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Seismic Hazard Analysis with a Deterministic Approach in Boroujerd City

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Abstract--- *With the help of seismic techniques and event analysis (from the point of view of temporal and spatial distribution), the mechanical nature of fractures can be determined using the physical parameters of the seismic source. However, long-term seismology (study of prehistoric events) has not been considered in Iran due to its high costs, and due to the presence of historical information in the study area, the behavior of seismic springs can be studied to some extent. Due to advances in seismic knowledge, the seismicity of each zone can be divided into two periods before and after the 20th century BC. The events of the 20th century BC can also be divided into two half-periods of the initial apparatus before 1963 and half of the new apparatus after 1963. In this study, to perform seismic analysis of the region, the catalog of historical and instrumental earthquakes that occurred in the region was firstly collected. Then, according to the available sources (reports, scientific articles, seismotectonics maps, etc.), active faults, and seismic springs in the area were determined. Finally, the seismicity of the area was analyzed using seismic data and faults.*

Keywords--- *Deterministic Approach, Seismic Sources, Seismic Data, Seismic Hazard Analysis.*

I. INTRODUCTION

Earthquake is one of the natural phenomena of the earth, which due to lack of sufficient knowledge of this phenomenon can be called an accidental phenomenon. Due to the advances in seismology, earthquake engineering, and geology, appropriate scientific solutions to predict this phenomenon have not been expressed and have always been discussed. Since the only way to deal with this phenomenon is to strengthen the structures and partially reduce the number of casualties caused by earthquakes, it is necessary to make a reliable estimate and assess the risk of earthquakes.

In reliable estimation of seismic hazard, all parameters that can affect the desired area are examined and considered in the calculations, and it can be said that studies of seismotectonics in the region take place. In seismotectonics studies, the relationship between tectonic processes and seismic is examined, which is the first step in estimating seismic hazard.

This study examines the seismotectonic and seismicity of Boroujerd city. The active and dynamic tectonics of the Zagros region, the expansion of urban construction and the tendency towards mass production, the ancient history of the region's civilization and the importance of strengthening the ancient buildings, show the necessity and importance of this study. Accurate knowledge of historical earthquakes and new faults is an important tool in understanding active tectonics and seismic hazard analysis. Seismic hazard analysis requires an estimate of the potential of future seismic in an area and estimates the size of the largest seismic event that may occur by a particular fault. The seismic potential of future faults is assessed based on estimation of fault fracture parameters, and these parameters are related to seismic magnitude. Prediction of the probability of future potential activities can be achieved by using a combination of our knowledge of

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historical and instrumental earthquakes, as well as the position of active faults. It is important to identify active faults in engineering work, as surface faults can cause displacement in engineering structures. One of the main elements in estimating seismic hazard is the detection of seismic sources. To predict seismic activity, we need to identify the fault date. Historical and ancient seismic are of great help, especially in determining important factors such as changes in the return periods of earthquakes during a fault. If seismic data are properly evaluated according to historical evidence, they can be reasonably attributed to the active Quaternary faults. Although it is difficult to link seismic with specific geological faults, seismic information, along with the results of geological and neo-tectonic studies of active folds, has made this somewhat practical.

II. GEOLOGY OF THE STUDY AREA

The study area is part of the orogeny belt of the Zagros in southwestern Iran and is located in the two structural zones of Sanandaj-Sirjan (northeast of the region) and the crushed Zagros (southwestern of the region) (Figure 1). With a length of approximately 1,500 km and a variable width of 250 to 300 km, this belt has an NW-SE trend and is located between the Arabian plate and Central Iran. The orogeny belt of the Zagros is one of the youngest and most active continental collision zones, created by the convergence of the Arabian and Eurasian [1, 2]. In fact, a part of Iran located in the southwest of the Zagros thrust region is called the Zagros zone. Geologists such as Falcon [3], Alavi [4] consider the northeastern part of the Zagros to be a zone with a complex structure along with metamorphic rocks that are widely used in the geological culture of Iran, it is widely referred to as Sanandaj-Sirjan zone. Nevertheless, many geological reports, including Stocklin [5], Nabavi [6], Berberian [7] and Alavi [4] Sedimentary and Structural Characteristics of the Paleo-Tethys Remnants in Northeastern Iran. Alavi [4] citing tectonic changes, magmatism-transformation, and different sedimentary conditions on both sides of the main Zagros thrust, the northeastern border of this area is considered to be the main frontal of the Zagros. From a geomorphological point of view, from northeast to southwest, the Zagros includes the high Zagros (inner Zagros), the folded Zagros (outer Zagros) and the Khuzestan plain, and in terms of structural pattern, from northeast to southwest, it includes thrust zone, folded belt, Dezful embayment and Abadan plain.

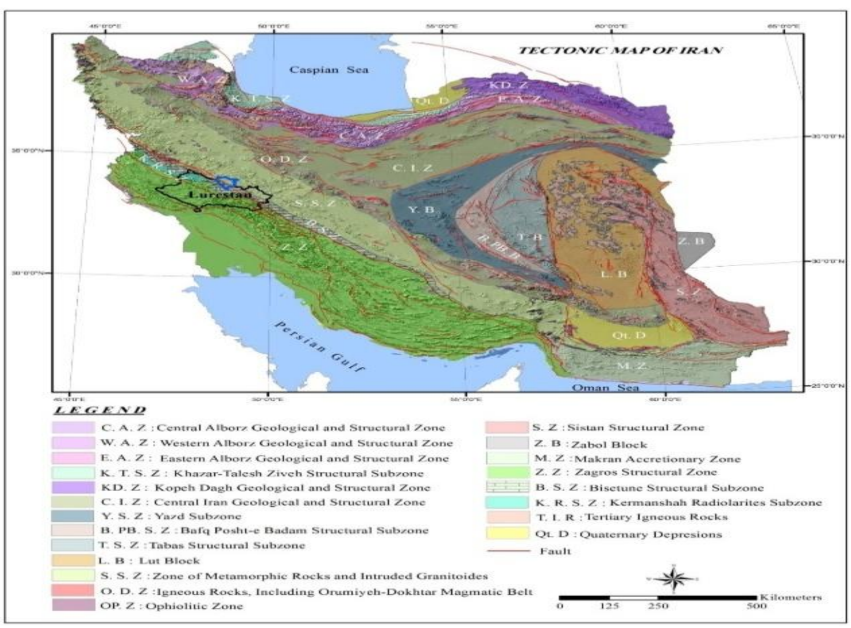

Figure 1. Map of Iran's structural zones and the location of the study area (black and blue box are Lorestan province and Boroujerd city, respectively)

