Infrastructure damage during the Feb, 10, 2017 Surigao, Philippines earthquake

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Key Facts

- Hazard Type: Earthquake
- Date of the disaster: February 10, 2017
- Location of the survey: Surigao, Philippines
- Date of the field survey: February 12, 13, 20 - 22, 2017
- Survey tools: digital cameras and measuring tapes
- Key findings
  1) The epicenter of the earthquake was approximately with a focal depth of 10 km. The 6.7 magnitude earthquake was of tectonic in origin that was generated from a reverse thrust movement of a previously uncharted faul line.
  2) Damage from this earthquake was significant and widespread that included roads and bridges, schools and hospitals, government and private buildings, houses, and airports.
  3) Landslides, liquefaction, sinkholes and lateral ground fissures where observed in numerous areas.

Key Words : *earthquake, liquefaction,cultural heritage structures, damage to infrastructures*

1. INTRODUCTION

Surigao del Norte (Fig.1) is a province located north east of Mindanao, Philippines. On February 10, 2017 at approximately 10:03pm (PST), a 6.7 magnitude earthquake hit the province, with Surigao City affected the most. The earthquake had also affected neighboring islands and provinces like Leyte, Cebu, Cagayan de Oro and Bohol. The Philippine Institute of Volcanology and Seismology (PHIVOLCS) had identified the epicenter at 9.83ºN 125.37ºE or 16km offshore northwest of Surigao City with a shallow focal depth of 10km.

The seismic activity was triggered by a strike-slip movement producing a 4.3km surface-rupture along Brgy Ipil, Surigao City and Brgys. Poblaio, Honrado and Macopa, San Francisco, Surigao del Norte. The fault was tectonic in origin. The last movement of the said fault was in 1879 which produced a 7.4 magnitude earthquake.

Fig. 1. Surigao del Norte, Philippines.

This earthquake registered a PEIS (Philippine Earthquake Instensity Scale) of VII that is characteristic of a destructive earthquake with the presence of liquefaction, lateral spreading and considerably damaged buildings and bridges.

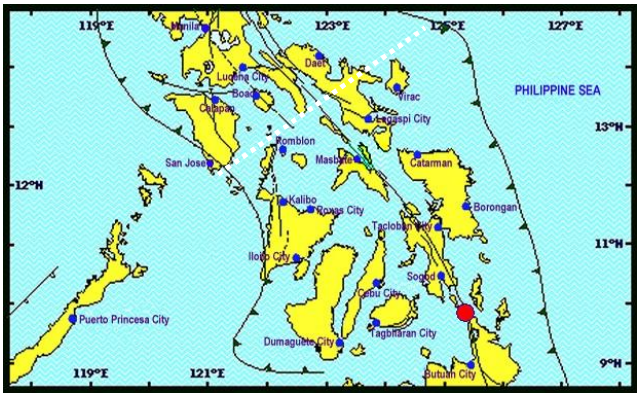

Fig. 2. Epicenter (source: PHIVOLCS)

According to a report by the National Disaster Risk Reduction and Management Council (NDRRMC), a total of 257 casualties were documented (8 deaths and 249 injured), including the aftershocks as of March 11, 2017. 10,691families or 53,455 persons in 82 barangays in Surigao del Norte were affected while a total of 1,567 families or 7,835 residents were accommodated outside evacuation centers.

The paper is divided into four chapters starting with the introduction with **Chapter 2** briefly explaining the geologic and tectonic setting of Surigao del Norte. **Chapter 3** expounds on the damage caused by the earthquake and **Chapter 4** summarizes the findings.

2. GEOLOGICAL AND TECTONIC SETTING

(1) Geological and tectonic setting

Surigao del Norte is an archipelago province of the CARAGA region or Region IX in Mindanao in the Philippines. It is the northernmost end of the Eastern Mindanao Ridge or the Eastern Mindanao Island Arc System (EMIAS). It is considered an important transportation center between Visayas and Mindanao. The province is approximately 1,972.93km^2 and houses a population of 250 persons per square kilometers in 20 municipalities.

