30 Mar 2001, 10:30 am - 12:30 pm

Definition of Seismic Hazard Degree of Dams and Their Territories, Armenia

Styopa Karapetyan
Institute of Geophysics and Engineering Seismology, Armenia

Tamara Babayan
Institute of Geophysics and Engineering Seismology, Armenia

Levon Manukyan
Institute of Geophysics and Engineering Seismology, Armenia

Definition of Seismic Hazard Degree of Dams and Their Territories, Armenia

Styopa Karapetyan
Institute of Geophysics and
Engineering Seismology, NAS RA
5, Leningradyan st, Gyumri, Armenia-377515

Tamara Babayan, Levon Manukyan
Institute of Geophysics and
Engineering Seismology, NAS RA
5, Leningradyan st, Gyumri, Armenia-377515

ABSTRACT

The work is devoted to define the seismic hazard degree of four dams of Armenia: Azat, Tavshoot, Hakhoom, and Joghaz. The problem required the execution of major geological-geophysical, seismological, tool and theoretical researches. Such studies of the dams in Armenia were carried out for the first time, on the complex of methods designed by us.

All research was reduced to a solution of the primary problem, i.e. definition of expected maximum horizontal accelerations (EMHA) of seismic vibrations on the altitude of the investigated dams with compiling of the corresponding epyuras of the distribution of accelerations. For obtaining epyuras the values of EMHA on real, characteristically ground conditions of the territory where the dams are located determined, i.e. holding of seismic microzoning of the investigated territories ground-hydrogeological zones of various seismic hazard with corresponding values of EMHA allocated.

As the definition of the marked values of seismic hazard on various ground conditions requires their comparison with the reference value of seismic intensity by particular detailed seismic zoning (DSZ), the research has begun just from operations on detail seismic zoning of regions around the water storage's.

INTRODUCTION

The researches were conducted for dams, exploited 10-25 years, necessary to reconstruct. To secure seismic resistance, in design calculations of dams the initial seismic intensity, disregarding of local ground conditions under dams, was accepted in the fundamentals. So it was necessary overestimate seismic hazard degree according to a modern scientific-technological level. Herein it was necessary to take into account the requirements of the new building code Republic of Armenia adopted in 1994. The Spitak, 1988 earthquake has caused to make changes in the map of seismic zoning of RA. Values of initial seismic intensity therefore have changed also. And so, the situation demanded, to specify and to overestimate seismic hazard degree of territories of dams, and dams behaviour at expected seismic effect.

DETALED SEISMIC ZONING

At this stage the complex analysis of the data of three-dimensional modelling of a gravitational field, depth seismic sounding and fault tectonics maps of the various authors has been made, and the schemes of fault-block tectonics of the territories of regions with a radius of 50km around the water storage's of Azat, Tavshoot, Hakhoom and Goghaz (H. Hovhannesyan, H. Gasparyan) are composed.

For an estimation of seismic hazard of regions where the water storage's are located, the parameters of the seismic regime A_{10}, K_{max} and their return period are defined. The corresponding maps of A_{10}, K_{max} and greatest possible earthquakes M_{max} (I_{calc}.) (E. Geodakyan, H. Sarkisyan) and the map of pleistoseistal areas of strongest earthquakes (T. Babayan), scale 1:200000, are composed. The probability estimation of the occurrence of earthquakes with M_{max}, I_{calc} for dams exploitation time T_1=50 year and T_2=100 year is determined. The initial values of expected maximum horizontal accelerations for each dam are defined: Tavshoot – A_{maxi}=0.277, I_i=8.6; Azat-A_{maxi}=0.396, I_i=9.5; Hakhoom-A_{maxi}=0.193, I_i=8.3; Joghaz-$A_{max\,i}$=0.189, I_i=8.4.

Detail Seismic Zoning maps, scale 1:200000, (T. Babayan, E. Geodakyan) of territories of 50km radius regions around Tavshoot, Azat, Hakhoom and Joghaz water storage's are composed. Because of the large volume of works, as an example we shall adduce only outcomes of the research of Azat dam (Figure 1).

