4th International Conference on Earthquake Geotechnical Engineering
June 25-28, 2007
Paper No. 1571

Evaluation of Horizontal Seismic Hazard of Karaj, Iran

Gholamreza GHODRATI AMIRI [1], Morteza RAEISI DEHKORDI [2], Seyed Ali RAZAVIAN AMREI [3], Mohammad Ali FARROKHI [4]

ABSTRACT

This paper presents probabilistic horizontal seismic hazard assessment of Karaj, Iran. It displays the probabilistic estimate of Peak Ground Horizontal Acceleration (PGHA) for return periods of 475 and 2475 years. The output of the probabilistic seismic hazard analysis is based on peak ground acceleration (PGA), which is the most common criterion in designing of buildings. A catalogue of seismic events that includes both historical and instrumental events was developed which covers the period from 4th century BC to 2005. The seismic sources that affect the hazard in Karaj were identified within the radius of 200 km and the recurrence relationships of these sources were generated by Kijko and Sellevoll [2000]. Finally two maps have been prepared to indicate the earthquake hazard of Karaj in the form of iso-acceleration contour lines for different hazard levels by using SEISRISK III.

Keywords: seismic hazard assessment, seismicity parameters, Karaj, Iran.

INTRODUCTION

Iran, one of the most seismic countries of the world, is situated over the Himalayan-Alpied seismic belt. Karaj with a population exceeding 5 million people is located in the west of Tehran, very close to the capital of Iran. Due to the population and existence of major economical and social centers there is a need of a very precise investigation of seismicity and seismic hazard. This paper presents a probabilistic horizontal seismic hazard assessment of Karaj.

SEISMOTECTONIC STRUCTURE OF KARAJ

Karaj city is situated on the south plateau of central Alborz Mountain. In order to evaluate the seismic hazard of a region or zone, all the probable seismic sources must be detected and their potential to produce strong ground motion must be checked. The major faults in Karaj region are North Tehran thrust, Mosha, Alamutrud, Eshtehard, Kahrizak, Taleghan and Qeshlag. The location of these faults with respect to Karaj is shown in Figure 1.

SEISMICITY OF KARAJ

[1] Associate Professor, Department of Civil Engineering, Iran University of Science & Technology - Islamic Azad University of Shahrekord, Iran, Email: ghodrati@iust.ac.ir
[2] Assistant Professor, Department of Civil Engineering, Islamic Azad University of Shahrekord, Iran.
[3] Ph.D. Student, Department of Civil Engineering, Iran University of Science & Technology, Iran, Email: ali_razavian@iust.ac.ir
[4] M.Sc. Student, Department of Civil Engineering, Islamic Azad University of Shahrekord, Iran, Email: mafarrokhi@yahoo.com

The seismicity of each region is indicated by the past earthquakes occurred in that region and to obtain the seismotectonic properties, a thorough list of each region's earthquake events must be collected and studied. The list of occurred earthquakes in a radius of 200 km around Karaj is given in Table 1 and shown in Figure 2.

