Proceedings:
Second International Conference on Seismology and Earthquake Engineering
May 15-17, 1995, Tehran, Islamic Republic of IRAN

AFTERSHOCK SEQUENCES - APPROXIMATIONS, APPLICATIONS

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ABSTRACT

A pair analysis has been applied for several good documented aftershock sequences, including well known earthquakes near Coalinga, USA, May 1983; Pap, Azerbaijan, February 1984 and Spitak, Armenia, December 1988. The time and space statistical distributions have been approximated with the best fitting functions for each pair of the consecutive aftershocks. The main aim of this approach is to create formal criteria for recognition of the different sources and strong earthquakes in different tectonic active areas. The results obtained show that this approach is relatively effective for these purposes.

INTRODUCTION

During the last years the pair analysis has been applied for different purposes: random or nonrandom seismic processes investigations, statistical models for earthquake prediction, separation of natural and induced seismic events, etc.[1],[2],[3].

It is well known that aftershocks are time and space dependent seismic events from the main shock magnitude. The applied analysis gives us the possibility to separate formally different time and space seismic processes for the source zones located in different tectonic environment. The statistical distributions of the differences in time and distances between every two consecutive aftershocks of the certain consequences have been investigated. Their empirical histograms have been approximated by the best fitting analytical functions. The parameters of these functions have been analysed carefully. Our previous results show the reasonability of such approach [1],[2].

DATA

Three major earthquakes and their aftershocks series have been investigated:

- Coalinga, California, May 2nd, 1983, M=6.7; Io=8 MM; no surface ruptures have been reported. Depth of the main shock hypocenter- 9.5 km, accuracy of the hypocenter's determination - 2-3 km; the fault plane solution - thrust type. The hypocenter is located at the axe of an anticline with NW-SE direction. Foreshock activity. The dimensions of the activated aftershock area - 12 x 25 km, with the same direction of the long axe as the anticline one. Total number of the aftershocks included 87 (from May 2nd to May 19th). The bigger part of them are with magnitudes greater than 3.0 and 27 of them with magnitudes greater than 4.0 and located mainly near the main shock location (from May 2nd to Aug. 1st, 1983) [4],[5].

- Pap, Azerbaijan, February 17, 1984, M=5.7, observed intensity I_o=8 MSK-64; depth of the main shock - 15 km; the fault-plane solution - thrust type; no surface ruptures reported. The hypocenter is located at the anticline NW-SE direction. Foreshock activity. Dimensions of the activated aftershock area - about 25 x 15 km, located northern and north-eastern from the main shock hypocenter. Total number of the aftershock included - 371; for the first 100 days - 347, 52 of them with magnitudes greater than 3.5 (from Feb., 17th to Nov., 28th, 1984) [6].

- Spitak, Armenia, December 12th, 1988, M=7.1, Io=10 MSK-64; double shock with dimensions of activated aftershock area 50 x 15 x 13 km; surface ruptures reported with length of 6 km. Hypocenter determination accuracy - about 5 km; fault-plane solution - thrust type. Total number of aftershocks included - 107 (from Dec. 7th, 1988 to Jan. 14th, 1989) [3].

METHODOLOGY

All differences between the distances and time occurrence of each pair of the aftershocks, following the main shock have been presented as a histogram distribution. For the optimal histogram interval we use the Sturges formulae for the above parameters:

$$dx = (dx_{max} - dx_{min}) / (1 + 3.321 \lg N) \qquad (1)$$

where N is the total number of the differences.

The results obtained have been presented in tabl.1.

Table 1.Statistical parameters of the aftershock sequences

Aftershocks	Distance					Time				
	x	S_x	V_x	A_x	E_x	t	S_t	V_t	A_t	E_t
					Coalinga 2/5/83					
all	8.85	6.04	0.68	0.38	-0.88	5.74	5.19	0.9	2.59	8.4
M≥4.0	10.63	7.22	0.67	0.44	-0.78	7.2	7.56	1.05	1.55	0.9
					Pap 17/2/84					
all	7.54	4.84	0.64	1.17	1.65	18.37	83.13	4.52	8.77	89.
100 days	7.54	4.79	0.63	1.18	1.65	6.78	20.58	3.03	6.19	44.5
M>3.5	6.51	4.23	0.63	1.43	2.86	17.68	38.3	2.16	2.88	7.5
					Spitak 07/12/88					
all	16.4	11.92	0.72	0.95	0.04	9.45	15.35	1.62	3.98	18.0

where, x is the mean distance, S_x - the standard deviation, V_x - the variance coefficient, A_x and E_x respectively - asymmetry and excess. The same parameters are presented for the time differences.

