Strong Motion Data of the 1994-2002 Earthquakes in Iran: A Catalogue of 100 Selected Records with Higher Qualities in the Low Frequencies

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ABSTRACT: *The recorded strong motion data in Iran since 1994 till the end of 2002 are investigated in order to investigate the well recorded (high signal to noise ratio) accelerometric data, specially in the long period ranges. The records having low signal to noise ratio in the frequency range of less than 0.3 Hz are excluded, and the rest of 100 records are processed and analyzed in this study. The site classification for these records is performed based on the receiver function method (estimating the H/V ratio for each of the recorded motions). According to this procedure, the number of the selected records were 46, 10, 16 and 28 for the site classes 1, 2, 3 and 4 respectively. The frequency contents of most of the records show dominant amplitudes between frequencies 0.2 and 10Hz. The Fmax values are systematically greater for the vertical components comparing to the horizontal ones. This selected catalog of 100 accelerograms obtained from 15 earthquakes provides a basis for the good quality/recent strong motion records in Iran, having good quality low frequencies contents. The response spectra of selected records having a PGA>0.05g are presented in the article and the normalized-mean spectra for the 4 site classes are introduced. The predominant periods of site classes 1, 2, 3 and 4 are found to be 0.09, 0.1, 0.13 and 0.2 sec for horizontal components and 0.08, 0.06, 0.11 and 0.15 sec for vertical components respectively.*

Keywords: Strong motion; Data; Iran; Low frequency; Process; Record

1. Introduction

The Iranian strong motion data are investigated in order to find the earthquakes for which more than one accelerograms are recorded with higher qualities in lower frequencies. In this study, the attention is paid to better quality records and those that could have less low frequency noises.

The accelerometric network of Iran comprises of more than 1500 stations, for which more than 3500 records are already recorded by March 2003. The records obtained from the great events are now available on web site of *BHRC* (Building and Housing Research Center; the organization who maintains the Iranian national strong motion network). The data studied for the Changureh 2002 earthquake in this paper are taken from the BHRC web site [8]. The stations are selected in all over the country, however, according to the importance of the capital, more than 30 stations are installed around Tehran (to be expanded to a local network of more than 50 stations). Meanwhile, according to higher seismicity of Zagros belt, and higher population density in this region (southwest and western Iran) comparing to eastern and southeastern Iran, more stations are selected in Zagros. Therefore, most of the records are actually corresponding to the Zagros belt.

The National Iranian Strong Motion network is installed first with the Kinemetrics *SMA*-1 analog instruments installed since 1975, and then they have been gradually expanded by the SSA-2 digital instruments since the Manjil earthquake of 1990;

*Mw*7.3, in *NW* Iran. The records which, are studied in this paper are all digitally recorded by the *SSA*2 instruments. A corrected listing based on the Iranian strong motion processed data until 1994 is presented in Bard et al [2]. The detailed parameters on such listing can be found in Zaré [20].

In this paper, first the procedure of data processing and selection of the records is presented, and then the strong motion parameters estimated based on selected records will be discussed. Finally a conclusion is placed based on the comparison of different strong motion parameters.

2. Criteria to Select the Records for This Study

The records for this study are selected based on their quality (evaluated according to their signal to noise ratio) and the existence of more than one record for an earthquake. The total available data for the period of 1994-2002 was about 2800 three-components accelerograms.

The epicenters of the 15 earthquakes for which the 100 strong motion three-component accelerograms recorded between 1994 and December 2002 are shown in Figure (1). The source specifications for these earthquakes are listed in Table (1) [9, 12, 14,

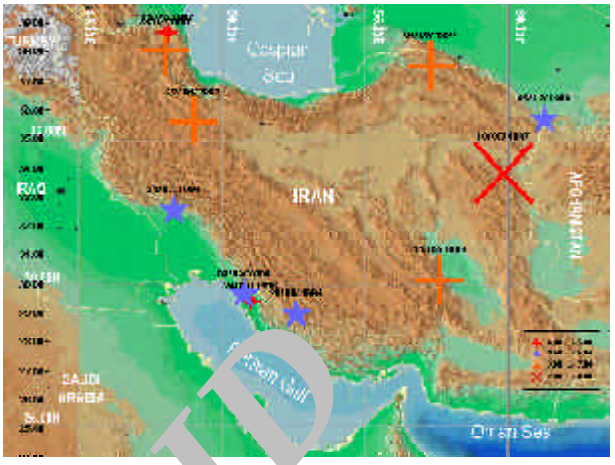


Figure 1. The epicenters of the earthquakes, for which the 100 records were selected and studied in this paper (listed in Table (1)). The base map is taken from USGS Digital Data Series (2001).

Table 1. The selected records from the Iranian strong motion dataset (1994-2002). FD: Focal Depth (estimated by Maggi et al [15]), Focal mechanisms; as reported by Harvard, Seismology Website 2003; Rv: Reverse, SS-strike-slip.

No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1492-16	Zarrat	29.21N	52.77E	4	0.2-40	318	112	280	1	9	11	1994/06/20	28.96N	52.61E	Ebrahimabad	6	6	6	9	SS	32
2	1493-02	Firouzabad	28.80N	52.57E	3	0.25-40	272	115	295	0.5		10	1994/06/20	28.96N	52.61E	Ebrahimabad	6	6	6	9	SS	34
3	1495-00	Maharloo	29.31N	52.78E	1	0.25-20	23	13	24	0.8		10	1994/06/20	28.96N	52.61E	Ebrahimabad	6	6	6	9	SS	32
4	1496-00	Sarvestan	29.30N	53.24E	1	0.2-30	14	9	17	0.5	5	7	1994/06/20	28.96N	52.61E	Ebrahimabad	6	6	6	9	SS	72
5	1498-00	Babanar	28.46N	53.23E	2	0.2-40	27	15	40	0.8		9	1994/06/20	28.96N	52.61E	Ebrahimabad	6	6	6	9	SS	24
6	1502-09	Zanjiran	29.10N	52.56E	2	0.2-40	1100				18	22	1994/06/20	28.96N	52.61E	Ebrahimabad	6	6	6	9	SS	16
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1506-01	Hosseinieh	32.73N	48.25E	4	0.15-40	195	105	82	1.2	11	18	1994/07/31	32.55N	48.36E	N.Dezful	5	5	6	14	Rv	24
2	1525-00	Karkheh Dam	32.44N	48.12E	1	0.2-30	13			0.5	8	11	1994/07/31	32.55N	48.36E	N.Dezful	5	5	6	14	Rv	14
3	1526-01	Dez Dam	32.68N	48.46E	1	0.2-30		27	18	0.5	11	11	1994/07/31	32.55N	48.36E	N.Dezful	5	5	6	14	Rv	20
4	1527-00	Andimeshk	32.45N	48.38E	1	0.2-40		24	23	0.5	9	12	1994/07/31	32.55N	48.36E	N.Dezful	5	5	6	14	Rv	34
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1506-11	Hosseinieh	32.73N	48.25E	4	0.3-	12	7	12	0.8	9	9	1994/09/20	32.50N	48.77E	N.Dezful	5	5	5			18
2	1507-00	Dez Dam	32.68N	48.46E	1	0.3-	24	19	26	1	8	11	1994/09/20	32.50N	48.77E	N.Dezful	5	5	5			14
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1571-10	Shabankareh	29.47	50.98E	4	40	57	37	80	3	11	18	1996/01/24	29.44N	51.03E	Borazjan	5	5	5		SS	18
2	1583-02	Saadabad	29.40		1	0.3	13	7	23	2	8	11	1996/01/24	29.44N	51.03E	Borazjan	5	5	5		SS	34
3	1665-01	Delvari dam	29.41N	51.1		0.25-40	29	15	20	2	8	10	1996/01/24	29.44N	51.03E	Borazjan	5	5	5		SS	30
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1571-33	Shabankareh	29.47N	50.98E	4	0.3-20	170	90	70	5.5	11	17	1996/01/26	29.34N	51.00E	Borazjan	5	4	5			80
2	1665-03	Delvari dam	29.41N	51.77	1	0.2-40	32	19	27	2.5	6	8	1996/01/26	29.34N	51.00E	Borazjan	5	4	5			22
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1659-02	Ashkhaneh	37.61N	56.92E	4	0.2-25	118	35	102	0.9	4	7	1997/02/04	37.56N	57.29E	Raz-Bojnourd	6	7	7	6	SS	50
2	1672-00	Kalaleh	37.38N	55.50E	4	0.3-20	22	12	18	1	3	5	1997/02/04	37.56N	57.29E	Raz-Bojnourd	6	7	7	6	SS	158
3	1674-00	Maraveh-Tappeh	37.87N	55.95E	3	0.3-25	25	11	26	0.8	4	6	1997/02/04	37.56N	57.29E	Raz-Bojnourd	6	7	7	6	SS	144
4	1676-01	Raz	37.92N	52.20E	3	0.2-40	36	37	42	0.8	3.5	5	1997/02/04	37.56N	57.29E	Raz-Bojnourd	6	7	7	6	SS	48
5	1707-02	Barezoo Dam	37.60N	57.97E	1	0.15-20	44	25	60	0.3	2	3	1997/02/04	37.56N	57.29E	Raz-Bojnourd	6	7	7	6	SS	60
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1687-00	Haris	38.28N	47.12E	4	0.1-40	15	9	17	1	4	6	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	32
2	1690-00	Niaragh	38.28N	48.62E	3	0.09-40	26	18	25	0.3	4	5	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	40
3	1691-00	Razi	38.62N	48.12E	1	0.09-40	38	23	46	0.8	9	11	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	64
4	1693-01	Ardebil-Ostandari	38.25N	48.30E	4	0.1-40	85	58	72	0.8	5	8	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	36
5	1695-00	Astara	38.40N	48.85E	4	0.1-40	54	18	40	0.8	4	6	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	40
6	1700-00	Meshkinshahr	38.38N	47.67E	1	0.08-40	27	18	25	0.4	4	5	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	56
7	1701-01	Ardebil-Maskan	38.24N	48.29E	4	0.08-40	122	64	130	0.7	4	5	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	35
8	1702-00	Germi	39.03N	48.08E	3	0.2-20	52	21	48	0.8	4	5	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	36
9	1716-00	Hir	38.60N	48.50E	2	0.15-30	59	20	34	0.8	6	7	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	96
10	1724-00	Namin	38.40N	48.48E	2	0.15-40	72	34	106	0.8	6	7	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	56
11	1725-00	Sarein	38.22N	48.08E	1	0.2-40	42	27	55	0.8	7	9	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	60
12	1833-02	Karigh	37.87N	48.05E	3	0.25-40	578	197	672	1	8	9	1997/02/28	38.05N	48.05E	Golestan	6	6	6	9	SS	26

Table 1. Continued ....

