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Selection of the Appropriate Methodology for Earthquake Safety Assessment of Dam Structures

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1. Introduction

Important lessons which reflect the seismic performance of dams under large earthquakes are available in the literature, (1971, San Fernando earthquake; 1985, Mexico earthquake; 1999, Kocaeli earthquake; 2001, Bhuj earthquake; 2008, Wenchuan earthquake). Seismic behavior of dams subjected to these severe earthquakes shows that earthquake safety of dams is an important phenomenon in dam engineering and requires a more comprehensive seismic studies.

Dams built on the site with high seismicity have a high-risk potential for downstream life and property. Active faults near dam sites can cause to damaging deformation of the embankment. In general, strong ground shaking can result instability of the dam and strength loss of foundations. (Seed et al., 1969; Seed et al., 1975; Jansen, 1988; Castro et al.,1985). In the last decade, large earthquakes have killed many thousands of people and caused economic devastation, commonly as a result of building failures in seismic events. Therefore, meaningful seismic parameters are needed to perform a satisfactory evaluation of dam structure (Tosun, 2002).

ICOLD (1989) stated that safety concerns for embankment dams subjected to earthquakes involve either the loss of stability due to a loss of strength of the embankment of foundation materials or excessive deformations such as slumping, settlement, cracking and planer or rotational slope failures. To obtain preliminary information about seismic parameters, the simplified procedures can be used. If the materials used in embankment are not susceptible to loss of strength and the hazard and risk ratings are low, the simplified analyses are entirely sufficient to define the seismic evaluation parameters. The safety concerns for concrete dams subjected to earthquakes involve evaluation of the overall stability of the structure, such as verifying its ability to resist induced lateral forces and moments and preventing excessive cracking of the concrete. For analyzing the loads, different procedures are performed. In the simplified analyses, peak ground motion parameters and response spectra are sufficient to define the seismic evaluation parameters. It is suggested the finite element method to be used for analyzing of most dams in high risk or hazard class.

The seismic hazard study at a dam site basically depends on the seismicity of a region, the types of structures involved and the consequences of failure. FEMA (2005) states that the design and evaluation of dams for earthquake loading should be based on a comparable level of study and analyses for each phase of the study including seismo-tectonic, geological, geotechnical and structural investigations. The level of study should reflect both the criticality of the structure and the complexity of the analysis procedures. Basic seismic studies for earthquake safety assessment of dams generally rely on existing seismological studies, available site data and simplified methods of design or evaluation developed for similar projects or structures. In other words, these studies use preliminary values of the ground motions obtained from existing studies, a simplified structural analysis and a general assessment of soil liquefaction and deformation. Detailed seismic studies involve the use of site-specific studies in evaluating the earthquake hazard and dynamic analyses for determining the response of project features to seismic loading. Detailed geological studies should define the seismic tectonic province, characterize the site, and investigate all faults that can be the source of ground shaking at the dam site.

Extensive field exploration and testing programs are necessary to perform earthquake safety assessment. The earthquake history, earthquake recurrence relationship and strong motion records should be defined by seismological investigation (Erdik et al, 1985). Structural investigations should consider all relevant factors that affect the seismic hazard at the specific site and the actual dynamic performance of the structure. Geotechnical studies should relieve the types and spatial distribution of foundation and embankment materials and the engineering properties of soil and rock, liquefaction potential of the foundation and embankment soils, stability of natural and artificial slopes and estimation of deformations. The final results of all studies should be used as a basis for making design or evaluation decisions and for designing remedial measures.

2. Selection of design and safety evaluation earthquake

The selection of site-dependent seismic input is an important stage for determining the safety evaluation of dam structures. The earthquakes have been specified by different terms such as the Operating Basis Earthquake (OBE), the Maximum Credible Earthquake (MDE) and the Safety Evaluation Earthquake (SEE). These earthquakes have been defined by separate organization with different value. FEMA (2005) has meaningfully defined those earthquakes in recent. Their short definitions are given below as based on this guideline of FEMA.

2.1 Operating Basis Earthquake (OBE)

This earthquake is defined for the ground motions at the site to be expected to occur within the service life of the project. FEMA (2005) states that the associated performance requirement is that the project function with little or no damage and without interruption of function. The OBE means to protect against economic losses from damage or loss of service. Consequently, the return period of the OBE can be based on economic considerations.

2.2 Maximum Credible Earthquake (MCE)

According to FEMA (2005), this is the largest earthquake magnitude that could occur along a recognized fault or within a particular seismo-tectonic province or source area under the

current tectonic framework. The loading resulting from MCE can be exceeded for probabilistic methods, which is discussed later on, for high return period faults close in, such as North Anatolian Fault in Turkey and San Andreas Fault in USA.

2.3 Maximum Design Earthquake (MDE) or Safety Evaluation Earthquake (SEE)

The MDE is the earthquake that produces the maximum level of ground motion for which a structure is to be designed, while SEE is defined just for safety evaluation. These earthquakes may be considered as earthquakes which are equal to the MCE or to a design earthquake less than the MCE. As based on the FEMA (2005), the associated performance requirement for the MDE or SEE is that the project performs without catastrophic failure, such as uncontrolled release of a reservoir, although significant damage or economic loss may be tolerated.

Earthquake ground motions at a particular site are estimated through a seismic hazard evaluation. The geologic and seismologic inputs needed for completing a seismic hazard evaluation. Two different methods are widely used for describing earthquake ground motions for seismic design. These are the deterministic seismic hazard analysis (DSHA) and the probabilistic seismic hazard analysis (PSHA). According to Kramer (1996), DSHA considers a seismic scenario that includes a four-step process. This procedure gives rational solutions for large dams because it provides a straightforward framework for evaluation of the worst situation. The DSHA procedure is outlined as below and introduced schematically in Figure 1.
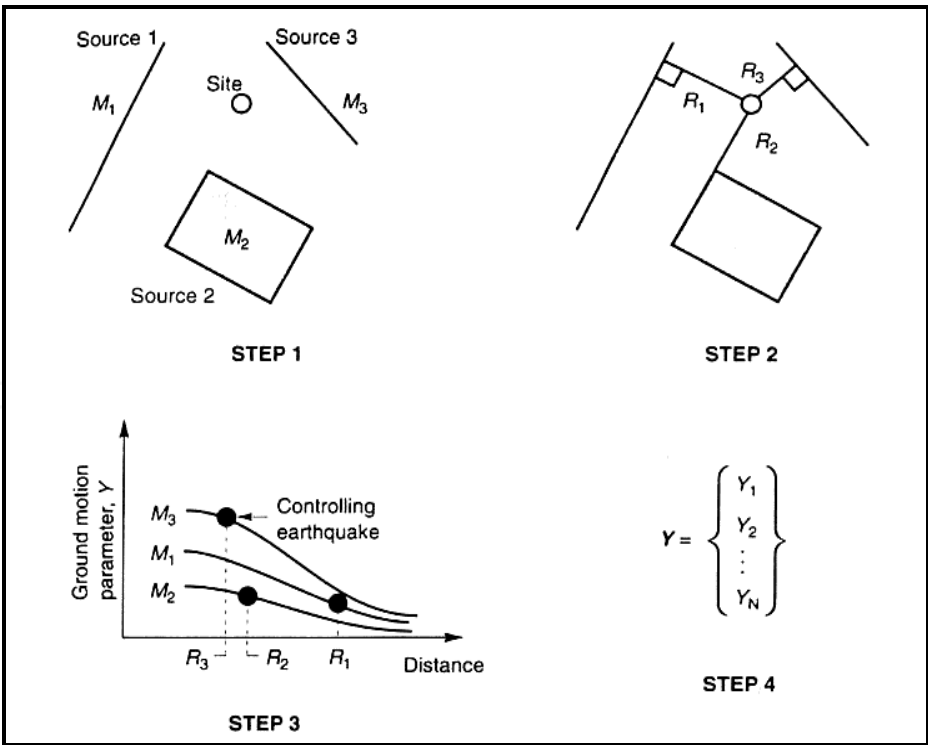

