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Comparison of Frequency Spectra for Micotremors, After Shocks (M=2.5-4.7) and the Main Shock of the Spitak Earthquake Obtained on Massive Lake-River Formations in the Region of Giumry (Armenia)

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ABSTRACT

On December 7, 1988 a disastrous earthquake with magnitude M=7.0 took place in the northern part of Armenia, during which in Giumry (former Leninakan) large-scale destruction of standardized buildings with epicentral distance 35 km was observed. This forced us to set a task: to find connection between large-scale destruction and some dynamic peculiarities of grounds on the territory of the city. The present article makes an attempt to explain the significance of the upper engineering-geological stratum (20-30 m) and that of the lower massive lake-river formations. Basing ourselves on a great number of instrumental observations we tried to compare prevailing periods of ground microthremors with frequency spectra of the Spitak earthquake main shock and its aftershocks and to reveal connection between them in order to ascertain the significance of own prevailing periods of grounds on the territory of Giumry in the large-scale destruction during the main shock as well as to prove that they didn't manifest themselves during the event.

The obtained results can be applied to drawing up of new seismic microzonation maps not only for Giumry, but for an territories of other cities as well, which are situated on massive lake-river formations. Besides the results can benefit creators of normative documents on seismostable building.

INTRODUCTION

Seismic microzonation requires not only prediction of the possible maximum intensity of tremors during a destructive earthquake on the given territory, but also prediction of frequency peculiarites of these tremors brought about by ground conditions. As it is known, earthquakes with equal epicentral distances significantly depend on geological conditions of registration place, physical-mechanical, solidity, deformation, acoustic characteristics of lying grounds. Besides, ground conditions greatly influence the spectral composition and duration of graund tremors. When studing the problem of dependence of seismic influences on ground conditions E.Khachiyan (1998) considered that the upper ground layer, which structure foundation is leant on, is of great importance in transmitting seismic wave energy to the structure. After the Spitak earthquake B.K.Karapetyan (1989), B.K. Karapetyan and K.B. Karapetyan (1998) supposed that one of the causes of such large-scale destruction is the coincidence of periods of ground tremors and the own tremor periods of buildings and structures erected on it. Some of the authors assert that in a number of geological conditions in Giumry increase of tremors and their duriation is due to thick layers of one or even several kilometres depth, and not to ground properties of 20-30 m depth, i.e. not to ground conditions as it is accepted in traditional approaches to microzonation (Khalturin et al., 1990).

Consequences of strong destructive earthquakes are well known, but those of the Spitak earthquake are beyond any limits of existing notions of a calamity. That is why we have set a task to reveal the cause of such large-scale destruction. The numerous obtained instrumental data, records of aftershocks, microtremors of ground varieties on the whole territory of Giumry, the record of the Spitak earthquake main shock, as well as comparision of their frequency spectra allowed to asertain if the own prevailing periods of grounds coincided with own periods of the same grounds during aftershocks and the main shock, i.e. to reveal if seismic tremor intensification in Giumry is connected with resonance phenomena.

BRIEF GEOLOGICAL CHARACTERICTICS OF THE CITY

The city of Giumry is situated in the Shirak Basin, which is filled up by lake-river sediments: sand, gravel, loam, volcanic ashes, as well as by thin tuff and basalt seams. Within the city limits depth of this sharply stratificated layer comes to 300-500 m; it stretches to the north and north-west for 20-30 km and gets narrower to the south and south-east. As a matter of fact, the basin represents the Akhurian river valley, which during the Quaternary period was re-covered more than once by volcanic outpourings of the Mount Aragats, in the result of which lakes with sediment accumulation originated periodically.

INSTRUMENTAL RESEARCH ON THE TERRITORY OF GIUMRY

From January 10 till May, 1989 at five points with different engineering-geological conditions most characteristic for the given territory day-and-night three-component registration of aftershock displacement was organized in basements of different buildings. At the same time ground microtremors were also registered during the whole observation period by means of the method accepted at the Institute of the Earth's Physics in the former USSR (Ershov, 1977). Periods twice exceeding the average level of frequency characteristics were regarded as earthquake prevailing periods. The confidental interval of microtremor prevailing periods was determined by everyday record processing from the most frequently repeating periods, which have more stable values during the whole measurement period.

SELECTION OF OBSERVATION POINTS BY ENGINEERING GEOLOGICAL CONDITIONS

The first observation point symbolically named "Marmashen" is situated in the north-western outskirts of Giumry on massive (300m) lake clays spread under pebble-gravel ground with sandy filler (about 20 m), which is covered by 8 m thick tuffs. The second observation point "BSR" is situated slightly to the east from the first one on massive (more than 300 m) lake clays, spread under 13m thick tuffs, which are covered by hard clays (up to 6 m) spread under 4 m thick loam with gravel inclusion. The third point "Krepost" is situated within the city limits on massive (more than 300 m) lake clays covered by watter-carrying sand and loamy ground (up to 20 m), which are in their turn covered by 6 m thick tuffs. The fourth observation point "Pobeda" is situated in the center of Giumry on massive (more than 300 m) lake clays spread under water-carrying sand and loamy ground (nearly 20 m). The fifth point "Arevik" is situated 3 km away from the city to the south-east on massive andesite-basalts (more than 100 m) covered by dense 3 m thick boulder-pebble sediments. The "Leninakan" stationary seismic station is based on thick (more than 300 m) lake clays covered by 7 m thick tuffs, which are in their turn covered by 13 m thick loam with gravel and detritus inclusion.

ANALYSIS OF THE OBTAINED RESULTS

The following table presents generalized (by three components) values of prevailing periods (T sec) of aftershoks and microtremors at 5 observation points.