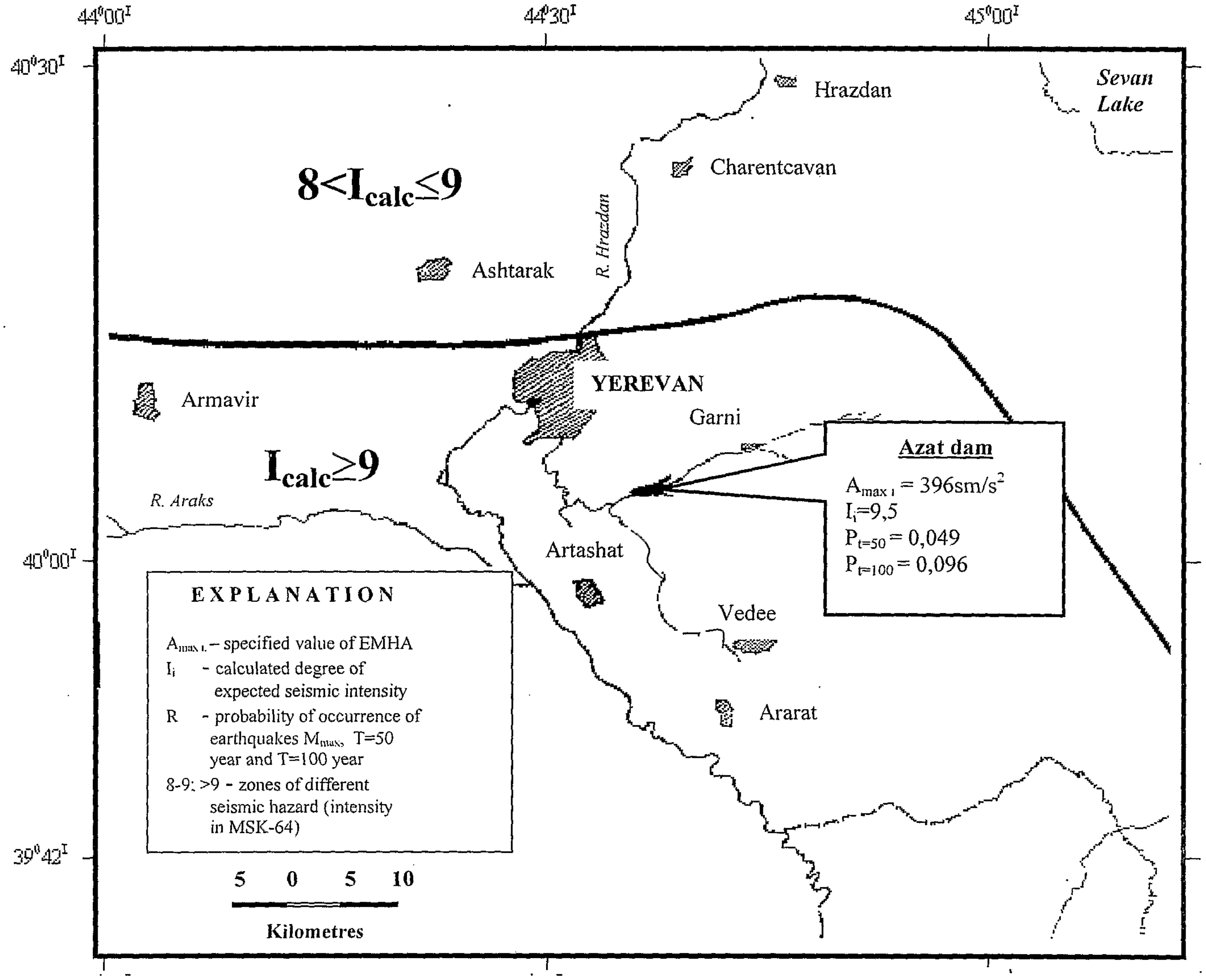

Fig. 1. The map of detailed seismic zoning of Azat dam region. Makers: T. Babayan, E. Geodakyan.

SEISMIC MICROZONING OF TERRITORIES OF THE DAMS LOCATION

The seismic microzoning of the territories of the dams' location is held on generally accepted seismic microzoning methodology (Seismic Microzoning, 1977; Babayan et al., 1989): method of engineering-geological analogies and complex of tool researches.

First of all, according to the method of engineering-geological analogies, analyzing and generalizing all material on engineering-geological and hydrogeological conditions of the territories of the dams' location, the types most typical for these territories' ground sections are defined (Table 1). Then, taking into account physical-mechanical parameters of grounds, the thickness of stratums included in the grounds' cross-section, and the ground water table, categories of seismic hazard are estimated by a method of the engineering-geological generalization (Babayan, 1976). Further in the investigated territory the zones of various seismic hazard are allocated. For each ground section the values of seismic intensity increments were specified using outcomes of tool observations.

