Build Change Post-Earthquake Reconnaissance Report

Surigao Del Norte, Mindanao, Philippines
10 February 2017

Survey Date: 23-25 February 2017
Report Date: 26 April 2017

Table of Contents

Foreword

Dear colleagues, partners and stakeholders,

Following the magnitude 6.7 Surigao earthquake in February 2017, Build Change sent a technical reconnaissance team to observe damaged and undamaged houses and schools to learn more about how buildings constructed using local practices and materials fare during disasters. Key takeaways include:

- Buildings that were generally compliant with the National Structural Code of the Philippines (NSCP) typically fared well, even if they were designed and built without professional advice.
- Conversely, the housing damages and collapses observed appear to be caused by identifiably inadequate design and poor quality construction.
- Instead of repairing houses (where they remain vulnerable to disasters) or enforcing relocation, damaged houses can be retrofit in a cost-effective manner which complies with the NSCP.
- There is an opportunity to build back better and create a culture of disaster-resistant design and construction for future construction, but it requires access to adequate financing, simplified technical assistance, and support from recovery and rehabilitation partners.

It is unsurprising that the most extensive damage in Surigao was to housing; millions of low-income families in the Philippines live in substandard housing, which makes them vulnerable to the impact of natural disasters and climate change. Residential housing built by homeowners is typically constructed using poor quality materials and unskilled labor, without professional inputs from an engineer or adherence to building codes.

But, it doesn't need to be this way. It is possible to support low-income families to design and build disaster-resistant housing within their means, using construction practices already common in the Philippines. It is also possible to retrofit, or structurally strengthen, existing substandard homes to meet the building code requirements.

Build Change's goal is to change the system, so that disaster-resistant design and construction practices become the norm, not the exception. We can't prevent earthquakes and typhoons from happening, but we can protect the lives, livelihoods and assets of the most vulnerable.

Both for the recovery and rehabilitation efforts in Surigao and as a nationwide effort to increase the safety of the housing stock and prevent catastrophic disaster loss, Build Change advocates for the following:

- Support for retrofitting programs for low-rise, residential homes
- Support for training programs for community builders (foremen, masons, carpenters, etc) in disaster-resistant design and construction practices
- Change in municipal permitting and inspection policies to address the barriers faced by families living in non-engineered homes
- Mobilization of grants, loans and incentives for disaster-resistant construction and retrofitting

We look forward to working with our partners from government, the private sector and charitable organizations to turn Surigao's recovery into an opportunity to build resilience among the Philippines' most vulnerable families.

Sincerely,

Kate Landry
Country Director
Build Change Philippines
kate@buildchange.org
+63 906 5495626

1.0 Background

At 10:03 PM local time Friday 10 February 2017 (2017-02-10 14:03:43 UTC), a 6.7 magnitude earthquake occurred off the coast of northeastern Mindanao, Philippines (M6.5 earthquake reported by USGS). According to the Philippines Institute of Volcanology and Seismology (PHIVOLCS), the rupture occurred at a depth of 10 kilometers with the epicenter located in the Surigao Strait (9.80° N, 125.35° E) approximately 16 kilometers from Surigao City, the capital of the Surigao del Norte Province.

Surigao del Norte is characterized by a narrow, rocky mountain range traversing a north-south axis along the western coast of Mindanao island. East of the mountain range the terrain is characterized by low-lying river plains and marshy agricultural land. Surigao City is a moderately dense urban environment with a population of approximately 160,000 people and land area of 245 km^2. The surrounding areas are less populated, rural agricultural communities. San Francisco, on the west coast of Surigao del Norte, maintains a population of approximately 15,000 people with an approximate land area of 56 km^2.

Although San Francisco suffered considerable damage during the earthquake, the reconnaissance team did not visit the town to perform observations because of restricted access. Major bridges and roadways were damaged by the earthquake such that visiting the area was deemed dangerous.