TABLE. GENERALIZED VALUES OF PREVAILING PERIODS (IN SEC) OF AFTERSHOKS AND MICROTREMORS

N	Magnitude (M)	Earthquake and microtremors registration stations									
		Marmashen		BSR		Krepost		Pobeda		Arevik	
		Earthq.	Microt.	Earthq.	Microt.	Earthq.	Microt.	Earthq.	Microt.	Earthq.	Microt.
1	3.7	0.5-0.6		0.60-0.65		0.67-0.7		0.73-.08		0.55-0.6	
2	2.6	0.6		0.56		0.60		0.75-0.85		0.4-0.45	
3	2.6	0.55-0.6		0.45-0.6		0.45-0.72		0.8		0.35-0.4	
4	2.6	0.6		0.5-0.55		0.5-0.65		0.6-0.8		0.45	
5	2.6	0.5-0.6		0.51-0.55		0.55-0.65		0.7-0.8		0.37-0.43	
6	2.7	0.55-0.65		0.5		0.65		0.8		0.4-0.43	
7	2.7	0.6		0.5-0.6		0.55-0.6		0.8-1.0		0.4-0.43	
8	4.2	0.65-0.8		0.7		0.80		0.7-1.0		0.45	
9	3.2	0.6-0.65	0.21-	0.6-0.7	0.25-	0.74-0.76	0.12	0.8-1.0	0.31-	0.5-0.60	0.09-
10	2.6	0.55-0.65	0.38	0.5-0.55	0.4	0.6-0.65	0.21-0.45	0.6-0.7	0.47	0.35-0.4	0.12
11	2.7	0.55-0.6	0.56	0.4-0.5	0.58	0.55-0.6	0.6	0.8	0.6	0.4-0.45	
12	2.7	0.55-0.6		0.55		0.6-0.70		0.60-0.65		0.37-0.48	
13	2.5	0.6-0.8		0.55		0.7-0.74		0.6-0.7		0.4-0.48	
14	2.6	0.6		0.5		0.65-0.7		0.60-0.62		0.58-0.6	
15	3.0	0.6		0.45-0.5		0.56-0.6		0.8-0.9		0.47-0.5	
16	2.6	0.51-0.6		0.55		0.55-0.6		0.7-0.9		0.38-0.44	
17	2.8	0.6-0.7		0.4-0.5		0.9-1.1		0.6-0.7		0.35-0.4	
18	3.9	0.6		0.55-0.57		0.8		0.75-0.8		0.5	
19	3.3	0.55-0.65		0.55		0.74		0.8-1.0		0.4	
20	2.6	0.5-0.65		0.45-0.5		0.45-0.7		0.6-1.0		0.35-0.5	

On December 31, 1988 a strong aftershok with M=4.7 was recorded at the "Leninakan" stationary seismic station. Prevailing periods dominant in the influence zug of the earthquake are in the range 0.6-2 sec (Khalturin et al., 1990). Acording to numerous records prevailing periods of ground microtremor at this point came to 0.4-0.6 sec. Unfortunately, the above-mentioned 5 points could not register the event as they began functioning only in January, 1989. Now let's assertain if there are any coincidences between the prevailing periods of ground microtremors and those of earthquakes. As it is seen from the table the obtained results at the first four observation points situated on massive lake-river formations are more or less similar. The results significantly differ from those obtained at the "Arevik" point, which is due to the fact that it is situated on massive fundamental andesite-bazalts (more than 100 m). Actually, prevailing periods microtremor at the first four points nearly coincide with those of earthquake with M=2.5-4.2. Comparision of the earthquake (M=4.7) spectrum and prevailing periods of microtremor at the first four points and at the registration point ("Leninakan" seismic station) showed that the lower limit of the earthquake prevailing periods (T=0.6 sec) approximately coincides with the upper limit of ground microtremor. Now let's consider the frequency composition of the Spitak earthquake (M=7.0) main shock registered at "Leninakan" seismic station. Periods domonant in the interference zug of this event lie in the range 1.2-3 sec and are far away from the frequency range of ground microtremors on the territory of Giumry (T_{pr}=0.12-0.6 sec). Own periods of destroyed standard buildings are in the range 0.35-0.6 sec i.e. no resonance phenomena between the ground and structures were observed during the main shock.

In 1993 working with our American colleagues from the Colombian University we tested Nakamura's method (1989) and revealed that the peak of an expected earthquake prevailing period is equal to 2 sec (Field et al., 1995), which once more proves the above-mentioned arguments.

As for the main causes of large-scale destruction of buildings they lie in baseless understatement of seismic hazard of the given territory, excessively inferior buildings, etc.

FINAL CONCLUSIONS

1. During an earthquake with M=2.5-4.7 its prevailing periods frequently coincide with those of microtremor, and the upper (25-30 m) engineering-geological stratum has certain significance.
2. When the earthquake magnitude is near to 7.0, coincidence between its prevailing periods and those of ground microtremor is eliminated. Here massive (more than 300 m) lake-river sediments are of dominant significance instead of the upper (25-30 m) engineering-geological stratum.
3. On massive lake-river sediments magnitude increase (beginning with 4.7) leads to the sharp shift of the earthquake prevailing periods to the low-frequency part of the spectrum.
4. On massive lake-river sediments ground microtremors cannot be used for prediction of an expected earthquake (M>5) frequency peculiarities.

Such methods will be possibly worked out in the future, which will allow to predict frequency composition of an expected earthquake in its full display.

Thus analysis of the obtained results allows to consider that prevailing periods of ground microtremor are not connected with its frequency characteristics during strong earthquakes on massive lake-river formations.

The obtained results can be applied for drawing up of new seismic microzonation maps not only for Giumry, but for other cities as well, which are situated on massive lake-river formations. They can also be useful for creators of normative documents on seismostable building (Abrahamyan, 1998).

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