Strong ground motion simulation for seismic hazard purposes in Mexico: two case examples

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Abstract

The methodologies developed for the simulation of strong ground motions to estimate the seismic hazard in Mexico City soft soils, and at a rock site in the southeast of Mexico are presented. For both sites a bayessian seismic hazard model is applied. In the former site the Montecarlo simulation technique was utilized to obtain the synthetics. For the latter site the empirical Green function technique is used for this purpose. The main conclusions of the work are: 1) In the Mexico City soft soils case the estimated seismic hazard, computed before the 1985 Michoacan earthquake, successfully predicted the maximum ground motion observations for this event. 2) The incorporation of the potential seismic activity of faults located nearby the site in the southeast of Mexico, has a large impact in the estimated seismic hazard, compared with the results obtained without considering that potential.

1. Introduction

The consequences of the occurrence of recent large earthquakes such as the 1985 in Mexico, the 1985 in Chile, the 1988 in Armenia, the 1989 and 1994 in California, the 1995 in Kobe, and the ones of 1999 in Turkey and Taiwan, stresses the importance of performing seismic hazard studies that reflect not only the uncertainties about the occurrence, location, and magnitude of future earthquakes, but also about the particular characteristics of the ground motions (i.e. amplitudes, frequency content, and duration) expected at a specific site on a given seismic region.
In this work we present the main features and results of the techniques developed since the early 80´s up to now, to estimate the seismic hazard in different sites of Mexico. In particular we will focus on two cases, the first corresponds to the work performed since the early 80´s and 90´s to assess the seismic hazard and the seismic safety of typical constructions located in Mexico City soft soils zone (MCSSZ), this case is addressed in chapter 2. The second case is the subject of chapter 3, in which we present a synthesis of our recent studies aiming to estimate the seismic hazard at rock or firm soils sites, located in the Isthmus of Tehuantepec (IT) in the southeast of Mexico. Finally, the main conclusions are presented in chapter 4.

2. Seismic hazard in Mexico City soft soil zone

The strategy for the estimation of the seismic hazard and of the expected strong ground motions for MCSSZ, rely upon the accelerograms obtained (since 1961) at different sites of this zone, for medium to large size interplate and intraplate earthquakes with magnitudes Ms>6.4 (Chavez and de Leon 1983[1], 1984[2], Chavez 1992[3]). In Figure 1, examples of typical velocity response spectra, Sv, (for a critical damping of 0 and 2%) observed at a MCSS site are shown. Also, in the same Figure the corresponding computed spectra obtained by a 1D modeling of the local site effects are presented (Herrera et al. 1965[4]).

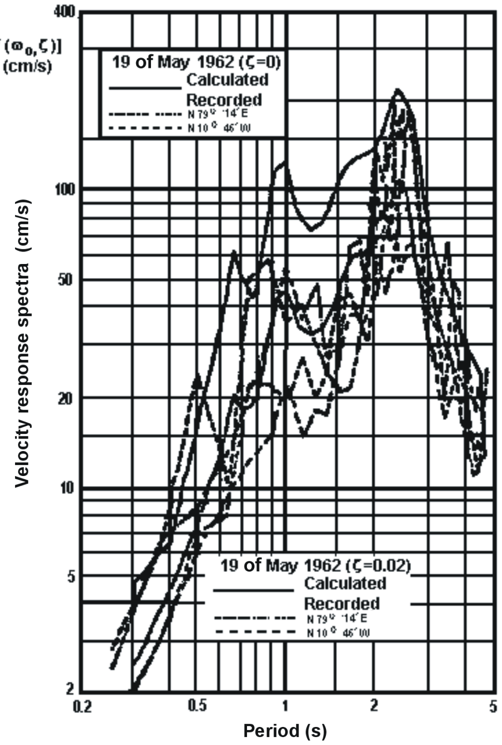

Figure 1: Observed and computed (1D modelling) velocity response spectra for the Ms=6.9, H=33Km, D=230Km, 19/05/1962 earthquake, recorded at the Alameda Park, Mexico City soft soil site (Modified from Herrera et al., 1965[4]).

Notice that the larger amplitudes of the spectra are at about 2.5s, and that the agreement between the observed and computed spectra are satisfactory.

