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Expected ground motion at a site based on hypothetical fault models in Greece

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ABSTRACT: In the present study, the distribution of the seismic acceleration at a base rock level has been computed for the Volos (Central Greece) earthquake of July 9, 1980, using a semi-empirical approach. Considering the geological conditions of the region under investigation, and thus a simplified amplification factor, the distribution of the peak ground acceleration has also been obtained. From the different rupture modes used for the computation the unilateral mode seems to be more realistic and is in consistency with the aftershock distribution.

1 INTRODUCTION

For seismic microzoning, the distribution of the strong ground motion is of great importance. The usual process to estimate the distribution of the ground motion parameters starts with investigation of the seismic motion at a base rock level, and then to the surface. The methods for estimating the seismic motion at the base rock are based on:

- empirical relationships derived from strong motion records,
- theoretical approaches considering a fault model for long period motions,
- semi-empirical approaches considering a fault model for short period motions,
- using macroseismic intensities from past earthquakes.

In the present study, seismic accelerations have been computed at a base rock level by using a semi-empirical method and by considering the fault model for the Volos (Central Greece) earthquake of July 9, 1980 (M_S=6.5).

The surface peak acceleration was estimated by multiplying the obtained acceleration values at the base rock with the amplification factor of the surface layers. The results are compared with the peak values recorded by SMA-1 instruments installed in the investigated area, for a smaller event.

2 ESTIMATION OF THE SEISMIC MOTION AT A BASEROCK LEVEL

Several studies have shown that the type of faulting can influence strong ground motions. It has been reported (Campbell, 1981) that accelerations from reverse faults are systematically about 20% to 30% higher on the average than those from other fault types. It has also been proposed (McGarr, 1982) an upper bound on peak acceleration, namely 2g for reverse faulting and 0.4g for normal faulting. Of course, these upper limits can be exceeded if local site effects amplify the motion.

However, the rupture propagation on the fault plane seems to play a predominant role on the ground motion, and several attempts have been made to take it into consideration in computing the expected peak accelerations at a site. Midorikawa and Kobayashi (1980) proposed a method for estimating the response envelope of near-field ground motion with regard to the rupture propagation.

The fault plane is divided into small subfaults. In this case, the envelope of the ground motion in short period range (0.1 to 5 seconds) is represented as the superposition of the subfaults. The characteristics of the seismic wave from each subfault, such as waveform envelope and response spectrum are determined from various empirical relations. This method has been applied in the present study in order to compute the peak acceleration values at a base rock level of the Volos (Central Greece) earthquake of July 9, 1980. Considering the general geological conditions of the investigated area, the corresponding values are obtained at the ground surface.

It is well known that the spectral shape of acceleration on the surface of bed-rock is influenced by the source mechanism of earthquakes and the formation through which seismic waves pass. The velocity response spectrum $S_V(M,X,T)$ with 5% damping ration on free field bed-rock is assumed to be the function of magnitude M and hypocentral distance X (km) in addition to period T (sec) as follows:

$$\log S_V(M,S,T) = a(T)M - b(t)\log X - c(T) \qquad (1)$$

The coefficients a(T), b(T), and c(T) as well as the velocity spectra are shown in Figures 1 and 2, respectively, (after Kobayashi and Midorikawa (1982)). In order to compute the peak acceleration values the following assumptions have been made (see and Figure 3):

(i) The envelope of the incident wave, E(T), is assumed to be of a triangle form. Its duration, d, is defined as the sum of the d_{source}, that is the rupture duration, and d_X is the time interval between the fastest and the latest wave arrival at the site under investigation.

(ii) The envelope of the incident wave is regarded as the superposition of the impulses from the finite elements of the fault plane, and the shape of the impulse is regarded as shown in Figure 3a.

(iii) The envelope of an oscillator whose damping coefficient is relatively large, is similar to that of the input motion.

(iv) The fault plane is divided into n elements as shown in Figure 3b, with a corresponding site configuration in Figure 3c. By superposition of the finite elements, the response envelope is obtained (Figure 3d).

