

ESTIMATION OF STRONG GROUND MOTION ACCELERATIONS AT A SITE
WITH REGARD TO FOCAL MECHANISM PARAMETERS AND
DIFFERENT MODES OF RUPTURE PROPAGATION. THE CORINTH,
CENTRAL GREECE, EARTHQUAKE SEQUENCE OF 1981.

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A B S T R A C T

The severity of strong ground motions in the near field play a predominant role on the earthquake damage. Several researchers have pointed out the relation between severity of the near field ground motions and the nature of fault rupture. In the present study, the distribution of seismic acceleration at a base rock level has been computed for the Corinth (Central Greece) main earthquake of Feb.24, 1981 ($M_s=6.7$) and its principal aftershocks of Feb.25 ($M_s=6.4$), and March 4 ($M_s=6.4$). For this computation a semi-empirical approach was used, taking into consideration the shape and dimension of the fault and the direction of rupture propagation. The surface peak accelerations were estimated by multiplying the obtained acceleration values at the base rock with the amplification factors of the surface layer. The results are compared with the peak values recorded by instruments in the investigated area, that recorded the Feb.24 and 25 shocks.

ΥΠΟΛΟΓΙΣΜΟΣ ΤΩΝ ΕΠΙΤΑΧΥΝΣΕΩΝ ΤΩΝ ΙΣΧΥΡΩΝ ΣΕΙΣΜΙΚΩΝ ΚΙΝΗΣΕΩΝ
ΣΕ ΜΙΑ ΠΕΡΙΟΧΗ, ΜΕ ΒΑΣΗ ΤΟ ΜΗΧΑΝΙΣΜΟ ΓΕΝΕΣΗΣ ΚΑΙ ΤΟΝ ΤΡΟΠΟ
ΔΙΑΔΟΣΗΣ ΤΗΣ ΔΙΑΡΡΗΞΗΣ: ΣΕΙΣΜΙΚΗ ΑΚΟΛΟΥΘΙΑ ΤΟΥ 1981
ΣΤΗΝ ΚΟΡΙΝΘΟ, ΚΕΝΤΡΙΚΗ ΕΛΛΑΔΑ.

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Π Ε Ρ Ι Λ Η Ψ Η

Στην εργασία αυτή γίνεται υπολογισμός των μέγιστων επιταχύνσεων, στο στερεό υπόβαθρο της ευρύτερης περιοχής του Κορινθιακού Κόλπου, εξαιτίας των σεισμών των Αλκυονίδων, στις 24, 25 Φεβρουαρίου και 4 Μαρτίου, 1981. Οι υπολογισμοί βασίζονται κύρια στα χαρακτηριστικά της διάρρηξης του κύριου σεισμού και των μεγαλύτερων μετασεισμών. Λαμβάνοντας υπόψη τις τοπικές εδαφικές συνθήκες, υπολογίστηκαν επίσης οι τιμές της σεισμικής επιτάχυνσης στην επιφάνεια του εδάφους. Τα αποτελέσματα που προέκυψαν συγκρίνονται με τις παρατηρούμενες τιμές.

INTRODUCTION

For earthquake resistance and disaster mitigation plans, the assessment of damages due to future earthquakes is very much important.

For the prediction of earthquake damages it is necessary to estimate the severity of the ground motion in the near field. The peak values of the ground motion expected to occur at a site are profoundly influenced by many factors such as the source process, the properties of the propagation path and the local soil conditions.

Consequently estimation of the distribution of the ground motion parameters should start with investigation of the seismic motion from the source to the baserock level and then to the surface.

The methods for estimating the seismic motion at the baserock level are based on:

- Empirical relationships derived from strong motion records; seismic motion is deduced as a function of the magnitude of the earthquake and the distance from the hypocenter.

- Theoretical approaches considering a fault model for long period motions.