In order to estimate the seismic hazard of MCSSZ we selected the maximum values of the Sv(10%) parameter (which showed a reduced variability for a wide band of frequencies) for a catalog of events recorded from 1961 to 1982 at several sites of the mentioned zone (Chavez and de Leon 1983[1], 1984[2]). To compute the annual rate of exceedance, ν, of the observed Sv(10%)max, it was assumed that the occurrence of the intraplate and interplate earthquakes follows a Poisson process, such that the intensities and the detailed ground motion associated to any two different events are statistically independent and identically distributed. Therefore, the probability that a particular Sv is exceeded can be expressed as:

$$P(Sv) = \exp(-\nu(Sv)\ To) \quad (1)$$

where To is the lapse of interest and ν(Sv) can be computed by the expression:

$$\nu(Sv) = k\ (Sv^{-q} - Sv_1^{-q}) \quad (2)$$

in (2) k and q depend on the seismicity of the region of interest, and Sv_1 is the maximum Sv which may occur in the site. The estimation of these parameters was performed by the application of bayessian statistics to the observed ν(Sv), and by assuming that the prior values of Sv_1 were around 400cm/sec, which corresponded to a maximum ground acceleration of about 500cm/s^2. The later value corresponded to plausible scenarios in which the occurrence of a large surficial event at short epicentral distance, or to the occurrence of a very large one at a medium epicentral distance, were considered.

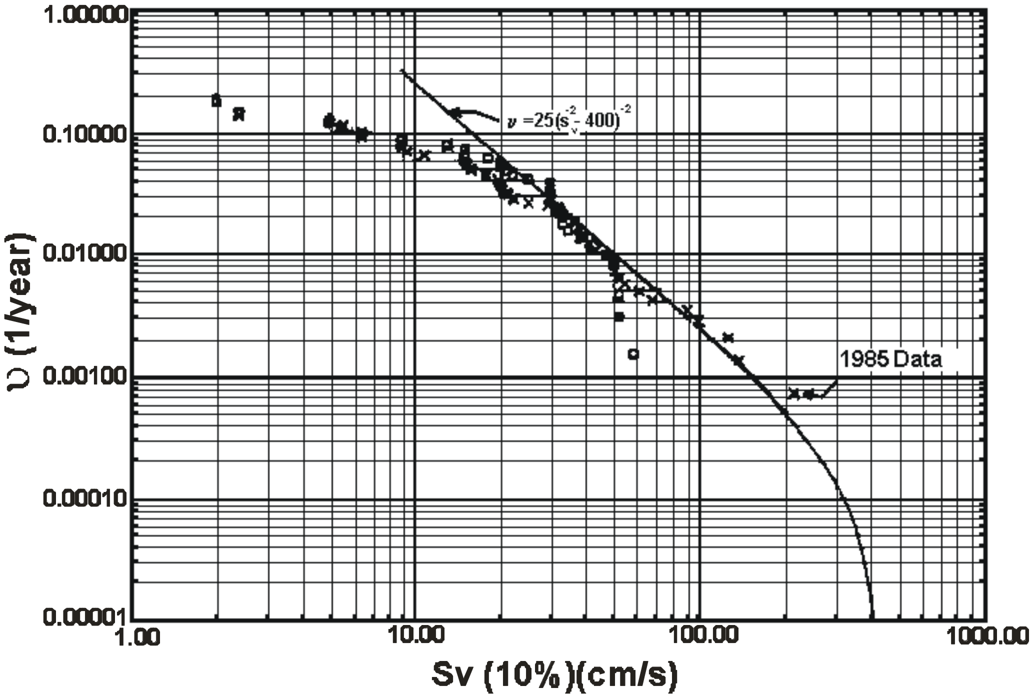

Fig. 2: Annual rate of exceedance, ν, of the maximum values of the seudovelocity response spectra Sv (10%) observed in Mexico City soft soils from 1961 to 1982 (   ), and from 1961 to 1991 (x), and the estimated seismic hazard (modified from Chavez and de Leon, 1983, 1984¸ Chavez, 1992).

The scenarios were based on historical observations of the very important damage that Mexico City constructions had suffered in previous centuries and as early as 1912 (Chavez and de Leon 1983[1], 1994[2]). This was not reflected in the 20 years record which included a maximum acceleration of about 50cm/s^2.
As the observed Sv(10%)max are assumed to be associated to independent events, it was also assumed that their accumulated probability distribution (the P of equation 1), for the 20 years sample, could be computed accordingly with the Gumbel´s criteria (i.e. the Pi corresponding to an Svi is equal to j/n+1, were j is the position of the Svi in the ascendent list of the observed Svi for the given lapse, and n is the sample size). Once the Pi´s are computed, their associated ν_i can be calculated with equation 1. In Figure 2 we present the results obtained for two sets of data, the one already mentioned, and the other which includes observations from 1961 to 1992, also the bayesian estimate of ν proposed by Chavez and de Leon (1983[1], 1984[2]) before the 1985 Mexico earthquake is included. Notice that the agreement of the proposed ν (with parameters k=25, and q=2 and Sv_1=400cm/sec) with the 1985 observations are reasonable.

