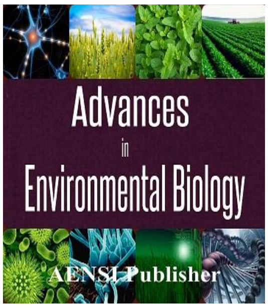
Advances in Environmental Biology, 9(2) January 2015, Pages: 628-634

AENSI Journals

Advances in Environmental Biology

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/



Assessing Earthquake - Fault Risk in Behbahan

[1]S. Zahermand, [2]M. Bosak, [2]S.M.R. Hadi, [2]H. Mahdeyan

[1]*Department of Civil Engineering, Dehdasht branch, Islamic Azad University, Dehdasht, Iran.*
[2]*Department of Civil Engineering, Yasooj Branch, Islamic Azad University, Yasooj, Iran.*

ARTICLE INFO

Article history:
Received 12 October 2014
Received in revised form 26 December 2014
Accepted 1 January 2015
Available online 17 February 2015

Keywords:
Tectonic earthquake, earthquake, return period, magnitude, acceleration, damping relations

ABSTRACT

Iran is one of the world's seismically active countries which has experienced devastating earthquakes in recent years and many small earthquakes every year and a large earthquake every ten years on average occur in it. Khuzestan Province and Behbahan are considered as high risk seismic zones of the country. Historical data indicate that destructive earthquakes with magnitudes of 6.8 and 5.8 on the Richter scale occurred in 1052 and 1085 AD which destroyed the city of Arjan and many people were killed. During the past 30 years more than 230 earthquakes in Khuzestan and 41 earthquakes in Behbahan with the magnitude of over 4 on the Richter scale have occurred. Therefore, it seems necessary to do some research to estimate the seismic risk in Khuzestan Province and Behbahan. In order to assess the seismic hazard in Behbahan in this study, deterministic and probabilistic methods are used and the properties of bedrock earthquake in Behbahan are identified.

To Cite This Article: S. Zahermand, M. Bosak, S.M.R. Hadi, H. Mahdeyan., Assessing Earthquake - Fault Risk in Behbahan. ***Adv. Environ. Biol., 9(2),*** *628-634, 2015*

INTRODUCTION

Iran is located in the boundary of Eurasian and Arabian tectonic plates and thus is considered as one of the seismically active countries of the world. Large earthquakes in Ghir and Karzin, Tabas, Naghan, Manjil, Ardebil, and Bam are some evidence for this claim. Many small earthquakes every year and a large earthquake every ten years on average occur in Iran which lead to financial losses and casualties; therefore, it seems necessary to do some studies on earthquake hazards in different regions of the country with regard to the presence of active faults in their vicinity. Khuzestan Province is located in the boundary of Iran and Saudi Arabia plates so that Khuzestan Province and Behbahan are considered as high risk seismic zones of the country. Behbahan is located in the boundary of tectonic units of Zagros and folded Zagros beside the mountain front fault which causes massive earthquakes with its own movements. Historical data indicate that destructive earthquakes with magnitudes of 6.8 and 5.8 on the Richter scale occurred in 1052 and 1085 AD which destroyed the city of Arjan and many people were killed. During the past 30 years more than 230 earthquakes in Khuzestan and 41 earthquakes in Behbahan with the magnitude of over 4 on the Richter scale have occurred. Khuzestan earthquake (15.7.1929) with the magnitude of 6 on the Richter scale, Izeh and Masjed Soleiman earthquake (14.12.1978) with the magnitude of 6.2 on the Richter scale, and Behbahan earthquake (14.11.1991) with the magnitude of 5.4 on the Richter scale are some of the most important earthquakes in this province.

Studies on the seismic hazard analysis for certain areas of the country particularly for important projects such as dams and seismic zoning of major cities have been conducted during the last few decades. Considering the urban development and the impossibility of developing cities in areas far from the faults, constructions are inevitably done in areas with high seismic risks and thus, for macro policy making within the area of housing and development it is necessary to do documented studies on seismic hazard analysis and seismic microzonation in different parts of the country.

