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Technical Note

IRAN STRONG MOTION NETWORK

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ABSTRACT

This paper describes current activities in the field of strong motion research in Iran. The seismotectonics and seismological background is explained and current strong motion monitoring in Iran is summarised. The Strong Ground Motion Network of Iran started its activities since 1973, and has recorded more than 4200 accelerograms. The highest ground acceleration recorded in this network was 1g at Zanjiran station in 1994 Zanjiran earthquake. At present the network consists of 986 digital and 71 analogue accelerograph. ISMN has been installed 92 accelerographs in 54 dams. The geophisical and geotechnical investigations for site geology have been conducted in 100 accelerograph stations.

Keywords: Iran strong motion network (ISMN), Iranian earthquakes, accelerographs

1. THE SEISMICITY OF IRAN

The Iranian plateau is one of the most seismically active areas of the world and frequently suffers destructive and catastrophic earthquakes that cause heavy life loss and widespread damages.

The Alpine-Himaliyan earthquake belt, where Iran is located, extends from west Portugal eastward along Southern Europe, including Iran and southern East Asia, and then encircling the Pacific Ocean. Major geological structures of Iran are the Alborz Mountains in the North, the Zagros belt in the west and south, the Kopet-dagh range in the northeast, the depression of the Great Kavir in the center, Lut in the east and the Caspian Sea in the north [1].

A review of the seismic history of Iran shows that this country is in a high seismic region, Figure 1. Major part of the seismic activity originates along the active faults, but there is some complexity in the distribution of seismic activity in the country. For better understanding of earthquake occurrence in the country we need to complete our knowledge about this natural phenomena. One of the most advanced methods in this process is direct recording and measurment of the strong ground motions during earthquakes. A knowledge of the ground motion is essential to an understanding of the earthquake and the behavior of

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structures. For this purpose, a network of strong motion accelerograph is maintained by the Building and Housing Research Center.

Iran is characterized by its active faults that have caused several strong earthquakes in the past. These earthquakes have brought about considerable mortalities and causalities, extensive damages to buildings and the disruption of agricultural and industrial facilities. Tabas earthquake of 16 September 1978; Roudbar-Manjil earthquake of 20 June 1990, Garmkhan earthquake of 4 February 1997, Ardakul earthquake of 10 May 1997 were the most catastrophic earthquakes occurred in this seismic region in the past 25 years. During this period, at least 60,000 people lost their lives and more than 1,000,000 were left homeless. These events show Iran's seismicity and vulnerability of the buildings to sever damage.