The proposed seismic hazard estimate proposed for MCSSZ shown in Figure 2, and the 20 years sample of accelerograms mentioned above were utilized to generate synthetics of the expected ground motions in MCSSZ for lapses of interest. Based an the analysis in the time and frequency domains of the sample of accelerograms, it was assumed that the details of the future ground motions would be similar to the ones of the sample, except for the amplitudes, which should reflect the estimated seismic hazard, this through the application on those amplitudes of a scaling factor obtained via Monte Carlo simulation as explained in (Chavez et al. 1983[1], 1984[2], 1992[3]). These types of synthetics were used to compute the structural safety of typical constructions located at MCSSZ. The results of the study agreed with the 1985 observations of the collapsed structures (Chavez, 1992[3]).

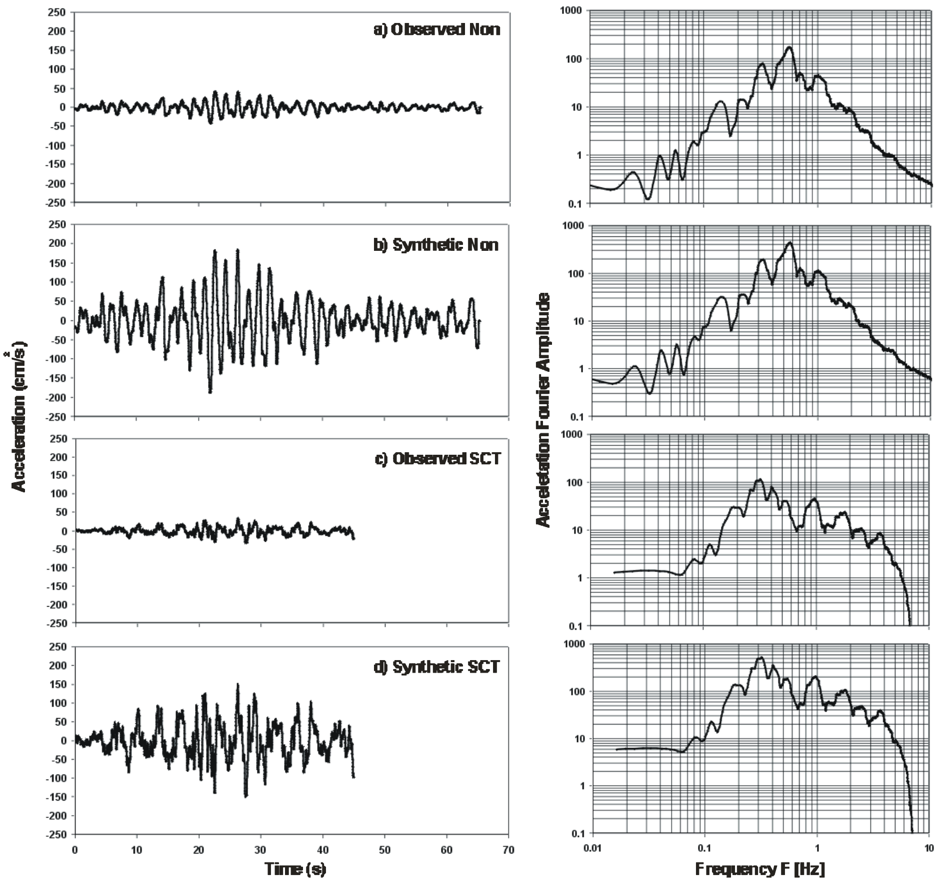

Fig. 3: Observed accelerograms and their synthetics for the: a) Ms=7.6, H=15Km, D=305Km, 14/03/1979, and c) Ms=7.0, H=65Km, D=190Km, 24/10/1980, earthquakes, recorded in Mexico city soft soils; their corresponding Fourier amplitude spectra are also shown.