- Semi-empirical approaches considering a fault model for short period motions, and

- 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 proposed by Kobayashi and Midorikawa (1982) for the Corinth (Central Greece) earthquake of February 24, 1981 ($M_s=6.7$) and its principal aftershocks of February 25, 1981 ($M_s=6.4$), and March 4, 1981 ($M_s=6.4$). The peak acceleration at the ground surface was estimated by multiplying the obtained acceleration values at the base rock with the amplification factor of the surface layers.

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 proposed (McGarr, 1982) an upper bound on peak acceleration, namely 2g for reverse faulting and 0.4g for normal faulting. Of course, these limits can be exceeded if local site effects amplify the motion.

It has also been pointed out that the intensity of the ground motion reflects strongly the nature of the fault rupture. Propagation of seismic waves due to the rupture of fault, have been studied recently and several theoretical methods were presented for estimation of ground motions on observed sites. However, these calculations are applicable for rather long period motions, and they are not adequate for short period motions.

Kobayashi and Midorikawa (1982) proposed a method for estimation of near-field earthquake ground motions with regard to the shape and dimension of the fault and the direction of rupture propagation, considering multi-point sources.

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 by the superposition of the impulses from the subfaults. The characteristics of the seismic wave from each subfault such as waveform envelope and response spectrum are determined from empirical relations.

As attenuation law for the seismic waves propagating from each element of the fault plane a semi-empirical formula shown in Fig.1, of the type:

$$\log SV_0(T) = a(T)(\log M_0 - 26.6) - b(T)\log(X) + 2.36 \quad (1a)$$

was used, (with 5% damping ratio on free-field), where $SV_0(T)$ is velocity response spectra of the incident waves, M_0 is seismic moment of earthquake by dyne.cm, X is hypocentral distance by km, and $a(T)$, $b(T)$ are coefficients which depend on the period T .

The coefficients $a(T)$, $b(T)$, and the velocity spectra are shown in Fig. 1 and 2, respectively, [after Kobayashi and Midorikawa (1982)].

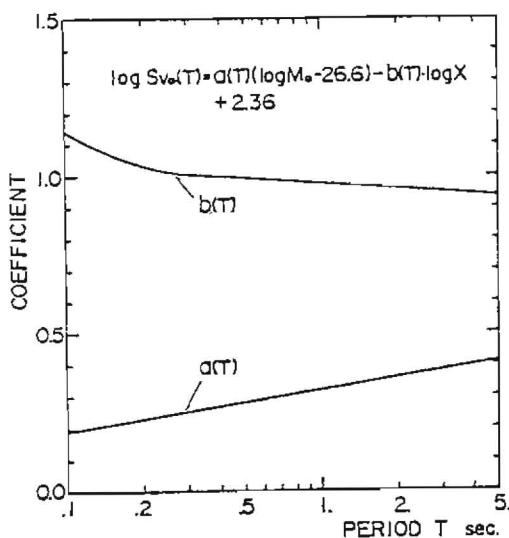


Fig.1. Variation of coefficients with period.

Since it's difficult to get M_0 corresponding to each earthquake, the empirical relation between M and M_0 presented in equation 1b was used; this relation was proposed by Kiratzi et al. (1985) for earthquakes in the area of Greece:

$$\log M_0 = 1.21 M_s + 17.66 \quad (1b)$$

In order to compute the peak acceleration values, the following assumptions have been made (see and Fig.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 that is the time interval between the fastest and the latest wave arrival at the

site under consideration. (Trifunac and Brady, 1975).

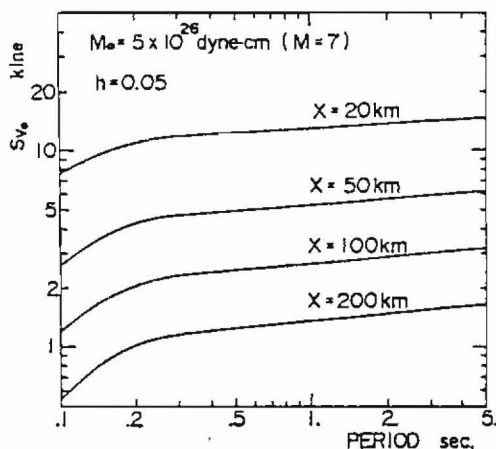


Fig.2. Velocity response spectra of incident waves.

