Journal of Theoretical
and Applied Mechanics
Sofia 1993, Year XXIV No 2

ASSESSMENT OF SEISMIC EXCITATION FOR LARGE DAM SITES

H. BONCHEVA, M. KOSTOV, G. VARBANOV, A. KANEVA, D. STEFANOV

Introduction

Large dams pose a significant threat to life and property because of the great area typically included in the dams' potential flood zone downstream. This threat is intensified if the dam is located in a seismic region. The seismic safety of every large dam should be evaluated, both for newly dam designs and also for existing dams. The first step is specifying the seismic excitation – the intensity, frequency content and duration of the earthquake motions at the site. Usually the expected excitation is expressed by a design response spectrum and acceleration time histories. The determination of the probable seismic excitation at large dam sites is required by the Bulgarian seismic regulations (1987).

In the present report, problems specific for large dam sites, related to the seismic excitation evaluation are discussed. They are illustrated by examples taken from some large dams projects performed.

Seismic hazard assessment

The seismic hazard estimation requires investigations on the seismotectonics, seismicity, geology, etc. for the dam site. Prognostic seismic characteristics should be determined for two levels of safety (ICOLD, 1989) corresponding to the Maximum Design Earthquake (MDE) and the Operating Basic Earthquake (OBE), both linked with the Maximum Credible Earthquake (MCE) depending on the social hazard. These two levels are related to the acceptable risk (probability of exceedance) and reflect to the design acceleration value. The probability of exceedance of the acceleration is related to the useful life (UL) of the structure (in years) and the return period (RP) (in years) of the seismic excitation. Usually UL=50 is accepted for level OBE and UL=200 for the second level. The RP or the risk also should be accepted. In Table 1 are given results, obtained for the "Tzankov Kamak" dam site (Report, 1989). In the case of RP=1000 years, UL=50 years and probability of exceedance (PE) 4.9%, the maximum acceleration is 0.175g and 0.31g for RP=4000, UL=200 and risk 4.8%. These values were accepted as design values for the two levels.

Table 1

Return Period	Maximum Acceleration	Risk (probability of exceedance)		
		UL=50 years	UL=100 years	UL=200 years
years	m/s^2	%	%	%
100	0.75	39.5	63.4	86.6
1000	1.75	4.9	9.5	18.6
2000	2.3	2.5	4.9	9.5
3000	2.8	1.65	3.3	6.4
4000	3.1	1.24	2.4	4.8
5000	3.3	0.99	1.9	3.9

UL – useful life of the structure

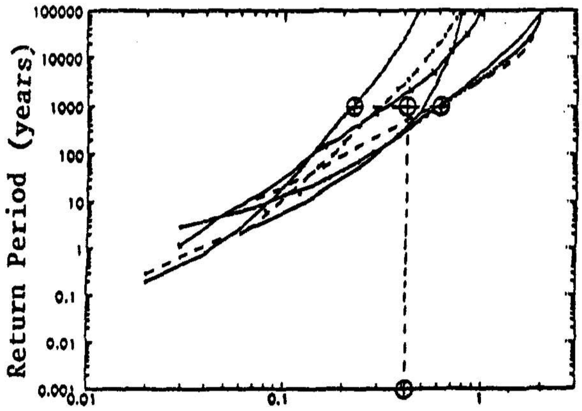

Fig. 1. Maximum Acceleration vs. Return Period for Different Attenuation Laws at "Belmeken" Dam Site.

The seismic hazard analysis is performed applying deterministic and probabilistic methods. The deterministic evaluation, using a model of the seismic sources spectra for the site of "Belmeken" dam (Report, 1992), shows the results given in Table 2. The mean and maximum values of the acceleration, velocity, displacement and duration are obtained for different magnitude ranges (M), epicentral distance (R) and stress drop (SD). The probabilistic method is applied in order to take into account the probability of earthquake occurrence, the spatial and temporal earthquake distribution. Using different attenuation laws, the results for the same site are shown graphically in Fig. 1. For RP=1000 years the average acceleration is 0.42g (accepted for design – OBE level). When the acceleration for the two levels is determined, the coefficient of importance, given in the code should be neglected.