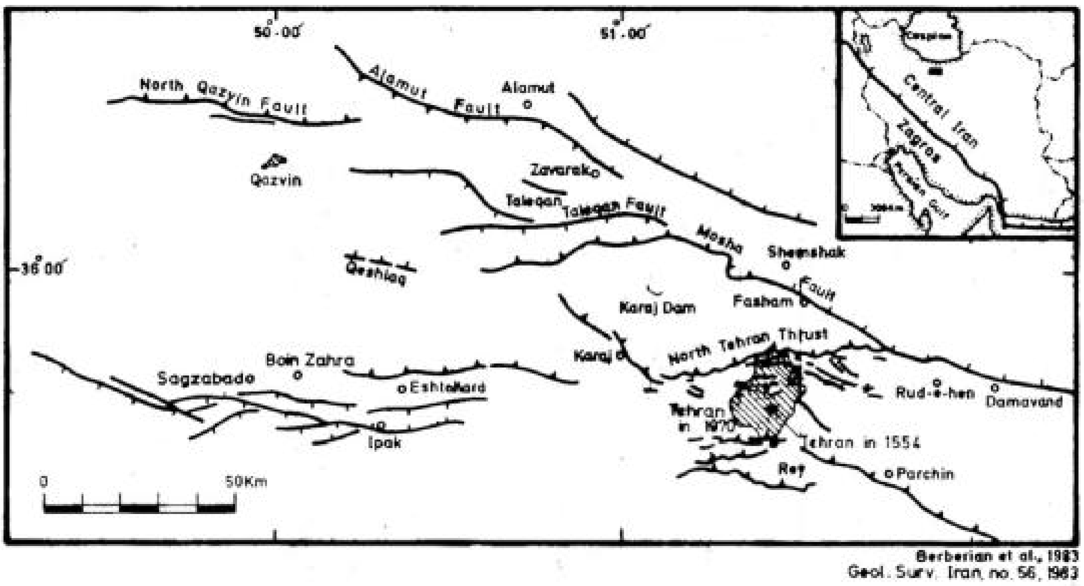

Figure 1. The active faults of Karaj (Berberian et al. [1983])

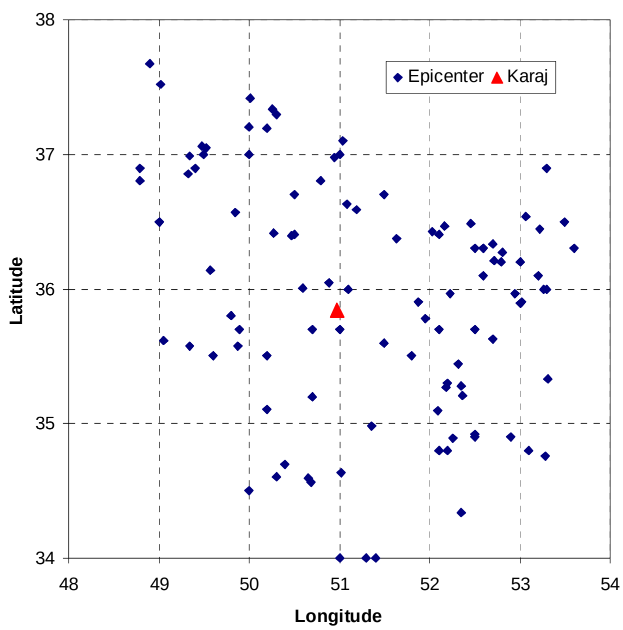

Figure 2. The distribution of earthquake occurred in Karaj based on Table 1

Karaj sismicity parameters

The evaluation of seismicity parameters is performed based on the seismic data of earthquakes occurred in the region under study and employing probabilistic methods. Since there are various magnitude scales in Table 1, in order to homogenize these scale all magnitudes were converted in Ms using relationships presented by Iranian Committee of Large Dams [IRCOLD, 1994]. The seismic catalogue has been collected, assuming that earthquakes follow a Poisson distribution. The method which is used to eliminate the foreshocks and aftershocks is the variable windowing method in time and space domains [Gardner and Knopoff, 1974].

Due to the very high importance of the seismicity parameters in seismic hazard evaluation, in this study the new Kijko method (2000) has been employed which is based on double truncated Gutenberg-Richter relationship and the maximum likelihood estimation method. In the maximum likelihood estimation method (Kijko-Sellevoll 2000), it is possible to use historic and instrumentally recorded data at the same time. The values of seismicity parameters β ,λ resulting from this method were: 1.52, 0.76. The annual average occurrence rate of earthquake versus magnitude for earthquakes with magnitude greater than M_S =4.0 in the extent of 200 km around Karaj is shown in Figure 3 based on these investigations and the performed calculations with Kijko [2000] method.

