ΠΡΑΚΤΙΚΑ

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1. ΣΕΙΣΜΟΛΟΓΙΑ

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PROCEEDINGS

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1. SEISMOLOGY

PRELIMINARY ANALYSIS OF GREEK ACCELEROGRAMS RECORDED AT STATIONS OF NOA'S NETWORK: TIME PERIOD 1973-1990

Stavrakakis,G.N., Kalogeras,I. and Drakopoulos,J.

National Observatory of Athens, Seismological Institute 11810 Athens, Greece

A B S T R A C T

In the present study, the results of the analysis of 45 strong motion records are presented. The accelerograms correspond to he time period 1973-1990, recorded at stations of the network of the National Observatory of Athens. The processing is based mainly on the standard procedure developed at the Earthquake Engineering Research Laboratory of the California Institute of Technology. Except the time histories of the corrected acceleration, velocity and dispacement as well as the response spectra, some important relationships are also derived.

ΠΡΟΚΑΤΑΡΚΤΙΚΗ ΑΝΑΛΥΣΗ ΤΩΝ ΕΓΓΡΑΦΩΝ ΤΩΝ ΕΠΙΤΑΧΥΝΣΙΟΓΡΑΦΩΝ ΤΟΥ ΔΙΚΤΥΟΥ ΤΟΥ ΕΘΝΙΚΟΥ ΑΣΤΕΡΟΣΚΟΠΕΙΟΥ ΑΘΗΝΩΝ ΓΙΑ ΤΗ ΧΡΟΝΙΚΗ ΠΕΡΙΟΔΟ 1973-1990.

Σταυρακάκης,Γ.Ν., Καλογεράς,Ι.Σ. και Δρακόπουλος,Ι.Κ.

Π Ε Ρ Ι Λ Η Ψ Η

Στην εργασία αυτή παρουσιάζονται το προκαταρκτικά αποτελέσματα της ανάλυσης 45 επιταχυνσιογραμμάτων του δικτύου του Εθνικού Αστεροσκοπείου Αθηνών της περιόδου 1973-1990. Η μέθοδος της ανάλυσης βασίζεται κύρια στη διαδικασία που εφαρμόζεται στο CALTECH με μικρές τροποποιήσεις σε διάφορες ρουτίνες. Εκτός από τις χρονικές εξελίξεις της επιτάχυνσης, ταχύτητας και μετατόπισης δίνονται επίσης διαγράμματα που απεικονίζουν διάφορες παραμέτρους.

INTRODUCTION

The records are digitized on an unequal time basis picking up all significant peaks, points of inflection, points crossing zeros, etc. with as many intermediate points which are needed for an accurate definition of shape.

The data contain long-period and high frequency errors. The principal sources of long period errors can be divided into several groups: (L1) Errors caused by the transverse play of the recording paper or film in the drive mechanism, (L2) errors due to the warping of records, caused by aging, and errors introduced by photographic processing of contact negatives, and translucent copies, (L3) errors caused by optical enlargement of film negatives, (L4) systematic errors due to imperfect mechanical transverse mechanisms of the cross-hair system on the digitizing table,(L5) random errors generated during digitization process.

On the other hand, the main sources of high frequency errors are: (H1) Modification of harmonic amplitudes and shift of phases caused by the finite, natural frequency of the accelerograph transducer, (H2) errors resulting from the imperfections in transducer design, (H3) random digitization errors, (H4) errors caused by inadequate resolution of digitizing equipment, and (H5) low-pass filtering effects in the optical-mechanical process.

Errors L1, L2 and L4 is a set of well defined errors. All information necessary to correct them is available during the digitization process. Corrections for the transverse play of recording paper or film, warping of records and systematic errors in the mechanical system of the digitization table can all be performed during processing of reading points of accelerograms.

The second group of errors represented by H1 and H2 is more difficult to correct exactly. They require extensive computational procedures. Errors resulting from excitation of higher modes of transducer are usually neglected in the standard processing.

The third group of errors represented by L5, H3 and H5 is the most complex. Typically, the nature of these errors is such that they cannot be corrected, but have to be eliminated from the accelerograms. The procedure which has been followed in this study, is described in the following three chapters and is illustrated in figure 1.

VOLUME I PROCESSING: SCALED UNCORRECTED DATA

The SMA-1 records (enlargements) are hand digitized with the aid of the DIGIT program on an unequal time basis, except the time mark trace which is digitized in equally time basis. Once all traces have been digitized the first stage of acceleration processing is to correct and smooth the data, to scale the data into the proper units of time and acceleration, and to fix a horizontal zero line for acceleration. In this way the raw digitized data are written into a file ready for further processing by the Strong Motion Data Analysis Software. To scale an acceleration trace we used either a fixed trace as a reference line and (or) a time mark trace for time scaling.

Moreover, the following scaling factors are used; the resolution of the digitizing tablet (SUMMAGRAPHICS, 10,000 counts/cm), the magnification factor (usual 2.0 or 4.0), the record sensitivity obtained from the calibration data in units of cm/G, and the length, in seconds, of each time mark interval.

For this purpose, the SCALE computer program (Kinemetrics, 1986) is used which processes one fixed (or time mark) trace and one acceleration trace as follows:

(1) Converts the digitizer coordinates to film coordinates. The acceleration trace data are corrected by calculating the angle of rotation between the fixed (or time mark) trace and the digitizer horizontal axis and then rotating the acceleration trace X, Y points by that angle.

(2) Converts the film coordinates to trace coordinates. The

acceleration trace Y data are further corrected by subtracting the corrected fixed (or time mark) trace Y data (from step 1).