III. COMPARISON OF EARTHQUAKE FREQUENCY AND MAGNITUDE

Based on the frequency of earthquakes versus their magnitude, different distribution functions such as Gutenberg-Richter are expressed and using different statistical methods, seismic parameters are calculated, which are the same constant coefficients of Gutenberg-Richter functions. In this regard, the cumulative frequency of earthquakes (Nc) is attributed linearly and by considering the following simple equation to magnitude (M).

$$\log Nc = a - b\,M \qquad (1)$$

By using this simple equation, by making a suitable classification for the magnitude of earthquakes, the seismic relationship and its related coefficients (coefficients a, b) can be obtained. As can be seen in Equation 1, the frequency of earthquakes in an area is inversely related to their magnitude, which means that as the magnitude of earthquakes increases, their frequency decreases, and vice versa (Table 1).

Table 1. The magnitude and their frequency of earthquakes in the year.

Descriptor	Magnitude Range	Frequency Per Year
Great	8.0 or more	1
Major	7.0 – 7.9	18
Strong	6.0 – 6.9	120
Moderate	5.0 – 5.9	800
Light	4.0 – 4.9	6,200
Minor	3.0 – 3.9	49,000
Very Minor	2.9 or less	Thousands per day

For this purpose, in the list of earthquakes, foreshocks and aftershocks have been identified and removed from the main events, and after removal, the fitting of the final data with the Poisson distribution function has been evaluated. Figure 2 shows the magnitude-frequency distribution of earthquakes in the study area. As can be seen, with increasing magnitude in Ms = 4.5 and above, the frequency of earthquakes decreases. Therefore, the magnitude of Ms = 4.5 is considered as Mc.

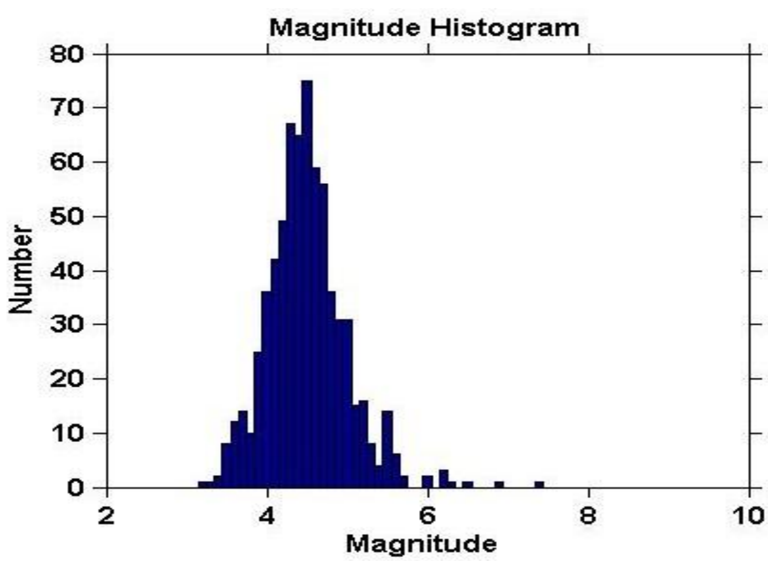

Figure 2. The magnitude-frequency curve of earthquakes in the study area

IV. MODELING PROCEDURE

Data collection of seismic information in the study area

Due to the location of the study area in terms of seismic and seismotectonics characteristics, the main earthquakes in the area of Boroujerd city have been collected and presented. For this purpose, it is necessary to have all the catalogs of earthquakes that have the most complete information about historical earthquakes (before 1900 AD) and instrumental earthquakes (after 1900 AD). In completing this catalog, we tried to use the seismic data of the International Seismological Center (ISC) (1900-1964 and 2002-2006), the Angdal catalog (1964-2002) as well as the data of the National Seismological Center affiliated with the Institute of Geophysics, University of Tehran (2006-2011).

Due to the incompleteness of the list of earthquakes for the focal depth and magnitude of earthquakes, it is necessary to use various methods such as statistical surveys or information about some earthquakes as well as seismotectonics data, these parameters to be included in the list of earthquakes.

Data collection of historical and instrumental catalogs

After data collection of historical and instrumental seismic data, two catalogs were aggregated for seismic analysis. In the aggregated catalog, a large Ms scale is used. For different time periods, the value of standard deviation of magnitude is as follows:

Islamic period: ± 0.5, Safavid era: ±0.4, 1900: ±0.3, 1964: ±0.1 and ±0.2

Catalog processing (removal of foreshocks and aftershocks in earthquake catalogs)

The basic assumption in seismic analysis of the scope of the design for the Cornell 1968 methods is that the annual distribution of the seismic event distribution is within the study area of Poisson.

To eliminate foreshocks and aftershocks, there are various models, including Gardner and Knopoff (1974), Reisenberg (1985), and so on. The first model selected in this study is Gardner and Knopoff's (1974) method(Table 2). For each specific area, according to the experience and engineering judgment in the range of these time and space windows, changes are considered and the annual distribution of the number of earthquakes is closer to the Poisson distribution. The steps for determining major earthquakes and removing aftershocks by Gardner and Knopoff (1974) are summarized as follows(Figure3,4,5):

Preparing a suitable earthquake catalog, arranged in chronological order for the study area

Selection of earthquakes and catalogs as major earthquakes

Assuming the aftershocks of all subsequent earthquakes in the catalog provided:

Being small from the first earthquake

Selection of earthquakes located in the time window related to the magnitude of the main earthquake by observing the condition (a)

Selection of earthquakes from stage (b) that is located in the location window of the main earthquake with a certain magnitude.

