SEISMIC HAZARD ASSESSMENT OF GILAN PROVINCE INCLUDING MANJIL IN IRAN

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ABSTRACT :

Manjil is an important city in Gilan province in Iran. It has experienced one of the largest earthquakes in Iran on 21 June 1990 with magnitude of Ms = 7.7 Richter that caused many destructions and human casualties. With respect to historical earthquakes in the region of Gilan province and existing active faults like Manjil-Rudbar and also according to the distribution of earthquakes, this region has high seismic potential.
With respect to the mentioned reasons, current study has been performed as seismic hazard analysis of Gilan province with different risk levels. It is needed to provide horizontal Peak Ground Acceleration (PGA) maps with different risk levels for different parts of the region. A category of historical and instrumental seismic data since the 4th century BC up to 2005 has been used and seismic sources in the radius of 200 km of the region have been modeled. In order to assess the seismicity parameters, with respect to the lack of proper seismic data and uncertainty of magnitudes in different times, the Kijko [2000] method has been used. In order to determine the PGA over bedrock three different attenuation relationships of Ramazi [1999], Ambaseys et al. [1996] and also Sarma and Srbulov [1996] relationships have been used. These three relationships have been mixed by using logic tree method with weighted coefficients of 0.4, 0.35 and 0.25 respectively and final results have been produced. The probabilistic hazard analysis of earthquakes has been performed for a 50*50 mesh which covers the region, by SEISRISK III [1987] for occurrence probability of 2% and 10% in 50 years.

KEYWORDS: Seismic Hazard Assessment, Seismicity Parameter, PGA, Gilan, Iran.

1. INTRODUCTION

Iran, one of the most seismic countries of the world, is situated over the Himalayan-Alpied seismic belt. One of the most important features of Iran plate is young tectonic movements. In Iran region faults movements do not have a logic process. In many regions especially in Alborz region horizontal movements can be observed along the faults in addition to vertical movements which are a reason for turbulent deformations. The best type of these deformations in central Alborz region has become apparent after 1990 Manjil - Rudbar earthquake. This paper presents probabilistic horizontal seismic hazard assessment of Gilan province.

2. TECTONIC OF GILAN PROVINCE

Gilan province is located in south western of Caspian Sea in mountainous area of Talesh and central Alborz range that endure many earthquakes up today.
The most ancient earthquake ever occurred in this area refers to Marlik civilization which is located near Rudbar – Rostam Abad. This ancient earthquake has destroyed this area in the first millennium B.C. [Berberian, et. al. 1992; Negahban, 1964, 1977]. One of the recent earthquake in the 20th century in this area is Rudbar earthquake in 21 Jun 1990 with magnitude Ms = 7.7 Richter that caused many destruction. In one hand according to complex tectonic of central Alborz and in the other hand locating Gilan in the south west of Caspian sea that demonstrate many seismic activities, it illustrates as a result that this area is one of the active high potential seismic area of Iran (Figure 1 and Table 1) .
The reason, why this area is so seismically hazardous is the changing of procedure of tectonic in the

semi oceanic crust in the bottom of Caspian sea. The progress of this procedure has illustrated in Lahijan fault and its magnetic groove in seashore.
According the above, the faults in this area are high potential seismic and it is expected, tectonic procedure cause destruction along the active faults, one of supporting reason for this hypothesis is, the Jun 1983 earthquake that occurred seven years before the big earthquake in 1990 [Tavakoli & Ghafory-Ashtiany, 1999].
The last earthquake in this area was on 29 Aug 1998 with magnitude M=4.9. There are some reported earthquakes in 1485 A.D. with magnitude M=7.2 and an other one in 1608 A.D. [Ambarseys and Melville, 1982]

Table 1 Main faults of Gilan Province [IIEES]

No.	Fault	Length (km)
1	Manjil Rudbar	152
2	Talesh	75
3	Fouman	60
4	Lahijan	51
5	Masoule	60
6	North Alborz	300
7	Khazar(Alborz)	600
8	Zardgoli	40
9	Banan	66
10	Javaherdasht	74
11	Taleghan	64
12	North Qazvin	60

