StEER: Structural Engineering Extreme Event Reconnaissance Network

2018 HAITI EARTHQUAKE
PRELIMINARY VIRTUAL ASSESSMENT TEAM (P-VAT) REPORT

Collapsed School Building in Gros-Morne, Haiti

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Executive Summary

On October 6, 2018, at 8:12 pm local time, a magnitude 5.9 earthquake, with a depth of 11.7 km, struck 19 km northwest of Port-de-Paix, Haiti. The earthquake damaged structures, killed at least 17 people, and injured 333 people at the time this report was authored. Shaking was felt as far away as Port-au-Prince, 219 km away from the epicenter. There were several aftershocks following the earthquake, including one with magnitude of 5.2.

The earthquake caused part of a hospital to collapse in Gros-Morne, damaged the façade of the Paroisse Saint Michel Archange de Plaisance church in Plaisance, caused a cultural center to collapse in Gros-Morne, damaged a holding cell at the Police Nationale d'Haiti Commissariat de Port-de-Paix in Port-de-Paix (allowing several detainees to escape), caused an auditorium to collapse in Gros-Morne, damaged several classrooms at San Gabriel National School in Gros-Morne, and destroyed houses in the communes of Chansolme, Gros-Morne, Plaisance, and Port-de-Paix as well as on the island of Tortuga. Until now, there are no reported cases of bridge damage or geotechnical failures.

Although the earthquake can be classified as a moderate earthquake according to its magnitude, in terms of learning from earthquakes, it is an important event considering the devastating 2010 Haiti earthquake that killed 220,000 people and the renewed emphasis on disaster preparedness and mitigation efforts since that event.

Introduction

StEER's response to the 2018 Haiti Earthquake will initially be limited to a Virtual Assessment Team (VAT). The focus of the VAT will be on compiling relevant information about the event from public sources and social media. StEER is also seeking collaborators on other teams proposing to visit the disaster zone and may look for opportunities to join one or more of those teams for field assessments.

The first objective of StEER's response is the compilation of information available immediately after the event, to improve our understanding of the performance of constructed facilities during a moderate earthquake in a country that was devastated by a 7.0 magnitude earthquake 8 years ago and has gone through a series of mitigation measures. Although buildings and structures in the US may perform better during the earthquake than those in Haiti, this earthquake still provides good lessons to learn in the form of hazard mitigation for a country that has a history of strong earthquakes (see Fig. 1).

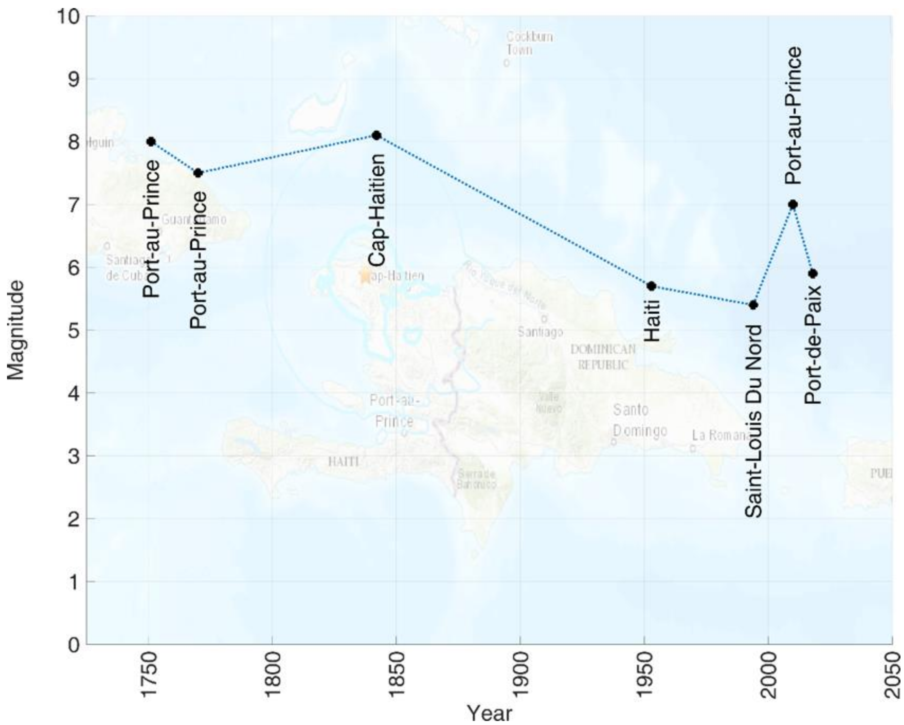


Figure 1: Timeline of major earthquakes in Haiti (primary data source: http://bit.ly/usgs-sig-eq).

