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Site effects modelling experiment

P. Teves-Costa & L.A. Mendes-Victor
Centro de Geofísica da Universidade de Lisboa, Portugal

ABSTRACT: In 1991 an experimental study was carried in Lisbon city in order to test the theoretical models proposed in 1988, for some alluvial valleys and the Castle hill, by application of the Aki-Larner method. This theoretical study has conducted to important site effects, specially on some alluvial valleys. The comparison of the experimental results with the theoretical models favours a reasonable agreement for the Castle hill.

1 INTRODUCTION

Lisbon is located near the boundary between the Eurasian and the African plates and, its historical seismicity presents the occurence of moderate to strong earthquakes, wich caused important damage all along the city. However, the damages were heterogeneous distributed suggesting the existence of site-effects due, probably, to the presence of different geological surface formations and of particular topographic features.

In 1982, a microzonation study of the town was performed producing a set of maps according to different earthquake source scenarios and to upper and lower estimations of MM intensities (Oliveira and Mendes Victor, 1984). This study was also performed in order to establish a structural model for the upper crust under the city, but due to spacing of stations and location, no particular site-effect was found. Last year a paper was presented on the Four International Conference on Seismic Zonation, taking into account all the work done for the microzonation of the city (Teves-Costa and Oliveira, 1991).

In this paper we are focusing the attention to some thin alluvial valleys and also to a significant topographic feature called the Castle hill, looking for better evidence of site-effects, according to previous theoretical studies and to the information of the damage distribution from historical reports.

2 EXPERIMENT DESCRIPTION

The field experiment consisted on recording the seismic impact produced by two explosions, one of 300Kg charge and another of 100Kg. The explosions were made on the Tagus River bed, during the night, in order to maximize the signal to noise ratio. Twenty-eight sites were selected for recording, according to the expected site-effects. Special attention was taken on the Castle hill, by putting seismic stations on both hillsides, and on alluvial valleys, by putting at least two stations on each valley, one at the center and another on the nearest hard rock site. Figure 1 displays the location of the seismic stations over the geothecnical map of Lisbon county.

A set of fourteen stations, of four different types, was moved from one shot to the other.

Due to technical problems the experiment was not completely successful and some stations on the hillsides of the Castle did not record the wave propagation. A third shot was made (shot C) but it was not well succeeded due to an unexpected amount of mud on the river bed. So, some gaps on the seismic profiles, didn't allow complete inversion procedures.

Before the first nigt experiment an experimental shot, on a quarry, was made in order to test and compare the different instrumental responses.