(v) The peak acceleration can be estimated from the spectrum intensity, by using the formula:

$$A_{max} = 1.2 \text{ X M.S.I} \qquad (2)$$

where, M.S.I. is the modified spectrum intensity. Moreover has been found the following relationship between intensity of response spectrum and peak acceleration:

$$A_{max} = 1.2 \text{ X} \int_{0.1}^{0.5} S_a(T)dT \qquad (3)$$

Once the peak acceleration has been computed at a base-rock level, the surface acceleration can be obtained following (Kobayashi and Midorikawa, 1982). They defined as a seismic bed-rock that boundary whose shear-wave velocity is approximately 3 km/sec. The same authors found that the amplification factor of ground for peak acceleration, A, is affected by the shear-wave velocity of surface layer, V_s, in spite of the composition of soil layer, as shown in the Figure 4.

The above mentioned procedure has been proposed by Midorikawa and Kobayashi (1980), Kobayashi and Midorikawa (1982), and has been applied, among others, by Makaris (1989), to compute the expected peak ground acceleration for Tokai and Kanto area by considering the "hypothetical Tokai earthquake", as well as by Stavrakakis et al. (1991), for the Kalamata (Southern Greece) earthquake of Sep. 13, 1986.

3 THE VOLOS (CENTRAL GREECE) EARTHQUAKE OF JULY 9, 1980

On July 9, 1980, a strong earthquake of surface wave magnitude $M_S=6.5$ occurred at a distance of about 15 km SE of Volos (Central Greece). This earthquake and its significant aftershock ($M_S=5.6$) caused serious damages in the epicentral area. A maximum macroseismic intensity of IX degrees on MM scale was observed. The fault plane solution determined by Papazachos et al. (1983) shows a normal faulting striking ENE-WSW and dipping SSE. The stress field in this region is extentional in the N-S direction (Papazachos and Comninakis (1976), McKenzie (1978)). For a smaller event occurred in the same region on April 30, 1985 ($M_S=5.7$), a peak ground acceleration of 305 gals (LONG, N90E) has been recorded at a distance of about 7 km from the epicenter (Makropoulos et al., 1989).

To compute the distribution of the seismic accelerations at a base rock level, as defined by Midorikawa and Kobayashi (1980) we used the above mentioned fault plane solutions and considered different modes of rupture propagation.

Figure 5 is a simplified geological map of the region under investigation. Using the amplification factors proposed by Midorikawa and Kobayashi (1980) (5.5 for Quaternary, 3.5 for Neogene, and 2.5 for Pre-Neogene), the peak ground accelerations were obtained as shown in Figures 6 to 9.

Figures 6a and 6b show the distribution of the seismic acceleration at the baserock level and surface, respectively, obtained by assuming a bilateral rupture mode (dip direction). Figure 7 corresponds to a bilateral rupture mode (strike direction), Figure 8 to a unilateral rupture mode (dip direction, lower to higher), and Figure 9 corresponds to a circular rupture mode.

However, based on the aftershock distribution (see Fig. 10), as obtained by Papazachos et al. (1983), we lead to the conclusion that the unilateral mode seems to be the most realistic one for the Volos earthquake of July 9, 1980. The distribution of the peak ground accelerations (see Fig. 8) might be considered as representative one for microzoning studies in this area.

4 DISCUSSION AND CONCLUSIONS

In the present study, the seismic accelerations at a baserock level have been computed using a semi-empirical approach, as proposed by Midorikawa and Kobayashi (1980). Considering the focal mechanism parameters for the Volos earthquake of July 9, 1980, as well as the main geological features of the broad epicentral area, we computed the peak acceleration values at the surface.

The peak values obtained by using a unilateral mode of the rupture propagation seems to be realistic for the region of interest.

The applied method appears to be useful for microzoning studies. Especially, for regions where a large earthquake is expected to occur, the distribution of the ground acceleration can be estimated by adopting "hypothetical fault models" on the basis of the seismotectonic characteristics of the investigated areas as well as on the past earthquakes.