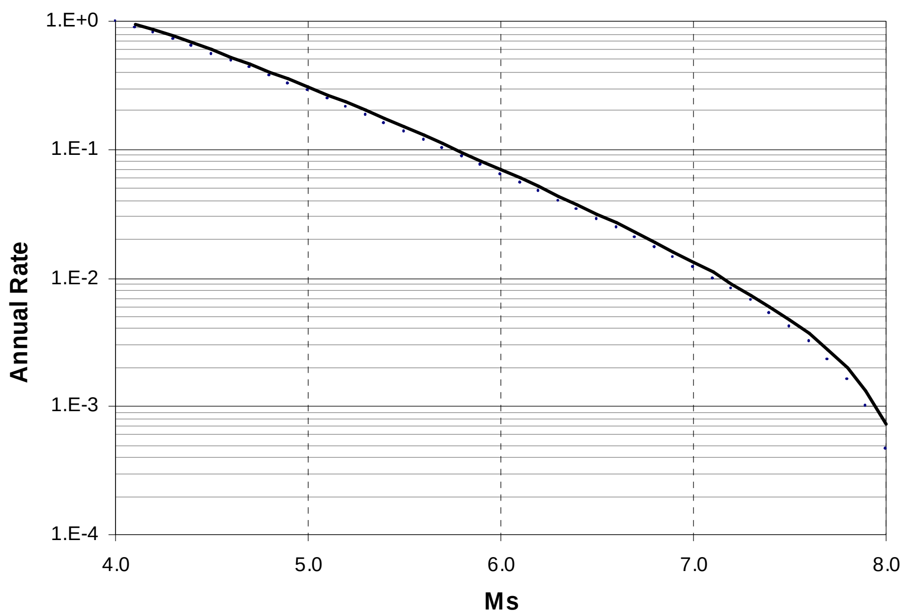

Figure 3. Annual rates estimated by Kijko method for Karaj

EVALUATION OF HORIZONTAL SEISMIC HAZARD

In order to evaluate Peak Ground Horizontal Acceleration (PGHA) for the return period of 475 and 2475 years, probabilistic seismic hazard analysis method has been used. In this method, seismicity parameters (β, λ) are given to the seismic sources (which were modeled as line sources) based on the seismicity investigations, then based on earthquake magnitude, distance of epicenter or hypocenter from site and application of an appropriate attenuation relationship, Peak Ground Horizontal Acceleration (PGHA) at the corresponding site is evaluated.

Attenuation relationship

Selection of appropriate attenuation relationship is very important in validity and reliability of the analysis results. Therefore, there are some important notes that must be paid attention to for the selection of attenuation relationships. The most important ones are source specifications, magnitude, fault rupture type, distance to the seismogenic sources, geology and topology of site.

The reason for the selection of these relationships was that the first and the last relationships (Ramazi, 1999 and Ghodrati et al., 2006) cover local conditions; the second relationship (Ambraseys and Bommer, 1991) satisfies regional conditions. Based on the mentioned remarks, in this research three weighted horizontal attenuation relationships; Ramazi [1999], 0.3, Ambraseys & Bommer [1991], 0.2, Ghodrati et al. [2006], 0.5, in Logic Tree method were employed. It should be mentioned that the mean level of these attenuation relations have been used as a base and then their standard deviation were included during the calculation.

Probabilistic seismic hazard analysis

For the seismic hazard probabilistic evaluation, the software SEISRISK III [Bender, 1987] was utilized to calculate the Peak Ground Horizontal Acceleration (PGHA) in the specific hazard level in the structure lifetime. The calculated values can be shown in the form of iso-acceleration lines for each specific hazard level in the structure lifetime. In this study the seismic hazard analysis carried out was based on the assumption of an ideal bedrock case and therefore no influence of local soil condition is taken into consideration. Based on the Iranian seismic rehabilitation code of the existing buildings [IIEES, 2002], 2 hazard levels are most considered: 10 % and 2 % probabilities of exceedence in 50 years. Before the calculations, a grid of sites must be considered in the region where seismic hazard analysis is performed. For this purpose a grid of 5×4 is considered. In each site, seismic hazard curve is drawn, for example, in Figure 4; a typical curve can be seen.

As a result, our outputs are Peak Ground Horizontal Acceleration (PGHA) with 2% and 10 % probabilities of exceedence in 50-year lifetime of structure. The result of the seismic hazard analysis is graphically shown in Figures 5 and 6.