Fig. 1. Four steps of deterministic seismic hazard analysis (Kramer, 1996)

1. Identification and characterization of all earthquake sources capable of producing significant ground motion at the site.

2. Selection of a source-to-site distance parameter for each source zone.
3. Selection of the controlling earthquake.
4. Definition of hazard at the site in terms of the ground motions produced at the site by controlling earthquake.

PSHA has allowed the uncertainties in the size, location and rate of recurrence of earthquakes, as well as in the variation of ground motion characteristics with earthquake size and location, to be explicitly considered in the evaluation of seismic hazards (Figure 2). This method is generally similar with DSHA and outlined as follows:

1. Identification and characterization of earthquake sources.
2. Characterization of seismic activity and temporal distribution of earthquake recurrence.
3. Determination of ground motion with use of predictive relationships.
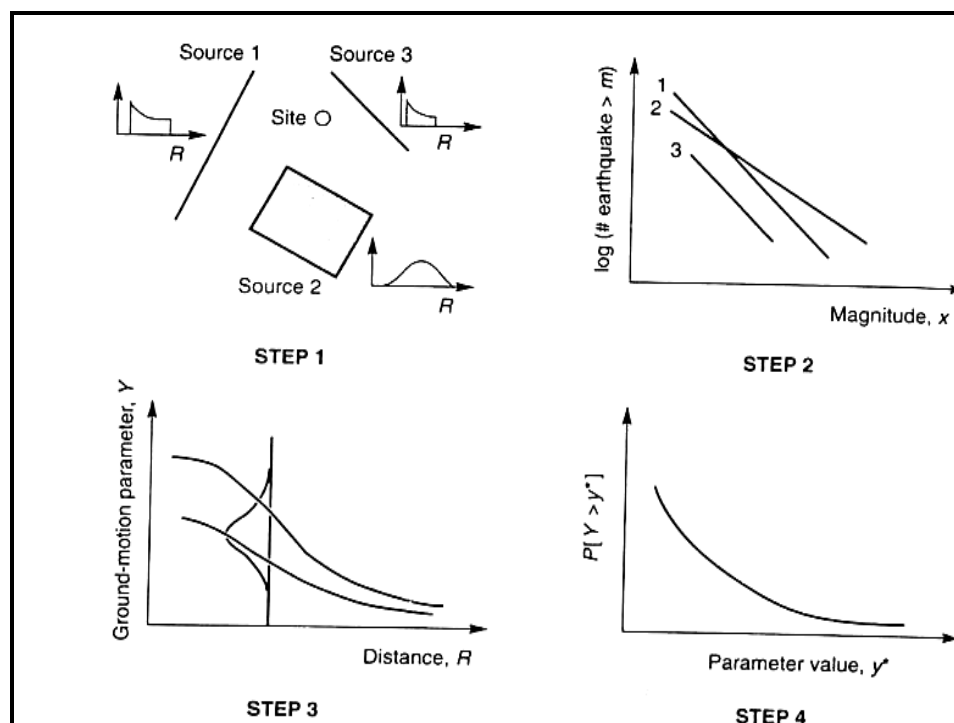4. Prediction of ground motion parameters

Fig. 2. Four steps of probabilistic seismic hazard analysis (Kramer, 1996)

DSHA and PSHA have been performed by different researchers in specific sites according to their project goals and importance (Chandler et al. 2001; Fat-Helbary and Tealb 2002; Al-Homoud, 2003; Ardeleanu et al. 2005; Simeonova et al. 2006; Orhan et al. 2007; Nakajima et al. 2007; Tosun and Seyrek, 2006; Tosun et al. 2007; Seyrek and Tosun, 2011).

Both probabilistic and deterministic methods have a role in hazard and risk analyses performed for decision-making purposes. One method may have priority over the other, depending on the seismic environment and the scope of the project (McGuire 2001). McGuire (2001) claims that the analysis of a specific site usually requires a probabilistic approach, but a deterministic check on the resulting decision is appropriate. Generally seismic sources contribute to the seismic hazard and risk at a site, and the integration of these through a probabilistic analysis provides the most insight.

Orozova and Suhadolc (1999) express that all the earthquakes with different magnitudes and distance influences the seismic hazard at a site and PSHA correctly reflects the actual knowledge of seismicity. Another advantage of probabilistic approach is that offers a rational framework for risk management by considering the frequency or probability of exceedance of the ground motion against which a structure or facility is designed (Bommer and Abrahamson 2006).

A severe criticism of PSHA came from Castanos and Lomnitz (2002), who consider that the problem with PSHA is that its data are inadequate and its logic is defective. They suggest that the deterministic procedures especially when coupled with engineering judgment to be more reliable and more scientific.

3. Methods of analysis

In this section, seismic hazard analysis results for two different methodology presented in previous section will be discussed by using acceleration values of dam site locations subjected to different seismicity and geological setting.