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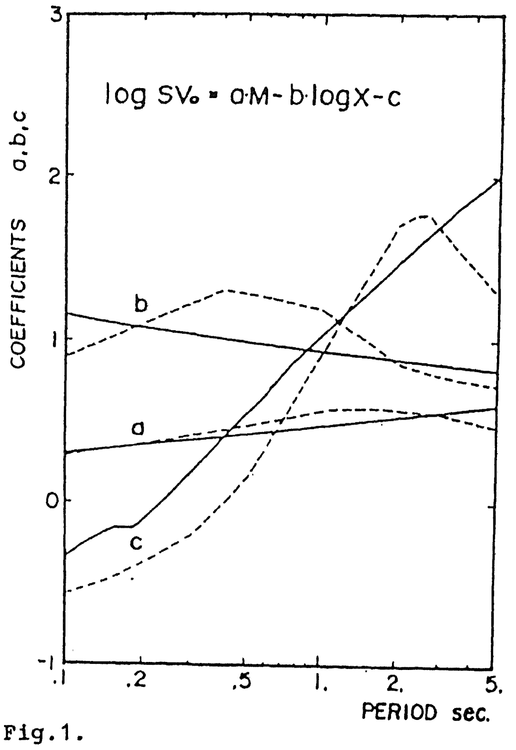


Fig.1.
VARIATION OF THREE COEFFICIENTS IN THE EXPERIMENTAL FORMULA OF VELOCITY RESPONSE SPECTRA ON SEISMIC BEDROCK (BROKEN LINE: AFTER KOBAYASHI & NAGAHASHI

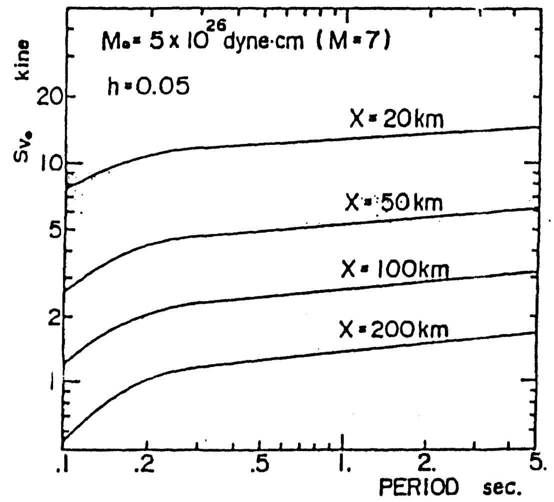


Fig.2 VELOCITY RESPONSE SPECTRA OF INCIDENT WAVES

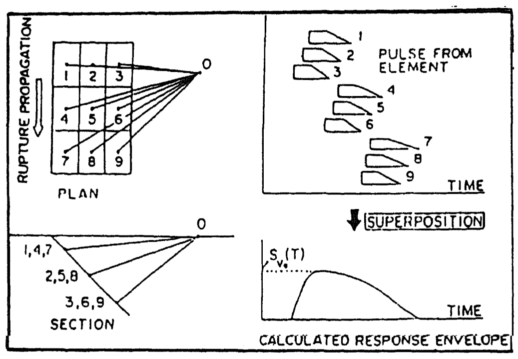


Fig.3 Schematic illustration on the proposed method

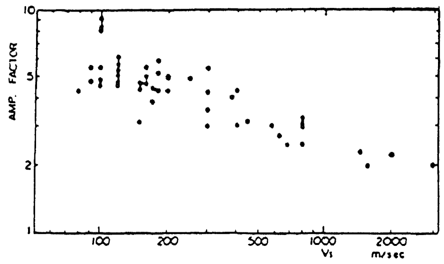


Fig.4 Amplification factor of ground VS. VS of surface layer (after Midorikawa & Kobayashi)

