

PSHA Study Using EZ-Frisk Software Case Study Baychebaq Dam Site

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Abstract: Awareness of seismicity, is the earliest requirement in seismic design of Dam constructions. This article is devoted to study on Seismotectonic and seismicity and also seismic risk analysis of the Baychebaq reservoir dam. These studies involve detecting seismic sources and assessing seismicity parameters. According to the studies, Peak Ground Acceleration (PGA) is 0.1 gal. This PHA may be related to there activation process of Takhte Soleiman which can produce an event around 6.8 Ms in the distance of 20 km from Baychebaq dam. According to the changes of Uniform Hazard Spectrum (UHS), Spectral acceleration parameter increases from period of 0 (0.03 gal) to a period of 0.175 (0.1 gal) and then reduced slightly. Based on the results, the controlling earthquake has a magnitude of 6.1 and 6.5 Mw at a period of 0 for return periods of 475 and 2475 years.

Keywords: Baychebaq Reservoir Dam, Seismotectonic, Controlling Earthquake, Uniform Hazard Spectrum

Introduction

A level of strong ground motion can be taken to account as one of the most effective factors on the feasibility study and economic development of various structures. That's why the seismicity analyses of project developments have always been emphasized on important structures (i.e. dams, organizations and government agencies). Baychebaq reservoir dam is located at 47.23 latitude and 36.88 longitudes (decimal degrees). The site located in northwest of Iran, Zanjan province, 40km northeast of Mahneshan city. The main aim of this Dam is to controlling the floodwater of the Qalechay River, (one of the leaves of Ghezeloan River). The dam is concrete type and its height is 120 m. Dam capacity is 75-millioncube-meters. Location of the dam in comparison of the other dams in the province is significantly shown in Fig. 1.

Methodology

Probabilistic Seismic Hazard Analysis (PSHA) is a four-step operation (Reiter, 1990). The first is to identify and determine the seismic sources. The second is accountable for introducing seismicity parameters, including λ , β and M_{\max} for each source. Selecting attenuation equations is the next. Finally, at the fourth step, uncertainty of location and magnitude related to the earthquake as well as earth movement parameter has

been combined with each other and the parameters of earth movement have been estimated for the event. UHS is the response spectra which have a same evidences probability on its whole range at various periods. UHS method is prepared and designed like producing PGA (Peak Ground Acceleration) maps by probabilistic methods. The number of m attenuation relationships is applied to spectra parameters at m periods or frequencies in UHS analysis, instead of one attenuation equations for the PGA. In another word, one spectra attenuation equations are applied for calculating each spectra parameter for each probability for desired period (i.e., 0.2, 0.3, or 0.5 sec) in terms of magnitude, distance and soil conditions (Baker and Cornell, 2006a; Douglas, 2011). Finally, instead of just one PGA map, m spectra iso-acceleration maps are available for desired period. Determining the probable level (50 in 50, 10 in 50, 2% in 50 years and ...), m spectra parameters are extracted for m periods. Consequently, they are utilized for UHS preparation. The high number of calculations and their complexity are the main restrictions of this method (Baker and Cornell, 2006b; Douglas, 2011). Seismic hazard separation is a suitable tool for determining the magnitude and average distance; also, it can be applied to identify the major source of each seismic activity in various points. This method helps the researchers to determine distance, azimuth and magnitude of seismic sources (simultaneously with their magnitude and average distance). These historical and instrumental

events can be applied for dynamic analyzing and seismic retrofitting (USNRC, 1997).

Tectonic Setting

Active faults have been studied based on satellite image processing and Seismotectonic map of Iran (Berberian, 1976). Considering the process, Takhte Soleiman fault, a reverse fault which has a dip toward east and 20 km from the Dam, is the most active structure in the region which can produce the greatest acceleration at the site.

The seismic potential of faults, existed in the area, have been calculated and, finally weighted based on experimental equations between rupture length and earthquake magnitude (Ambraseys and Melville, 1982; Zare, 1995; Wells and Coppersmith, 1994a; Nowroozi, 1985) and also logic tree (Bommer *et al.*, 2008; Jarahi *et al.*, 2011), (Fig. 2 and Table 1). The rupture length (surface refaulting) has been assessed around 37% of total length of the fault (Zare, 1995).

Seismicity

Statistical Studies

In order to study maximum potential seismicity of the region and also determining dispersion of events at the site, all instrumental (Engdahl *et al.*, 2006) and historical (Ambraseys and Melville, 1982; Berberian and Arshadi, 1976) earthquakes have been collected, processed and analyzed after eliminating foreshocks and aftershocks (Powell and Duda, 1975). Moreover, in order to obtain better aspect of the seismicity potential of the region,

focal depths and magnitudes of the events which happened in the region up to 50, 100, 150 and 200 km are presented in Fig. 1 and 3. It is concluded that the average depth of events is 7.5 to 12.5 km and magnitudes between 3 shows a great range among the whole events. Furthermore, it is concluded that in the further distance the frequency of events increases significantly.