Table 2

M	R	SD	Acceler.		Velocity		Displ.		Duration	
			mean	max	mean	max	mean	max	mean	max
	km	*bar*	m/s^2	m/s^2	m/s	m/s	m	m	s	s
7.6–8.0	25	60	3.91	5.10	.5	1.05	.22	.42	7.70	29.90
		90	5.34	7.17	.72	1.42	.29	.57	6.09	28.10
7.1–7.5	40	40	1.42	2.12	.18	.40	.07	.17	0.82	23.91
		60	2.04	2.82	.25	.52	.09	.23	8.36	20.32
6.6–7.0	40	35	.75	.99	.09	.13	.03	.06	1.95	13.16
		55	1.04	1.25	.11	.17	.04	.07	0.35	11.26
6.1–6.5	40	30	.17	.22	.06	.09	.02	.03	7.03	8.00
		40	.75	.91	.08	.12	.02	.05	6.30	7.45
5.6–6.0	25	30	.57	.82	.05	.09	.02	.03	3.90	4.70
		45	.79	1.12	.06	.12	.02	.04	3.60	4.10

Design spectra

The frequency content of the ground motion is given by the design spectrum shape. It is influenced very much by the local geology and topographic feature of the site. Because of irregular surface topography, the canyon motion should be evaluated by a set of plane models of the local geology, the assemblage of which could describe the spatial peculiarities of the site. Those models are situated perpendicular to the river stream and the results, obtained by all models (geological profiles), after statistical treatment, could be represented as normalized acceleration response spectra. The envelope of those spectra is the dynamic coefficient proposed for the design of the dam. Such spectra for the ground surface are shown in Fig. 2. The nonelastic effects in the soil medium are taken into consideration, applying the equivalent linear method of one- and two-dimensional analysis. This analysis is absolutely necessary when alluvium deposits exist (Report, 1991). The soil – structure – water interaction should be investigated also.

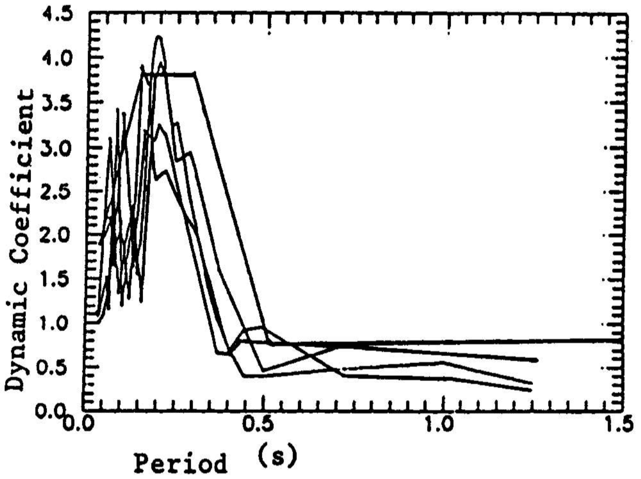

Fig. 2. Design Spectrum for "Belmeken" Dam Site.

Acceleration distribution and prognostic accelerograms

The distribution of the acceleration over the ground surface along the dam axis as well as in depth of the soil medium is required. The accelerations, determined by the seismic hazard analysis represent horizontal vectors, but three components of the ground motion should be specified. The 2D analysis gives results – horizontal and vertical components, obtained by horizontal and vertical input motion, which should be finally combined. Usually the SRSS procedure is used. The frequency content of horizontal and vertical motion could be different but commonly one design response spectrum is accepted. The maximum horizontal acceleration distribution (mean values and values with 90% probability of not–exceedance) are shown by isolines in Fig. 3a and 3b for one geological profile of the "Kardzali" dam site. Isolines of maximum vertical accelerations for another profile (in the case of a full lake) are given in Fig. 4.

The acceleration time histories required by the code could be generated on the base of the proposed design spectrum. The matching of that spectrum with the spectra of generated accelerograms is necessary but additional requirements should be given.

Conclusion

On the base of authors' experience (Reports, 1989, 1991, 1992, 1988) some recommendations for new requirements to be included in the code could be drawn. These requirements concern: two levels of safety; the area around the dam site that should be investigated; the useful life of structure and the risk value (or return period); the factor of importance; the corrections of the dynamic coefficient; the spatial acceleration distribution and combination of ground motion components; the generation of acceleration time histories; the seismicity induced by the reservoir water; second-order seismic effects, due to considerable deformations in the soil medium; etc. Respective guidelines should be elaborated.