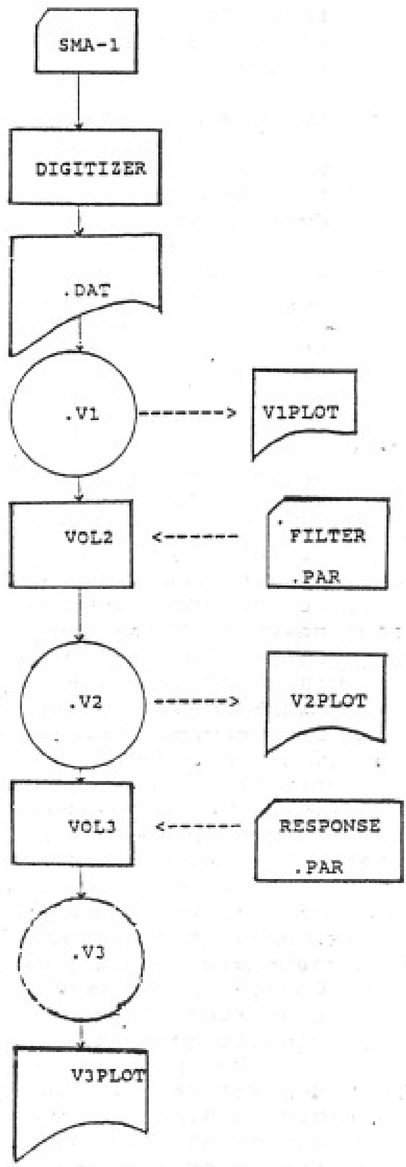

Fig.1. Flow chart showing the procedure followed in the present study.

(3) The corrected acceleration trace X data is scaled to time in seconds.

(4) The zero line of the acceleration data is determined. The corrected acceleration trace Y data are averaged and then the average is subtracted from each Y point. These translated values are finally scaled to give acceleration data in G/10.

The scaled acceleration data are written to a Volume I (.V1) file. The V1PLOT program allows us to view the data graphically and compare the plot with the original record. The resulting Volume I file is now ready for further processing.

Instrument Correction

The acceleration traces are interpolated to equally spaced points in time with an interval $\Delta t=0.01$ sec, low-pass filtered to reduce digitization noise, and finally decimated. The accelerograms are then corrected for the instrument response.

The existing CALTECH model assumes that the relative displacement response y(t) of a single-of-freedom transducer is approximately proportional to the ground acceleration a(t). Thus, to derive estimates of the ground acceleration from the recorded relative displacement response, the following correction is applied:

$$a(t) = -y(t) - 2\xi\omega n\dot{y}(t) - \omega n2\ddot{y}(t)$$

where, ωn, is the transducer natural frequency, and ξ, is the viscous damping ratio.

The basic problem in designing an instrument correction filter is linked to the process of differentiation required to obtain $\dot{y}(t)$ and $\ddot{y}(t)$ from y(t). The CALTECH model uses a second-order central difference approximation for this purpose. However it has been shown by Sunder and Connor, (1982) that the central difference filter differs considerably from the exact relation, and the nature of the discrepancy is to suppress the high-frequency components of the ground acceleration signal at frequencies greater than approximately 1/4 the Nyquist frequency.

In order for the central difference instrument correction filter to be acceptable, the data sampling period must correspond to a Nyquist frequency that is approximately four times the frequency up to which the correction needs to be performed.

In the present analysis, in most cases, the upper limit of 25 Hz is adopted. This value defines a Nyquist frequency of 100 Hz, and thus a sampling period T=0.005 sec is required. For this reason, the corrected acceleration, velocity, and displacement data are reinterpolated using T=0.005 sec. However, Sunder and Connor (1982) have noted that the standard instrument-correction algorithm inadequately corrects for the instrument response at high frequencies (15-25 Hz).

The problem is that the bridging-formula approximating the derivative has an increasingly large error at frequencies approaching the Nyquist frequency. This suggests the simple expedient of performing the instrument-correction process using that same simple algorithm but applying it prior to desampling of the data from 100 down to 50 points/sec. This shifts the inaccuracy of the bridging operator to frequencies higher than the final 25 Hz Nyquist frequency. The relevant modifications have been proposed by Shakal and Ragsdale (1984) and have been incorporated in the present analysis of the accelerograms.

The low-pass filtering using an Ormsby filter is expressed by the discrete convolution sum:

$$y(n) = X(n) \cdot h(n) = \sum_{k=1}^{n-1} H(k) \cdot X(n-k)$$

where, X(n), is the equispaced sequence of the time history to be filtered, y(n), is the filtered version of X(n), and h(n), is the sequence of the filter weights of the Ormsby impulse response function.

After the instrument correction has been performed a straight-line fit by least-squares is subtracted from the acceleration, and trial calculations for velocity and displacement are made. More specifically a line ($V=Vo + \alpha t$, V=velocity, Vo=initial velocity, α=slope, t=time) is least squares' fitted to the velocity and α is subtracted from the acceleration. The acceleration is high-passed filtered, and a new velocity and displacement are calculated from the adjusted acceleration. Further high-pass filtering is done on the velocity and a new displacement is calculated from the adjusted velocity. Finally, a high-pass filter is performed on the new displacement. Alltogether, high-pass filtering is performed three times to remove long-period errors that arise from the unknown inital velocity and displacement.

However, Shakal (1982) has noted that the particular method of long-period filtering used in the standard Caltech procedures (Trifunac and Lee, 1973) can cause spurious long period results for certain input frequencies.

Energy in the accelerogram near 5 Hz and its multiples is erroneously introduced through the aliasing associated with decimation, at long periods, i.e. 6 to 10 seconds and greater. It has been shown that adequate filtering prior to decimation, instead of simply applying the running-mean operator, removes the problem. Some modifications in the standard code have been made by Shakal and Ragsdale (1984) and have been also adopted in the present report. The accuracy of the filter is a function of the difference $\Delta f=fLt-fL$ (fL, is the low cutoff frequency, fLT, is the low cutoff transition width). The error is reduced by making Δf larger. The fL frequency is primarily selected on the basis of 1/fL equal to one-quarter of the record length. The frequency Δf may varies from 0.1 up to 0.5 Hz. However , the Ormsby high-pass filter introduces errors into the displacement and careful consideration must be given to constructing a filter response.