GEOTHECNICAL MAP WITH SEISMIC STATIONS

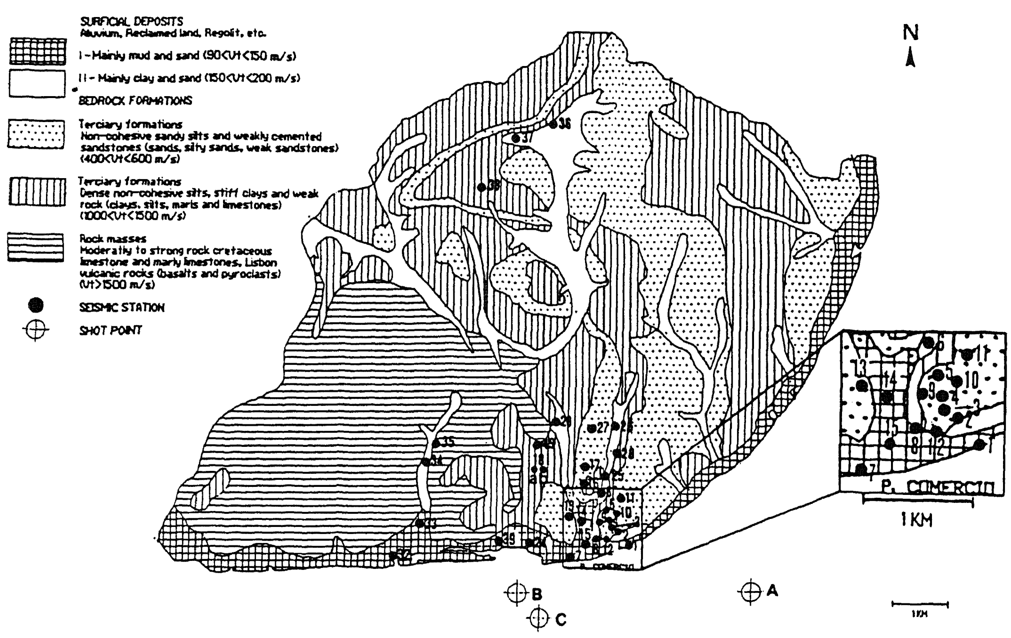

Figure 1. Location of seismic stations on the field experiment.

3 DATA PROCESSING

The data processing was made on the LGIT, in Grenoble, and consisted on several steps described below:

a) Data reduction in order to avoid the different instrumental responses is the first processing step. This step was performed, in an approximative way, taking into account the records of the experimental shot and filtering all the data by a Butterworth low-pass filter of 12.5Hz with 3 poles.

b) The record sections were defined for each shot and for every component.

c) Some computations were performed in order to estimate the attenuation of seismic energy with distance, for several frequencies bands, taking into account the different shots and the different components. However the large dispersion obtained seems to demonstrate that there is no physical significance of that approach.

d) The significant duration of the signals, according to the definition made by Husid(1969) and using the Trifunac and Brady(1975) levels, has been computed.

e) Finally, some spectral ratios between pairs of stations have been computed, in order to observe the amplification or attenuation due to local soil conditions or topographic features.

4 RESULTS AND DISCUSSION

Due to the limitation of the size of this paper, we will present and discuss here only two examples, one corresponding to the topographic feature and the other corresponding to an alluvial valley.

Figure 2 displays the record section of the longitudinal component for shot A. From this figure we can see that the station 9 (E9) presents greater amplitudes for frequencies between 1.7 and 2.2Hz and also a coda wave more important at the same frequencies. The staion is located at the top of the Castle hill and the ratio between the power spectral density functions of this station and station 3, located at the bottom of the hill, shows two peaks of 3.5 amplitude to 2.15 and 7.25Hz (figure 3).

Comparing this result with the theoretical model computed by Teves-Costa et al., 1989, we can see also an amplification nearly 3 for a frequency about 2.2Hz, and an increase on amplitude for frequencies greater than 6Hz (figure 4).

The peak ground velocity is also greater at station 9 where the epicentral distance is larger.

Figure 5 displays the transversal records for stations 36 and 38, located inside and outside a thin alluvial va-

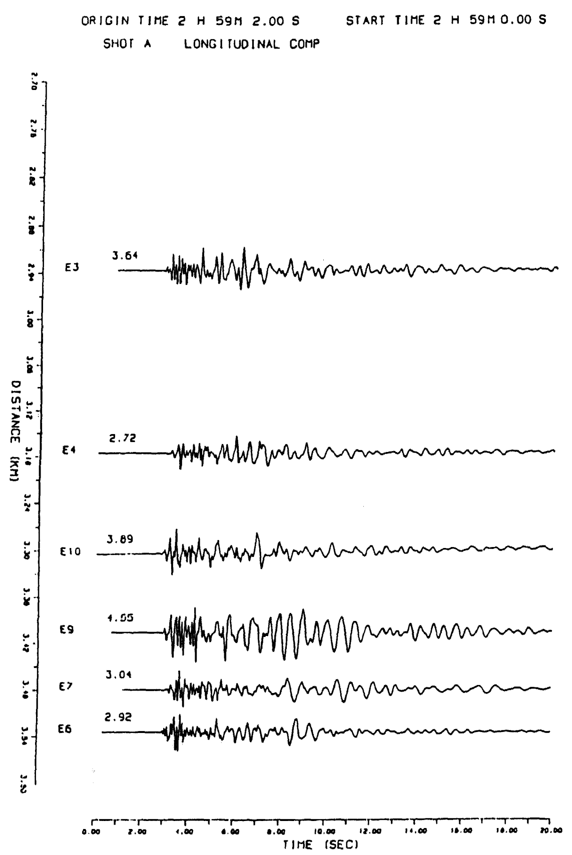

Figure 2. Record section for shot A (longitudinal component).

lley (5 to 10m thick). The station located over the alluvial deposit presents higher energy at low frequencies (aproximately 1.7Hz).