Regional Seismic Hazard

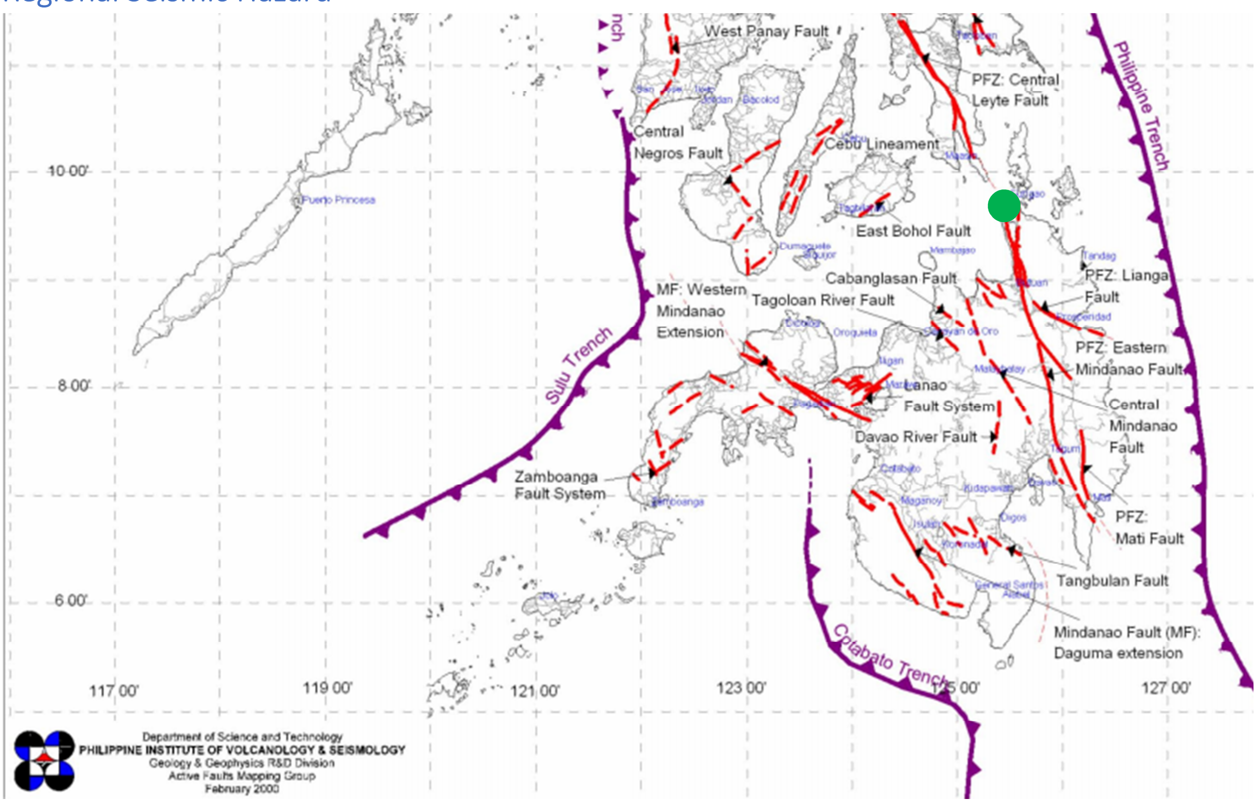

Figure 1.1 – Faults and trenches in Mindanao, Philippines. The Philippine Fault ("PFZ" above) denoted by solid red line. Surigao City denoted by green dot. (Source: PHILVOLCS)

The Philippines is located in a very complex tectonic setting, sitting on two tectonic micro plates, the Philippine Sea Plate and the Sunda Plate, which are surrounded by two much larger plates, the Eurasian Plate and the Pacific Plate. The movement of converging plates creates a subduction zone at the east and west boundaries. These subduction systems establish the trenches at the margin plate and faults that spread all over the Philippines.

Between the east and west subduction trenches a major transform fault known as the Philippine Fault runs over 1,200 km north-south from the northern island of Luzon down to the southern island of Mindanao. The Philippine Fault is a strike-slip fault, meaning the motion of the earth surface is primarily horizontal on either side of the faultline. This type of fault does not produce tsunamis because the lack of vertical displacement of ocean floor. The Philippine Fault has been associated with major historical earthquakes, including the destructive M7.6 Luzon earthquake of 1990.

Earthquake Information

PHILVOLCS reported the following details on the earthquake:
Magnitude: 6.7
Time: 2017-02-10 14:03:43 UTC
Depth: 10 kilometers
Epicenter: 9.80° N, 125.35° E

The Earthquake occurred off the northeast shore of Mindanao Island and resulted in strong to severe intensity within approximately 60 km of the epicenter. Based on preliminary intensity reports, the strongest ground shaking was experienced in Surigao City corresponding to a rating of VII (Destructive) according to the PHIVOLCS Earthquake Intensity Scale (PEIS). The municipalities of Pintuyan in Southern Leyte, and San Francisco in Surigao del Norte experienced intensities at PEIS VI (Very Strong), while the municipalities of Mainit and Placer in Surigao Del Norte, Libjo and San Jose in Dinagat Island, San Ricardo, Limasawa and San Francisco in Southern Leyte and Manduae City felt the shaking at PEIS V (Strong). The earthquake was felt at PEIS IV (Moderately Strong) up to 250 km away from the epicenter in Butuan City, Ormoc City, Tacloban City, Catbalogan City, Bislig City, Cebu City, Cagayan De Oro City, Dumaguete City and Tagbilaran City. The strong ground shaking near the epicenter resulted in damages to buildings, roads and bridges.

NOTE: The PHIVOLCS Earthquake Intensity Scale (PEIS) is similar to the Modified Mercalli Intensity Scale (MMI) which would characterize the highest earthquake as intensity VII, very strong shaking with moderate potential damage.