VOLUME II PROCESSING: CORRECTED ACCELERATION, VELOCITY AND DISPLACEMENT

The scaled, uncorrected acceleration data obtained from the first stage of processing are now retrieved to be corrected for instrument frequency response and base-line adjustment as described by Hudson and Brady (1971), Trifunac and Lee, (1973), Trifunac et al.,(1973), Hudson (1979), Trifunac and Lee,(1979).

At the same time, the accelerogram is integrated to obtain the velocity and displacement records. An input file called FILTER.PAR is prepared which contains the Ormsby filter parameters for the bandpass filter. We used the filters proposed by Basili and Brady (1978) and have already been applied by other researchers for analyzing strong motion in Greece (Carydis et al., 1984; Margaris, 1986; Carydis et al.,1988; Anagnostopoulos et al., 1986; Makropoulos et al., 1989; Lekidis et al., 1991). These filters are a linear ramp of 0.05-0.125 Hz and 25-27 Hz. For small earthquakes with small duration these filters have been appropriately changed.

To obtain as much as possible high accuracy at higher frequencies, a decimation factor 4:1 is used. However, this factor requires long run time and large storage space, at the Volume II stage and at the next one.

The accelerograms corrected for instrument response are next baseline corrected by high-pass filtering with an Ormsby bandpass filter having a low cutoff corner f1, low cutoff transition width f2, high cutoff corner f3, and high cutoff transition width f4.

To avoid long period errors, for periods longer than 16 sec, resulting from the uncertainties involved in estimating the initial velocity and displacement of ground motion (Hudson 1979, Fletcher et al., 1980), the computed velocity and displacement curves are high-pass filtered using the same Ormsby bandpass filter as above.

The corrected acceleration, velocity and displacement for each component of an earthquake record are plotted to appropriate scales by the program V2PLOT (Kinemetrics, 1986). Details concerning identification and peak values of acceleration, velocity, and displacement are given at the top of each plot.

Finally, the corrected acceleration, velocity and displacement data are written in a filename with an extension .V2 ready for further processing.

VOLUME III PROCESSING: CALCULATION OF RESPONSE SPECTRA

The volume III stage of processing includes the calculation of response spectra for up to five user specified values of damping, and up to 45 values of period. At the same time, the Fourier amplitude spectra are also calculated, by means of the Cooley-Tukey algorithm.

The spectra are computed based on the exact analytical solution of the Duhamel integral as described by Nigam and Jennings (1968).

Calling the program V3PLOT (Kinemetrics, 1986) a plot of the Pseudo Velocity Response Spectrum, PSV, together with the Relative Displacement Spectrum, SD, and the Pseudo Acceleration Spectrum, PSA, in the tripartite logarithmic plot versus period is obtained. The units are inch./sec, inch., and g, respectively.

ANALYSIS OF ACCELEROGRAMMS RECORDED AT NOA'S STATIONS DURING THE TIME: 1973-1992

The Accelerographic Network of NOA:

Figure 2 shows the locations of the accelerograph stations of the Seismological Institute of the National Observatory of Athens. The permanent stations are shown by solid triangles, while the temporarily installed instruments are shown by solid circles. These instruments have been installed at specific areas for monitoring aftershock sequences (Kalamata 1986, Elia 1988). Table 1 summarizes all information on the instruments and the

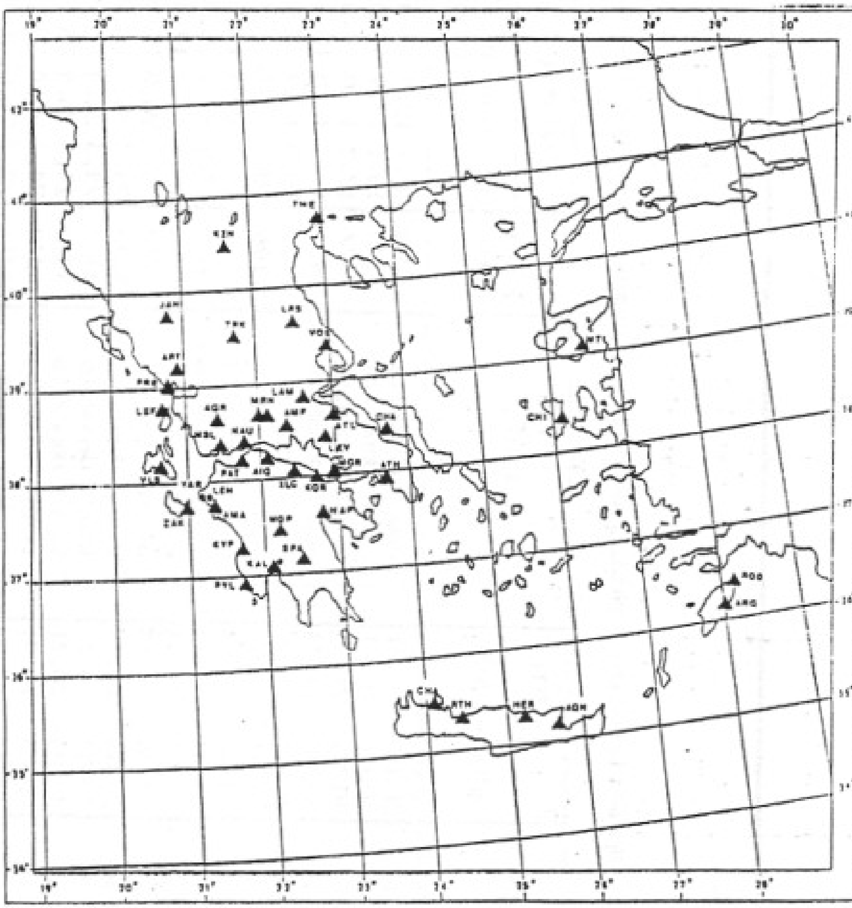

Fig.2. The strong motion network of the National Observatory of Athens. Permanent stations are shown by solid triangles, temporary stations by solid Circles.