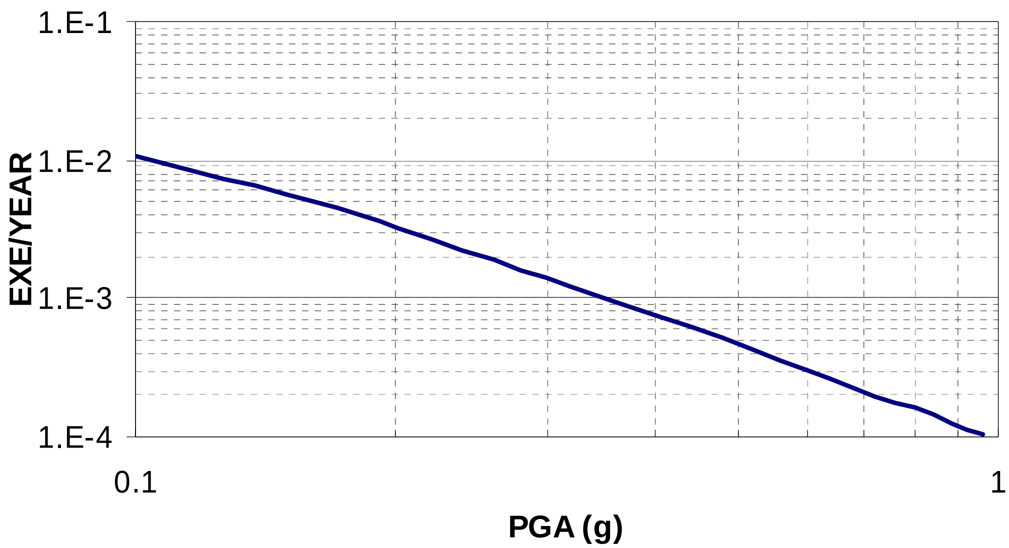

Figure 4. Mean seismic hazard curve for a site in Karaj

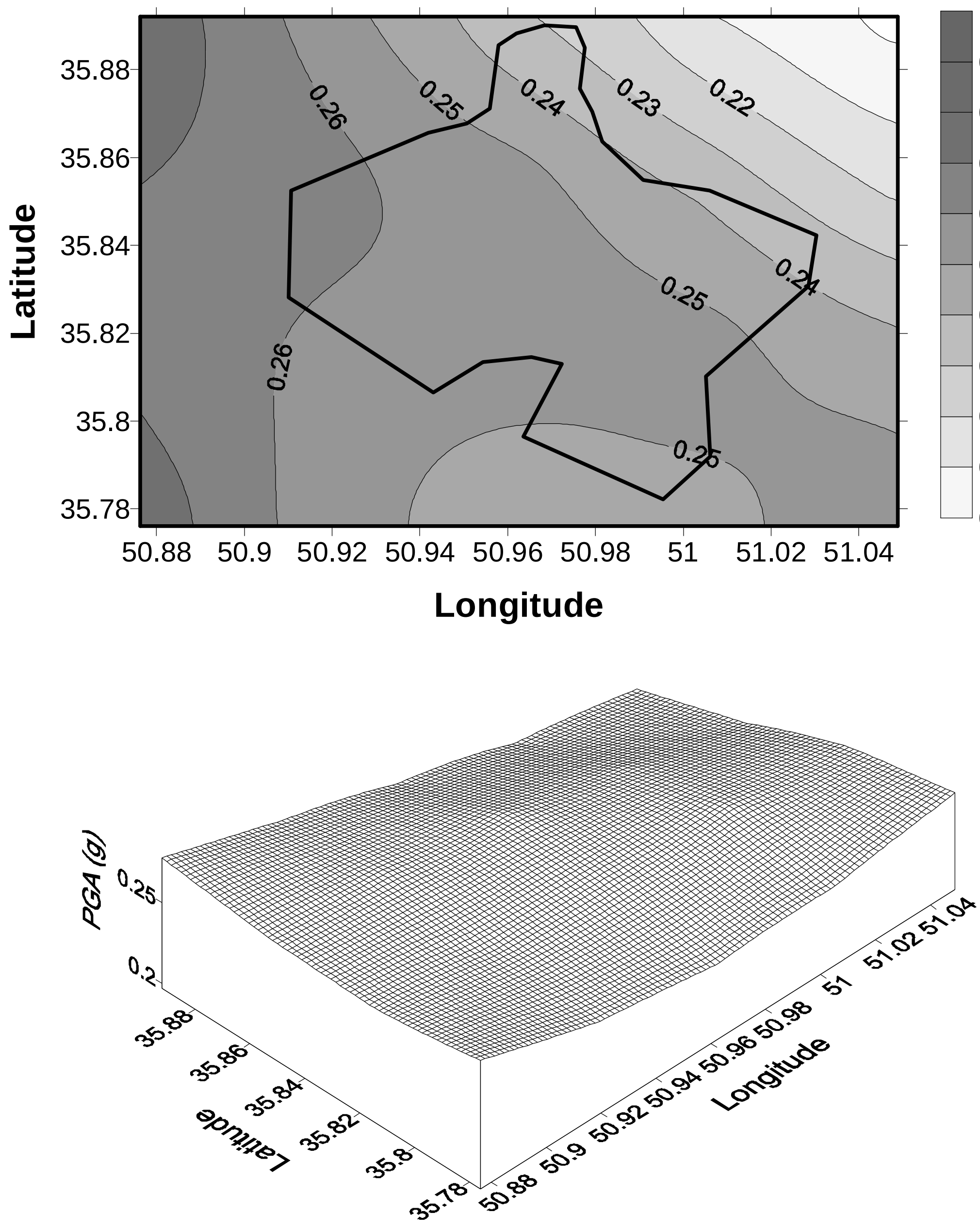

Figure 5. Horizontal seismic hazard map of Karaj and its vicinity using logic tree for 475 year return period: (up) two-dimensional zoning map and the border of Karaj (thick line), (down) three-dimensional zoning map showing accelerations in g.

