NEW SEISMIC RISK SCENARIOS FOR GUATEMALA CITY

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***Abstract**: Guatemala City is one of Central American and Caribbean's most important cities. It is one of the largest urban centers in the region that has accelerated growth due to its economic and social importance. However, this accelerated growth increased the vulnerability of buildings and the poor management of natural disasters. In addition, Guatemala is in a zone with a high seismic hazard. The last major earthquake was in 1976, which destroyed a large part of the country, and generated much damage and deaths.*

For this reason, the analysis of seismic risk in Guatemala is necessary and of great social importance for the sustainable and safe development of the country. To estimate the damage caused by the seismic hazard in Guatemala City, it is necessary to calculate that hazard. The seismic hazard estimate for Guatemala City was developed in collaboration with the KUK APHÁN research project. The work to update the seismic catalog of Central America was used as a basis.

The response spectra used for the calculation of seismic risk correspond to the data provided by the Probabilistic Seismic Hazard Assessment (PSHA). The study was performed in Guatemala City. For this purpose, two possible scenarios have been used, with their respective accelerations. These two scenarios are adjusted with a return period of 475 years and 975 years.

In addition, the study uses the first seismic exposure model published recently. This study proposes the new classification of the most common structural typologies in Guatemala City while reviewing the existing literature to assign fragility and capacity curves to adequately consider their behavior.

Therefore, this new study not only contemplates the results of the seismic risk, but also makes a tour of the three fundamental components for the calculation of seismic risk: exposure, vulnerability, and hazard. In this way, it is one of the most advanced studies carried out in the country and with updated information.

1 Introduction

To calculate seismic *risk,* it is necessary to define two components: the estimation of seismic hazard (which includes the definition of the scenario and soil class) and the assignment of building typologies and their vulnerability characteristics. Therefore, the main lines of the study are:

1. Definition of the seismic scenarios and hazard analysis.
2. Identification of typologies and vulnerability, and definition of capacity and fragility curves.
3. Application of the risk calculation method and definition of risk scenarios for Guatemala City.

Evaluating the seismic risk in an urban area consists mainly of estimating the expected structural damage to buildings and its consequences because of the defined seismic scenario. The evaluation is presented in degrees of damage defined in the FEMA (1999) methodology. Other parameters related to losses caused by earthquakes can be obtained from the estimation of the degrees of damage to the buildings. These losses can be divided into economic and human losses. Economic losses refer directly to the costs of reconstruction and repair of buildings damaged during the seismic event. Human losses refer to fatalities and injuries resulting from collapsed buildings, as well as the population left homeless after the earthquake because of structural damage to buildings.

In the case of Guatemala, there is no model previously tested and evaluated with experiences in past earthquakes. Therefore, this study presents the first seismic risk assessment study using the most updated and duly analysed information sources to link it to the reality of the country. The main studies carried out in the country are the PREPARE project promoted by USAID (Miyamoto, 2021), research elaborated by the GEM initiative (Calderón, 2017), and finally the results of the RESIS II project (Benito and Fernández, 2009; Lang, et al. 2009). The contribution presented in this study is the use of an updated exposure model published by Dávila (2022), the proposals for the most common structural typologies in Guatemala proposed in Dávila (2023), the elaboration of a bank of fragility curves and capacity curves used in the region assessing their relationship with the country applying the methodology proposed by Navas, et al. (2023) and finally the use of an updated seismic catalogue for the Central American region and therefore of a better valued seismic scenario presented by Gamboa et al. (2022).

Therefore, the structure of this work is the definition of the seismic scenario, the final proposal of the capacity and fragility curves, and finally the results of the risk scenario.

2 Seismic Scenario

For the estimation of damages resulting from the seismic hazard in Guatemala City, it is necessary to first perform a hazard calculation to determine the representative response spectra of the expected seismic actions in Guatemala City, including possible local effects depending on the existing soil in different areas of the city. After this first calculation, hazard disaggregation must be performed to identify the dominant control earthquakes for the target motions associated with the desired probabilities. This part of the study was done in collaboration with the KUK APHÁN project, using the seismic catalogue updated to 2022 for Central America published by Gamboa, et al. (2022). For the study, risk scenarios have been simulated for two return periods: 475 and 975 years. In the first step, the seismic hazard was calculated using a logic tree with the ground motion models (GMM) of Cauzzi et al. (2015), Akkar et al. (2014), and Boore et al. (2014). Then the uniform probability spectra (UHS) were determined for each of these periods. Spectral accelerations were obtained for different structural periods in the range of 0 to 2 seconds. Disaggregation was then performed to determine the earthquakes that contributed most to the estimated PGA value for each of the return periods mentioned.

A control earthquake was obtained for the return period of 475 years, corresponding to an earthquake of magnitude Mw 6.5 located between 10 and 50 km away from Guatemala City, and another earthquake for 975 years, corresponding to an earthquake of magnitude Mw 6.5-7.0 located between 10 and 50 km from Guatemala City. These earthquakes could be considered basic earthquakes and severe earthquakes, respectively, according to criteria followed by the AGIES NSE 2 standard of Guatemala. The two control earthquakes identified are compatible with scenarios that have as their origin the Motagua transform fault, which was also the scenario of the 1976 earthquake.