The second objective of this StEER response is to use this international event to exercise the protocols, procedures, policies and workflows that StEER will be developing over the next two years in collaboration with the Earthquake Engineering research community, e.g., the Pacific Earthquake Engineering Research (PEER) Center, the Natural Hazards Engineering Research Infrastructure (NHERI) and other members of the Extreme Events Reconnaissance Consortium.

The first product of the StEER response to the 2018 Haiti Earthquake is this **Preliminary Virtual Assessment Team (P-VAT) report**, which is intended to:

1. provide an overview of the 2018 Haiti Earthquake, particularly relating to sequential effects on building structures,

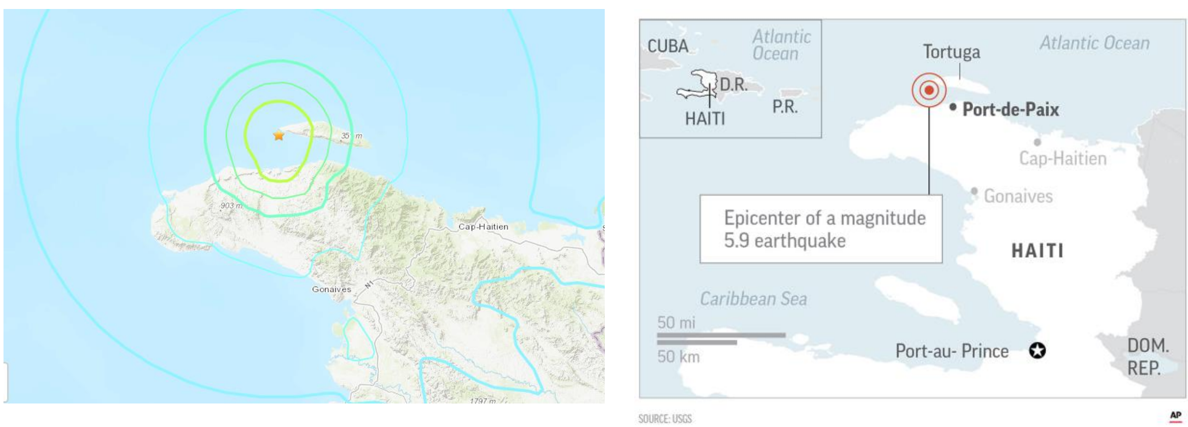
2. provide brief information about the preparedness and mitigation efforts conducted after the devastating 2010 Haiti Earthquake as demonstrated by this 2018 event,
3. overview StEER's event strategy in response to the 2018 Haiti Earthquake,
4. summarize the preliminary findings related to damage caused by the earthquake, and
5. build capacity within the earthquake reconnaissance community for rapid response and assessment to moderate and major earthquake events.

It should be emphasized that all results herein are preliminary and based on the rapid assessment of publicly available online data within 3 days of the event. Damage assessments discussed herein are based largely on the judgement of the authors without access to additional aerial imagery and ground-truthing.

Earthquake Details

On October 6, 2018, at approximately 8:12 pm local time, a magnitude 5.9 earthquake, with a depth of 11.7 km, struck 19 km northwest of Port-de-Paix, Haiti. (Fig. 2) (USGS, 2018; The New York Times, 2018). Epicenter of the earthquake was located offshore in the "canal de la Tortue", with coordinates of 20.013ºN and 73.006ºW (Civil Protection, 2018). The earthquake originated from the Septentrional portion of the Septentrional-Oriente fault zone (Fig. 3), which is a system of coaxial left lateral-moving strike slip faults that runs along the northern side of the island of Hispaniola where Haiti and the Dominican Republic are located. A major earthquake on this fault destroyed the city of Cap-Haïtien and other cities in the northern part of Haiti and the Dominican Republic on May 7, 1842. There has not been a major earthquake in this fault zone since then. Prior to the October 6 earthquake, there have been several low-to-moderate-level earthquakes on this fault, including a magnitude 5.2 earthquake that took place on September 23, 2018 (Government Seismic Bulletin, 2018).