No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1916-00	Ardebil-Ostandari	38.25N	48.30E	4	0.3-30	22	10	14	1	6	7	1997/03/21	38.68N	48.13E	Ardebil	5		5			32
2	1917-00	Ardebil-Maskan	38.24N	48.29E	4	0.25-20	17	7	19	1	5	7	1997/03/21	38.68N	48.13E	Ardebil	5		5			36
3	1920-04	Karigh	37.87N	48.05E	3	0.2-30	68	19	53	1	8	10	1997/03/21	38.68N	48.13E	Ardebil	5		5			30
4	1921-01	Sarein	38.22N	48.08E	1	0.2-40	38	63	42	1	11	15	1997/03/21	38.68N	48.13E	Ardebil	5		5			12
5	1927-03	Nir	38.08N	47.97E	3	0.2-40	127	48	125	1	10	15	1997/03/21	38.68N	48.13E	Ardebil	5		5			16
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1739-00	Boskabad	34.03N	58.75E	1	0.1-15	13	10	23	0.3	2	3	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	56
2	1740-00	Dasht-e-Bayaz	34.05N	57.81E	2	0.06-20	17	13	19	0.2	2	5	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	76
3	1741-00	Feyzabad	35.02N	58.80E	4	0.06-25	28	22	27	0.2	2	3	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	156
4	1742-00	Gonabad	34.38N	58.73E	4	0.05-40	26	23	27	0.2	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	94
5	1750-02	Marak	32.95N	59.48E	3	0.05-25	44	20	40	0.2	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	109
6	1753-00	Sangan	34.38N	60.26E	1	0.08-40	118	82	112	0.4	4	5	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	80
7	1758-00	Torbat-e-Heydarieh	35.25N	59.22E	4	0.08-20	40	18	52	0.3	2	3	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	167
8	1770-00	Mussaviyeh	33.30N	58.93E	1	0.06-20	17	11	18	0.2	3	4	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	76
9	1771-00	Shahid-Yaghoubi	35.08N	59.52E	1	0.07-20	37	21	45	0.15	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	152
10	1751-00	Mud	32.75N	59.52E	1	0.2-30	18	16	18	0.4	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	8	7	13	SS	135
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1864-01	Abaragh	29.38N	57.92E	1	0.2-40	12	8	13	0.4	4	6	1998/03/14	30.15N	57.60E	Fandogha	6	7	7	5	SS	74
2	1866-00	Baghein	30.21N	56.78E	1	0.15-25	14	12	17	0.4	5	6	1998/03/14	30.15N	57.60E	Fandogha	6	7	7	5	SS	58
3	1870-00	Fahraj	28.95N	58.87E	3	0.15-18	32	18	36	0.4	3	4	1998/03/14	30.15N	57.60E	Fandogha	6	7	7	5	SS	72
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	2037-00	Andohjerd	30.23N	57.75E	1	0.3-20	38	35	32	2	10	15	1998/11/18	30.30N	57.56E	Shahdad	5	5	5		SS	38
2	2047-02	Joshan	30.15N	57.60E	1	0.3-20	22	14	27	1	8	10	1998/11/18	30.30N	57.56E	Shahdad	5	5	5		SS	44
3	2048-00	Kerman-Maskan	30.27N	57.12E	4	0.2-20	21	9	17	1	5	6	1998/11/18	30.30N	57.56E	Shahdad	5	5	5		SS	52
4	2161-00	Kerman-Farmandari	30.27N	57.11E	4	0.3-20	31	22	58	1	6	8	1998/11/18	30.30N	57.56E	Shahdad	5	5	5		SS	50
5	2163-00	Khurjand	30.66N	57.17E	1	0.2-20	9	5	12	1	6	8	1998/11/18	30.30N	57.56E	Shahdad	5	5	5		SS	48
6	2176-01	Shahdad	30.39N	57.73E	1	0.2-20	52	38	48	1	7	8	1998/11/18	30.30N	57.56E	Shahdad	5	5	5		SS	24
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	2373-01	Yekan	38.72N	48.42E	1	0.2-30	57	42	38	2	10	11	1998/11/18	38.37N	47.17E	West-Urumieh	5		5			44
2	2322-00	Zanjireh	38.45N	45.35E	2	0.2-30	98	33	82	2	10	15	1998/11/18	38.37N	47.17E	West-Urumieh	5		5			24
3	2369-01	Tasuj	38.30N	45.40E	4	0.3-40	59	27	56	2	6	8	1998/11/18	38.37N	47.17E	West-Urumieh	5		5			28
4	2188-01	Qaraqeshlaq	38.23N	44.98E	3	0.2-20	33	10	46	1	8	9	1998/11/18	38.37N	47.17E	West-Urumieh	5		5			20
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	2224-03	Derakht-e Toot	35.75N	61.10E	1	0.15-40	138	145	245	2	10	15	1999/12/05	35.67N	61.23E	Salehabad	5		5		Rv	14
2	2225-11	Salehabad	35.70N	61.10E	1	0.2-40	138	142	102	1	8	11	1999/12/05	35.67N	61.23E	Salehabad	5		5		Rv	17
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)			PGA (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	2286-05	Nargeszar	29.45N	51.90E	2	0.15-40	143	87	195	1	9	11	1999/12/05	29.41N	51.76E	Kazerun	5		5			14
2	2351-01	Roumanghan	29.21E	52.16E	3	0.15-18	34	18	44	1	6	8	1999/12/05	29.41N	51.76E	Kazerun	5		5			47
3	2355-03	Baladeh	29.28N	51.93E	2	0.25-40	78	44	75	1	9	11	1999/12/05	29.41N	51.76E	Kazerun	5		5			44
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	2347-00	Delvari Dam	29.41N	51.17E	4	0.2-40	19	14	17	1	10	15	2000/05/03	29.66N	50.80E	N. Genaveh			5.1		R-SS	34
2	2462-02	Bandar-Rig	29.47N	50.65E	1	0.3-30	23	9	19	1	10	12	2000/05/03	29.66N	50.80E	N. Genaveh			5.1		R-SS	50
3	2465-01	Chehel-Zarei	29.46N	50.85E	4	0.2-35	65	33	76	1	8	10	2000/05/03	29.66N	50.80E	N. Genaveh			5.1		R-SS	35
4	2469-01	Genaveh	29.60N	50.52E	4	0.3-30	14	10	12	1	10	15	2000/05/03	29.66N	50.80E	N. Genaveh			5.1		R-SS	44
No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	2748-01	Abegarm	35.74N	49.28E	4	0.11-28	130	55	125	0.2	5	7	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	34
2	2749-01	Avaj	35.58N	49.22E	3	0.10-25	465	250	445	0.3	20	22	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	28
3	2750	Bahar	34.90N	48.42E	1	0.10-25	27	17	39	0.4	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	120
4	2751-01	Danisfahan	35.78N	49.72E	4	0.15-10	27	16	25	0.2	5	8	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	72
5	2752	Garmab	35.83N	48.22E	1	0.18-18	17	18	21	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	68
6	2753	Khodabandeh	36.12N	48.59E	1	0.10-20	22	16	17	0.2	9	11	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	56
7	2754-01	Kabodar-Ahang	35.20N	48.73E	1	0.20-40	78	71	155	0.4	12	15	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	78
8	2756-01	Razan	35.39N	49.02E	4	0.18-40	182	132	200	0.5	12	15	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	55
9	2758	Zarrinabad	36.41N	48.28E	1	0.15-15	15	6	11	0.25	7	9	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	100
10	2759	Buin-Zahra	35.77N	50.05E	1	0.10-12	21	12	30	0.2	4	6	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	100
11	2760-02	Ziaabad	35.99N	49.45E	1	0.10-20	34	20	37	0.25	8	10	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	54
12	2763	Abhar	36.15N	49.22E	4	0.18-20	32	27	73	0.3	5	7	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	55
13	2768	Deh-Jalal	36.31N	48.70E	1	0.10-15	17	21	22	0.3	9	10	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	66
14	2769	Darsachin	36.03N	49.23E	4	0.15-20	52	44	72	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	54
15	2770	Halab	36.30N	48.05E	1	0.20-20	17	7	12	0.2	7	8	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	64
16	2771	Meymundarreh	36.12N	49.13E	1	0.30-30	32	10	22	0.3	10	18	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	48
17	2772	Saein-Ghaleh	36.30N	49.07E	4	0.10-15	37	20	33	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	80
18	2773	Eshtehard	35.72N	50.38E	4	0.20-11	18	8	16	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	126
19	2777	Goltappeh	35.22N	48.20E	1	0.10-30	30	24	31	0.4	11	15	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	97
20	2778	Ghohrud	35.47N	48.07E	3	0.08-18	51	23	88	0.3	9	15	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	95
21	2780	Hamedan	34.78N	48.52E	2	0.10-18	22	7	12	0.3	8	12	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	125
22	2781	Shirinsu	35.50N	48.46E	3	0.10-35	170	78	125	0.4	18	22	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	65
23	2787	Bakandi	36.40N	49.60E	2	0.18-20	42	13	31	0.25	8	10	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	75
24	2792	Rostamabad	35.67N	49.85E	3	0.10-12	22	19	20	0.25	8	10	2002/06/22	35.63N	49.05E	Changureh	6	6	6		Rv	72

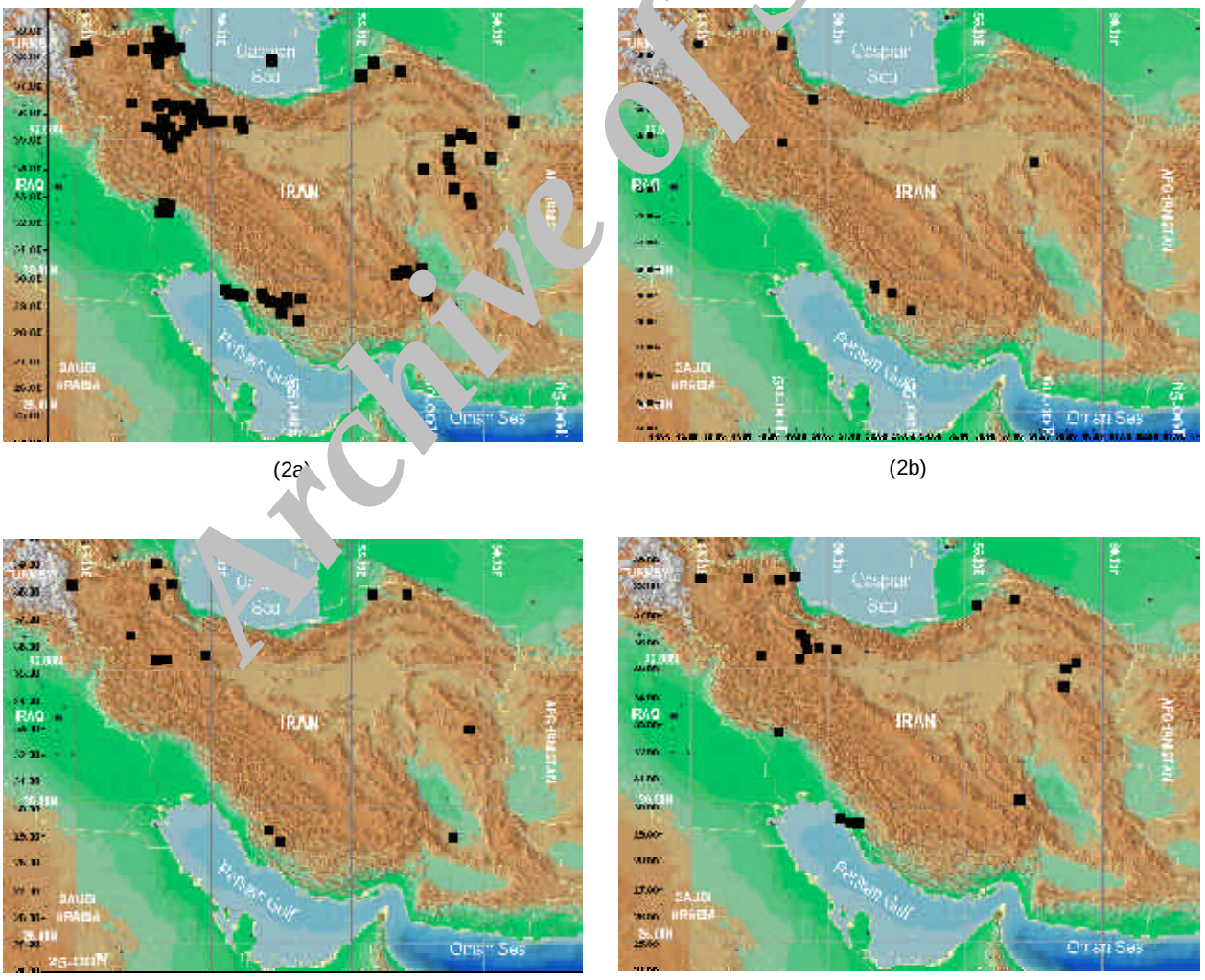
16, 18, 19], along with the details on the selected records. The coordinates of the epicenters and the strong motion stations are given as well in Table (1). These stations are shown in Figures (2a) to (2d) based on their site conditions; of class '1' to class '4', respectively. These site classes are assigned based on a detailed site effect study in Iran on the strong motion station [20].

This database is composed by fairly well known source parameters which were very well recorded, and for which no source data was directly available. The moment magnitude and hypocentral distance for these records have thus been estimated directly from the strong motion records. The hypocentral distance was obtained from the *S-P* time difference, while the seismic moment was directly calculated from the level of acceleration spectra plateau and the corner frequency [2].

The magnitude range for the whole dataset of records was 4.6-7.2, see Table (2). The distributions of magnitude against hypocentral distance are shown in Figures (3) and (4a) to (4d) for different site classes. The range for hypocentral distance is 12-167*km*. The focal depth range for the events relocated recently by Maggi et al [15] is 5-14*km* (column 21 of Table (1)), and the teleseismic information on focal depths are excluded from Table (1), since such type of determination is very imprecise [2]. The two horizontal components of each record are included separately in the study, therefore the number of the horizontal records entered to the regressions was twice the vertical ones.