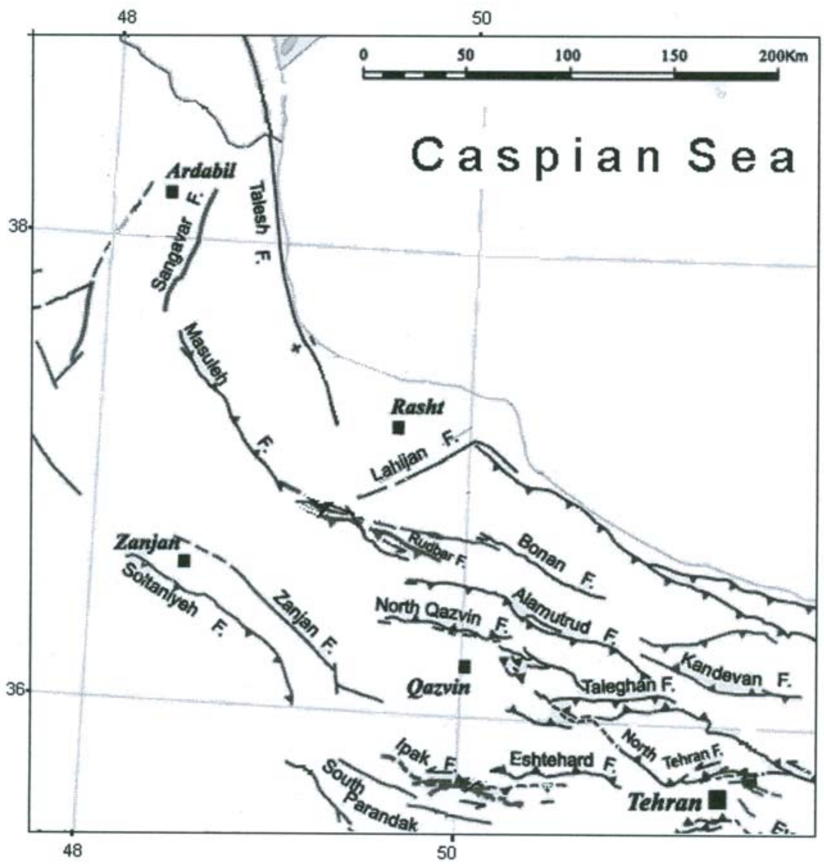

Figure 1 The active faults of Gilan province [IIEES]

3. MAGNITUDE OF THE EARTHQUAKES

In hazard analysis one kind of magnitude is used, for example surface wave magnitude (Ms) or body wave magnitude (mb). But according to missing the value of mb or Ms in some of earthquakes. It is supposed to find a way to estimate these missing values. One of the best probabilistic ways to calculate the missing values is the regression analysis. In this study the relationship given by Iranian Committee of Large Dams [IRCORD, 1994] for all area in Iran plateau is used in this regard.

4. DETERMINATION OF SEISMIC PARAMETERS

Calculation of seismic parameters usually is based on occurrence of earthquake and magnitude abundance, in order to calculate these parameters, there were given several methods based on initial Guttenberg Richter [1954] relationship.
Gardner and Knopoff [1974] method is used to eliminate the foreshocks and aftershocks in the catalogue, which is the variable windowing method in time and space domains.
In this study, the new Kijko [2000] relationship is used that is based on Gutenberg Richter [1954] relationship and the maximum likelihood estimation method.
The assumptions are:

- The earthquakes follow the poisson process, so they are independent in time and space zone.
- The studying area in 200 km range is seismically homogenous and has certain seismic characteristics.

The items considered during choosing the method and distribution function in order to determine the seismic parameters are listed below:

- Using the distribution function that cause more precise and more actual magnitude abundance relationship such as Gutenberg Richter relationship.
- Using appropriate statistics methods with used distribution function such us maximum likelihood estimation.
- Using a proper classification to use both ancient earthquakes and new earthquakes recorded by seismograph.
- The ability to consider magnitude error according to its group.
- The ability to assume different threshold magnitude and maximum probable magnitude for each group.
- The ability to consider some interval to show the shortage of seismic record.

4.1. Determination of seismic parameters based on Kijko method

As it is known the error in recording the earthquakes magnitudes in different time differs then it does not seem that initial Guttenberg Richter relationship has a good output. Therefore, a method which matches more with Iran tectonic is used.
In this method, with assumption different error values in different periods and considering Kijko [2000] method, the seismic parameters, maximum acceptable magnitude, return period, occurrence probability in different times can be calculated.
In this method generally the earthquakes has divided in three classes.

- First group, the ancient earthquakes which are recorded in well, middle and bad conditions that respectively assumed with 0.3, 0.4 and 0.5 magnitude error.
- Second group , the earthquakes before installing the world seismograph network from 1900 to 1963 A.D. which assumed with 0.2 magnitude error and threshold magnitude of Ms = 4.5 Richter.
- Third group, the earthquakes recorded by seismograph after 1964 A.D. so they have less error, which assumed with 0.1 magnitude error and threshold magnitude of Ms = 4 Richter.

In order to consider the seismic process in the centuries, Kijko method in three shapes is applied. The results of this method are shown in Table 2 and Figure 2.