The archipelago of Surigao del Norte and most of the Philippines is contained in the Philippine Mobile Belt (PMB) which is a zone of deformation and active seismicity that accommodates by large stresses caused by the northwestward movement of the Philippine Sea Plate. This zone is bounded in the west by east-dipping subduction zones in the Manila, Sulu, Negros and Cotobato trenches and in the east by west-dipping subduction zones mainly following the outline of the Philippine trench. In addition, within the PMB lies the left-lateral Philippine Fault that is roughly 1400 km in length and spans almost the whole of the country. Lastly, southwest of the PMB located is the aseismic Palawan-Mindoro block[3] (see **Fig. 3**).

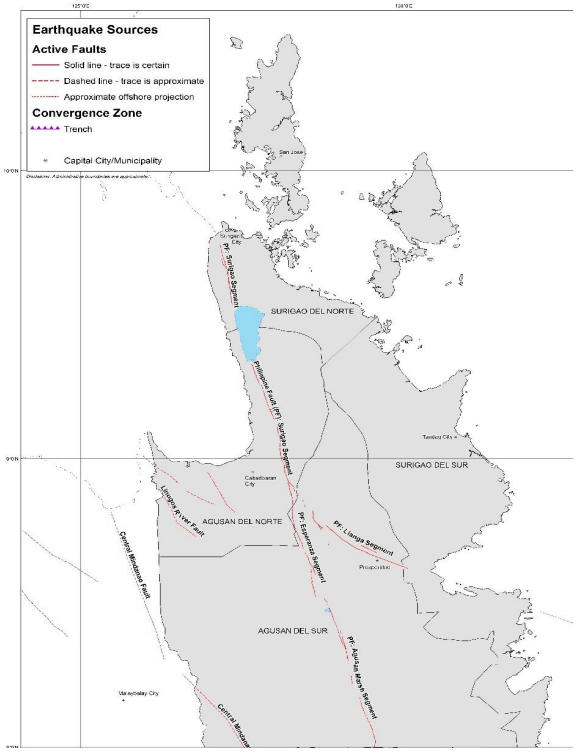

Fig. 3. Fault system in Region IX (CARAGA).

(2) Fault setting

The earthquake in Surigao del Norte was tectonic in origin and exhibited a striked-slip movement as observed during the field observations. The earthquake was generated by the movement of the Surigao segment of the Philippine Fault.

(3) Main shock and aftershocks

As of March 10, 2017, a total of 297 aftershocks were documented by PHIVOCS. Two largest aftershocks were recorded with a magnitude of 5.9 and 5.0 occurred at March 5 and February 14, 2017 respectively. The 5.9 aftershock increased the number of casualties by 42 (1 death and 41 injured). The aftershock was located a 9.77^{o}N 125.38^{o}E – 12km S80^{o}W of Surigao City, having a focal depth of 10km.

3. DAMAGE TO STRUCTURES

This recent earthquake was one of the strongest in Philippine history. The damage was widespread it affected houses, bridges, schools, roads, highways, public and private building, flood control structures, seaports, airports and hospitals.

According to NDRRMC site report, as many as 8 persons lost their lives, 249 were injured.

The following sub-chapters are the damage observed during the site inspection and assessment.

(1) Damage to houses

Damage to houses was enormous and affected dwellings made of timber, reinforced concrete as well as houses made of indigenous materials. According to NDRRMC more than 10,645 homes were damaged, 555 were totally damaged and 10,090 were partially damaged.

Residents whose houses were badly damaged were forced to evacuate to town centers or evacuation areas. Home owners whose houses sustained moderate damage moved out of their houses and pitched camp adjacent to their homes for fear of further damage to their homes due to the aftershocks.

Houses in Barangays in Baya-ag and Biabid in Municipality of Sison were damaged while residential houses in the Municipality of Mainit acquired minor damages.

Fig. 4. Soft-storey column failure of a two-storey house.