The studies on seismic hazard analysis aim to identify the features of earthquake in an area based on the design of that area. In seismic hazard analysis studies the deterministic and probabilistic methods are used [5]. In the probabilistic method according to the features of previous earthquakes within the radius of about 200 km and statistical and probabilistic review of them and considering the return periods and various risks, different

Corresponding Author: S. Zahermand, Department of Civil Engineering, Dehdasht branch, Islamic Azad University, Dehdasht, Iran.
E-mail: samadzahermand@yahoo.com

relationships and time distribution functions are used to calculate seismic parameters such as return period, earthquake magnitude, and maximum horizontal bedrock acceleration. In deterministic method, active faults are studied within the range of 150 km in the region and with regard to the length of fault, its distance from the studied area and damping relations the faults with the highest seismic potential in the region are identified and the ground motion parameters are estimated based on the possible movement of the faults.

In this paper which is a part of the authors' research on the seismic microzonation in Behbahan, the results of seismic hazard analysis are presented for Behbahan via deterministic and probabilistic methods. In the deterministic method, within the range of 150 km of the studied area, 11 active faults with the NW-SE trending strike-slip components which can cause seismicity in Behbahan are identified and ground movement parameters based on the possible motion of total fault length and possible motion of half of the faults which are respectively known as MCE and MPE design earthquake, are estimated. In probabilistic method, based on the characteristics of previous earthquakes within the radius of 250 km from Behbahan and statistical and probabilistic review of them and considering the useful life of 25, 50, and 100 years and the risks of 5, 10, 37, and 64% of Gutenberg-Richter relations and the final values of functions of I, II, S and using the time distribution functions, the seismic parameters are calculated.

In this study, the earthquake horizontal acceleration for the two returns periods of 475 and 950 years in the stone bed of Behbahan is estimated to be 0.27 and 0.35 of acceleration of gravity, respectively. The results of the studies indicate that Behbahan has high seismicity potential and there is the probability of earthquakes with magnitudes greater than 7.2 on the Richter scale.

The materials in the paper are presented as the following: in the second section, Behbahan seismotectonic is described. Seismic hazard analysis through probabilistic and deterministic methods is presented in sections 3 and 4 and finally in section 5 the results of the research are summarized.

2. Behbahan Tectonic Earthquake:

The studied area is located at longitude 49°47´to 50°33´E of Greenwich Meridian and latitude 30°10´ to 30°56´ N from the equator in the boundary beneath the tectonic units of folded Zagros and pit in the northwestern Zagros beside the mountain front fault. The mountains of Zagros have been introduced as the morphological transformation zone separating Arabia and Eurasia sheets.

The general seismicity of Behbahan, according to the third edition of Standard 84-2800 of Building and Housing Research Center under the title of Earthquake Resistant Buildings Code, is ranked as the relatively high risk zone and thus the selection of the base acceleration of 0.3 g in pseudo static analysis is recommended [2]. There is no detailed information available about the exact location of Behbahan bedrock. Given that the focus of large earthquakes in Zagros is at the depth of 10 to 20 km, i.e. beneath the sediment layer and Precambrian basement, therefore, the relative focal depth of earthquakes in this research was considered to be 10 km. since all the deep faults in Zagros are unknown the earthquakes in this zone are imagined to be moving. Thus, the largest earthquake in Zagros (Ghir and Karzin Earthquake by $M_s = 7.1$) in April 10, 1972 can be imagined to occur at every point in Zagros and consequently under Behbahan site area. In addition to faulting and earthquake, another danger in the Zagros range and consequently, in Behbahan site zone is the setting and the height of mountains due to pressure from Africa and Arabia zones with a speed of about 5 cm per year [3]. With regard to ranking the earthquake hazard in Khuzestan the cities of Behbahan, Andimeshk, Masjed Soleiman, Lali, and Baghmalek have the highest seismic risk and the cities of Khoramshahr, Abadan, Bandar Mahshahr, and Shadegan have the lowest seismic risk among the cities in Khuzestan. During the past 30 years, 64, 41, 29, and 28 earthquakes with the magnitudes over 4 on the Richter have respectively occurred in Andimeshk, Behbahan, Lali, and Masjed Soleiman while no earthquake has been reported in Abadan [4].