Table 2 Seismicity parameters in different cases for Gilan province

Catalog	Parameters	Value	Data Contribution to the parameters (%)		
			Case 1	Case 2	Case 3
Instrumental Earthquakes	Beta	1.77		40.4	34.7
	Lambda (Ms=4)	0.38		44.0	56.0
Historical Earthquakes	Beta	2.28	100		
	Lambda (Ms=4)	0.60	100		
Instrumental & Historical Earthquakes	Beta	1.64	53.9	25.1	21.1
	Lambda (Ms=4)	0.41	34.2	28.9	36.9

Based on this study with Kijko method annual occurrence rate of the earthquakes versus magnitude for earthquakes with magnitude more than Ms = 4 in this area (200 km) is shown in Figure 2.

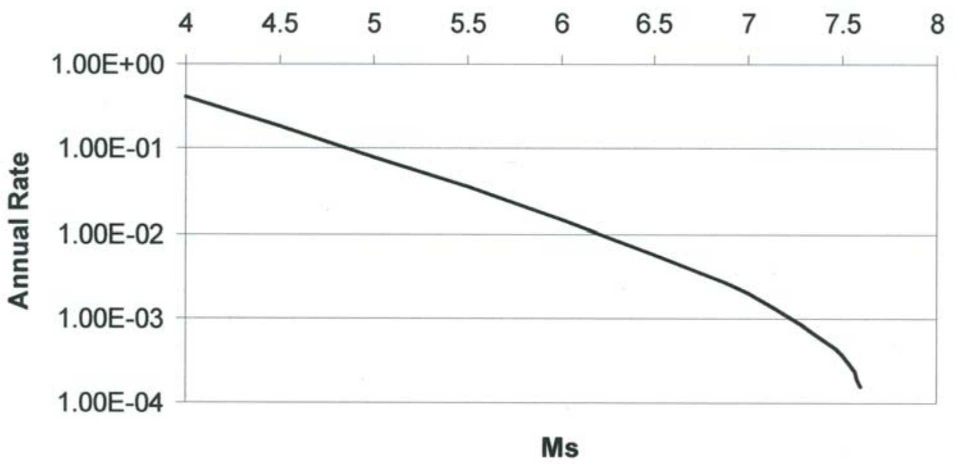

Figure 2 Annual rates estimated by Kijko method for Gilan province

4.2. Determination of seismic parameters based on Tavakoli [1996] method

In 1996 Tavakoli divided Iran to twenty territories and calculated seismic parameters for each territory and Gilan province is located in 20th territory thus its seismic parameters is shown in Table 3.

Table 3 Seismicity parameters for seismotectonic province of Gilan province [Tavakoli, 1996]

Province No.	Span of Time	Beta	Mmax	Lambda (Ms = 4.5)
20	1929-1995	2.32 ± 0.16	7.5 ± 0.9	0.33

5. ATTENUATION RELATIONSHIP

Attenuation relationship express the relation between fault deflection, magnitude and distance and depends on many factors such as:

- Source characteristics, magnitude, distance from source and type of rapture.
- Path of wave, reflection, refraction, absorption of energy because of wave environment.
- Geography and topography of field.

In calculating the PGA’S, different attenuation relationships were used: Ramazi [1999], Ambarseys et al. [1996] and Samara and Srbulov [1996]. These relationships and the two methods, Kijko [2000] and Tavakoli [1996] are combined using logic tree with different weights.

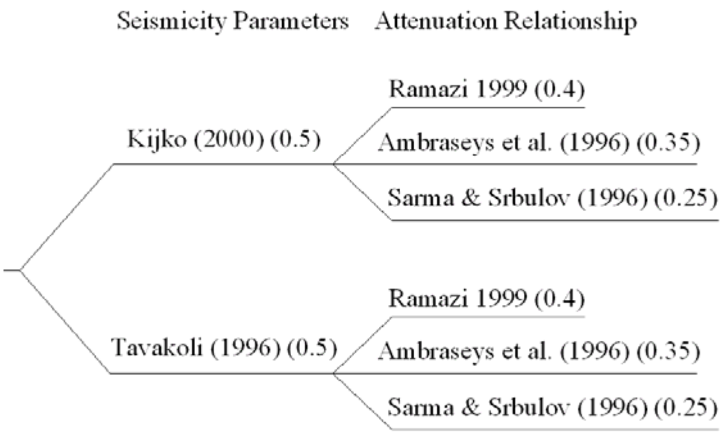

Figure 3 Applied logic tree for seismic hazard analysis

6. THE PROBABILISTIC SEISMIC HAZARD ANALYSIS

In this section based on seismic source modeled and with the seismic parameters, the maximum bedrock acceleration (PGA), are calculated by the software SEISRISK III [1987] during the useful life of structures.
Based on the seismic rehabilitation code for existing buildings in Iran [IIEES, 2002], two hazard levels are most considered: 10% and 2% probabilities of exceedence in 50 years. The maximum horizontal acceleration on bedrock in different hazard levels is shown in Figures 4 and 5.