For each control earthquake, characterized by a magnitude-distance pair, a specific response spectrum has been estimated, which constitutes the demand curve in the subsequent risk calculation. Each spectrum is first estimated under rock conditions and then the local effect is included considering the soil in each part of the city. Figure 1 shows the specific spectra of the control earthquakes for the geometric center of Zone 10 of Guatemala City for return periods of 475 and 975 years, including the local effect. At the same time, Figure 2 shows a schematic map of the possible source of the designed seismic scenario.

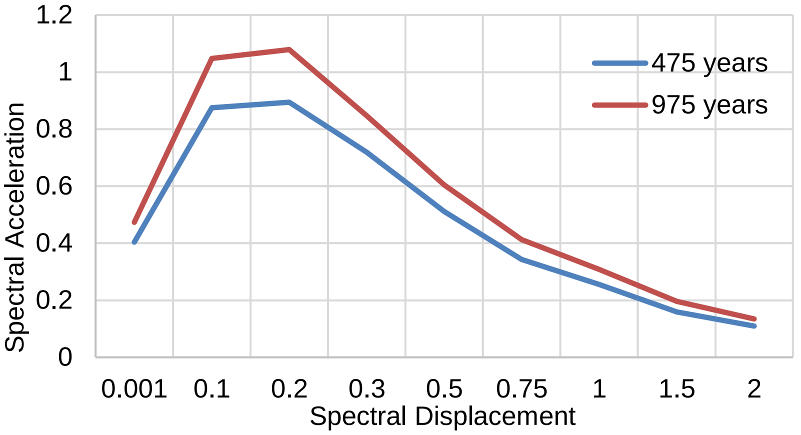


Figure 1: Specific control earthquake spectra for Zone 10 of Guatemala City.

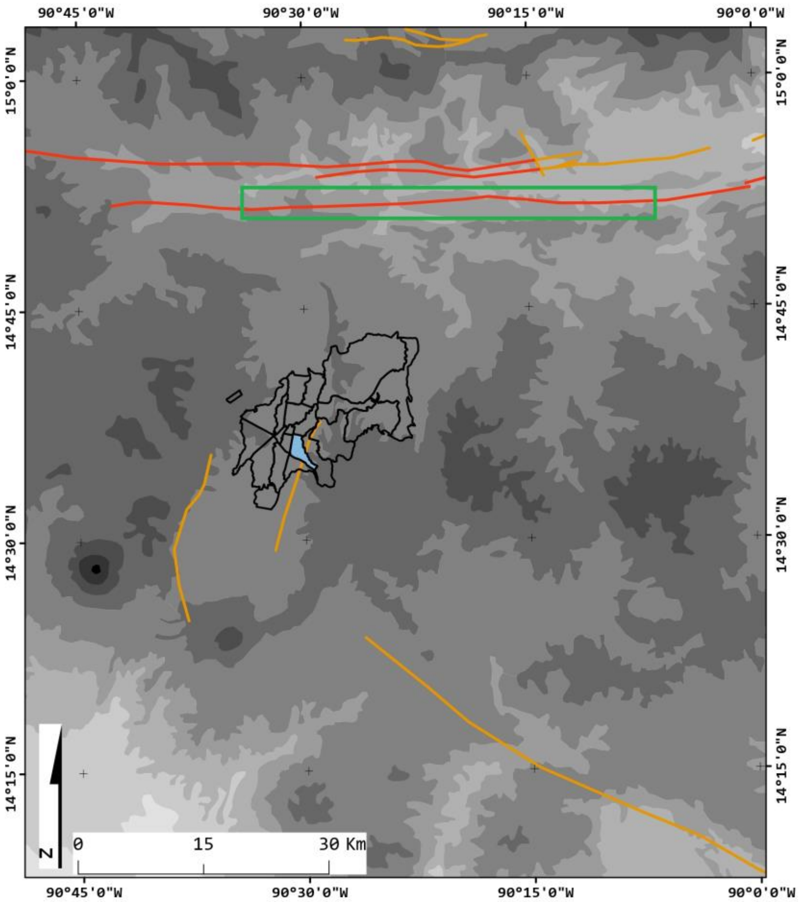


Figure 2: Map of the seismic source. The different zones of Guatemala City are drawn with a black line. Zone 10 of Guatemala City is highlighted in light blue. In red is the approximate trace of the Motagua fault. In orange other minor faults. In green, is the box of the possible area where the seismic scenario occurs, approximately between 20 and 50 km away.

3 Characterization of structural typologies and their vulnerability

3.1 Identification of Structural Typologies

In seismic risk studies, it is necessary to have a capacity curve for each type or class of vulnerability identified in the housing stock of the population to be studied. This curve allows for estimating the degree of damage that each vulnerability class will experience under the seismic action corresponding to the hazard scenario considered.

The selection of the capacity curves for each structural typology represents one of the fundamental steps for the estimation of the physical damage to the buildings. However, in the specific case of Guatemala and the Central American region, there is a great lack of information on this subject.

