Assessment of Structural Damages due to the Earthquakes in Puerto Rico Occurred on January 2020

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Abstract

The objective of this research is to develop a comprehensive classification and documentation of the failures in buildings that occurred in Puerto Rico in January 2020 as a result of the southern earthquakes, determine the causes of those failures, and develop general recommendations that decrease the propensity of these failures to occur.

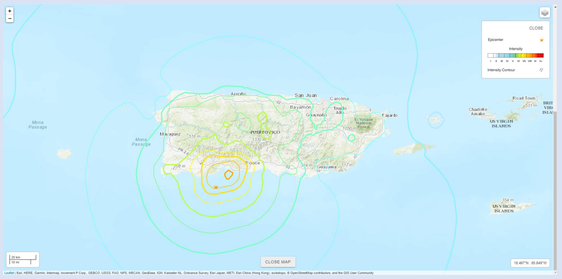
The methods that were used consisted in: first to decide how to structure the documentation, second search for images and information on the failures induced by the earthquake in Puerto Rico. Then develop a comprehensive report classifying and documenting failures, and finally implement a Google Map layer with the geolocation of case studies complemented with representative images.

The benefits of this research are providing a documentation of failures and damages that could be used to improve the design and construction processes, the availability of a GIS tool with geolocation of the case studies, with images and descriptions, that could be used as a study, research and planning tool; that could be extended for damages caused by other natural disasters, such as hurricanes.

This research was carried out under the guidance of my mentors: Dr. Gustavo Pacheco Crosetti and Dr. Omaira Collazos Ordoñez.

Introduction

On January 7, 2020, an earthquake (magnitude of 6.4) occurred in the southern area of Puerto Rico, and to this day the aftershocks continue. This earthquake brought great structural damage to several buildings in the area. Many homes, public buildings, and schools suffered serious damage. These damages should be documented to learn from the deficiencies and encourage the improvement of the construction process.

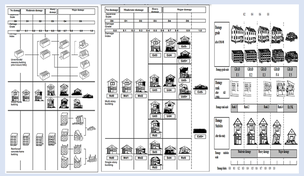


Based on the reports done by the Geotechnical Extreme Events Reconnaissance (GEER) and the Structural Extreme Events Reconnaissance (StEER), demonstrated that the January 7th earthquake dealt with great economic loss, but very few fatalities.

Figure 4.4. PAGER estimated probability of (a) fatalities and (b) economic losses for the January 7th, 2020, Mw 6.4 earthquake (USGS, 2020a).

This type of research has also been done in other places, such as Japan, Mexico, and Chile. They are constantly revising them, because technology changes and the Earth is in a constant change in terms of seismic activity, so each earthquake is a new learning opportunity.

Name of scale	Organizer	No. of class	Building type
Damage grade	***EMS-98***	6	Masonry buildings
Grade 0:Nodamage Grade 1:Slight damage (Hair-line cracks in few walls) Grade 2:Moderate damage (Fall of large pieces of plaster) Grade 3:Heavy damage (Large and extensive cracks in walls) Grade 4:Very heavy damage (Serious failure of walls) Grade 5:Destruction (Total collapse)			
Damage statistics	**Japan Prime Minister's Office**	4	Wood frame buildings
No damage Moderate damage (A part of building is damaged) Heavy damage (Structural damage cost occupies from 20 to 50% of total repair cost) Major damage (Structural damage cost occupies over half of total repair cost)			
Damage rank	***Architectural Institute of Japan***	6	RC buildings
Rank 0:No damage Rank 1:Negligible damage (Hair line cracks in columns and beams of frame) Rank 2:Slight damage (Shear cracks in non-structural walls) Rank 3:Moderate damage (Shear cracks in columns and beams and in structural walls) Rank 4:Major damage (Spalling of concrete cover, Buckling of reinforced rods) Rank 5:Collapse (Collapse of total or parts of building)			



Objectives

Develop a comprehensive classification and documentation of the failures in buildings that occurred because of the southern earthquakes, determine the causes of those failures, and develop general recommendations that will decrease the propensity for these failures to occur. Also, implement a GIS layer that allows the geolocation of the case studies, and the exploration of the damages and failures occurred in each location, that could be used as a study, research, and planning tool.

This report could be extremely valuable for the construction industry and the resiliency of structures in Puerto Rico.

Methodology

1. **Decide how to structure fault documentation:**
Develop a comprehensive classification and documentation of the failures in buildings that occurred because of the southern earthquakes, determine the causes of those failures, and develop general recommendations that decrease the propensity for these failures to occur.

2. **Search for images and information:**
   a) Prof. Pacheco-Crosetti & associates
   b) Previous studies
   c) Newspapers and social networks

This photo shows a soft-story failure on the first floor of the house, that resulted in a total collapse. The building fell one floor and experienced a translation to the left side of the structure. The walls of the second floor exhibit some cracks, the columns has some cracks at the bottom, but the rest of structure of this floor remained mostly undamaged.