TABLE 1. Summarized information on the instruments and the stations.

CODE	SITE	LOCATION φ°N	λ°E	GEOLOGY	SERIAL No	INSTRUMENT'S CONSTANTS Nat. Freq. (Hz) LONG	VERT	TRAN	Sensitiv. (cm/g) LONG	VERT	TRAN	ORIENTATION
LEF4	Levkas	38.83	20.71	Present deposits	1195	18.1	17.9	17.8	3.86	3.64	3.68	N25°W
LEF3	Levkas	38.83	20.71	Present deposits	1195	18.1	17.9	17.8	3.86	3.64	3.68	N25°W
PAT7	Patra	38.25	21.73	Present deposits	627	17.3	17.0	18.6	4.06	3.66	3.76	S15°W
PAT8	Patra	38.25	21.73	Present deposits	627	17.3	17.0	18.6	4.06	3.66	3.76	S15°W
THE1	Thessaloniki	40.63	22.96	Present deposits	2710	18.0	17.9	18.6	3.50	3.82	3.58	–
KOR2	Korinthos	37.93	22.93	Present deposits	1196	18.3	17.7	17.4	3.64	3.86	3.92	N30°E
XLC2	Xilokastro	38.00	22.63	Present deposits	626	17.3	18.3	17.5	4.10	3.60	4.00	–
ATH1	Athina	37.98	23.73	Crystaline limestone	613	24.9	25.1	25.5	1.90	1.78	1.80	–
KOR3	Korinthos	37.93	22.93	Present deposits	1196	18.3	17.7	17.4	3.64	3.86	3.92	N30°E
PRE1	Preveza	38.96	20.75	Coastal deposits	4342	25.6	26.0	25.4	1.84	1.72	1.87	N-S
LEF5	Levkas	38.83	20.71	Present deposits	4340	24.3	26.4	25.2	2.03	1.80	1.91	N25°E
LEF6	Levkas	38.83	20.71	Present deposits	4340	24.3	26.4	25.2	2.03	1.80	1.91	N25°E
LEF7	Levkas	38.83	20.71	Present deposits	4340	24.3	26.4	25.2	2.03	1.80	1.91	N25°E
LEF8	Levkas	38.83	20.71	Present deposits	4340	24.3	26.4	25.2	2.03	1.80	1.91	N25°E
HER1	Heraklio	35.33	25.13	Recent deposits	4341	25.2	26.0	26.3	1.88	1.80	1.82	–
HER2	Heraklio	35.33	25.13	Recent deposits	4341	25.2	26.0	26.3	1.88	1.80	1.82	–
XLC1	Xilokastro	38.00	22.63	Present deposits	626	26.1	25.6	25.2	1.68	1.79	1.90	N80°E
AMA1	Amaliada	37.80	21.35	Old alluvial deposits	1199	17.5	17.7	17.5	4.00	3.80	3.78	N80°E
PRE2	Preveza	38.96	20.75	Coastal deposits	4342	25.6	26.0	25.4	1.84	1.72	1.87	N-S
LEF2	Levkas	38.83	20.71	Present deposits	4340	24.3	26.4	25.2	2.03	1.80	1.91	N25°E
KAL1	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W
SPA1	Sparti	37.08	22.43	Recent deposits	5074	26.8	25.4	26.6	1.68	1.90	1.73	S5°E
KAL1A	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W
KAL2	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W
KAL3	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W
KAL4	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W

continued

CODE	SITE	LOCATION φ°N	LOCATION λ°E	GEOLOGY	SERIAL No	INSTRUMENT'S CONSTANTS Nat. Freq. (Hz) LONG	VERT	TRAN	Sensitiv. (cm/g) LONG	VERT	TRAN	ORIENTATION
KAL5	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W
KAL6	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W
KAL7	Kalamata	37.03	22.12	Present deposits	1197	17.8	18.1	17.8	3.72	3.66	3.96	S85°W
KAL8	Kalamata	37.04	22.13	Present deposits	5101	26.1	26.6	26.5	1.78	1.76	1.79	-
AMA2	Amaliada	37.80	21.35	Old alluvial deposits	1199	17.5	17.7	17.5	4.00	3.80	3.78	N80°E
ROD1	Rhodos	36.43	28.22	Old alluvial deposits	4339	25.5	26.1	25.1	1.87	1.85	1.91	S-N
ARG1	Archangelos	36.20	28.13	Marl and sand	5080	25.6	26.3	25.8	1.88	1.68	1.85	S55°W
LEF1	Levkas	38.83	20.71	Present deposits	4340	24.3	26.4	25.2	2.03	1.80	1.71	S80°E
VLS1	Valsamata	38.17	20.60	Cretaceous Limestone	4336	25.1	26.1	25.3	1.91	1.83	1.81	-
VLS2	Valsamata	38.17	20.60	Cretaceous Limestone	4336	25.1	26.1	25.3	1.91	1.83	1.81	-
KOR1	Korinthos	37.93	22.93	Present deposits	1196	18.3	17.7	17.4	3.64	3.86	3.92	N30°E
AMA7	Amaliada	37.80	21.35	Old alluvial deposits	1199	17.5	17.7	17.5	4.00	3.80	3.78	N80°E
AMA4	Amaliada	37.80	21.35	Old alluvial deposits	1199	17.5	17.7	17.5	4.00	3.80	3.78	N80°E
AMA5	Amaliada	37.80	21.35	Old alluvial deposits	1199	17.5	17.7	17.5	4.00	3.80	3.78	N80°E
AMA6	Amaliada	37.80	21.35	Old alluvial deposits	1199	17.5	17.7	17.5	4.00	3.80	3.78	N80°E
PAT5	Patra	38.75	21.73	Present deposits	627	17.3	17.0	18.6	4.06	3.66	3.76	S15°W
VAR3	Vartholomio	37.87	21.20	Present deposits	1648	25.7	24.8	25.5	1.72	1.92	1.82	N75°W
VAR4	Vartholomio	37.87	21.20	Present deposits	1648	25.7	24.8	25.5	1.72	1.92	1.82	N75°W
AMA3	Amaliada	37.80	21.35	Old alluvial deposits	1199	17.5	17.7	17.5	4.00	3.80	3.78	N80°E
NAV1	Navpaktos	38.40	21.83	Present deposits	617	25.0	26.0	26.0	1.82	1.87	1.80	N84°W
PAT4	Patra	38.25	21.73	Present deposits	627	17.3	17.0	18.6	4.06	3.66	3.76	S15°W
PAT1	Patra	38.25	21.73	Present deposits	627	17.3	17.0	18.6	4.06	3.66	3.76	S15°W
PAT2	Patra	38.25	21.73	Present deposits	627	17.3	17.0	18.6	4.06	3.66	3.76	S15°W
PAT3	Patra	38.25	21.73	Present deposits	627	17.3	17.0	18.6	4.06	3.66	3.76	S15°W
AIG1	Egion	38.25	22.08	Present deposits	5097	25.4	26.2	26.0	1.88	1.83	1.80	N60°E

