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HAZARD SEISMIC STUDIES FOR THE ROMANIAN CAPITAL – APPLING THE SHAKE MAP METHOD

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The shake map methodology for seismic hazard studies has been applied to a sector of Bucharest, the capital of Romania. Geological and geotechnical profiles are known for this region. We have chosen as seismic input the event of 30 August 1986, $M_W = 7.1$. We discuss the propagation of a synthetic signal with known source characteristics, from source to bedrock and back to surface. It is possible to produce surface synthetic signals in the studied area, having very similar characteristics (accelerations) to the observed ones.

Keywords: acceleration; bedrock; seismic hazard; shake map

Introduction

The shake map method enables us to represent the effects of an earthquake over an area. Such a representation is different from the usual characteristics of the seismic event: magnitude, intensity, epicentral location. The shake map method takes into account the shaking of the sites and not the parameters, which describe the seismic source.

An earthquake with a magnitude and a defined epicenter, produces a level of shaking in the sites around it, these depending on the epicentral distance, the geological strata crossed by the seismic waves, local superficial strata etc.

The seismic effects at a certain on sites can be represented by: accelerations, velocities, response spectra etc. The shake map method is a very important tool in the pre- and post-earthquake management.

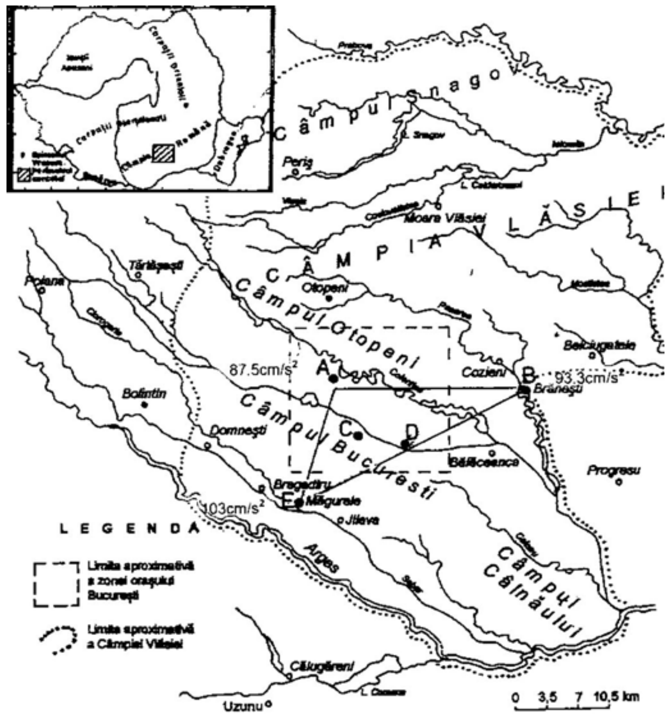

Fig. 1. Sites chosen for analysis (A, B, C, D and E); dotted line is the boundary of the Buchrest City area

Methodology

The choice of a region for the compilation of a shake map implies the availability of a large amount of data about: geology of the region, geotechnical data, density of stations (the greater the density, the more accurate the results), existence of records, etc. For the present study, we have chosen a sector of the capital of Romania – Bucharest (Fig. 1).

The principal and most destructive seismic source in Romania is the Vrancea region, which had generated there both strongest earthquakes in the 20th century: 10 November 1940 of magnitude 7.4 and 4 March 1977 (more than 1500 people died and property damage in 2 billion $ – 1977 value).

The seismic hazard study is carried out using the earthquake of 30 August 1986, as seismic input, because, the density of station which recorded strong motions optimum for the actual conditions of Romania.

The characteristics of this earthquake are: hipocentral depth 131 km, the distance epicenter – different parts of the considered sector is 120–130 km, source mechanism parameters: dip: 65 degree, rake: 104 degree and strike: 227 degree, magnitude: $M_W = 7.1$; $M_0 = 6 \cdot 10^{19}$ Nm. This earthquake is the strongest among those for which sufficient records are available and has a specific Vrancea mechanism.