3. Seismic hazard in rock site in the southeast of Mexico

The site of interest is located in the center of the Isthmus of Tehuantepec (IT) which is shown in Figure 4.This region is located were it is supposed that the North American, the Cocos and the Caribbean plates form a triple joint. The region is poorly instrumented. In Figure 4 the type of seismicity which characterizes the region, obtained during a recent microseismic campaing, is shown (Chavez et al. 1999[5]. Based on the historical information about the events with Ms larger than 6, occurred in the region from 1900 to 1990, on the microseismic data, and on the results reported by (Chavez et al., 1999[5]) it was possible to apply the empirical Green function technique proposed by Irikura, to obtain synthetics at a rock site located in the center of the IT, an example of the type of results obtained is shown in Figure 5. In this Figure the empirical Green function is identified by F.E.G.7, and the synthetic by Synthetic 3.

The bayessian seismic hazard estimate for the site of interest was obtained by following the procedure described in chapter 2. The results are shown in Figure 6. Notice that the hazard for the site is larger when the contribution of nearby potentially active faults is included.

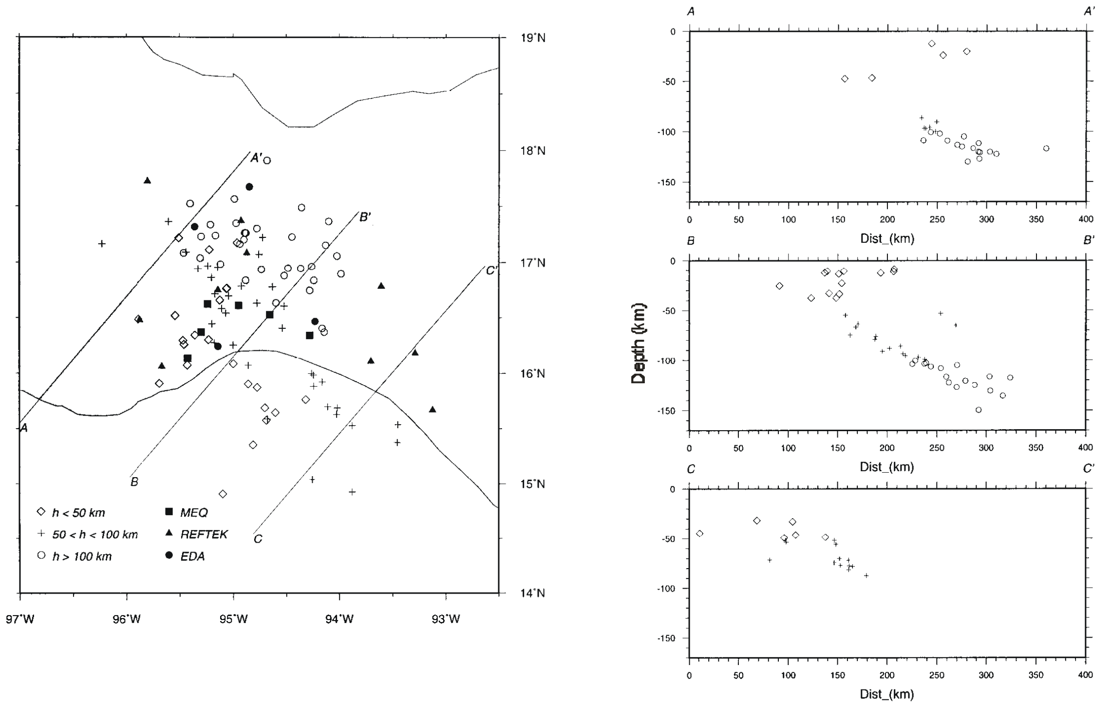

Fig. 4: Location of temporal seismological stations and epicenters of about 100 events with Ml betwen 0.6 and 3.6, detected in the fall of 1995 in the Isthmus of Tehuantepec, Mexico, and the profiles AA´, BB´,CC´.

