EVENT BRIEFING

Event: 22/23 April, 2019 Philippines Earthquakes

Region: Southeast Asia

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Key Lessons

- Relatively low levels of ground shaking in the second earthquake can be attributed to the large depth of this earthquake, highlighting the importance of reporting other factors to the public, such as the focal depth and ground shaking levels, as compared to using only earthquake magnitude to describe the intensity of earthquakes.
- Similar to many previous earthquakes, the Philippines quake highlighted the vulnerability of non-ductile reinforced concrete structures and historical masonry structures indicating the immediate need for retrofits to avoid such damages in the future. In that regard, research should continue on developing proper retrofit techniques for these types of structures, while maintaining the cultural value and distinctive architecture of historical structures.
- Observed tilting of a 10-story school demonstrates the effect of far field ground motions and the ground motion amplification due to local soil conditions, considering that the distance between the epicenter of the earthquake and Manila is around 60 km. The fact that this is a school increases the severity of the situation.
- The total repair costs of dams are expected to be $2.5 million, highlighting the consequences of even low levels of damage after moderate earthquakes. This demonstrates the importance of performance-based earthquake engineering for the design and assessment of not only buildings, but also for critical infrastructure.
- There was no damage observed in power and transportation networks. However, power outages were reported in several provinces and train lines in Metro Manila were closed for the rest of the day, disrupting community functionality for less than a day, which is a reasonable outcome for this level of an earthquake.

StEER Response Strategy

The objectives of this event briefing are:

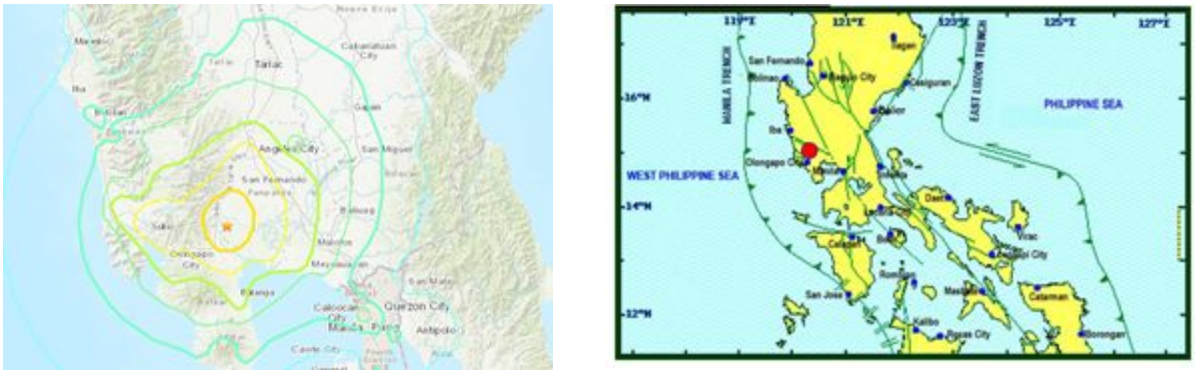
1. to summarize the seismic characteristics of the 22/23 April 2019 Philippines earthquakes
2. to overview damage to buildings and other infrastructure, as well as disruption to the community in terms of downtime and economic losses
3. to summarize key lessons learned.

Information provided herein was gathered from various websites, news channels, USGS and the Philippine Institute of Volcanology and Seismology. Therefore, this briefing does not include insights from detailed field investigations. StEER may decide to continue to form a Virtual Assessment Structural Team (VAST) to collect and process additional public data relating to these earthquakes. These data will be used to develop a more detailed Preliminary Virtual Assessment Report (PVAR) that will augment this event briefing. StEER is coordinating with other organizations including GEER, PEER, EERI and SEER, GHI and Build Change to determine how best to collect on-site data for this event.

Earthquake Details

On April 22, 2019, at approximately 5:37 pm local time, a magnitude 6.1 earthquake with a depth of 10 km struck 18 km northeast of Castillejos in the province of Zambales in the Philippines (USGS, 2019; Philippine Institute of Volcanology and Seismology, 2019). Epicenter of the earthquake was located in the island of Luzon, in the province of Zambales, with coordinates of 11.79 °N, 125.37 °E (see Fig. 1). The earthquake is estimated to have originated from the Iba Fault or the East Zambales Fault.

The USGS PAGER tool estimated no fatalities with a probability of 65% and less than 10 fatalities with a probability of 30% (Fig. 2). At the time this briefing was authored, there were at least 18 dead, 3 missing and 256 injured. PAGER estimated economic losses due to damage as less than $1 million, between $1 million and $10 million, and between $10 million and $100 million with probabilities of 50%, 40% and 9%, respectively.