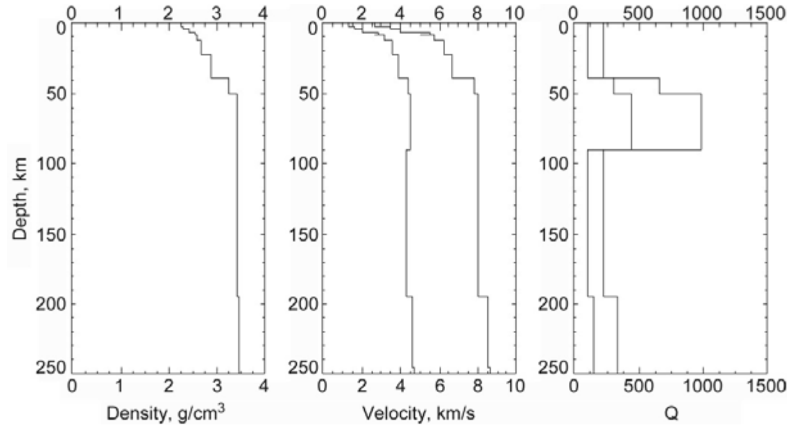

Fig. 2. “isra” stack of layers

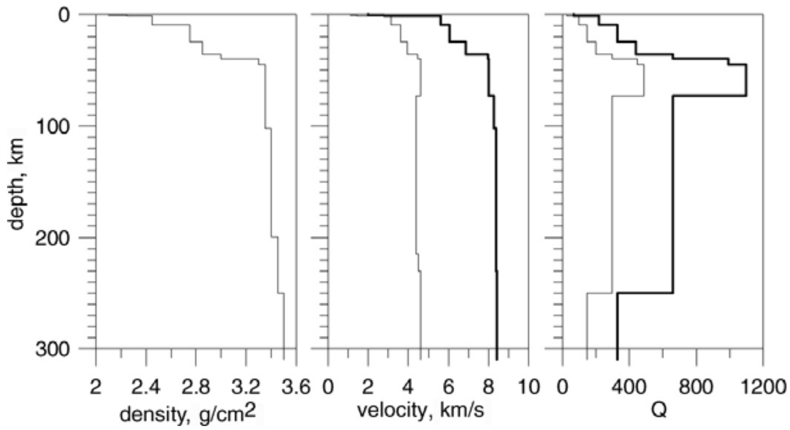

Fig. 3. “sing” stack of layers

The following seismic stations are situated in the studied sector of Bucharest (Fig. 1). Magurele (E) in the southern, Branesti (B) in the eastern, Titulescu (A) in the northern, Carlton (C) and Panduri (D) in the western part.

A synthetic signal is generated in the seismic source, with the characteristics of the 30.08.1986 earthquake, which is then transferred to the bedrock of the different points in the studied sector of the city, using the method of summing multimode media in semi stratified space.

The synthetic accelerograms at the bedrock level are calculated by means of modal summation technique (Panza 1993, Florsch et al. 1991, Panza et al. 2000) using a point source model with a conventional unit of seismic moment of 10^7 Nm. The use of synthetic data is the only way in which the shake map methodology can be applied in a situation like in Bucharest, where no bedrock records are available.

For scaling of the synthetic seismograms we use the Gusev curves (Gusev 1983)