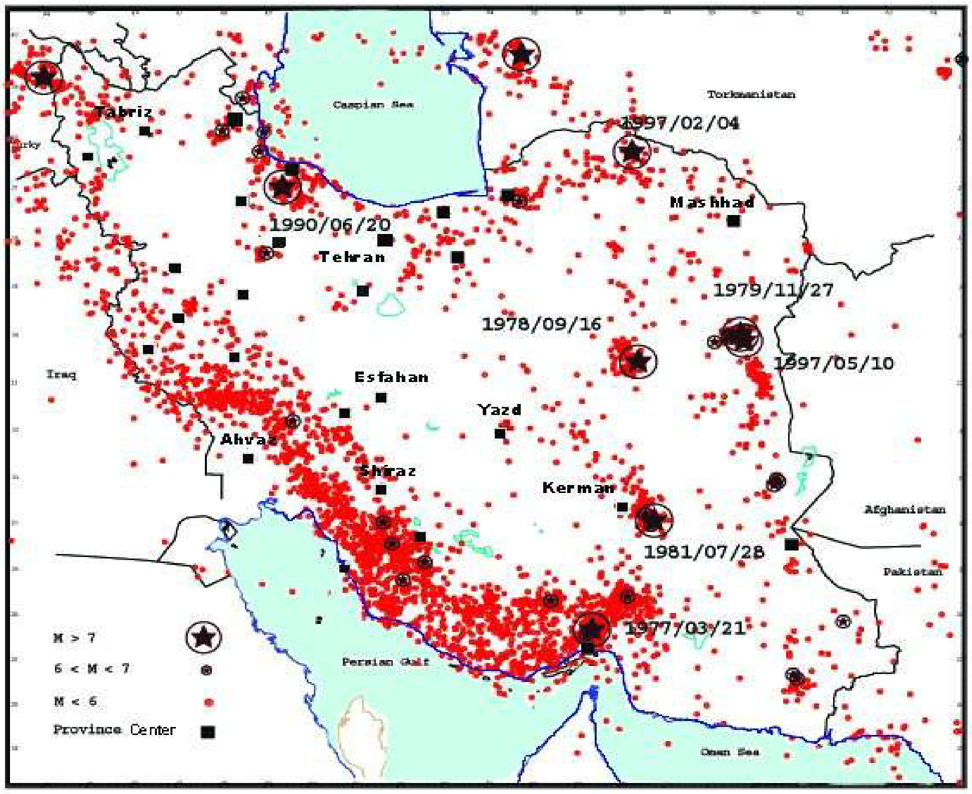


Figure 1. Map of seismicity zones in Iran

2. THE HISTORY OF IRAN STRONG MOTION NETWORK

The Strong Motion Network of Iran started its activities in 1973 at the Planning and Budget Organization. In 1981 the Network was transferred to Building and Housing Research Center and a new stage of its activities was born. Initially the network consisted of 274 accelerographs, (until 1992). At the present time the network consists of 986 digital accelerographs and 71 analogue accelerographs, Figure 2. The number of accelerographs installed in Khorasan Province is the greatest, and the maximum number of accelerograms were obtained in Fars province (780 records). Most of the accelerograph stations are concentrated in seismic active areas or in densely populated and industrialized areas, Figure 3.