USGS PAGER tool estimated the fatalities to be between 10 and 100 with a probability of 35% (Fig. 4), and according to the current number of 17 deaths, this estimation seems to be correct. Economic loss and damage were expected to be quite low according to PAGER, which turned out to be an underestimation, as there were several collapses and cases of severe damage in critical facilities.



(a) (b)

Figure 2: Epicenter of the 2018 Earthquake from sources (a) USGS, and (b) the Associated Press

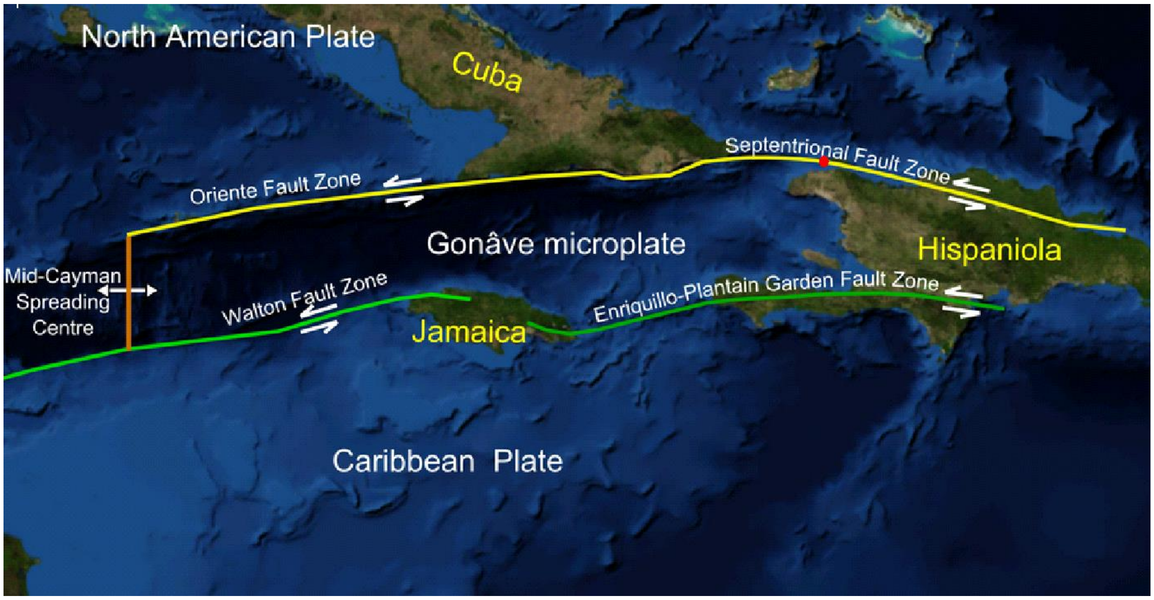


Figure 3: Septentrional-Oriente fault zone with the epicenter of the earthquake marked on the Septentrional fault (Wikipedia, 2018)