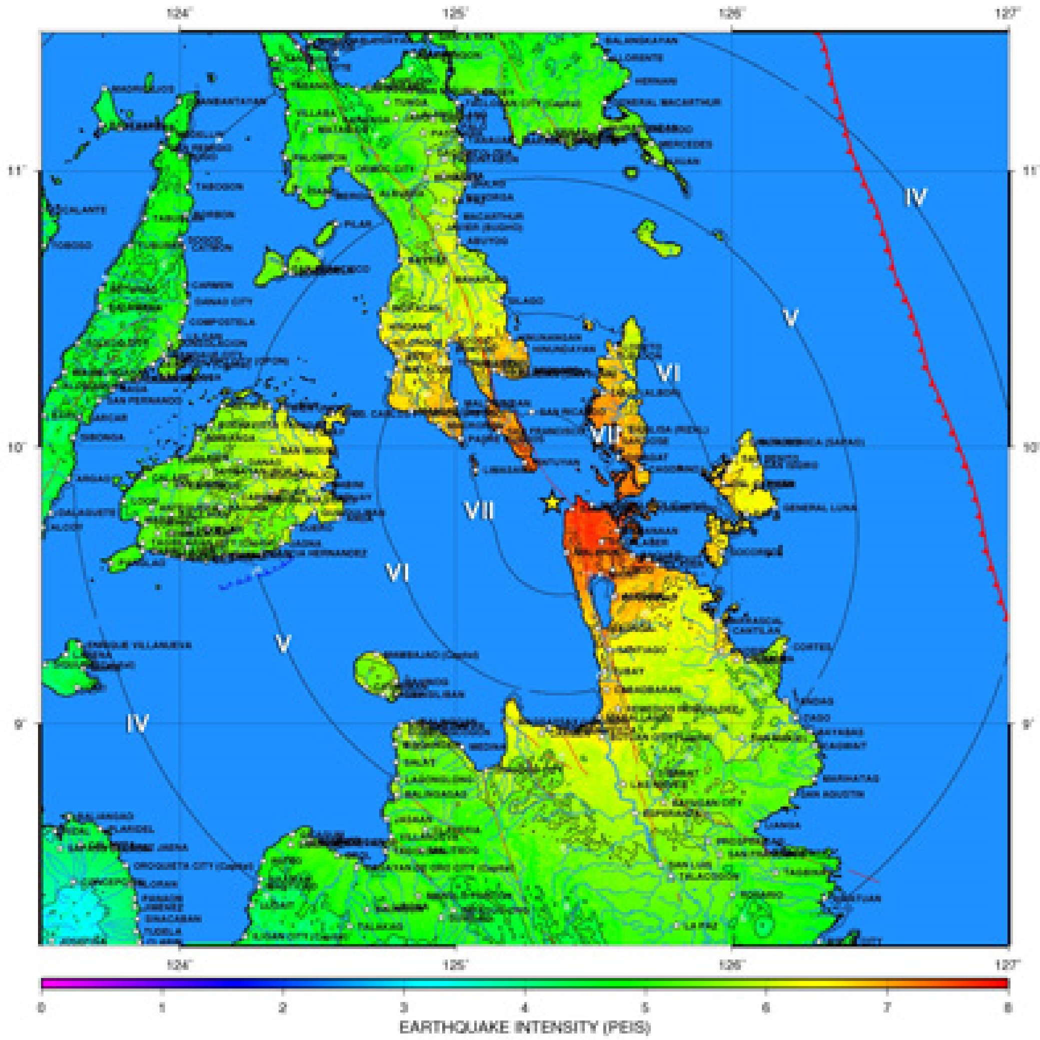

Figure 1.2 – Epicenter and intensity map (Source: PHILVOLCS)

Surigao del Norte is located in Zone 4, the highest seismic region, of the National Structural Code of the Philippines (NSCP) seismic mapping and is adjacent to the Surigao section of the Philippine Fault Zone (PFZ). Assuming a seismic source capable of producing magnitude M6.5 to M7.0 events, a building site within 5 km of the seismic source or fault, and typical soil profile D the seismic coefficient is equal to 0.44g for short period structures. Combined with the spectral design factors the design acceleration is then equal to 1.1g for short period structures.

The peak ground acceleration (PGA) determined by the USGS is equal to 0.77g but this value is derived from the earthquake magnitude recordings and does not include an amplification factor for local geology. Direct recordings of the ground motions at the PHILVOLCS Surigao seismic station indicate PGA equal to 0.39g in the east-west component but the accelerometer was unable to record data in the north-south component. The ground shaking was dominant in the north-south component, thus a higher PGA would have resulted. The derived USGS PGA value, even if amplified by 25%, is well below the NSCP design ground acceleration. This indicates that buildings constructed according to the standards of the NSCP should not be in danger of suffering catastrophic damage.