Activity Rate (λ)

One of the most fundamental parameters in accounting ground acceleration related to a seismic component is an activity rate (Kijko, 2011; Kijko and Sellevoll, 1989; Gutenberg and Richter, 1956). Rate of seismic activity at the minimum magnitude was weighted by logical tree Fig. 2 for seismic sources. Finally, with applying appropriate weight, the significant results are obtained and presented in Fig. 4. Table 2 presents specifications of seismic sources in order to apply for software's analysis, which is calculated based on previous calculation and parameters of ruptures (Wells and Coppersmith, 1994b).

Peak Horizontal Acceleration (PHA)

In this article, a probabilistic method has been used to calculate ground acceleration for different return periods. Hence, considering seismic coefficients of each source and calculating the function of magnitude probability density and applying the use of probability theory and finally performing logical tree Fig. 2, utilized attenuation relations have been weighted and curves of seismic hazard were obtained at the site. Table 3 and Fig. 6 present the results of this analysis.

Table 1: Seismic sources in the study region

Seismic source	Mechanism	Length (km)	Distance to dam (km)	M_{max} (M_W)
Takhte soleiman	Reverse	64	20	6.8
Qozlu strike	Slip	65	40	6.8
Qezelkabir	Reverse	55	43	6.7
Sangvar	Strike slip	70	54	6.8
Zanjan	Strike slip	83	55	6.9
N-Tabriz	Strike slip	140	60	7.7
Bozqush	Reverse	92	73	7.0
Khorkhoreh	Strike slip	86	93	7.0
Masuleh	Reverse	90	112	7.0

Table 2: Seismic specification applied in analysis

Seismic sources	Seismicity parameters			
	Activity rate (λ)	M_{min}	M_{max}	Beta
Takhte soleiman	1E-01	4.3	6.8	2.10
Qozlu	8E-02	4.3	6.8	2.12
Qezelkabir	8E-02	4.3	6.7	2.05
Sangvar	8E-02	4.3	6.8	1.99
Zanjan	8E-02	4.3	6.9	2.00
N-Tabriz	2E-02	4.3	7.7	2.40
Bozqush	8E-02	4.3	7.0	2.10
Khorkhoreh	6E-02	4.3	7.0	2.15
Masuleh	7E-02	4.3	7.0	2.00