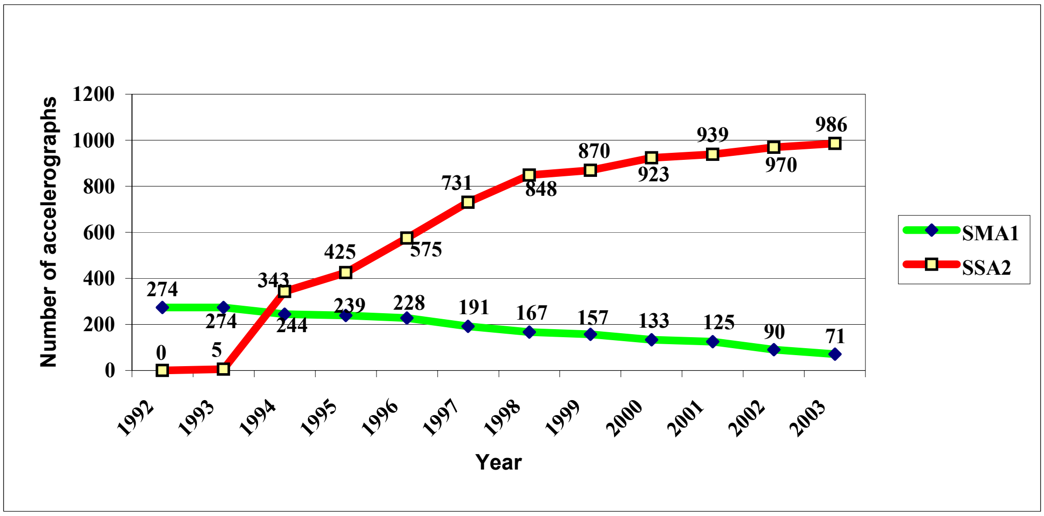


Figure 2. Number of accelerographs installed in Iran by BHRC

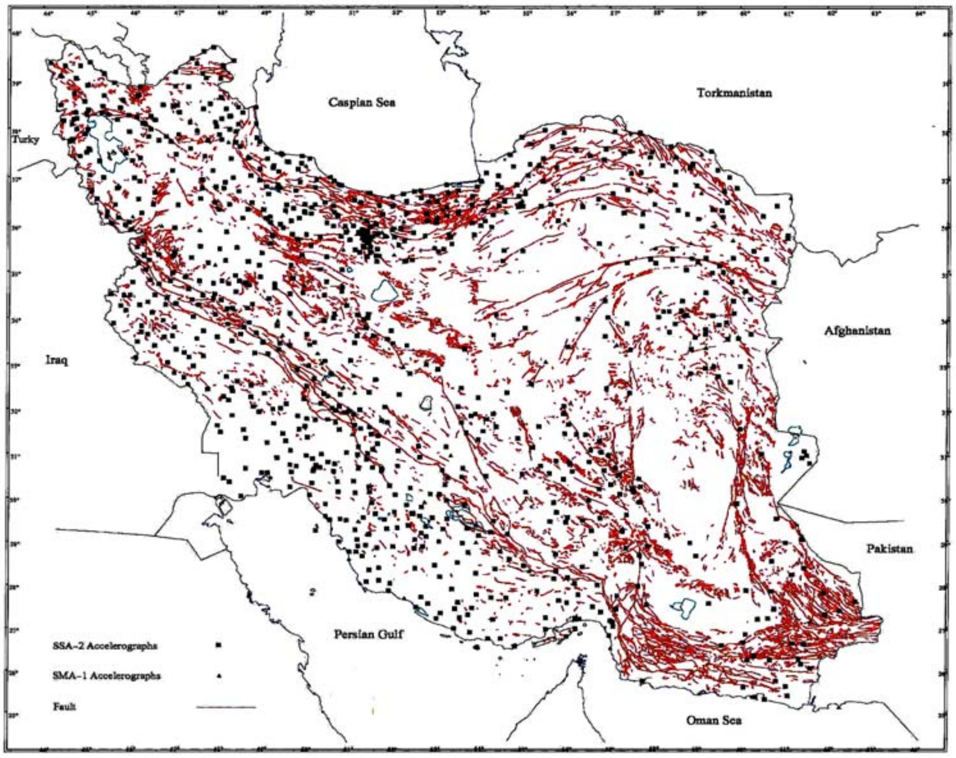


Figure 3. Map of Iran Strong Motion Network

3. ACCELEROGRAPHS IN THE IRAN STRONG GROUND MOTION NETWORK (ISMN)

3.1 SMA-1

The SMA-1 records the triaxial acceleration and time data on 70 mm photographic films. Developed in 1969, the SMA-1 is the most widely used accelerograph network in the world today with nearly 8000 units installed in more than 20 countries, Figure 4a

Its principal advantages over the competing low-cost accelerographs are:

- easy maintenance because of electro-mechanical-optical technology.
- proven reliability.
- readily available playback system (a dark room)
- large capacity media.

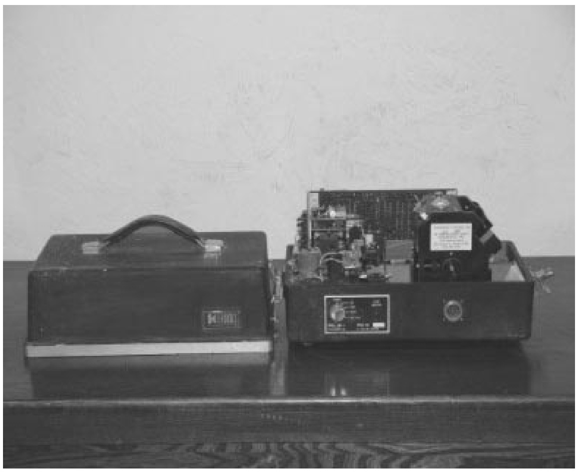
The SMA-1 remains in a standby condition until an earthquake casuses the starter to actuate the light source and film drive motor [2].