2.1. Filtering of the Accelerograms

In this study, the signal to noise ratio was considered to be significant only when the signal to noise ratio R_{sn} for both components exceeds a given threshold value, taken equal to 3. The signal to noise



(2a) (2b)

(2c) (2d)

Figure 2. The locations of the stations in which the records are selected, distinguished based on the site classes; 2a: class '1'; 2b: class '2'; 2c: class '3'; 2d: class '4'. The base maps are taken from USGS Digital Data Series (2001).

Table 2-1. The selected records from the Iranian strong motion dataset (1994-2002). FD: Focal Depth (estimated by Maggi et al [15], Focal mechanisms; as reported by Harvard, Seismology Web site 2003; Rv: Reverse, SS-strike-slip (for site class 1).

No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km)
1	1495-00	Maharloo	29.31N	52.78E	1	0.25-20	23	13	24	0.8	8	10	1994/06/20	28.96N	52.61E	Ebrahimabad	5.9	5.7	5.9	9	SS	32
2	1496-00	Sarvestan	29.30N	53.24E	1	0.2-30	14	9	17	0.5	5	7	1994/06/20	28.96N	52.61E	Ebrahimabad	5.9	5.7	5.9	9	SS	72
3	1525-00	Karkheh Dam	32.44N	48.12E	1	0.2-30	13	17	14	0.5	8	11	1994/07/31	32.55N	48.36E	N.Dezful	5.3	5.3	5.6	14	Rv	14
4	1526-01	Dez Dam	32.68N	48.46E	1	0.2-30	24	27	18	0.5	11	11	1994/07/31	32.55N	48.36E	N.Dezful	5.3	5.3	5.6	14	Rv	20
5	1527-00	Andimeshk	32.45N	48.38E	1	0.2-40	28	24	23	0.5	9	12	1994/07/31	32.55N	48.36E	N.Dezful	5.3	5.3	5.6	14	Rv	34
6	1507-00	Dez Dam	32.68N	48.46E	1	0.3-40	24	19	26	1	8	11	1994/09/20	32.50N	48.77E	N. Dezful	5	5.4	5.2			14
7	1583-02	Saadabad	29.40N	51.12E	1	0.3-40	13	7	23	2	8	11	1996/01/24	29.44N	51.03E	Borazjan	4.7	4.6	4.7		SS	34
8	1665-01	Delvari Dam	29.41N	51.17E	1	0.25-40	29	15	20	2	8	10	1996/01/24	29.44N	51.03E	Borazjan	4.7	4.6	4.7		SS	30
9	1665-03	Delvari Dam	29.41N	51.17E	1	0.2-40	32	19	27	2.5	6	8	1996/01/26	29.34N	51.00E	Borazjan	4.6	4.3	4.6			22
10	*1707-02*	Barezoo Dam	37.60N	57.97E	1	0.15-20	44	25	60	0.3	2	3	1997/02/04	37.56N	57.29E	Raz-Bojnourd	5.9	6.8	6.5	6	SS	60
11	1691-00	Razi	38.62N	48.12E	1	0.09-40	38	23	46	0.8	9	11	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	64
12	1700-00	Meshkinshahr	38.38N	47.67E	1	0.08-40	27	18	25	0.4	4	5	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	56
13	*1725-00*	Sarein	38.22N	48.08E	1	0.2-40	42	27	55	0.8	7	9	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	60
14	*1921-01*	Sarein	38.22N	48.08E	1	0.2-40	38	63	42	1	11	15	1997/03/21	38.68N	48.13E	Ardebil	4.6		4.6			12
15	1739-00	Boskabad	34.03N	58.75E	1	0.1-15	13	10	23	0.3	2	3	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	56
16	*1753-00*	Sangan	34.38N	60.26E	1	0.08-40	118	82	112	0.4	4	5	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	80
17	1770-00	Mussaviyeh	33.30N	58.93E	1	0.06-20	17	11	18	0.2	3	4	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	76
18	1771-00	Shahid-Yaghoubi	35.08N	59.52E	1	0.07-20	37	21	45	0.15	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	152
19	1751-00	Mud	32.75N	59.52E	1	0.2-30	18	16	18	0.4	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	135
20	1864-01	Abaragh	29.38N	57.92E	1	0.2-40	12	8	13	0.4	4	6	1998/03/14	30.15N	57.60E	Fandogha	5.9	6.9	6.6	5	SS	74
21	1866-00	Baghein	30.21N	56.78E	1	0.15-25	14	12	17	0.4	5	6	1998/03/14	30.15N	57.60E	Fandogha	5.9	6.9	6.6	5	SS	58
22	2037-00	Andohjerd	30.23N	57.75E	1	0.3-20	38	35	32	2	10	15	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	38
23	2047-02	Joshan	30.15N	57.60E	1	0.3-20	22	14	27	1	8	10	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	44
24	2163-00	Khurjand	30.66N	57.17E	1	0.2-20	9	5	12	1	6	8	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	48
25	*2176-01*	Shahdad	30.39N	57.73E	1	0.2-20	52	38	48	1	7	8	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	24
26	*2373-01*	Yekan	38.72N	48.42E	1	0.2-30	57	42	38	2	10	11	1998/11/18	38.37N	47.17E	West-Urumieh	4.8		4.9			44
27	*2224-03*	Derakht-eToot	35.75N	61.10E	1	0.15-40	138	145	245	2	10	15	1999/12/05	35.67N	61.23E	Salehabad	5.1		5.1		Rv	14
28	*2225-11*	Salehabad	35.70N	61.10E	1	0.2-40	138	142	102	1	8	11	1999/12/05	35.67N	61.23E	Salehabad	5.1		5.1		Rv	17
29	2462-02	Bandar-Rig	29.47N	50.65E	1	0.3-30	23	9	19	1	10	12	2000/05/03	29.66N	50.80E	N. Genaveh			5.1		R-SS	50
30	2750	Bahar	34.90N	48.42E	1	0.10-25	27	17	39	0.4	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	120
31	2752	Garmab	35.83N	48.22E	1	0.18-18	17	18	21	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	68
32	2753	Khodabandeh	36.12N	48.59E	1	0.10-20	22	16	17	0.2	9	11	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	56
33	*2754-01*	Kabodar-Ahang	35.20N	48.73E	1	0.20-40	78	71	155	0.4	12	15	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	78
34	2758	Zarrinabad	36.41N	48.28E	1	0.15-15	15	6	11	0.25	7	9	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	100
35	2759	Buin-Zahra	35.77N	50.05E	1	0.10-12	21	12	30	0.2	4	6	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	100
36	2760-02	Ziaabad	35.99N	49.45E	1	0.10-20	34	20	37	0.25	8	10	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	54
37	2768	Deh-Jalal	36.31N	48.70E	1	0.10-15	17	21	22	0.3	9	10	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	66
38	2770	Halab	36.30N	48.05E	1	0.20-20	17	7	12	0.2	7	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	64
39	2771	Meymundarreh	36.12N	49.13E	1	0.30-30	32	10	22	0.3	10	18	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	48
40	2777	Goltappeh	35.22N	48.20E	1	0.10-30	30	24	31	0.4	11	15	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	97
41	2793	Takestan	36.06N	49.70E	1	0.15-15	12	11	11	0.2	8	10	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	76
42	2819	Vahnabad	35.45N	51.17E	1	0.30-10	13	7	11	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	70
43	2832	Garmdarreh	35.70N	51.06E	1	0.30-10	11	6	9	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	60

Table 2-2. The selected records from the Iranian strong motion dataset (1994-2002). FD: Focal Depth (estimated by Maggi et al [15] Focal mechanisms; as reported by Harvard, Seismology Web site 2003; Rv: Reverse, SS-strike-slip (for site class 2).

No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km
1	1498-00	Babanar	28.46N	53.23E	2	0.2-40	27	15	40	0.8	8	9	1994/06/20	28.96N	52.61E	Ebrahimabad	6	5.7	5.9	9	SS	24
2	*1502-09*	Zanjiran	29.10N	52.56E	2	0.2-40	1100	990	1090	1	18	22	1994/06/20	28.96N	52.61E	Ebrahimabad	6	5.7	5.9	9	SS	16
3	*1716-00*	Hir	38.60N	48.50E	2	0.15-30	59	20	34	0.8	6	7	1997/02/28	38.05N	48.05E	Golestan	6	6.1	6.1	9	SS	96
4	*1724-00*	Namin	38.40N	48.48E	2	0.15-40	72	34	106	0.8	6	7	1997/02/28	38.05N	48.05E	Golestan	6	6.1	6.1	9	SS	56
5	1740-00	Dasht-e-Bayaz	34.05N	57.81E	2	0.06-20	17	13	19	0.2	2	5	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6	7.7	7.2	13	SS	76
6	*2322-00*	Zanjireh	38.45N	45.35E	2	0.2-30	98	33	82	2	10	15	1998/11/18	38.37N	47.17E	West-Urumieh	5		4.9			24
7	*2286-05*	Nargeszar	29.45N	51.90E	2	0.15-40	143	87	195	1	9	11	1999/12/05	29.41N	51.76E	Kazerun	5		4.5			14
8	*2355-03*	Baladeh	29.28N	51.93E	2	0.25-40	78	44	75	1	9	11	1999/12/05	29.41N	51.76E	Kazerun	5		4.5			44
9	2780	Hamedan	34.78N	48.52E	2	0.10-18	22	7	12	0.3	8	12	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	125
10	2787	Bakandi	36.40N	49.60E	2	0.18-20	42	13	31	0.25	8	10	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	75

Table 2-3. The selected records from the Iranian strong motion dataset (1994-2002). FD: Focal Depth (estimated by Maggi et al [15] Focal mechanisms; as reported by Harvard, Seismology Web site 2003; Rv: Reverse, SS-strike-slip (for site class 3).

No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km
1	*1493-02*	Firouzabad	28.80N	52.57E	3	0.25-40	272	115	295	0.5	6	10	1994/06/20	28.96N	52.61E	Ebrahimabad	5.9	5.7	5.9	9	SS	34
2	1674-00	Maraveh-Tappeh	37.87N	55.95E	3	0.3-25	25	11	26	0.8	4	6	1997/02/04	37.56N	57.29E	Raz-Bojnourd	5.9	6.8	6.5	6	SS	144
3	1676-01	Raz	37.92N	52.20E	3	0.2-40	36	37	42	0.8	3.5	5	1997/02/04	37.56N	57.29E	Raz-Bojnourd	5.9	6.8	6.5	6	SS	48
4	1690-00	Niaragh	38.28N	48.62E	3	0.09-40	26	18	25	0.3	4	5	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	40
5	*1702-00*	Germi	39.03N	48.08E	3	0.2-20	52	21	48	0.8	4	5	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	36
6	*1833-02*	Karigh	37.87N	48.05E	3	0.25-40	578	197	672	1	8	9	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	26
7	*1920-04*	Karigh	37.87N	48.05E	3	0.2-30	68	19	53	1	8	10	1997/03/21	38.68N	48.13E	Ardebil	4.6		4.6			30
8	*1927-03*	Nir	38.08N	47.97E	3	0.2-40	127	48	125	1	10	15	1997/03/21	38.68N	48.13E	Ardebil	4.6		4.6			16
9	1750-02	Marak	32.95N	59.48E	3	0.05-25	44	20	40	0.2	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	109
10	1870-00	Fahraj	28.95N	58.87E	3	0.15-18	32	18	36	0.4	3	4	1998/03/14	30.15N	57.60E	Fandogha	5.9	6.9	6.6	5	SS	72
11	2188-01	Qaraqeshlag	38.23N	44.98E	3	0.2-20	33	10	46	1	8	9	1998/11/18	38.37N	47.17E	West-Urumieh	4.8		4.9			20
12	2351-01	Roumangh an	29.21E	52.16E	3	0.15-18	34	18	44	1	6	8	1999/12/05	29.41N	51.76E	Kazerun	4.5		4.5			47
13	*2749-01*	Avaj	35.58N	49.22E	3	0.10-25	465	250	445	0.3	20	22	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	28
14	*2778*	Ghohrud	35.47N	48.07E	3	0.08-18	51	23	88	0.3	9	15	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	95
15	*2781*	Shirinsu	35.50N	48.46E	3	0.10-35	170	78	125	0.4	18	22	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	65
16	2792	Rostamaba d	35.67.N	49.85E	3	0.10-12	22	19	20	0.25	8	10	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	72
17	2852	Takab	36.41N	47.10E	3	0.30-10	16	4	17	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	64

Table 2-4. The selected records from the Iranian strong motion dataset (1994-2002). FD: Focal Depth (estimated by Maggi et al [15] Focal mechanisms; as reported by Harvard, Seismology Web site 2003; Rv: Reverse, SS-strike-slip (for site class 4).