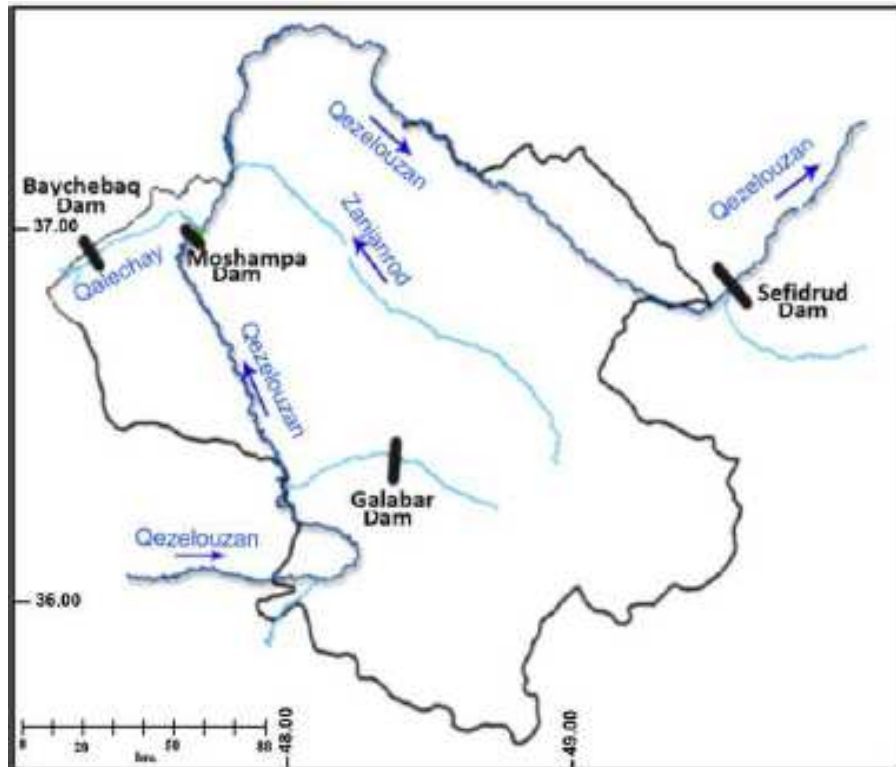


Fig. 1: Location of Baychebaq Dam across the Qezelouzan River, Zanjan province

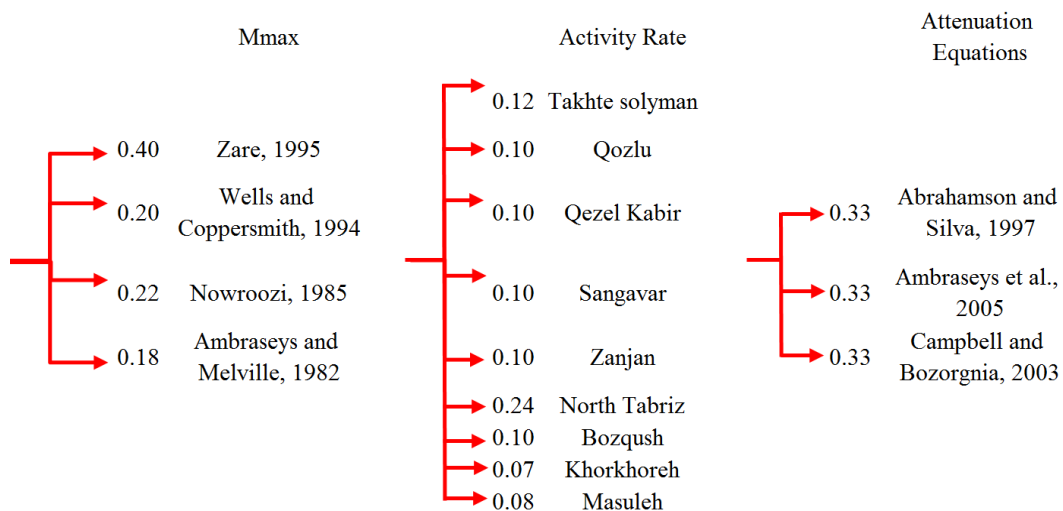


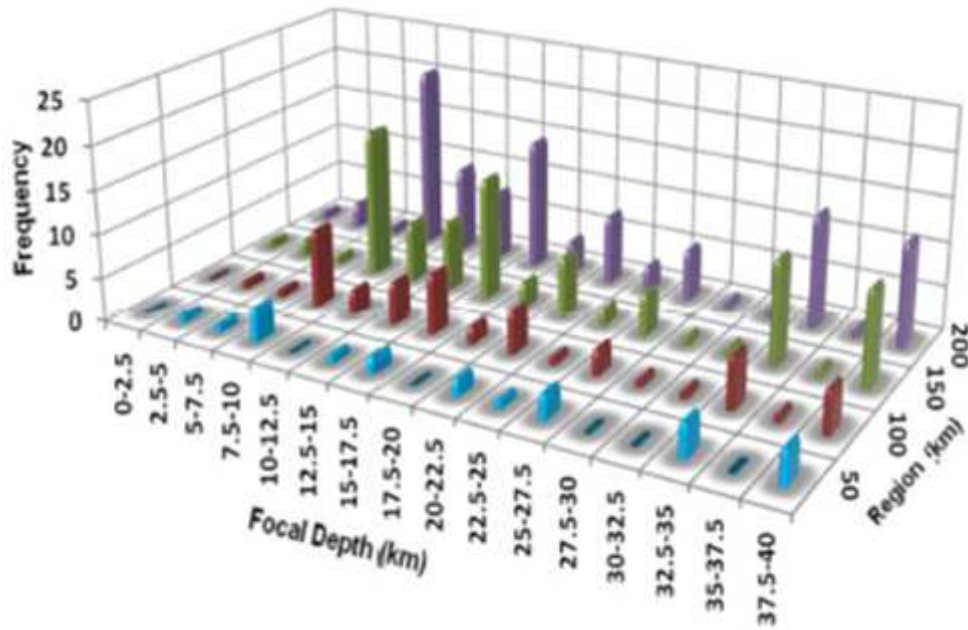
Fig. 2: The logical tree for numerical weighting (Bommer *et al.*, 2008; Jarahi *et al.*, 2011)