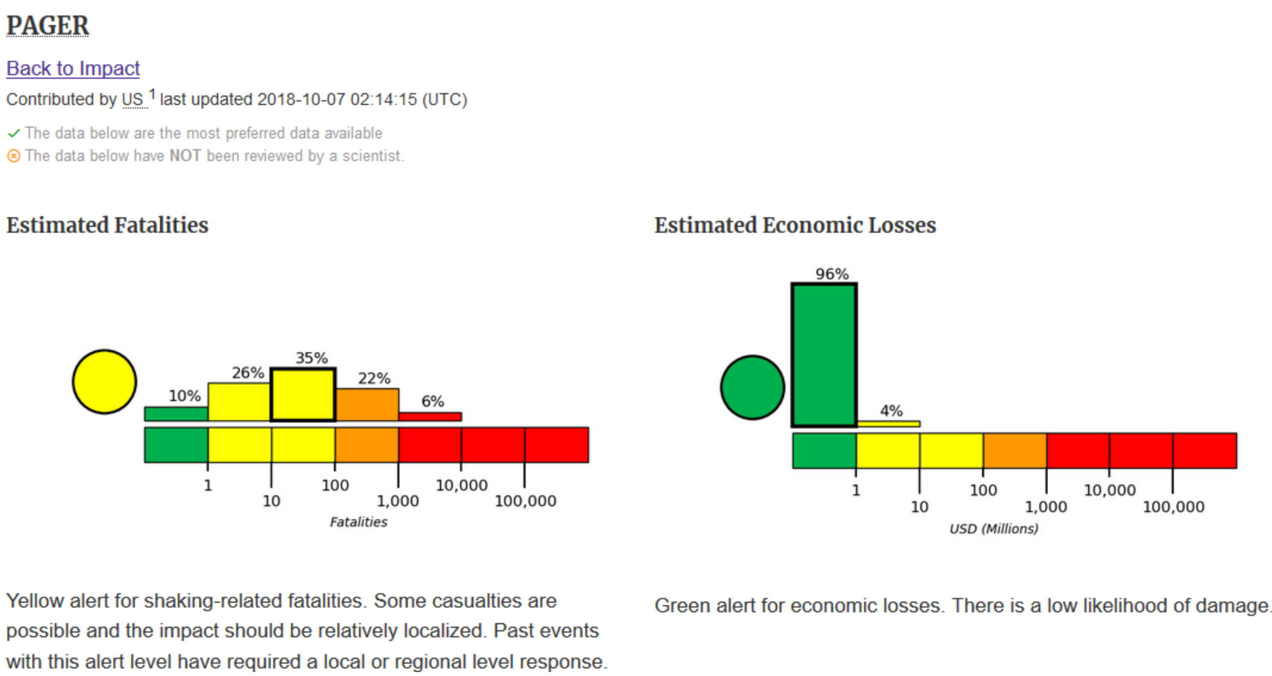


Figure 4: USGS PAGER loss estimates (USGS, 2018a)

After the 2010 Earthquake, Frankel et al. (2011) produced probabilistic seismic hazard maps of Haiti for peak ground acceleration and response spectral accelerations that include the hazard from the major crustal faults, subduction zones, and background earthquakes (Fig. 5). According to this figure, the areas close to the epicenter of the earthquake, marked with a blue rounded rectangle, can experience peak ground accelerations as large as 0.6g and 0.8g in the earthquake events with probabilities of exceedance of 10% and 2% in 50 years. There were no ground motion recordings available during the 2010 Haiti Earthquake, but a ground motion network has been set up after that earthquake. The 2018 Earthquake was recorded by one NetQuakes instrument in Port-au-Prince and possibly by other instruments as well. Currently, the StEER team is trying to access the ground motion data, which are not available as of the date this report was authored.

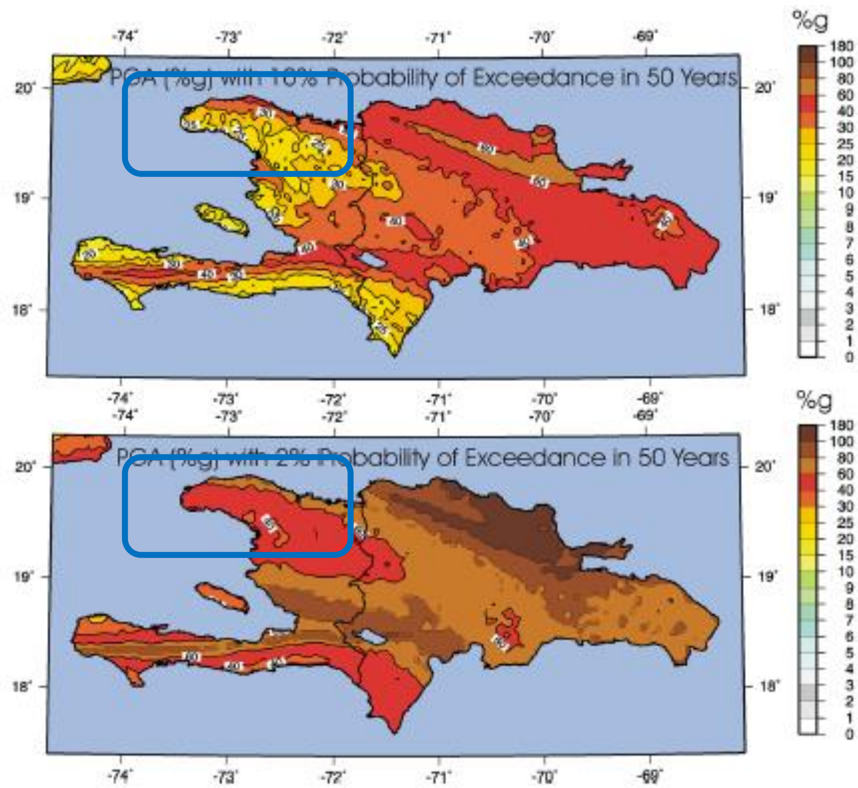


Figure 5: Seismic hazard maps of Haiti for events with probability of exceedance of 10% and 2% in 50 years (Frankel et al., 2011)