(2) Damage to bridges

A total of 6 bridges were also reported damaged. The superstructure of Anao-aon bridge which connects the Municipalities of San Francisco and Malimono (**Fig. 5**) collapsed and was considered unpassable; however, the bridge itself was in need of repair prior to the earthquake. Malico bridge obtained a depressed approach slab and damaged concrete railing, only light vehicles on one lane could pass (**Fig. 6**).

Fig.5 Failure of a Anao-aon bridge in San Francisco.

Fig. 6 Damaged to Malico Bridge.

Kinabutan Bridge I obtained cracks, buckling and pop-up of steel plate as well as damaged concrete railing, passable for only light vehicles in one lane. Kinabutan Bridge II obtained a depressed approach slab and damaged concrete railing. Friendship Brigdge had damaged slope protection and noted cracks found on girders, one lane can be used for all types of vehicles. And lastly, Banahaw Bridge had only damaged slope protection but all types of vehicles could pass.

(3) Damage to schools

Schools also sustained structural as well as non-structural damage. A total of forty-severn school facilities were affected by the earthquake. One of the buildings in San Nicolas High School was severely damaged by the earthquake (**Fig 7**).

Fig 7. A damage building in San Nicolas in San Francisco, Surigao del Norte.

(4) Damage to roads and highways

Roads and highways also sustained damage due to the intense ground shaking. Daang Maharlika Road was damaged but still passable to all types of vehicles. Surigao-Davao Coastal Road, Magpayang-Mainit Wharf Road, Surigao-San Juan Coastal Road and Surigao Wharf Road obtained minor cracks on carriageway.

Fig.8 Damaged airport runway I Surigao del Norte.

Runway in the Surigao City Domestic Airport had sustained damage (**Fig 8**).

(5) Damage to other facilities

Several water systems in different municipalities were damaged, temporarily stopping water distribution. Areas such as Malimono, Mainit, San Francisco and Surigao City were affected.

(6) Damage by the aftershocks

The 5.9 magnitude aftershock caused additional damage to some of the building in Surigao City, namely the Provinvial Sports Complex (collapsed back portion; immediate repair was needed) and Gaisano Capital Mall (collapsed portion).

(7) Total Damage Cost

The damaged caused by the earthquake incurred a total of Php 719,558,532.91 worth of damaged infrastructures. Table 1 shows the breakdown of the total cost of damage.

Table 1. Cost of Damages of the Surigao Earthquake

INFRASTRUCTURE	COST
Roads	Php 14,250,000.00
Bridges	Php 89,200,000.00
CARAGA Regional Hospital	Php 10,020,000.00
Drug Treatment and Rehabilitaion Center	Php 2,000,000.00
LGU Health Facilities	Php 115,000.00
School Facilities (Surigao City Division)	Php 7,698,000.00
School Facilities (Surigao del Norte Division)	Php 6,825,000.00
MLGU Placer Infrastructures	Php 6,800,000.00
Taganaan & Gov't Bldg./Facilities, Houses & Irrigation	Php 3,150,000.00
Surigao State College of Technology	
Surigao City Campus	Php 150,000,000.00
Quezon Campus	Php 12,000,000.00
Port Facilities	Php 161,500,000.00
Electric Power	Php 7,309,532.91
Water Supply	Php 2,300,000.00
San Francisco Infrastructure and Residential Houses	Php 27,000,000.00
Provincial Government Buildings/Infranstructure	Php 104,391,000.00
Provincial Bridge (Anao-aon Bridge)	Php 115,000,000.00
TOTAL	**Php 719,558,532.91**

4. SUMMARY

A strong earthquake occurred inland in Surigao del Sur on February 10, 2017. The strong ground motion was caused by a strike-slip movement of Surigao segment of the Philippine Fault. This surface-ruptured movement caused widespread damage to lives and properties especially on the westside of the fault line. This paper reports the damage of Surigao City after the event. It was observed that damage to structures was significant and widespread that included houses, bridges, schools, roads, highways, public and private building, flood control structures, seaports, airports and hospitals.

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