(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 Fig.3b.

(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 of the finite planes as shown in Fig.3a, with a corresponding site configuration in Figure 3c. By superposition of the finite elements, the response envelope is obtained. (Figure 3d).

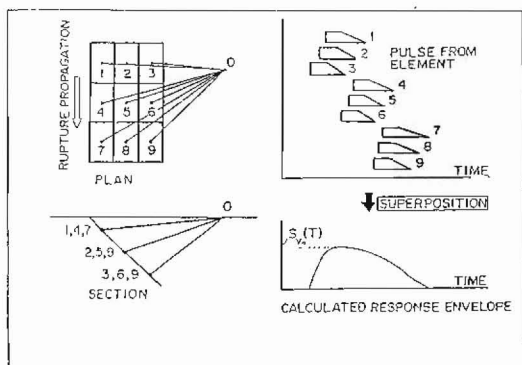


Fig.3. Schematic illustration on the proposed method.

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

$$A_{max} = 1.2 \cdot M.S.I. \quad (2)$$

where, M.S.I. is the modified spectrum intensity. M.S.I. is derived by Midorikawa and Kobayashi (1978) from Housner's definition (1965) for S.I. (spectrum intensity).

$$M.S.I. = \int_{0.1}^{0.5} S_a(T) dt \quad (3)$$

where, $S_a(T)$ is acceleration response spectrum for damping factor $h=0.05$.

(vii) Once the peak acceleration has been computed at a base rock level, the surface acceleration can be obtained following Midorikawa and Kobayashi, (1980). They defined as a seismic bedrock that boundary of which shear-wave velocity is approximately 3 km/sec. The same authors found that the amplification factor of ground for peak acceleration F , is affected by the composition of soil layer as shown in the Fig.4.

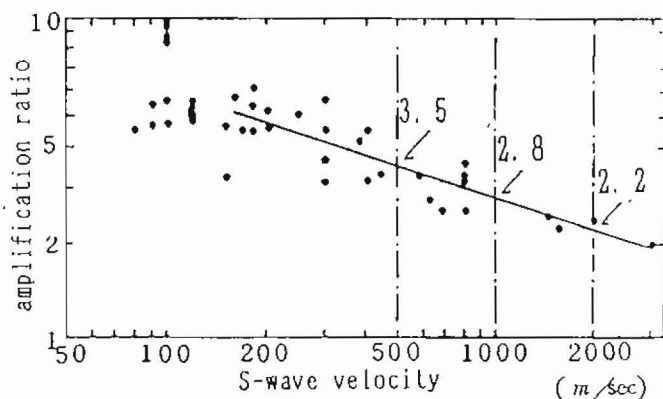


Fig.4. Amplification factor versus V_s of surface Layer (after Midorikawa and Kobayashi, 1980)

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, Japan, by considering the "hypothetical Tokai eq.", as well as by Stavrakakis et al. (1991) for the Kalamata (Southern Greece) earthquake of Sep.13,1986, and Makaris et al. (1992) for the Volos (Central Greece) earthquake of July 7, 1980.

THE CORINTH (CENTRAL GREECE) EARTHQUAKE SEQUENCE OF 1981

On February 24, 1981 (20h 53m 37s) a strong earthquake of magnitude $M_s=6.7$ occurred in the eastern part of the Gulf of Corinth, Central Greece (Fig. 5 relocated epicenter after Jackson et al., (1982)). The earthquake was followed by two large aftershocks of magnitude $M_s=6.4$ on Feb.25 (02h 35m) and March 4 (21h 58m) and by numerous aftershocks.