Table 3: Value of PHA and Annual Frequency of Exceedance (AFE) at the site

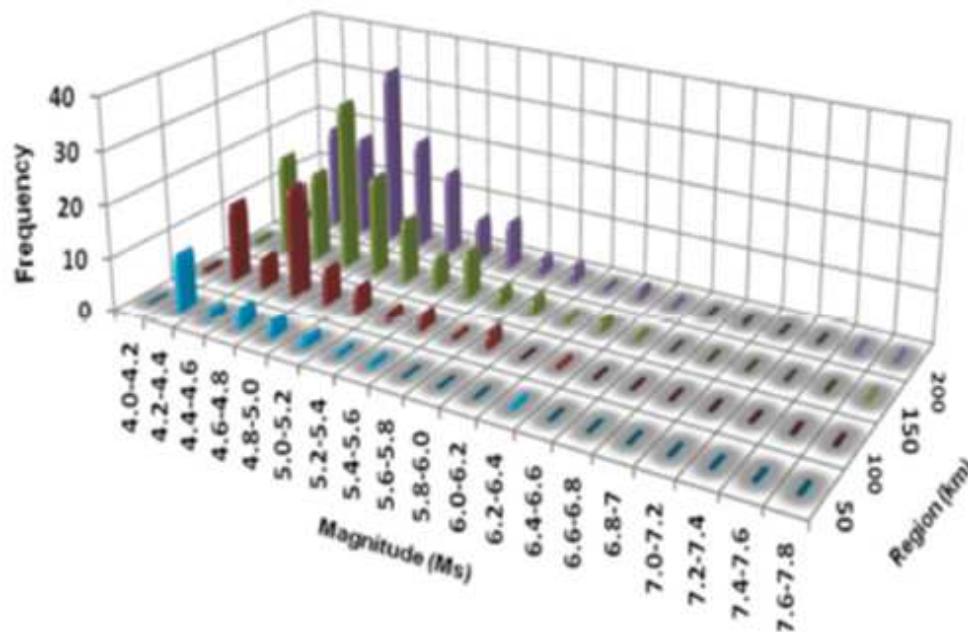
PHA (g)	AFE	Return period (year)
6E-02	2E-02	50
1E-01	1E-02	100
1E-01	7E-03	145
3E-01	2E-03	475
4E-01	1E-03	975
6E-01	4E-04	2475
8E-01	4E-04	4975

Table 4: Controlling earthquake in terms of distance for 475 and 2475 return periods

Period (second)	Distance (km)	Return Periods (year)	
		475	2475
PGA	10.5	6.1	6.5
0.2	11.6	6.1	6.5
0.5	17.2	6.5	6.5
2.0	30	6.8	6.9
4.0	32.4	7.0	7.0



(A)



(B)

