Proceedings of the 6rd International Conference on Civil Structural and Transportation Engineering (ICCSTE'21)
~~Niagara Falls, Canada~~ – May 17-19, 2021
Paper No. 138
DOI: 10.11159/iccste21.138

Total Risk and Seismic Stability of Existing Large CFRD's in Turkey

Hasan Tosun[1]
[1]Eskisehir Osmangazi University, Engineering and Architecture Faculty
Bati Meselik, Eskisehir, Turkey
htosun@ogu.edu.tr

Abstract **-** The concrete-faced rockfill dam (CFRD) has been constructed with increasing frequency in last decade, because of no settlement problems through the use of compacted rockfill. It is advantagely regarded that there can be no pore water pressure due to earthquake shaking, because the embankment does not include water inside. Dam specialists had a decision that CFRD's have a high resistance to seismic loading when well compacted. However, its dynamic behaviour was questioned after Wenchuan earthquake, occurred on May 12, 2008 in China. Author states that CFRD's are more critical structures for earthquake case when compared with other types of embankment dams as based on studies which have been carried out for the dams in the locations where are very close to energy sources in Turkey. There are so many dams, which are under the effect of near-source zones in Turkey. One of largest CFRD's , namely Ilisu dam is now built on Tigris river, Eastern Turkey. This study summarizes a dynamic analysis procedure for CFRD's subjected to strong seismic excitation and introduces the total risk and seismic stability of nine large existing CFRD's having structural heights of 60 m to 100 m, in Turkey.

Keywords**:** Concrete-faced rockfill dam, earthquake, seismic hazard, total risk

1. Introduction

Design and construction stages seem very simple for the concrete-faced rockfill dams (CFRD), when compared with other types of embankment dam. It is generally designed on the basis of previous experience. In some cases, the leakage problems were observed and resulted to remedial measures. The author points out the fact that it is necessary to have more attention about plinth construction, foundation preparation, rockfill selection and placement, upstream face control, handling of waterstops and upstream face construction by slip forming. Durability of concrete face slab is important factor acting on long-term behavior of this type [1].

Separation between concrete face slab and cushion layer, as a time-dependent deformation, is the one of the most significant problems of high concrete-faced rockfill dams during static condition. Therefore, installation of rockfill material should be made with care to prevent unpredicted settlement during water impounding. Well-graded rockfill or gravel (with free drainage) is commonly adopted as an excellent material in practice of the developed countries. Some design engineers state that weathered rockfill or dirty gravel can also be used, if zoning is taken into account and compaction for rockfill material is well provided. Its settlement behavior is largely dependable on deformability characteristics of embankment materials. It means that good quality rock material should be used in embankment during construction stage [2,3]. Leakage problem in the CFRDs is usually resulted to the development of tensile cracks in concrete face slabs [1].

Dam specialists had considered the fact that well-compacted CFRD has a high resistance to earthquake loading. This thought was based on several factors including acceptable past performance of similar dams, a recognition that the entire embankment is unsaturated and the fact that compacted rockfill develops high frictional resistance. Uddin [4] and Bouzaiene et al [5] introduced a dynamic analysis procedure for concrete-faced rockfill dams subjected to strong seismic excitation. Numerical solutions performed for CFRD indicated that it is safe as well as other embankment dams. However, intensive investigations after Sichuan earthquake, which occurred on May 12, 2008 in China, have been performed to explain their behavior under dynamic loading. These studies indicate that their behavior is questionable, when they are subjected to seismic loading, which is caused by near energy zone.

Author thinks the fact that near source effect is the most serious problem for CFRDs. Tosun [6] states that active faults, which are very close to the foundation of dams, have the potential to cause damaging displacement of the structure. Especially Concrete Faced Rockfill Dams (CFRD's) have high risk potential when considered near source effect (earthquake epicenter to dam axis is less than 10 km). This phenomenon is dealed with the fact that the transferred energy by rockfill is not absorbed by concrete face during earthquake. Wieland [7] discussed that the seismic performance of concrete face rockfill dams under strong ground Shaking and stated that until the Wenchuan earthquake of 12 May 2008 no large concrete face rockfill dam (CFRD) was subjected to strong ground shaking [8]. He questioned that faced concrete of CFRD's can have a behavior as the river embankment which was subjected the 21 September 1999 Chi-Chi earthquake in Taiwan [9 and 10].