TOOL RESEARCHES

Into the complex of tool researches seismic properties of varieties of ground conditions of these territories entered the method of seismic rigidities and the method of high-frequency microseisms.

For implementing the method of seismic rigidities the values V_P and V_S were determined with the help of the digital accumulative recording system «Talgar-3». The generation of seismic waves was produced by shock of a sledge of a 5kg weight on a metallic plate. The systems of observations Z and Y-Y were applied to registration of waves V_P, V_S accordingly.

TABLE 1. INCREMENTS OF SEISMIC INTENSITY AND EMHA OF AZAT DAM TERRITORY

Part of territory	Ground Cross-section	Thickness H meter	Density g/cm^3	Ground water table GWT meter	Velocity of seismic waves m/s Vp	Velocity of seismic waves m/s Vs	Seismic rigidity ρVs	Seismic Intensity increment ΔI bal ρVs	Seismic Intensity increment ΔI bal GWT	Seismic Intensity increment ΔI bal total	Dominant period sec	Category of grounds	A_{max} cm/s^2
Right slope of the river	Sandstone's, argillites, tuff-sandstone's	>20	2.4	-	2000-3000	700-1000	2040	-0.93	-	-0.93	0.13-0.15	I	208
Left slope of the river	Sandstone's, argillites, tuff-sandstone's	>20	2.4	-	2000-3000	700-1000	2040	-0.93	-	-0.93	0.12-0.14	I	208
River-bed	Gravel-pebbles	14	2.1	1	850-1000	375-430							
	sandstones, argillites, tuff-sandstones	>20	2.4		2250-3300	750-900	1417	-0.52	0.46	-0.06	0.12-0.15	II	380

The profiles of seismic observations were installed on characteristic ground conditions. The values of seismic intensity increments (ΔI) in various ground conditions of the territories of the dams were determined, accepting calculation depth equal to 20-30m, on defined values of transversal wave velocities (V_s), values of density (ρ) and thickness of each layer in any condition, and ground water level, under the known formula of Medvedev (Medvedev 1972). Further for the territory of each dam and the maximum expected values of seismic intensity (seismic hazard) for each zone in comparison with initial ground conditions both in balls, and in accelerations are obtained (Table 1). The study of high-frequency microseisms was done to reveal the values of dominant oscillation periods of characteristic ground sections and the body of the dam. For this, the complex of standard instrumentation of linear dynamic range in periods 0.08-1.0sec was used. Enlargement of the channel in this range of periods has compounded 20000.

MAPS OF SEISMIC MICROZONING

On defined by tool observations more accurate boundaries of various seismic hazard zones and values of increments of seismic intensity, on a certain method the seismic microzoning maps of dams location territories are composed. On these maps the zones by certain maximum expected seismic hazard are allocated (Figure 2). The greatest values of acceleration (in case of Azat dam on the riverbed) were accepted as the value of maximal expected hazard for territory of the dam.

On the basis of this value and in view of dynamic parameters of the foundation grounds, for each dam the accelerograms – analogous are selected, serving as a basis for definition EMHA at various on altitude points of dams.

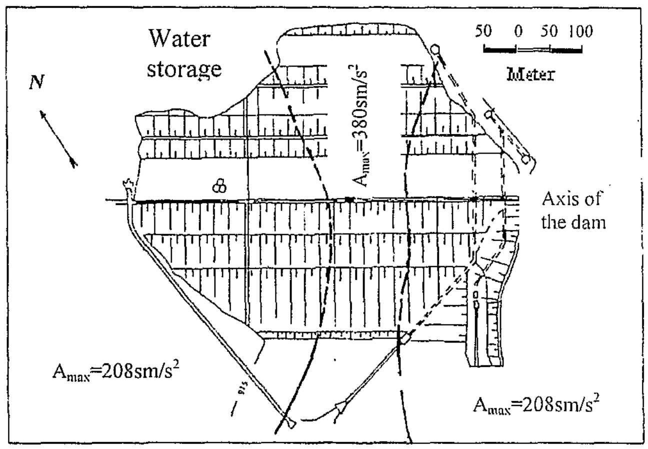

Fig. 2. The seismic microzoning map of territory of Azat dam. A_{max} = 380cm/s^2; A_{max} = 208cm/s^2; A_{max} = 208cm/s^2 are EMHA on the riverbed, on right and left beads accordingly.