Elimination of earthquakes including condition a, b and c, starting work from the next earthquake remaining in the catalog and repeating it to the last remaining earthquake; first the next smaller earthquakes (in terms of time delay) are selected compared to the first earthquake, the time window condition is then applied. The time window is smaller if the main earthquake is smaller and it is larger, if the main earthquake is large, for example, for an earthquake with a magnitude of 4.5 Richter, the time window is about 80 days, and for a magnitude 7.5 Richter, the time window is more than 1000 days. For earthquakes smaller than the main earthquake, which is located in the time window specific to the magnitude of the main earthquake, the condition of the space window is applied. All earthquakes caused by the application of the space window will be removed, the earthquake catalog will be reconstructed, and the same steps will be repeated for the next earthquakes to reach the last catalog earthquake.

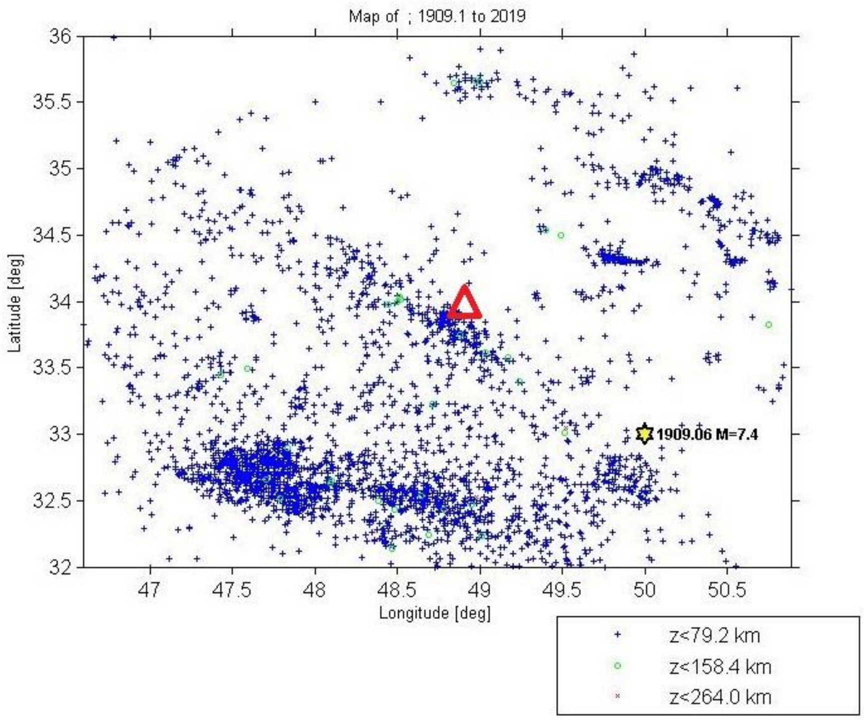

Figure 3. Location of earthquakes in the region before the elimination of dependent events

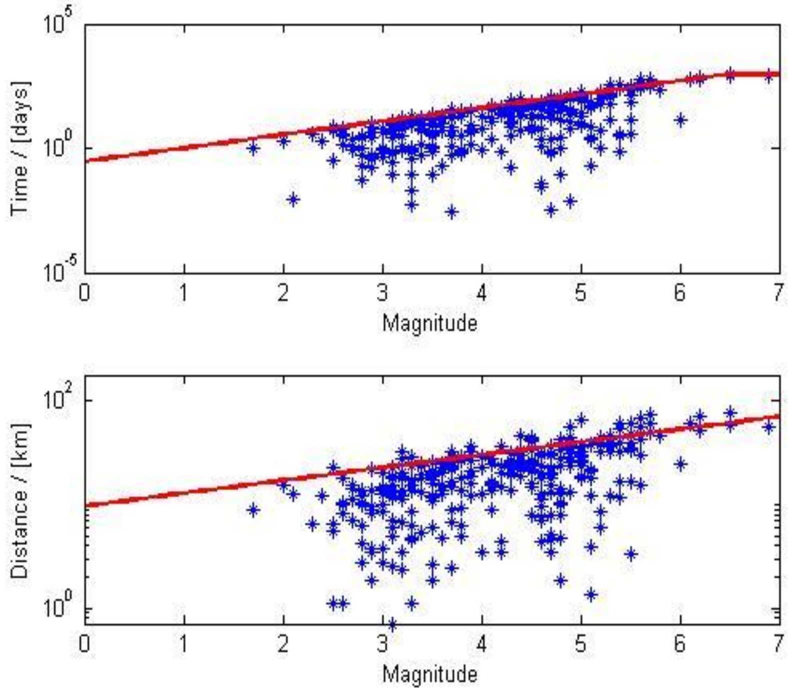

Figure 4. Results from the removal of Gardner & Knopoff-related events (1974)

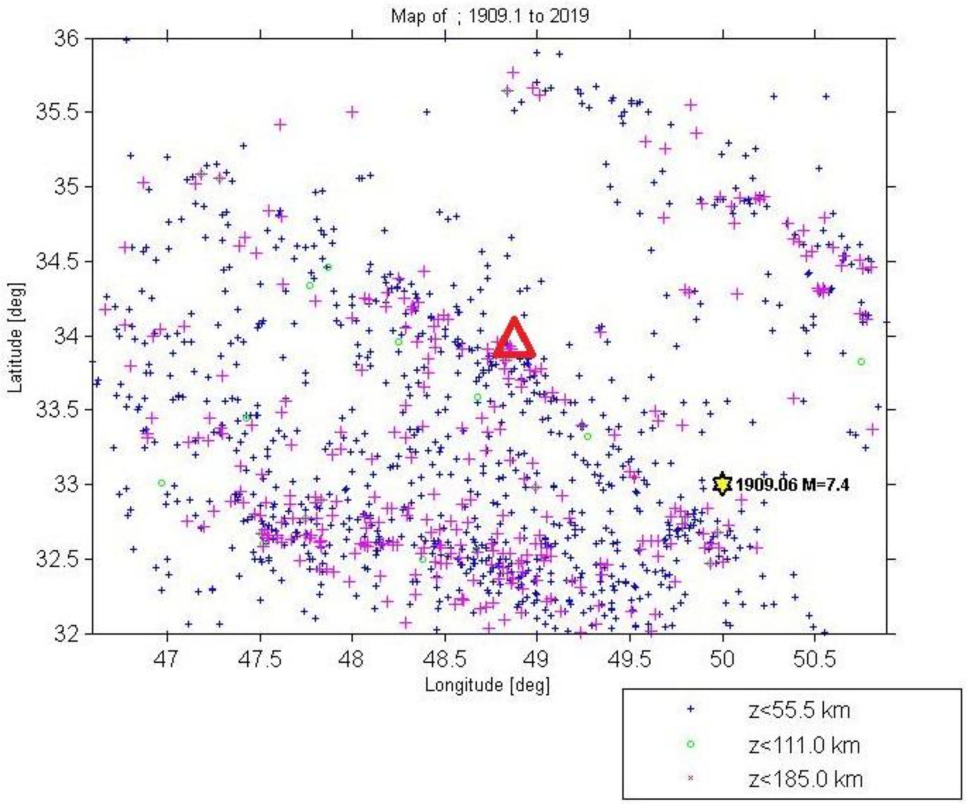

Figure 5. Location of earthquakes in the region after the elimination of dependent events

Table 2. Time and space window for removing aftershocks -Gardner and Knopoff.