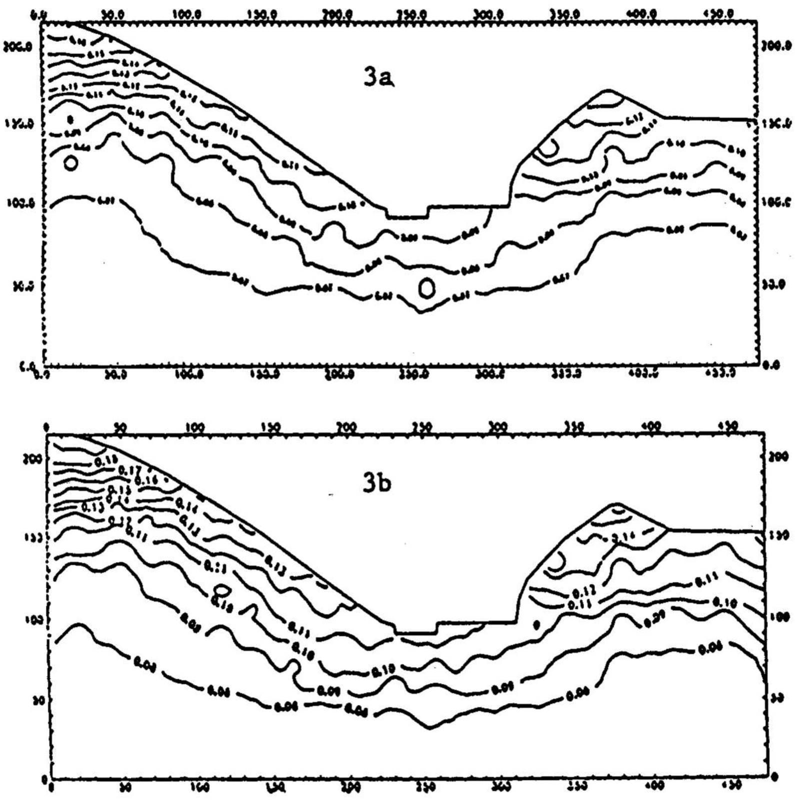

Fig. 3. Isolines of Maximum Horizontal Acceleration in a Model of "Kardzali" Dam Site.

3a – mean values

3b – 90% confidence level

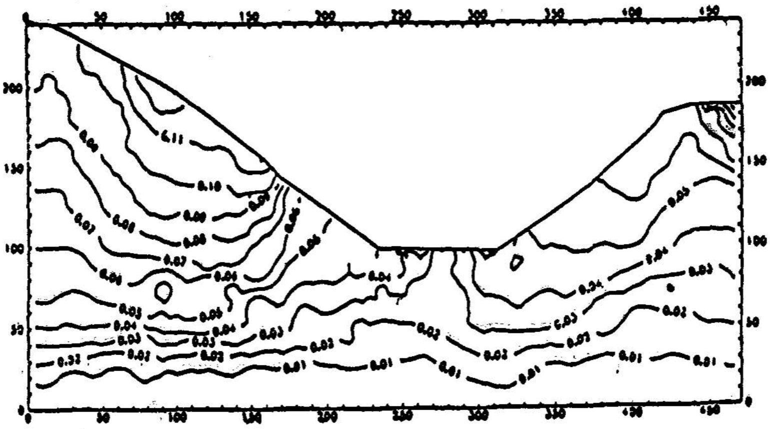

Fig. 4. Isolines of Maximum Vertical Acceleration in a Model of "Kardzali" Dam Site.

REFERENCES

[1] Regulations for Design of Buildings and Structures in Seismic Regions, Sofia, 1987

[2] ICOLD, Selecting Seismic Parameters for Large Dams, Guidelines, 1989

[3] KOSTOV, M. et al. Report on Seismic Characteristics Determination for Design of "Tzankov Kamak" Dam, Archives of Energoproject, 1989

[4] KOSTOV, M. et al. Report on Design Seismic Characteristics for "Kardzali" Dam Region, Archives of Energoproject, 1991

[5] KOSTOV, M. et al. Report on Seismic Hazard and Design Seismic Characteristics for "Belmeken" Dam Site, Archives of Energoproject, 1992

[6] BONCHEVA, H. et al. Report on Seismic Characteristics Determination for "Draginovo" Dam Site, Archives of CLSMEE, 1988

Presented at the 7th Congress on Theoretical and Applied Mechanics, Sofia, August 30 - September 1, 1993
section: Applied Mechanics