Assessment of Damage Potential of Seismic Ground Motions

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I. Introduction

One reason to study earthquakes is contributing to reduce or avoid the damage that some earthquakes trigger. In this topic, the analysis of seismic records is an important activity to obtain valuable information about the features of the seismic waves on a site. For instance, this analysis allows assessing diverse parameters that have been identified as a reasonable reference to assess potential damage of seismic ground motions. In this document, we described some relevant aspects of the analysis of seismic records with the purpose of assessing parameters related to the damage potential associated with earthquakes. For this objective, we applied the computer code Seismograms Analyzer-e [1]. On the other hand, the earthquakes that are analyzed in the present document have in common that in all of them occurred damage in buildings and unfortunately, people died.

II. Analysis and processing of seismic ground motions related to two damaging earthquakes of Mexico

Mexico City recives seismic waves that are generated by earthquakes that occur in different regions of Mexico. For instance, Table I shows fundamental data about two damaging earthquakes that affected to Mexico City. The first earthquake is known as the Michoacán earthquake and it had its epicenter near to the Coast of Michoacán. The second event is Puebla earthquake and it had its epicenter in the south region of Puebla.

A. Michoacán earthquake of magnitude 8.1 (September 19, 1985)

According to Table I Michoacán earthquake of 1985 produced a maximum PGA (Peak Ground Acceleration) equal to 169 cm/s^2 at SCT station located at one of the diverse regions of soft soil in Mexico City. However, it is important to notice that the SCT station is located 425 km from the epicenter. Similarly, this earthquake produced a maximum PGA equal to 33.8 cm/s^2 at UNAM station which is located at a rock site in Mexico City (Table I). Therefore, for this earthquake, the PGA at the SCT station was 5 times greater than the PGA at the UNAM station. This type of behaviour during the Michoacán earthquake was the key to confirm the importance of the local effects in the final features of the seismic waves that arrive at a specific site. The same earthquake produced a maximum PGA equal to 258 cm/s^2 at Zacatula, Michoacán located to 81 km from the epicenter.

B. Puebla earthquake of magnitude 7.1 (September 19, 2017)

One of the particularities of this earthquake is the fact that it also occurred on September 19 as in the case of the 1985 earthquake. However, in this case, the earthquake occurred 32 years after the 1985 earthquake. Unfortunately, in both

TABLE I. Basic data and results related to seismic records of two damaging earthquakes of Mexico

EQ	Seismic station	dist [km]	PGA & Comp. [cm/s2]	CAV_{STD} [cm/s]	Warning CAV_{STD} [1]
Michoacan Mexico	1.SCT Mexico City	425	96.7 NS	1630	Yes
09-19-1985 M=8.1			169 EW	1980	Yes
	2.UNAM Mexico City	419.5	31.1 NS	89.3	No
			33.8 EW	55.6	No
	3.MCH Zacatula	81	258 NS	2080	Yes
			171 EW	1720	Yes
Puebla Mexico	1.UNAM Mexico City	116.4	44.3 NS	183	Yes
09-19-2017 M=7.1			51.7 EW	213	Yes

1

In this column the word Yes means that CAV_{STD} is greater than 156.96 cm/s (0.16 g.s) which is the threshold chosen for this study. Similarly, the word No means that CAV_{STD} is not greater than 156.96 cm/s earthquakes the amount of damage triggered in Mexico City was important. According to Table I the Puebla earthquake of 2017 generated a maximum PGA equal to 51.7 cm/s^2 at the UNAM station. This station is located to 116.4 km from the epicenter and is situated in a rock site.

III. Damage potential of ground motions

The seismic records give us relevant information. For instance, the seismic records are an essential data for the appropriate operation of Earthquake Early Warning systems, because the rapid detection of the size of an earthquake allows generating useful warnings to evacuate buildings, to activate special protection protocols, etcetera. At the same time, there is interest in to know the damage potential related to each seismic record. For this purpose different parameters have been proposed. One of these parameters is CAV_{STD} (standardized cumulative absolute velocity) [2]. The computation of this parameter can give us an idea of the damage potential of a ground motion. For instance, just when an earthquake occurred, we can process automatically the seismic record to compute the CAV_{STD} and the result can be included in a report that can be sent automatically to diverse stakeholders but essentially to authorities of civil protection. Then if values of CAV_{STD} exceed a threshold then the probabilities of damage in buildings can be considered as relevant. Therefore, in these cases, the authorities can obtain a rapid assessment of the urban area to identify the regions with more probabilities to suffer damage in their buildings and infrastructure. Consequently, this information can be used as a reference to organize emergency activities.

For instance, we can use 0.16g.s (156.96 cm/s) [3] for the threshold of CAV_{STD}. Therefore, according to this reference value and the data of Table I, we can identify that if a new earthquake similar to the Michoacán earthquake of 1985 occur

TABLE II. Main data of three earthquakes that triggered damage in urban areas

EQ	Seismic station	dist [km]	PGA & Comp. [cm/s^2]	CAV$_{STD}$ [cm/s]	Warning CAV$_{STD}$ [2]
Lorca Spain	1.LOR Lorca City	4.6	364 N30W	211	Yes
11-05-2011 M=5.1			154 E30N	113	No
LAquila Italy	1.Aterno LAquila City	4.85	612 EW	1110	Yes
04-06-2009 M=6.3					
Colima Mexico	1.COJ Cofradia	37	1250 NS	407	Yes
31-05-2007 M=5.1			680 EW	254	Yes