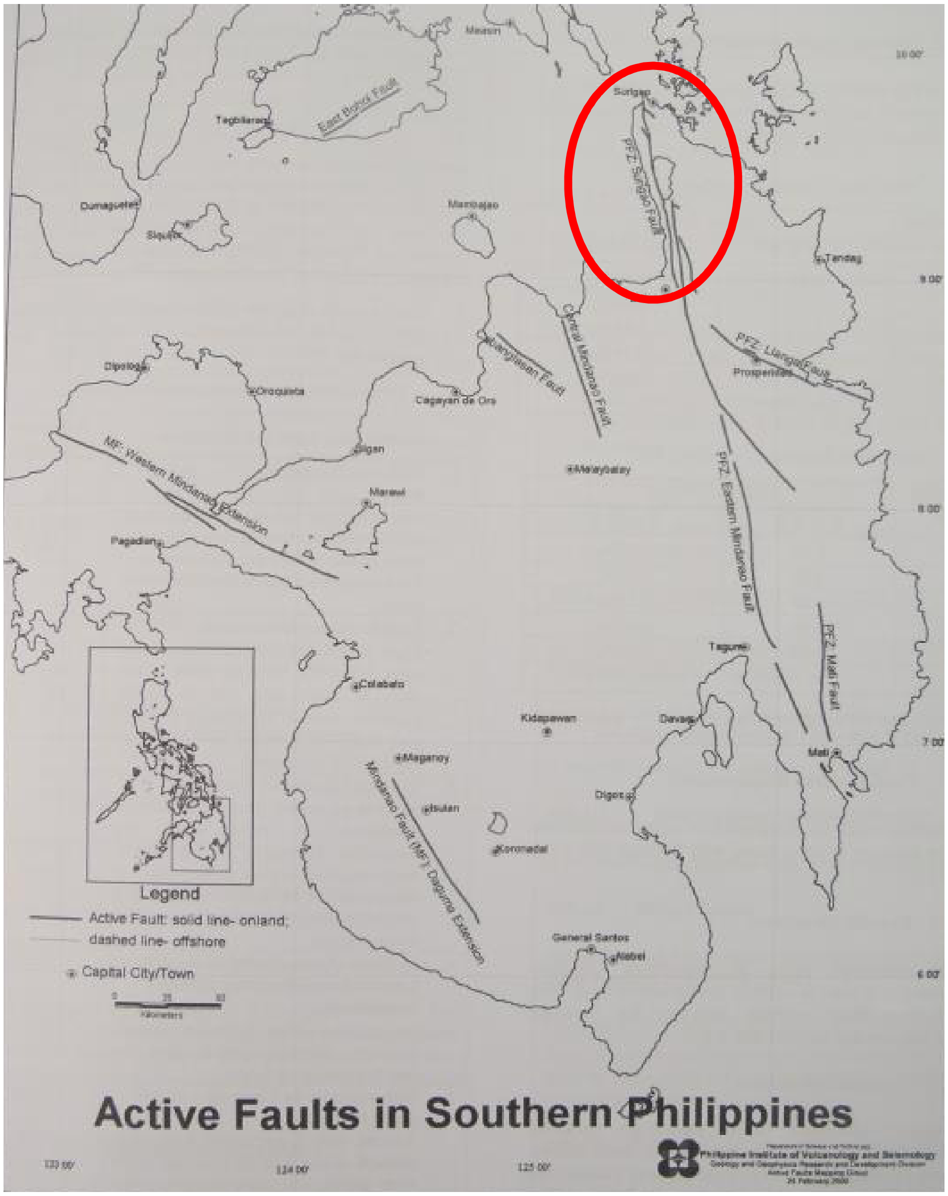

Figure 1.3 – 2010 NSCP Figure 208-2E Seismic Sources: Active Faults in the Southern Philippines. Surigao del Norte circled in red.

Reconnaissance Team

- Carl Fosholt (Project Engineer, Philippines)
- Linnel Ballesteros (Staff Engineer, Philippines)

Reconnaissance Objectives

1. Characterize the common construction typologies in the area and compare common practices with other regions in the Philippines.
2. Determine construction typologies most likely to exhibit damage and typologies least likely to exhibit damage.

3. Evaluate 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.
4. Evaluate buildings with minor or no damage to understand where common building types achieve successful earthquake resilience.
5. Understand how homes in dense, urban environments respond in an earthquake.

The objectives mentioned above are intended to gather information to inform best practice strategies for implementing post- and pre-earthquake retrofitting activities in cities throughout the Philippines. Retrofitting is a cost effective way for families and communities to recover from an earthquake, however pre-earthquake retrofitting can be implemented to greatly reduce death and injuries suffered during a significant disaster event.

2.0 Field Observations in Surigao City

The Surigao City Airport runway was severely damaged due to ground ruptures, therefore all services were suspended. The team flew to Butuan City, about 3 hours south of Surigao City by car, and drove north along the path of the Philippine Fault to the affect areas in Surigao del Norte. The team drove through rural and agricultural regions along the main roadway where building damage was not evident.

Although the city of San Francisco on the west cost of Surigao del Norte experienced severe shaking and damage to buildings, collapsed bridges and damaged roadways prohibited exploration of the area during the trip. Therefore the Build Change reconnaissance focused on the urban areas of Surigao City. Rapid evaluation building surveys were performed to obtain a understanding of the typical building response in the affected areas. Detailed evaluations were not performed. Barangays Taft and Washington are the most densely developed areas where housing exists adjacent to larger commercial buildings, universities and hotels. San Juan is entirely residential and high density only adjacent to the rivers. Luna is farther from the city center and less dense, but it is directly along the fault line and experienced significant damage to large buildings.

A wide variety of construction typologies for housing were observed including unreinforced masonry, concrete frame with masonry infill, masonry skirt wall, timber post with masonry infill, lightweight timber, and masonry ground story with timber upper story construction. Timber houses were primarily observed in the marshy flood plains near the river delta and were erected on stilts without cripple walls or bracing.