The significant duration of the signal is 11.53s for station 36 and 6.42s for station 38, it means that the duration on the alluvial deposit is almost twice the duration on the rock formation.

These two stations are located over the weak rocks of the terciary formation (see figure 1), the second stiff formation on the city.

The peak ground velocity is also greater for station 36, although its greater epicentral distance.

The spectral ratio between the two power spectral density functions (figure 6) shows an amplification peak of 4.8 for 3.7Hz.

The theoretical transfer function (figure 7) shows an amplification factor of 3 for 3 Hz and a maximal amplification of 5.5 for 6 Hz. These amplifications are not present on our data probably because the theoretical study was performed for a vertical incidence of a SH plane wave and the transfer function was refered to an homogeneous substractum.

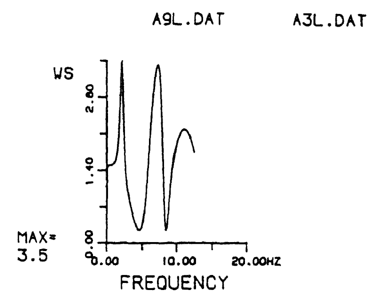

Figure 3. Spectral ratio between longitudinal components of stations 9 and 3.

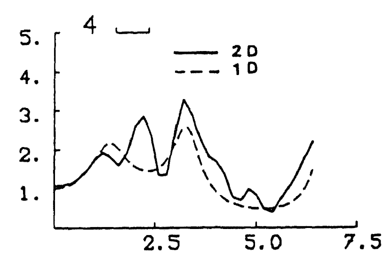

Figure 4. Theoretical model for the top of the Castle hill.

On the experimental data, the transversal movement was the result of propagation of different wave types, and the substractum beneath the stations is stratified, as we can see on the geological map of Lisbon county (Almeida,1986).

5 CONCLUSION

The results described above show that the theoretical models must be implemented, in order to take into account the complexity of the surface geology of the city, specially on the alluvial valleys. This work has been undertaken at this stage.

For the Castle hill, the model developed is matching quite well the experimental results.

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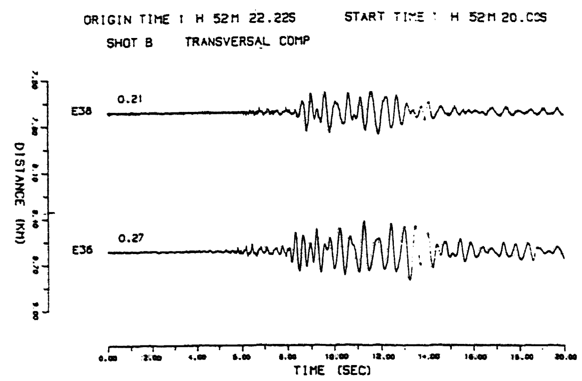

Figure 5. Transversal records for stations 36 and 38.

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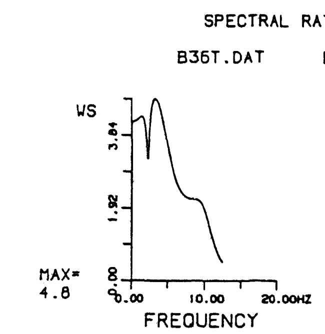

Figure 6. Spectral ratio between transversal components of stations 36 and 38.

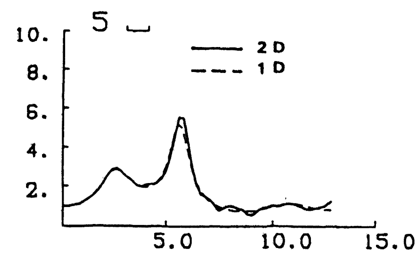

Figure 7. Theoretical model for the center of the alluvial valley.