Fig. 3: (A) Frequency dispersion of focal depth (B) magnitude of the earthquakes

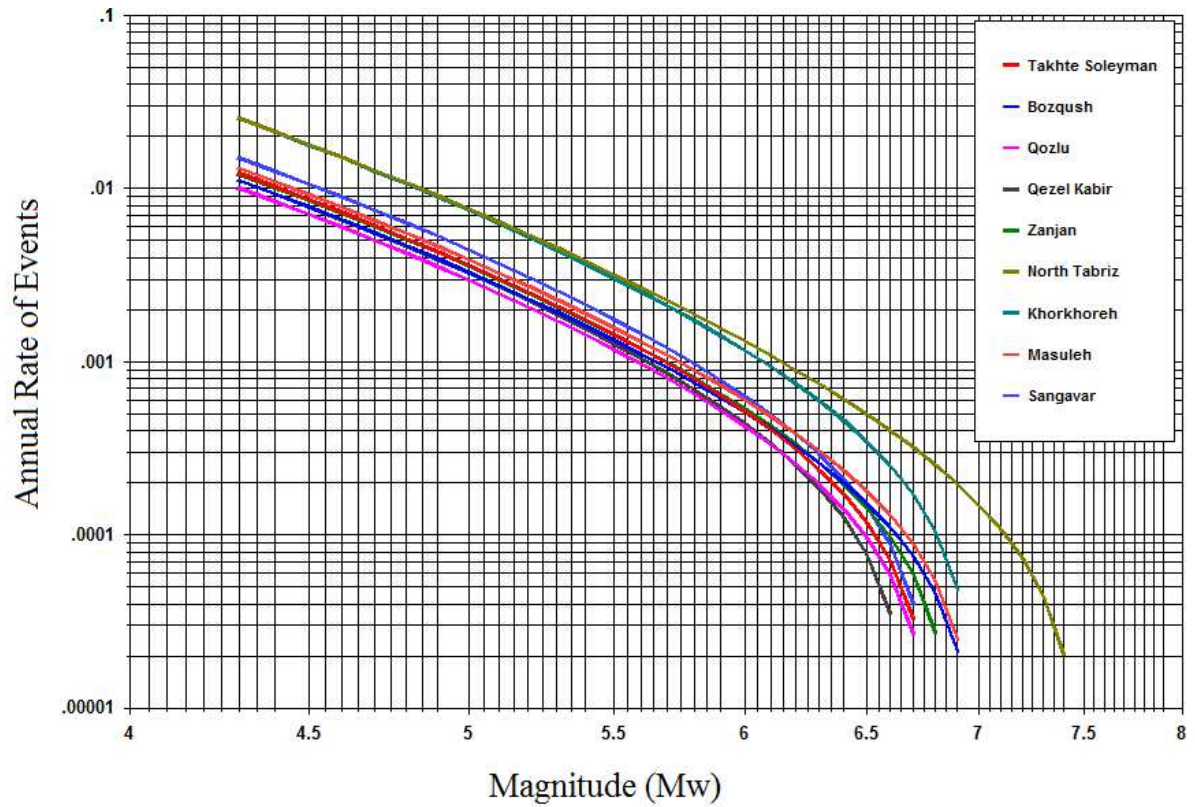


Fig. 4: Rate of seismic activity for seismic sources

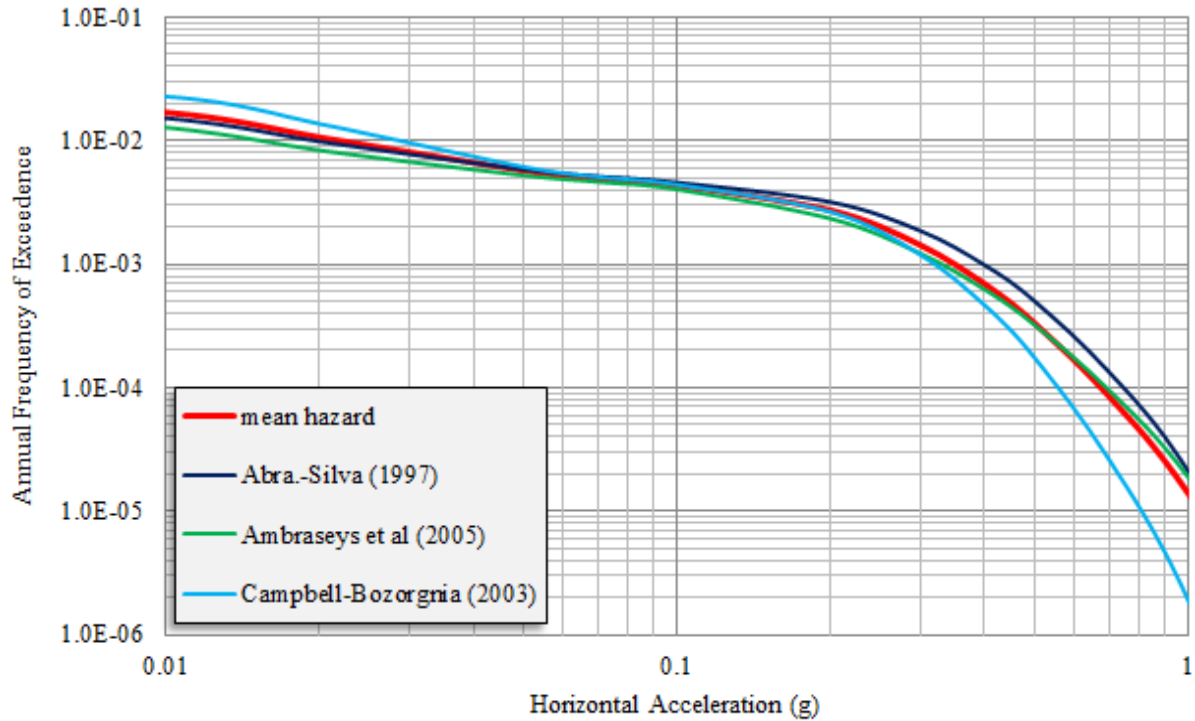


Fig. 5: The hazard curve, based on the increased

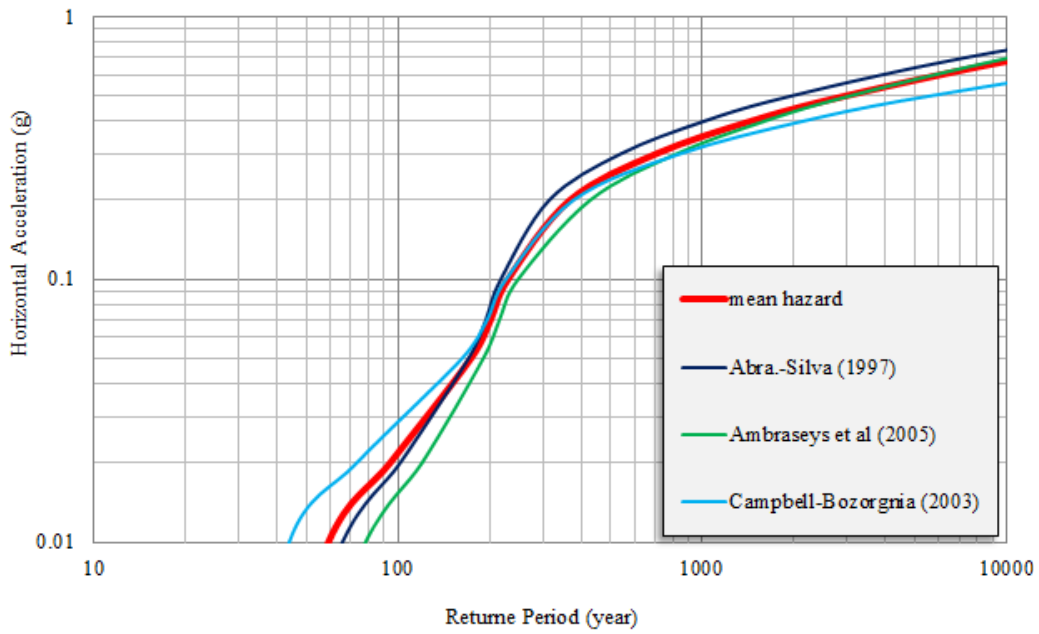


Fig. 6: The horizontal acceleration curve, based on a return period

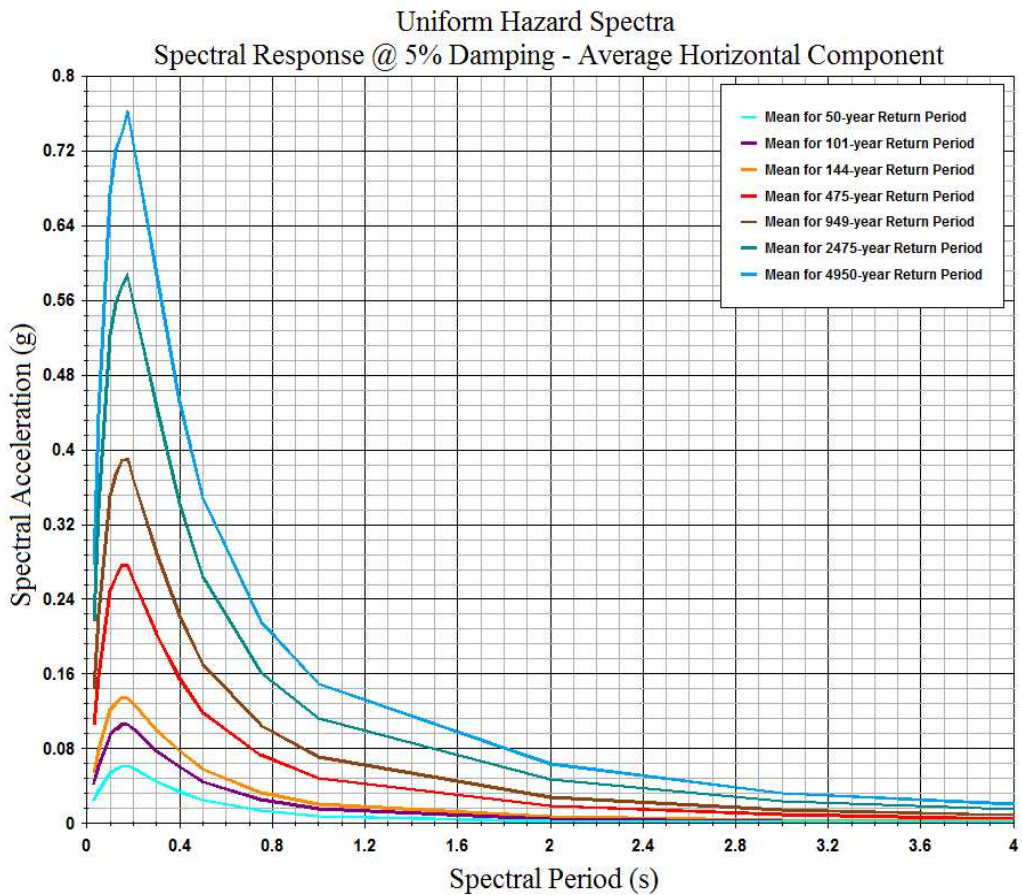


Fig. 7: The horizontal UHS, calculated by PSHA method

Uniform Hazard Spectra (UHS)

Calculating spectral acceleration (Jarahi, 2011; Jarahi *et al.*, 2015; Jarahi *et al.*, 2016; Jarahi, 2016; Haerifard *et al.*, 2018; Pourmohamad, 2006; Baker and Cornell, 2006a) is one of the most important steps in seismic designing for infrastructures like concrete dams. UHS is calculated for a period of 0 to 4 sec by probabilistic method with the unified weight (Bommer *et al.*, 2008) to each spectral attenuation equations (Abrahamson and Silva, 1997; Campbell and Bozorgnia, 2003; Ambraseys *et al.*, 2005) by using EZ-Frisk software Fig. 7. Based on the analysis, Spectral acceleration increased during a period of 0 to 0.175 sec and then it reduced dramatically.