The school buildings observed were concrete frame with masonry infill walls and lightweight roofing. School buildings with two stories were constructed with concrete framing on the first floor and lightweight roofing.

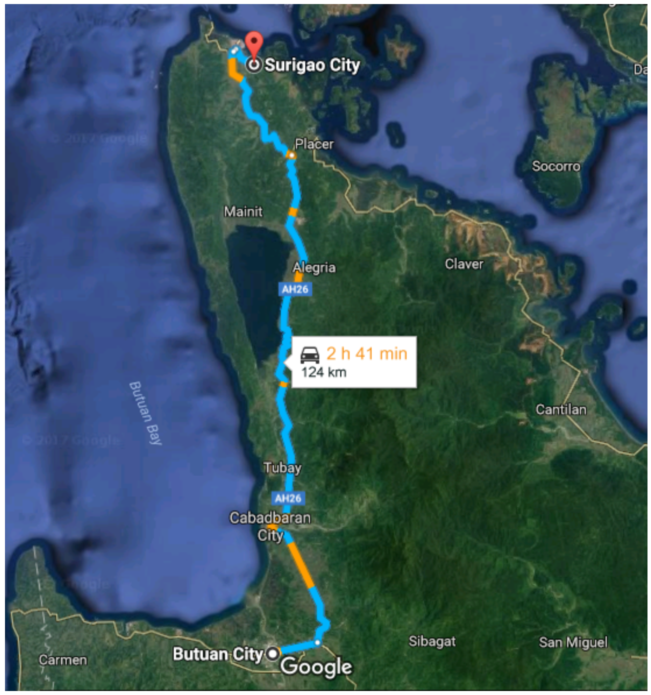

Figure 2.1 – Investigation Path (Source: Google Maps)

Figure 2.2 – Surigao City Barangay Map (Source: Surigao City Tourism)

Figure 2.3 – Typical concrete frame with masonry infill construction: two story homes with lightweight roofs

Figure 2.4 – Masonry/timber combination house: timber upper story above masonry ground story (top) and timber/masonry upper story above masonry ground story (bottom)

Figure 2.5 – Timber framed houses. Note the lack of cripple walls or braces below floor level.

Figure 2.6 – Typical school building in Brgy San Juan. No damage to classroom buildings occurred at this site.

Generally speaking, the buildings in the Surigao City area performed well. Few completely collapsed buildings were observed with damage typically consisting of out-of-plane wall failure in unconfined or masonry infill construction. Buildings that were fully collapsed were built with noticeably poor construction quality or with a clear lack of adequate funding, typically of non-engineered informal housing. Small housing performed well while the most substantial widespread damaged was experienced by large commercial buildings, university buildings, and hospitals of reinforced concrete with masonry infill construction five stories or taller.

Barangay San Juan

Barangay San Juan is located on the north side of the city and is separated from the main part of the island by river tributaries. San Juan is primarily residential with lower average density than Washington and Taft due to the distance from the city center. Houses in the area are typically 2 stories or less with lightweight timber or steel framing and CGI decking roof construction. Occasional 3 story masonry buildings with lightweight roofs were observed. Construction appears to be of good quality in most homes and the buildings appear to be built with few incremental expansions. This indicates a moderate income level for most residents. The soil in San Juan is soft and clayey, especially near the river tributaries and where stilted timber houses appear to be constructed on a marshy river plain periodically flooded during the rainy season. The houses built on the river floodplain appear to represent the lowest income level of residents in Barangay San Juan and experienced the most widespread damage.

According to the Initial Damage Assessment Report developed by the Surigao City Disaster Risk Reduction and Management Office (DRRMO), 127 homes were destroyedand 484 homes were partially damaged in Barangay San Juan. In San Juan, 605 people were forced to evacuate following the earthquake, making this Barangay the most significantly affected Barangay in Surigao City. However, the majority of buildings observed were unaffected by the earthquake. Most concrete frame with masonry infill construction exhibited minor or no damage. Damage to schools in the area consisted of minor cracks or damage to property walls, no major damage experienced.

Figure 2.7 – 3 story concrete frame with masonry infill and cantilever walls showing no sign of damage

Minor damage of masonry construction houses observed included minor wall cracking and cracking of masonry gable walls where no ring beam or concrete diaphragm was present to brace the gable wall out-of-plane. Although these damages appear superficial, they can weaken the structure, lead to dangerous collapse in future events, and should be addressed and repaired/replaced.

Figure 2.8 – 3 story concrete frame with masonry infill wall with minor in-plane cracking on front wall

Figure 2.9 – Out-of-plane wall failure; masonry gable wall cracking.

Total damage or building collapse appears to be caused by poor design and poor construction (typical of non-engineered, informal housing) insufficient to meet the NSCP requirements. Buildings that collapsed due the shaking are closest to the river where the soil conditions are the softest and where the highest concentration of low-income housing are located.

Figure 2.10 – Soft/weak story collapse of 3 story concrete frame with masonry infill. The coarse aggregate was found to be intact at concrete column failures indicating a potentially low-strength concrete mix with insufficient cement or too much water.

Figure 2.11 – 2 story masonry home with permanent tilt. Soft soil adjacent to river appears to have settled during the earthquake, resulting on one half of the building permanently sinking such that building is out of plumb. Lack of sufficient foundation expected.