Magnitude	L (km)	T (days)
2.5	1.95	6
3.0	22.5	11.5
3.5	26	22
4.0	30	42
4.5	35	83
5.0	40	155
5.5	47	290
6.0	54	510
7.0	70	915
7.5	81	960
8.0	94	985

In terms of uncertainties in magnitude and space coordinates of the catalog

The low number of seismic stations, the poor distribution of stations, and the inadequacy of speed models for Iran has led to significant uncertainty in various parameters (magnitude, center and focal depth) obtained for earthquakes. Earthquake magnitude as a key element in determining the seismic parameters and geographical coordinates of the center of the earthquake as a guide in describing and determining the potential sources of earthquakes play a key role in estimating seismic hazard. Therefore, it is necessary to consider the uncertainty in these parameters at different stages of such studies (Mirzaei et al., 1997).

Evaluate the completeness of the catalog

For a comprehensive seismic study, a complete and homogeneous seismic catalog is required. Seismic cataloging is one of the most important achievements of seismology, which provides basic data for the study of seismotectonics, seismology, seismic physics, and seismic hazard analysis. In accurate estimation of seismic parameters, one of the most important factors is the completeness and homogeneity of seismic catalogs in the study area (Wiemer and Wyss, 2002). Therefore, proper determination of the minimum magnitude of the seismic catalog is essential. For this purpose, after assimilating the magnitude of earthquakes (converting different magnitudes to Ms) to obtain the magnitude of the threshold, from which the complete catalog is considered, the Gutenberg-Richter analysis was performed. At this stage, the magnitude of completeness (Mc) of the data was calculated. The maximum curvature method was used to calculate Mc. This method has been widely used (Wiemer and Katsumata, 1999; Wiemer, 2001). In this method, the point indicating the maximum curvature in the non-cumulative distribution curve of magnitude-frequency is considered as Mc (Zamani and Agh-Atabai, 2009). The value of Mc was obtained 4.5 for earthquakes in the region.

Determining the potential sources of earthquakes in study area

The first step in analyzing seismic hazard is to determine the source in which the earthquake is likely to occur. The purpose of determining the seismic source is to determine the limited range of points where there is a uniform seismic power in all these points. Determining seismic sources is often a major part of seismic hazard analysis that requires knowledge of geology, seismicity, and regional tectonics. A basic assumption in determining seismic sources is the repetition of seismicity. This assumption suggests that major earthquakes occur preferably near the site of past earthquakes, so that if earthquakes occurred on a fault, the probability of an earthquake on that fault with short distances from the center of the previous earthquake is much higher than the areas far from the fault. Determining the correct location of past earthquakes is very important in determining seismic sources. Seismic sources range from well-known structures (such as seismic faults) to lesser-known structures and structures that have little information about their characteristics.

The results of previous research, including the map of active faults in Iran (Hesami Azar et al., 2003) and seismic data and the focal mechanism of earthquakes in the study area, introduced in Table 3 as the seismic sources of the region.

Table 3. Seismic sources within 200 km from Boroujerd.

Row	Fault name	Mechanism	Fault length (Km)	Row	Fault name	Mechanism	Fault length (Km)
1	Parandak	Reverse		12	Morvarid	strike slip	
2	Koshk-Nosrat	Reverse		13	F3	Reverse	
3	F1	Reverse		14	H. Z. F	Reverse	
4	Indes	Reverse		15	Zardkooh	Reverse	
5	F2	Reverse		16	Ardal	Reverse	
6	Tafresh	Reverse		17	M. F. F. 1	Reverse	
7	M. Z. R.F	Reverse		18	M. F. F. 2	Reverse	
8	Dorod	strike slip		19	M. F. F. 3	Reverse	

9	Nahavand	strike slip		20	Balarood	Reverse	
10	Garoon	strike slip		21	Lahbari	Reverse	
11	Sahneh	strike slip					

Calculation of seismic parameters

Based on the frequency of earthquakes and their magnitude, Gutenberg-Richter functions are expressed and seismic parameters are calculated using different statistical methods. In this research, the basic method of Gutenberg-Richter as well as the updated method of Kiko-Cellulus, which is based on the distribution function of the bounded set of Gothenburg-Richter, has been used to compare the results and determine the importance of using methods that are more modern.

The basic assumptions in this study are as follows:

Earthquake compliance with the Poisson process means that earthquakes are independent of time and space.

Homogeneity of the desired range in terms of seismicity and having specific seismic characteristics

Use distribution functions that have the ability to accurately calculate magnitude-frequency equations, such as the Gutenberg-Richter bounded distribution function, which has a high and low limit to enter the magnitude of earthquakes in calculations.

Appropriate statistical methods consistent with the distribution function used, such as statistical estimates of the maximum correctness used in the Kiko-Cellulus method

Ability to perform appropriate categories for seismic due to the magnitude and scattering of seismic relative to magnitude and time, as well as the correct use of historical earthquakes with registered instrumental seismic

Ability to enter uncertainty of magnitude seismic as variables for different categories in calculations

Consider the threshold and maximum magnitude for different categories

Consider intervals to indicate the lack of seismic information that may be present for a variety of reasons, including lack of information or seismicity in the area.

It should be noted that the first two conditions are the basic assumptions in seismic studies, based on which all calculations are performed. Therefore, the raw list of earthquakes must be processed in order to follow the Poisson process. Of course, there are other theories, but the Poisson process is the most practical hypothesis. For this purpose, in the list of earthquakes, foreshocks and aftershocks have been identified and removed from the main events, and after removal, the fitting of the final data with the Poisson distribution function has been evaluated.