Seismic Hazard Deaggregation (SHD)

In recent decades there has been a discussion with the earthquake risk analysis, raised as SHD (Harmsen and

Frankel, 2001; Harmsen *et al.*, 1999; Bazzurro and Cornell, 1999). Determining the relative contribution of the seismic hazard in terms of magnitude and distance is called SHD. The participation rate of seismic sources on the acceleration of the event is assessed by this parameter (for various distances and magnitudes) in order to identify the most effective source which significantly caused the greatest acceleration in the region. In this method, the seismic risk is presented by one or more major earthquakes with Magnitude (M) and distance (R) and Earthquake parameters are chosen for engineering purposes by using this pair of M and R. Figures of separated seismic hazard curves are usually presented as vertical columns which each height is proportional to the contribution of each source of seismic hazard and the horizontal axes are distance and magnitude of the earthquake as shown in Fig. 5.

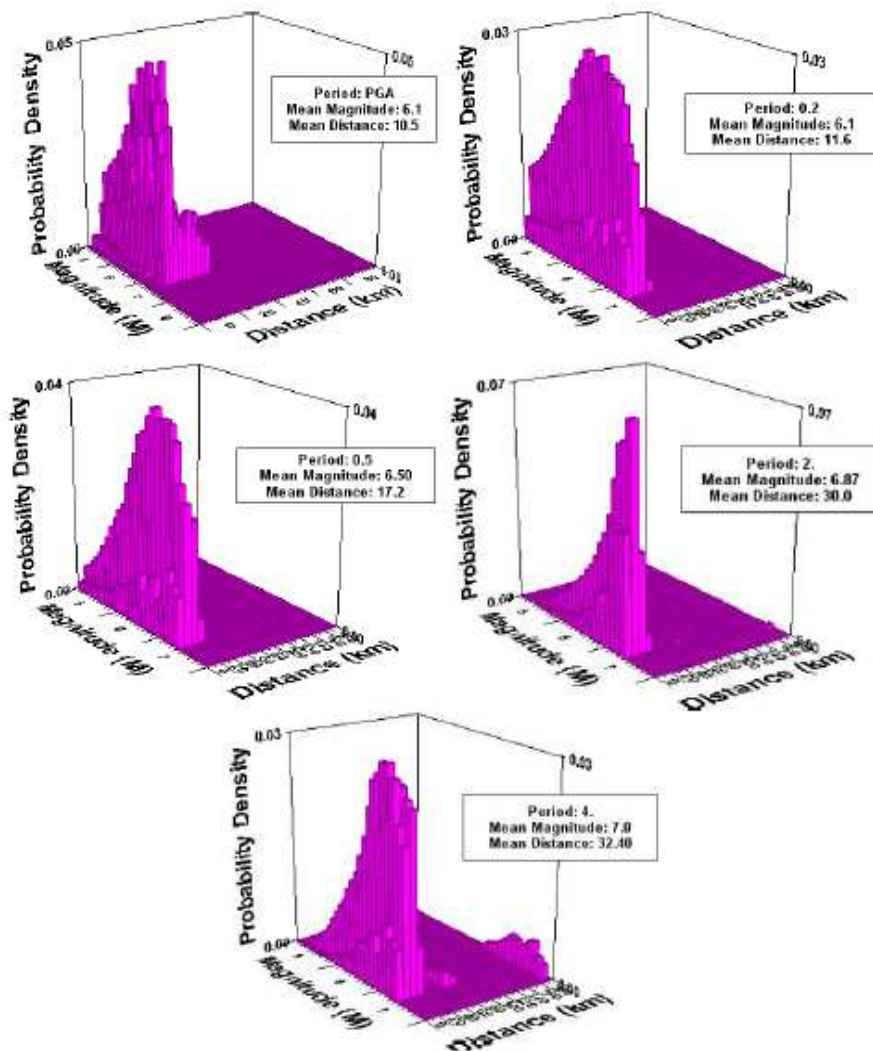


Fig. 8: Seismic hazard deaggregation (Return period of 475 years) for the particular PGA period of 0.2, 0.5, 2 and 4 sec