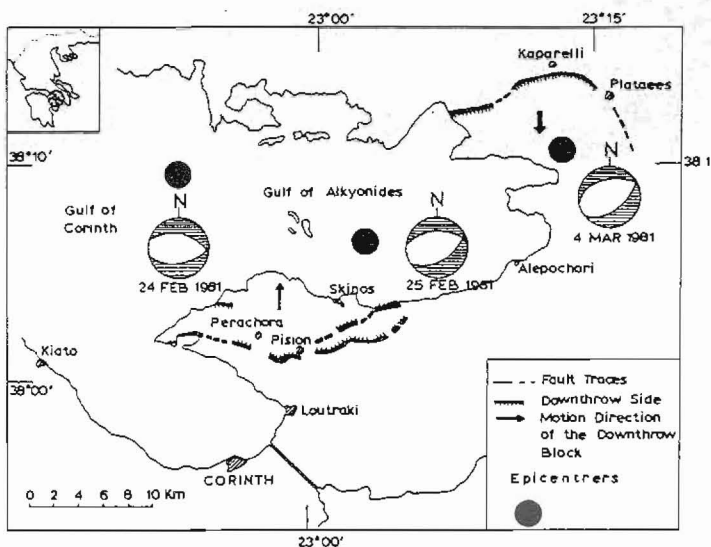


Fig.5. Map of Epicentral area showing surface ruptures (modified from Papazachos et al., 1984).

Surface ruptures were mapped into two main systems of fracture lines as shown in Fig.5. The southern line was observed in the Perachora peninsula after the occurrence of the 25 Feb. shock and displacements of about 50-70 cm were reported (Jackson et al., 1982; Papazachos et al., 1984). The northern line was observed after the shock of March 4; the total visible length of this fracture line is about 15 km with an observed dip of 70°-90°S and an average displacement of about 60cm with downthrow to the south (Papazachos et al., 1984). Several investigators studied the 1981 Corinth earthquake sequence extensively, proposing -among others- fault mechanism solutions for the main shock and its two principal aftershocks.

The source parameters of this earthquake sequence, have been determined by Jackson et al., 1982; Kim et al., 1984; Papazachos et al., 1984; Stavrakakis et al., 1986.

In order to compute the distribution of seismic accelerations at a base rock level, as defined by Midorikawa and Kobayashi (1980), we used the fault plane solution proposed by Jackson et al. (1982).

Fig.6 is a simplified geological map of the region under investigation.

The amplification factors proposed by Midorikawa and Kobayashi (1980) are the following:

$$\begin{aligned}
 F &= 5.5 \text{ (Quaternary)} \\
 F &= 3.5 \text{ (Neogene)} \\
 F &= 2.5 \text{ (Pre-Neogene)}
 \end{aligned}$$

We have tried to apply these factors and in some cases, especially in near field, the values obtained were extremely high. This is due to the fact that the above mentioned coefficients have been derived using Japanese data. As a first

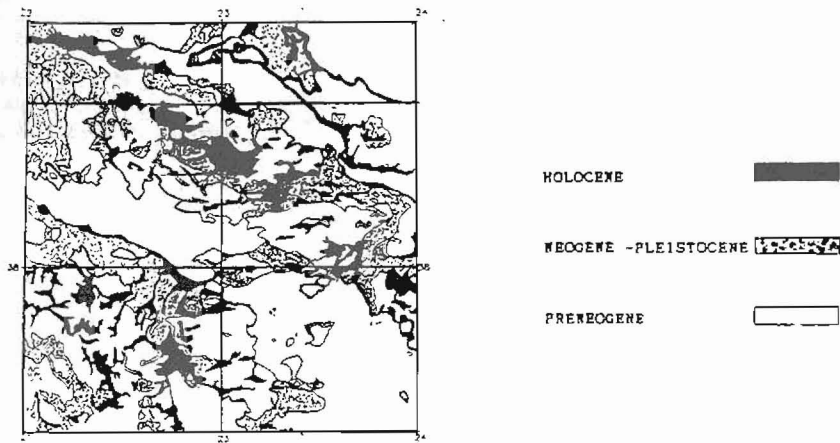


Fig.6. Simplified geological map.