The construction of concrete-faced rockfill dam has been started in 1997 in Turkey, although it is a common-used type in the world since 1940. However, the concrete-faced rockfill dam has been used with increasing frequency in recent years in Turkey. Authors and co-workers have so many research studies for structures discussed here [11, 12, 13, 14, 15, 16, 17, 18]. This paper summaries fundamental general principles of seismic design for existing large embankment dams and deals with an evaluation of seismic hazard and local site effects and evaluates ten large CFRDs, which have a structural height between 60 and 142 m, on the different basins in Turkey. Table 1 introduces the physical properties of the structures considered in this study. Nine of them has been designed as concrete faced rockfill type, while another one has a type of concrete faced earthfill dam (namely Karacasu dam).

Table 1. Dams considered in the study

#	Dam	River	Aim (*)	Completed Year	Height from river bed (m)	Height from foundation (m)	Volume of embankment (m^3) X1000	Volume of reservoir (hm^3)
1	Alakopru	Dragon	D+I+E	2014	94	99	2 343	130.5
2	Atasu	G-Kustul	D+E	2012	116	118	4 650	35.8
3	Cokal	Kocadere	I+D	2011	57	81	3 500	204.0
4	Dim	Dim	D+I+FC+E	2009	124	135	4 867	254.7
5	Gordes	Gordes	I+D	2010	83	95	4 500	448.5
6	Kandil	Ceyhan	E	2013	101	104	2 210	438.7
7	Karacasu	Dardanaz	D+I	2012	54	60	2 320	17.2
8	Kurtun	Harsit	E	2003	110	133	3 000	109.5
9	Marmaris	Kocalan	I+D	2005	49	58	7 060	30.0
10	Torul	Harsit	E	2008	137	142	4 600	168.0

(*) E = Energy I = Irrigation F= Flood control D = Domestic Water

2. Materials and Methodology

For the seismic hazard analysis of the dam sites, all possible seismic sources are identified and their potential is evaluated in detail, as based on the guidelines [19,20]. The study of seismic activity includes deterministic and probabilistic seismic hazard analyses. The deterministic seismic hazard analysis considers a seismic scenario that includes a four-step process. It is a very simple procedure and gives rational solutions for large dams because it provides a straightforward framework for evaluation of the worst ground motions. The probabilistic seismic hazard analysis is widely used and considers uncertainties in size, location and recurrence rate of earthquakes. The probabilistic seismic hazard analysis provides a framework in which the uncertainties can be identified and combined in a rational manner to provide a more complete picture of the seismic hazard [21]. deterministic seismic hazard analysis considers geology and seismic history to identify earthquake sources and to interpret the strongest earthquake with regardless of time [22]. Due to the unavailability of strong motion records, various attenuation relationships were adopted to calculate the peak ground acceleration (PGA) acting on dam sites. For this study six separate predictive relationships for horizontal peak ground acceleration were considered [23, 24, 25, 26, 27, 28]. Most of large dams in Turkey were analyzed by using these definitions.

For all analyses throughout this study, the peak ground acceleration was obtained by considering FEMA's earthquake definition by two methods [29]. According to this guideline, the Operating Basis Earthquake (OBE) was defined by means of the probabilistic methods mentioned above. It is known as the earthquake that produces the ground motions at the site that can reasonably be expected to occur within the service life of the project. Maximum Credible Earthquake (MCE), which 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, was obtained for each zone, and the most critical framework for the dam site was selected as Controlling Maximum Credible Earthquake (CMCE). The Maximum Design Earthquake (MDE) was then defined. The MDE, which is normally characterized by a level of motion equal to that expected at the dam site from the occurrence of deterministically evaluated MCE and Safety Evaluation Earthquake (SEE), should be used for critical structures located in very active seismic area [30].