3.2 SSA-2

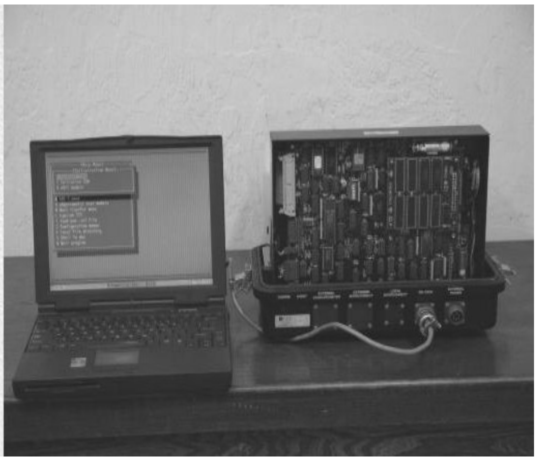
The solid state accelerograph SSA-2, is a fully self-contained, 3 channel digital recording strong motion accelerograph.The units contain electronics,sensors,battery power and data storage all in a watertight enclosure, Figure 4b.

Acceleration data from the three sensors are digitized by A/D convertor on the analog to digital convertor/power supply board and are continuously monitored signals that satisfy event detection criteria.When these criteria are satisfied,the event is stored in CMOS battery backed-up RAM until later retrieval by the users.

The SSA-2 can be operated as a single unit, or interconnected in sets of several units for large multi-channel applications.The SSA-2 is most useful for regional strong ground motion seismological networks [3].



(a)



(b)

Figure 4. Analogue and digital accelerograph

4. DATA RETRIEVAL

There are several ways to playback or retrieve data using a PC or a compatible computer and the SSA-2 in monitor mode. Events can be transferred to the PC in any order, either in uncompressed or compressed form. The data retrieval computer requires a communications program.

Since the beginning of operation of the network, more than 4221 accelerograms, Figure 5, from hundreds of earthquakes with various magnitudes have been recorded, Figure 4. ISMN recorded 289 accelerograms with PGA >0.1g, Figure 6. All the information produced is processed and stored in a database. Among these recorded accelerograms, the maximum peak acceleration of 1g is related to Zanjiran Earthquake 1994 with M=6.1 of Zanjiran station.

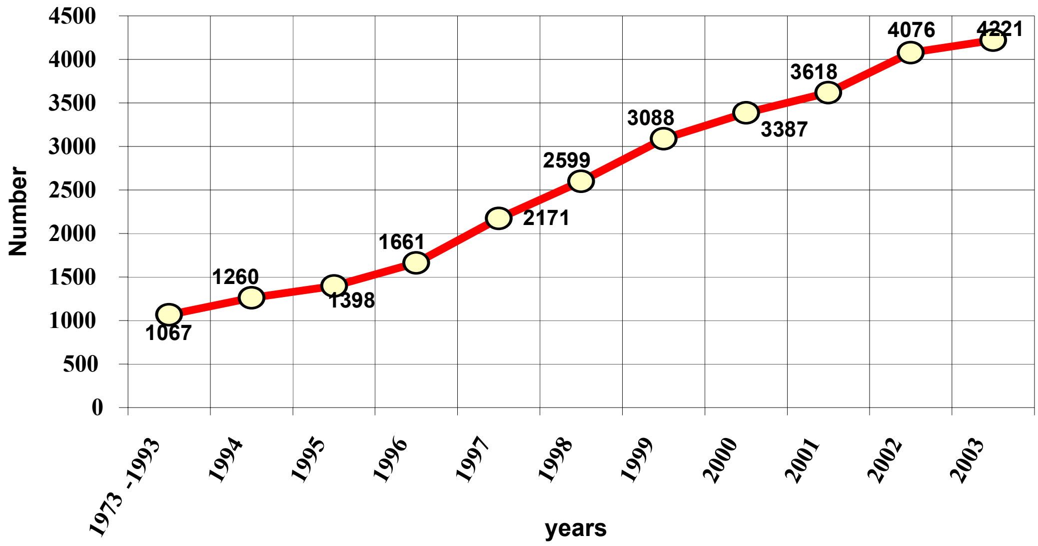


Figure 5. Number of accelerograms recorded by ISMN

5. STRONG MOTION DATA PROCESSING

The raw data obtained from a strong motion instrument may include errors from several possible sources, each of which must be carefully evaluated and corrected to produce an accurate record to the actual ground motion. Raw data often includes background noise from different sources.

