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Механика на непрекъснатите среди

Some Results of the Processing and Analysis of Strong Motion Records of the Strazhitsa Earthquake of 7. 12. 1986 and the Aftershock of 21. 01. 1987

G. Georgiev, I. Paskaleva

Introduction

The earthquake of 7. 12. 1986 and the strong aftershocks that followed it were recorded by the network of accelerographs situated in the region of the town of Strazhitsa on an area of about 2000 km². A number of records were obtained, but here only records of 7. 12. 1986 with M=5,7 and the records of the aftershock of 21.01. 1987 with M=3,9 will be analysed. 14 horizontal and 7 vertical components are processed and analysed.

Processing steps

The functional structure of the processing procedure of strong ground motion can be devided into three main groups:

— digitization and preparation of uncorrected data;
— instrument correction and its preliminary anti-aliasing;
— base-line correction or long period removal of various types. Each one of these processing groups has been considered recently in our efforts to upgrade the quality of corrected data, making use of the most recent research results.

The first step in the computer processing of the records is the determination of the basic uncorrected data of the seismic acceleration. The uncorrected accelerogram should reproduce an acceleration near to the actual one recorded by the accelerograph. At this stage both determination of the real values of acceleration by the calibration data for each accelerograph is made as well as the interpolation of data at an interval $\Delta t=0.01$ *s*. The accuracy of the uncorrected accelerogram before all about the high frequency components is not sufficient for detailed studies in earthquake engineering [1]. In order to restore the frequencies up to the natural frequency of the accelerometer it is necessary to make an instrument correction by solving the equation.

$$\ddot{y}[n]+2\Omega_0\xi_0\dot{y}[n]+\Omega_0^2 y[n]=-a[n], \tag{1}$$

where: $y[n]=y[n\Delta t]$ – digital sequence of a relative displacement of the accelerometer;
$a[n]$ — digitized accelerogram
$n=0,1,2,\ldots$ — number of sampling

Ω_0, ξ_0 — natural frequency and critical damping.
The direct solution of (1) however can lead to great errors as a consiquence of unwanted high frequence noise introduced in the process of obtaining the uncorrected accelerogram. For this purpose it is filtered first by a lowpass filter with cutoff frequency f_L determined by the natural frequency of accelerometer.

The accelerograms which are instrumentally corrected are further a subject of the base-line correction aiming the removal of the long period components. At this stage the determination of the cutoff frequency for a highpass filter, f_H plays the main role. In the process of the continuous investigations [2] it becomes clear that f_H should vary for the different records, but the criteria for its selection are different too. The frequency range can be limited to f_H from the requirement for a true reproduction of the accelerogram depending on the signal-to-noise ratio. Since this relationship depends on the magnitude of the earthquake, on the local geology, on the epicentral distance and the amplitude of the accelerogram, then f_H will vary for the different records. The determination of the relationship signal-to-noise (f_H respectively) is best when comparing the amplitude spectra of Fourier of the signal and those of the noise [3].

Selection of filter

For a lowpass filter at the instrument correction and for highpass filter correcting the baseline of the accelerogram we use a class of nonrecursive filters that are monotone (vary smoothly) over the whole frequency band interval. The main consideration for our preferences to this type of filters are: their stability, easy realization and strictly linear phase characteristic — an important condition when they are applied for the purposes of earthquake engineering. The transition between passband and stopband can be much steeper if a procedure given in [4] can be applied. If transfer function of smooth lowpass filter is marked by $H_M(w)$, then the transfer function of the new lowpass filter, $H_0(w)$, will be given by:

$$H_0(w) = H_M^2(w)\{3y[n] - 2H_M(w)\}. \tag{2}$$

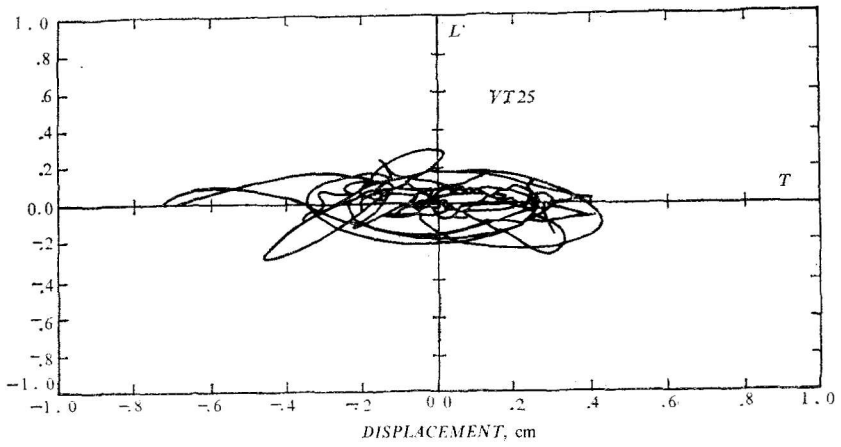
Compared with the transfer function of the Ormsby filter [5] this filter has much sharper and narrower tranzition zone around the cutoff frequency.

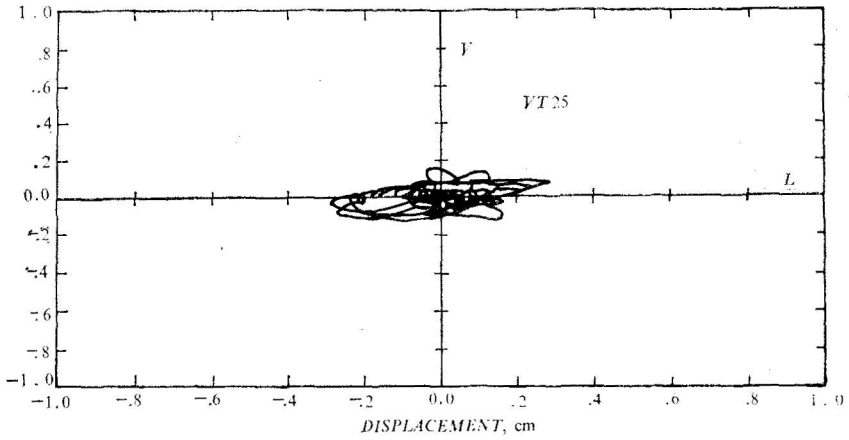
Numerical results. Analysis of the experimental data

By the procedure thus described the records of the earthquake of 7. 12. 1986 are processed. These records are registrated by the accelerographs installed in Tirnovo (*VT*25) and for the aftershock of 21. 01. 1987 by the accelerographs mounted in the local network in the area Strazhitsa, Asenovo, Popovo (*STR*41, *ASN*38, *POP*39). The choice of places where the accelerographs are mounted has been made on the basis of different considerations, the main of which is the characteristic of the local geological conditions.

1. Soil vibration characteristics during the earthquake of 7. 12. 1986 and the aftershock of 21. 01. 1987

The acceleration records and the obtained from them displacement and velocity show the following specific characteristics:


L
VT25
T
DISPLACEMENT, cm


V
VT25
L
DISPLACEMENT, cm

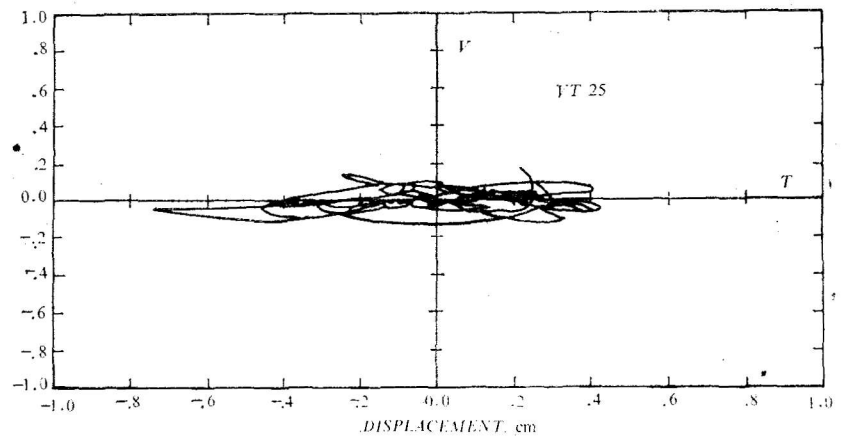

V
VT 25
T
DISPLACEMENT, cm

Fig. 1

— The horizontal accelerations are of lower frequency than the vertical ones. The mean value of the horizontal and the vertical periods ratio is $T_h/T_v=1{,}45$.

— The horizontal acceleration amplitude maximal values are higher than the vertical ones. The amplitude ratio mean value is $a_{h\max}/a_{v\max}=1{,}75$ for the main earthquake and $a_{h\max}/a_{v\max}=4{,}5$ for the aftershock sequence.

— The vertical acceleration phase maximum comes later than the horizontal acceleration phase maximum usually. The ratio mean value of the maximal acceleration amplitude moments from the beginning of the record is $t_h/t_v=0{,}81$.