Among the international methodologies that evaluate seismic risk, there are differences among the proposed methodologies, for example, the classification of typologies by the number of floors, construction materials, and structural systems. These classifications respond directly to the circumstances of each geographical location and to the construction traditions of each country. For this reason, for Guatemala, it is necessary to make a study of the existing literature.

In this sense, it is possible to group the main research projects for Guatemala and the Central American region. In the first place, the RESIS II project (Benito and Fernández, 2009; Lang, et al. 2009), provides an accurate definition of the structural systems and construction processes of the Central American region. However, the definition of capacity and fragility curves are not necessarily adapted to the reality of Guatemala.

In a second group are all the studies that have been developed around the GEM project, mainly Calderón, 2017. The advantage of these studies is that they are based on in-depth research driven by the GEM platform. However, the greatest progress has been made in Costa Rica, which limits the applicability of the typologies to the rest of the countries (Calderón and Silva, 2019 and 2021).

Finally, it is possible to group together all the studies that have been promoted by USAID. The greatest contribution is the methodology used for the development of PREPARE studies in different Latin American countries (Miyamoto, 2019 and 2021). However, these studies do not carry out a detailed analysis of the structural typologies of Latin American countries but rather make an approximation through various correction factors of the curves proposed for the United States by FEMA.

Despite these studies, the lack of technical and scientific information on the structural typologies specific to Guatemala City is striking. In addition, to this difficulty of lack of basic information, international studies generally assume different constructive descriptions for the same structural typology. Therefore, it is possible to verify that there is a wide range of attributes assigned to structural typologies.

The most common structural typologies for Guatemala City are defined in the seismic exposure model presented by Dávila (2022) and are presented in Table 1. As a result of the analysis of the existing literature and the judgment of experts, it is possible to verify that not all structural typologies specific to Guatemala City have capacity curves with the same attributes and characteristics. As an example, the fragility curves of the Adobe structural typology are presented in Figure 3, where the dispersion of data for the same structural typology evaluated in Guatemala is shown.

Table 1. Classification of the structural typologies of buildings for Zone 10 of Guatemala City.

Structural typology	**Final acronym**
Simple stone masonry and calicanto (limestone)	MP
Adobe	AD
Simple masonry	MS
Simple masonry (Concrete floors)	MSH
Simple masonry (Great Height)	MSG
Confined and reinforced masonry	MC
Confined and Reinforced Masonry (High Rise)	MCG
Reinforced Concrete (1-3 floors)	HP1_P
Reinforced Concrete (4-7 floors)	HP2_P
Reinforced Concrete (+8 floors)	HP3_P
Dual Reinforced Concrete (1-3 floors)	HD1_P
Dual Reinforced Concrete (4-7 floors)	HD2_M
Dual Reinforced Concrete (+8 floors)	HD3_P
Informal	IN
Gantry structure	EP

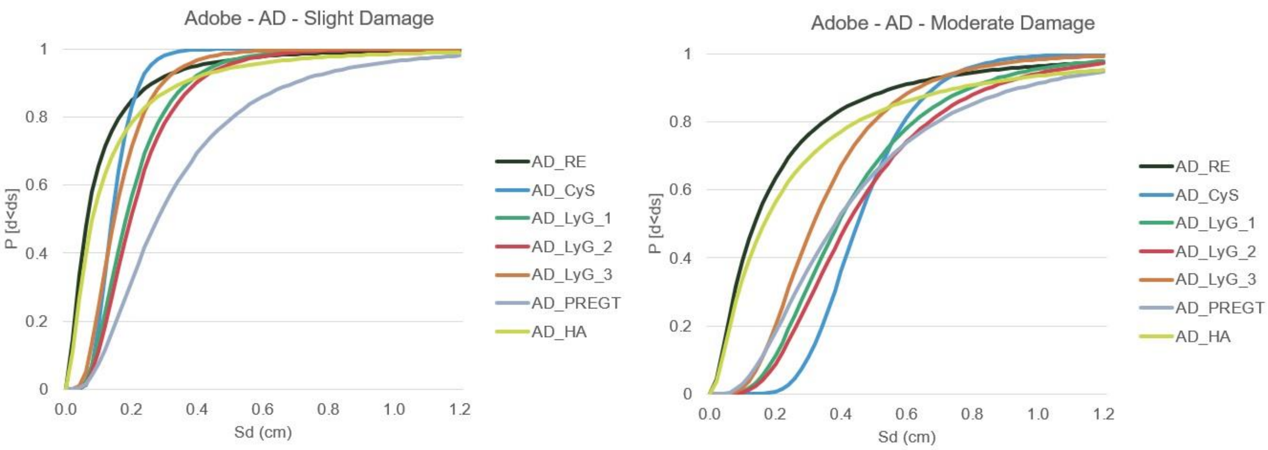


Figure 3: Different fragility curves for Adobe typology. AD_RE: Lang D. et al. (2009). AD_CyS: Calderón A., Silva V. (2019). AD_LyG_1-3: Lagomarsino S., Giovinazzi S. (2006). AD_PREGT: Miyamoto (2021). AD_HA: FEMA (1999).