TABLE 2. The parameters of the earthquakes used, and the strong motion data as derived from the interpretation.

EARTHQUAKE DATA								STRONG MOTION DATA								
CODE	DATE	Orig. Time	LOCATION φ°N – λ°N	Epic. Dist. (km)	M_s	M_L	I_{max}	Max. Acceleration (g)			Max. Velocity ($cm.sec^{-1}$)			Max. Displacement (cm)		
								LONG	VERT	TRAN	LONG	VERT	TRAN	LONG	VERT	TRAN
LEF4	04/11/73	15:52	38.90 20.50	20	5.8	5.8	VII+	0.514	0.118	0.257	55.17	7.27	26.33	12.30	1.65	6.06
LEF3	04/11/73	16:11	38.80 20.50	19	5.0	5.0	–	0.041	0.021	0.074	3.17	1.92	4.81	1.06	1.09	1.00
PAT7	29/12/77	16:53	38.50 22.30	57	5.2	–	V+	0.010	0.011	0.016	0.84	0.81	1.32	0.13	0.10	0.15
PAT8	18/05/78	00:19	38.30 21.70	6	4.9	3.9	V	0.010	0.011	0.023	0.37	0.39	0.93	0.05	0.04	0.06
THE1	20/06/78	20:03	40.80 23.20	28	6.5	6.1	VIII+	0.138	0.129	0.142	12.34	6.07	16.28	3.69	1.44	4.01
KOR2	24/02/81	20:54	38.20 23.00	31	6.7	5.9	IX	0.233	0.108	0.281	23.86	9.90	32.20	6.02	3.66	9.69
XLC2	24/02/81	20:54	38.20 23.00	35	6.7	5.9	IX	0.288	0.184	0.116	26.25	25.82	8.19	9.42	8.09	2.49
ATH1	24/02/81	20:54	38.20 23.00	69	6.7	5.9	IX	0.221	0.057	0.096	25.95	6.01	11.78	5.88	3.39	4.29
KOR3	25/02/81	02:36	38.20 23.10	33	6.4	5.6	VIII	0.117	0.044	0.120	12.21	5.11	13.11	4.14	1.88	5.66
PRE1	10/03/81	15:16	39.30 20.80	39	5.8	5.8	VII+	0.140	0.085	0.137	9.38	3.52	10.76	1.64	1.03	2.74
LEF5	10/03/81	15:16	39.30 20.80	53	5.8	5.8	VII+	0.107	0.045	0.198	6.31	3.56	10.05	0.55	0.52	1.14
LEF6	10/04/81	08:33	38.90 21.00	34	4.7	4.5	VI+	0.041	0.018	–	2.01	0.71	–	0.33	0.11	–
LEF7	25/05/81	23:04	38.80 21.00	25	4.7	4.3	–	0.104	0.039	–	4.01	0.94	–	0.87	0.09	–
LEF8	27/05/81	15:04	38.80 20.70	3	5.5	4.8	–	0.218	0.088	0.190	8.97	2.12	8.53	0.70	0.22	0.46
HER1	19/03/83	21:42	35.35 25.32	38	5.7	5.7	V+	0.079	0.064	0.172	3.72	1.46	6.23	0.24	0.11	0.30
HER2	01/03/84	09:08	35.45 25.50	30	4.7	4.5	–	0.106	0.048	0.197	5.19	1.67	6.75	0.38	0.21	0.50
XLC1	17/08/84	21:23	38.14 22.56	9	4.7	4.5	–	0.027	0.025	0.022	1.08	0.49	1.32	0.12	0.05	0.18
AMA1	13/08/85	13:49	37.78 21.05	26	5.4	4.9	VI+	0.093	0.033	0.057	1.96	2.45	1.23	0.40	1.21	0.54
PRE2	31/08/85	06:04	39.01 20.48	24	5.3	–	VII+	0.082	0.039	0.044	4.25	1.91	3.06	0.79	1.23	1.14
KAL1	13/09/86	17:25	37.10 22.19	10	6.0	6.0	X	0.214	0.327	0.297	32.47	14.98	33.01	7.42	2.39	7.02
KAL3	13/09/86	18:30	37.11 22.14	13	3.8	–	–	0.037	0.032	0.033	1.38	1.36	1.42	0.12	0.09	0.13
KAL4	13/09/86	22:40	37.12 22.16	11	4.1	3.8	–	0.049	0.024	0.039	1.64	0.81	1.16	0.14	0.14	0.12
KAL5	14/09/86	00:29	37.16 22.14	15	3.8	–	–	0.044	0.027	0.024	2.20	0.99	1.12	0.18	0.11	0.11