For the seismic hazard analysis of the dams in Turkey, all possible seismic sources were identified and their potential was evaluated in detail, as based on the guidelines given by Fraser and Howard (2002). Various seismic source models and active fault maps have been previously reported in Turkey (Yücemen, 1982; Erdik et al. 1985; Erdik et al. 1999; Şaroğlu et al. 1992; Kayabalı and Akın, 2003; Ulusay et al. 2004). These seismic-source models have been modified taking advantage of recent neotectonic and seismic data for Turkey (Figure 3). The data about 20th century instrumentally recorded earthquakes for Turkey and vicinity
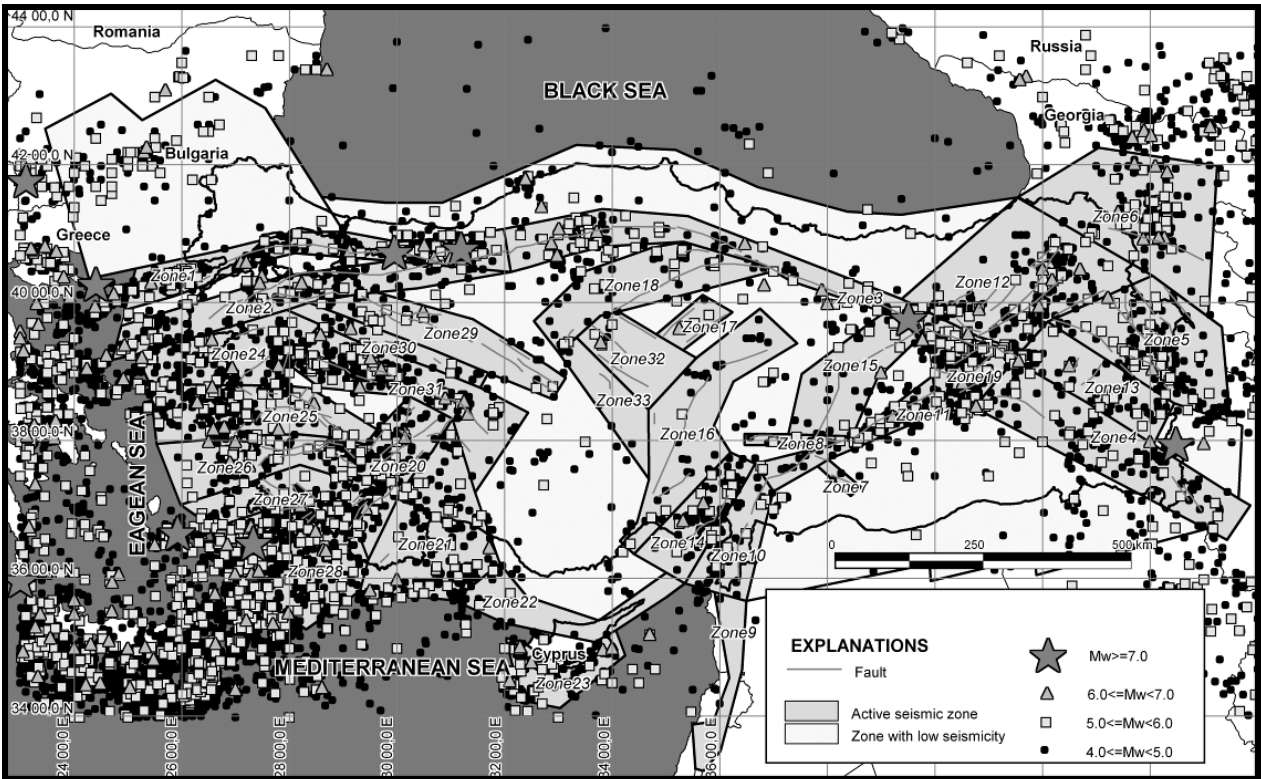

Fig. 3. Seismo-tectonic map of Turkey

were collected by the Bogazici University Kandilli Observatory and Earthquake Research Institute, National Earthquake Monitoring Center. It should be noted that moment magnitude scale is used for hazard calculations.

To research the effect of seismic hazard models on the results, Altinkaya, Ayhanlar, Boztepe, Hatap ve Kilickaya dam sites are considered (Figure 4). Three of them are located in Yesilirmak basin and others are in Kizilirmak basin. The neotectonics of the region around the dams is governed by four major elements: (1) the North Anatolian Fault (NAF), which is the main structural feature in the basin, (2) the Ezinepazari Fault, which lies in south-west direction as a secondary feature of NAF, (3) Ecemis Fault, which starts from Mediterranean Sea at the south and has approximately same direction as Ezinepazari Fault. (4) Shear zone including secondary faults at the central part of basin (Figure 4).

The North Anatolian Fault is one of the best-known strike-slip faults in the world, because of its significant seismic activity and well developed surface features. It is approximately 1,500 km long and extends from eastern Turkey at the east to Greece at the west. Its width ranges from a single zone of a few hundred meters to multiple shear zones of 40 km. This fault produces very large earthquakes, which have resulted in the death of one thousand people and severe structural damages. The Ezinepazari fault which is a secondary branch of NAF has approximately 260 km length and extends to the central part of Anatolia in south-west direction. Its width can be defined by a single zone of a few hundred meters. This zone also comprises the Bala fault, which recently generated the earthquake near Ankara city, and Merzifon fault, which is known as the source of large earthquakes occurred in the past. The Ecemis fault, presently called as Central Anatolian Fault Zone, is also a strike-slip fault, which is located at the southern part of basin. It is composed of several Fault segments and its width ranges from 2 to 15 km. Kocyigit and Beyhan (1997) stated that this fault connects to the North Anatolian Fault and extends to south as far as the Hellenic trench, reaching up to several hundred kilometers in length. The shear zone, which is located from the central part to the south-west of Kızılırmak basin, contains structural features such as Kırsehir, Gumuskent, Delice, Akpinar, and Bala faults. Seyrek and Tosun (2011) remark that this zone has low seismic activity, although an earthquake with moderate magnitude occurred in 1938.

During the analysis process, seismic zones and earthquakes within the area having a radius of 100 km around the dam site were considered. Deterministic and probabilistic seismic hazard analyses were performed by the computer program DAMHA, which was developed at the Earthquake Research Center, Eskişehir Osmangazi University. DAMHA is capable of performing the deterministic and probabilistic seismic hazard analyses on digitized tectonic map of Turkey. This program includes databases for earthquakes, faults, area seismic sources and attenuation equations (Seyrek, 2009). This program calculates the probabilistic hazard for three hazard level as OBE, MDE and SEE. These levels correspond to the return periods of 144, 475 and 2475 years respectively.

For horizontal peak ground acceleration calculation, eight separate predictive relationships (Campbell, 1981; Boore et al. 1993; Campbell and Bozorgnia, 1994; Ambraseys et al. 1995; Boore et al. 1997; Gülkan and Kalkan, 2002; Kalkan and Gülkan, 2004; Ambraseys et al. 2005) were considered. It is clear that the use of several attenuation laws can result in more reliable evaluation than a single relationship (ICOLD 1989). It was noted that Gülkan and