Using the standard procedure for approximation of the statistical frequency distributions with the analytical ones we were able to obtain the best fitting approximation for each distribution. That analysis of the obtained function's parameters gives us the possibility to compare different functions and approximations.

For the time differences we were not able to use equal histogram step, so the time intervals are not equal. The calculation experiment shows us that the error of this approach is less than 10%.

Following our previous results [1, 2] we were able to try *beta*-distribution for approximation, because it is well applicable for the non-dependent seismic events. In the case of aftershocks the fitting was established nonaplicable. So other functions have been experimented. The best approximation we obtained with the function:

$$f(x) = a_x.x^{c_x}.\exp(-b_x.x) \tag{2}$$

for the distance differences $x = x_{i+1} - x_i$ and for the time intervals $t=t_{i+1}-t_i$

$$f(t) = a_t.t^{-bt} \tag{3}$$

and $$f_t(t) = a_t . t^{b_t} + c_t \qquad (4)$$

The calculated values of all functional parameters are presented in Tabl.2.

Table 2. Parameters of the approximating functions and error estimation.

Aftershock's	Distance				Time			
	a_x	b_x	c_x	err.	a_t	b_t	c_t	err.
				Coalinga				
all	0.202	0.07	0.032	0.065	3.161	1.366	0	0.05
M>4	0.297	0.074	0.174	0.013	3.66	1.51	0	0.063
				Pap				
all	0.117	0.34	1.535	0.033	0.164	1.568	0.018	0.013
M>3.5	0.142	0.348	1.529	0.031	0.292	0.65	0.034	0.045
100 days	0.112	0.349	1.597	0.034	0.168	1.625	0.019	0.014
				Spitak				
all	0.111	0.093	0.65	0.039	3.075	1.402	0	0.016

DISCUSSION

The careful analysis of the data from Table 1, shows similarity for the parameter's values for the similar sequences in the frame of expected errors. The dramatically differences can be obtained for the different events - Pap, Coalinga and Spitak aftershocks sequences - especially for the asymmetry and excess parameters for distance and means and standard deviations for the time differences.

The analysis of the approximating functions for the normalised distributions for both parameters - distance and time, show interesting peculiarities (Tabl.2). The coefficients a_x, b_x are from the same order. c_x is different for all cases. For the time distributions a_t and b_t for Coalinga and Spitak cases are very close and similar. The Pap sequence is completely different.

We suggest the explanation of this result: probably this is due to the time duration limitations and magnitude inhomogenities as a result of noncompletnes of the investigated sequences. But the similarity in the best fitting functions suggests that this method is applicable for comparative analysis for the similar events in different tectonic areas or for the different events in similar tectonic conditions. It is clear that the suggested method needs checking for a bigger amount of data. From another point of view it is very important to estimate the influence of the accuracy of the approximation, to be sure that the investigated approximation functions do not fluctuate in the frame of expected error.

It is also important to estimate the accuracy of the input data as well as the accuracy of the approximation. The checking of the statistical hypothesis for acceptance or rejection of the similarity for the approximation curves needs quantitative approach to be sure that the obtained results are exact. The method needs new and comparable investigations for completeness of the data and techniques used.

CONCLUSIONS

Three relatively complete aftershock sequences - after Spitak, Pap and Coalinga earthquakes, have been investigated by so called „pair analysis". The statistical distributions of the distance and time differences between each pair of the consecutive aftershock events have been investigated.

New methods for comparison of the approximated functions, called „fitting similarity" have been performed to show similar or not are the functions approximated the respective distributions for the different earthquake's aftershocks.

The results obtained show that the applied method is promising for such a procedure. The method needs for checking new, massive and complete data for aftershocks from different events in different or similar tectonic areas.

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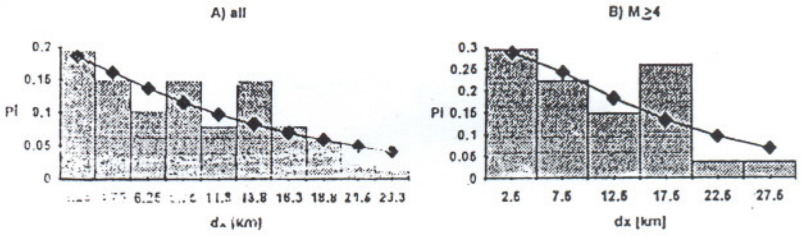

Figure-1. Histograms and analytical curves. Distributions of the distances between consecutive aftershocks (Coalinga case).