Table 2 introduces the selection of design earthquake as based on risk classification in Turkey. It was stated that the seismic coefficient is equal to the peak ground acceleration (PGA) when the value of PGA, which is obtained by deterministic method is less than 0.22g. Otherwise, a formula should be considered for determining the seismic coefficient to be used for pseudo-static analysis [31].

Table 2. Selection of Design Earthquake as based on risk classification [33].

Hazard Analysis		Deterministic Method	Probabilistic Method
Class	Hazard Ratio		
I	Low	50 %	T_R = 224 years (*)
II	Moderate	50 %	T_R = 475 years
III	High	84 %	T_R = 975 years
IV	Very high	84 %	T_R = 2475 years

(*) Tr = Return time

The total risk for dam structures mainly depends on the seismic hazard rating of dam site and the risk rating of the dam structure. Throughout this study, two methods have been considered. In DSI guidelines, total risk factor depends to reservoir capacity, height, evacuation requirement and potential hazard [31]. The Bureau method [32], which considers dam type, age, size, downstream damage potential and evacuation requirements, was utilized to realize the risk analyses of the basin.

4. Analyses

For the seismic hazard analyses of the dam sites, a detailed study was performed to identify all possible seismic sources, as based on the macro seismo-tectonic model prepared by the National Disaster Organization and other Institutes [33,34]. However it was modified by the author and his co-workers. Local geological features and seismic history were also taken into account to quantify the rate of seismic activity in dam sites.

The results of deterministic and probabilistic seismic hazard analyses are summarized in Table 3. In this table, M_{max} is the maximum earthquake magnitude in M_w and R_{min} is the minimum distance to fault segment. For deterministic method, mean PGA + 50% and mean PGA + 84% are mean peak ground acceleration at the 50^{th} percentile and Mean Peak Ground Acceleration at the 84^{th} percentile, respectively. The OBE, MDE and SEE are respectively the Operation Based Earthquake, Maximum Design Earthquake and Safety Evaluation Earthquake for probabilistic method.

The deterministic seismic hazard analysis indicates that the maximum values of peak ground acceleration (PGA) belong to Gordes dam. The PGA values ranges from 0.022g to 0.442g for the mean Peak Ground Acceleration at the 50^{th} percentile and from 0.038g to 0.702g for the mean Peak Ground Acceleration at the 84^{th} percentile. According to the updated DSI guidelines, the PGA values at the 84^{th} percentile should be taken into account for all dams analysed throughout the study, when considered deterministic approach [31]. The probabilistic seismic hazard analyses give PGA values within a wide range. the MDE values are between 0.074g and 0.720g, while the OBE values ranges from 0.059g to 0.575g

Table 3. Results of deterministic and probabilistic analyses

No	Dam	Deterministic Method *				Probabilistic Method **			Total Risk (Bureau, 2003)		
		M_{max}	R_{min} (km)	Risk ratio	Mean PGA + 84 % in g	OBE in g	MDE in g	SEE in g	Risk factor	Risk class	Risk ratio
1	Alakopru	6.0	135.0	0.022	0.038	0.059	0.074	0.094	85.9	II	Moderate
2	Atasu	7.3	114.7	0.048	0.081	0.086	0.108	0.140	122.4	II	Moderate
3	Cokal	6.3	2.7	0.327	0.540	0.509	0.639	0.825	141.1	III	High
4	Dim	6.0	98.0	0.029	0.049	0.076	0.095	0.122	91.1	II	Moderate
5	Gordes	6.7	1.1	0.442	0.702	0.575	0.720	0.931	155.6	III	High
6	Kandil	6.9	3.3	0.396	0.584	0.346	0.441	0.628	170.4	III	High
7	Karacasu	5.6	0.4	0.242	0.396	0.481	0.646	0.879	167.0	III	High
8	Kurtun	7.3	82.0	0.065	0.111	0.093	0.122	0.164	131.4	III	High
9	Marmaris	6.1	12.2	0.164	0.284	0.481	0.585	0.724	116.7	II	Moderate
10	Torul	7.3	78.2	0.068	0.115	0.096	0.125	0.169	135.8	III	High