Kalkan (2002) and Ambraseys et al. 2005 were derived from Turkey earthquakes. Other attenuation relationships used for this study were selected owing to the similarities between the mechanisms of North Anatolia Fault Zone and San Andreas Fault.
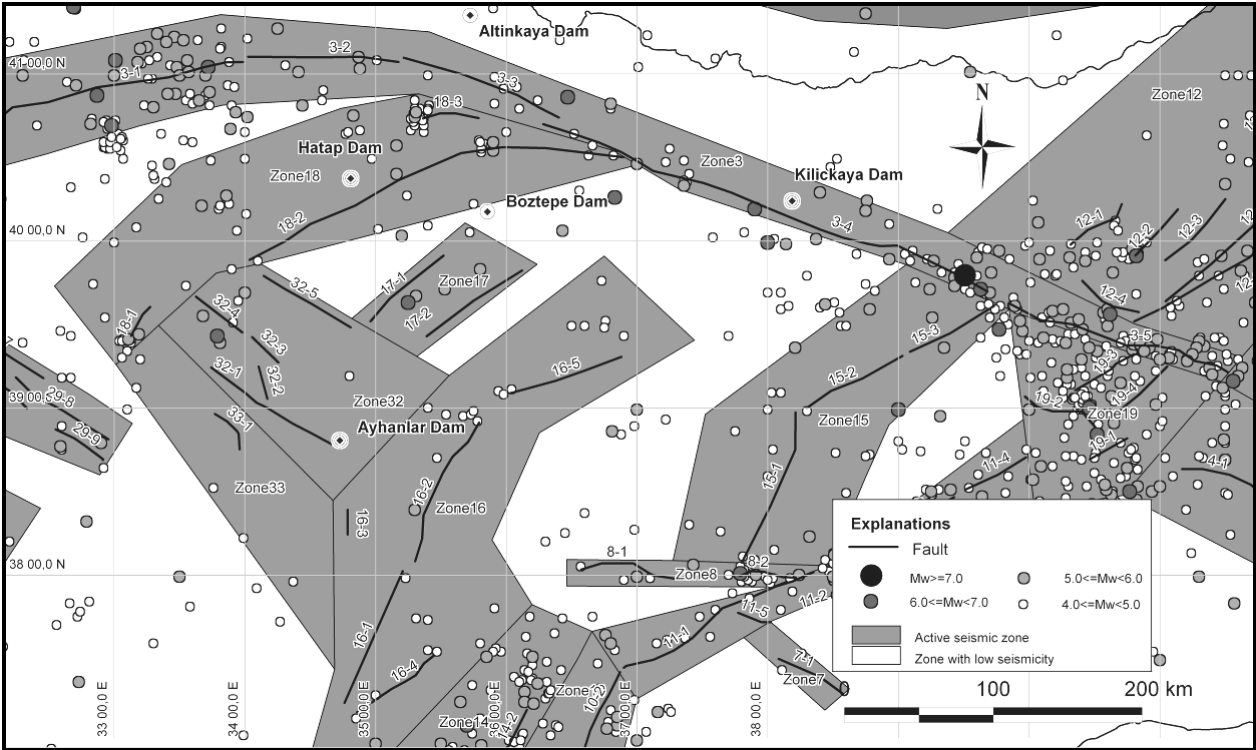

Fig. 4. Locations of dams on seismo-tectonic map

One of the most important parameters of source seismicity is the size (magnitude) of the maximum earthquake. The general assumption is that one-third to half of the total length of the fault would break when it generates the maximum earthquake (Mark, 1977). In this study, for each source the maximum earthquake magnitude was determined using the empirical relationships proposed by Wells and Coppersmith (1994) as given in Table 1. Where M_w is the earthquake moment magnitude and L is the fault rupture length in km.

Fault type	Equation
Strike slip	$M_w = 5.16 + 1.12 \log L$
Reverse	$M_w = 5.00 + 1.22 \log L$
Normal	$M_w = 4.86 + 1.32 \log L$
All	$M_w = 5.08 + 1.16 \log L$

Table 1. Relationship between earthquake magnitude (M_w) and rupture length (L)

Once the maximum earthquake magnitude is determined for each seismic source, a linear regression is performed to estimate the coefficients of Gutenberg-Richter (1944) relationship using the computer program DAMHA. Orhan et al. (2007) express that the records which have a magnitude equal to or greater than 4.0 is more credible in Turkish earthquake catalogue.

4. Analyses and results

For the seismic hazard analyses of the dam sites, a detailed study was performed. Local geological features and seismic history referred in previous section were used to quantify the rate of seismic activity in the basin. To present the effect of methodology on seismic hazard results, five dam sites are chosen. Below, details of analysis results will be given for each dam site.

4.1 Altinkaya dam

Altinkaya dam with a storage capacity of 5763 hm³ is also located on a Kizilirmak river (Figure 5). It was designed as rockfill dam and its construction was finished in 1988. Its height from river bed is 195 meter. It produces electricity of 1632 GWh per year with an installed capacity of 700 MW. Altinkaya dam is one the most important dam projects in Kizilirmak basin.

Fig. 5. View of the Altinkaya dam

As a result of detailed evaluation, two seismic sources are considered for hazard calculations. Seismic parameters used for hazard assessment are given in Table 2.

Results of deterministic and probabilistic analyses are given in Table 3. It should be noted that each PGA value introduced for a dam site in these tables represent the average of those obtained from eight different attenuation relationships discussed in previous section. Total seismic hazard curve of Altinkaya dam site is presented in Figure 6. PGA value for SEE level is 0.25 g.

Zone no	Fault no	Fault name	Fault type*	M_{max}	a**	b**
3	3-1	North Anatolian Fault Zone Segment	SS*	7.7	5.172	0.684
	3-2	North Anatolian Fault Zone Segment	SS	7.4		
	3-3	North Anatolian Fault Zone Segment	SS	7.4		
	3-4	North Anatolian Fault Zone Segment	SS	7.9		
	3-5	North Anatolian Fault Zone Segment	SS	7.6		
18	18-1	Bala Fault	N	6.7	5.457	0.878
	18-2	Ezinepazari Fault	SS	7.9		
	18-3	Merzifon Fault	SS	6.9		

* SS : Strike slip   N: Normal
**from Gutenberg-Richter (1944) law

Table 2. Hazard parameters of seismic sources for Altinkaya dam site

Critical Zone	Critical Segment	Closest distance (km)	PGA (g)				
			DSHA		PSHA		
			50th percentile	84th percentile	OBE	MDE	SEE
3	3-3	39.8	0.11	0.19	0.13	0.18	0.25