approximation, and by considering the study of E. Shima, T. Imai (1982), we introduced smaller coefficients:

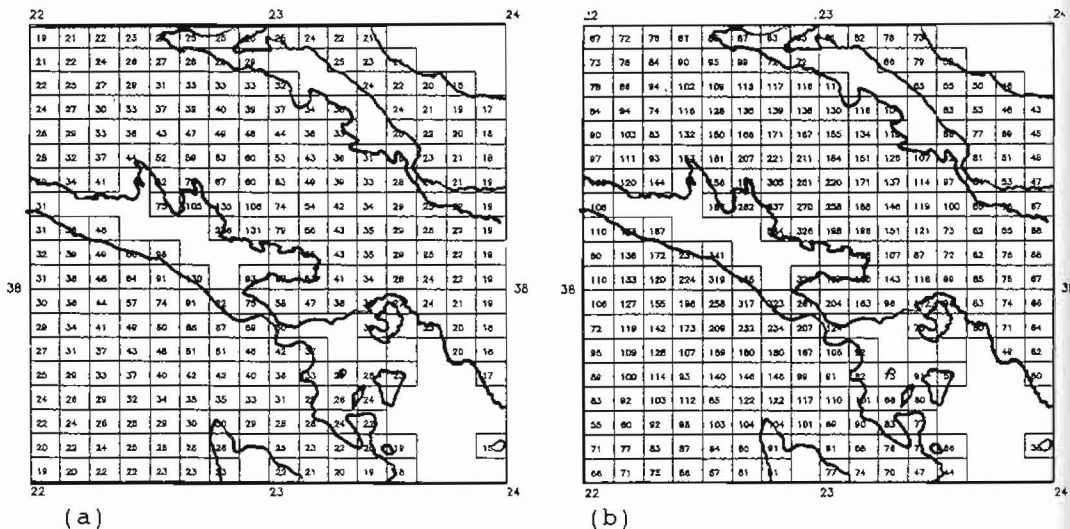
$$F = 3.5 \text{ (Neogene - Quaternary)}$$

$$F = 2.5 \text{ (Pre-Neogene)}$$

The surface peak accelerations were estimated by multiplying the obtained acceleration values at the base rock with the amplification factors of the surface layers.

Figures 7, 8 correspond to the main shock of Feb. 24, 1981.

Figures 7a and 7b show the distribution of the seismic acceleration at the base rock and surface, respectively, obtained by assuming a bilateral rupture mode (dip direction). Figure 8 is for a unilateral rupture mode.

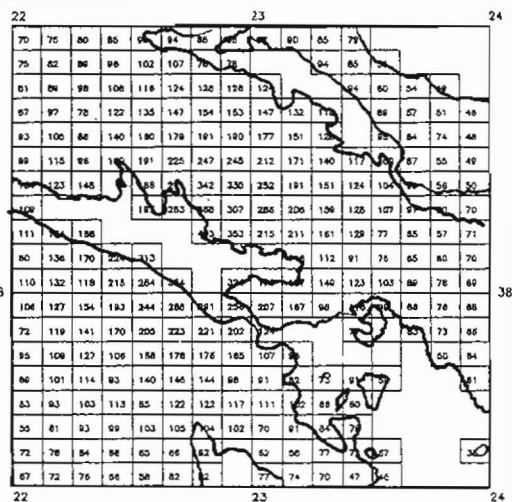
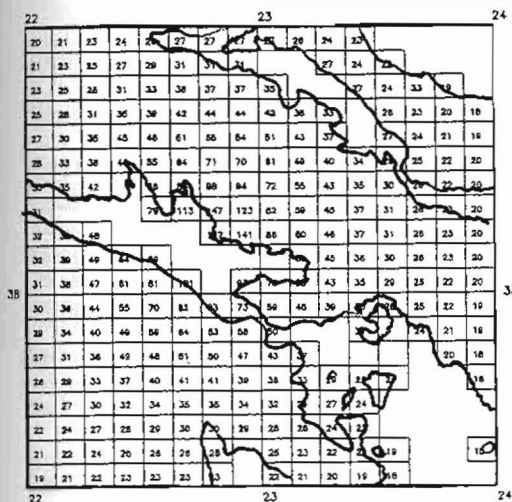