3. Estimating the Seismicity Parameters of Behbahan through Probabilistic Statistical Method:

Studying the seismicity parameters of a region is necessary to achieve a seismicity model [1]. Therefore, the seismic data of the region for a period of 200 years (1803 to 2003) as far as the radius of 250 km from Behbahan were collected from reliable sources which were totally 1237 cases. Since the earthquakes before the 20^{th} century are announced in terms of surface waves of M_s and the magnitude of the earthquakes in the 20^{th} century is expressed based on M_b, and also due to the application of magnitude M_s in the attenuation relations of ground motion parameters, it is necessary to convert the magnitude M_b of the earthquakes without the magnitude M_s to the magnitude of surface waves. In this study, using the earthquakes which have been reported for both magnitudes and eliminating inappropriate data of the correlation between 219 pairs of magnitude, the following equation is presented by means of the statistical method of the lowest squares [5] and finding the equation of the best line to express the correlation between these two parameters.

$$M_s = 1.1135\, M_b - 0.8898 \qquad (1)$$

In order to determine the seismicity coefficient in Behbahan the Gutenberg-Richter law is used. In order to use the Gutenberg-Richter law and to investigate the seismicity of a region the reported earthquakes are classified based on their magnitudes, the frequency of each category is counted and their cumulative frequency is calculated and then Gutenberg-Richter distribution function [1,5] is obtained. The relationship between magnitude and frequency of the occurred earthquakes in Behbahan area is shown in Table (1) and the graph plotted to determine the Gutenberg-Richter distribution function is displayed in Figure (1). As it is observed in Figure (1), the distribution function of Gutenberg-Richter is calculated as follows:

$$LogN_c = 5.8567 - 0.8216\, M_s \tag{2}$$

In Equation (2), N_c is the cumulative frequency of the earthquakes and M_s is the surface magnitude of the earthquake.

Table 1: The frequency of the earthquakes occurred in Behbahan area.

< Magnitude M_s	Cumulative frequency N_c	< Magnitude M_s	Cumulative frequency N_c
3	1075	4/8	82
3/1	1062	4/9	68
3/2	1049	5	53
3/3	1008	5/1	41
3/4	956	5/2	37
3/5	945	5/3	35
3/6	885	5/4	29
3/7	804	5/5	27
3/8	715	5/6	21
3/9	647	5/7	17
4	546	5/8	12
4/1	454	5/9	11
4/2	359	6	11
4/3	281	6/1	9
4/4	217	6/2	7
4/5	209	6/3	4
4/6	155	6/4	2
4/7	109	6/5	1

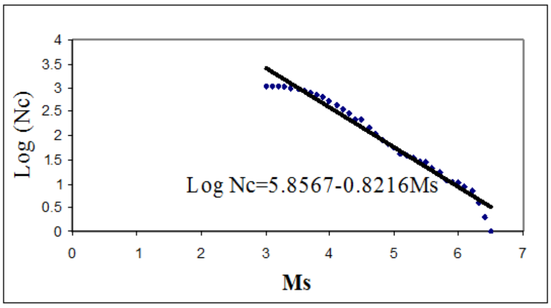


Fig. 1: The linear relationship between frequency and magnitude of the earthquakes in the range of 250 km from Behbahan.

3.1. Return Period of the Earthquakes in the Studied Area:

In order to calculate the return period of the earthquakes the Gutenberg-Richter equation and the functions of final values [1, 5] have been used. After calculating the coefficients, the linear relationship between frequency and magnitude (coefficients of 5.8567 and 0.8216 in Equation 2), the return period of the earthquakes for Gutenberg-Richter relation will be determined as the following equation:

$$M = \frac{5.8567 - Log(200/T_R)}{0.8216} \tag{3}$$

In the above equation, T_R is the return period of the earthquake per year.

The return period for different magnitudes of the earthquake is displayed in Table (2) which is relatively short in this area. Table (2) is also displayed as Figure (2). Now, by using Equation (4) and selecting the risks of 64, 37, 10, and 5%, the return period of earthquake in Behbahan for the useful life span of 25, 50, and 100 years can be estimated:

Table 2: Return period and magnitude of the earthquake obtained based on the Gutenberg – Richter method.

200	150	100	75	50	25	15	10	5	Return period of the earthquake (year)
7/1	7/0	6/8	6/6	6/4	6/0	5/8	5/5	5/2	Earthquake magnitude (M_s)

$$R_t = 1 - \exp(-t / T_R) \quad (4)$$

In this equation, R_t is the risk percentage, t is the desired duration (useful life of structure) and T_R is the return period of earthquake.

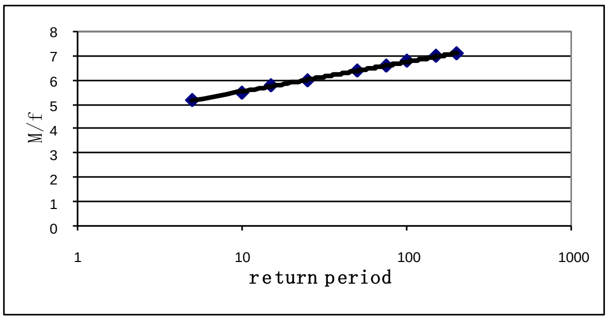


Fig. 2: The curve of earthquake return period and magnitude M_s in an area with the radius of 250 km from Behbahan using Gutenberg-Richter function.