No	Record	Station	Lat.N	Long.E	Site	BP Filter (Hz)	HPGA1 (Gal)	VPGA (Gal)	HPGA2 (Gal)	Fc (Hz)	Fmax-H	Fmax-V	Earthquake	Lat.N	Long.E	Region	mb	Ms	Mw	FD (km)	Focal Mechanism	Hypocentral Distance (km
1	1495-00	Maharloo	29.31N	52.78E	1	0.25-20	23	13	24	0.8	8	#	1994/06/20	28.96N	52.61E	Ebrahimabad	5.9	5.7	5.9	9	SS	32
2	1496-00	Sarvestan	29.30N	53.24E	1	0.2-30	14	9	17	0.5	5	7	1994/06/20	28.96N	52.61E	Ebrahimabad	5.9	5.7	5.9	9	SS	72
3	1525-00	Karkheh Dam	32.44N	48.12E	1	0.2-30	13	17	14	0.5	8	#	1994/07/31	32.55N	48.36E	N.Dezful	5.3	5.3	5.6	14	Rv	14
4	1526-01	Dez Dam	32.68N	48.46E	1	0.2-30	24	27	18	0.5	11	#	1994/07/31	32.55N	48.36E	N.Dezful	5.3	5.3	5.6	14	Rv	20
5	1527-00	Andimeshk	32.45N	48.38E	1	0.2-40	28	24	23	0.5	9	#	1994/07/31	32.55N	48.36E	N.Dezful	5.3	5.3	5.6	14	Rv	34
6	1507-00	Dez Dam	32.68N	48.46E	1	0.3-40	24	19	26	1	8	#	1994/09/20	32.50N	48.77E	N. Dezful	5	5.4	5.2			14
7	1583-02	Saadabad	29.40N	51.12E	1	0.3-40	13	7	23	2	8	#	1996/01/24	29.44N	51.03E	Borazjan	4.7	4.6	4.7		SS	34
8	1665-01	Delvari dam	29.41N	51.17E	1	0.25-40	29	15	20	2	8	#	1996/01/24	29.44N	51.03E	Borazjan	4.7	4.6	4.7		SS	30
9	1665-03	Delvari dam	29.41N	51.17E	1	0.2-40	32	19	27	2.5	6	8	1996/01/26	29.34N	51.00E	Borazjan	4.6	4.3	4.6			22
10	*1707-02*	Barezoo Dam	37.60N	57.97E	1	0.15-20	44	25	60	0.3	2	3	1997/02/04	37.56N	57.29E	Raz-Bojnourd	5.9	6.8	6.5	6	SS	60
11	1691-00	Razi	38.62N	48.12E	1	0.09-40	38	23	46	0.8	9	#	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	64
12	1700-00	Meshkinshahr	38.38N	47.67E	1	0.08-40	27	18	25	0.4	4	5	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	56
13	*1725-00*	Sarein	38.22N	48.08E	1	0.2-40	42	27	55	0.8	7	9	1997/02/28	38.05N	48.05E	Golestan	5.5	6.1	6.1	9	SS	60
14	*1921-01*	Sarein	38.22N	48.08E	1	0.2-40	38	63	42	1	11	#	1997/03/21	38.68N	48.13E	Ardebil	4.6		4.6			12
15	1739-00	Boskabad	34.03N	58.75E	1	0.1-15	13	10	23	0.3	2	3	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	56
16	*1753-00*	Sangan	34.38N	60.26E	1	0.08-40	118	82	112	0.4	4	5	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	80
17	1770-00	Mussaviyeh	33.30N	58.93E	1	0.06-20	17	11	18	0.2	3	4	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	76
18	1771-00	Shahid-Yaghoubi	35.08N	59.52E	1	0.07-20	37	21	45	0.15	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	152
19	1751-00	Mud	32.75N	59.52E	1	0.2-30	18	16	18	0.4	4	6	1997/05/10	33.83N	59.81E	Ardekul-Ghaen	6.4	7.7	7.2	13	SS	135
20	1864-01	Abaragh	29.38N	57.92E	1	0.2-40	12	8	13	0.4	4	6	1998/03/14	30.15N	57.60E	Fandogha	5.9	6.9	6.6	5	SS	74
21	1866-00	Baghein	30.21N	56.78E	1	0.15-25	14	12	17	0.4	5	6	1998/03/14	30.15N	57.60E	Fandogha	5.9	6.9	6.6	5	SS	58
22	2037-00	Andohjerd	30.23N	57.75E	1	0.3-20	38	35	32	2	10	#	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	38
23	2047-02	Joshan	30.15N	57.60E	1	0.3-20	22	14	27	1	8	#	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	44
24	2163-00	Khurjand	30.66N	57.17E	1	0.2-20	9	5	12	1	6	8	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	48
25	*2176-01*	Shahdad	30.39N	57.73E	1	0.2-20	52	38	48	1	7	8	1998/11/18	30.30N	57.56E	Shahdad	4.9	5.1	5.3		SS	24
26	*2373-01*	Yekan	38.72N	48.42E	1	0.2-30	57	42	38	2	10	#	1998/11/18	38.37N	47.17E	West-Urumieh	4.8		4.9			44
27	*2224-03*	Derakht-eToot	35.75N	61.10E	1	0.15-40	138	145	245	2	10	#	1999/12/05	35.67N	61.23E	Salehabad	5.1		5.1		Rv	14
28	*2225-11*	Salehabad	35.70N	61.10E	1	0.2-40	138	142	102	1	8	#	1999/12/05	35.67N	61.23E	Salehabad	5.1		5.1		Rv	17
29	2462-02	Bandar-Rig	29.47N	50.65E	1	0.3-30	23	9	19	1	10	#	2000/05/03	29.66N	50.80E	N. Genaveh			5.1		R-SS	50
30	2750	Bahar	34.90N	48.42E	1	0.10-25	27	17	39	0.4	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	120
31	2752	Garmab	35.83N	48.22E	1	0.18-18	17	18	21	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	68
32	2753	Khodabandeh	36.12N	48.59E	1	0.10-20	22	16	17	0.2	9	#	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	56
33	*2754-01*	Kabodar-Ahang	35.20N	48.73E	1	0.20-40	78	71	155	0.4	12	#	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	78
34	2758	Zarrinabad	36.41N	48.28E	1	0.15-15	15	6	11	0.25	7	9	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	100
35	2759	Buin-Zahra	35.77N	50.05E	1	0.10-12	21	12	30	0.2	4	6	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	100
36	2760-02	Ziaabad	35.99N	49.45E	1	0.10-20	34	20	37	0.25	8	#	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	54
37	2768	Deh-Jalal	36.31N	48.70E	1	0.10-15	17	21	22	0.3	9	#	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	66
38	2770	Halab	36.30N	48.05E	1	0.20-20	17	7	12	0.2	7	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	64
39	2771	Meymundarreh	36.12N	49.13E	1	0.30-30	32	10	22	0.3	10	#	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	48
40	2777	Goltappeh	35.22N	48.20E	1	0.10-30	30	24	31	0.4	11	#	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	97
41	2793	Takestan	36.06N	49.70E	1	0.15-15	12	11	11	0.2	8	#	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	76
42	2819	Vahnabad	35.45N	51.17E	1	0.30-10	13	7	11	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	70
43	2832	Garmdarreh	35.70N	51.06E	1	0.30-10	11	6	9	0.3	6	8	2002/06/22	35.63N	49.05E	Changureh	6	6.3	6.3		Rv	60

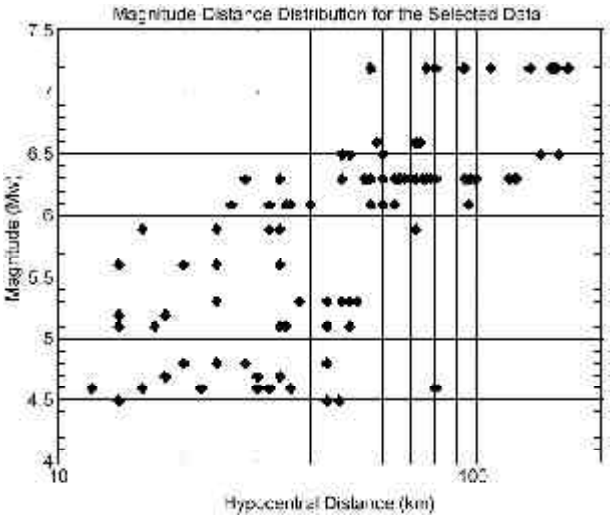
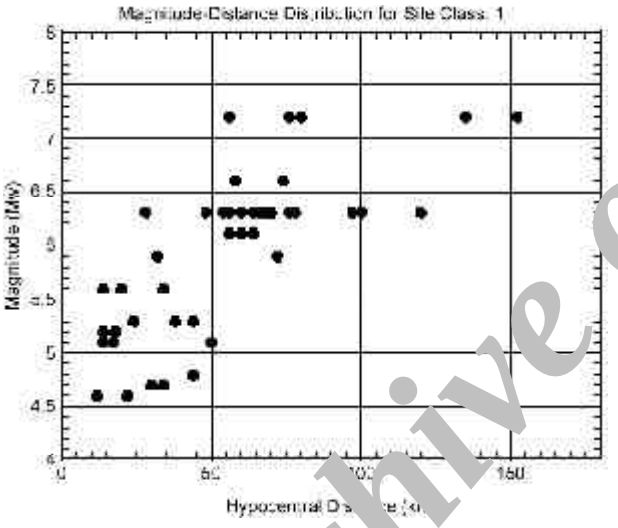


Figure 3. The magnitude-distribution for all of the data presented in Table (1).

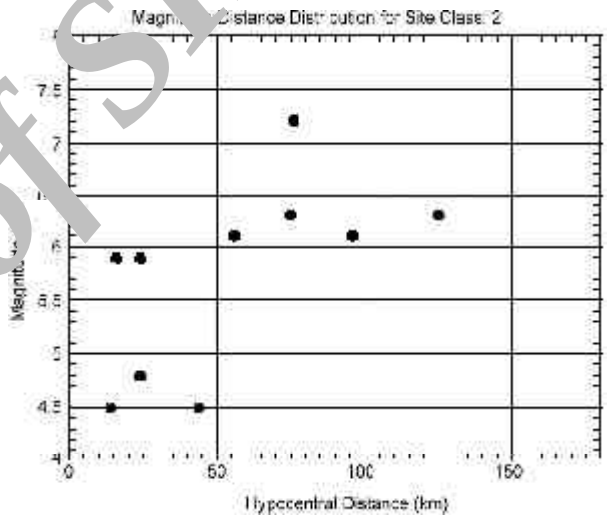
ratio (R_{sn}) is computed (as estimated by Theodulidis and Bard [2]) as:

$$R_{sn} = \frac{S(f)/\sqrt{t_1}}{N(f)/\sqrt{t_2}} \qquad (1)$$

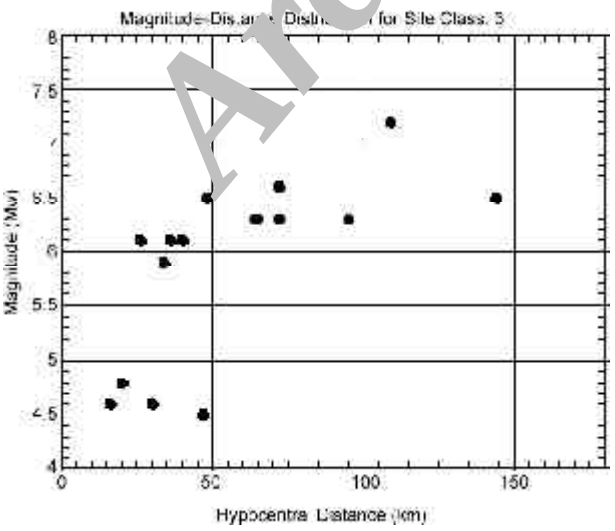
Where t_1 and t_2 are the window duration for the signal and noise parts, respectively. Since the records applied in this study are all digitally recorded, the time windows for noise parts (t_2) are selected before the p-unset (in the pre-event part of the records, mostly from 0 to 4 seconds, in the selected records). A R_{sn} ratio over 3 is selected as the proper ratio to distinguish the signal from the noise. The data having low signal qualities below 0.3*Hz* are excluded in order to keep the records having acceptable low frequency contents.