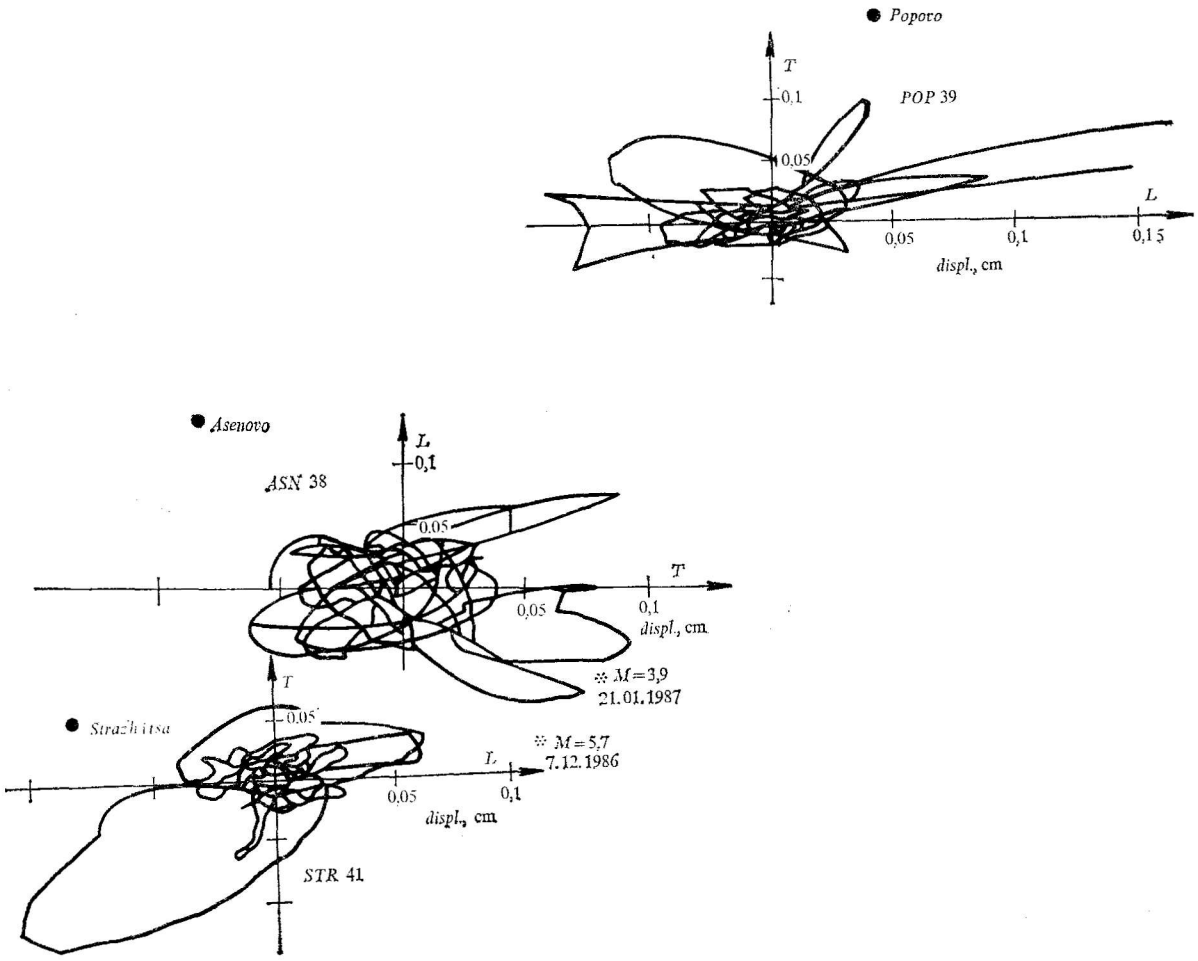


Fig. 2

The acceleration, velocity and displacement maximum values (in numerator) and the corresponding time moments (in denumerator) from the beginning of the record are given in Table 1. On data of F. F. Aptikaev and U. F. Kopnichev [6] the ratio of

a_h/a_v by 35 records of earthquakes with a different source mechanism has values of 1,48 (fault) up to 2,23 (strike-slip). For the ratio of periods T_h/T_v—1,98 (fault) and 1,26 (strike-slip) – it is observed.

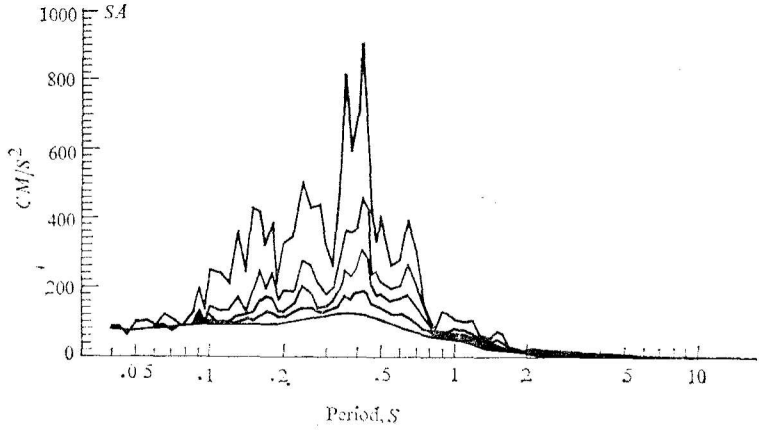


Fig. 3

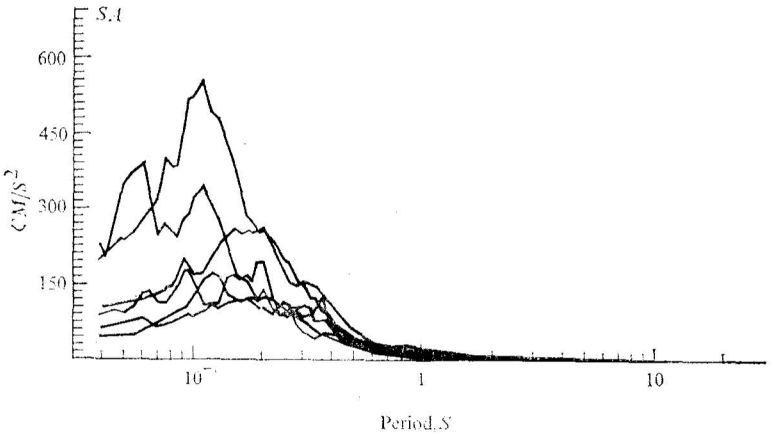


Fig. 4

— The time moments of the velocity and displacement maximal values come within the interval $3 \div 8$ *s* for the main event and within $1 \div 5$ *s* for the aftershock. The aftershock displacement records have simple form as an impulse followed by a sequence of low amplitude vibrations which is typical for the hypocentral distances of 10-20 km.