Seismic parameters of the study area

The Gutenberg-Richter distribution function was introduced in 1958. In this equation, the seismic frequency (Nm) is attributed linearly to magnitude, taking into account the following simple equation.

$$\text{Log}\ Nm = a - bm \qquad (2)$$

$$\text{Ln}Nm = \alpha - \beta m \qquad (3)$$

In order to better compare the results, the seismic scales were examined in the 200 km area of Boroujerd city center and then using statistical method of least squares, coefficients of a-value & b-value were calculated in Gutenberg-Richter equation, the results of which are presented in Figure 6. It is worth noting that the main earthquakes were used to calculate the base coefficients of Gothenburg-Richter and after the elimination of related earthquakes.

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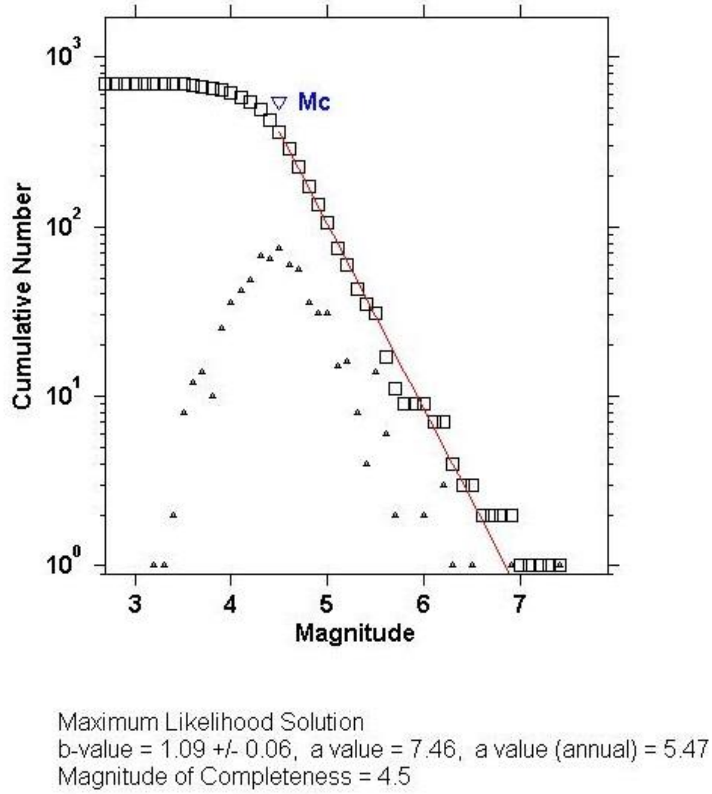

Figure 6. Gutenberg-Richter curve and calculation of a-value, b-value and Mc seismic coefficients

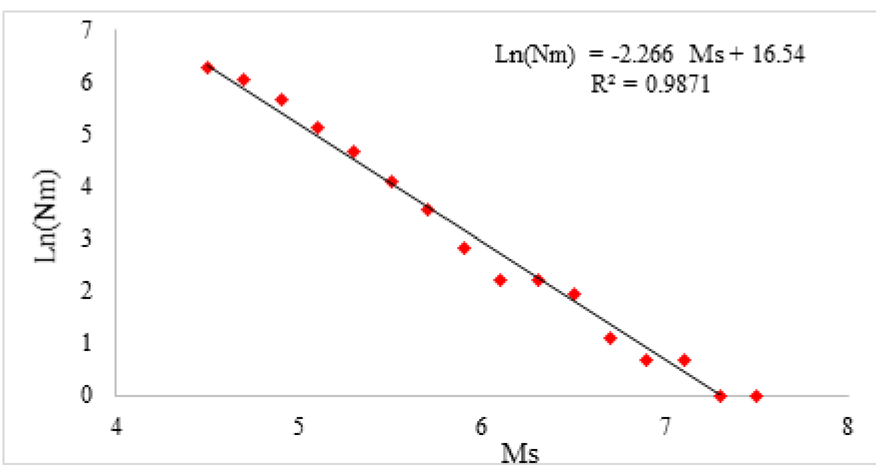

Figure 7. Gutenberg-Richter curve and calculation of seismic coefficients of α and β

Based on the above diagram7, the coefficients of a and b are estimated to be 7.46 and 1.09 for the study area, respectively.

Based on the above diagram, the coefficients of α and β are estimated to be 16.54 and 2.266 for the study area, respectively.

Kiko-Cellulus 2004 method

Based on this method and using the computer program version 2004, the return period of earthquakes with a certain magnitude and the probability of a magnitude earthquake event was calculated(Figure8,9).

The results of seismic coefficients are as follows:

