, probably from other seismic events (Pictures 5, 6, 7, and 8).



Picture 5. Matanza village church.

Pictures 6, 7, and 8. Previously repaired and reopened cracks on the church façade.

Where partial or total collapse of buildings was found (mainly in rural areas), the buildings were constructed of unreinforced masonry with no confining elements, such as reinforced concrete beams and columns. Additionally, these more damaged buildings typically were composed of a combination of masonry types, further increasing their vulnerability. This mix of masonry is likely due to the progressive construction process of lower-income homes. In these cases, the homeowners build their houses as funds become available, and purchase the most affordable construction materials available at that time (Pictures 9 and 10).

Pictures 9 and 10. Examples of residential damage observed in Matanza.

2.2.1 La Capilla

The village of La Capilla in the municipality of Matanza presents widespread damage, mainly in earth construction and in unreinforced or not fully confined masonry wall types. It was common to find cracks with a stepwise trend, in two directions in unreinforced masonry houses. The school and day care center that have a simple adobe masonry wall structure were completely demolished, as were many homes (Pictures 11, 12, 13, and 14).

Pictures 11, 12, 13, and 14. Damages in houses of the rural and urban area of La Capilla; Diagonal cracks on the bearing walls and partial collapse of a house built in unreinforced masonry.

Picture 15. House in rural area of La Capilla, construction in confined masonry with no damage.

2.2.2 Santa Cruz de La Colina

In Santa Cruz de la Colina, also in Matanza, the damage was isolated to earth buildings in the village. Many dispersed rural homes were also significantly damaged, most of which are reported to be earth based construction also.

In homes built of adobe and masonry walls of rammed earth, it is common to see separation in the corners where walls meet, a result related to a lack of competent connections between walls and the heavy weight of the walls generating out-of-plane movement. This was the most frequently observed failure caused by the earthquake (Pictures 16, 17, 18, 19, and 20).

Pictures 16, 17, 18, 19, and 20. Houses damaged in Santa Cruz de la Colina

2.3 Visit to Betulia

In Betulia, approximately one-third of the houses in the town suffered some type of damage. The percentage of buildings damaged increased slightly for the surrounding rural areas.

Institutional buildings, such as community centers, churches, and schools, did not appear to have significant damage that would jeopardize the stability of the buildings. One exception was the ¨Nuestra Señora de Lourdes¨ School, which suffered partial collapse of the gable wall elements, mainly in the façade.

Picture 21. House partially collapsed in Betulia, cracking in areas of wall corner intersection, with combination of masonry types.

2.3.1 General overview of the houses

As noted in Matanza, most failures were found in the more traditionally-built homes of earth construction, and characterized by separation and significant cracking in wall corners; this separation is between the exterior walls at the corners due to the lack interconnection between walls and heavy walls generating higher out-of-plane loads. Build Change also observed frequent partial collapse of unbraced unreinforced masonry elements and partial collapses of roofs (Pictures 21 and 23).

Due to the relatively low ground accelerations experienced, even confined masonry homes with relatively open fronts, which would be considered vulnerable to earthquake damage, seemed to be relatively undamaged in Betulia (Picture 22). The majority of damage observed was in the more traditional construction types of adobe and rammed earth.

Picture 22. House that did not suffer damage in rural area of Betulia, construction in confined masonry with combination of types of masonry.

Picture 23. House partially damaged in urban area of Betulia, construction in adobe and rammed earth.

2.3.2 Nuestra Señora de Lourdes School

Nuestra Señora de Lourdes is a secondary school for approximately 200 students. Damage was observed in two of the school buildings: a split level three-story classroom building with a moment frame structure, with some frame infills with unreinforced masonry, and others without infill. In this building there was partial damage in non-structural elements, like collapse of the masonry infill of the frames and collapse of the gable wall. The theater building, in simple brick masonry, also suffered damage (Picture 24).

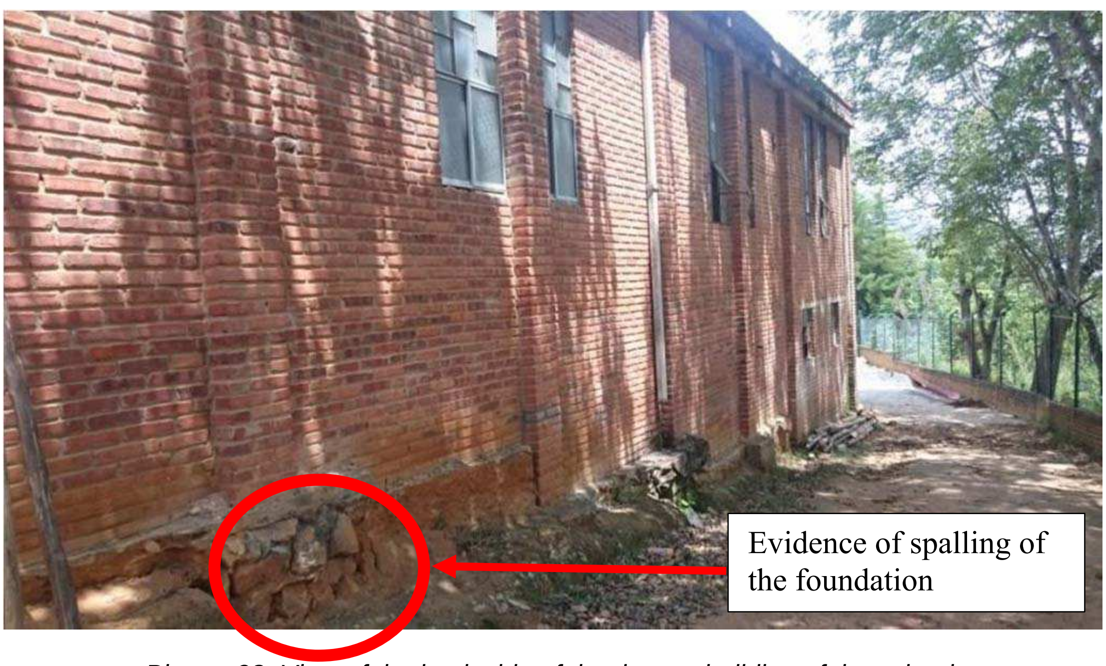
The earthquake occurred while the roof of three-story classroom building was being replaced. This left the masonry walls unbraced at the top, leading to toppling of portions of the upper masonry in some areas. Many portions of the gable wall which had collapsed were already rebuilt (Pictures 24 and 25) and visible as unpainted brick at the time of the team's visit. Other walls were cracked and damaged due to out-of-plane movements of the unbraced walls (Pictures 25, 26, and 27).