Earthquake Preparedness and Mitigation Efforts After the 2010 Earthquake

There has been a series of earthquake preparedness and mitigation efforts in Haiti after the 2010 Earthquake. One of these efforts was organized by GeoHazards International (GHI, www.geohaz.org) who worked in parts of Haiti that may experience the next major earthquake: places with high seismic hazard that have not had an earthquake recently. Following the 2010 earthquake, GHI designed a project to reduce the earthquake and tsunami risk of the northern coast of Haiti, near the Septentrional-Oriente fault zone, the fault zone where the October 6 earthquake originated. Under the resulting United Nations Development Programme's (UNDP) Plan Nord, GHI trained construction workers such as masons and material suppliers in earthquake-resistant design and construction techniques. Plan Nord also included the Bureau de Recherches Géologiques et Minières of France, which performed microzonation studies in some of Haiti's cities. Some other notable activities included the development of a national seismic hazard map, a national building code, several new buildings designed and built according to the seismic code (notably the new administrative quarter of Port-au-Prince), training of construction professionals, development of an operational seismic network, several Haitian PhD students trained abroad and now working in Haiti, and a new master's program at the State University of Haiti in geosciences-geohazards.

Another set of important activities in relation to seismic preparedness and mitigation of Haiti were undertaken by Build Change (https://www.buildchange.org/locations/haiti/). Among these activities, some of the important ones are upgrading current technologies and common construction practices; implementing low-cost improvement solutions; capacity building activities; encouraging the use of better materials; and retrofits to prevent building collapse and achieve safer schools.

Throughout the broader Caribbean region, several efforts have enhanced earthquake and tsunami monitoring since the 2010 Haiti earthquake. The Continuously Operating Caribbean GPS Observational Network (COCONet) in Caribbean and Caribbean-border nations is a geodetic network operated by UNAVCO, with support from the U.S. National Science Foundation and partners from many other countries and now provides real time geodetic data for studies of plate kinematics, the earthquake cycle, volcanic processes and even hurricane tracking. The United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Coordinating Group (ICG) for the Tsunami and other Coastal Hazards Early Warning System for the Caribbean and Adjacent Regions (CARIBE-EWS) has developed performance standards for detection and analysis of earthquakes, and now over 100 seismic stations, from nearly every nation in the Caribbean region, contribute real-time data to tsunami warning centers (McNamara et al., 2016). These projects provide data essential for understanding the processes leading to major earthquakes and tsunamis.

Despite all the above-mentioned efforts, very little efforts have been made in the North at the affected area, in terms of actually improving buildings and infrastructure. Level of damage and impact from this moderate-size earthquake at least 19 km distance from population centers might serve as a warning that buildings in this part of the country are highly vulnerable to earthquake damage. It should also be noted that the 2018 report of the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) reports that 1.9 million Haitians are still in need of aid, and that continued investment in preparedness and disaster risk reduction is required (which includes hurricanes in addition to earthquakes).

Damage to Structures

During the 2018 Haiti earthquake, damage mainly focused on building structures. A number of building structures were damaged in Port-de-Paix and Gros-Morne in the Artibonite province, Chansolme and Tortuga Island. No damage was reported in the capital of Haiti (Port-au-Prince), as well as in the neighboring Dominican Republic and in eastern Cuba, where the earthquake was slightly felt.

Buildings

Cases of notable damage were observed during the earthquake. They are described briefly below:

1. **A Hospital in Gros-Morne**

   A hospital is reported to have partially collapsed in Gros-Morne during the earthquake. However, no images of the damaged hospital were accessible by the time of completion of this report.

2. **Cultural Center Collapse in Gros-Morne**

   A cultural center collapsed in Gros-Morne, but no images of the cultural center collapse are currently available.