Figure 2.12 – Soft/weak story failure of stilted masonry home on river plain. Note the lack of reinforcing on the supporting concrete posts(red circle). No positive connection existed between the concrete post and the floor.

Lightweight stilted houses in the river plain performed poorly due to the lack of cripple walls or diagonal bracing below the floor level (no direct load path to the ground) and the lack of adequate foundations.

Figure 2.13 – Soft/weak story collapse of stilted timber homes in the flood plain. No cripple wall or bracing present below floors and foundations were likely not present.

Figure 2.14 – Floor collapse of stilted home in river plain caused by collapsed posts supporting floors and walls. The posts were not supported by foundations.

Barangay Washington

Barangay Washington is a diverse neighborhood bridging the lower density areas of San Juan with the highest density areas closest to the city center in Barangay Taft. Residential neighborhoods exist adjacent to the river tributary between San Juan and Washington as well as in the higher elevation hills inland from the ocean. Moderate income families reside in the hills where homes exhibited little to no damage. Lower income families reside adjacent to the river tributary where density is higher, construction quality is noticeably lower, and soil conditions appear less favorable. Housing near the river consists primarily of 1 story masonry homes with lightweight roofing. The homes closest to the river utilize timber stilted construction similar to those in San Juan and were also highly vulnerable to collapse. In the city center at the border of Barangay Taft, multistory residential buildings are interspersed with commercial buildings and other service facilities. These buildings are constructed with concrete frame and masonry infill.

According to the Initial Damage Assessment Report by the DRRMO, 24 homes were destroyed and 1,676 homes were partially damaged in Barangay Washington. The large number of partially damaged homes is indicative of the lower average family income. Commercial buildings 4 stories or higher suffered extensive wall cracking and one hospital in the area was closed due to damages. The majority of buildings in the city center were undamaged and services were returned to normal operation shortly following the event on February 10.

The most common failure mechanism observed in Washington was out-of-plane collapse of masonry infill walls and masonry gable walls. Collapsed walls were lacking ring beams, connections to supporting diaphragms and/or adequate connections to columns on either end of the wall. Few unreinforced masonry walls were observed. Failed masonry walls contained some amount of reinforcement, although development of the reinforcement as well as size and spacing were inadequate.

Figure 2.15 – Out-of-plane gable wall collapse and out-of-plane wall collapse in masonry wall with timber post construction. No ring beams or diaphragm support present at top of walls.

Figure 2.16 – Out-of-plane wall collapse. No columns or ring beams present. House exhibited extensive in plane and out-of-plane damage to 4" CHB walls with insufficient reinforcement.

Figure 2.17 – Out-of-plane wall collapse. No ring beams present and only 2 bars with insufficient lap splices were used to connect wall to column. In plane diagonal cracking can also be seen on perpendicular wall.

Rupture of the ground surface was visible adjacent to the river in Barangay Washington and appeared to directly transverse numerous homes. Poorly constructed homes adjacent to visible ground ruptures experienced significant damage, however other homes adjacent to the ground ruptures experienced little to no damage. The distinct variation of performance of neighboring homes emphasizes the necessity of deliberate design and diligent construction quality that is required for achieving a disaster resistant home.

Figure 2.18 – Surface ruptures in ground. Surface rupture on right extends through slab on grade but stops at wall foundation.

Figure 2.19 – Well constructed concrete frame with masonry infill home, minor cracking on shear walls and no damage to foundations observable, despite evidence of ground rupture immediately adjacent to building on exterior sidewalk concrete and heavily damaged neighbor house next door.

Similar to Barangay San Juan, non-engineered informal housing adjacent to the river exhibited the lowest family income and the lowest construction quality. Lightweight timber structures without cripple walls or bracing below the floor level collapsed completely due to the lack of a complete lateral load path and due to a suspected lack of foundation.

Figure 2.20 – Soft/weak story collapse of lightweight timber structures adjacent to the river.

Several concrete hollow block manufacturers were encountered in Washington. Manufacturers appeared to use insufficient cement ratios, rounded and large river stones for coarse aggregate, and water sequestered from the nearby river in production. The manufacturing process appears to be unsatisfactory as evidenced by the piles of broken blocks in the production yard.

Figure 2.21 – Production of poor quality concrete hollow blocks encountered in Barangay Washington

Washington is home to a number of education facilities including elementary schools, special vocational schools and a technical university. Elementary school classroom buildings observed were constructed in the typical 2-story concrete frame with masonry infill common throughout the Philippines. Surigao City Central Elementary School suffered minor damage to masonry infill walls, masonry gable walls, and the masonry property wall, but the primary structure remained intact.

Figure 2.21 – Minor cracks due to insufficient out-of-plane support on gable wall and nonstructural masonry wall. In a more severe earthquake, walls would likely collapse and become a safety hazard.

One building on the Surigao State College of Technology campus experienced severe damage to nonstructural components. The structural system was a reinforced concrete moment frame; the concrete masonry infill walls were not detailed to accommodate the large deflections experienced by the moment frame building. A masonry roof parapet with insufficient reinforcement and connection to the main structure collapsed and destroyed the glass entry structure at the front of the building. Although the damage was to nonstructural components, both pose a significant threat to life safety and emphasize the necessity of properly detailing all building components to resist earthquake shaking.