(*) M_{maks} = Maximum earthquake magnitude in M_w R_{min} = Minimum distance to fault segment
Mean PGA + 50% = Mean Peak Ground Acceleration at the 50th percentile
Mean PGA + 84% = Mean Peak Ground Acceleration at the 84th percentile
(**) OBE= Operational Based Earthquake MDE = Maximum Design Earthquake SEE = Safety Evaluation Earthquake

The total analyses were performed for ten dams throughout this study. The results with total risk of each dam are given table 4. Seven dams are identified in classes of I and II with low and moderate hazard rating while other three ones are classified in class IV with high hazard rating. ICOLD [35] state that if the PGA value is greater than 0.25 g and the energy source is closer than 10 km from the dam site, it is classified as hazard class IV with hazard rating of extreme.

Throughout this study, two methods have been considered to quantify the total risk for dam structures. In DSI guidelines, total risk factor depends to reservoir capacity, height, evacuation requirement and potential hazard [31]. According to DSI Guidelines all dams are categorized in IV risk classes with very high risk rating. Following Bureau's method, six large dams are classified in risk class III, a very high-risk rating. In Bureau method, the values of the TRF range from 85.9 to 170.4 (Table 4).

5.Discussions

In this study, ten large CFRDs are considered. The geology of some dam sites are very complicated and frequently jointed, fractured and faulted. Four of them are also impacted by near energy sources The dams considered in this study are briefly discussed below:

The Alakopru dam is constructed on Dragon River at the southern portion of Turkey. It is a multi-purpose dam for proving drinkable water, irrigation and energy. Its height from riverbed and foundation is 94 m and 99 m, respectively. When the reservoir is at normal capacity, the facility impounds 130.5 cu.hm of water with a reservoir surface area of 4.45 sq.km. Its construction was started in 2010 and completed in 2014. The crest width is 10 m and the side slopes of main embankment is 1.41H:1V for upstream and downstream (H=horizontal and V=vertical). According to the seismic hazard analyses of this study, it will be subjected to a peak ground acceleration of 0.135 g by an earthquake of 6.0 magnitude. It seems safe on critical case for earthquake conditions as a result of pseudo-static analyses. It is identified as class II with moderate risk. Dam site is located 135 km for away from an active fault. It is one of more safe dams considered in this study, when considered earthquake safety.

The Atasu dam is a 122 m high structure, with a total embankment volume of 4.65 cu. hm. It is located 17 km southeast of the Macka County and designed as a multi-purpose dam for providing water supply of Trabzon city and producing electricity. When it is completed, it will produce electricity of 150 GWh per year with an installed capacity of 45 MW. Its construction was started in 1998 and will be finished in 2007. When the reservoir is at operation stage with normal water level, the facility approximately impounds 35.7 cu. hm of water with a reservoir surface area of 0.83 sq.km. The crest width is 10 m and the side slopes of main embankment is 1.41H:1V for upstream and 1.5H:1V for downstream (H=horizontal and V=vertical). The upstream and downstream shells are composed of large-sized crushed rocks. A 2-m thick alluvium, which is composed of sand, gravel, clay and silt mixtures, was entirely removed before beginning to the construction of main embankment. Thus, the dam was based on good quality bedrock. The seismic hazard analyses performed throughout this study indicates that Atasu dam is one of the safe dams within the basin. It will be subjected to a peak ground acceleration of 0.048g by an earthquake of 7.3 magnitude and it is not close to the fault segment (114.7 km).