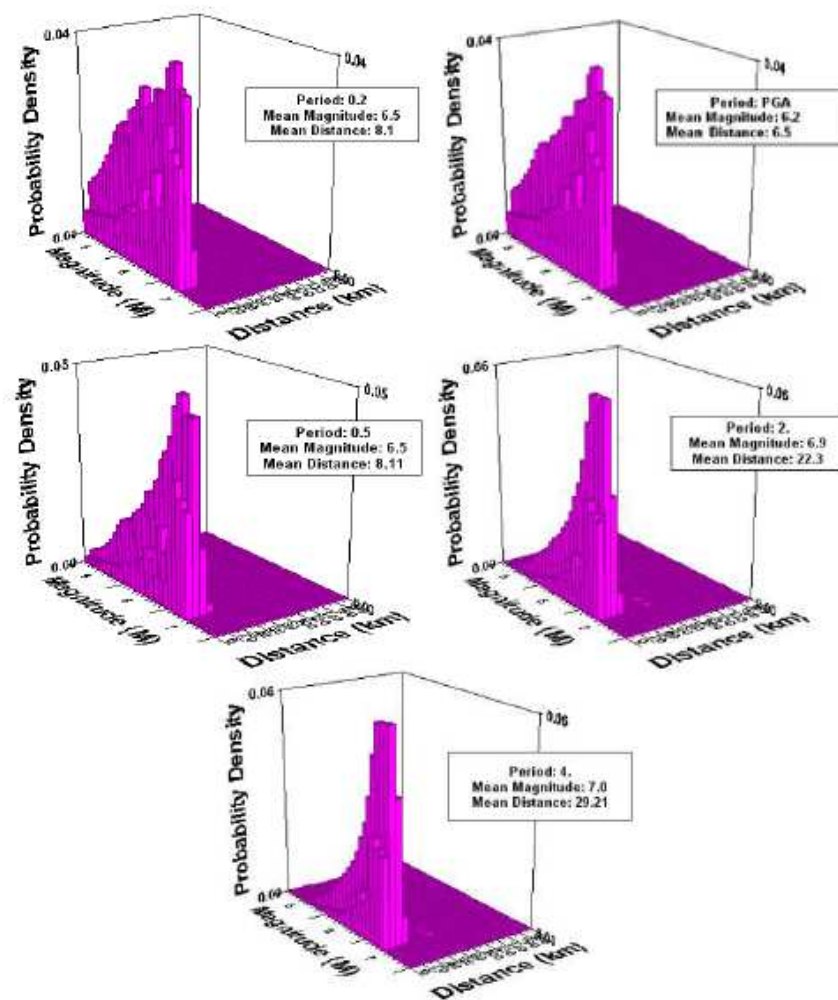


Fig. 9: Seismic hazard deaggregation (Return period of 2475 years) for the particular PGA period of 0.2, 0.5, 2 and 4 sec

In fact, the separation of PSHA stands against assessment of earthquake risk by a probabilistic method which the contributions of different sources add together in order to calculate the seismic hazard. Hence, selecting these parameters is a logical selection for simulating earthquakes. Controlling magnitude is a midpoint of a range of earthquake magnitudes that may control the design (Jarahi, 2011; Jarahi *et al.*, 2016; Jarahi, 2016). Considering SHD, the controlling earthquakes is evaluated for return periods of 475 and 2475 years with the PGA and periods of 0.2, 0.5, 2 and 4 sec (Table 4 and Fig. 8 and 9).

Conclusion

In this paper the PHA is calculated about 0.1 g at the period of 0 sec for a return period of 475 years (period of Damlife). This PHA may be related to the reactivation process of Takhte Soleiman fault which can produce an event around 6.8 Ms in the distance of 20 km from

Baychebaq Dam. According to the changes of UHS, Spectral acceleration parameter increases from the period of 0 (0.03 gal) to a period of 0.175 (0.1 gal) and then reduced slightly. In addition, the process of SHD has been obtained to determine the controlling earthquake for PGA and periods of 0.2, 0.5, 2 and 4 sec. According to the process, the controlling earthquakes have a magnitude of 6.1 and 6.5 Mw at a period of 0 sec for return periods of 475 and 2475 years. Both magnitude is located 10.5 km far from the dam.

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Ethics

This article is original and contains unpublished materials. The corresponding author confirms that all of

the other authors have read and approved the manuscript and there are no ethical issues involved.

Data and Resources

Data retrieved from the International Seismological Centre (ISC), On-line Bulletin, <http://www.isc.ac.uk>, Internatl. Seismol. Cent., Thatcham, United Kingdom, 2014.

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