Figure 2.22 – Masonry infill wall cracking (above) and entry structure destroyed by collapsed parapet wall (below). Main structure remained undamaged, but nonstructural components could be life threatening.

Barangay Taft

Barangay Taft is the most densely populated neighborhood in Surigao City, adjacent to the ferry terminal and surrounding the city center. Commercial buildings, hotels, and businesses are closely located along with multistory housing structures. Residential structures surrounded by commercial development appear to be non-engineered structures and show signs of incremental expansion indicative of low-income demographics. Timber post construction with masonry infill, a construction typology particularly susceptible to earthquake damage, was common among residential buildings in Taft. Non-residential buildings are typically constructed with concrete frame and masonry infill technology.

Figure 2.23 – Complete collapse of timber structure above concrete lower story. Cause of collapse unknown. This was the only complete collapse observed in Barangay Taft.

Similar to other barangays, out-of-plane wall failure was the most common failure mechanism observed. Masonry infill walls without ring beams and with timber posts are minimally restrained, causing collapse. In most cases the buildings are small enough such that the entire building did not collapse, but the future risk of progressive failure is high. Commercial buildings, hotels, and higher budget residential buildings exhibited favorable performance. Cracking was evident on ground floor shear walls on the largest structures and at wall openings where proper detailing was not present but the primary structural systems performed well.

Figure 2.24 – Out-of-plane wall failure. Masonry wall cannot accommodate deflection of the more flexible timber post. No tension connection between timber post and masonry wall.

Figure 2.25 – Out-of-plane wall failure. Masonry wall with no columns and no ring beam (left). Masonry wall with timber posts and no floor diaphragm connection (right). The wall on the right was unbraced for 2 full stories, thus the total destruction of the wall.

The Mariano Espina Memorial Central Elementary School in Barangay Taft experienced severe damage to the floor slabs of classroom buildings due to ground rupture, some walls experienced minor in plane cracking, one wall failed out-of-plane, and the perimeter fence experienced widespread collapse. Given the severity of the ground rupture however, the building systems performed rather well. No major structural or nonstructural elements collapsed that could become a life safety hazard. Some repair is necessary to return affected classrooms to functionality.

Figure 2.26 – Minor cracking between reinforced concrete column and masonry infill wall.

Figure 2.27 – Ground rupture in classroom building. Slab on grade does not contain reinforcement.

Figure 2.28 – Out-of-plane wall failure. No confining columns or beams present in wall (bottom left). Collapsed perimeter fence wall (bottom right). Perimeter wall constructed in masonry without sufficient reinforcement or confining elements

Barangay Luna

Barangay Luna is located south of the central city region and is lightly populated. All buildings are located close to the main highway and a developed urban area is not present. Residential structures were typically lightweight wooden farmhouses and did not exhibit widespread damage. The Surigao Airport is located in Luna and was closed due to extensive ground rupture damage of the runway. The St Paul Hospital facility in Luna was closed due to extensive damage as well as a major mall complex.

