

Infrastructure damage analysis of the April 22, 2019 Pampanga, Philippines earthquake

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Key Facts

- Hazard Type: Earthquake
- Date of Disaster: April 22, 2019
- Location of the survey: Porac, Pampanga, Philippines
- Date of the field survey: April 24, 2019
- Survey tools: Laser meter, Drone
- Key Findings
 - 1) Various structural and non-structural damages within the Central Luzon Region were observed. The collapse of the Chuzon Supermarket in Porac, Pampanga, was the leading major aftermath of the earthquake.
 - 2) Majority of structures suffered minimal structural damage, most damages were to non-structural components.
 - 3) The probable fault of the earthquake is the Lubao Lineament.
 - 4) An earthquake-induced landslide occurred in Zambales, Philippines

Key Words: *earthquake, infrastructure damage, infrastructure collapse, structural damage, non-structural damage*

1. INTRODUCTION

The provinces of Pampanga and Zambales are located to the north of Metro Manila in the Philippines (see **Fig. 1**). On April 22, 2019, a magnitude 6.1 tectonic earthquake occurred approximately at 5:11 PM (PST). The focal depth of the earthquake, according to the Philippine Institute of Seismology and Volcanology (PHIVOLCS) is 10 kilometers while the epicenter of the earthquake is located 15.02°N, 120.34°E and eighteen (18) kilometers N 58° E of Castillejos, Zambales¹⁾ (see **Fig. 2**). However, the United States Geological Survey (USGS) described the epicenter of the Pampanga quake to be located at 14.897N, 120.497E at Gutad, Floridablanca, Pampanga with a focal depth of 20 kilometers.



Fig. 1. Location of Pampanga, Philippines (Source: Google Images)

This earthquake registered a PEIS (PHIVOLCS Earthquake Intensity 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 of the earthquake (Source: PHIVOLCS)

According to a report by the National Disaster Risk Reduction and Management Council (NDRRMC), there were a total of 18 casualties, 256 injured, and 3 missing persons reported. In addition, 18,086 persons were affected by the earthquake in 41 Barangays within Region III (Central Luzon), an administrative region composed of 7 provinces. 2,962 persons were served inside six evacuation centers while 4,756 persons were served outside the evacuation centers²⁾. The paper is divided into five 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. A Study Team by the Association of Structural Engineers of the Philippines (ASEP) was mobilized to Pampanga to study and observe the damages incurred due to the earthquake (see **Fig. 3**).



Fig. 3. ASEP Study Team

The field study consisted of inspection of the damaged sites within the province of Pampanga using a laser meter and drone. The laser meter was used to measure the dimensions of the structural and non-structural components and the architectural façade of the damaged structures, such as the height of the damaged structures and the dimensions of the beams and columns. On the other hand, the drone was used for taking an aerial view of the damaged structures and in viewing the interior of collapsed and inaccessible buildings.

2. GEOLOGICAL AND TECTONIC SETTING

(1) Geological and tectonic setting

The Philippines is divided into three island groups and a total of 17 administrative divisions, better shown in **Fig. 4**. The island group of Luzon, the largest of the Philippine islands, consists of the first 8 of these 17 regions.

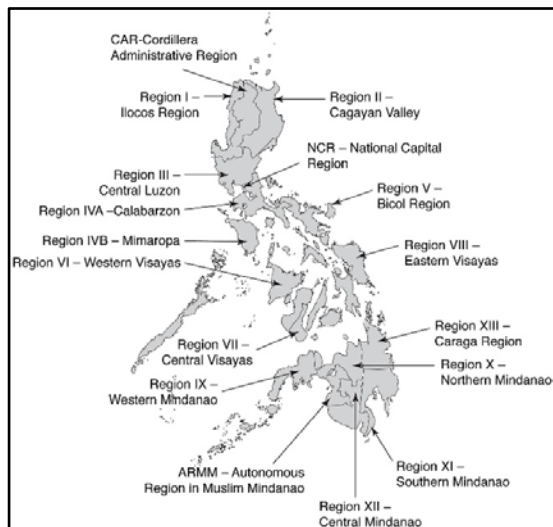


Fig. 4. The Administrative Divisions of the Philippines (Source: www.plos.figshare.com)

Pampanga is a province located in Region III (Central Luzon). The province has a total land area of approximately 2,180.68 km² it has 19 municipalities, 3 cities, and 538 barangays with a total population of 2,014,019 persons and 416,271 households³.