(Continued)

EARTHQUAKE DATA								STRONG MOTION DATA								
CODE	DATE	Orig. Time	LOCATION φ°N – λ°N	Epic. Dist. (km)	M_w	M_L	I_{max}	Max. Acceleration (g)			Max. Velocity (cm.sec^{-1})			Max. Displacement (cm)		
								LONG	VERT	TRAN	LONG	VERT	TRAN	LONG	VERT	TRAN
KAL6	14/09/86	22:49	37.15 22.04	15	3.9	–	–	0.047	0.025	0.024	2.71	0.87	0.85	0.16	0.20	0.19
KAL2	15/09/86	11:41	37.08 22.07	7	5.3	4.9	VII	0.327	0.172	0.159	26.38	7.53	6.96	4.13	0.83	0.77
KAL7	15/09/86	12:48	37.09 22.04	10	4.1		–	0.050	0.029	–	1.60	0.83	–	0.29	0.17	–
AIG2	14/05/87	06:29	38.14 22.07	12	4.4	–	–	0.027	0.029	0.031	0.93	1.37	2.48	0.16	0.82	1.54
ROD1	05/10/87	09:27	36.29 28.46	27	5.6	5.0	VI+	0.055	0.021	0.052	2.20	0.71	2.63	0.18	0.13	0.24
ARG1	05/10/87	09:27	36.29 28.46	31	5.6	5.0	VI+	0.031	–	0.047	1.39	–	2.11	0.19	–	0.21
LEF1	24/04/88	10:11	38.84 20.33	33	5.0	4.2	VI	0.111	0.051	–	7.86	1.89	–	0.64	0.55	–
VLS1	18/05/88	05:18	38.35 20.47	23	5.8	5.4	VI	–	0.037	0.087	–	2.22	4.29	–	0.42	0.89
VLS2	22/05/88	03:44	38.35 20.54	21	5.5	5.0	VI	0.052	0.033	0.078	1.69	1.53	2.41	0.13	0.19	0.28
KOR1	05/07/88	20:35	38.10 22.85	20	4.7	5.0	V+	0.029	0.020	0.020	1.48	0.55	0.84	0.11	0.04	0.09
AMA7	22/09/88	12:06	37.99 21.11	30	5.5	5.0	VI	0.020	0.014	0.036	0.86	0.56	1.67	0.14	0.08	0.18
AMA4	30/09/88	11:04	37.71 21.36	10	4.5	4.4	–	0.022	0.013	0.009	0.58	0.45	0.42	0.04	0.02	0.04
AMA5	30/09/88	13:03	37.69 21.33	12	4.7	4.6	–	0.018	0.022	0.021	1.06	0.64	1.22	0.14	0.06	0.09
AMA6	16/10/88	12:34	37.90 20.96	36	6.0	5.5	VIII	0.082	0.040	0.156	4.07	1.78	9.04	0.40	0.16	0.93
VAR3	19/10/88	00:27	37.86 20.98	19	4.4	4.0	–	0.062	0.018	0.041	3.68	0.59	2.22	0.26	0.07	0.16
VAR4	31/10/88	03:00	37.85 21.01	17	4.8	4.2	–	–	–	0.034	–	–	1.81	–	–	0.14
AMA3	13/12/88	11:01	37.75 21.24	11	4.7	4.7	–	0.024	0.012	–	0.69	0.31	–	0.05	0.03	–
NAV1	22/12/88	09:57	38.43 21.75	10	5.0	4.6	VI	0.108	0.048	0.099	8.40	3.55	5.83	0.90	0.22	0.74
PAT4	22/12/88	09:57	38.43 21.75	10	5.0	4.6	VI	0.032	0.017	0.026	2.60	0.72	1.05	0.28	0.10	0.13
PAT2	07/06/89	19:46	37.99 21.65	30	5.3	5.0	VII	0.021	0.014	0.072	1.45	0.08	1.82	0.17	0.12	0.20
PAT3	31/08/89	21:29	38.14 21.87	17	4.8	4.4	V+	0.069	0.017	0.046	3.35	0.94	3.59	0.35	0.10	0.35
AIG1	17/05/90	08:44	38.39 22.22	20	5.0	4.8		0.114	0.114	0.202	5.10	5.10	11.44	0.38	0.38	0.64