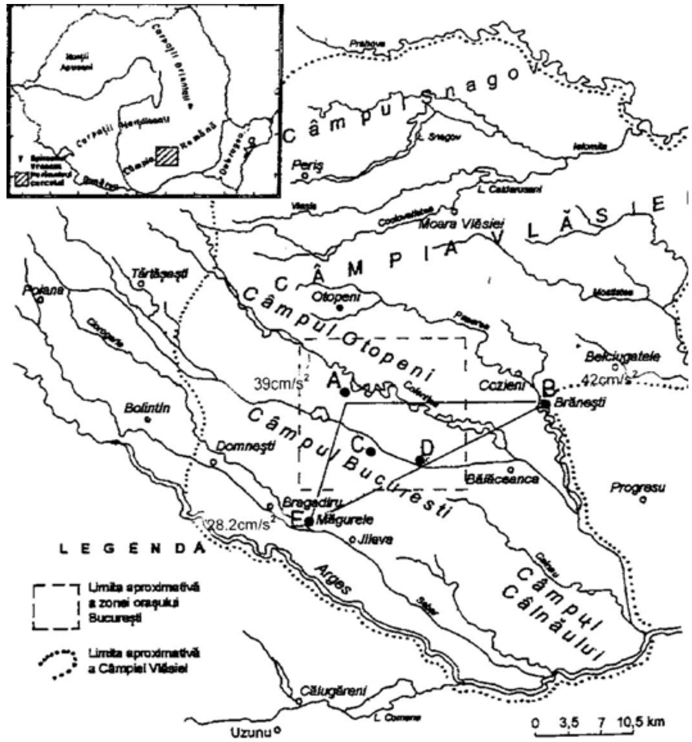

Fig. 4. Map of the analyzed region with recorded maximum accelerations at the surface, filtered for the frequency domain used in simulations

modified for Vrancea intermediate depth events (Radulian et al. 2000). These curves have a particular scaling for the intermediate earthquakes, compared with less deep sources, so the corner frequency (source dimension) is an order of magnitude greater for the same seismic moment. The shake map is based on a geotechnical data base which contains all soil characteristics and soil profiles for the sites where seismic hazard study was made.

The stack of layers, through which the transfer of seismic waves from the source to the bedrock was calculated, is based on the “isra” stack of layers shown in Fig. 2.

The National Institute of Research Development for Earth Physics and the University of Karlsruhe developed by taking in to account new research (complex geophysical measurements including seismic tomography on the seismic profile Bacau – Giurgiu) a new model for the bedrock called “sing” (after the village Singureni, near Bucharest). The most important characteristics of the stack of layers called “sing” are presented in Fig. 3.

A comparison of the two models is seen in Fig. 2 (“isra” model) and Fig. 3 (“sing” model). We preferred to use the “sing” model because these layers, are very near to the realistic conditions, they in plain are (as is the path between the source

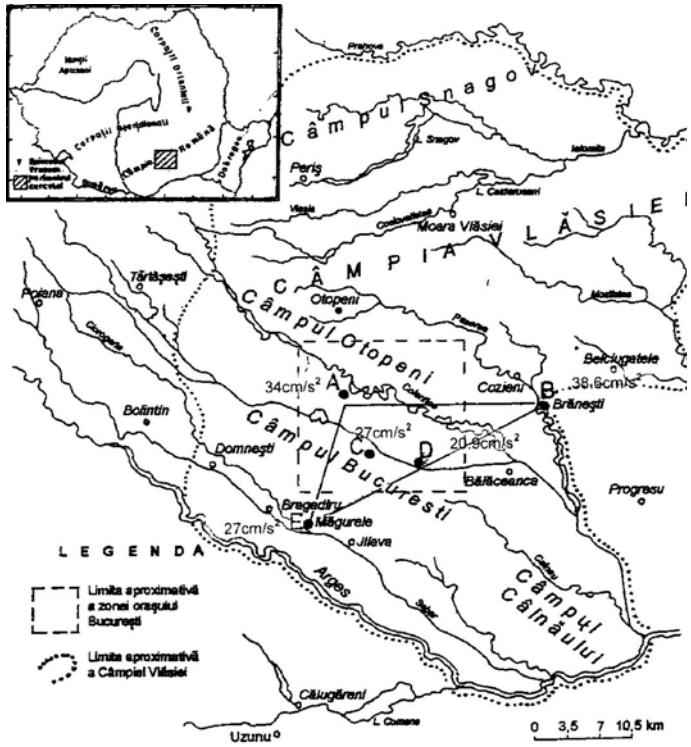

Fig. 5. Map of the analyzed region with maximum accelerations at the surface as a result of the Shake analysis (input signals are the filtered ones)

and bedrock), compared with "isra" stack of layers which are in a mountainous region.