β= 2.71±0.11

λ=53.32± 6.3, for Mmin=3.5

b= 1.18 ± 0.05

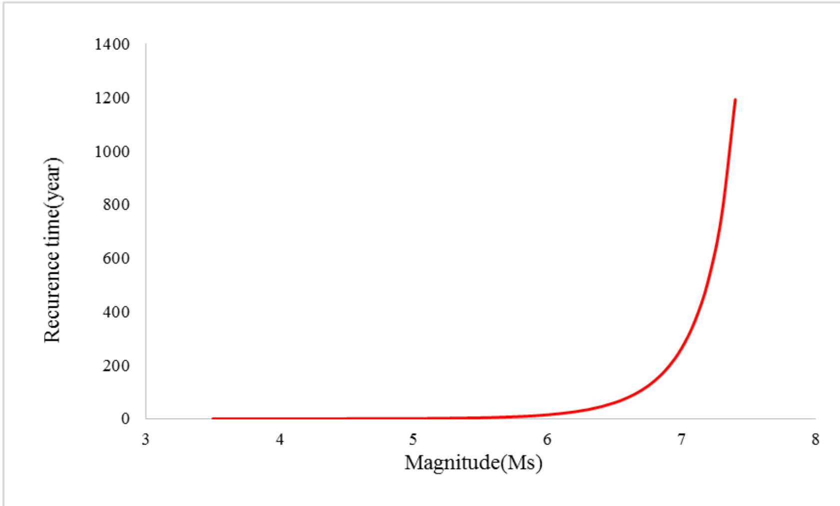

Figure 8. The return period of the magnitude earthquakes in the range of 200 km

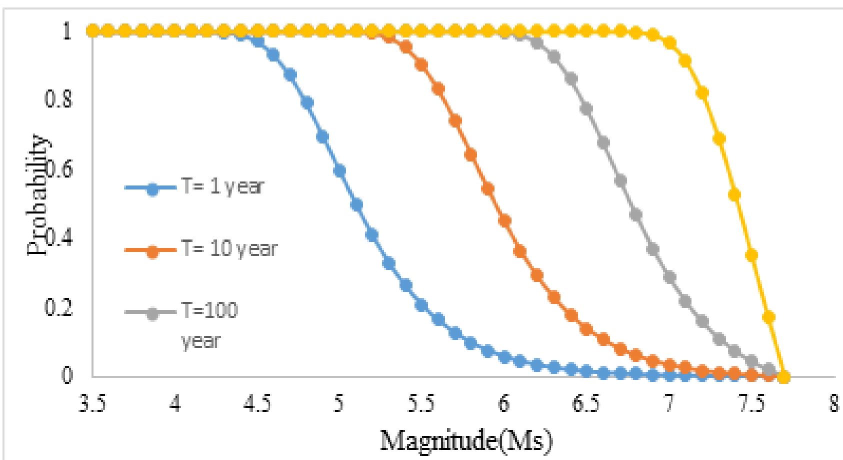

Figure 9. The probability of magnitude earthquakes in 1, 10, 100 and 1000 years in the range of 200 km

Fault and deep seismic mechanism of the study area

Data from solving the focal mechanism of earthquakes were used to investigate the depth mechanism of the studied seismic earthquakes. For this purpose, the focal data of earthquake seismic mechanism up to 200 km were extracted from sites of USGS, NEIC and CMT and their focal mechanism was drawn using WinTensor software. Figure 10 shows the seismotectonics map of the study area along with the depth mechanism of the earthquakes that occurred. As shown in Figure 10, the mechanisms of the studied seismic earthquakes are often strike slip with reverse component or reverse with strike slip component.

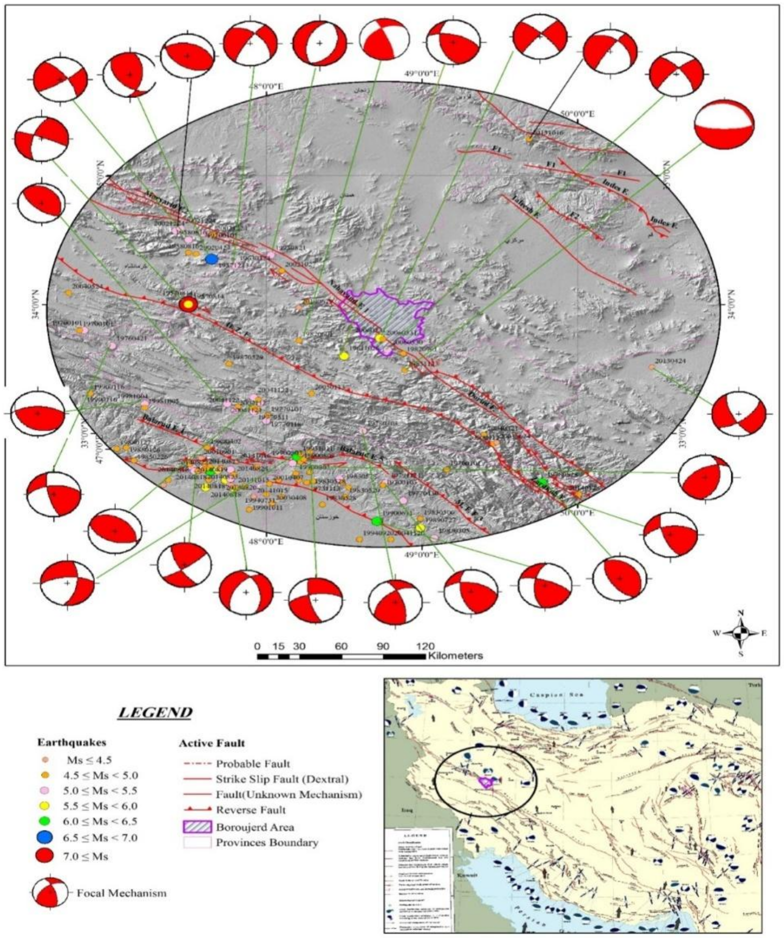

Figure 10. Seismotectonics map of the study area

The main approach in seismic hazard analysis

In general, there are two basic approaches to conducting seismic hazard analysis for a given structure, the first and second methods are Deterministic Seismic Hazard Analysis (DSHA) and Probabilistic Seismic Hazard Analysis (PSHA), respectively.

The first method is based on experimental work and research, and the second method is based on statistical studies of past earthquakes in the region and determining the characteristics of future seismic events with different probabilities.

On the other hand, the most important part of studies is seismic hazard analysis related to recognizing seismic sources, determining their characteristics, which is also possible using geological evidence, and in DSHA method has been paid special attention to these valuable documents.

V. 5. RESULTS

Seismic hazard analysis with deterministic approach

To analyze the hazard with a deterministic approach, it is necessary to take the following steps: 1. Identify the sources, 2. Selection of controlling earthquakes for each source, 3. Select the appropriate attenuation relationship for the Earth's intense movement and 4. Calculate the parameters of the Earth's intense motion.

Step 1: Identify the sources

At this stage, it is necessary to examine all the seismic sources around the structure in question, which could possibly cause a destructive earthquake. Seismic sources are determined based on geological, geophysical and seismic data.

Step 2: Selection of controlling earthquakes

Once all sources have been identified, controlled earthquakes must be determined for each source. The characteristics of the controlled earthquake depend mainly on the structure under study, what hazard can destroy the structure. For a structure whose degradation is possible with a low hazard, a controlled earthquake can be considered as an event that may occur during the useful life of the structure.

For sensitive structures such as nuclear power plants or chemical plants, controlled earthquake is considered an earthquake with maximum magnitude (M_{max}), which can create a specific source. M_{max} can be used to identify the largest historical earthquake, magnitude- fault length relationships, as well as a long-term study of seismology by digging a trench. The distance of each of the controlled earthquakes to the intended site must be calculated. In this case, the distance from a part of the more active fault to the construction site and the closest distance from the fault to the construction site can be considered. For sensitive structures, the closest distance is usually used. It should be noted that if the direction of this distance is on the desired plane, this distance might be different from the distance by considering the angle of the fault surface with the horizontal plane. This distance needs to be calculated based on the definition of distance in the attenuation relationship.