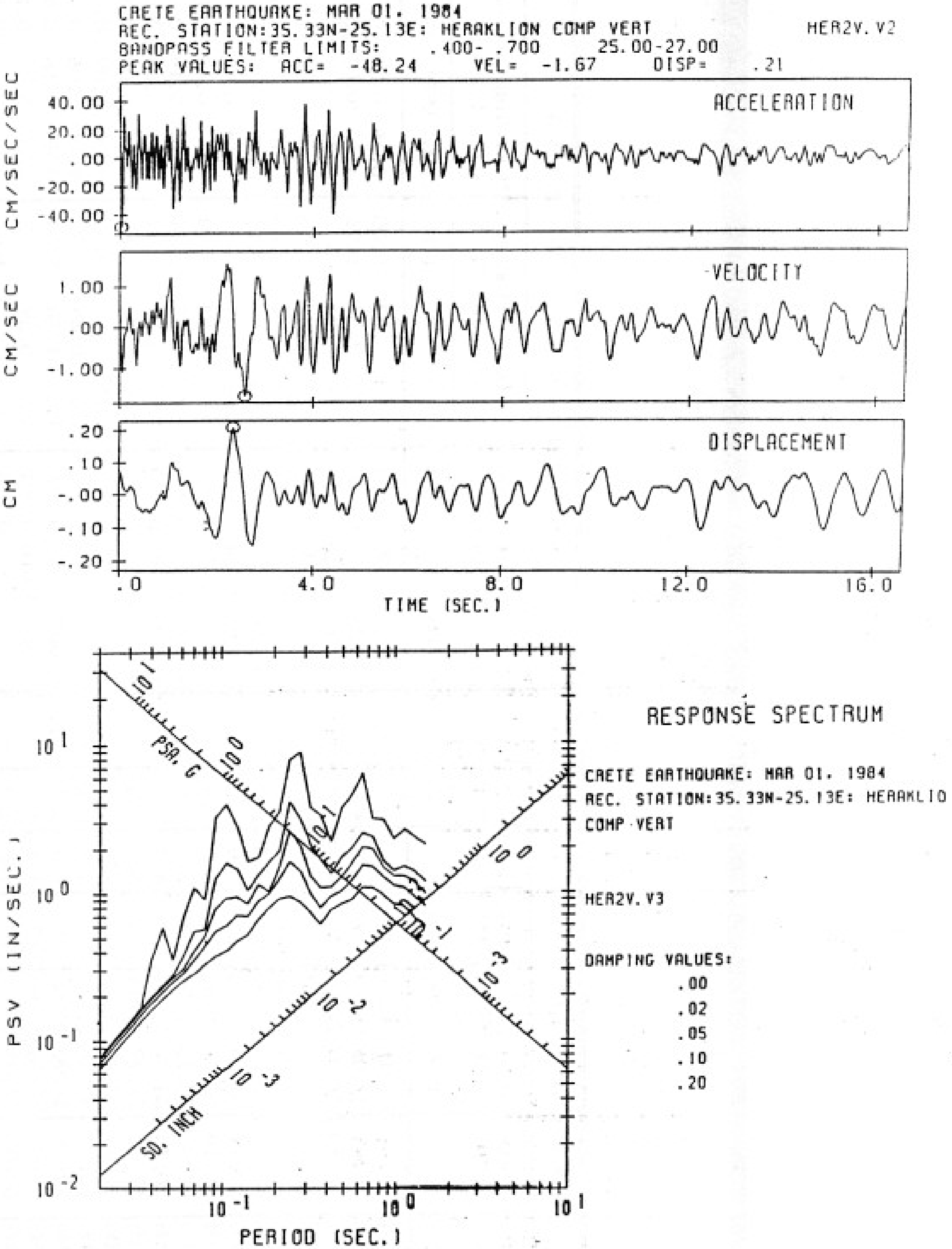

Fig.3. An example of the corrected acceleration, velocity, displacement and the spectra.

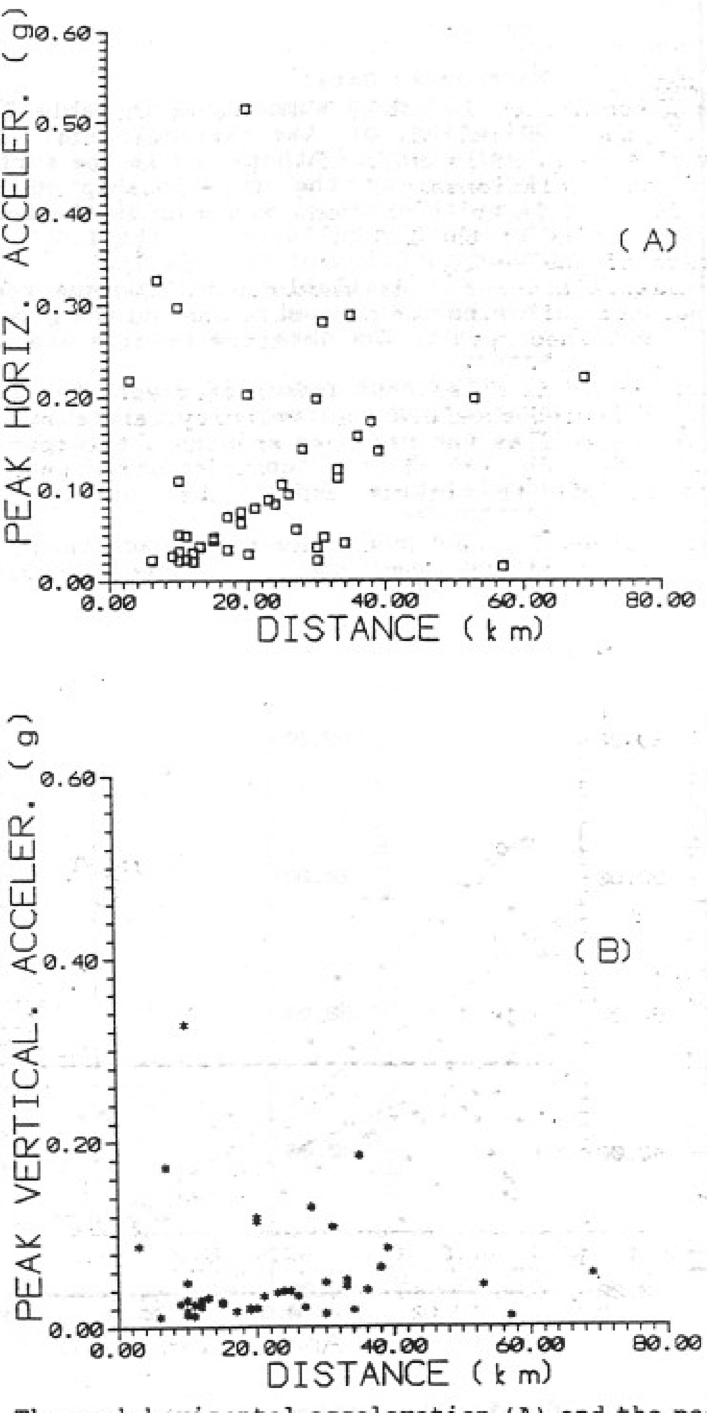

Fig.4. The peak horizontal acceleration (A) and the peak ver acceleration (B) versus distance.

stations.