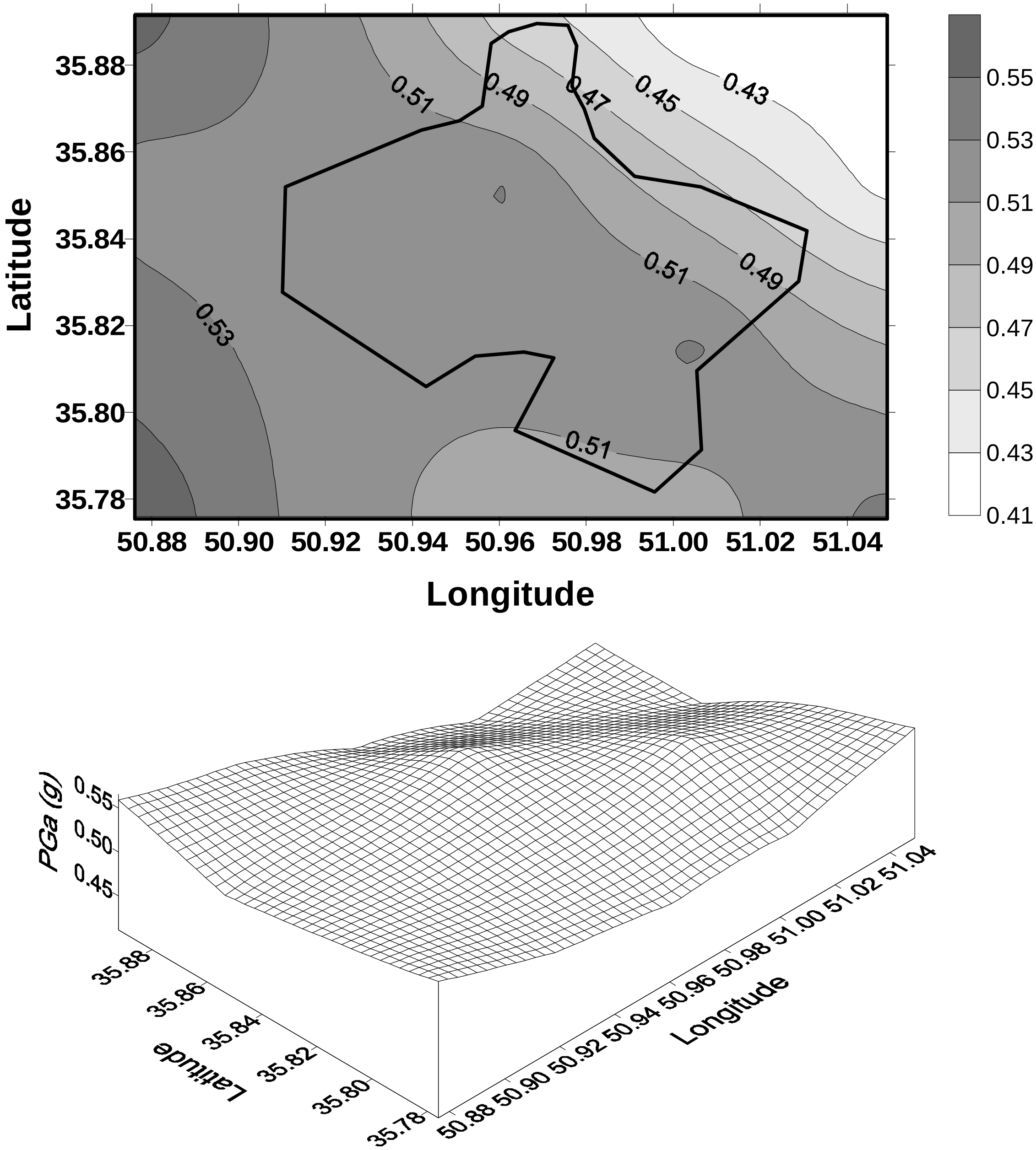

Figure 6. Horizontal seismic hazard map of Karaj and its vicinity using logic tree for 2475 year return period: (up) two-dimensional zoning map and the border of Karaj (thick line), (down) three-dimensional zoning map showing accelerations in g.

CONCLUSIONS

This paper presents seismic hazard maps of Karaj and its vicinity based on Peak Ground Horizontal Acceleration (PGHA) for 2% and 10% probabilities of exceedence in a time span of 50 years. The significant results of this study can be summarized as:

(1) The contour levels of the horizontal acceleration hazard maps showed that the PGHA for 2% ranges from 0.41(g) to around 0.56(g) and PGHA for 10% ranges from 0.20(g) to around 0.30(g).

(2) The highest acceleration contours locate in the west parts of Karaj.

(3) The smallest accelerations are expected in the northeast of Karaj.

Table 1. Earthquake Catalogue

NO	DATE	TIME	LAT-N	LONG-E	FD (Km)	mb	ML	Ms	REF.
1	400 BC		35.50	51.80				7.6	AMB
2	743		35.30	52.20				7.2	AMB
3	855		35.60	51.50				7.1	AMB
4	864/01		35.70	51.00				5.3	AMB
5	958/02/23		36.00	51.10				7.7	AMB
6	1119/12/10	18:00:00	35.70	49.90				6.5	AMB
7	1127		36.30	53.60				6.8	AMB
8	1177/05		35.70	50.70				7.2	AMB
9	1301		36.10	53.20				6.7	AMB
10	1485/08/15	18:00:00	36.70	50.50				7.2	AMB
11	1495		34.50	50.00				5.9	AMB
12	1608/04/20	12:00:00	36.40	50.50				7.6	AMB
13	1665		35.70	52.10				6.5	AMB
14	1678/02/03	06:00:00	37.20	50.00				6.5	AMB