3. **An Auditorium in the Town of Gros-Morne**

   First story of a reinforced concrete auditorium in the town of Gros-Morne collapsed during the earthquake on October 6 2018 (Fig. 6), killing one person. By the morning of October 7 2018, it was entirely cleared and debris was removed (Fig. 7). A video of the clearance of the collapsed auditorium can be found at: https://www.thesun.co.uk/news/7436302/haiti-earthquake-magnitude-ring-of-fire-island/amp/#.

Figure 6: The collapsed auditorium after the 2018 Haiti Earthquake

Figure 7: The debris of the collapsed auditorium after the 2018 Haiti Earthquake

4. A Police Station in Port-de-Paix

A police station, named Police Nationale d'Haiti Commissariat de Port-de-Paix, in Port-de-Paix was damaged (Fig. 8), allowing several detainees to escape.

Figure 8: The damaged police station after the 2018 Haiti Earthquake

5. Catholic Church Roof Collapse in Plaisance

The front facade of the Catholic church, Paroisse Saint Michel Archange de Plaisance collapsed (Figures 9-11). A house next to the church also collapsed, according to Lemoine Bonneau from Haitian newspaper *Le Nouvelliste*.

Figure 9: Google Map Street View image of Paroisse Saint Michel Archange de Plaisance church before the 2018 Haiti Earthquake

Figure 10: Google Map Street View image of Paroisse Saint Michel Archange de Plaisance church before the 2018 Haiti Earthquake

Figure 11: Damaged Paroisse Saint Michel Archange de Plaisance church after the 2018 Haiti Earthquake, note the decorative gable atop the front face in Figures 8 and 9 detached in the earthquake.

6. **San Gabriel National School in Gros Morne**

San Gabriel National School in Gros-Morne is a 2-story RC moment resisting frame that collapsed due to the damage of the first-story columns (Fig. 12). Some beams on the second floor and some external walls were also destroyed, severely damaging several classrooms. The block of classrooms was just built in 2016. The construction materials shown in Figure 11b possibly seem to be easily crushed, which suggests questionable material quality and levels of confinement.

Fortunately the earthquake happened outside of school hours, thus avoiding what could have been a severe loss of life. Nun Maryse Alsaint, director of the San Gabriel National School, said that about 500 students would not be able to return to school on Monday, October 8, 2018.

(a)

(b)

(c)

(d)

Figure 12: Collapsed San Gabriel National School in Gros-Morne after the 2018 Haiti Earthquake

7. **Lycee Jacques Roumain Educational Center in Gros-Morne**

Moderate damage was observed at the Lycee Jacques Roumain Educational Center in Gros-Morne (Fig. 13).

Figure 13. Damaged infill wall of the Lycee Jacques Roumain Educational Center in Gros-Morne after the 2018 Haiti Earthquake

8. Residential Houses

Some residential houses collapsed and others experienced moderate to heavy damage. A bed is covered by rubble from a CMU wall that collapsed in Figure 14a (AP Photo/Dieu Nalio Chery), representative of the weakly confined load bearing masonry construction common in modern Haitian residential construction. A Haiti citizen, Marcorel Maurice, stands inside his wooden post and beam home, a more traditional residential typology, which suffered damage to the stone infill (AP Photo/Dieu Nalio Chery) in Figure 14b.

(a) (b)

Figure 14. (a) A bed is covered by rubble from a CMU wall that collapsed, and (b) A Haitian man stands inside the failed infill wall in his damaged home

Figures 15 and 16 provide other examples of damage to CMU load bearing masonry homes, with shear cracks adjacent to louvered and vented block windows. Note the absence of any confining elements at the corner of the upper floor of the damaged home in Figure 15. In Port-de-Paix, Haiti, residents are asking for temporary shelter after their homes were destroyed by the earthquake; many were frightened to return to homes that survived the first earthquake for fear they would collapse in the subsequent aftershocks. Videos of some damaged houses can be found at https://twitter.com/esteelavoie.

(a) (b)

Figure 15. Large cracks observed in the walls of a masonry house after the 2018 Haiti Earthquake (Dieu Nalio Chery/Associated Press)

(a) (b)

Figure 16. Heavily damaged homes in Port-de-Paix after the 2018 Haiti Earthquake

Damage to Infrastructure

No major damage has been reported yet regarding the road, harbor, sport and telecommunication infrastructures.