3.2 Identification of Capacity and Fragility Curves

Fragility and capacity curves are an essential component for the study of seismic risk. However, again in the case of Guatemala City, the problem of the state of the art is the lack of information directly linked to the reality of the construction techniques and materials of the city. For this reason, within the framework of the Kuk Aphán Project, a methodology is published for the selection of the most suitable curves according to a given geographical area and specific typology, Navas, et al. (2023).

The methodology classifies the various capacity and fragility curves of each typology in three dimensions: technical, local, and class suitability. The first mainly evaluates the study proposing the curves and the methods used to obtain them. The second dimension evaluates the correct adequacy of the curves to the study locality. The last dimension evaluates the similarity of the parameters of the typology to be considered. Finally, a rating and a suitability class are assigned. Table 2 shows the curves selected for each structural typology in Guatemala City and the parameters corresponding to the fragility curves and capacity curves.

Table 2. Parameters of Fragility Curves Fragility Curves and Capacity Curves of the structural typologies for Guatemala City. Acronym reference: _RE: Kappos A., Panagopoulos G. (2008). _CyS: Calderón A., Silva V. (2019). _RI: Milutinovi Z., Trendafiloski G.S. (2003).

Typology Parameters for Guatemala City												
Acronym	Fragility Curve								Capacity Curve			
	Slight		Moderate		Severe		Complete		Dy (cm)	Ay (g)	Du (cm)	Au (g)
	Sd (cm)	β	Sd (cm)	β	Sd (cm)	β	Sd (cm)	β				
AD_CyS	0.14	0.371	0.45	0.326	0.7	0.328	1.2	0.346	0.2	0.473	1.2	0.473
MP_RI	0.266	0.364	0.38	0.493	0.768	0.75	1.93	0.963	0.38	0.173	1.93	0.173
MS_CyS	0.21	0.31	0.525	0.328	0.75	0.322	1.2	0.317	0.3	0.675	1.2	0.675
MSH_RI	0.371	0.375	0.53	0.523	1.193	0.817	3.18	1.046	0.53	0.297	3.18	0.297
MSG_RI	0.644	0.347	0.92	0.449	1.608	0.653	3.67	0.842	0.92	0.099	3.67	0.099
MC_CyS	0.42	0.407	1.175	0.394	1.75	0.377	2.9	0.382	0.6	0.971	2.9	0.971
MCG_CyS	1.26	0.355	3.425	0.434	5.05	0.513	8.3	0.656	1.8	0.312	8.3	0.312
EP_CyS	0.63	0.403	1.85	0.45	2.8	0.449	4.7	0.573	0.9	1.916	4.7	1.916
IN_CyS	0.63	0.36	1.475	0.401	2.05	0.362	3.2	0.378	0.9	0.959	3.2	0.959
HP1_CyS	0.98	0.333	2.45	0.319	3.5	0.372	5.6	0.437	1.4	0.731	5.6	0.731

HP2_CyS	3.92	0.327	7.075	0.35	8.55	0.404	11.5	0.525	5.6	0.179	11.5	0.179
HP3_RE	4.8	0.3	10.28	0.33	10.54	0.39	14.23	0.52	6.856	1.138	14.226	1.26
HD1_RE	0.3	0.4	0.64	0.58	1.99	0.95	3.55	1.21	0.428	3.959	3.545	5.122
HD2_RE	0.61	0.38	1.3	0.53	3.13	0.83	5.39	1.06	0.865	2.265	5.391	2.792
HD3_RE	2.02	0.35	4.33	0.46	7.6	0.68	12.32	0.88	2.885	2.338	12.323	2.516

4 Damage Simulation

The software used for building damage simulation was DAMMUM, developed by members of the Kuk Aphán research project team, and published in Quirós Hernández, 2017. The software can run two types of methodologies: I-DCM and MADRS. The database used for the calculation of seismic risk by the DAMMUM program must have the following information:

- A first column corresponding to the identification of the working unit, it can be a building or a set of buildings. In this case, it corresponds to the identification of each building previously identified in Zone 10 of Guatemala City, published in Dávila (2022).
- A second column with the soil type according to the FEMA 2020 classification contained in the NEHRP.
- A third column indicating the construction typology of the work unit.
- Finally, nine columns corresponding to the demand spectrum for the work unit, indicating the values of the following spectral ordinates.

In addition, the necessary parameters of the capacity and fragility curves chosen for each structural typology assigned for the buildings in Zone 10 of Guatemala City are included in another Excel file. These parameters have already been described in Table 2. The results obtained are in terms of the displacement at the performance point of each typology with respect to the given demand spectrum. At the same time, the percentage of damage achieved is calculated for each of the degrees of damage for each building in Zone 10.