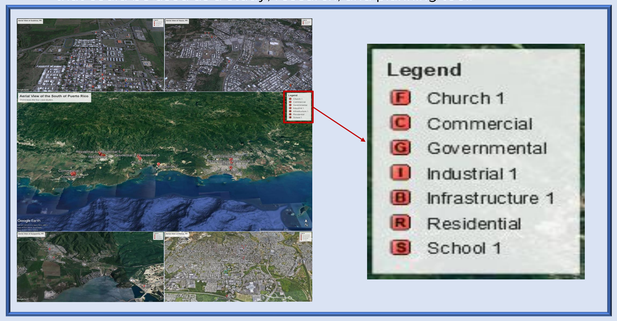
This photo shows short-column failure on the first two floors of a school building, which caused both floors to collapse. The third floor shows the same type of damages in the columns, but it did not collapse.

This photo shows in-plane damage to the walls and columns of a house, and no proper transverse reinforcement on the columns.

This photo showcases damages to a historic masonry wall building. It experienced a total collapse of the parapet, that fell down onto the street. The parapet had no structural reinforcement. Fortunately, the building did not completely collapse.

3. **Develop a comprehensive report classifying and documenting failures:**
   a) Case study 1: Guánica
      - Residential Buildings (5 residential buildings were documented)
      - School Buildings (2 school buildings were documented)
      - Commercial Buildings (4 commercial buildings were documented)
   b) Case study 2: Yauco
      - Residential Buildings (6 residential buildings were documented)
      - School Building (1 school building was documented)
   c) Case study 3: Guayanilla
      - Church Building (1 church was documented)
      - Residential Buildings (3 residential building were documented)
      - Industrial Buildings (1 industrial building was documented)
   d) Case study 4: Ponce
      - Residential Buildings (2 residential building were documented)
      - School Building (1 school building was documented)
      - Governmental Building (2 governmental buildings were documented)
      - Infrastructure (1 structure was documented)

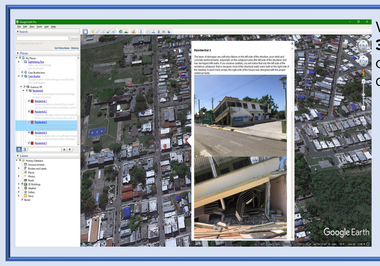
4. **The geolocation and insertion of images:**
   a) Implement a GIS layer that allows the geolocation of the case studies, and the exploration of the damages and failures occurred in each location, that could be used as a study, research, and planning tool.



Analysis and Results

At the bottom is the result of the implementation of the case studies on Google Earth. We will use Guánica as an example.

For the case of Guánica, the cases in the region were divided into three categories:
- **Residential**
- **School**
- **Commercial**



We will now select **Residential 3**, in order to see the insertion of images and with its damage description.

For this case, the damage description says the following:
"The types of damages are soft-story failure on the left side of the structure, poor concrete quality and steel reinforcement details, especially on the collapsed area (the left side of the structure) and has damaged infill walls. If you observe carefully, you will notice that only the left side of the residence collapsed, that is because most of the structural walls were built on the right side of the building. Although the presence of walls only on one side triggered undesired torsional effects, this is one of many cases observed where the presence of walls played a significant role in avoiding collapse."

The following QR code is a link for a video that demonstrates all the structures that were analyzed and were classified on the Google Earth program.

Conclusion

As mentioned in the introduction of this poster, at the beginning of the year 2020, an earthquake (magnitude of 6.4) occurred in the southern area of Puerto Rico, and to this day the aftershocks continue. This earthquake brought great structural damage to several buildings in the area. The damage caused to many structures shows that Puerto Rico was not prepared for this type of event. As shown on this report, many schools, homes, public buildings, among others suffered serious damage. One of the main problems in Puerto Rico appeared to be the informal construction without following the specifications required by the codes, which would result in a construction with structural defects. This system of classification can help promoting people to start doing proper construction. The main objective of this research is to facilitate the identification of structural failures caused by earthquakes and this objective was met. In conclusion, this research can help current and future engineers on better understand the damages caused by natural disasters using current technology, like Google Earth, and help find solutions for these problems and prevent them from happening in the future, by making sure that the building codes are being applied to each structure.

Recommendations

Some of the recommendations are to continue with the process of classifying structural failures that were not evaluated in this project. Expand the area of investigation, moving from the south to the north of the island. Even if the earthquakes did not affect as much on these areas as compared to the south, there might be some cases on the north of the island, especially on the metropolitan area, considering that it is the most populated area of the entire island. Another recommendation is to install this Google Earth Layer in a place accessible to the general public, so that it can be used as a learning and research tool.

Future Work

The next step would be to use the data collected from these case studies, find the solutions for each case, and make a pattern chart, where the solution for the failure is predetermined. Another recommendation for future work would be to partner with other institutions to enlarge the data set, and to expand the GIS project to include the effect of natural disasters.

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