The province of Pampanga and most of the Philippines is contained in the Philippine Mobile Belt (PMB) which is a zone of deformation and active seismicity that accommodates the 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 Cotabato 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, the seismic Palawan-Mindoro block is located southwest of the PMB³ (see **Fig. 5**).

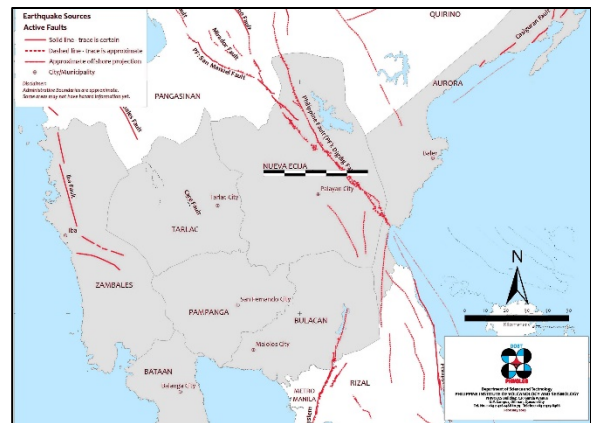


Fig. 5. Fault Systems in Region III (Source: PHIVOLCS)

(2) Fault setting

The earthquake in Pampanga was tectonic in origin. According to an interview with PHIVOLCS through the local news media Philstar, the earthquake that hit Pampanga was caused by a blind or hidden fault, it is yet to be determined⁴. However, the Study Team determined that the probable fault was the Lubao Lineament, which coincides with the reported epicenter of the USGS (see **Fig. 6**).



Fig. 6. Location of Lubao Lineament with respect to the Study Team Route colored blue

(3) Main shock and aftershocks

The main shock of the earthquake was reordered with a magnitude of 6.1 and reported an intensity VII on the PEIS. As of April 28, 2019, 1,097 aftershocks were documented by PHIVOLCS with 16 of these felt by the population. The aftershocks were recorded with a magnitude ranging from 1.4 to 2.5 and reported an intensity of I to III on the PEIS.

3. DAMAGE TO STRUCTURE

This earthquake was one of the strongest in recent Philippine history. The damage was widespread, and houses, bridges, schools, roads, highways, public and private buildings, airports, and hospitals were affected. According to NDRRMC site report, 18 persons lost their lives, 243 were reported injured, and 5 were declared missing. The following sub-chapters explain the damages observed during the site inspection and assessment. These damages are defined to be both structural damage and non-structural damage.

(1) Damage to houses

Damage to houses was immense, and dwellings made of timber, reinforced concrete as well as houses made of indigenous materials were affected. According to NDRRMC, more than 1,549 homes were damaged - 162 were totally damaged and 1,387 were partially damaged. However, majority of the homes experienced non-structural damages or minimal structural damages only and have not completely collapsed. **Table 1** shows the breakdown of the locations of the houses damaged by the earthquake.

Table 1. Damaged Houses caused by the Pampanga Earthquake (Source: NDRMMC)

Region/ Province/ Municipality	No. of Damaged Houses	
	Totally	Partially
Bataan	1	113
Abucay	1	3
Bagac	-	1
Hermosa	-	107
Orani	-	2
Pampanga	1,044	3,162
Bacolor	15	23
Floridablanca	419	1,448
Guagua	17	68
Lubao	11	309
Mexico	-	1
Porac	565	1,132
City of San Fernando	6	7
Santa Rita	1	-
Sasmuan	10	174
Zambales	1	54

Region/ Province/ Municipality	No. of Damaged Houses	
	Totally	Partially
Subic	1	54
Grand Total	1,046	3,329

Using 2018 data retrieved from the Philippine Statistics Authority⁵⁾, the number of households for the province of Pampanga is equal to 479,082. The percentage of damaged houses, both partially and totally damaged, in Pampanga with respect to the number of households is equal to 0.88%. Similarly, for the Province of Bataan, with a total number of households equal to 173,212, the percent damaged houses are equal to 0.06%. Lastly, for the Province of Zambales, the percentage of damaged houses to total number of households is equal to 0.04% for all 142,218 households. This is further summarized in **Fig. 7**.