For all the sites A, B, C, D and E the signal calculated at the bedrock is transfer to the surface of the site (0.00 m) using the Shake software. This software makes a nonlinear complex analysis about the variation of the shear modulus and the damping ratio with the strain induced in the soil deposit by the seismic movement.

Results

Figure 1 represents the map of the analyzed region with the maximum recorded acceleration during the 30 August 1986 quake for sites A, B and E, where seismic records are available. All the recorded signals used in this analysis are unfiltered when nothing else is mentioned.

Figure 4 represents the map of the analyzed region with recorded maximum accelerations at the surface, 0.00 m, filtered for the frequency domain used in the simulations.

Figure 5 shows the map of the analyzed region with maximum accelerations at the surface 0.00 m as a result of the Shake analysis (input signals are the filtered ones).

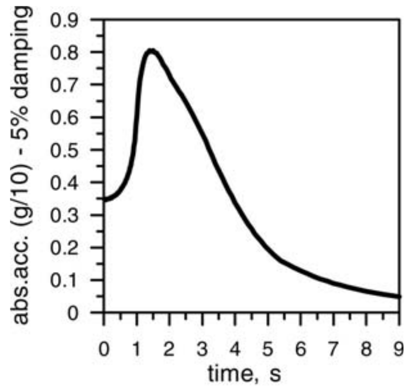

Fig. 6. Response spectrum for the site A

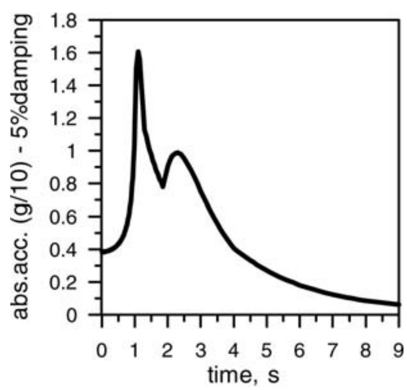

Fig. 7. Response spectrum for the site B

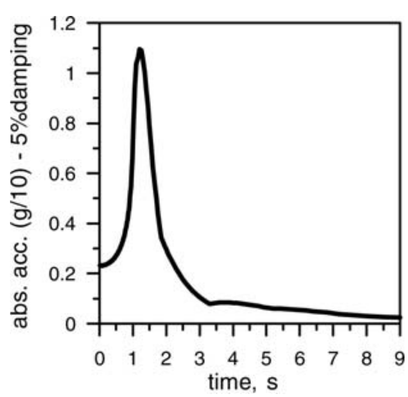

Fig. 8. Response spectrum for the site D

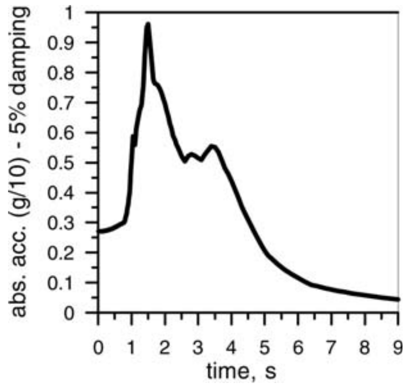

Fig. 9. Response spectrum for the site E

Figures 6, 7, 8, 9 represent responses spectra for the A, B, D, E sites computed with the SHAKE software.

Conclusions

The maps in Figs 4 and 5 show that the difference between the realistic records and the simulated ones is not exceeding 10 percent. This proves that the simulation technique has worked well in these cases and it is possible to get good results also in other sites of the city, where we do not have records, by using this method. We shall continue the research in this area with new tests.

The response spectra presented in this paper, Figs 6, 7, 8 and 9 are in accordance with the geological and geotechnical profiles of the studied area.

Taking into account all the previous results using the "shake map" method accelerations and response spectra (in this case) as well as velocities can be calculated. They have equivalents in seismic intensities, for a necessary number of sites in a region where geology, geotechnical profiles and data about the seismic input are known, namely source and path of the seismic signal: source – base bedrock-surface.

All these help us very much for further analysis of seismic hazard.

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