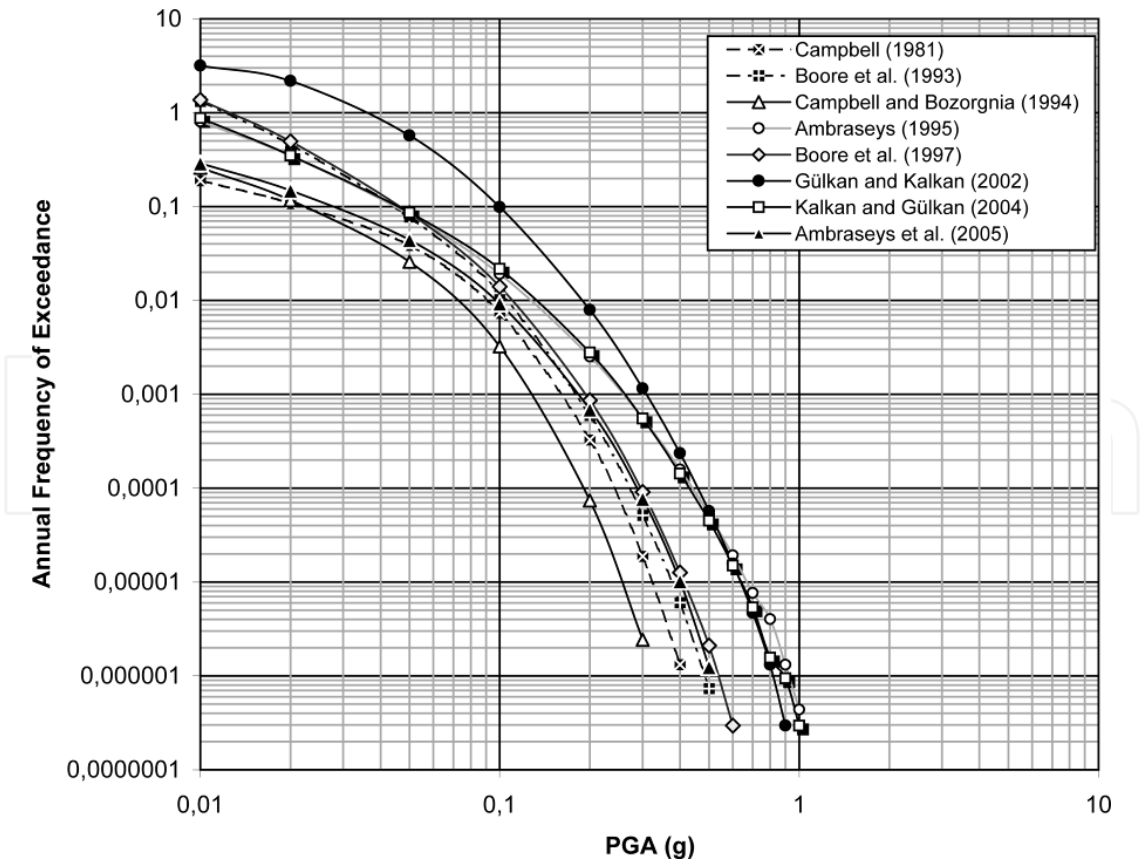Table 3. DSHA and PSHA results for Altinkaya dam site

Fig. 6. Seismic hazard curve for Altinkaya dam site

4.2 Kilickaya dam

Kilickaya dam is one of the large dams located in Yesilirmak basin and was constructed on Kelkit river for energy and flood control purposes. It was designed as rockfill dam and finished in 1990. When the reservoir is at normal capacity, the facility impounds 1400 hm³ of water with a reservoir surface area of 64 km². It has a height of 103 m from river bed. It produces the electricity with an installed capacity of 124 MW (Figure 7).

Fig. 7. View of the Kilickaya dam

North Anatolian Fault Zone and Malatya Ovacik Fault Zone are taken into consideration for hazard calculations. Seismic parameters used for hazard assessment are given in Table 4.

Zone no	Fault no	Fault name	Fault type*	M_{max}	a**	b**
3	3-1	North Anatolian Fault Zone Segment	SS*	7.7	5.172	0.684
	3-2	North Anatolian Fault Zone Segment	SS	7.4		
	3-3	North Anatolian Fault Zone Segment	SS	7.4		
	3-4	North Anatolian Fault Zone Segment	SS	7.9		
	3-5	North Anatolian Fault Zone Segment	SS	7.6		
15	15-1	Malatya Ovacik Fault Zone	SS	7.4	4.084	0.626
	15-2	Malatya Ovacik Fault Zone	SS	7.2		
	15-3	Malatya Ovacik Fault Zone	SS	7.2		

* SS : Strike slip
**from Gutenberg-Richter (1944) law

Table 4. Hazard parameters of seismic sources for Altinkaya dam site

The analyses show that the most critical zone is North Anatolian Fault Zone and closest distance from this seismic source to dam site is 11.0 km. PGA value for 84th percentile is greater than SEE level (Table 5). Total seismic hazard curve of Altinkaya dam site is presented in Figure 8. PGA value for 84th percentile is greater than SEE level.

Critical Zone	Critical Segment	Closest distance (km)	PGA (g)				
			DSHA		PSHA		
			50th percentile	84th percentile	OBE	MDE	SEE
3	3-4	11.0	0.37	0.60	0.17	0.26	0.40

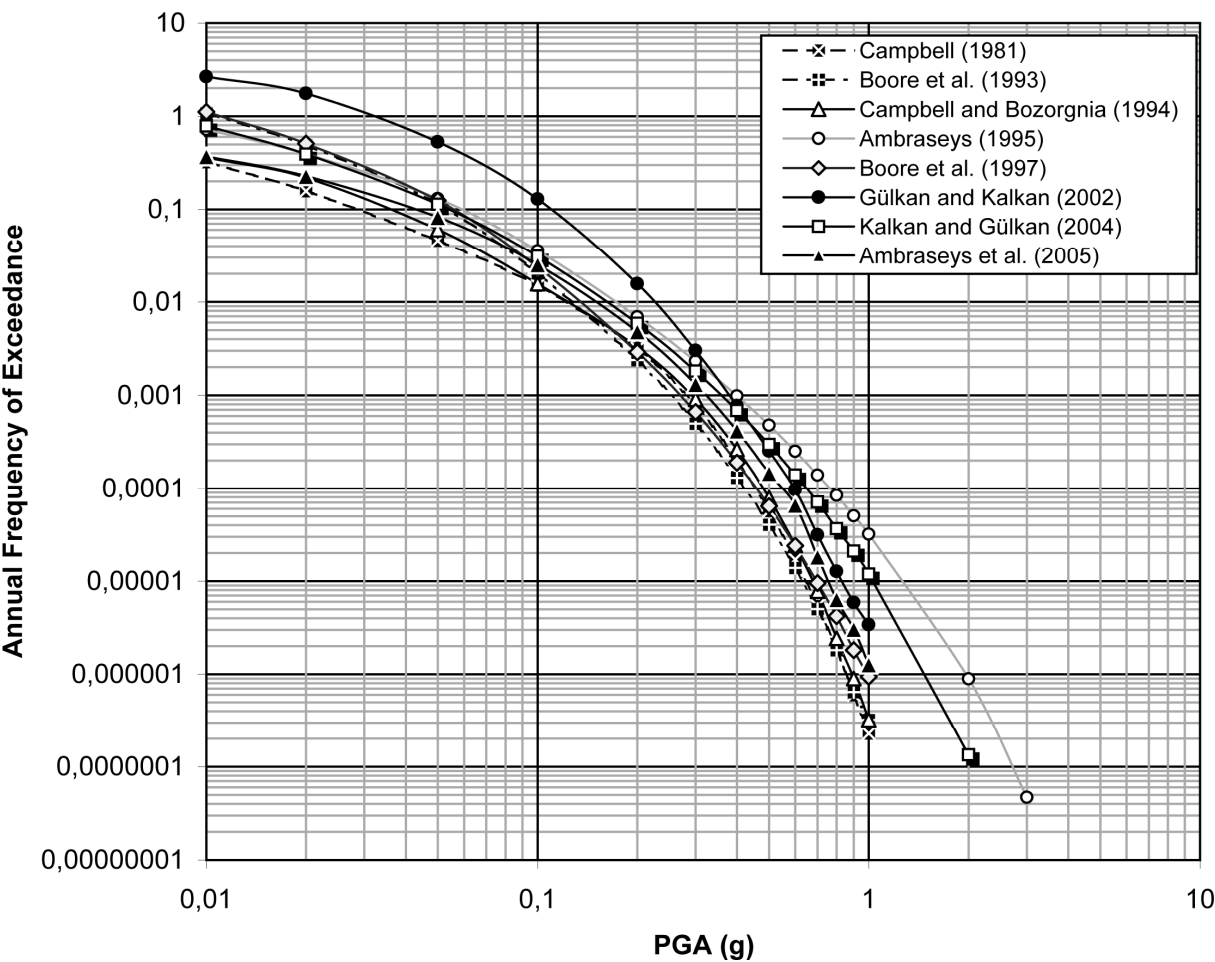Table 5. DSHA and PSHA results for Kilickaya dam site