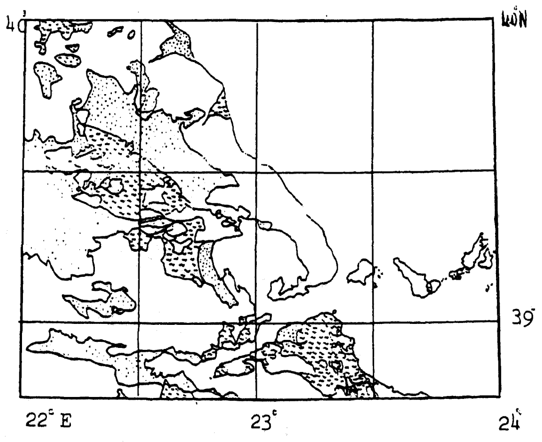


Fig.5 Simplified Geological Map

⁘ Quaternary

〰 Neogene

☐ Preneogene

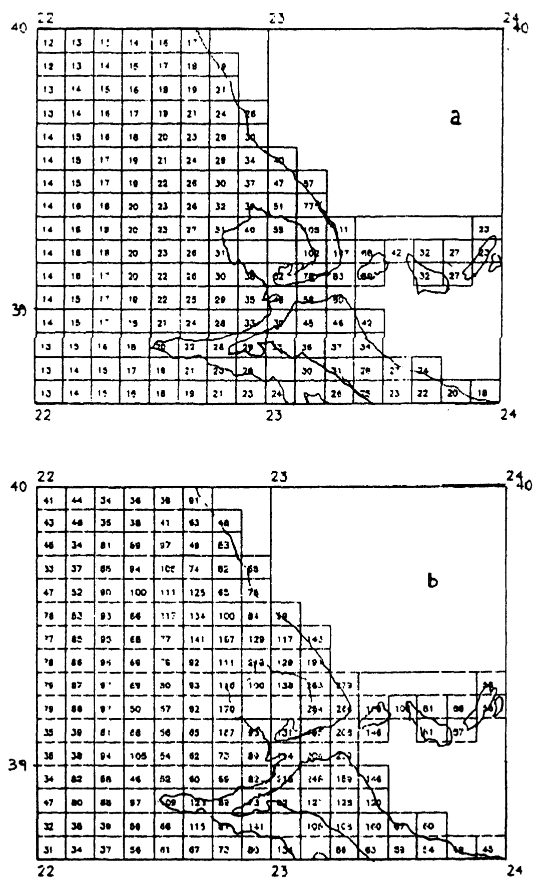


Fig. 6 Acceleration distribution in base rock (a) and surface (b) for a bilateral rupture mode

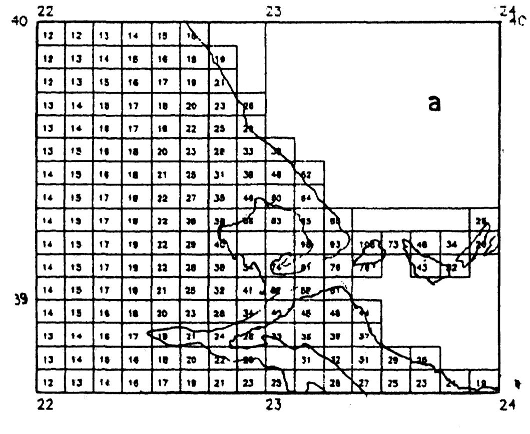


Fig.7-A

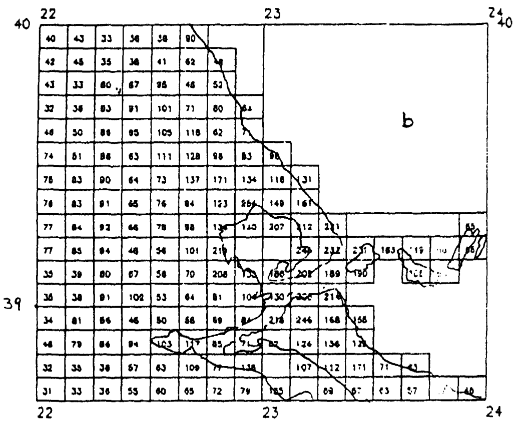
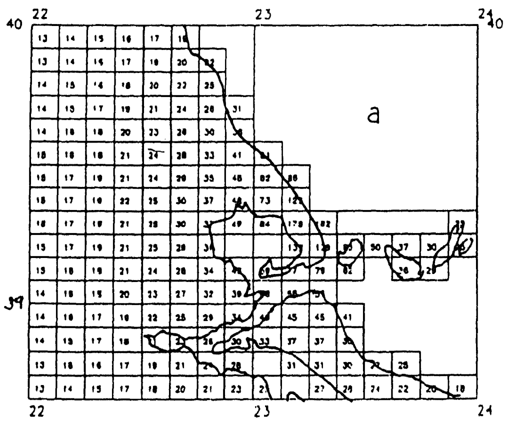