15	1687		36.30	52.60				6.5	AMB
16	1755/06/07		34.00	51.40				5.9	AMB
17	1778/12/15		34.00	51.30				6.2	AMB
18	1809	12:00:00	36.30	52.50				6.5	AMB
19	1825		36.10	52.60				6.7	AMB
20	1830/03/27	12:00:00	35.70	52.50				7.1	AMB
21	1868/08/01	20:00:00	34.90	52.50				6.4	AMB
22	1876/10/20	15:00:00	35.80	49.80				5.7	AMB
23	1901/05/20	12:29:00	36.39	50.48				5.4	AMB
24	1927/10/31	6:23:00	36.50	49.00		4.5			ISS
25	1930/10/02	15:33:12	35.78	51.96	33	5.5			BER, M
26	1932/05/20	19:16:11	36.50	53.50		5.6			USGS
27	1935/03/05	10:26:00	36.20	53.00		5.5			ISS
28	1935/04/13	2:29:00	34.80	52.20		5.0			ISS
29	1937/04/07	18:30:00	34.80	52.10		5.5			ISS
30	1940/09/25	19:31:00	36.40	52.10		5.5			ISS
31	1945/05/11	20:17:00	34.80	52.10		4.7			ISS
32	1948/06/17	14:08:00	36.50	49.00		5.2			ISS
33	1956/04/12	22:34:49	37.33	50.26	30		5.5		NOW
34	1957/03/16	0:43:00	34.90	52.90		5.5			ISS
35	1957/07/02	0:42:00	36.21	52.72		6.5			ISS
36	1958/11/02	9:14:00	36.70	51.50		4.5			BCIS
37	1960/06/23	3:37:42	37.00	49.50			6.5		FS
38	1962/09/01	19:20:00	35.58	49.88	29	7.2			ISC
39	1962/09/29	19:23:00	36.00	53.30		4.5			MOS
40	1964/02/08	6:28:00	37.10	51.04	40	4.6			ISC
41	1967/06/23	13:15:00	35.50	49.60	38	4.4			ISC
42	1968/04/26	2:58:00	35.10	50.20	21	5.3			NEIC
43	1968/08/02	3:59:27	36.85	49.33	36	4.7			ISC
44	1970/01/19	17:19:26	36.90	48.80	27	4.4			NEIC
45	1970/06/26	7:57:53	35.20	50.70	14	4.9			NEIC
46	1971/04/30	9:06:16	34.60	50.30	42	4.7			NEIC