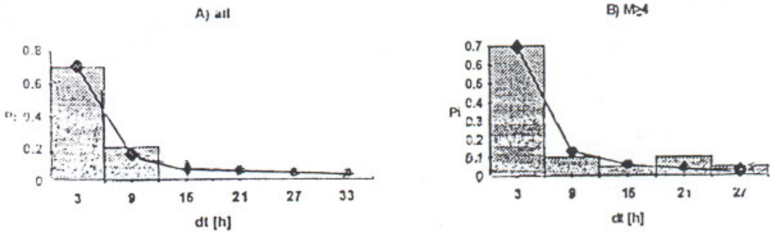

Figure-2. Histograms and analytical curves. Distributions of the time differences between consecutive aftershocks (Coalinga case).

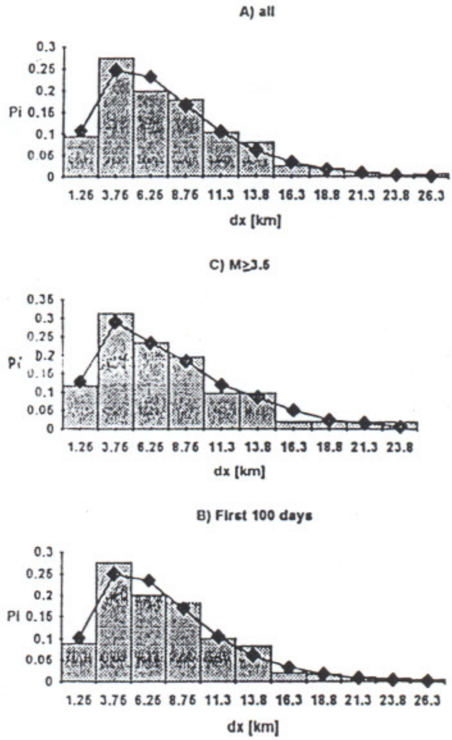

Figure-3. Same as fig.1 (Pap case).

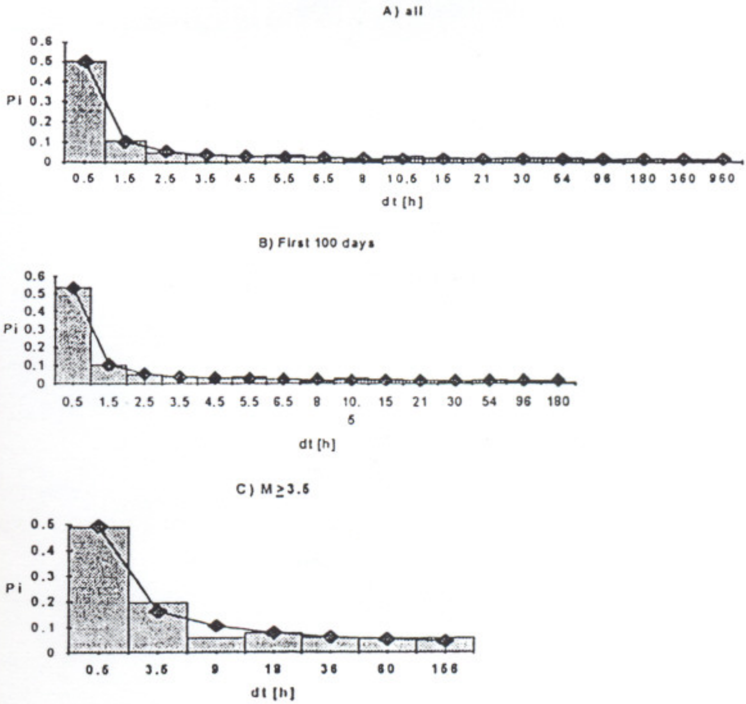

Figure-4. Same as fig.2 (Pap case)

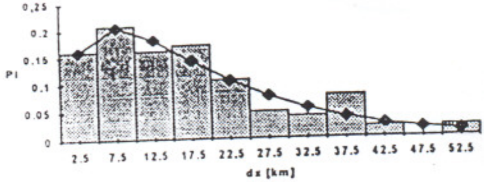

Figure-5. Same as fig.1 (Spitak case)

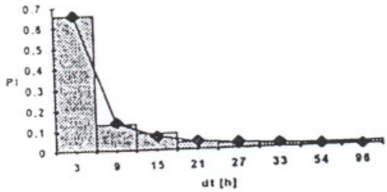

Figure-6. Same as fig.2 (Spitak case)

PROCEEDINGS
OF THE
SECOND INTERNATIONAL
CONFERENCE ON

SEISMOLOGY AND EARTHQUAKE ENGINEERING (SEE -2)

MAY 15-17, 1995
TEHRAN, I.R. IRAN

VOLUME (I)

EDITORS :
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