(a) (b)

Figure 1. Epicenter of the earthquake from sources (a) USGS, and (b) Philippine Institute of Volcanology and Seismology

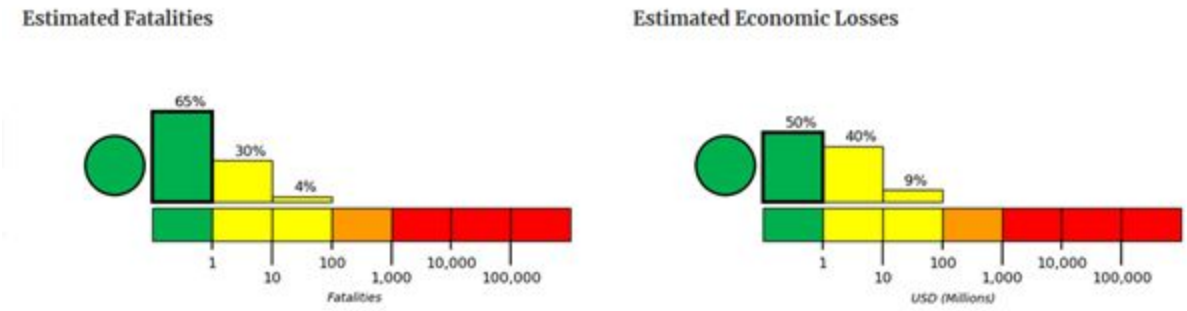


Figure 2. USGS PAGER loss estimates (USGS, 2019)

Although ground motion recordings were not available at the time this briefing was authored, USGS ShakeMap (Fig. 1a) indicates Peak Ground Accelerations (PGA) in the range of 0.2g~0.3g and Intensity levels of VII and VIII. This is supported by the Intensity levels of up to VII reported by the Philippine Institute of Volcanology and Seismology.

After this earthquake, on April 23, 2019, at approximately 1:37 pm local time, a magnitude 6.4 earthquake with a depth of 61 km struck 10 km northwest of San Julian in the Philippines. As shown in Figure 3, the epicenter of this earthquake was around 575 km away from the epicenter of the April 22, 6.1 magnitude earthquake (USGS, 2019; Philippine Institute of Volcanology and Seismology, 2019; Rollins and Stein, 2019). The USGS ShakeMap estimated the PGA in the range of 0.1g~0.2g. Relatively low levels of ground shaking in the second earthquake can be attributed to the large depth of this earthquake, highlighting the importance of reporting other factors to the public, such as the focal depth and ground shaking levels, as compared to using only earthquake magnitude to describe the intensity of earthquakes. Note that the damage reported in the following section is due to the first earthquake.

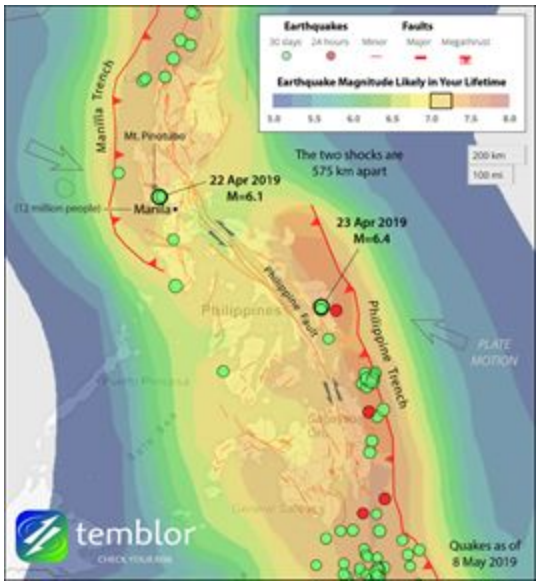


Figure 3. Locations of the April 22 and 23, 2019 earthquakes (Rollins and Stein, 2019)

Damage to Structures

Buildings

The province of Zambales, the epicenter of the earthquake, had been spared from the earthquake destruction, while the neighboring province of Pampanga suffered damage to 29 structures/buildings and was the area most affected by the earthquake due to the presence of soft sediment and alluvial soil sites. Several structures in the province were damaged by the quake, including a 4-story supermarket in Porac, Fig. 4 (CNN, 2019), the Bataan-Pampanga boundary arch and the main terminal of Clark International Airport. Damage was observed in historical churches in Lubao and Porac, where the stone bell tower of the 19th-century Santa Catalina de Alejandria Church collapsed (Fig. 5). Considering the relatively moderate level of shaking with the fact that collapse and similar damage was not observed in nearby structures, it can be stated that the collapse of the 4-story supermarket is due to the structural deficiencies such as short columns and deficient beam-column joints, Fig. 4.