DEFINITION OF EMHA ON ALTITUDE OF DAMS

The set task was solved with the help of empirical transfer functions or their impulse transition functions (ITF). For correct definition ITF a number of factors were allowed: three-dimensional space character of the foundation - dam - water system operation, heterogeneity of the body of the dam and the foundation, interaction of the dam with the basis and water environment etc. As the analytical definition ITF, in view of the marked factors is bound with major and practically insuperable difficulties of analytical and computing nature, therefore they are defined by an experimental way on dams. With this purpose, according to the requirements of the experiment, engineering - seismometrical profiles on beads of dams were organised.

The profile was including four points of observations, first of which was on the ground, at the foot, the second and third points were on the berms of the lower board, and fourth - on the ridge of dams located. The generation of oscillations of the grounds and bodies of the dams is produced with the help of falling cargo (on Azat dam of weight 3.7 tons, from altitude6m, at distance 60m from the first registration point). Absolute water level in water storage in the moment of the experiment was 1030.85m. The registration of oscillations was produced on engineering-seismological oscillographs K-12-22. The velocities of oscillations were register by the seismographs SM-3 with galvanometers NU-80, 160Hz, and accelerations–by the seismographs OSP, with galvanometers NU-80, 60Hz. The recordings, obtained as a result of experiments, are entered by digital rows in the computer for further calculations of transition functions. The values of maximum velocities and accelerations obtained at the experiment on Azat dam are shown in Table 2.

TABLE 2. OUTCOMES OF EXPERIMENTAL RESEARCHES

Points of observation	Hypsometric mark of points of observation	V_{max} cm/s	A_{max} cm/s^2
N1	976	0,0362	7,508
N2	1012,7	0,0325	1,308
N3	1034	0,0262	1,215
N4	1053,5	0,0177	0,518

At a solution of the problem the allowance was done, that the system fundament-dam-water at the time of the seismic influence is linear. In principle the definition of seismic loads would be expected to hold on the basis of nonlinear theory of seismic resistance. However outcomes of using the nonlinear theory of seismic resistance point, that the seismic forces, defined under the earthquake resistance linear theory, are more than their defined with taking into account elastically–plastic deformation of the system. Therefore, in a safety factor and stability of a dam the calculation of seismic acceleration in linear decree is quite justified. So, we accept that the dam is a linear system by the constant parameters. For such system the entry and the output sequences are related by a relation such as convolution

$$u(x,t) = \int_0^t h(x, t-\tau) w(\tau) d\tau \qquad (1)$$

where: t - time, $w(\tau)$ - entry sequence (displacement, velocity or acceleration of the foundation of dams); u(x,t)- output sequence or response of a dam in a point $x(x_1,x_2,x_3)$; h(x,t) - impulse transition function (ITF) of the system (dam); ITF h(x, t) - is the alone characteristic of the system and completely determines it's dynamic properties. Determined function enables to calculate of a dam response from arbitrary influence, for example, from potentially expected earthquake.

Using the Fourier transforms apparatus as the main method of investigating of the equation (1), the formal solution of the task is gained

$$U(x,\omega) = H(x,\omega)\ W(\omega), \qquad (2)$$

whence we define a transfer function (TF) - Fourier transform ITF of a dam

$$H(x,\omega) = U(x,\omega) / W(\omega), \qquad (3)$$

where $W(\omega)$, $U(x,\omega)$ - Fourier transform of the experimentally registered sequences of entry influence (foundation of a dam) and response (body of a dam); $H(x,\omega)$ - TF of a dam between an inlet and point $x(x_1,x_2,x_3)$.

For calculation of response in an arbitrary point x of a dam from real seismic influence, there is enough to multiply it's frequency characteristic on TF and with the help of Fourier inverse transformation to pass in time area.

$$u^*(x,t) = F^{-1}(H(x,\omega)\ W^*(\omega)), \qquad (4)$$

where $W^*(\omega)$ - Fourier transformation of real seismic influence, for example accelerograms; $u^*(x,t)$ - response in an arbitrary point $x(x_1,x_2,x_3)$.