Fig. 8. Seismic hazard curve for Kilickaya dam site

4.3 Hatap dam

Hatap dam with a body volume of 1.25 hm^3 was designed as rockfill dam with a clay core. The construction of the dam was finished in 2009. It is located on the Hatap creek and has

42-m height from river bed (Figure 9). Main purposes are irrigation and water supply. When the reservoir is at normal capacity, the facility impounds 11.6 hm^3 of water with a reservoir surface area of 1.02 km^2.

The project site are affected from source zone 3, 17, 18 and 32. Seismic parameters used for hazard assessment are given in Table 6.

Zone no	Fault no	Fault name	Fault type*	M_{max}	a**	b**
3	3-1	North Anatolian Fault Zone Segment	SS*	7.7	5.172	0.684
	3-2	North Anatolian Fault Zone Segment	SS	7.4		
	3-3	North Anatolian Fault Zone Segment	SS	7.4		
	3-4	North Anatolian Fault Zone Segment	SS	7.9		
	3-5	North Anatolian Fault Zone Segment	SS	7.6		
17	17-1	Sorgun Fault	SS	7.2	2.655	0.413
	17-2	Sarikaya Akdagmadeni Fault	SS	7.3		
18	18-1	Bala Fault	N	6.7	5.457	0.878
	18-2	Ezinepazari Fault	SS	7.9		
	18-3	Merzifon Fault	SS	6.9		
32	32-1	Gumuskent Fault	SS	7.4	3.054	0.476
	32-2	Kirsehir Fault	SS	6.6		
	32-3	Akpinar-Kirsehir Fault Zone	SS	6.7		
	32-4	Akpinar-Kirsehir Fault Zone	SS	6.9		
	32-5	Delice(Yerkoy) Fault	SS	7.2		

*SS: Strike slip N: Normal U: Unknown
**from Gutenberg-Richter (1944) law

Table 6. Hazard parameters of seismic sources for Hatap dam site

Seismic hazard analysis results are presented in Table 7. The critical segment is Ezinepazari Fault with a closest distance of 17.7m from dam site. Figure 10 gives the probabilistic hazard curve based on different attenuation relationships. Average PGA values are 0.16, 0.24 and 0.37 g respectively.
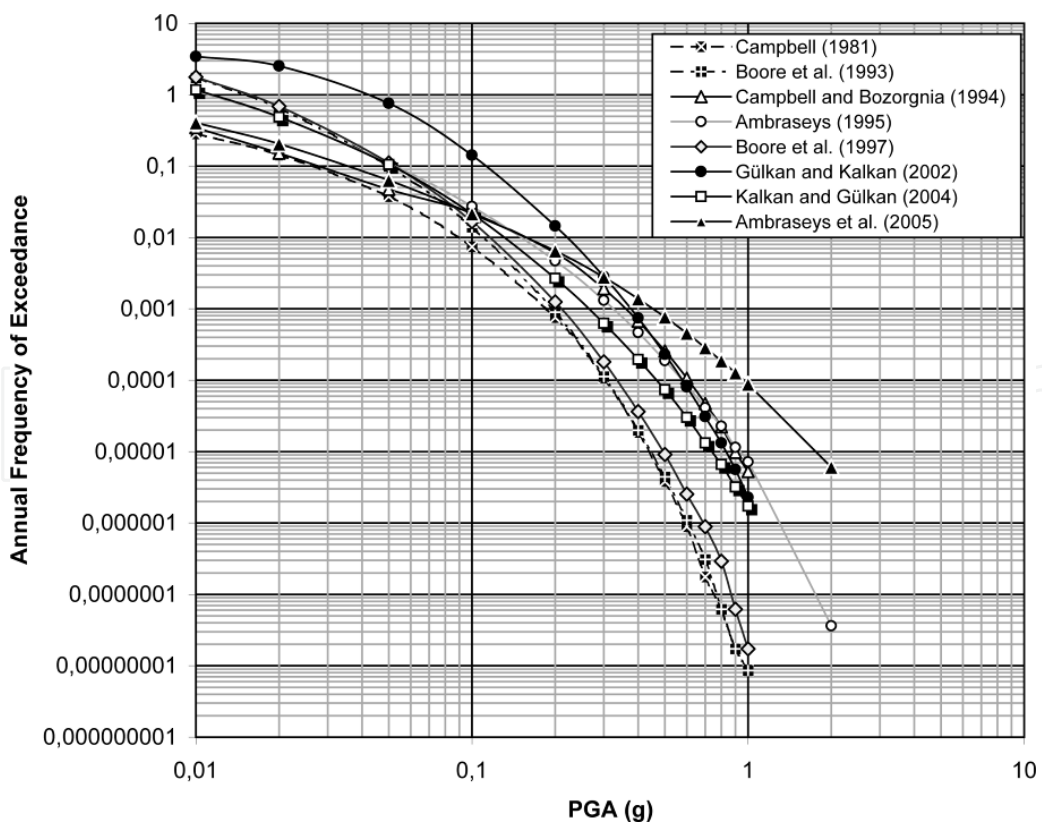
Fig. 9. View of the Hatap dam

Fig. 10. Seismic hazard curve for Hatap dam site

Critical Zone	Critical Segment	Closest distance (km)	PGA (g)				
			DSHA		PSHA		
			50th percentile	84th percentile	OBE	MDE	SEE
18	18-2	17.7	0.27	0.45	0.16	0.24	0.37

Table 7. DSHA and PSHA results for Hatap dam site

4.4 Ayhanlar dam

Ayhanlar dam is located on Kiziloz creek with a storage capacity of 21.8 hm³ (Figure 11). It was designed as earthfill dam and its construction was finished in 2003. Its body volume is 1.2 hm³ and height from river bed is 35 m. Main purpose is to perform irrigation.