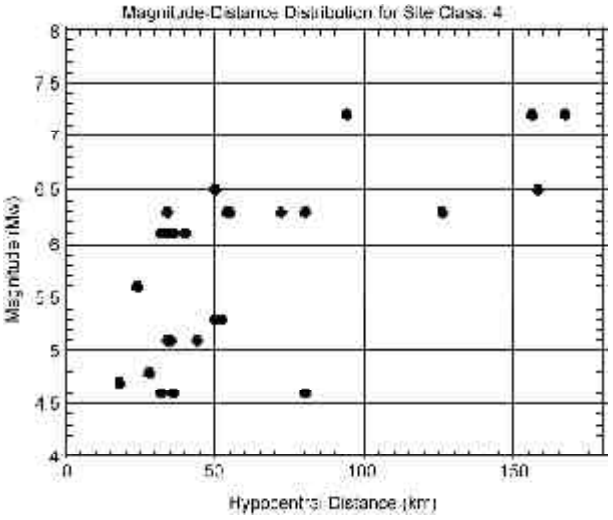
(4a)



(4b)



(4c)



(4d)

Figure 4. The magnitude-distance distribution for stations on different site classes; Figure (4a): class '1'; Figure (4b): class '2'; Figure (4c): class '3'; Figure (4d): class '4'.

The result of the estimation of R_{sn} ratios for four greater records (after processing, having a peak ground accelerations greater than $300 cm/sec^2$) obtained in the stations of Zarrat, Zanjiran, Karigh and Avaj (Table (1)) are shown in Figures (5) to (8), respectively. The high-pass and low pass filters are hence selected for

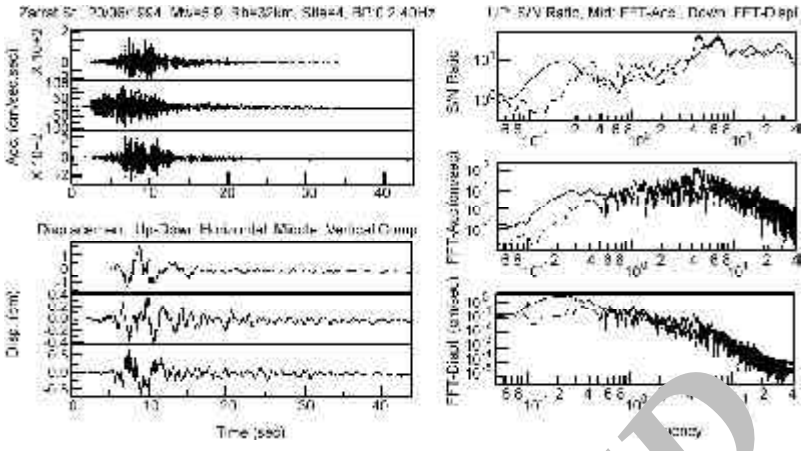


Figure 5. The processing of the Zarrat record of 20/06/1994, Mw 5.9 earthquake; above- left: three-component accelerograms (up and down traces are the horizontal components and the middle trace is the vertical one), below-left: double integrated displacement time-histories, above-right: Signal to noise ratio, middle-right: FFT of Accelerations, below-right: FFT of displacements. The dashed lines indicate the vertical components and the continuous lines are for horizontal ones.

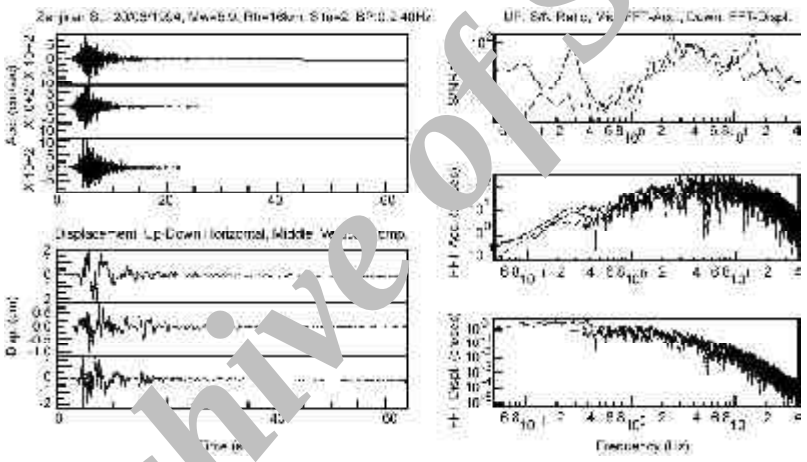


Figure 6. The processing of the Zanjiran record of 20/06/1994, Mw 5.9 earthquake; above- left: three-component accelerograms (up and down traces are the horizontal components and the middle trace is the vertical one), below-left: double integrated displacement time-histories, above-right: Signal to noise ratio, middle-right: FFT of Accelerations, below-right: FFT of displacements. The dashed lines indicate the vertical components and the continuous lines are for horizontal ones.

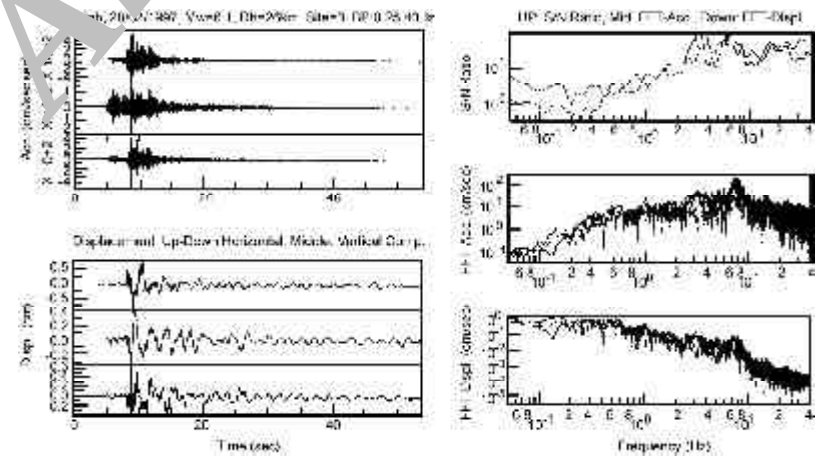


Figure 7. The processing of the Karigh record of 28/02/1997, Mw 5.9 earthquake; above- left: three-component accelerograms (up and down traces are the horizontal components and the middle trace is the vertical one), below-left: double integrated displacement time-histories, above-right: Signal to noise ratio, middle-right: FFT of Accelerations, below-right: FFT of displacements. The dashed lines indicate the vertical components and the continuous lines are for horizontal ones.

the parts having the signal to noise ratio greater than 3, and are given in the column 7 of Table (1) (same filter bands are found for both horizontal and vertical components).

The signal to noise ratios for all records are given in Figures (9) and (10) for horizontal and vertical

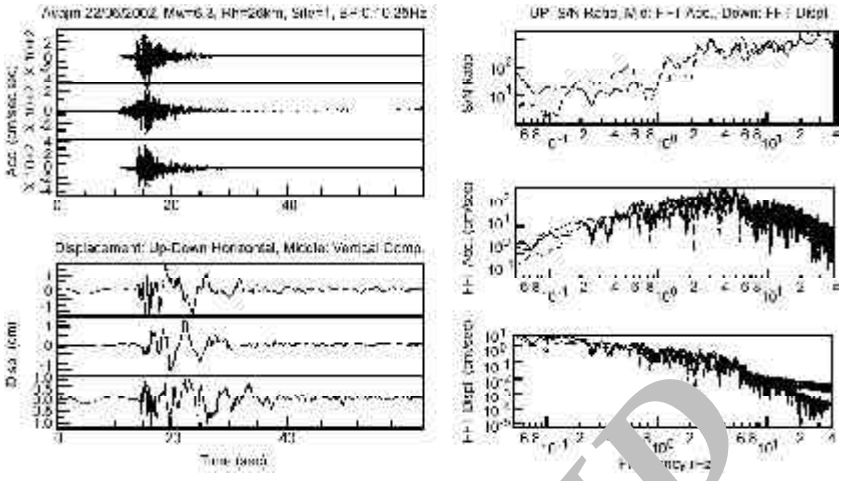


Figure 8. The processing of the Avaj record of 22/06/2002, Mw 6.3 earthquake, above- left: three-component accelerograms (up and down traces are the horizontal components and the middle trace is the vertical one), below-left: double integrated displacement time-histories, above-right: Signal to noise ratio, middle-right: FFT of Accelerations, below-right: FFT of displacements. The dashed lines indicate the vertical components and the continuous lines are for horizontal ones.

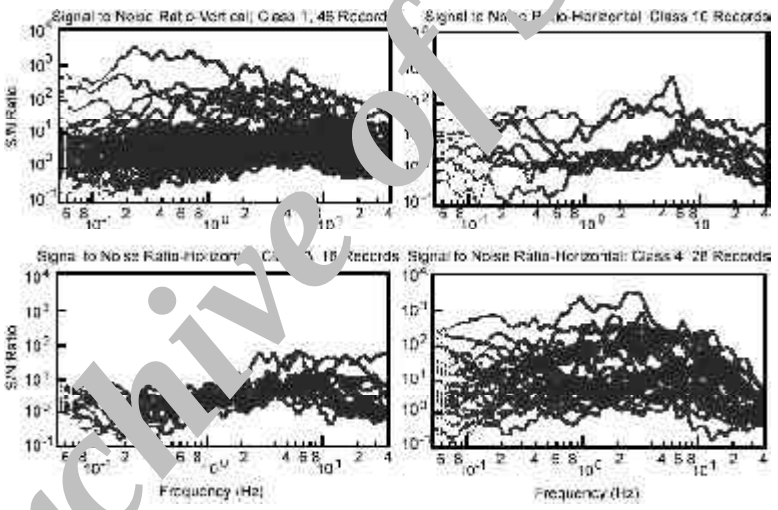


Figure 9. The signal to noise ratios for all of the records, distinguished for site classes '1' (above-left), '2' (above-right), '3' (below-left), and '4' (below-right); horizontal components.

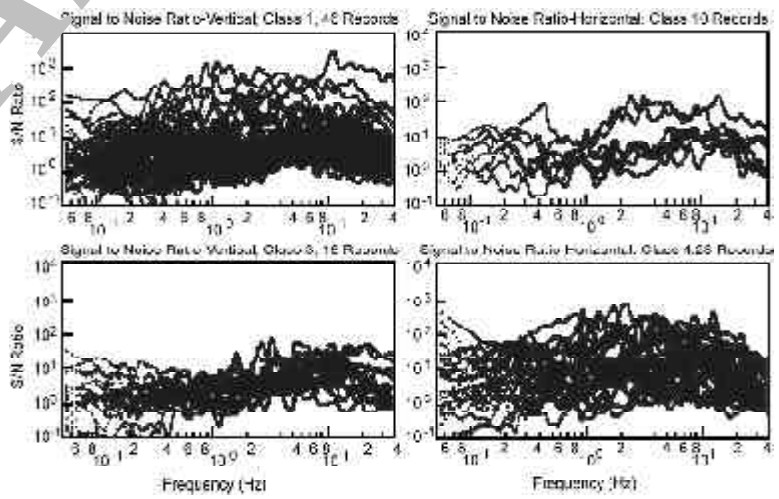


Figure 10. The signal to noise ratios for all of the records, distinguished for site classes '1' (above-left), '2' (above-right), '3' (below-left), and '4' (below-right); vertical components.

components respectively. These figures show the dominance of the frequency band of the good quality signals between 0.2 and 10*Hz* for most of the cases. However the qualities of the signals are found to be lower for records assigned to site class '3', comparing to other site classes.