Fig. 7 Acceleration distribution in base rock (a) and surface for a (b) bilateral mode (strike direction)



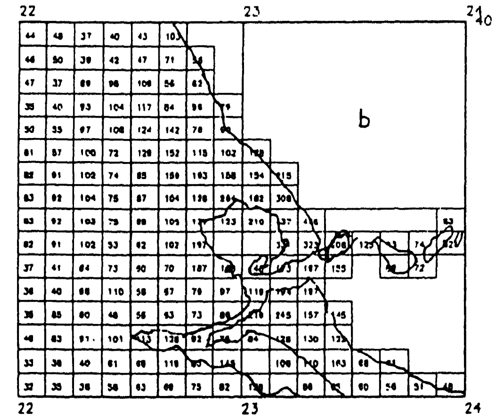
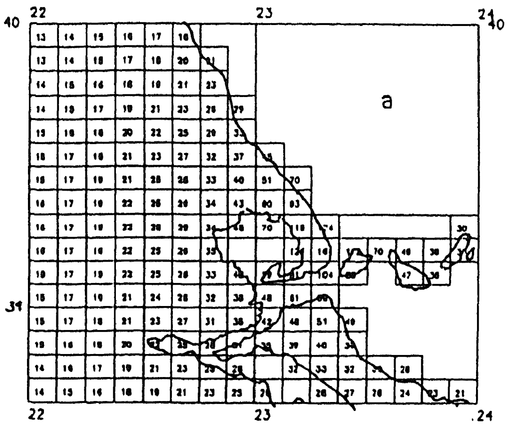


Fig.8 Acceleration distribution in base rock (a) and surface (b) for a unilateral rupture mode (dip direction)



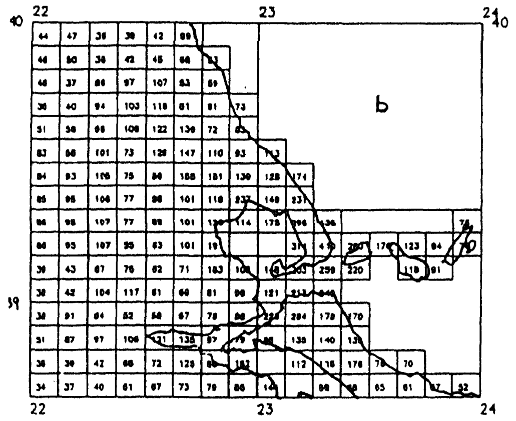


Fig.9 Acceleration distribution in a base rock (a) and surface (b) for a circular rupture mode

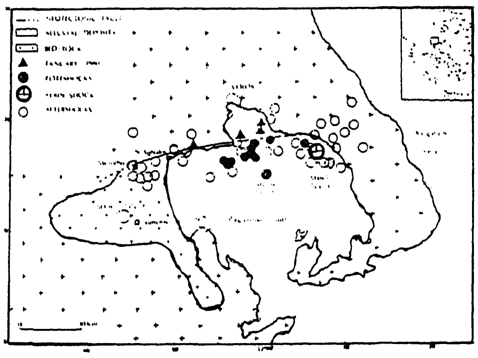


Fig. 10 Distribution of the epicenters of the shocks with M 4.2 of the sequence of the July 9, 1980 Volos earthquake and the strike of the neotectonic fault (Papazachow et al)