The Cokal dam is located on Kocadere river of Maramara Basin. It has a 81-m height from foundation. When the reservoir is at maximum capacity, the facility impounds 204 cu.hm of water with a reservoir surface area of 8.96 sq.km. Its construction was finished in 2011. It was designed to irrigate land of 12 757 ha and provide domestic water of 18.93 cu.hm. The main embankment consists of crushed rock and transition zone to concrete face. The upstream and downstream fills are large-sized crushed rocks at which the most durable and high strengthened ones are located on the outer part of the shell. The crest width is 10 m and the side slopes of main embankment is 1.41H:1V for upstream and 1.4H:1V for downstream (H=horizontal and V=vertical). According to the seismic hazard analyses of this study, it will be subjected to a peak ground acceleration of 0.396 g by an earthquake of 6.3 magnitude. It is identified as class III with high risk. Dam site is located 2.7 km far away from an active fault. . It is one of most critical dams in this study, when considered earthquake safety.Therefore, a detail seismic hazard analysis should urgently be performed for Cokal Dam.

The Dim dam is designed as a multi-purpose structure to be built at the southern part of Turkey. It is a 134.5 m height and has a crest length of 391 m. When the reservoir is at operation stage with normal water level, the facility approximately impounds 254.7 cu.hm of water with a reservoir surface area of 5.26 sq.km. The upstream and downstream shells are composed of large-sized crushed rocks. The embankment was founded on good quality bedrock. It was finished in 2009. The crest width is 10 m and the side slopes of main embankment is 1.41H:1V for upstream and 1.5H:1V for downstream (H=horizontal and V=vertical). According to the seismic hazard analyses of this study, it will be subjected to a peak ground acceleration of 0.029 g by an earthquake of 6.0 magnitude. It is identified as class III with high risk. Dam site is located 98 km far away from an active fault. It is one of more safe dams in this study, when considered earthquake safety.

The Gordes dam is located on Gordes River at the western portion of Turkey. It is a multi-purpose dam for proving drinkable water of Izmir metropolitan area and irrigating an area of 14 423 ha. Its height from riverbed and foundation is 82.9 m and 94.9 m, respectively. It has the largest capacity of concrete-faced rockfill dams in Turkey. When the reservoir is at normal capacity, the facility impounds 448.5 cu.hm of water with a reservoir surface area of 14.05 sq.km. Its construction was started in 1998 and will be completed in 2010. The main embankment consists of crushed rock and transition zone to concrete face. The upstream and downstream fills are large-sized crushed rocks at which the most durable and high strengthened ones are located on the outer part of the shell. The crest width is 8 m and the side slopes of main embankment is 1.5H:1V for upstream and 1.4H:1V for downstream (H=horizontal and V=vertical). According to the seismic hazard analyses of this study, it will be subjected to a peak ground acceleration of 0.442 g by an earthquake of 6.7 magnitude. It seems safe on critical case for earthquake conditions as a result of pseudo-static analyses. It is identified as class III with high risk. Dam site is located 1.1 km for away from an active fault [36, 37]. A leakage problem from face concrete slab was observed at the end of 2016. The reservoir water was totally released and then re-built. Its total risk is very high. It is the most critical CFRD in Turkey, when considered earthquake safety. Therefore, a detail seismic hazard analysis should be performed for Gordes Dam and design and construction measures should be taken into account urgently. consider.

The Kandil dam is a concrete faced rockfill dam on the main river of Ceyhan Basin. It has a 101-m height from river bed. When the reservoir is at maximum capacity, the facility impounds 438.7 hm3 of water with a reservoir surface area of 14.10 km2. Its construction was finished in 2013. It was designed to generate electricity with a install capacity of 208 MW. The main embankment consists of crushed rock and transition zone to concrete face. The upstream and downstream fills are large-sized crushed rocks at which the most durable and high strengthened ones are located on the outer part of the shell. The crest width is 10 m and the side slopes of main embankment is 1.41H:1V for both upstream and downstream (H=horizontal and V=vertical). According to the seismic hazard analyses of this study, it will be subjected to a peak ground acceleration of 0.396 g by an earthquake of 6.9 magnitude. It seems safe on critical case for earthquake conditions as a result of pseudo-static analyses, when considered the k-values, which are calculated according to mean peak ground acceleration at the 50th percentile. It is identified as class III with high risk. Dam site is located 3.3 km far away from an active fault. An active fault segment of the shear zone crossing the reservoir area can trigger earthquake activity in the dam and its vicinity. Therefore, a detail seismic hazard analysis, which includes the triggering earthquake phenomena, should be executed for Kandil Dam.