Fig. 11. View of the Ayhanlar dam

From seismo-tectonic map of the investigation area, four zones with eleven segment are included into the seismic hazard analyses. Details of the seismic hazard parameters of each source are given in Table 8.

PGA values of dam site are given on the basis of deterministic and probabilistic approach (Table 9). The critical segment is Gumuskent Fault with a magnitude of 7.4. Figure 12 presents the probabilistic hazard results by means of seismic hazard curve. PGA values for return period of 475 and 2475 years are 0.16 and 0.30g respectively.

Zone no	Fault no	Fault name	Fault type**	M_{max}	a***	b***
16	16-1	Ecemis Fault Zone Segment	SS	7.4	4.805	0.814
	16-2	Ecemis Fault Zone Segment	SS	7.4		
	16-3	Derinkuyu Fault	N	6.5		
	16-4	Karsanti-Karaisali Fault Zone	SS	7.2		
	16-5	Deliler Fault	SS	7.3		
17	17-1	Sorgun Fault	SS	7.2	2.655	0.413
	17-2	Sarikaya Akdagmadeni Fault	SS	7.3		
32	32-1	Gumuskent Fault	SS	7.4	3.054	0.476
	32-2	Kirsehir Fault	SS	6.6		
	32-3	Akpinar-Kirsehir Fault Zone	SS	6.7		
	32-4	Akpinar-Kirsehir Fault Zone	SS	6.9		
	32-5	Delice(Yerkoy) Fault	SS	7.2		
33	33-1	NA*	U	6.8	4.112	0.846

* NA: Non available
**SS: Strike slip   N: Normal   U: Unknown
***from Gutenberg-Richter (1944) law

Table 8. Hazard parameters of seismic sources for Hatap dam site

Critical Zone	Critical Segment	Closest distance (km)	PGA (g)				
			DSHA		PSHA		
			50th percentile	84th percentile	OBE	MDE	SEE
32	32-1	6.9	0.38	0.64	0.09	0.16	0.30

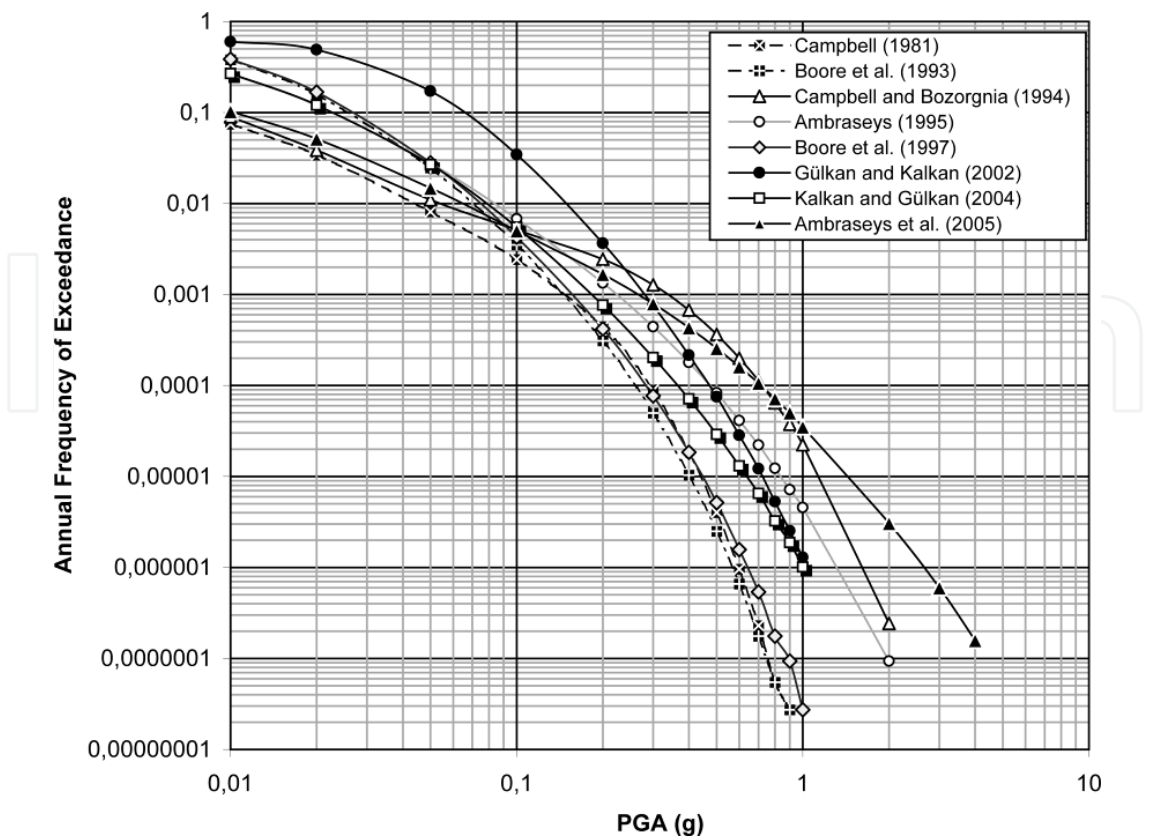Table 9. DSHA and PSHA results for Hatap dam site

Fig. 12. Seismic hazard curve for Ayhanlar dam site

4.5 Boztepe dam

Boztepe dam with a storage capacity of 14.2 hm^3 is also located on a Boztepe creek (Figure 13). It was designed as earthfill dam and its construction was finished in 1984. Its height from river bed is 27 meter. Main aim of this dam is irrigation.

Fig. 13. View of the Boztepe dam

Five seismic source zone are included into the analyses. Seismic parameters used for hazard assessment are given in Table 10.

Zone no	Fault no	Fault name	Fault type*	M_{max}	a**	b**
8	8-1	Elbistan Fault	SS	6.9	5.050	0.831
	8-2	Surgu Fault	SS	6.6		
10	10-1	East Anatolian Fault Zone Segment	SS	7.0	5.585	0.925
	10-2	East Anatolian Fault Zone Segment	SS	6.8		
11	11-1	East Anatolian Fault Zone Segment	SS	7.0	5.882	0.948
	11-2	East Anatolian Fault Zone Segment	SS	6.6		
	11-3	East Anatolian Fault Zone Segment	SS	7.0		
	11-4	East Anatolian Fault Zone Segment	SS	6.7		
	11-5	Tut Fault	SS	6.3		
14	14-1	Karatas-Osmaniye Fault Zone	SS	6.8	5.280	0.818
	14-2	Karatas-Osmaniye Fault Zone	SS	6.5		
16	16-1	Ecemis Fault Zone Segment	SS	7.4	4.805	0.814
	16-2	Ecemis Fault Zone Segment	SS	7.4		
	16-3	Derinkuyu Fault	N	6.5		
	16-4	Karsanti-Karaisali Fault Zone	SS	7.2		
	16-5	Deliler Fault	SS	7.3		

*SS: Strike slip N: Normal U: Unknown
***from Gutenberg-Richter (1944) law

Table 10. Hazard parameters of seismic sources for Boztepe dam site

Results of deterministic and probabilistic analyses are given in Table 11. Average PGA values from eight different attenuation relationships are seen in this table. Total seismic hazard curve of Boztepe dam site is presented in Figure 14. PGA value for SEE level is 0.24 g.