2.2. Magnitude Values

Magnitude used here is the moment magnitude, to give a uniform and reliable scale for comparison of different parameters. The moment magnitude was systematically calculated for all selected records, which are well recorded earthquakes (with little noise).

The source model used to estimate the moment magnitude in this study is based on Haskell [13], who proposed a simple source model for the estimation of high frequency ground motions. The simple seismic source models are explained by Aki [1] and Brune [6, 7]. In this model, the far field displacement spectrum is characterized by a flat level $\overline{W}_0$ proportional to M_o at long periods, a corner frequency f_c proportional to inverse of the source dimension, and a high frequency spectral decay in the form $(f / fc)^{-g}$. Taking the g values as 2 or 3, we have the ω-square or ω-cube model, respectively (ω is the angular frequency in radians per second, equal to $2\pi f$). Hanks [10] has shown that with a w-square model, for which the acceleration spectra will be flat after the corner frequency, f_c, the high frequency decay may be explained by the attenuation caused by the path effects. The more complicated ω-cube model [7], as a dynamic model, shows that the rupture nucleation generates high frequency energy, which is proportional to ω^{-3}. As proposed by Hanks and Kanamori [11], the displacement spectra may be represented by;

$$\overline{W} = \frac{\overline{W}_0}{1+\left(\frac{f}{f_c}\right)^{\gamma}} \qquad (2)$$

If $\overline{W}_0$ is the value of the flat part of the displacement spectrum, the value of the flat part of the acceleration spectrum, A_0, may be related to $\overline{W}(0)$ with $A_0 = \overline{W}_0 \cdot \omega_c^2$ proportional to the seismic moment; M_o. For far-field S-waves, due to a double couple source embedded in an elastic, homogeneous, isotropic bounded medium [11], we have:

$$M_o = \frac{A_0}{(2\pi f_c)^2} \cdot \frac{4\pi R_h \cdot \rho \cdot \beta^3}{R'_{\theta\varphi} \cdot F_s} \qquad (3)$$

Where β is the shear wave velocity of the medium; ρ is the density of elastic medium; around $(2.8\text{x}10^3)kg/m^3$, R_h *is* the hypocentral distance, $R'_{\theta\varphi}$ is the double couple radiation patter for *SH* or *SV* waves (about 0.6 in average), F_s is the free space amplification factor (to be taken equal to 2) [3]. In the following, to calculate M_o (in *N-m*), we take *b* equal to 3500*m/sec* [14]; $\rho = 2.8\text{x}10^3)kg/m^3$.

Hanks and Kanamori [11] defined a new magnitude scale based on the seismic moment, that is more reliable measure of the size of the great earthquakes. This scale with taking into account the coefficients for N-m unit of M_o, could be written as follows:

$$M_w = 0.667\ M_o - 6.0 \qquad (4)$$

The author has used the formula (3) and (4) to calculate M_w for the events listed in Table (1).

Based on the estimated M_w for each of the earthquakes, and after filtering the records (explained in 2.1) the values of peak ground acceleration (*PGA*) for different components are shown in columns 8 to 10 of Table (1). The estimated corner frequencies *(fc)* and maximum frequencies (*fmax*) for horizontal and vertical components are given in columns 11 to 13 of Table (1). The distribution of *PGA* against magnitudes and hypocentral distances are shown in Figure (11). The horizontal and vertical *PGA* are shown against the horizontal and vertical *fmax*, respectively, in Figure (12). The corner frequencies are compared as well with the *PGA* in Figure (13), and with *fmax* values in Figure (14). These figures show that most of the data are distributed over the hypocentral distances of 10 to 100 kilometers and the *fmax* values found for the vertical components are systematically greater for vertical components.

2.3. Site Classification

The site classes are estimated based on the transfer function method, in which the H/V amplification function is calculated, in order to find the fundamental frequency of the site [21]. However the site specific studies are performed for some of the sites studied in this paper (Zarrat, Firouzabad, Zanjiran, Hosseinieh, Saadabad, Shabankareh, Dasht-Bayaz, Gonabad, Kerman, Buin-Zahra, Abhar and Eshtehard; Table (1)) in view point of the microtremor measurements and the seismic wave velocity profiling [21]. The formulation used for the *H/V* method is based on the spectral ratio (R_{hv}) between the smoothed horizontal components and the smoothed vertical component:

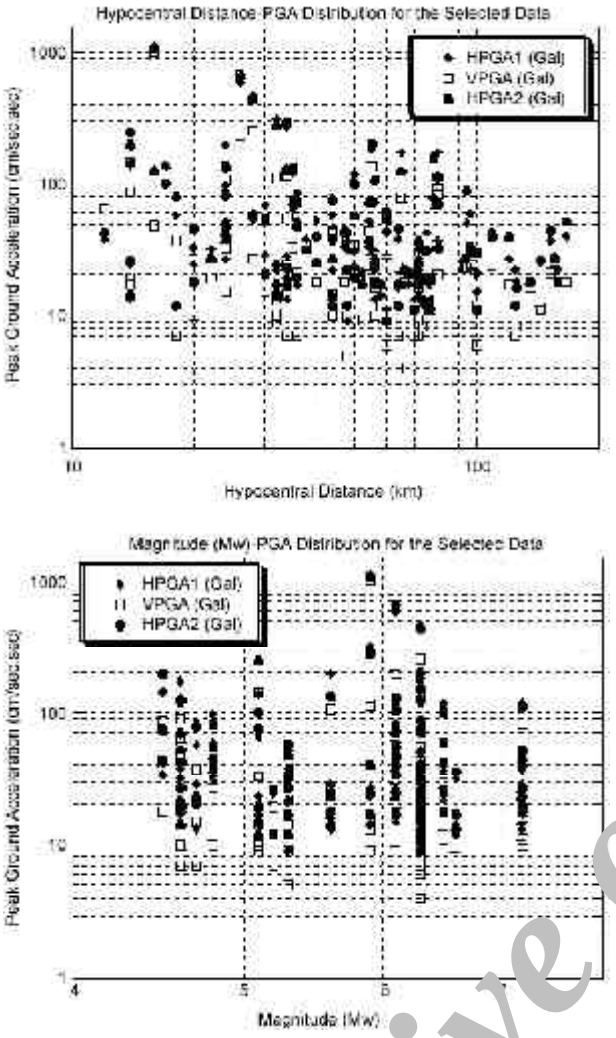


Figure 11. The distribution of the records against hypocentral distance (above) and magnitude (below).

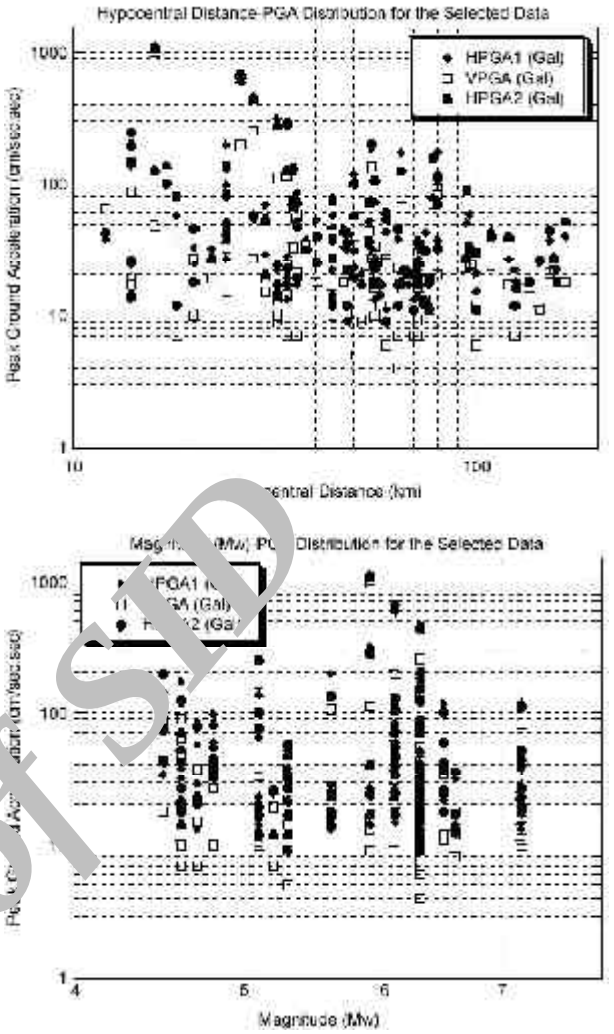


Figure 12. The distribution of Fmax values against PGA for horizontal components (above) and vertical components (below).

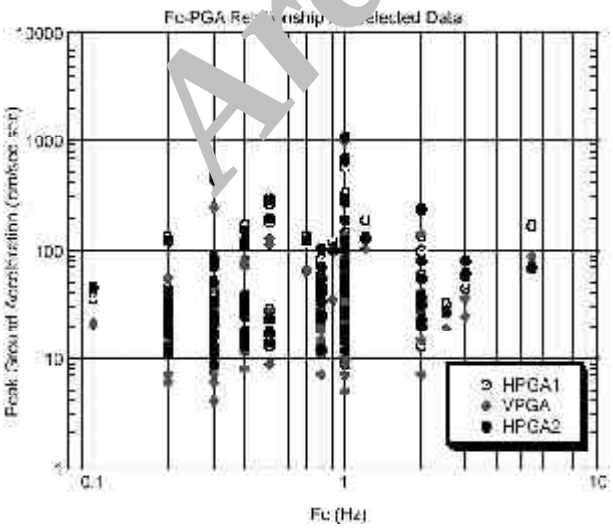


Figure 13. The distribution of fc values against PGA for horizontal and vertical components.

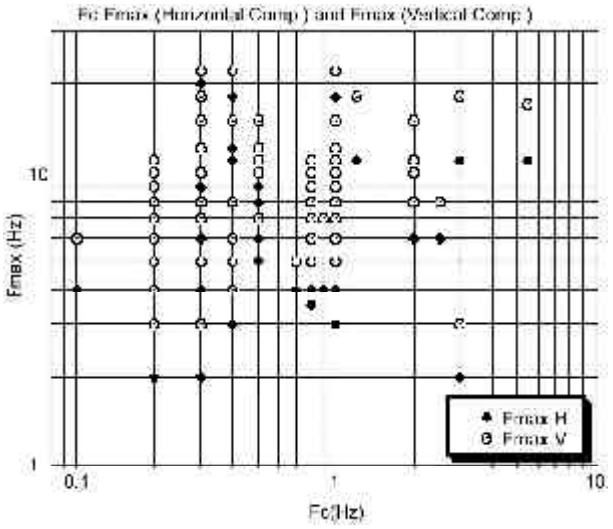


Figure 14. The distribution of fc values against fmax for horizontal and vertical components.

$$R_{hv} = \frac{\sqrt{S_{H1}^2 / 2\sqrt{T_{H1}} + S_{H2}^2 / 2\sqrt{T_{H2}}}}{S_v(f) / \sqrt{T_V}} \quad (5)$$

Where T_{H1}, T_{H2} and T_V are the signal duration for the horizontals and vertical components respectively. Since the same time windows are used the same for all components, this relationship might be simplified as;

$$R_{hv} = \frac{[1/2(S_{H1}(f) + S_{H2}(f))]}{S_v(f)} \quad (6)$$

Site class '1' is defined as sites that do not exhibit any significant amplification below 15*Hz*. It corresponds to rock and stiff sediment sites with an average S-wave velocity over the top 30 meters in excess of 700*m/sec*. Site class 2 determined as sites for which the receiver function (*RF*) exhibits a fundamental peak exceeding 3 at a frequency located between 5 and 15*Hz*. It was shown to correspond to stiff sediments and/or soft rocks with Vs_{30} between 500 and 700 *m/sec*. Site class 3 is representative for the sites for which *RF* shows the peaks between 2 and 5*Hz* and corresponds to the alluvial sites with Vs_{30} between 300 and 500*m/sec*. Finally site class 4 is defined as sites for which *RF* indicates the peaks in frequencies below 2*Hz*, and it may be viewed corresponding to thick soft alluvium. This ranking was the result of the geotechnical measurements on 50 sites (compressional and shear wave velocity and microtremors) and the calculation of the receiver function for the strong motions using the three component accelerograms. This categorization show some similarity to that of Boore et al [4, 5] (based on the average *Vs* for the 1st 30*m*) for the northwestern American data. The average *Vs* limits to distinguish the site classes in Boore et al [4, 5] reports are 180*m/sec*, 360*m/sec*, 750*m/sec* and greater than 750*m/sec* (to be compared with our values of 300, 500 and 700*m/sec*).