5 Results

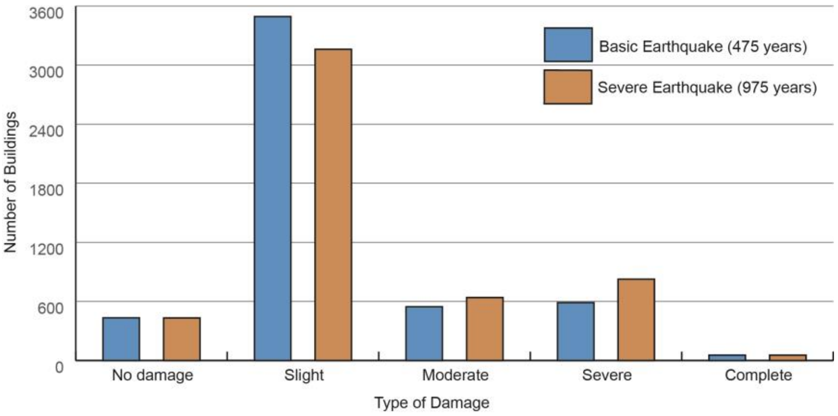
This section presents the results obtained from the seismic risk analysis for the buildings in Zone 10 of Guatemala City. The damage results representative of the seismic risk is the average of the two obtained with the two methodologies used by the DAMMUM software. It is currently impossible to assign different weights in a logic tree to these methodologies because of the state of the art regarding vulnerability and seismic risk for Guatemala.

The classification of soil type obtained by superimposing the database of buildings in Zone 10 of Guatemala City with the results of the microzoning study resulted in 94% of the cases of soil type C and 6% of soil type CD (Gamboa and Flores, 2021).

5.1 Damage to Buildings

The probabilities of damage in the buildings of Zone 10 of Guatemala City are presented for the following degrees of damage: Nil, Slight, Moderate, Severe, and Complete. Figure 4 shows the result of the average damage state obtained after the simulation with the two methodologies used (MADRS and I-DCM) of the Zone 10 buildings for the two design earthquakes. When analysing the Figure presented on the expected damage in the buildings of Zone 10 of Guatemala City, about twelve percent of the buildings would be severely and completely damaged, a very considerable amount of the total number of buildings. Therefore, these results reveal that Guatemala City has a high level of seismic risk, driven mainly by having a high number of vulnerable buildings.

Figure 4: Histogram of buildings in Zone 10 of Guatemala City according to damage status in seismic scenarios seismic scenarios.

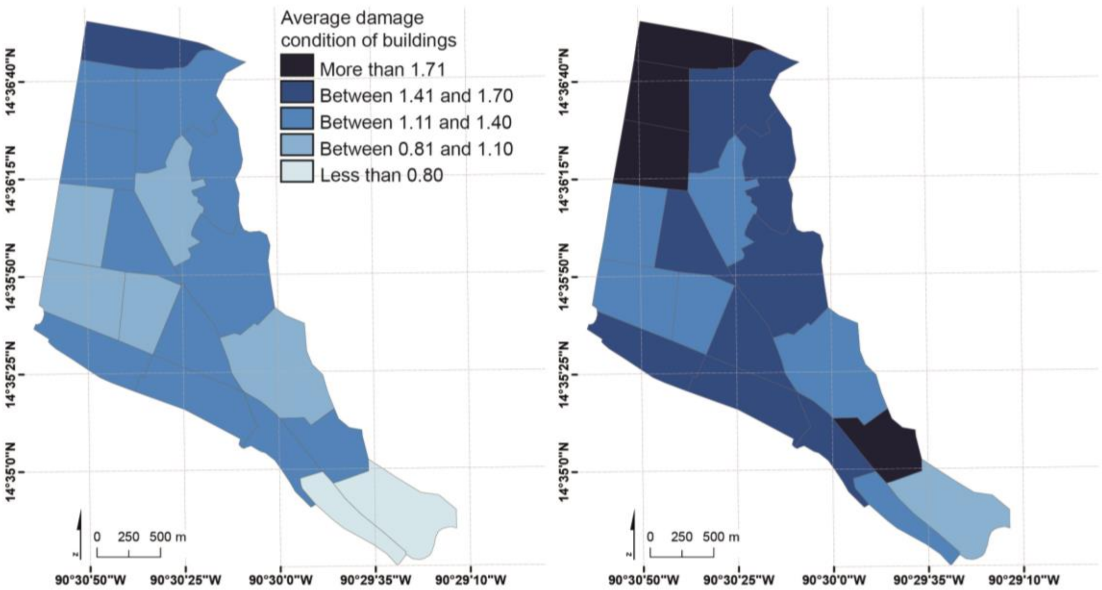


The average damage, Dm, can be calculated from the different degrees of damage reached in the buildings, weighting each degree by the number of buildings suffering such damage. If the Hazus scale is used, which defines four degrees of damage in addition to zero, the average damage is calculated by the expression:

$$Dm = \sum_{j=0}^{4} P_{ij} \times D_j \tag{1}$$

Figure 5 shows the average damage distribution of the neighbourhoods of Zone 10 of Guatemala City for the basic earthquake on the left and for the severe earthquake on the right. This index is obtained by applying equation (1) to all the buildings in each neighbourhood. By calculating the average damage state per neighbourhood, it is possible to establish an order of the neighbourhoods that are likely to have a higher degree of damage.

Figure 5: Map of the neighbourhoods in Zone 10 of Guatemala City according to the average of average damage of the buildings: left basic earthquake and right severe earthquake.