Let's remark, that the integral equations of a type (1) compound one of classes of the incorrect problems (Tikhonov, Arsenin, 1986). The solution (3) can not exist, and if exists, has not property of stability to errors of the experimentally defined functions u(x,t) and w(t). From the physical point of view TF of the real system $H(x,\omega)$ tends to zero at $|\omega| \to \infty$. The special interest for the seismic resistance building represents the spectrum of seismic effects in an interval (0.07Hz, 30Hz). Therefore with the sufficiently accuracy it is possible to consider, that the function $H(x,\omega) \equiv 0$ outside of some interval (ω_1,ω_2), i.e. h(x,t) is the function with a finite spectrum (Khourgin,Yakovlev, 1971). Allowing this circumstance, steady to the noise free TF is possible to determine as follows

$$H_f(\omega) = H(\omega)\ f(\omega), \qquad (5)$$

where $f(\omega)$ – stabilising factor being the bandpass filter.
Substituting the $H_f(\omega)$ function in (4), we shall receive the steady design formula for definition $u_f^*(x,t)$

$$u_f^*(x,t) = F^{-1}(H_f(x,\omega)\ W^*(\omega)), \qquad (6)$$

on the explained method the accelerograms on points of observations 2,3,4 and appropriate epyuras of allocation of maximum horizontal accelerations on altitude of dams are obtained (Figure.3).

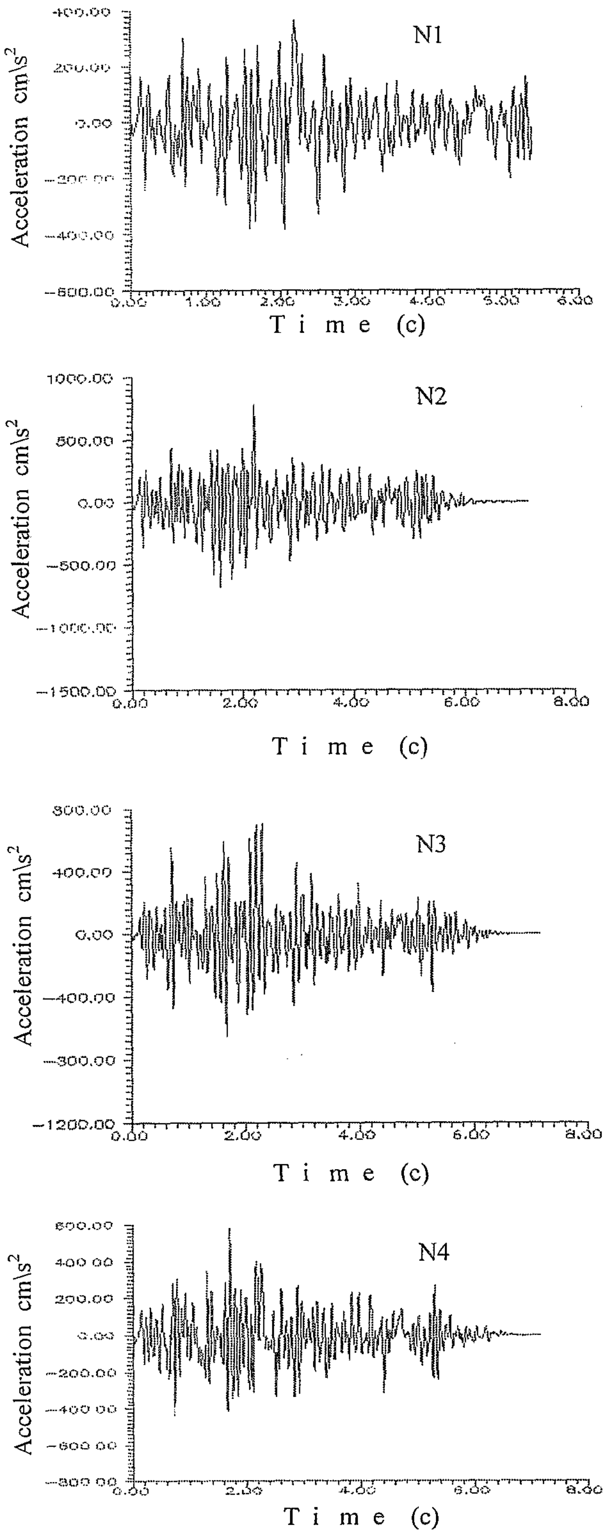

Fig. 3. The computed absolute accelerations of Azat dam: N1-bottom of the dam; N2,3- intermediate points; N4- a ridge of the dam.

Alongside with the epyura on altitude of Azat dam is considered expedient to adduce also epuras of above mentioned three investigated dams (Figure.4).