Critical Zone	Critical Segment	Closest distance (km)	PGA (g)				
			DSHA		PSHA		
			50th percentile	84th percentile	OBE	MDE	SEE
10	10-2	27.6	0.11	0.19	0.13	0.18	0.24

Table 11. DSHA and PSHA results for Boztepe dam site
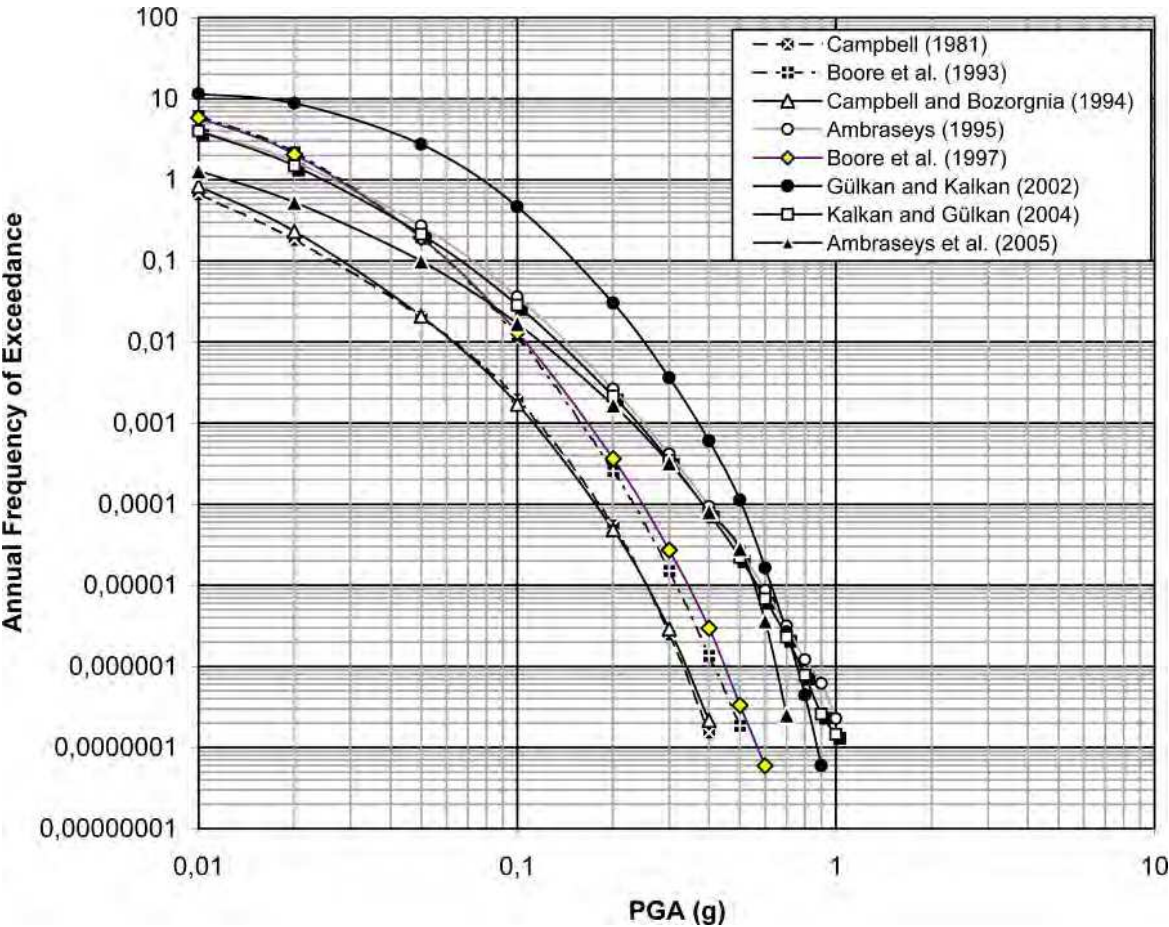
Fig. 14. Seismic hazard curve for Boztepe dam site

5. Discussions

Turkey, which has at least 1200 large dams, is one of the most seismically active regions in the world and major earthquakes with the potential of threading life and property occur frequently here. It is obvious that many of the large dams planned in Turkey are located in

zones of moderate-high seismicity. Thus it is very important that dams to be resistant to the strong earthquakes. Many of guidelines about earthquake safety of dams promise different methodology for dam site locations with different seismicity.

The seismic hazard of a dam site is based on the peak ground acceleration. This value derived from the defined design earthquake produces the main seismic loads. For preliminary study, the existing map of seismic zones can be used to estimate the seismic hazard of a dam site. However, authors believe that the detailed seismic hazard analyses should be performed for safety evaluation of existing dams. Because, the main requirement of an earthquake–resistant design of a dam is to protect public safety and property. Therefore, seismic criteria and analysis parameters for dams should be selected more conservatively than for conventional structures since the failures are more disastrous.

To reveal the effects of methodologies on seismic hazard results, five dam sites are chosen and repetitive analyses are performed. Deterministic and probabilistic methods give different results for each dam sites. It is obvious that deterministic method (84th percentile) gives the maximum value for dams within a near seismic source zone. For the dams which are not close to the seismic sources, deterministic PGA value is lower than SEE level. But it is necessary to perform a lot of examination for locations with low to high seismicity. Another important effect on these differences is sensitiveness of attenuation equations to distance and earthquake magnitude. For further study, analysis results should be compared for each attenuation equation.

Authors state that seismic performance of dams within the near source zone must be reevaluated in detail. Large dams which have high-risk class should be evaluated with highest priority as a part of the National Dam Safety Program. Both DSHA and PSHA must be performed for these dams.

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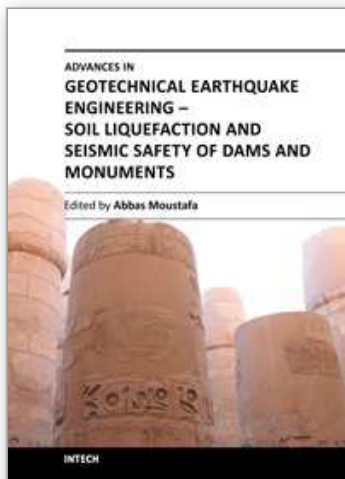
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