Picture 24. Nuestra Señora de Lourdes School (classroom building on left, theater building on right).

Picture 25. Façade walls previously partially collapsed, view of the reconstructed new wall (red brick).

Pictures 26 and 27. Lateral façade with pieces of masonry on the ground and locations from which they fell at the top.

The theater building is an unreinforced brick masonry structure. It is one-story with a walk-out basement at one end of the building where the exterior grade slopes down. Localized damage was observed at the ground level near some of the column/pillar locations. This was observed as settlement and cracking at interior floor around the columns and spalling of the foundation wall around the columns at the exterior. Minimal cracking of the masonry walls was observed (Pictures 28 and 29).



Picture 28. View of the back side of the theatre building of the school.

Picture 29. View from the interior of the theatre, the floor sinks at the wall intersection, possible evidence of a failure of the foundation.

3. Conclusions and Discussion

The main building types common in the area were identified. These are (in order of most common to least):

- Adobe and Rammed Earth Wall Systems (common in urban and rural areas).
- Unreinforced Masonry Wall Systems (common in urban and rural areas).
- Confined Masonry Shear Walls (more common in urban areas).
- Moment Frame, with and without infill (limited to Nuestra Señora de Lourdes School).

Damage commonly observed for these building types during earthquakes:

- Adobe and Rammed Earth Shear Walls: Some wall collapse, separation between the exterior walls at the corners due to the lack interconnection between walls.
- Unreinforced Masonry Shear Walls: Some wall collapse, shear cracking.
- Moment Frames: Partial damage in non-structural elements like collapses of the masonry infill of the frames.

Little damage was observed in more modern, confined masonry buildings.

While the types of damage were not usual, the extent of damage, particularly in the cases of building and wall collapse, was unacceptably high given the low intensity of recorded ground accelerations compared to the design accelerations. In events such as this, where the ground motion is only a fraction (<20%) of that which buildings should be designed to resist, buildings should not collapse or experience significant damage. Under-performing homes have two significantly negative impacts on communities:

- A high level of danger to the well-being and safety of occupants due premature partial or full collapse.
- An unnecessary drain on homeowners' already limited resources when they need to repair or rebuild their homes after frequent, relatively small earthquakes.

In the design earthquake, where accelerations may be up to five times higher than those experienced in the Los Santos, Santander March 10th, 2015 earthquake, widespread collapse of unreinforced masonry and earth wall system buildings can be expected, as well as damage to poorly configured or constructed modern buildings.

The poor performance of homes in this earthquake emphasizes the need to systematically replace or substantially strengthen traditional building types to make them life-safe for the design earthquake, as well as ensure that new homes are built to be earthquake-resistant using appropriate techniques that are recognized by the Colombian building code (NSR-10).

It is recommended that the affected areas be supported with funding for reconstruction as well as technical assistance to help the communities rebuild homes that are earthquake-resistant and more resilient to future earthquakes, minor or major.

Technical assistance should build the capacity of homeowners, as well as builders who will participate in the reconstruction of destroyed homes and strengthening of damaged homes in understanding and implementing disaster-resistant construction practices that meet the requirements of NSR-10. This approach of providing technical assistance plus construction funding directly to the homeowner and community, as opposed only providing funding, or providing contractor-built homes, more effectively builds the capacity of the community in earthquake-resistance construction. Disaster-resistant design and construction is then a skill that they can continue to use in future house construction, after the post-earthquake assistance is complete.

4. References

El Sismo De Los Santos, Santander Del 10 De Marzo De 2015 – Servicio Geológico Colombia

En la Figura 2, se muestra el Mapa de Intensidades Instrumentales en donde la Intensidad Instrumental alcanzada fue de V para la zona epicentral y de VI para las zonas cercanas al epicentro, que corresponden a aceleraciones registradas entre 9 a 15 (%g). Información adicional puede ser consultada en la web a través del enlace.
http://seisan.sgc.gov.co/RSNC/shakemap/sc/shake/intensidad.html

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