The *H/V* amplification ratios are shown for all records in Figure (15). These spectral ratios are averaged in Figure (16) for each of the four site classes. These two figures coincide well the defined criteria by Zaré et al [21] in order to classify the sites of the strong motion stations based on the frequency band of the predominant frequency of the site as described above.

2.4. Distance Variable

When discussing the choice of the "distance parameter" one must keep in mind the significant uncertainties in the teleseismic epicenter localization and large uncertainties in determining of focal depths for the Iranian earthquakes. It is important however to define this parameter so that the future application of these data to establish the attenuation laws will be easy.

We have decided to define the distance variable for the regression as the "hypocentral distance". This distance is controlled by the difference in the arrivals of the compressional and shear wave for each record. Such information is available without any ambiguity

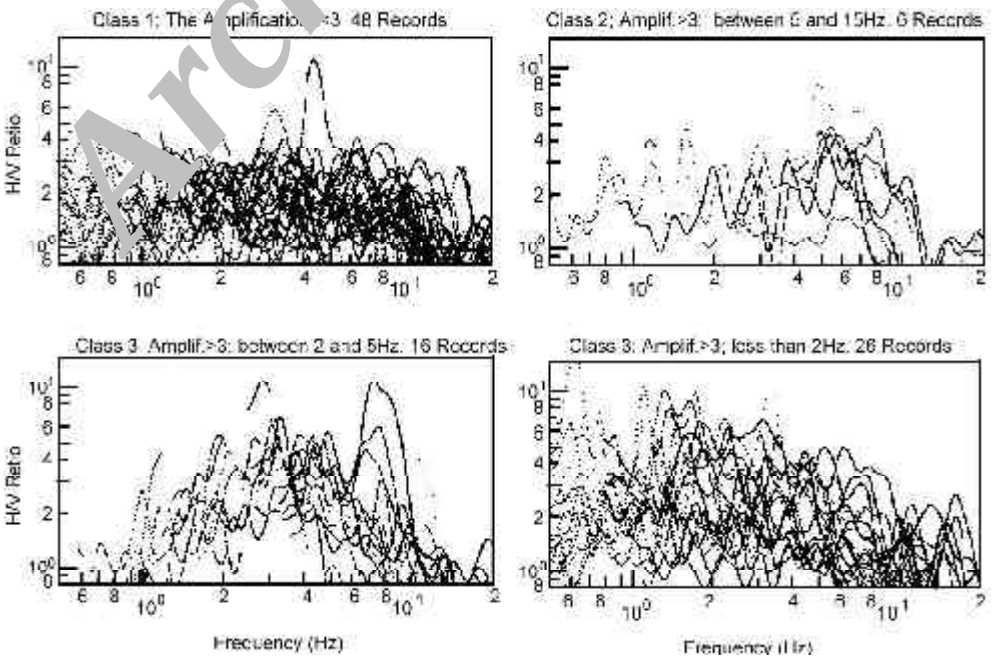


Figure 15. The H/V ratios distinguished for site classes '1' (above-left), '2' (above-right), '3' (below-left), and '4' (below-right).

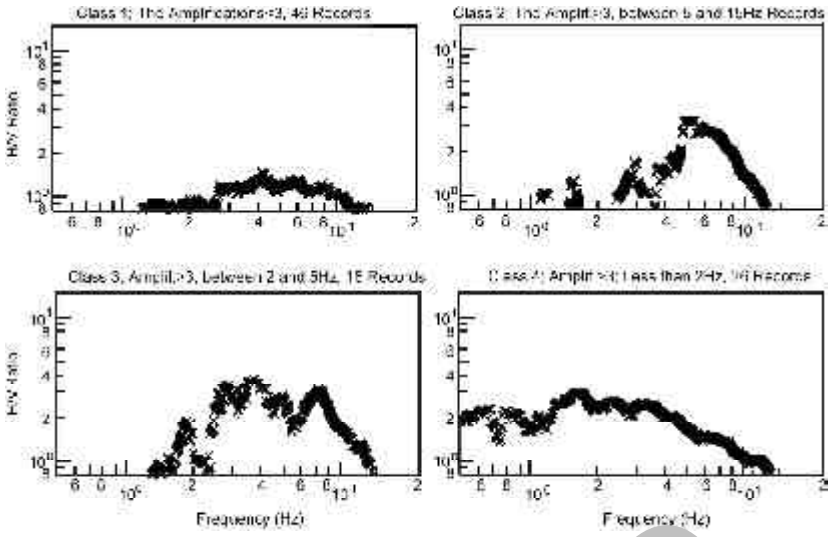


Figure 16. The average of H/V ratios distinguished for site classes '1' (above-left), '2' (above-right), '3' (below-left), and '4' (below-right).

only with the *SSA*-2 digital records (all records studied herein were obtained by such type of recorders). The results of these estimations are given in column 23 of Table (1).

2.5. Fault mechanism

According to the regional tectonic conditions of the Iranian plateau, the fault mechanisms of most of the earthquakes are compressional, strike-slip or a combination of these two mechanisms. The fault mechanisms of most of the earthquakes used in the present study were strike-slip, compressional or a combination of these two mechanisms (Harvard, Seismology web site, 2003 [15], IRSC web site, 2003 [16]). The available information on focal mechanisms are presented in column 22 of Table (1). In an earlier study [2, 10], it is shown that the focal mechanisms of the records for which the source parameters could be found comprise mostly strike-slip/reverse mechanisms, pure strike slip, pure reverse and pure vertical plane.

3. Response Spectra

The response spectra of the studied records are studied. The spectra for the greater events (records having a greatest *PGA* greater or equal 0.05*g*, in one or all of the three components) are selected for comparison in this paper. The records that had such condition for the site classes 1, 2, 3 and 4 have been 9, 6, 8, and 16 respectively (Table (1)). Having two horizontal components, the horizontal response spectra applied in the comparisons are doubled the mention numbers. The response spectra for the site class '1' are shown in Figure (17) ('a' and 'b' for horizontal and vertical components, respectively). The spectra

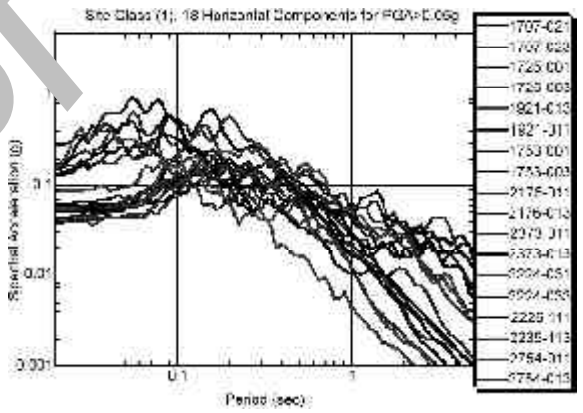


Figure 17a. The response spectra for 11 records obtained on the site class '1' (22 horizontal components).

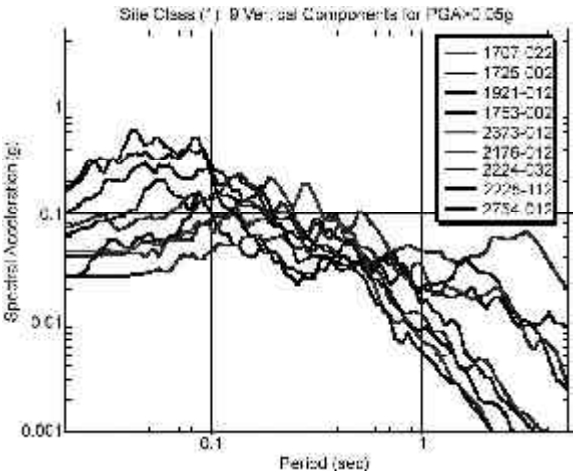


Figure 17b. The response spectra for 11 records obtained on the site class '1' (vertical components).

for the site classes '2', '3' and '4' are shown in Figures (18), (19) and (20), respectively. The values of the normalized spectra for the site classes 1 to 4 are presented in Figures (21), (22), (23) and (24) respectively. The normalized response spectra are compare for 4 site classes in Figures (25a) and (25b), for horizontal and vertical components, respectively. According to these figures, the response spectra for different site classes are distinguished. As it is clear in Figures (21) to (24), the softer the site, the longer

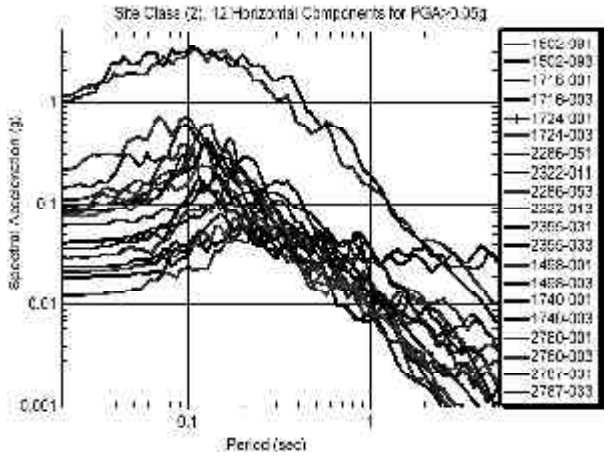


Figure 18a. The response spectra for 6 records obtained on the site class '2' (12 horizontal components).

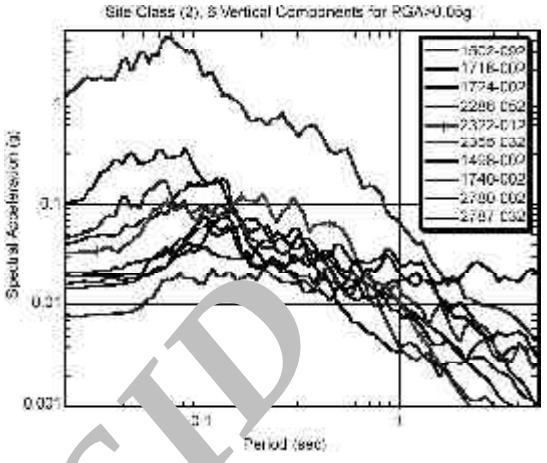


Figure 18b. The response spectra for 6 records obtained on the site class '2' (vertical components).

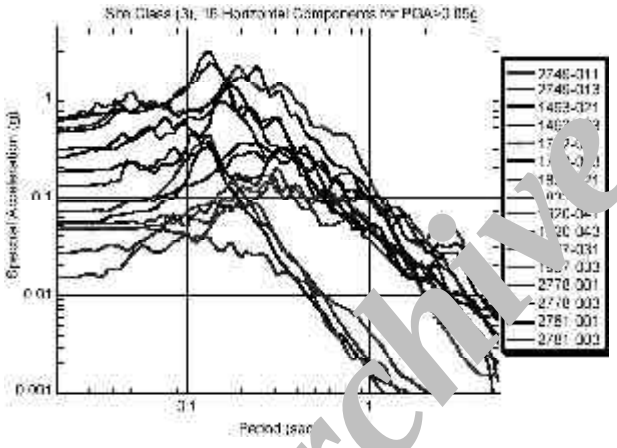


Figure 19a. The response spectra for 8 records obtained on the site class '3' (16 horizontal components).

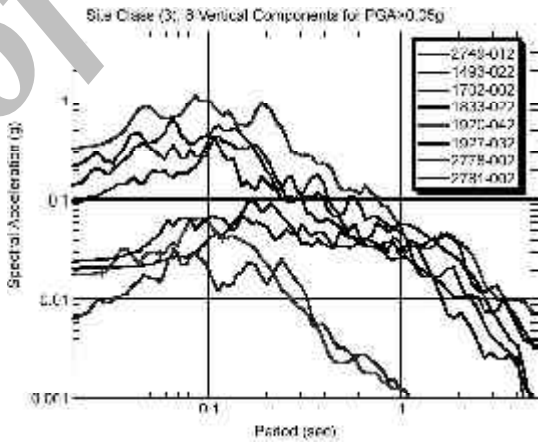


Figure 19b. The response spectra for 8 records obtained on the site class '3' (vertical components).

