AN EARTHQUAKE DAMAGE ESTIMATION TOOL FOR HAITI

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ABSTRACT

In order to increase the awareness of decision makers and the population in general in Haiti, an earthquake damage estimation tool is needed. Thus, this study focused on developing a practical earthquake damage estimation tool adapted to the conditions of Haiti. RADIUS, the most appropriate to developing countries, will be adjusted.

RADIUS is applied on Port-au-Prince, with the earthquake of January 12th 2010 that destroyed this capital, as a scenario earthquake. There was a significant difference between the actual damage recorded from the last event in Haiti and the results obtained from the RADIUS program. But after some parameters adjustment taking into account the reality of Haiti, in the constant data of the program, such as: inhabitant parameters, vulnerability curve, casualty coefficient, the results become close to the actual data. Therefore, this modified version of RADIUS can be applied in Haiti on other earthquake prone cities such as the second largest city Cap Haitian and Port-de-Paix to promote earthquake risk mitigation.

Keywords: Earthquake Damage Estimation, Awareness, Earthquake risk.

1. INTRODUCTION

The Republic of Haiti is a Caribbean country, sharing the island of Hispaniola with the Dominican Republic. It's a country constantly exposed to natural disasters: hurricanes, floods and landslides from heavy rains. It is also a country with a high seismic risk as it is located at the boundary of the Caribbean Plate and the North American Plate, one moving relative to the other at about 2cms/year and surrounded by two active faults the "Septentrional Fault" and the "Enriquillo Fault". The country has experienced similar earthquakes in its past; the capital Port-au-Prince was already destroyed in 1751 and in 1770, in 1842, an earthquake destroyed the second largest city of Cap- Haitian in north of the country. And the last event, a magnitude 7.0 earthquake showed how unprepared and how much vulnerable Haiti is against earthquakes. A damage estimation tool adapted to the conditions of Haiti can help to achieve this goal.

This study aims to develop a practical damage estimation tool appropriate to the conditions of Haiti by adjusting RADIUS, so that earthquake risk awareness among decision makers and the population in general can be increased.

To achieve the objective of: developing an earthquake damage estimation for Haiti, this study will take into account the damages caused by the January 12, 2010 earthquake on the capital Port-au-Prince, analyzing the main deficiencies of Haiti. Then, an appropriated damage estimation tool will be calibrated, highlighting the different input data needed to run its general process. The output expected: peak ground acceleration, building damage, deaths and injuries, will be compared to the data recorded

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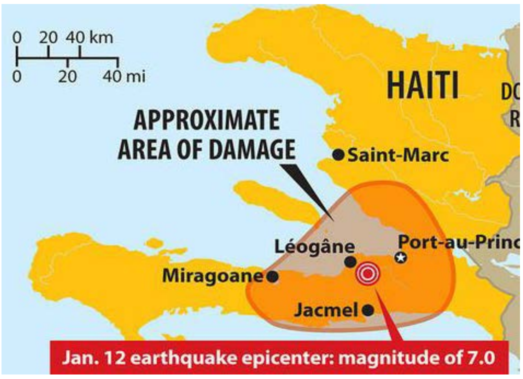
from the last event, so that the parameters in need of adjustment can be noted and modified. A final comparison will permit an evaluation of the adjustment.

2. JANUARY 2010 EARTHQUAKE DAMAGE.

2.1 Outline of January 12th , 2010 Earthquake

On Tuesday, 12th January 2010, at 4:53 PM local time, a magnitude 7.0 (USGS) earthquake hit Haiti. Three departments were seriously affected; the West, especially in the vicinity of Port-au-Prince, the South-East, and Nippes. The epicenter was located at 18.457°N and 72.533°W, 25 km south-west of the capital Port-au-Prince. It was a shallow and crustal earthquake with a depth of less than 13 km. The Figure 4 shows the approximate area of damage.



2.2 January 12th, 2010 Earthquake Damage

It was a terrible disaster; government buildings, schools, public offices, and public assemblies were severely damaged. According to the assessment campaign lead by The Ministry of Public works, transportation and Communication (MTPTC), 51% of the schools, 46% of residential buildings, 36% of healthcare buildings, 44% of civic facilities and 36% of commercial and industrial facilities were affected. The government recorded more than 230,000 deaths, 300,000 injuries, and 600,000 made homeless.