5.2 Homelessness

One of the most interesting aspects after an earthquake is the impact it has on the habitability of the urban environment. Analysing and estimating the number of uninhabitable buildings after an earthquake is essential for the design of humanitarian actions and homeless camps. A formula for estimating uninhabitable buildings was proposed by Risk-EU:

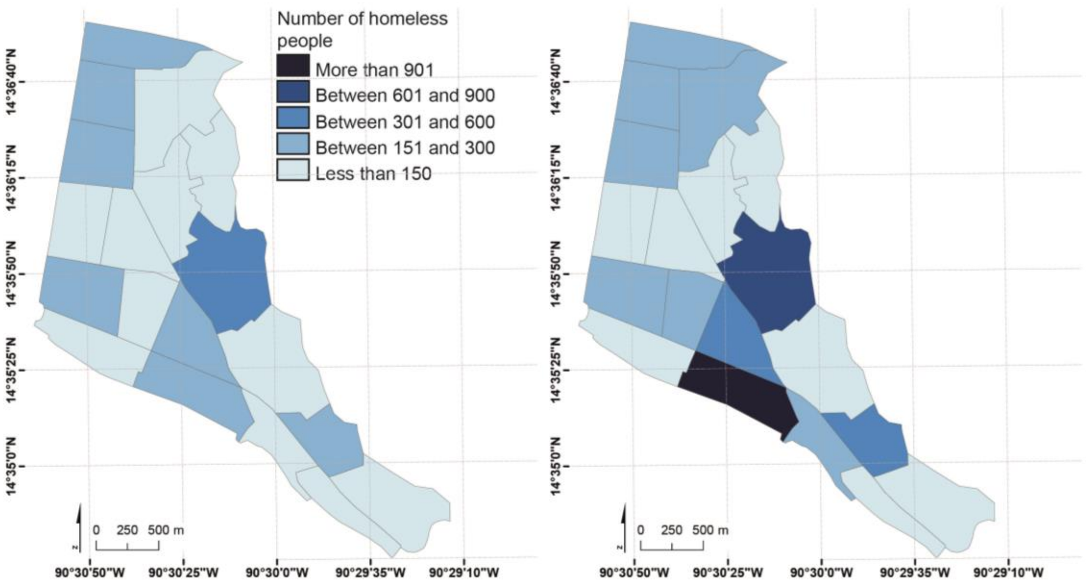
$$Nei = Ne \times PC + Ne \times PS \times 0.9 \tag{2}$$

Where the number of buildings in the study area Ne is multiplied by the probabilities of complete damage PC and severe damage PS. It is considered that around ninety percent of the buildings with severe damage are uninhabitable because the occupants are reluctant to inhabit them for fear of collapse, mainly due to the structural damage observed. The number of homeless inhabitants would be calculated by the product of the number of uninhabitable buildings Nei by the average number of inhabitants. For Guatemala City, this corresponds to an average density of 4.5 inhabitants per dwelling (INE, 2018).

The calculation of the number of dwellings destroyed by the earthquake and the number of people left homeless is based on complete and severe damage to the buildings. Equation (2) is applied to calculate the number of people who would be left homeless after the seismic events. The result of a basic earthquake is 563 uninhabited dwellings and 2,534 homeless people in Zone 10 of Guatemala City. On the other hand, the result of a severe earthquake is 1,022 uninhabited dwellings and 4,599 homeless people in the same zone.

Figure 6 shows the distribution of the homeless population by neighbourhood in Zone 10 of Guatemala City after the basic earthquake on the left and after a severe earthquake on the right.

Figure 6: Map of the neighbourhoods of Zone 10 of Guatemala City according to the number of people homeless after an earthquake: basic on the left and severe on the right.



5.3 Economic Losses

To determine the unit price per m² according to the structural typology, the Guatemalan Chamber of Construction was consulted. Due to the difficulty of estimating the price per m² for all typologies, they have been grouped into two groups. The first group includes masonry buildings in all their variations (confined and reinforced, simple and adobe), informal and porch structures, and the second group includes all buildings with reinforced concrete typologies (porches and walls). For the first group, a value of 3,500 GTQ per m² (450 USD) has been used, and for the second group, a cost of 10,500 GTQ per m² (1350 USD) has been used. The cost assigned to each typology is therefore indicative, but the results obtained are very interesting for the interpretation of seismic risk.

Thus, the economic cost CR is defined by the following expression:

$$CR = ST \times PC \times PU \tag{3}$$

Where ST is the total built-up area, PC is the probability of complete damage and PU is the unit price of the building.

In global terms, for a basic earthquake defined in the first scenario, the costs associated with the reconstruction and repair of damage to buildings in Zone 10 of Guatemala City would be around 412 million GTQ, some 51 million dollars. For a severe earthquake defined in the second scenario, the costs associated with the reconstruction and repair of damage to buildings in Zone 10 of Guatemala City would be around 1,052 million GTQ, or US$131 million.