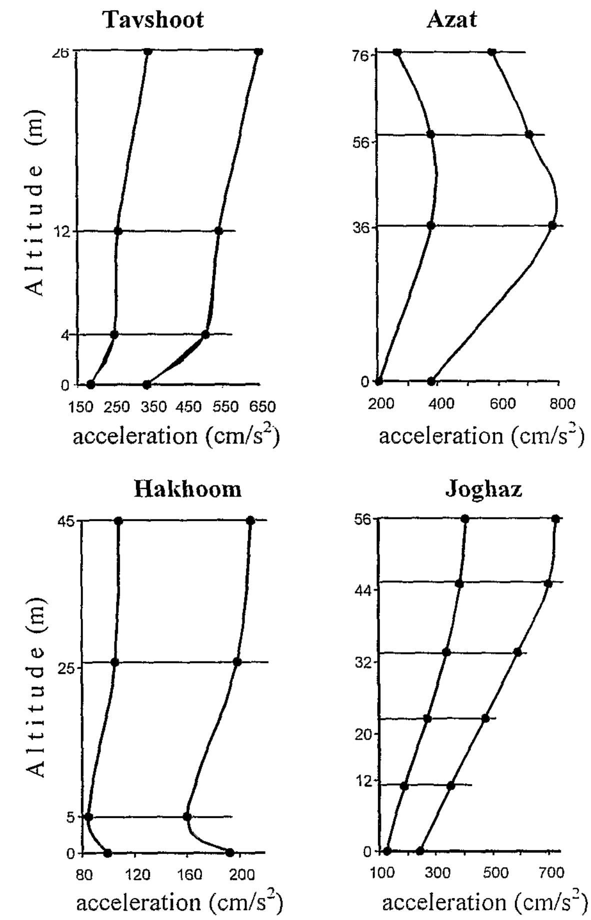

Fig. 4. Epuras of maximum (1) and average (2) accelerations.

CONCLUSIONS

As a result of the carried out researches on DSZ of the regions, where the dams are located, the initial values of maximal expected seismic hazard, marked in building code 1994, Armenia, are specified. For Azat dam after specification it has appeared equal $A_{max\ i.}$=0.396g (I_i=9.5) instead of previous estimation-0.4g, and for other dams accordingly: Tavshoot - $A_{max\ i.}$=0.277g ($I_{i.}$=8.6) instead of 0.3g; Hakhoom - $A_{max\ i}$=0.193g (I_i=8.3) instead of 0.2g; Joghaz - $A_{max\ i.}$=0.189g ($I_{i.}$=8.4) instead of 0.2g.

The values of expected maximum horizontal accelerations of territories of dams revealed in SMZ stage has appeared equal: Azat - A_{max}=0.380g (I=8.89); Tavshoot - $A_{max.}$=0.344g (I=8.75); Hakhoom - A_{max}=0.193g (I=8.3)g; Joghaz - A_{max}=0.242g (I=8.23).

Research have shown, that the dominant periods of ground conditions are in the following range: 1. rocks and gravel-pebbles with the filling less than 30% (I category) –

0.1sec<T<0.2sec; 2.gravel-pebbles with the sandy and sandy clay filling more than 30%, sandy clays and sands sometimes underplayed by rocks (II category) -0.2sec<T<0.3sec; 3.sandy clays of 15 meters underplayed by rocks, ground water level-2m (III category) – 0.3sec<T<0.35sec. The bodies of dams have values of the dominant periods in the range T=0.2-0.4s. The complex of experimental - theoretical researches has allowed to determine distribution accelerations on height of dams, beginning from the ground at the foot, and to make them epuras.

The works have shown necessity of such complex researches both before construction, and after construction of dams.

REFERENCES

Seismic Microzoning [1977]. Edited by Medvedev S.V., Moscow, «Science».

Babayan T.Ho. [1976]. Seismic Microzoning of Leninakan City Territory. In the book «Seismic microzoning», Alma-Ata, «Science».

Medvedev S.V. [1972]. Engineering Seismology. Moscow, «Science».

Babayan T.Ho. and S.S. Karapetyan [1989]. Engineering seismological Researches of the Behavior of Characteristic for Leninakan City Territory Different Grounds. Transaction's of the International Conference on a Geodesy and Seismology, Deformation and Prognosis, Moscow, 20-22.

Tikhonov A.N. and V.Ya. Arsenin [1986]. Methods of Solution of the Incorrect Problems. Moscow, «Science».

Khourgin Ya.I. and V.P. Yakovlev [1971]. Finite Functions in Physics and Engineering. Moscow, «Science».