47	1971/08/09	2:54:35	36.27	52.81	12	5.2			ISC
48	1972/08/08	0:44:55	36.30	52.60	47	4.7			NEIC
49	1973/02/15	15:13:09	36.90	53.30		4.5			ISC
50	1973/09/17	4:06:03	36.59	51.19	40	4.7			ISC
51	1974/11/05	20:02:22	36.20	52.80	68	4.5			ISC
52	1975/04/11	14.26.44	35.50	50.20	50	4.7			ISC
53	1975/11/06	4:09:31	35.90	53.03	3	4.7			NEIS
54	1977/02/20	5.56.23	36.45	53.22	33	4.5			NEIC
55	1977/05/25	11:01:45	34.89	52.26	26	5.4		4.3	NEIC
56	1978/05/26	13:43:31	37.00	50.00		6.3			HFSI
57	1978/11/03	18:52:59	37.00	51.00		5.0			HFS
58	1978/11/04	15:21:41	34.00	51.00		6.5			HFS
59	1978/11/04	15:22:19	37.67	48.90	34	6.1			NEIC
60	1979/03/18	5:19:51	36.49	52.46	33	4.5			NEIC
61	1979/03/25	2:32:22	34.92	52.51	20	4.6		3.6	NEIC
62	1980/07/22	5:17:10	37.19	50.20	62	5.4.			NEIC
63	1980/12/19	1:16:56	34.59	50.65	33	5.6		5.8	NEIC
64	1982/07/05	15:54:24	34.63	51.02	33	4.4			NEIC
65	1982/10/25	16:54:51	35.21	52.36	33	4.6		5.4	NEIC
66	1983/03/26	4:07:19	35.96	52.23	33	5.4		4.7	NEIC
67	1983/05/29	17:15:39	35.27	52.19	33	4.5			NEIC
68	1983/12/20	22:21:05	36.80	50.79	42	4.8			NEIC
69	1984/09/09	17:54:59	35.58	49.34	33	4.6			NEIC
70	1985/02/11	9:26:45	34.56	50.68	50	4.7			NEIC
71	1985/10/14	15:28:31	35.63	52.70	10	4.8			USCGS
72	1988/01/14	11:29:20	36.01	50.60	33	4.6			NEIC
73	1988/08/22	21.23.34	35.28	52.35	10	5.0		4.7	NEIC
74	1988/10/26	14:49:24	34.34	52.35	33	4.7			NEIC
75	1989/02/15	10:10:08	37.29	50.30	53	4.6			NEIC
76	1990/01/20	01:27:10	35.89	53.00	25	5.5		5.8	ISC
77	1990/06/20	21:00:10	36.99	49.35	19	6.2		7.4	ISC
78	1990/06/20	23:55:47	37.42	50.01	10	4.4			NEIC
79	1990/08/06	11:24:52	36.14	49.58	33	4.5			ISC
80	1991/01/22	12:04:25	35.44	52.32	33	4.5			ISC
81	1991/08/23	22:14:21	35.99	53.27	42	5.0		4.5	ISC
82	1991/09/08	04:20:35	35.33	53.31	66	4.5			NEIC
83	1992/09/22	14:05:55	36.33	52.70	35	5.2			NEIC
84	1993/03/08	19:13:22	36.63	51.08	33	4.4			NEIC
85	1993/06/09	17:33:36	34.76	53.28	30	5.0			NEIC
86	1993/08/19	10:04:28	35.09	52.09	18	4.6			NEIC
87	1994/11/21	18:55:16	35.90	51.88	33	4.5			NEIC
88	1995/04/26	11:46:12	37.05	49.53	33	4.8			NEIC
89	1995/10/15	06:56:34	37.06	49.48	33			5.6	NEIC
90	1996/08/25	14:17:08	35.96	52.95	33	4.4			NEIC
91	1997/06/07	20:29:48	36.41	50.28	33	4.4			NEIC
92	1997/08/26	0:44:50	36.54	53.07	33	4.5			NEIC
93	1997/11/05	22:42:57	34.98	51.36	33	4.5			NEIC
94	1998/01/09	19:06:13	36.47	52.17	33	4.8		4.2	NEIC
95	1998/09/28	17:17:19	36.80	48.80	33	4.9			IIEES
96	1998/12/03	13:13:33	36.05	50.88	33	4.5			NEIC