2.3 Vulnerability of Haiti.

The damage caused by this earthquake is considerably disproportionate to the magnitude

Haiti is particularly vulnerable as:

- Earthquakes are not a frequent hazard in Haiti. The last event occurred about one hundred years ago.
- There is no disaster education at any level. Therefore, an entire generation of politicians, the general public and even engineers were not concerned with earthquake risk.
- Haiti does not have any seismic design code
- Inadequate structural systems
- Quality of construction
- Quality of materials: cement, sand, water. There is no standard cement and people think that they can use any kind of water to make concrete.

There was also a lack of immediate response. Government, and the population, at large were unprepared for this disaster. During the first hours or days, emergency response was quite insufficient.

- The metropolitan area has a high population density. According to IHSI, there are 369 inhabitants per km^2 and annual population growth is 2.5%/year.

There is also an anarchic occupation of the space around the major cities.

3. DAMAGE ESTIMATION

3.1. General Information

Damage estimation is a very important step in the field of disaster management: it is the starting point in the disaster management process. The various forms of data such as: distribution of earthquake shaking, buildings damage, deaths and injuries, lifeline damage, from a given earthquake allow us to know the weaknesses and resilience of a city, so that decision makers can decide how to mitigate the risk. Several tools have been developed to estimate earthquake-related loss and damage such as: HAZUS, GESI, and RADIUS.

3.2. RADIUS Program

RADIUS is the most appropriate for developing countries. It was developed as part of the RADIUS project, UN, whose purpose was to promote mitigation of the impact of seismic disasters in urban areas particularly in developing countries. To implement this program, users are expected to enter generic information such as: shape of target region by mesh, total population and distribution, total number of building, building type and distribution, ground soil type and an earthquake scenario. As results, the program produces: Seismic intensity, such as PGA and MMI Intensity, building damage, lifeline damage, casualties, such as number of deaths and injuries.

4. RADIUS APPLICATION ON PORT-AU-PINCE AND RESULTS

4.1. RADIUS APPLICATION

The municipality of Port-au-Prince is an area of 36.04km^2 divided into three communal sections: Turgeau, Hospital Mountain and Martissant As Turgeau represents more than fifty percent of the target area, with some significant variation in density and typology of buildings, and Martissant and Hospital Mountain, also, contain inhabited areas, the municipality of Port-au-Prince is subdivided in 10 parts in this study. The total population is 897,859 habitants and the total number of buildings in 96,596.

Figure 2 shows the Target Region Identification.

Three categories of soil are considered, soft soil, medium soil and unknown.

In the application of RADIUS for the municipality of Port-au-Prince, the following classification of buildings should be considered:

RES1: Small non-engineered and unreinforced masonry houses, constructed with very poor quality HCB and mortar with metal sheet roofs.
RES2: one story building with roof in reinforce concrete (RC).
RES3: two to three story buildings.
RES4: four and more stories.
COM: commercial buildings
IND: Industrial buildings
MED1: Hospital up to two stories.
MED2: Hospital of three and more stories.
EDU1: school buildings up to two stories.

EDU2: school buildings of three and more stories.

Substandard housing (RES1)

URM-RC:RES2

URM-RC: RES3.

Buildings with four and more stories: RES4.

- The parameters of the earthquake of January 12, 2010 have been adopted. A grid of the center of Martissant (cell 37) or area A is employed to fix distance from the epicenter to the target region. The epicenter was located 25 km from the center of Port-au-Prince, thus the distance from the reference mesh ID can be estimated at 25 km.