2

In this column the word Yes means that CAV_{STD} is greater than 156.96 cm/s (0.16 g.s) which is the threshold chosen for this study. Similarly, the word No means that CAV_{STD} is not greater than 156.96 cm/s

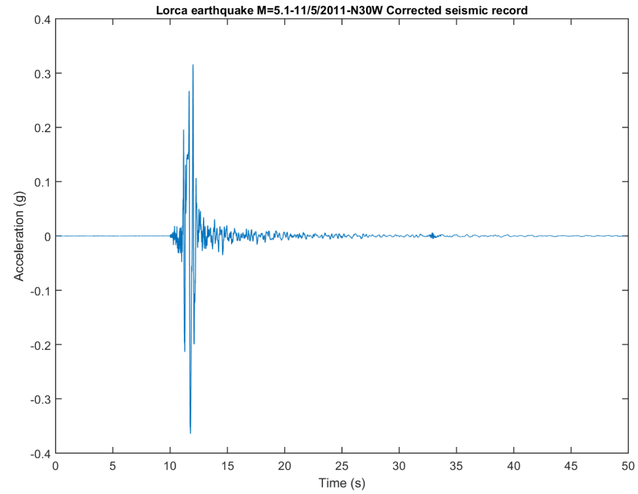

Fig. 1. The nort-30-west component of the LOR accelerogram obtained in the 2011 Lorca (Spain) earthquake. This seismic record was processed by Seismograms Analyzer-e software. [1].

in Mexico we would expect the following: a) the generation of significant seismic damage in the regions where both the SCT (Mexico City) and MCH (Zacatula, Michoacán) stations are located; b) a significantly greater concentration of damage in the SCT region of Mexico City than the concentration of damage in the UNAM region. This last affirmation is based on the fact that the maximum CAV_{STD} for the SCT station is equal to 1980 cm/s which is significantly greater than the threshold of 156.96 cm/s, and it is also based on the certainty that the maximum CAV_{STD} for the UNAM station is equal to 89.3 cm/s which is lower than the 156.96 cm/s. Therefore, if a new earthquake similar to the Michoacán earthquake occurs then the SCT region will require major emergency resources than the UNAM region.

On the other hand, for the Puebla earthquake of 2017, we would identify that seismic damage can occur at the buildings located in the same region than the UNAM station due to the fact that the maximum CAV_{STD} for this site is equal to 213 cm/s which exceeds the reference value of 156.96 cm/s.

The same previous criteria can be used for the earthquakes of Table II. For instance, in the Lorca earthquake case, it is possible to observe that CAV_{STD} value due to the E30N component does not exceed the reference value of 156.96 cm/s, but the CAV_{STD} value due to the N30W component is greater than the mentioned reference value. Therefore, in this case, the computation of these values suggest that the ground motion generated by the Lorca earthquake could generate seismic damage in buildings in the region where the LOR station is located. For this earthquake, the maximum PGA recorded was equal to 364 cm/s^2 (Fig. 1).

Additionally, we can observe that for the seismic records of the L'Aquila earthquake and of the Colima earthquake (Table II), the values of CAV_{STD} exceeds the reference value of 156 cm/s. Moreover, we also can observe that the maximum CAV_{STD} for the L'Aquila earthquake is equal to 1110 cm/s for a seismic record with a PGA equal to 612 cm/s^2 (Fig. 2). But, for the Colima earthquake, the maximum CAV_{STD} is equal to 407 cm/s for a seismic record with a PGA equal to 1250 cm/s^2. Therefore, according to the values

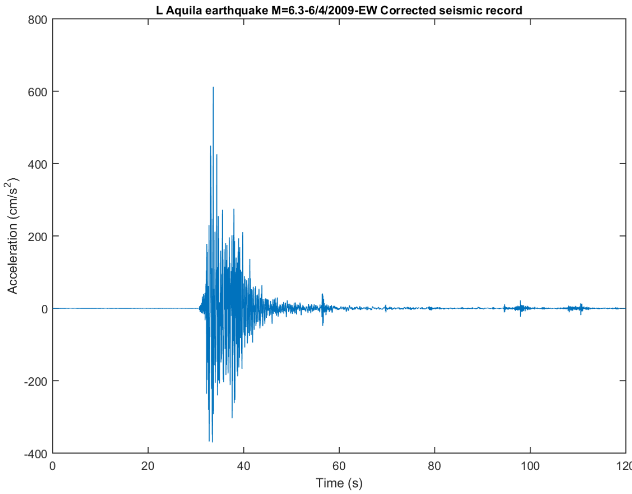

Fig. 2. The east-west component of the Aterno accelerogram obtained in the 2009 L'Aquila (Italy) earthquake. This seismic record was processed by Seismograms Analyzer-e software. [1].

of PGA and CAV_{STD} for both the L'Aquila and Colima earthquakes, respectively, we can observe that there is not a linear relationship between PGA and CAV_{STD}. However, in the cases analyzed in the present document the value of 156 cm/s was an appropriate threshold, because in the whole cases of the present study damage occurred when CAV_{STD} exceeded 156 cm/s.

IV. Conclusions and Future Works

According to the preliminary results obtained in the present study, it is possible to confirm that CAV_{STD} is a reasonable parameter to assess the damage potential of specific seismic ground motion. However, in order to do an extensive sensitivity analysis about the reliability in the threshold equal to 0.16g.s, it is convenient to compute CAV_{STD} using a significantly greater database of ground motions than the one used in this study. This new work will allow examining with major detail the reliability of CAV_{STD} as an estimator of the damage potential of seismic ground motions, and at the same time, this new work could be used to try to define more than one threshold in function of probabilities of occurrence of different levels of damage.

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