— For all records at orientation of the accelerographs $N-S$ an elongation of the vector of displacement in direction $E-W$ is observed.

Although a double integration of the accelerograms has greatly smoothed the ground motions, significant differences in the orbits are distinguishable. The LT orbits for the main shock shows an $E-W$ orientation, Fig. 1. The shape and the orientation of the loop for the aftershock, Fig. 2, is fairly constant for all three stations (Strazhitsa, Asenovo, Popovo). The partial motion in the VL plane is almost linear in all records. Finally, the VT diagrams confirm that vertical displacements are relatively small and the ground particles are moving predominantly in a horizontal plane with the largest amplitudes in the transverse direction.

Table 1

Ref. #	Comp. L			Comp. V			Comp. T		
	a_{max}/t_{max} cm/s^2/S	V_{max}/t_{max} cm/s/S	d_{max}/t_{max} cm/S	a_{max}/t_{max} cm/s^2/S	V_{max}/t_{max} cm/s/S	d_{max}/t_{max} cm/S	a_{max}/t_{max} cm/s^2/S	V_{max}/t_{max} cm/s/S	d_{max}/t_{max} cm/S
1 *VT* 25	—66.928 5.58	3.476 5.52	—0.29 7.46	—40.534 6.12	2.774 6.08	0.164 8.24	74.502 4.94	4.229 3.14	—0.738 4.12
2 *STR* 36	72.23 1.82	—2.635 1.76	0.169 1.68	—17.17 0.1	0.406 1.84	0.009 4.26	—38.82 1.78	1.368 1.66	0.06 1.72
3 *STR* 40	—41.68 1.74	1.65 1.68	0.093 1.76	—14.74 1.94	0.407 1.9	0.011 1.94	—67.17 1.84	1.83 1.82	—0.096 1.72
4 *STR* 41	57.29 1.46	1.91 1.5	—0.134 1.46	11.35 1.66	0.326 3.24	0.022 2.5	46.55 1.48	—1.63 1.44	—0.105 1.48
5 *ASN* 38	—135.101 1.04	1.74 1.02	0.16 1.04	34.25 1.82	1.134 1.86	0.03 3.26	—194.76 0.98	—4.54 0.96	—0.144 1.0
6 *POP* 37	—43.87 3.38	1.843 3.32	—0.059 3.26	10.89 2.38	—0.404 3.5	0.019 5.28	—108.23 2.3	—2.918 2.14	—0.129 2.2
7 *POP* 39	78.87 2.36	—2.03 2.94	0.099 2.9	—24.201 3.28	—0.788 2.86	0.032 3.12	—105.96 2.14	—2.94 2.18	0.181 2.14

2. Engineering characteristics of the vibrations

As engineering characteristics we may use the response spectra and the spectral-time diagrams of oscilator accelerations. For an estimation of the seismic forces response spectra are used, which are curves of the maximal response of oscilators depending on the periods, T_0 and damping ξ, $y''\max = f(T_0, \xi)$. In Fig. 3 there is a response spectra for the earthquake of 7. 12. 1986 for 0, 2, 5, 10 and 20% of critical damping. The predominating period is $T_0 = 0{,}4$ *s* and the dynamic effect $\beta \geq 4$.

Figure 4 presents response spectra for 5% damping for records of the earthquake of 21.01. 1987 made in Strazhitsa, Asenovo and Popovo. The earthquake is of an impulse type with small values of the velocity and the displacements and with big values of the accelerations of short duration and low dynamic effect $\beta = 2 \div 3{,}5$ within the range $T_0 = 0{,}1 \div 0{,}2$ *s*.

Conclusion

The results obtained are a good base for establishing a quantitative connection between the parameters of seismic effects on the surface and the source mechanism. An important problem for future investigations is the use of the accelerograms for determining the physical parameters of the earthquakes as well as defining the attenuation law of the accelerations with the distance.

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