In order to calculate the return period of earthquakes through the function of the final values of I and III, at first the effects of aftershocks and foreshocks are deleted and the largest earthquake during the period of 5 years is selected and the rest of the data will be deleted. Then, the remaining earthquakes will be sorted in ascending order and the cumulative frequency of the earthquake will be obtained [5]. According to what was explained the equation of the functions of the final values of I and III for Behbahan area is respectively obtained as follows.

$$P = \exp\{-51948.078[2.3562 \ln(-M_i)]\} \quad (5)$$

$$P = \exp\{-0.0021205\,[5.0742 \ln(7.8 - M_i)]\} \quad (6)$$

The maximum expected earthquake for Behbahan area is 7.8 in the function of type III which is displayed by Aghajari Fault and this amount is obtained through the analysis of faults and P is the probability of the largest earthquake per year. Now through the following equations and by using equations (5) and (6) and selecting the risks the return period and the magnitude of earthquake in Behbahan Area can be estimated for the useful life of 25, 50, and 100 years.

$$P = (1 - R_t)^{1/t} \quad (7)$$

$$T_R = 1/[1 - (1 - R_t)^{1/t}] \quad (8)$$

According to calculations made for the useful life of 25, 50, and 100 years and risk probabilities of 5, 10, 37, and 64%, the return period of earthquake based on the surface magnitude for the functions of Gutenberg-Richter, I and III is calculated in Table (3).

3.2. Estimating Horizontal Acceleration of Bedrock:

In order to calculate the horizontal acceleration of Behbahan bedrock the damping relations of Esteva and Villiaverde (1974), Mc. Guire (1974), Makropoulos and Burton (1985), and Orphal and Lahoud (1974) have been used. Then, the functions of the final amounts of type III and S for each damping relations will be calculated separately. In order to calculate the accumulative function of type III and S for each damping relations, the maximum ground acceleration for all statistical data of the earthquake in the studied area will be calculated. Then, the largest rate of acceleration within the period of 5 years is selected among them. Afterwards, the obtained results will be sorted in ascending order and their cumulative frequency will be calculated. In functions of type III and S that the maximum acceleration of probable earthquake in the region is necessary to be inserted in the relationship, the maximum acceleration for every damping relation is extracted and used [5]. In Table (4) the values of horizontal acceleration estimated for the useful life and the percentage of various risks are presented for 4 damping relations using the final functions of type III and S.

4. Estimating Ground Motion Parameters through Deterministic Method:

In order to assess the seismic hazards for a region all the probable sources of seismic activity should be identified and their ability in producing strong ground motion in future should be evaluated [1]. In this research in order to investigate important faults around Behbahan the geological maps have been used. Among the discussed faults to the radius of 100 km from Behbahan, with regard to the distance from the site and the length of faults, 11 faults with the NW-SE trending strike-slip components which can have greater impact on the site have been selected including the faults of Aghajari, Ramhormoz, Rag Sefid, Behbahan, Mishan, Arjan Bozorg (great) Dogonbadan, Anneh, Basht, Northern Dehdasht, and Arjan Koochek (small) [4]. The mechanism of all main known faults in Behbahan site area and surrounding is based on the reverse faults and it should be noted that the reverse faults compared with strike-slip and extension faults are more energetic, the time period of earthquake in their direction is relatively longer, horizontal gravity is more along them, and they can cause large devastating earthquakes. In deterministic method, ground motion parameters are estimated based on the probable motion of total fault length and probable motion of half of the length of known faults on Earth within the radial range of 100 km from Behbahan which are respectively introduced as the MCE and MPE design earthquakes. The maximum seismic power of each fault was estimated based on the average of 13 relationships (Tocher (1958), Press (1967), Housner (1967), Slemmons (1966), (1967) and (1982), Mohajer, Ashjai, and Nowroozi (1978), Bonilia, Mark, and Lienkaemper (1984) and King and Knopoff (1968)) (Table 5). Mean comparison of the magnitude and intensity of the earthquake for the present faults indicates that maximum credible earthquake (MCE) with the magnitude of 7.8 (Ms = 7.8) and maximum probable earthquake (MPE) with the magnitude of 7.84 belong to Aghajari Fault. Therefore, it can be concluded that the maximum capability of the earthquake in the region is determined by Aghajari Fault.