Microseismic from ocean waves can be detected by sensitive instruments. Other noises may be caused by traffic, construction operations, wind (transmitted to the ground by vibration of trees, building, etc.) and even atmospheric pressure change. Obviously, this range of sources can produce non-seismic noise at both low and high frequencies. To isloate the motion actually produced by the earthquake, background noise must be removed or at least suppressed. Other corrections such as instrument correction and baseline correction are the most correction process on the accelerograms [4].

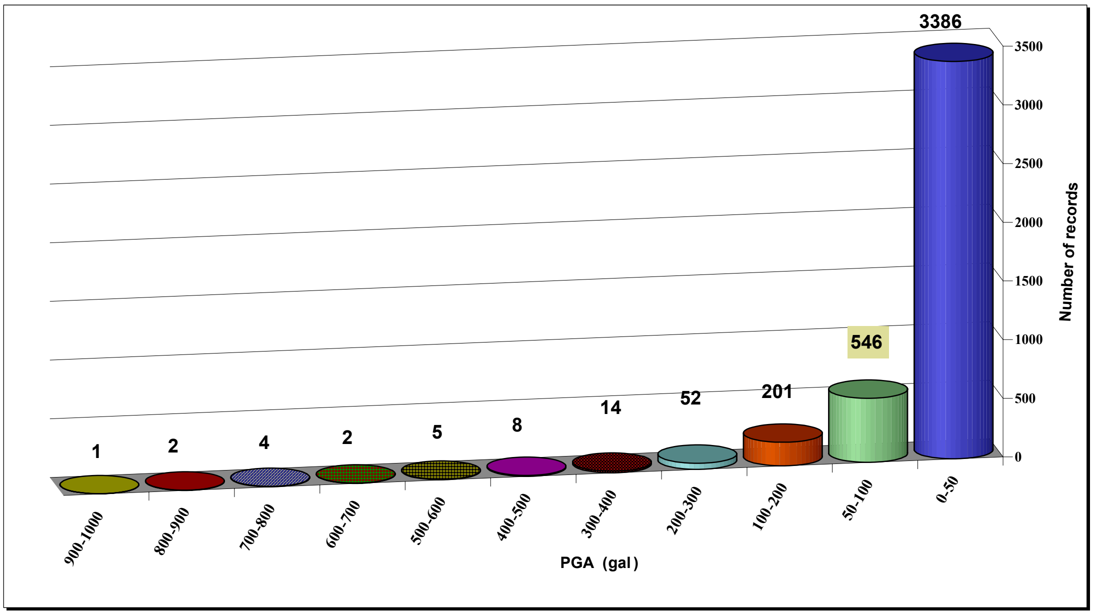


Figure 6. PGA recorded in Iran

5.1 Instrument correction

All accelerographs have their own dynamic response characteristics, or instrument response, that can influence the motions they measure. Consequently, instrument response must be corrected in strong motion processing .

Instrument response corrections are usually performed by modeling the instrument itself as a Single Degree of Freedom (SDOF) system and using the SDOF model to decouple the response of the instrument from the actual ground motion. The output from accelerographs, which do not have instrument correction built in, is the relative displacement response, y(t). The equation of this accelerographs is: [5]

$$\ddot{y}(t) + 2\beta\omega\dot{y}(t) + \omega^2 y(t) = \ddot{u}$$

Where β is the ratio of critical damping , ω is the transducer natural angular frequency, $\ddot{u}$ is the ground acceleration. The transducer natural angular frequency, ω is usually high enough so that y(t) is proportional to the ground acceleration, $\ddot{u}$ is the ground acceleration. A number of different methods have been used to achieve such a correction, for example a finite difference method and digital differentiation.