(a)

(b)

MAIN SHOCK - 24 FEB. 1981

Fig.7. a) Acceleration distribution at base rock for a bilateral rupture mode (dip direction). b) Acceleration distribution at surface for bilateral rupture mode (dip direction).



(a)

(b)

MAIN SHOCK - 24 FEB. 1981

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

Additional to that, several attempts have also been made by using different rupture modes. Due to space limitations we include only those which are most representative for the Gulf of Corinth.

Moreover, we have tried to compute the accelerations by changing the source parameters in order to investigate their influence in the peak values. It has been found that the rise time and the rupture length are the most important parameters which affect the acceleration, especially in the near field.

For the main shock (24/2/1981, $M_s=6.7$) and for the first principal aftershock (25/2/1981, $M_s=6.4$) peak ground accelerations which have been recorded (Stavarakakis et al., 1992) and the equivalent computed ones are:

MAINSHOCK (24/2/81)

STATION	RECORDED P.G.A.	COMPUTED P.G.A.
CORINTH (25km from epicenter)	0.233g(LONG)	0.256g(unilateral rupt.mode) 0.264g(bilateral rupt.mode)
XYLOKASTRO (30km from epicenter)	0.288g(LONG)	0.284g(unilateral rupt.mode) 0.319g(bilateral rupt.mode)
ATHENS (65km from epicenter)	0.221g(LONG)	0.084g(unilateral rupt.mode) 0.086g(bilateral rupt.mode)

AFTERSHOCK (25/2/81)

STATION	RECORDED	COMPUTED
P.G.A.	P.G.A.	
CORINTH	0.117g(LONG)	0.172g(unilateral rupt.mode)
(25km from epicenter)		0.246g(bilateral rupt.mode)

Comparing the distribution of seismic acceleration at the earth's surface with peak accelerations recorded from various stations near the epicenter we led to the following conclusions:

(i) It is obvious that the proposed models give very good agreement with the observed values. The peak values obtained by using a unilateral mode seem to be most realistic for the region of interest.

(ii) The difference between the recorded and the computed values in Athens station is due to the fact that the accelerometer is installed in the last floor of a highrise building.

(iii) Due to the migration pattern of the sequence unilateral rupture mode seems to be more realistic for the Corinth main earthquake of February 24, 1981 and its principal aftershocks of February 25, 1981 and March 4, 1981.

DISCUSSION AND CONCLUSIONS

In the present study, the seismic accelerations at a base rock level have been computed using a semi-empirical approach, as proposed by Kobayashi and Midorikawa (1982).

Considering the focal mechanism parameters for the Corinth (Central Greece) main shock of February 24, 1981, as well as its principal aftershocks of February 25, 1981 and of March 4, 1981, taking into account the main geological features of the broad epicentral area, we finally computed the peak acceleration values at the surface of the earth.

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

The applied method seems 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 area, as well as on the past earthquakes.

However, it is also important to note that, as we already mentioned, the results obtained in the present study are based on the amplification factors and velocity response spectra used in Japan by Kobayashi and Midorikawa (1982).

Thus, in order to get more realistic results, we have to incorporate in our model the factors obtained by using data for earthquakes in Greece (Θεοδοουλίδης, 1991), (Theodulidis and Papazachos, 1992) and to compare the differences, if any.

This will be done in the near future, because a lot of modifications of the numerical algorithms are needed.

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