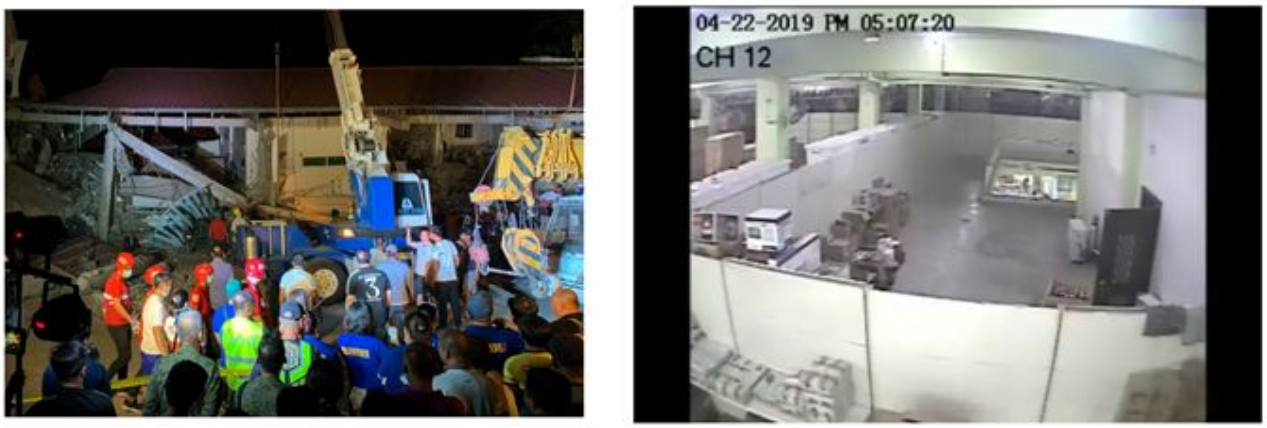


Figure 4. Collapsed four story structure: (left) photo after collapse, (right) snapshot from the video footage just before collapse showing the presence of short columns.

Similar to many previous earthquakes, the Philippines quake highlighted the vulnerability of non-ductile reinforced concrete structures and historical masonry structures indicating the immediate need for retrofit to avoid such damages in the future. In that regard, research should continue to develop proper retrofit techniques for these types of structures, while maintaining the cultural value and distinctive architecture of historical structures.

Figure 5. Collapsed stone bell tower of the 19th-century Santa Catalina de Alejandria Church

A 10-story school building in Manila (Emilio Aguinaldo College) was reported to have tilted and leaned onto the adjacent building (Fig. 6). Soil liquefaction underneath the building was indicated as the probable cause. This tilting demonstrates the effect of far field ground motions and the ground motion amplification due to local soil conditions, considering that the distance between the epicenter of the earthquake and Manila is around 60 km. Furthermore, the structure being a school building increases the severity of the situation.

Figure 6. Tilted 10 story school building in Manila

Other Infrastructure

Five dams in Central Luzon were damaged and needed immediate repairs according to the National Irrigation Administration (NIA, ABS-CBN News, 2019). The Cong Dadong Dam in Arayat, Pampanga showed cracks, with repairs estimated to be around $1 million. The Mangindong Dam in Dinalupihan, Bataan had cracks on a footbridge with repairs estimated at $0.5 million. Moreover, damages in Bataan included the Balsik Dam in the town of Hermosa, where a portion of the main canal collapsed. Repairs to the dam are expected to cost $0.25 million. In Zambales, NIA also reported cracks on a portion of the Bucao Intake facility in the town of Bucao. Cracks were also noted on the retaining walls of a diversion dam in the Barangay of San Pablo in the town of Castillejos. Repairs to the two facilities are expected to be around $0.75 million, according to NIA. The total repair costs of dams are expected to be $2.5 million, highlighting the consequences of even low levels of damage after moderate earthquakes. This demonstrates the importance of performance-based earthquake engineering for the design and assessment of not only buildings, but also for critical infrastructure.

There was no damage observed in power and transportation networks. However, power outages were reported in several provinces and train lines in Metro Manila were closed for the rest of the day, disrupting community functionality for less than a day, which is a reasonable outcome for this level of an earthquake.

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