Earthquake Data

All data summarized in table 2 are taken from the Monthly Bulletins of the Seismological Institute of the National Observatory of Athens. MS is the surface magnitude as it has been obtained by the relationship MS = ML + 0.5 (Kiratzi and Papazachos 1984), while Mb is the body wave magnitude taken from the monthly bulletins of the I.S.C.

Interpretation of the Results

All available accelerograms recorded by the NOA's network have been analysed following the procedure described in the above sections. The obtained results are interpreted in the following manner.

For each record is given: the uncorrected acceleration time history, the corrected acceleration, velocity, and displacement time histories as well as the response spectrum. The four digits at the right top corner of the plot of the uncorrected acceleration depicts the origin time (hour, minute) of the earthquake.

The peak values for each trace are marked on the plots and listed numerically at the top of the figures showing the corrected

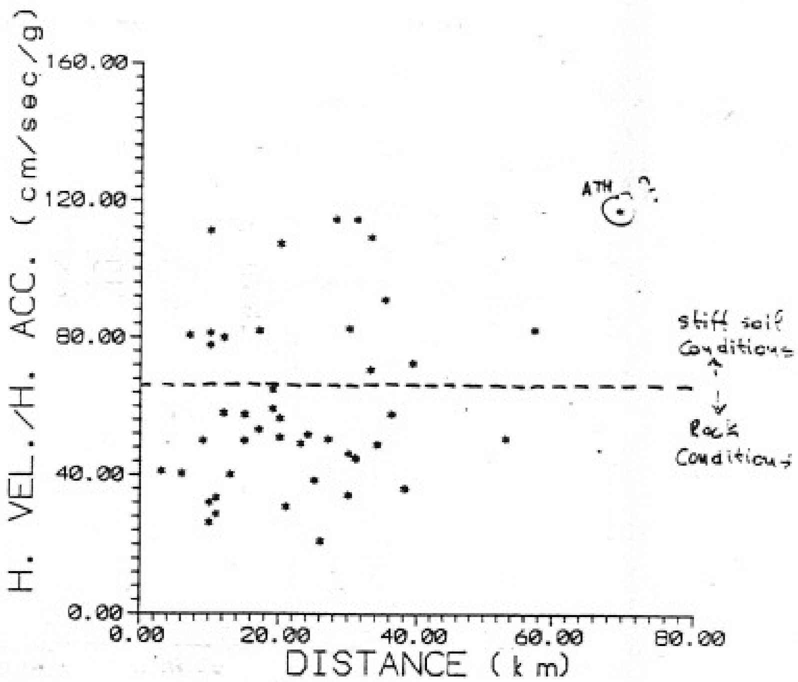

Fig.5. The ration of the horizontal velocity to horizontal acceleration versus distance.

acceleration, velocity and displacement. Due to space limitations only an example of the analysis is presented in figure 3. Table 2 summarizes not only the parameters of the earthquakes analysed in the present study, but the peak corrected values of the acceleration, velocity and displacement as well. Figure 3 includes also the response spectra for the same as above record.

Figure 4 shows the peak horizontal (A) and the peak vertical accelerations (B), respectively, as a function of the distance.

Figure 5 shows the ratio of the horizontal velocity to horizontal acceleration versus distance and an attempt has been made to correlate our results to those by Seed et al (1976). However, the response of the building seems to play a quite significant role. For example, although figure 5 shows that ATH1 gives the highest value and this, according to Seed et al (1976), means that the geological conditions of the installation should refer to deep cohesionless soil, this is not true. This high value propably contains the response of the fifteen-stores building in the twelfth of which the SMA-1 is installed.

Figure 6 shows the ratio of peak horizontal to peak vertical

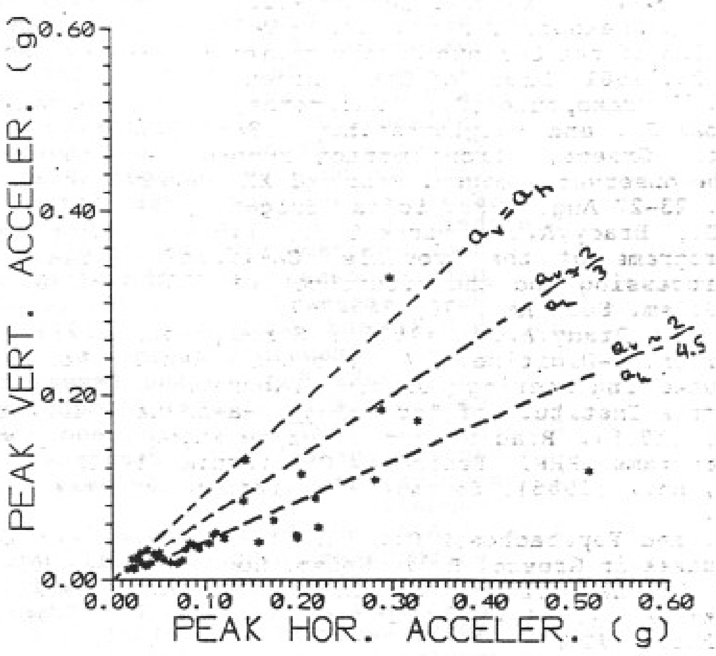

Fig.6. The ratio of peak horizontal (α_h) to peak vertical acceleration (α_v).

acceleration, which gives an average value of the order of 2.3, although a widely accepted value is of the order of 1.5. This could illustrate the extremely significant meaning of the horizontal component for the area of Greece.

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