The Karacasu dam is located in the western portion of Turkey. It has a 60-m height from foundation. It has a reservoir with 17.2 hm3 and crest length of 649 m. Its main embankment construction was started in 2010 and completed in 2012. It was designed a multi-purpose structure for irrigating lands and providing domestic water. It irrigates an area of 1 125 ha and provides 10.72 hm3 water for domestic use. Karacasu dam is a concrete faced earthfill dam with internal drainage system. The embankment is mainly composed of sandy gravel. There is a transition section of sand between the face concrete lining and sandy gravely materials. The side slopes of main embankment are 1.6H: 1V for upstream and downstream. The main elements of embankment are pervious sandy gravel. The deterministic seismic hazard analysis shows that peak ground acceleration is 0.242g and 0.396g for 50 and 84 percentiles, respectively. For OBE, MDE and SEE (for 2475 years), the PGA value was considered as 0.481g, 0.646g and 0.879g, respectively. As based on this study, Total Risk Factor (TRF) value is 123.99 and it is identified as risk class of II. The seismic hazard analyses performed throughout this study indicates that Karacasu dam is one of the critical dams within the basin.

The Kurtun dam is the first concrete-faced rockfill dam of Turkey. It impounds 109.5 cu.hm of water at maximum water level, It has 133 m high from foundation and 300 m long on crest. It was completed in 2003. It was originally designed as a rockfill dam with central core. However, its type was revised to concrete-faced rockfill type, as a result of intensive geotechnical studies. Intrusive volcanic rocks, regarded as an appropriate rock for dam foundation, form the basement of Kurtun dam. The crest width is 14 m and the side slopes of main embankment are 1.4H: 1V for upstream and 1.5H: 1V for downstream. It produces 198 GWh per year with an installed capacity of 80 MW. According to the seismic hazard analyses of this study, it will be subjected to a peak ground acceleration of 0.065 g by an earthquake of 7.3 magnitude. It is identified as class III with high risk. Dam site is located 82.0 km far away from an active fault. It is one of more safe dams in this study, when considered earthquake safety. This dam site is in excellent condition. However, landslides on reservoir area seem as problem for overall stability of this project.

The Marmaris Dam is the first concrete-faced rockfill dam of country, which was constructed by a municipality with international finance model. It provides drinkable water for Marmaris city and its vicinity, which is one of most fantastic area for tourism sector. It has a 58 m height from foundation. It impounds 30 cu.hm of water at maximum water level,It was planned to supply water for the region up to 2040. The deterministic seismic hazard analysis shows that peak ground acceleration is 0.164g and 0.284g for 50 and 84 percentiles, respectively. For OBE, MDE and SEE (for 2475 years), the PGA value was determined as 0.481g, 0.585g and 0.0.724g, respectively. As based on this study, Total Risk Factor (TRF) value is 116.7 and it is identified as risk class of II.

The Torul dam, located 5 km east of the reservoir of Kurtun dam in the northern portion of Turkey, is a 142-m high dam on the Harsit River. When the reservoir is at normal capacity, the facility impounds 168 cu. hm of water with a reservoir surface area of 3.86 sq.km. Its construction was started in 2000 and was entirely finished in 2008. It was designed to produce electricity of 322 GWh per year with an installed capacity of 103 MW. The main embankment consists of four major zones. The impervious section of the embankment is a concrete slab and plinth structure on upstream. The main elements of embankment are large-sized crushed rocks at which the most durable and high strengthen ones are located on the outer part of the shell. The crest width is 15 m and the side slopes of main embankment are 1.4H: 1V for upstream and 1.5H: 1V for downstream. According to the seismic hazard analyses of this study, it will be subjected to a peak ground acceleration of 0.068 g by an earthquake of 7.3 magnitude. It is identified as class III with high risk. Dam site is located 78.2 km far away from an active fault. It is one of more safe dams in this study, when considered earthquake safety.