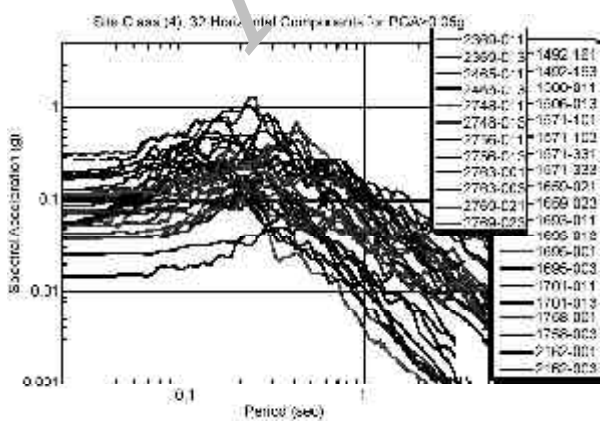


Figure 20a. The response spectra for 16 records obtained on the site class '4' (32 horizontal components).

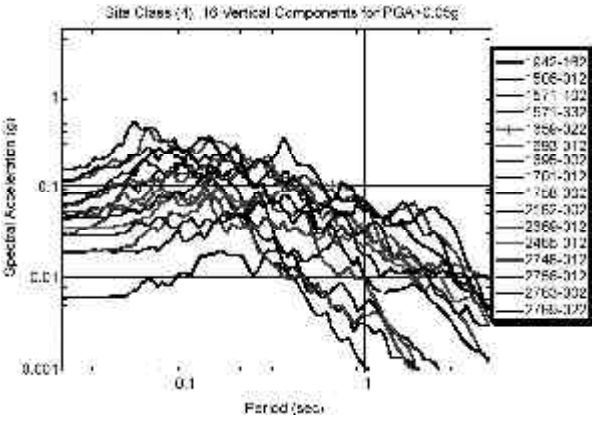


Figure 20b. The response spectra for 16 records obtained on the site class '4' (vertical components).

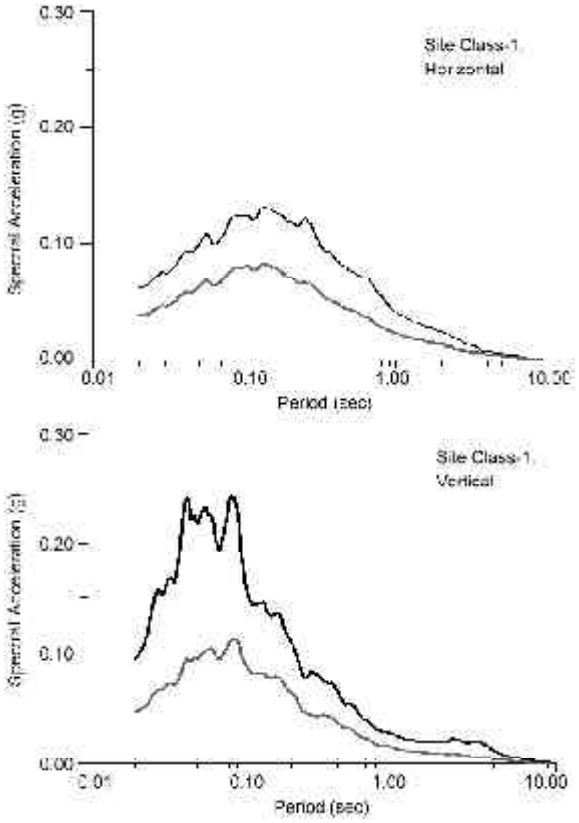


Figure 21. The mean and mean plus sigma response spectra for site class "1" (Horizontal; up, and vertical; down).

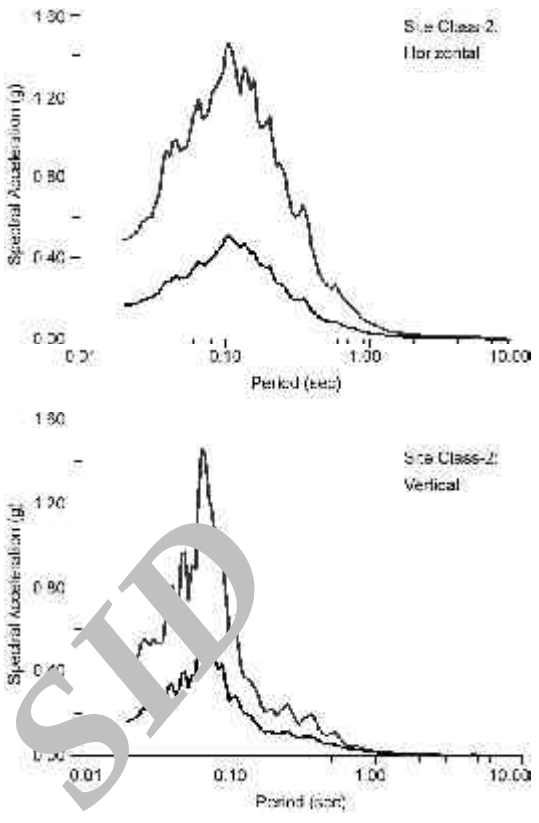


Figure 22. The mean and mean plus sigma response spectra for site class "2" (Horizontal; up, and vertical; down).

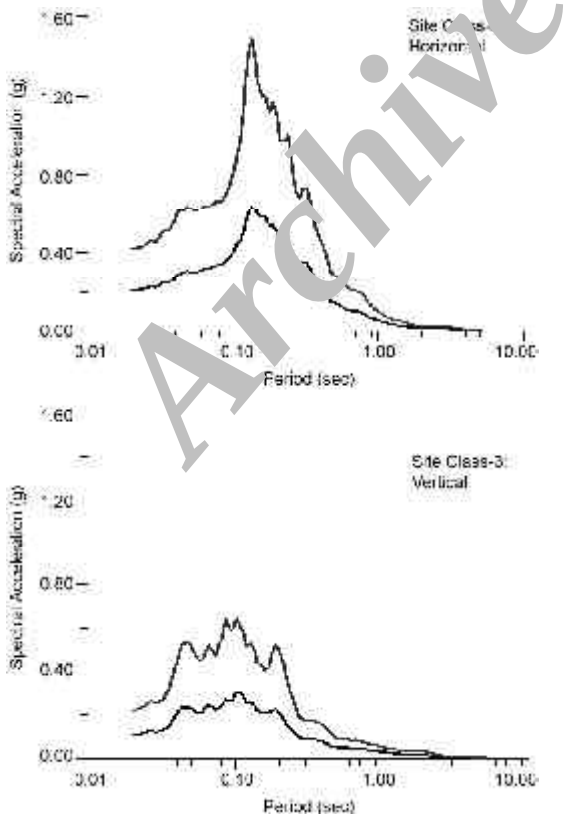


Figure 23. The mean and mean plus sigma response spectra for site class "3" (Horizontal; up, and vertical; down).

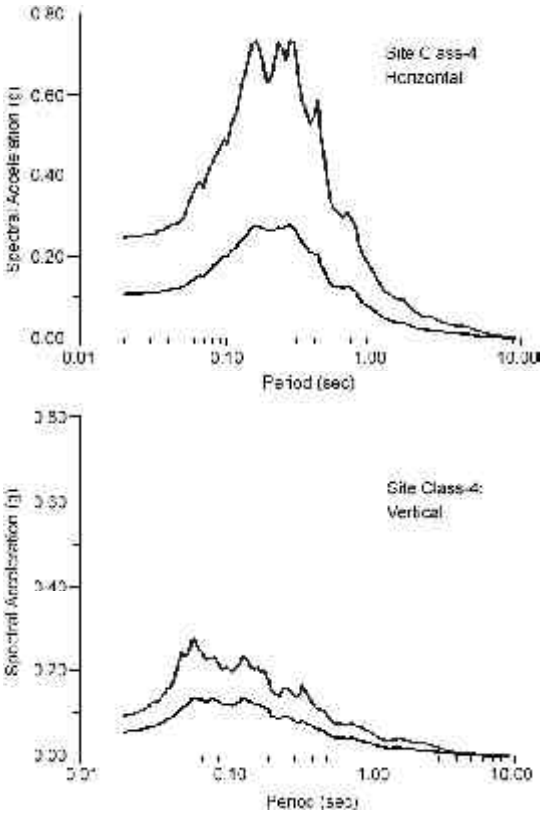


Figure 24. The mean and mean plus sigma response spectra for site class "4" (Horizontal; up, and vertical; down).

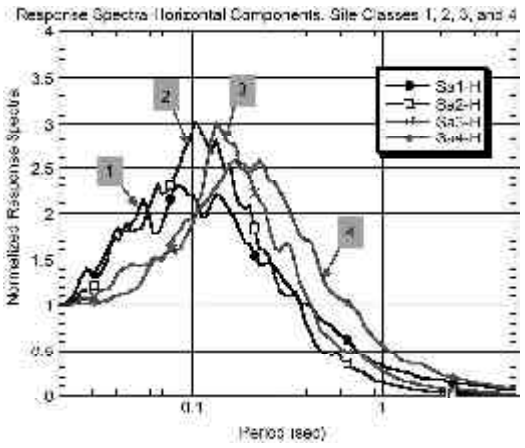


Figure 25a. The normalized response spectra for site classes '1, 2, 3, and 4' for horizontal component.

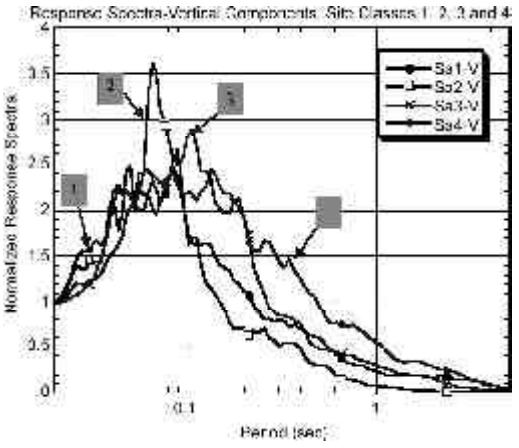


Figure 25b. The normalized response spectra for site classes '1, 2, 3, and 4' for vertical component.

the predominant period of response spectra will be. The predominant periods of 0.09, 0.1, 0.13 and 0.2 seconds are found on the horizontal components, for the site classes 1, 2, 3 and 4, respectively. These values on the vertical components are 0.08, 0.06, 0.11 and 0.15 seconds for the site classes 1, 2, 3 and 4, respectively. This shows the difference between frequency contents of the horizontal and vertical components.

4. Discussions

The selected records are listed in Table (1). The records are presented based on their code assigned by the Building and Housing Research Center, BHRC [8]), station name, site class, band-pass filter selected for each record, *PGA* (the greatest of three components), the event's date, coordinates, epicentral region, reported magnitude, focal depths, focal mechanisms and the hypocentral distances. The hypocentral distances are estimated for each record based on the s-p interval time method. The displacement time-histories (after 2 times integrals), as well as the *FFT* of displacement are shown as well, for 4 greater records in order to indicate the relative stability of the mentioned records in low frequencies. 100 records corresponding to 15 earthquakes are finally selected.

The selected records have different frequency contents and specifications. This difference corresponds to the magnitude and hypocentral distances, as well as to the instrument type. Most of the records are noisy in the frequencies less than 0.3*Hz*. However, some records show high signal to noise ratios in the frequency band of 0.3*Hz* or lower. These records are listed in Table (1).

The response spectra for horizontal and vertical components are classified as well. The class '4' shows that the form of the response spectra is shifted towards the longer periods. The normalized spectra show that the predominant periods change in different site classes between 0.09 and 0.2 seconds for horizontal components. The normalized vertical spectra for the class '1' shows lower the predominant period than that of class '1'. This may be resulted from the number of the available records selected for these classes (6 records for site class '2'). Otherwise such problems should be controlled in the further studies based on the recently obtained digital records (after 2000). Except for the Changureh (22 June 2002) earthquake, such better quality recent records were not available at the time of the present study.

5. Conclusion

This study was aimed to select the recent strong motion records obtained in Iran (1994-2002) in order to study the earthquakes for which several records (2 or more) are available. 100 records relating to 15 earthquakes are selected. These records had better quality in the frequency bands less than 0.3*Hz*. These data seem to provide a sufficient basis for the long period strong motion studies, such as rupture modeling and strong motion displacement studies. The normalized response spectra for the records having greater *PGA* values shows the longer predominant periods for the softer site classes.

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