5.2 Baseline correction

Another correction is required to reduce the effect of errors in ground motion measurments, such as those associated with the triggering of analogue accelerographs. If a seismograph does not start until some triggering level of motion is reached, the entire accelerogram is in error by the level of motion at the time of triggering. Integration of an uncorrected acceleration time history, for example, will produce a linear error in velocity and a quadratic error in displacement.

An acceleration error as small as 0.001g at the beginning of the 30-second long accelerogram would erronously predict a permanent displacement of 441 cm at the end of the motion. Correction of such errors ,termed baseline correction, was originally accomplished by subtracting a best-fit parabola from the accelerogram before integrating velocity and displacement but is now performed using high-pass filters and modern data processing techniques, Ref. [4].

5.3 Filtering

In order to remove the short and long period errors from accelerograms, the time-histories are often filtered. Many different types of filters have been used for strong motion records, for example Ormsby filters, frequency-domain filters, elliptical filters and Butterworth filters. This filtering will remove the errors in the stop bands, however it will also remove any ground motions within these period ranges and hence outside the pass band the corrected accelerograms can no longer be expected to adequately represent the true ground motion, Ref. [6].

5.4 Computing of corrected acceleration,velocity and displacement

The next step of the strong motion data correction procedure is the calculation of the corrected acceleration,velocity and displacement data using SWS program. The velocity data are obtained by integration of the accelerations and removing the long period component from the velocity function.The displacement data are obtained in the same manner, from the velocities.

5.6 Response spectra and Fourier amplitude spectrum

Response spectra and Fourier amplitude spectrum are very important characteristics of ground motions during strong earthquake. They are directly applied in aseismic design of structures, and are also used for investigation of a large number of problems from the field of engineering seismology such as frequency content of ground motion, characteristics of source mechanism etc.

In the strong motion network of Iran, using the SWS and SGMP programs for calculation of response spectra of absolute acceleration, relative displacement, relative velocity and pseudo-relative velocity, as well as the Fourier amplitude apectrum for the acceleration time history is carried out.

6. EARTHQUAKE STUDIES

The history of Iranian earthquakes is provided by Ambraseys and Melville [7]. It is now agreed by several investigators that the seismicity of Iran is related to the local surface geology and tectonics. Many destructive earthquakes in Iran confirm this phenomenon. Therefore, the Iranian plateau is one of the seismically active areas of the world and frequently suffers destructive and catastrophic earthquakes that cause heavy loss of human life and wide-spread damages. Table 1 indicates the number of earthquakes in the past 25 years. In this period, Iran has experienced 6 strong earthquakes with magnitude over 7M. In the same period, 22 earthquakes between 6M to 7M, and 265 between 5M to 6M occured. The seismicity of Iran in the past 25 years is presented in Figure 8. It shows the high heterogeneous activity in this plateau. Most of these earthquakes occurred in Zagros, However, earthquakes longer than M>7 have not been experienced in Zagros region. In other parts of Iran (Alborz and Kopetdagh) the earthquakes with magnitude over M>7 have occurred, Figure 7, the epicenters of earthquakes in the past 25 years are shown in Figure 8.