In order to perform deterministic analysis, using the seismic sources determined in the previous steps, it is necessary to make a hypothetical loading of a possible earthquake for the studied structure so that a logical judgment can be made about the effects of that loading (value of earth movement parameters). Controlled seismicity for sensitive structures with high percentage of hazards such as power plants, high dams, etc. is usually defined as the seismic field with the maximum magnitude of M_{max}, which is obtained from a hypothetical and probable seismic source.

One of the methods in determining M_{max} can be derived from geological observations. Examples include the use of an existing relationship between fault length and M_{max} of the area of believable earthquakes (MCL). Digging trenches on faults and determining the amount of slippage and maximum displacement from old seismic events can also help determine M_{max}. In this study, M_{max} has been determined by using the experimental relationship of magnitude- fault length of Vells & Coppersmith, Nowruzi, Zare and Ambraseys.

Vells & Coppersmith has calculated its relationships based on data from around the world, including Iran, and can therefore be used for Iran. In addition, the results of this relationship are very consistent with the relationships provided by Iranian researchers, including Nowruzi (1985).

Wells and Coppersmith (1994) also based on all the data in the world, including Iran, established experimental relationships between all the lengths of faults and the magnitude of earthquakes(Table4).

Table 4. Experimental relationships between fault length and earthquake magnitude (Wales and Coopersmith, 1994).

$M= 5.16+1.12 \text{ Log}(L_R)$	Strike slip
$M= 5+1.22 \text{ Log}(L_R)$	Reverse
$M=4.86+1.321 \text{ Log}(L_R)$	Normal
$M= 5.08+1.161 \text{ Log}(L_R)$	All faults

Zare et al. (1999) based on exponential correlation between the rupture length of 22 seismic faults in Iran has provided the following relationship for calculating the fault rupture length (at ground level).

$$MW= 0.9 \text{ Ln}(LR)+3.66 \quad (4)$$

LR: Surface rupture length caused by seismic fault movement (km)

$$LR= 0.37 \times LF \quad (5)$$

The Ambraseys relationship is as follows:

$$Ms= 4.629+1.429Log(LR) \quad (6)$$

In estimating the maximum magnitude attributed to faults, the fault rupture length is considered as follows:

In the case of faults above 100 km, it is assumed that 30 to 50% of the fault length has been broken. For faults smaller than 100 km and larger than 10 km, 50% of the fault length was broken, and for faults smaller than 10 km, it was assumed that the fault length was 100% broken. Based on this, Table 5 shows the experimental magnitude calculated for the faults in the study area.

Table 5. Maximum seismic power using experimental relationships.

Fault name	Mechanism	Fault length (Km)	Rupture length (Km)	Seismic power			
				Ambraseys	Coppersmith	Zare	Average
Parandak	Reverse	107.3	53.65	7.1	7.1	7.0	7.1
Koshk-Nosrat	Reverse	222.5	100	7.4	7.4	7.6	7.5
F1	Reverse	110	55	7.1	7.1	7.0	7.1
Indes	Reverse	97	48.5	7.0	7.0	6.9	7.0
F2	Reverse	58	29	6.8	6.8	6.4	6.7
Tafresh	Reverse	118	59	7.1	7.1	7.1	7.1
M. Z. R.F	Reverse	650	100	7.4	7.4	8.6	7.8
Dorod	strike slip	104	52	7.1	7.1	6.9	7.0
Nahavand	strike slip	104	52	7.1	7.1	6.9	7.0
Garoon	strike slip	25	12.5	6.4	6.4	5.7	6.1
Sahneh	strike slip	84	42	7.0	7.0	6.8	6.9
Morvarid	strike slip	136	68	7.2	7.2	7.2	7.2
F3	Reverse	172	86	7.3	7.3	7.4	7.4
H. Z. F	Reverse	360	100	7.4	7.4	8.1	7.6
Zardkooh	Reverse	141	70.5	7.2	7.2	7.2	7.2
Ardal	Reverse	175	87.5	7.3	7.3	7.4	7.4
M. F. F. 1	Reverse	43.3	21.65	6.7	6.6	6.2	6.5
M. F. F. 2	Reverse	15	7.5	6.1	6.1	5.2	5.8
M. F. F. 3	Reverse	91.7	45.85	7.0	7.0	6.8	7.0
Balarood	Reverse	175	87.5	7.3	7.3	7.4	7.4
Lahbari	Reverse	235	100	7.4	7.4	7.7	7.5

As can be seen in Table 5, the maximum seismic power of the faults varies on average from 5.8 to 7.8 on the Richter scale. Also, the highest seismic power is related to the main thrust faults of the Zagros, the high Zagros, Koshk-Nosrat, Lahbari, F3, Zardkooh and Ardal.

Step 3: Select the appropriate attenuation relationship

The peak ground acceleration (PGA) is commonly used to indicate intense ground motion. In this regard, the magnitude and distance for a given hypothetical event can be used to calculate the acceleration. Therefore, it is necessary to pay attention to the tectonics regime of the region, because the acceleration decrease in different tectonics regimes as well as different parts of the earth's crust is different due to different seismic characteristics (in terms of durability, frequency content and stress drop). In this case, the controlled seismic for the construction site is the seismic field that creates the largest movement in the building.

As we move away from the seismological center, the Earth's motion becomes less intense, indicating the damping earth movement. The extent of this damping is related to various factors, including geological conditions and the type of fault movement. Therefore, the extent of this damping varies in different regions and extensive studies have been conducted by researchers and presented in the name of attenuation relationships. This relationship is generally in terms of magnitude and focal length, and their general form is as follows:

$$Y = b_1 f_1(M) f_2(R) f_3(M,R) f_4(\rho)\varepsilon \quad (7)$$

Where M is the magnitude of the earthquake, R is the distance between the source and the structure, ρ is the characteristics of the seismic source and the wave transmission path, and ε is error. In order to choose a attenuation relationship, a relationship must be selected that is most compatible with the area under study in terms of seismotectonics, for this purpose, attenuation relationships of Zare (2004) and Nowruzi have been used and the peak acceleration has been selected from this.