5. Conclusion

Earthquake –resistant design of a dam is the main requirement to protect public safety and property. Therefore, seismic criteria and analyses parameters for dams should be selected more conservatively than for conventional structures since the failures are more disastrous. In this study ten CFRDs are analyzed when considered dam safety. The seismic hazard analyses indicate that there are critical dams for earthquake safety. The Gordes, Kandil and Cokal dams are the most critical structures because of being very close to energy source. Therefore, detail analyses should be performed and then considered design and construction measures for these dams if needed. The Karacasu dam, which is the concrete-faced earthfill dam, is also critical dam even if it is classified in moderate hazard.

.

References

[1] H.Tosun, E.Seyrek, M. Turkoz, H.Savas, "Seismic Hazard and Total Risk Analyses of Concrete Faced Rockfill Dams In Turkey" *in Proceeding of 4th International Conference on Earthquake Geotechnical Engineering,* June 25-28, 2007.

[2] H.Tosun, "Discussion of "Construction of Concrete-Faced Rockfill Dams with Weak Rocks" by Hao-Feng Xing, Xiao-Nan Gong, Xiao-Guang Zhou, and Hai-Feng Fu" *Journal of Geotechnical and Geoenvironmental,* V.134, I.8, 1224-1225, 2008

[3] Y.S. Yoon, J.P, Won, S.K,Woo, and Y.C. Song, "Enhanced durability performance of fly ash concrete for concrete-faced rockfill dam application" *Cement and Concrete Research* 32, 23-30,2002.

[4] N.Uddin, "A dynamic analysis procedure for concrete-faced rockfill dams subjected to strong seismic excitation" *Computers and Structures* 72, 409-421, 1999.

[5] H. Bouzaiene, C. Chartrand, Y.Hammamji, "Analysis of the behavior of the Toulnoustouc CFRD dam" Proceeding in *CDA Annual Conference*, Sep.30-Oct.6, Quebec, Canada, 2006.

[6] H.Tosun, "Earthquakes and Dams", *in Earthquake Engineering - From Engineering Seismology to Optimal Seismic Design of Engineering Structures, edited by Abbas Moustafa, IntechOpen*, May 2015, (DOI: 10.5772/59372).

[7] M. Wieland, "Features of seismic hazard in large dam projects and strong motion monitoring of large dams", *Front. Archit. Civ. Eng. China* **4,** 56–64, 2010.

[8] Wieland, M, "The seismic performance of concrete face rockfill dams under strong ground Shaking", *International Water Power and Dam Construction, April, 18-20, 2007.*

[9] Wieland, M, "Seismic design of major components", *International Water Power and Dam Construction,* February, 16-19, 2013.

[10] Wieland, M., "Seismic hazard and seismic design and safety aspects of large dam projects. Second European Conference on Earthquake Engineering and Seismology, Istanbul, Aug. 25-29, 2014.

[11] H. Tosun, "Seismic studies", *International Water Power & Dam Construction,* 58 (2), 20-23, 2006.

[12] H.Tosun, M.Turkoz, S.Savas, E.Seyrek, "River basin risk analysis", *International Water Power and Dam Construction,* 59 (5), 30, 2007.

[13] H.Tosun, M.Turkoz, "Total risk-analyzing methods for dam structures and a case study in Turkey", *in Proceeding of CDA Annual Conference,* 2007.

[14] H. Tosun, S.Batmaz, E.O.Ayvaz, "CFRD Practice in Turkey", *International Water Power & Dam Construction,* 17 April, 2007.

[15] H.Tosun, M.Turkoz, "Re-evaluation of the concrete-faced rockfill dams in Turkey", *in Proceeding of CDA Annual Conference*, 2006.

[16] H.Tosun, K.Tosun, "Dynamic analyzing procedures adopted for concrete-faced rockfill dams in Turkey", *in Proceeding of CDA Annual Conference,* 2008.

[17] H.Tosun, "Behavior of a concrete Faced Rockfill Dam under ground shaking and a case study", *in Proceeding of CDA Annual Conference,* 2010.