5.4 Debris

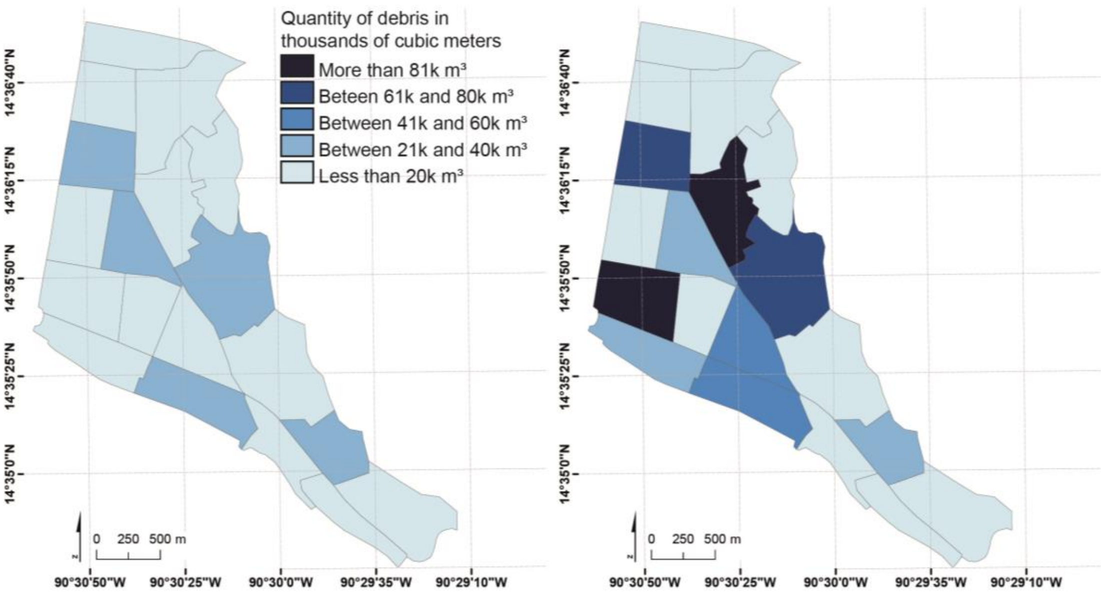
The volume of debris has been calculated using the method proposed by Miyamoto, 2021 for Guatemala City. The methodology uses as a reference what was observed after the Haiti Earthquake by Miyamoto, 2011. The following equation is therefore proposed for the calculation of the debris volume V:

$$V = \sum_{1}^{N_R} w \times A_i \times N_i \quad (4)$$

Where NR is the number of buildings with severe and complete damage, Ai is the footprint of the area of each building, Ni is the number of floors of each building, and w is the coefficient according to the volume of debris per square metre built depending on the structural typology of the building.

In global figures, for a basic earthquake, the volume of debris generated is 265,922 m^3. For a severe earthquake, this volume rises to 630,930 m^3. The distribution of debris by neighbourhood is shown in Figure 7 for basic and severe earthquakes, respectively.

Figure 7: Map of the neighbourhoods of Zone 10 of Guatemala City according to the quantity of m³ of debris generated by a basic earthquake on the left and by a severe earthquake on the right (figures in thousands of m³).



5.5 Fatalities

The calculation of human losses is based on Coburn and Spence, 2002. The victims of an earthquake are directly related to the number of collapsed buildings and the number of occupants of the building.

The calculation of casualties Ki is given by the following expression:

$$Ki = C \times M1 \times M2 \times M3\,(M4 + M5 \times (1 - M4)) \quad (5)$$

Where C represents the number of collapsed buildings of a particular typology.

$M1$ corresponds to the occupancy rate of the building. For the calculation of the occupation of buildings in Guatemala City, the classification proposed by CONRED 2019 has been chosen because it has a higher degree of conservation. In the case of dwellings, the average number of inhabitants per dwelling published by INE 2018 has been used.

$M2$ is the percentage of people in the building as a function of the time of day. For each simulated earthquake, occupancy has been evaluated at two times of the day: at four o'clock in the morning and at twelve o'clock noon. The occupancy values for Zone 10 of Guatemala City are: for four o'clock in the morning it is more than 140,000 people and for twelve o'clock noon around 825,000 people.

$M3$ is the percentage of people trapped by collapse. This factor is influenced by two parameters: the building typology and the macroseismic intensity of the earthquake. For the basic earthquake a macroseismic intensity of VIII is used, while for the severe earthquake, a macroseismic intensity of IX is used, which corresponds to the average value of the 1976 earthquake.

M4 is the percentage of casualties due to collapse. Of all the people trapped in a collapsed building, a certain percentage are injured with varying degrees of severity and others die.

M5 is the percentage of casualties after the earthquake because people trapped in the rubble of collapsed buildings may or may not be rescued and cared for. This percentage depends mostly on the effectiveness and efficiency of the rescue efforts. It has been assumed that Guatemala City has the capacity to organise emergency squads within 12 hours of the seismic event.

Although the numbers of fatalities and injuries are not high, they are of a magnitude that is very important to consider for prevention plans. The percentage is between 1.5% and 2.6% of fatalities in the two scenarios and between 5.7% and 9.3% of injuries of all types in the two scenarios for the estimated occupancy of the study area. However, when comparing these results with the effects produced by the 1976 earthquake, it can be determined that the designed scenarios produced similar percentage figures for casualties and injuries after the 1976 earthquake. According to Espinoza, 1976, the 1976 earthquake affected more than 2.5 million inhabitants and impacted more than 2,000 km² at magnitude VIII and just under 150 km² at magnitude IX.