Zare attenuation relationship (2004)

$$\mathrm{Log}(PGA) = a_1 M + a_2 M^2 + b.\mathrm{Log}(R) + c_i S_i + \sigma P \quad (8)$$

Table 6 is used to calculate PGA.

Table 6. Acceleration attenuation coefficient in Zare attenuation relationship (2004).

PGA	a1	a2	B	c1	c2	c3	c4	s
Horiz.	0.5781	-0.0317	-0.4352	-2.6224	-2.5154	-2.4654	-2.6213	0.2768
Vert.	0.5593	-0.0258	-0.6119	-2.6261	-2.6667	-2.5633	-2.7346	0.2961

Nowruzi attenuation relationship

$$Ln(PGA) = a_1 + a_2.(M-6) - b.Ln(\sqrt{R^2+100}) + C.S \quad (9)$$

Table 7. Acceleration attenuation coefficient in Nowruzi attenuation relationship.

PGA	a1	a2	B	c1	c2	c3	c4	s
Horizontal	7/969	1/22	1/131	0/212	0/212	0/212	0/212	0/825
Vertical	7/262	1/214	1/094	0/103	0/103	0/103	0/103	0/773

Step 4: Calculate the parameters of the Earth's intense motion for design

Using the attenuation relationships(Table7) (step 3) for the controlled earthquakes related to each source, the peak ground acceleration is calculated. In this case, the seismic field that creates the most PGA in the target structure is considered as the seismic surface of the design surface.

Based on the above calculations, the maximum acceleration values for each of the main sources relative to the structure have been calculated for the seismic power and the distance of the modeled faults from the center of Boroujerd city and the application of the appropriate attenuation relationship. In this study, the high Zagros, Nahavand and Dorod fault, due to its proximity to the studied structure, create the most acceleration in the range compared to other faults (Table 8,9). It should be noted that in this method, if seismic design is performed for the worst conditions, the desired safety for the studied area against seismic hazard would be obtained conservatively and efficiently. Therefore, the parameters obtained from this method are suitable for the maximum acceptable seismic design of MCE.

Table 8. Calculated values of maximum horizontal acceleration by deterministic approach.

Maximum horizontal acceleration			Distance to the construction site (Km)	magnitude	Linear source
Largest PGA	Nowruzi	Zare			
0.09	0.04	0.09	215	7.1	Parandak
0.11	0.08	0.11	186	7.5	Koshk-Nosrat
0.11	0.05	0.11	163	7.1	F1
0.10	0.04	0.10	175	7	Indes
0.10	0.04	0.10	137	6.7	F2
0.12	0.07	0.12	123	7.1	Tafresh
0.11	0.09	0.11	230	7.8	M. Z. R.F
0.17	0.17	0.17	53	7	Dorod
0.18	0.18	0.17	50	7	Nahavand
0.11	0.05	0.11	60	6.1	Garoon
0.15	0.12	0.15	94	6.9	Sahneh
0.12	0.08	0.12	150	7.2	Morvarid
0.10	0.06	0.10	205	7.4	F3
0.23	0.23	0.17	68	7.6	H. Z. F
0.10	0.05	0.10	206	7.2	Zardkooh
0.10	0.05	0.10	220	7.4	Ardal
0.08	0.02	0.08	190	6.5	M. F. F. 1
0.06	0.01	0.06	168	5.8	M. F. F. 2
0.10	0.05	0.10	157	7	M. F. F. 3
0.13	0.10	0.13	135	7.4	Balarood
0.11	0.07	0.11	205	7.5	Lahbari

Table 9. Calculated values of maximum vertical acceleration by deterministic approach.

Maximum horizontal acceleration			Distance to the construction site (Km)	magnitude	Linear source
Largest PGA	Nowruzi	Zare			
0.04	0.02	0.04	215	7.1	Parandak
0.05	0.04	0.05	186	7.5	Koshk-Nosrat
0.04	0.03	0.04	163	7.1	F1
0.04	0.02	0.04	175	7	Indes
0.04	0.02	0.04	137	6.7	F2
0.05	0.03	0.05	123	7.1	Tafresh
0.05	0.04	0.05	230	7.8	M. Z. R.F
0.08	0.08	0.08	53	7	Dorod

0.09	0.08	0.09	50	7	Nahavand
0.05	0.02	0.05	60	6.1	Garoon
0.07	0.05	0.07	94	6.9	Sahneh
0.05	0.04	0.05	150	7.2	Morvarid
0.04	0.03	0.04	205	7.4	F3
0.11	0.11	0.09	68	7.6	H. Z. F
0.04	0.02	0.04	206	7.2	Zardkooh
0.04	0.03	0.04	220	7.4	Ardal
0.03	0.01	0.03	190	6.5	M. F. F. 1
0.02	0.01	0.02	168	5.8	M. F. F. 2
0.04	0.02	0.04	157	7	M. F. F. 3
0.06	0.05	0.06	135	7.4	Balarood
0.05	0.03	0.05	205	7.5	Lahbari

VI. DISCUSSION AND CONCLUSION

Understanding seismic hazard requires the study of tectonic processes near the site. Even with little information, it would be necessary to provide a seismotectonic model. This model defines the framework contain possible future earthquakes. The formation of a seismotectonic model requires the dissolution of the fault seismic plane of the event earthquakes because they provide an estimate of the orientation of the active fault planes below the earth's surface and for slipping on these planes. Based on the obtained results, the maximum seismic power of the desired faults varies on average from 5.8 to 7.8 on the Richter scale. Also, the highest seismic power is related to the main thrust faults of Zagros (M = 7.8), high Zagros (M = 7.6), Koshk-Nosrat (M = 7.5), Lahbari (M = 7.5), F3 (M = 7.4), Zardkooh (M = 7.2) and Ardal (M = 7.4). The largest horizontal accelerations obtained in the deterministic approach are 0.23 g, 0.18 g and 0.17 g, which are related to the high Zagros faults (H.Z.F), Nahavand and Dorod, respectively. In addition, the largest vertical acceleration obtained in the deterministic approach is 0.11 g, 0.09 g and 0.08 g, which are related to the high Zagros faults (H.Z.F), Nahavand and Dorod, respectively.

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