Table 3: Maximum earthquake magnitude M_s and related return period with regard to the useful life and percentage of different risks in an area with the radius of 250 km from Behbahan (Functions of Gutenberg-Richter, I, III).

Maximum earthquake magnitude M_s resulting from various functions			Return period	Risk percentage	Useful life
Type III	Type I	Gutenberg-Richter			
6	6	6	25	64	25
6/3	6/3	6/4	55	37	
6/6	7	7/2	238	10	
6/8	7/2	7/6	488	5	
6/2	6/3	6/4	49	64	50
6/5	6/6	6/8	109	37	
6/8	7/2	7/6	475	10	
6/9	7/5	8	975	5	
6/4	6/6	6/8	98	64	100
6/6	7	7/2	217	37	
6/9	7/5	8	950	10	
7	7/8	8/3	1950	5	

4.1. Estimating Horizontal Acceleration of Ground:

In order to calculate the maximum acceleration resulting from the seismicity of each fault in Behbahan the means of damping relations ((Esteva and Villiaverde (1974), Mc.Guire (1974), Makropoulos and Burton (1985), Donovan (1974), Orphal and Lahoud (1974), Esteva and Rosenblueth (1964), Dames and Moore (1979), Makropoulos and Burton (1969), Esteva and Hendron (1985)) have been used (Table 5). The review of Table (5) shows that among the known faults, Behbahan fault with the seismic power of an earthquake with magnitude of 7.22 (M_s = 7.22) and the distance of 5 km from the north of Behbahan can create the biggest hazard in Behbahan and according to probable motion it can create half of the length of acceleration fault equal to 0.534g in Behbahan. As it is observed, in this review although Aghajari fault forms the biggest seismic linear source which is capable of producing an earthquake with the magnitude of 7.8 (M_s+7.8), the acceleration which strikes Behbahan from the activity of this fault is assessed as poor in comparison with Behbahan Fault.

In this research the maximum horizontal acceleration is estimated (Table 6) through deterministic method and based on the past earthquakes in Arjan by means of five relations of acceleration attenuation. In order to use damping relations, the deep focus of earthquakes in Behbahan is placed at the depth of 10 km. in order to calculate the maximum velocity five damping relations have been used and the Mc.Guire (1974) relation has been used to calculate maximum motion. The reviews show that seismic faults in Behbahan area have been able to produce horizontal acceleration equal to 0.35 to 0.36 of ground gravity in Behbahan during the occurrence of earthquake in Arjan in 1052. Therefore, according to the calculations in this research and the earthquake of 1052 it can be said that the lowest possible horizontal acceleration of gravity for large structures such as dams in Behbahan, would be around 0.35% of the acceleration of ground gravity.

Advances in Environmental Biology, 9(2) January 2015, Pages: 628-634

Table 4: Estimation of maximum horizontal acceleration of ground motion in Behbahan site according to distribution functions of III, S and different damping relations.

Estimation of expected maximum horizontal acceleration of ground motion in Behbahan area (cm/s²)											
AVE	O&L		B&M		Mc.G		E&V				
S , III	S	III	S	III	S	III	S	III	T_r	R_i	t
26/93 59/13 185/57 285/46	21/85 55/19 202/89 425/22	24/30 51/00 131/84 181/04	22/21 62/09 268/01 413/08	24/87 55/47 157/38 224/16	33/08 64/59 180/07 254/64	35/22 60/10 125/26 163/10	25/68 66/20 265/00 406/26	28/25 58/42 154/12 216/17	24/97 54/61 /78 237 /89 487	64 % 37 % 10 % %5	25
54/14 107/49 266/20 342/68	49/35 110/96 293/78 379/20	46/93 84/43 179/16 230/34	54/79 135/67 407/70 544/89	50/67 96/23 221/55 293/98	59/49 109/67 251/03 262/31	56/52 87/98 161/66 211/15	66/55 137/83 401/00 538/15	53/78 97/10 213/75 281/46	49/44 /72 108 /06 475 /29 975	64 % 37 % 10 % %5	50
99/20 175/41 346/39 420/12	101/20 191/04 376/35 443/46	79/04 125/87 228/44 278/75	122/38 250/38 540/22 650/17	89/51 149/49 291/24 365/17	102/09 171/02 322/49 386/49	83/62 120/64 199/68 239/31	124/97 248/06 533/42 647/73	90/78 146/79 278/89 348/85	98/38 /93 216 /62 949 /07 1950	64 % 37 % 10 % %5	10 0

Table 5: Introducing the main faults of the studied area and the maximum acceleration of strong motion of ground.