[18] H.Tosun, "Dynamic Behavior Of CFRDs Subjected To Strong Seismic Excitation And A Case Study", *in Proceeding of* USSD Annual Conference, Miami, 1-15, 2018.

[19] W.A.Fraser, J.K.Howard, "Guidelines for Use of the Consequence-Hazard matrix and Selection of Ground Motion Parameters*", Technical Publication, Department of Water Resources,* Division of Safety of Dams, 2002.

[20] M.J.Jiminez, D.Giardini, G.Grünthal, "Unified Seismic Hazard Modelling throughout the Mediterranean Region*", Bolettino di Geofisica Teorica ed Applicata*, Vol.42, N.1-2, Mar-Jun., 3-18., 2001.
[21] S.L.Kramer, 1996. "Geotechnical Earthquake Engineering" *Prentice-Hall*, *Upper Saddle River*, NJ 653 p.
[22] E.Krinitzsky, "Discussion on Problems in the Application of the SSHAC Probability Method for Assessing Earthquake Hazards at Swiss nuclear power plants". *Eng. Geol. 78 285-307; Eng.Geo.* 82, 62-68. 2005.
[23] K.W. Campbell, "Near-Source Attenuation of Peak Horizontal Acceleration" *Bulletin Seism. Soc. Am.*, V.71, N.6, 2039-2070, 1981.
[24] D.M. Boore, W.B.Joyner, T.E.Fumal, "Estimation of response spectra and peak accelerations from Western North American earthquakes*", An interim report. Open file report* 93-509.U.S.G.S, 1993.
[25] N.N.Ambraseys, "The Prediction of Earthquake Peak Ground Acceleration in Europe*", Earthquake Engineering and Structural Dynamics*, V.24, 467-490, 1995.
[26] D.M.Boore, W.B. Joyner, T.E.Fumal, "Equation for Estimating Horizontal Response Spectra and Peak Acceleration from Western North American Earthquakes*", A Summary of recent Work. Seismological Research Letters*, V.68, N.1, January /February, 128-153, 1997.
[27] P.Gulkan, E.Kalkan, "Attenuation modeling of recent earthquakes in Turkey*", Journal of Seismology*, 6 (3), 397-409, 2002.
[28] E.Kalkan, P.Gulkan, "Site-Dependent Spectra Derived from Ground Motion Records in Turkey", *Earthquake Spectra*, 20, 4, 1111-1138, 2004.
[29] FEMA. "Federal Guidelines for Dam Safety—Earthquake Analyses and Design of Dams*"2005*.
[30] ICOLD. "Selecting Seismic Parameters for Large Dams-Guidelines*". ICOLD*, Bulletin 148, 2016.
[31] DSİ, "Selection of Seismic Parameters for Dam Design", *State Hydraulic Works*, Ankara, 29 p, 2012 (in Turkish).
[32] G.J. Bureau, "Dams and Appurtenant Facilities in Earthquake Engineering Handbook*" edited by Chenh, W.F and Scawthorn,C.* CRS press, Bora Raton 26.1-26.47, 2003.
[33] General Directorate Of Mineral Research And Explorations (MTA), Geoscience Map Viewer and Drawing Editor, http://yerbilimleri.mta.gov.tr/
[34] DSİ, *Dams of Turkey*. TR-COLD, Ankara, 602 p, 2016.
[35] ICOLD, "Selecting Parameters for Large Dams-Guidelines and Recommendations*", ICOLD Committee on Seismic Aspects of Large Dams*, Bulletin 72, 1989.
[36] H.Tosun, T.V.Tosun, M.A. Hariri-Ardebili, "Total risk and seismic hazard analysis of large embankment dams: case study of Northwest Anatolia, Turkey" *Life Cycle Reliability and Safety Engineering*, 1-10, 2020 (https://doi.org/10.1007/s41872-020-00113-4).
[37] T.V. Tosun, H.Tosun, "Total Risk and seismic hazard analyses of large dams in Northwest Anatolia, Turkey" *in Proceeding of 85th Annual Meeting of International Commission on Large Dams*, Prague, 165-165, 2017.