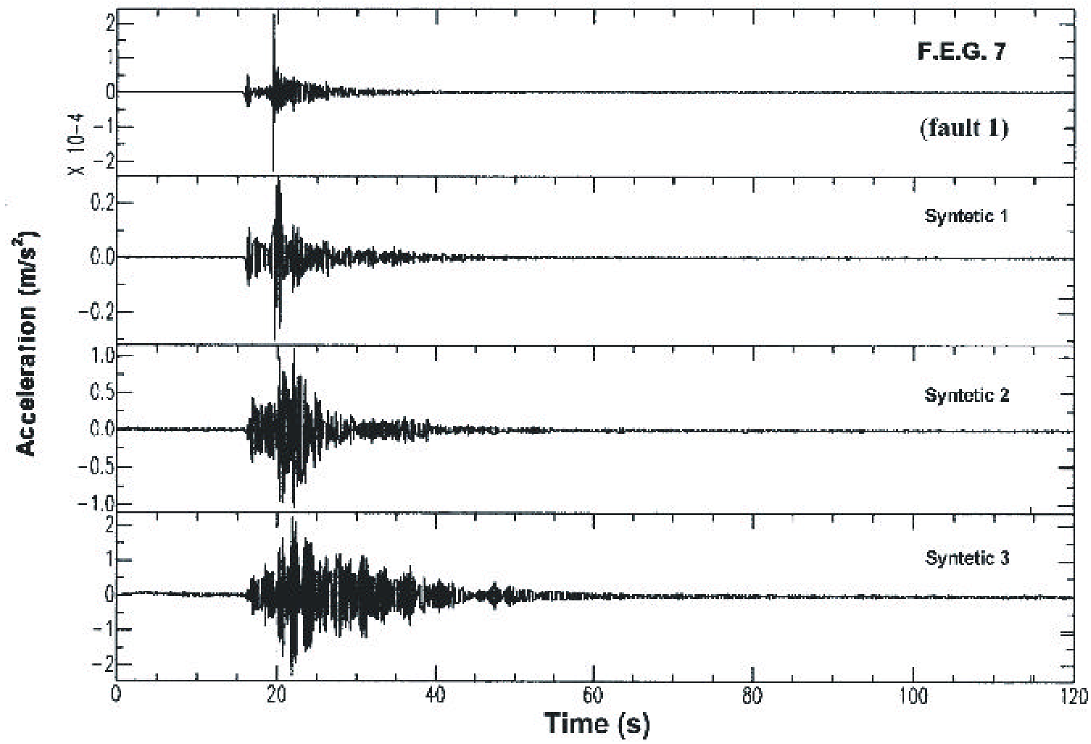

Fig. 5: Synthetics obtained with the empirical Green Function technique of Irikura, for an Ms=5.6, H=10Km, d=15Km, earhtquake, expected at a rock site in the Central part of the Isthmus of Tehuantepec.

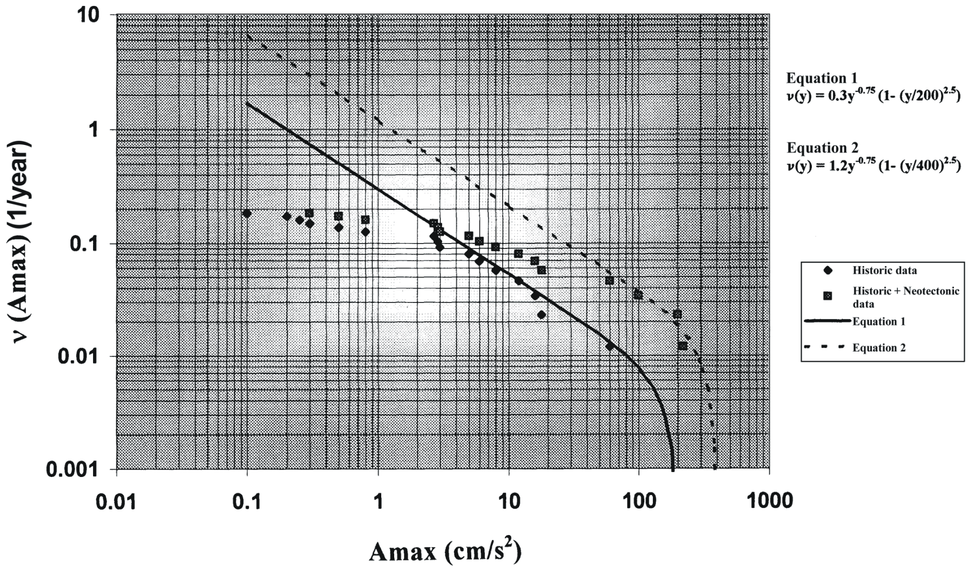

Fig. 6: Annual rate of exceedance, ν, of the maximum acceleration, Amax, expected at a rock site in the central part of the Isthmus of Tehuantepec, Mexico. The estimated ν curves are: Equation 1 for the historical events (1900-1990, Ms >6); Equation 2 for the historical events plus the contribution of potentially active nearby surficial faults.

4. Conclusions

The use of strong motion simulation for seismic hazard purposes was succesfully applied for Mexico City soft soils zone, and also allowed the improvement of the estimate for rock site located in a poorly instrumented region of the southeast of Mexico. Based on those results the author believes that the use of simulated records opens new possibilities in the very complex and sometimes frustrating task of estimating the seismic hazard in different seismic enviroments.

Acknowledgments

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