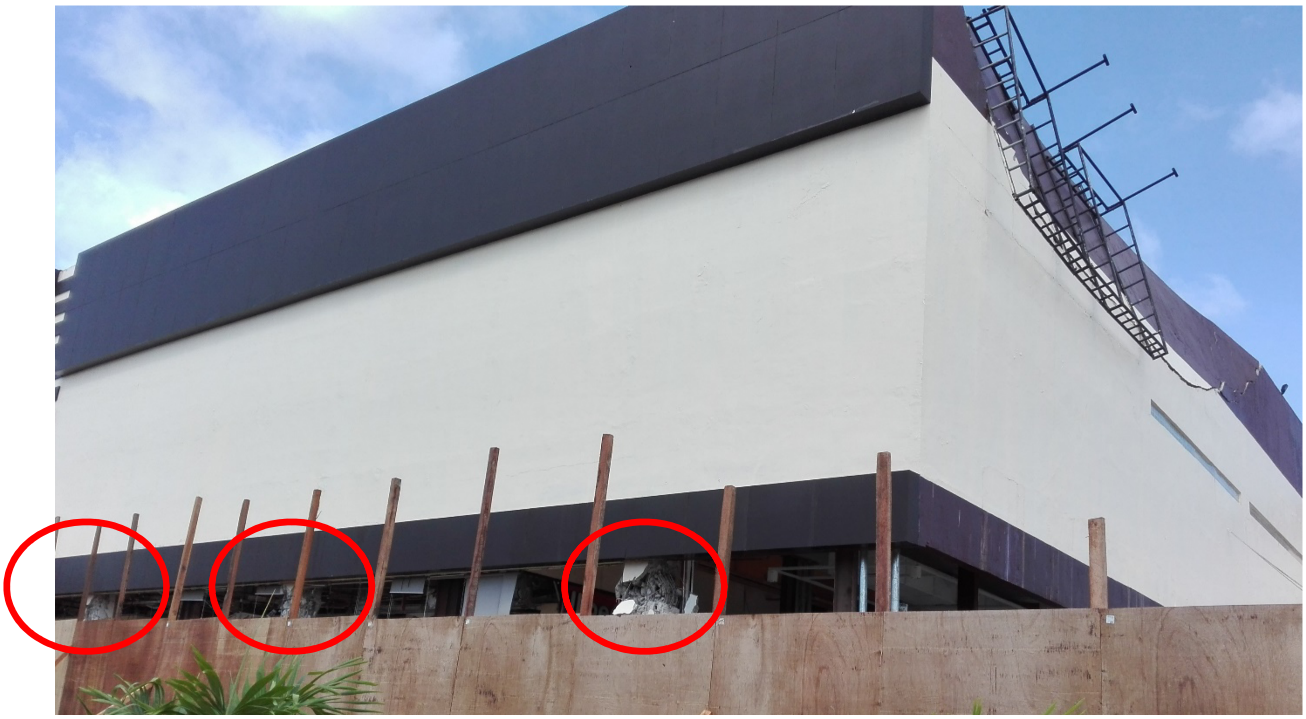

Figure 2.29 – Shear failure of reinforced concrete columns and parapet failure – mall complex/shopping center.

The Margarita Memorial Central Elementary School in Barangay Luna experienced spalling damage to concrete columns and collapse of a perimeter fence wall.

Figure 2.30 – Out-of-plane failure at perimeter fence wall.

Figure 2.31 – Spalling of concrete column at auditorium stage. Longitudinal rebar exposed and in danger of future buckling if not

3.0 Conclusions and Recommendations

Given the magnitude of USGS derived peak ground acceleration compared to the design acceleration determined by the NSCP, the majority of buildings in the Surigao City area performed adequately. To reach the design acceleration, the derived PGA would need to be increased by approximately 42% to account for local geological features, which may be accurate for soft soils in the river flood plains. In the static force procedure of the NSCP, the most practical seismic design procedure for residential housing, design accelerations are then reduced by a ductility factor known as an R-factor to determine an equivalent lateral force used to design the building. The building is designed to accommodate an acceptable amount of damage as determined by the R factor to dissipate the earthquake energy without collapsing the building. Therefore, minor damage of buildings is to be expected, especially in poor soil conditions. However, because the derived ground acceleration is substantially less than design acceleration, building collapse is due to deficient construction not meeting NSCP design standards.

The most common construction typology observed in Surigao City is concrete frame with masonry infill for both residential homes and larger commercial buildings. As expected, concrete frame with infill buildings experienced minor to extensive damage of the concrete infill while the overall structure typically maintained its integrity.

Significant damaged/collapse occurred in buildings that indicated clear signs of poor construction quality and a lack of NSCP directed design. Out-of-plane wall failure was common in both unconfined masonry (no concrete elements to support the masonry walls) and masonry walls where the confining elements were constructed with timber. Timber stilted homes without cripple walls or bracing below the floor level were also highly susceptible to collapse due to the lack of a complete lateral load path. Inadequate or non-existent foundations also led to severe damage. Finally, soft/weak story failure is a particularly severe mode of failure observed than can be avoided with proper design consideration. Recommendations for construction typology are as follows:

1. Unconfined masonry and timber frame with masonry infill construction is an unacceptable construction typology in high seismic zones. These buildings should be demolished or retrofitted to prevent future failures.

2. Stilted timber homes should be retrofitted with lateral bracing below the floor level to prevent soft/weak story collapse.
3. All buildings, including lightweight timber construction, require adequately sized reinforced concrete foundations. Soil investigations should be performed if practical, and conservative bearing design values should be employed if an investigation is not possible. Liquefaction zones and surface fault rupture zones should be avoided.
4. Large openings on the ground floor should be avoided to prevent soft/weak story failures.

It is recommended that the affected areas be supported with subsidies for retrofitting or reconstruction. Technical assistance is recommended to help the communities rebuild homes that are earthquake and typhoon-resistant or to implement technical retrofitting instead of repair. Builders and foremen should receive training in disaster-resistant construction to bolster their current skills and enable them to build better quality, safer homes. Technical assistance should build the understanding of disaster-resistant construction practices for homeowners and builders in both reconstruction of destroyed homes and strengthening of damaged homes. Homeowner-driven construction (where loans or subsidies are provided directly to homeowners for reconstruction or retrofitting) supported by technical assistance effectively builds the capacity of the community in earthquake-resistance construction. Disaster-resistant design and construction can become a common practice of the community after post-disaster assistance is completed.

4.0 References

Association of Structural Engineers of the Philippines (2010). *National Structural Code of the Philippines (NSCP) 2010, Sixth Edition*. Quezon City, Philippines. Association of Structural Engineers of the Philippines, Inc.

Philippines Institute of Volcanology and Seismology (PHIVOLCS) Situation Reporting following the earthquake event. http://www.phivolcs.dost.gov.ph/

United States Geological Survey (USGS) Earthquake event page. https://earthquake.usgs.gov/earthquakes/eventpage/us20008ixa#executive

Build Change (2016). *Residential Design and Construction Guidelines*. Cebu City, Philippines. Build Change.