4.2. RESULTS

<table>
<tr><th>Scenario Earthquake 12 January 2010</th><th>Total Buildings Count</th><th>Total Population</th><th>Building damage</th><th>Death</th><th>Injuries</th></tr>
<tr><td>Magnitude 7.0</td><td rowspan="7">86,596</td><td rowspan="7">897,859</td><td rowspan="7">23,753</td><td rowspan="7">4,000</td><td rowspan="7">38,755</td></tr>
<tr><td>Time: 16:46</td></tr>
<tr><td>Depth : 13 km</td></tr>
<tr><td>Epicenter 25 km</td></tr>
<tr><td>Direction: South West</td></tr>
<tr><td>Average PGA: 0.3g</td></tr>
<tr><td>Average MMI: 8</td></tr>
</table>

Table1. Summary of different outputs.

4.3. PARAMETERS ADJUSTMENT

These results don’t resemble to realty:

- The ratio actual number of building damage and RADIUS estimation is 2.12.
- Actual number of deaths was larger than this estimation; the ratio is 40.
- The ratio Actual number of injuries, and the number recorded from the program is about 4.64.

Some assumptions do not correspond to Haiti. Some parameters must be modified so that the program can become applicable for Haiti. Thus some coefficients in inhabitant parameters are modified:

- In RES4 the coefficient of 10 is replaced by a coefficient of 5 for Night-Time because these buildings type are multi-usage; they are not only residential buildings.
- In EDU1, the coefficient of 10 is replaced by 200, and in EDU2 25 is replaced also by 200. During day-time, the ratio people present in a school building and in building type RES1 is around 200.

The primary damage curve is modified as well:

- The parameters for RES4 and RES1 are switched, and the same is done for RES2 and RES3 because in RADIUS, small housings are likely to suffer damage than the large ones, while in Haiti, large structures according to observations from the last event are the weakest, as they have been constructed without earthquake- proof design.
- Then these parameters in RES1, RES2, RES3, and RES4 are multiplied by 1.5 from MMI4 to 9 because for MMI8, the ratio data estimated from the last event and RADIUS estimation is around 2.
- MED1, COM, IND received the same coefficients as they are of same the typology, and they experienced the same level of damage in the last event.

For modification of injuries:

- The parameters in RES4 and RES1 are switched, and the same is done for RES2 and RES3 in M4s (severe injury) for the same reason in the primary damage curve. M4l (light injury) and M4m (moderate injury) are used with no modification and each coefficient in M6 is multiplied by 1.4 to take into account the large number of injured recorded from the last event.

Casualty M3 (occupants trapped by collapse) coefficient is adjusted:

- Firstly, parameters in RES4 and RES1 are switched, and the same is done for RES2 and RES3 for the same reason in the primary damage curve (large buildings more dangerous than small ones).
- The RES1 coefficient is modified from MMI 8 to 12, because very few people can be trapped by building type RES1.
- The RES2, RES3, and RES4 receive a modification only on the coefficient related to MMI 8 because the ratio occupants present and occupants trapped during the last event can be estimated at 0.35 instead of 0.30 in RADIUS.
- EDU1, MED1, COM, and IND receive the same coefficient than RES3 and EDU2, MED2 the same than RES4 because they are the same type.

In the casualty M4 (mortality at collapse) new assumptions are done:

- In buildings of type RES1 5% of occupants will be killed instead of 20% because they are very light.
- In buildings of type RES2, 25% of occupants will be immediately killed instead of 12.5% because of lack of ductility and they are heavier than the RES1 type.
- In buildings of type RES3, EDU1, MED1, COM, and IND, 80% because these buildings type are heavier than those in RES1 and RES2 with no earthquake-proof design.
- In buildings of type RES4, EDU2, and MED2 90% for the same reason in RES3.

In M5d (mortality post-collapse):

- Every coefficient is multiplied by 10.

5. CONCLUSION

After these modifications, the program becomes more applicable to the conditions of Haiti:

- The ratio actual Deaths and estimated Deaths by the program, becomes 1.02 instead of 40 before.
- The ratio actual injuries and estimated becomes 1.02 instead of 4.64 before.
- The ratio actual building damage and estimated becomes 1.21 instead of 2.12 before.

6. RECOMMENDATION

This Program will be very useful for Haiti; it will be used to increase awareness in the second city (Cap-Haitian) and Port-de-Paix, both already destroyed in the past by earthquake hazard. It can be applied also after some time to the Metropolitan area, to see how much the progress is of point of view of earthquake risk mitigation.

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