6 Final Discussion

One of the major contributions of this study is to have obtained results of the integral calculation of seismic risk, having developed in greater depth the characterization of the seismic exposure and vulnerability of Guatemala City using Zone 10 as a model for the extrapolation of the results to the rest of the city. As mentioned in the different sections, the results of the exposure analysis have been combined with the characterization of seismic vulnerability and the definition of seismic scenarios and their consequences, obtaining results on the risk associated with two seismic scenarios that provide a large amount of information of great interest for emergency management.

Figure 8: Histogram of buildings of Zone 10 of Guatemala City by structural typologies according to the state of damage after a severe earthquake.

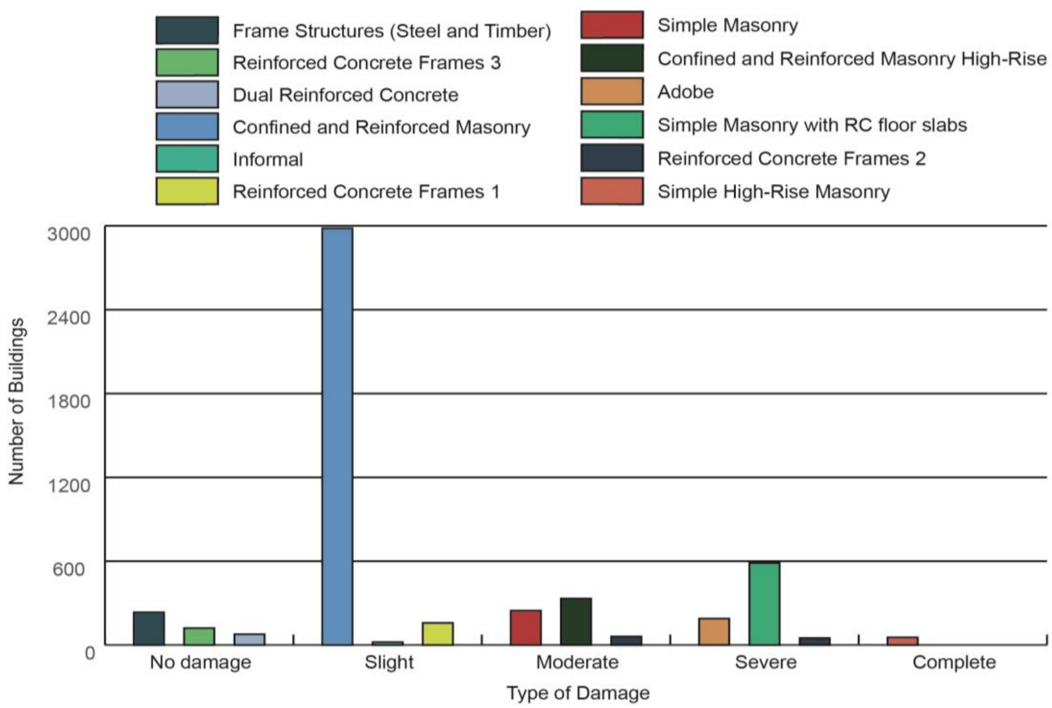


Figure 8 shows the relationship between the structural typologies defined in this study and the state of damage reached in the simulated seismic scenarios, corresponding to a basic and a severe earthquake, associated to return periods of 475 and 975 years, respectively. Older structural typologies show a worse behaviour in the seismic scenarios.

The simple masonry typology is the most vulnerable according to the analysis of the results of the seismic scenarios. The Adobe (AD) typology, although assigned the highest seismic vulnerability index, turns out not to be the type of building that would reach the highest degree of damage, although it does appear with a high state of damage in the different scenarios. Confined and reinforced masonry performs well, reaching in most cases a state of slight damage. However, buildings with more than three stories result in moderate damage in a severe earthquake. This is a consideration widely shared by the country's experts.

Reinforced concrete typologies with shear walls (HD1-HD3) have shown little or almost no damage in the two seismic scenarios. And finally, the reinforced concrete portal frame typologies have shown a surprising result. Except for the high-rise buildings (HP3), which perform adequately, the rest show some damage. Low-rise buildings show slight damage in both seismic scenarios. The most damaged are the structures between 4 and 7 stories (HP2) whose state of damage is between moderate and severe damage.

On the other hand, the fatality and injury rates are very similar to the results of the PREPARE study for Guatemala City (Miyamoto, 2021). The report estimates a rate of 0.9-1.0% of fatalities and 7-8% of injuries. The results obtained for the simulated basic and severe earthquakes put the rate between 1.5-2.6% for fatalities and between 5.7-9.3% for injuries.

As is evident, the Guatemala City Zone 10 exposure model has been used as a pilot scheme for seismic risk assessment. Part of the development of the risk assessment involves a few assumptions with large uncertainties due to the lack of specialized literature about Guatemala. However, the results obtained through the analysis show a catastrophic scenario in case of a high-magnitude earthquake.

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