Fig. 7. Summary of damaged houses and locations in Central Luzon

Residents whose houses were badly damaged were forced to evacuate to town centers or evacuation areas. Homeowners 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.

(2) Damage to bridges

One (1) bridge located in Floridablanca, Pampanga was also reported damaged and rendered not passable to vehicles, as seen in **Fig. 8** below. This bridge was reported to have slab deck cracks and depression along one of the approaches before it was repaired.



Fig. 8. Damage to Consuela Bridge in Floridablanca, Pampanga (Source: www.bworldonline.com)

(3) Damage to roads and highways

One roadway in Lubao, Pampanga was rendered not passable after the earthquake due to the collapsed slope protection and scouring from the embankment and half of the carriageway.

(4) Damage to structures and buildings

In total, 739 structures and buildings were reported damaged due to the earthquake in Regions I, III, and IVA, and the National Capital Region (NCR). This includes the collapse of Chuzon Supermarket, a four-storey supermarket, in Porac, Pampanga and damages to its surrounding structures (see **Fig. 9** and **Fig. 10**). Five of the 18 casualties reported in the province of Pampanga were retrieved from the supermarket collapse, according to Del Rosario from the Philippine News Agency⁶).



Fig. 9. Damaged exterior of Chuzon Supermarket



Fig. 10. Observed damages to the Chuzon Supermarket

Non-structural damages through a damaged ceiling were observed in the Clark International Airport located in Angeles City, Pampanga (see **Fig. 11**).



Fig. 11. Damaged ceiling in Clark International Airport

Similarly, damaged bell towers of three churches within Pampanga were observed. These churches were namely the Santa Catalina Church (see **Fig. 12**) and Pio Church (see **Fig. 13**) in Porac, and the St. Augustine Church in Lubao (see **Fig. 14**).



Fig. 12. Bell Tower damage to Santa Catalina Church



Fig. 13. Damaged bell tower of Pio Church (Source: www.inquirer.net)



Fig. 14. Damaged bell tower of St. Augustine Church (Source: www.thesummitexpress.com)

(5) Damage Cost

The damage to schools, roads, and bridges caused by the earthquake was estimated to be Php 505,920,000.00. **Table 2** shows the breakdown of the damage cost in million pesos.

Table 2. Cost of Damages to Schools, Roads, and Bridges of the Pampanga Earthquake (Source: NDRMMC)

Region	Cost of Damages to Schools	Cost of Damages to Roads and Bridges
NCR	Php 17 M	-
I	Php 41.5 M	-
III	Php 210.5 M	Php 200 M
IVA	Php 70 M	-
Total	Php 339 M	Php 200 M

(6) Earthquake-induced Hazards

An earthquake-induced landslide occurred in Mt. Bimmukel, San Marcelino, Zambales, that caused the evacuation of 120 families around the area. These families were provided with relief packs by the Department of Social Welfare and Development (DSWD).

4. SUMMARY

A strong earthquake inland in Central Luzon on April 22, 2019. The source of the strong ground motion is likely the Lubao Lineament. This ground movement caused widespread damage to lives and properties especially in the Pampanga province. This paper reports the results of the inspection and investigation of the damage in Central Luzon due to the earthquake. Most damages were on non-structural elements of the structure. It was observed that damage to structures was significant and widespread that affected houses, bridges, schools, churches, roads, highways, public and private buildings, airports, and hospitals. Majority of structures manifested zero to minimal structural damages. The most significant of these damaged structures was the collapse of the Chuzon Supermarket that significantly affected the province of Pampanga which took the lives of five (5) persons. Further study of the structures which withstood the earthquake may be explored to establish why these buildings sustained minimal damages.

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