Geotechnical Failures

There are no geotechnical failures reported as of the date this report was authored.

Current Situation

According to the report prepared by the Civil Protection (2018), the current situation for several of the cities are listed as follows:

Gonaives: 20 people injured, 5 houses with cracks

Gros-Morne: 7 fatalities, 118 people injured, 115 houses collapsed, 2050 houses damaged

Terre-Neuve: 4 people injured, 8 houses collapsed

Cap-Haitien: 14 injuries

Plaisance: Partial collapse of the façade of the Catholic Church, 4 people injured

Nord-Ouest (Department): 245 people injured, 10 fatalities (9 of which in Port-de-Paix), 163 houses collapsed, 4387 houses damaged.

Overall: 7783 families are in urgent need of assistance, due to the partial or total collapse of their house. Damage is mainly concentrated at Port-de-Paix (Nord-Ouest) and Gros-Morne (Artibonite) with 353 collapsed houses and 7430 severely to lightly damaged houses, including some cracks. Some health and education infrastructure have been damaged. In the department of Artibonite, 42 institutional buildings (schools, churches and other) are either severely or lightly damaged at Gros Morne. Four national and private schools collapsed at Pilate in the Nord department.

StEER Response Strategy

StEER will continue to engage its Virtual Assessment Team (VAT) to collect and process additional public data relating to the 2018 Haiti Earthquake. These data will be used to develop a more detailed VAT report that will augment this preliminary report. StEER is coordinating with other organizations including GEER, PEER, EERI, SEER, GHI, and Build Change to determine how best to collect on-site data for this event.

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About StEER

The National Science Foundation (NSF) awarded a 2-year EAGER grant (CMMI 1841667) to a consortium of universities to form the Structural Extreme Events Reconnaissance (StEER) Network. StEER's mission is to deepen the structural natural hazards engineering (NHE) community's capacity for reliable post-event reconnaissance by: (1) promoting community-driven standards, best practices, and training for RAPID field work; (2) coordinating official event responses in collaboration with other stakeholders and reconnaissance groups; and (3) representing structural engineering within the wider extreme events reconnaissance (EER) consortium in geotechnical engineering (GEER) and social sciences (SSEER) to foster greater potentials for truly interdisciplinary reconnaissance. StEER also works closely with the NSF- supported Natural Hazards Engineering Research Infrastructure (NHERI) RAPID facility and cyberinfrastructure Reconnaissance Portal to more effectively leverage these resources to benefit StEER missions.

StEER relies upon the engagement of the broad NHE community, including creating institutional linkages with dedicated liaisons to existing post-event communities and partnerships with other key stakeholders. While the network currently consists of the three primary nodes located at the University of Notre Dame (Coordinating Node), University of Florida (Atlantic/Gulf Regional Node), and University of California, Berkeley (Pacific Regional Node), StEER aspires to build a network of regional nodes worldwide to enable swift and high quality responses to major disasters globally.

StEER's founding organizational structure includes a governance layer comprised of core leadership with Associate Directors for each of the primary hazards as well as cross-cutting areas of Assessment Technologies and Data Standards, led by the following individuals:

- **Tracy Kijewski-Correa (PI),** University of Notre Dame, serves as StEER Director responsible with overseeing the design and operationalization of the network.
- **Khalid Mosalam (co-PI),** University of California, Berkeley, serves as StEER Associate Director for Seismic Hazards, leading StEER's Pacific Regional node and serving as primary liaison to the Earthquake Engineering community.
- **David O. Prevatt (co-PI),** University of Florida, serves as StEER Associate Director for Wind Hazards, leading StEER's Atlantic/Gulf Regional node and serving as primary liaison to the Wind Engineering community.
- **Ian Robertson (co-PI),** University of Hawai'i at Manoa, serves as StEER Associate Director for Assessment Technologies, guiding StEER's development of a robust approach to damage assessment across the hazards.
- **David Roueche (co-PI),** Auburn University, serves as StEER Associate Director for Data Standards, ensuring StEER processes deliver reliable and standardized reconnaissance data.

StEER's response to the 2018 Haiti Earthquake preceded the formation of its official policies, protocols and membership, which are still in active development. All policies, procedures and protocols described in this report should be considered preliminary and will be refined with community input as part of StEER's operationalization in 2018-2019.