97	1998/12/19	04:54:00	36.98	50.95	33	4.4			NEIC
98	1998/12/26	23:11:30	34.70	50.40	33	4.8			IIEES
99	1999/05/21	19:40:28	34.80	53.10	33	4.4			IIEES
100	2002/01/05	14:43:42	37.52	49.02	21	4.5			NEIC
101	2002/02/14	20:06:24	36.90	49.40	49	4.5			NEIC
102	2002/04/08	18:30:58	36.42	52.03	46	4.8			NEIC
103	2002/04/19	13:46:50	36.57	49.85	33	5.1			NEIC
104	2002/06/22	2:58:21	35.62	49.05	10		6.5		NEIC
105	2004/05/28	12:38:46	36.37	51.64	28			6.3	IIEES

REFERENCES

Ambraseys NN and Bommer JJ. "The attenuation of ground accelerations in Europe," Earthquake Engineering and Structural Dynamics, 20, Issue 12, 1179-1202, 1991.

Bender B and Perkins DM., "SEISRISK III, A computer program for seismic hazard estimation," Bulletin of U.S. Geological Survey, 1772, 1987.

Berberian M, Ghoreishi M, Ravesh BA and Ashjaei AM. Seismotectonic and Earthquake Fault Hazard Investigations in the Tehran Region, Geological Survey of Iran, Report No. 56, 1983.

Ghodrati Amiri G, Mahdavian A and Manouchehri Dana F. "Attenuation relationships for Iran," Journal of Earthquake Engineering. (accepted in Sept. 2006)

International Institute of Earthquake Engineering and Seismology (IIEES). Seismic Rehabilitation Code for Existing Buildings in Iran. 2002. (In Persian)

Iranian Committee of Large Dams (IRCOLD). Relationship Between Fault Length and Maximum Expected Magnitude. Internal Report. 1994. (In Persian)

Kijko A. "Statistical estimation of maximum regional earthquake magnitude Mmax," Workshop of Seismicity Modeling in Seismic Hazard Mapping, Poljce, Slovenia, 2000.

Gardner JK and Knopoff L. "Is the sequence of earthquake in southern California, with aftershocks removed, Poissonian?," Bulletin of the Seismological Society of America, 64, Issue 5, 1363-1367, 1974.

Ramazi HR. "Attenuation laws of Iranian earthquakes," Proceedings of the 3rd International Conference on Seismology and Earthquake Engineering, Tehran, Iran, 1,337-344, 1999.