Horizontal component		Seismicity power M_s		50% length of fault	100% length of fault	Distance from north of city	Name of Fault
MPE	MCE	MPE	MCE				
319/26	400/84	7/48	7/80	70	140	35	Aghajari
190/16	238/11	7/32	7/64	50	100	50	Ramhormoz
164/15	205/41	7/27	7/59	45	90	55	Rageh Sefid
524/32	640/44	7/22	7/54	40	80	5	Behbahan
100/79	125/99	7/16	7/48	35	70	80	Mishan
505/78	617/42	7/09	7/41	30	60	3	Arjan Bozorg
157/43	196/95	7/05	7/37	27/5	55	50	Dogonbadan
203/13	254/46	7/05	7/37	27/5	55	40	Anneh
83/58	104/33	7/00	7/32	25	50	85	Basht
219/51	275/13	6/95	7/27	22/5	45	35	North Dehdasht
274/62	334/76	6/15	6/47	4	8	4	Arjan Koochek

5. Summary and Conclusion:

Earthquake hazard analysis in Behbahan was done through deterministic and Probabilistic methods. Accurate recognition of quaternary faults in the studied area is the first step in assessing the risk of earthquake-fault in the studied area. There are a lot of active faults in Behbahan area and each one has high seismicity ability and indicates the occurrence of major earthquakes in the past and future. Therefore, the most important faults which have the highest seismicity ability in the range of 100 km from Behbahan were identified and the maximum seismic power of each fault was calculated through 13 empirical relations and the maximum horizontal acceleration of ground motion resulting from the faults in the north of Behbahan was calculated via

10 damping relations. Among the known faults, Behbahan fault according to probable motion of half of the length of fault creates the magnitude of 7.22 in surface waves and the acceleration equal to 0.534 of gravity acceleration in Behbahan.

Table 6: Estimating maximum acceleration, velocity and motion in Behbahan based on historical earthquakes.

DATA (Yr)		Parameter
108 5	105 2	
5/8	6/8	Magnitude (M_s)
0/19	0/35	Horizontal acceleration (g)
/52 21	/08 52	Velocity (cm/s)
5/04	/68 13	Motion (cm)

In probabilistic method, the seismic data of the region for a period of 200 years in the radius of 250 km from Behbahan were collected. Then, for the useful life of structures and the percentage of different risks, and by means of appropriate statistical methods such as Gutenberg-Richter and the functions of the final values of I, III, and S, the parameters of seismicity, return period based on magnitude, and maximum horizontal acceleration of ground motion were calculated according to the final functions of III, S, and different damping relations. The results of investigation of the maximum relations of the function of final values and Gutenberg-Richter for the studied area and the useful life of 25, 50, and 100 years were considered for the design and acceptance of various risks of calculating the return period and maximum acceleration and accordingly, the earthquake that might be possible to occur based on the determined risk would be selected. For instance, for the useful life of 25, 50, and 100 years and accepting the risk of 10%, the return periods have been estimated as 238, 475, and 950 years and the maximum magnitude of the earthquake by the mean of functions I and III, Gutenberg-Richter function, was calculated as 6.9, 7.2, and 7.5, respectively in the surface waves. The maximum horizontal acceleration of ground motion in Behbahan area by the mean of functions III and S has been evaluated respectively as 0.21, 0.27, and 0.35 of the gravity acceleration.

REFERENCES

[1] Kramer, S., 1996. Geotechnical Earthquake Engineering, Prentice Hall, Upper Saddle River, New Jersey, 07458.
[2] Building and Housing Research Center, 2005. Regulations of designing buildings against earthquakes, Standard No. 2800, Third Edition.
[3] Poor Kermani, M., M. Arian, 1997. Seismotectonic (Tectonics Earthquakes), Dezab Consulting Engineering Company.
[4] Tahmasebi Nejad, H., 2003. Investigating faults and eqrthquakes in Khuzestan Province with emphasis on Behbahan.
[5] Daneshjoo, F., 1999. Fundamentals of earthquake engineering and risk analysis, Danesh Farda Publications.