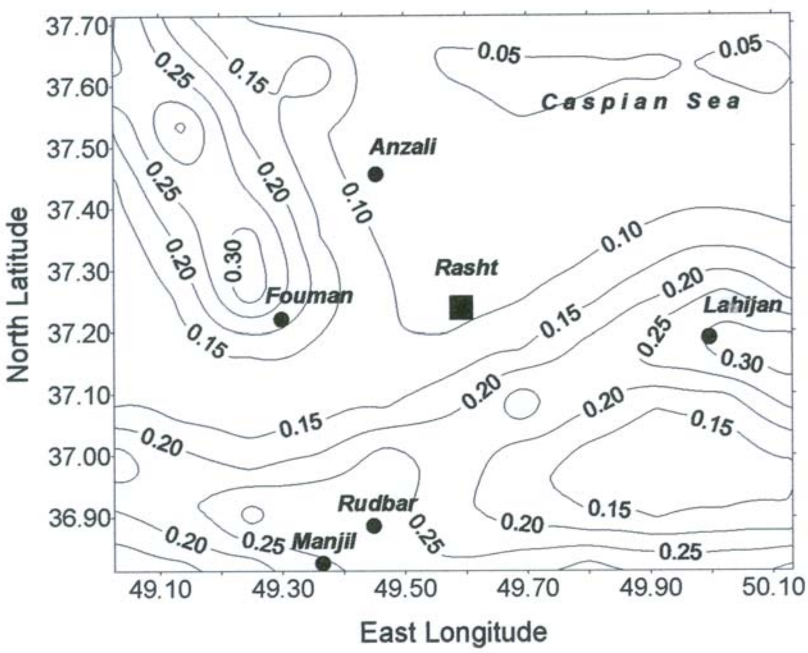

Figure 4 Horizontal seismic hazard (PGA over bedrock) map of Gilan province using logic tree for 475 year return period

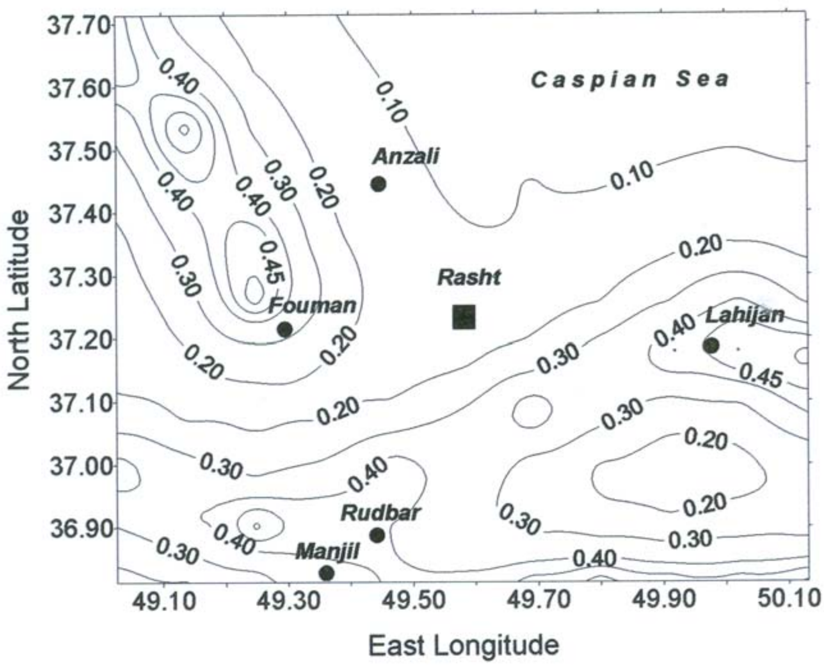

Figure 5 Horizontal seismic hazard (PGA over bedrock) map of Gilan province using logic tree for 2475 year return period

7. CONCLUSION

This paper studied seismic hazard and seismic zoning of Gilan province based on probabilistic approach. The significant results of this study can be summarized as: (1) Generation of a preliminary seismic zoning map (PGA over bedrock) that can be used, with caution, as a guide for determining the design earthquake, (2) Production of an updated and complete earthquake catalogue considering both historical and instrumental events, and (3) Utilization of different worldwide attenuation relationships using logic tree method. The seismic hazard analysis carried out in this paper was based on the assumption of an ideal bedrock case and therefore no influence of local soil condition is taken into consideration.

This research presents the map of maximum probable acceleration over bedrock for 475 and 2475 year return periods. The PGA in the interested area, ranges from 0.10g to 0.30g and 0.20g to 0.45g for 475 and 2475 year return periods, respectively.

By observing the maps of Peak Ground Acceleration over bedrock (PGA), we can conclude that in Lahijan, Fouman, Rudbar and Manjil in regard with the closeness to the main faults the values of the PGA increase.

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