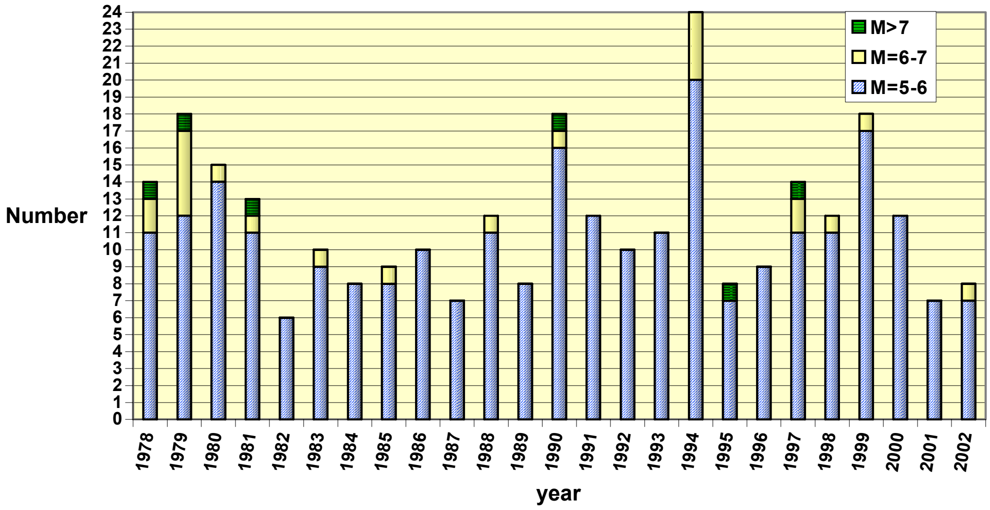


Figure 7. Number of earthquakes in the past 25 years with magnitude longer than 5

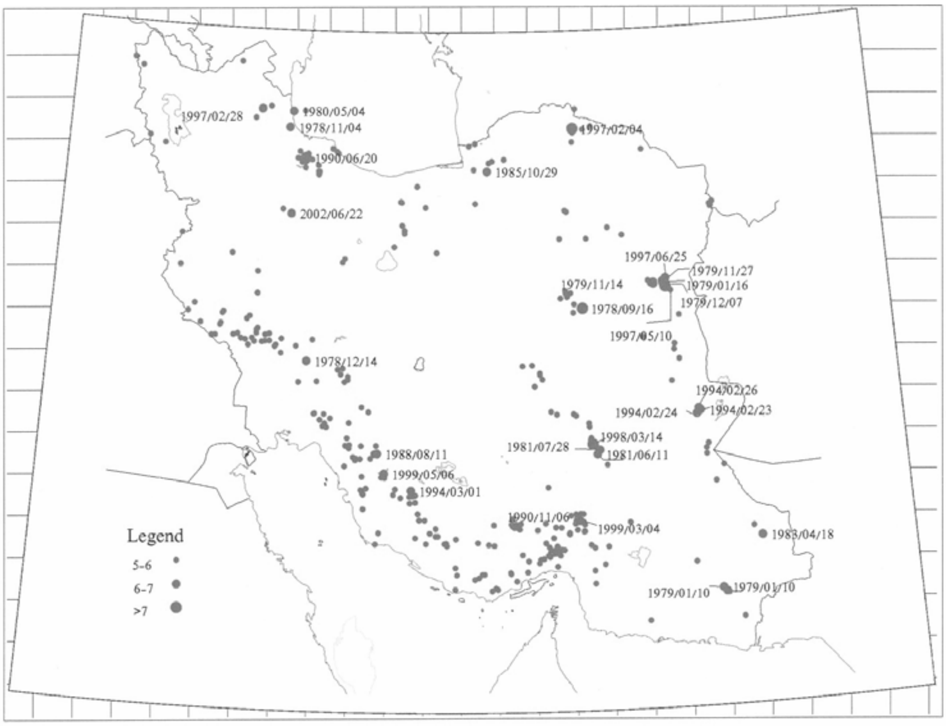


Figure 8. Epicenter of earthquakes in the past 25 years

Table 1: The most important earthquakes in the past 25 years

Data	Time	M	N	E	Location	Dead	Injured	Record	PGA (gal)
1978 09 16	15:35:56	7.8	33.39	57.43	Tabas	18220	Many	9	915
1978 11 04	15:22:19	6.1	37.67	48.9	Ardebil			1	281
1978 12 14	07:05:20	6.2	32.14	49.65	Khouzestan			NO	No
1979 01 10	01:26:09	6	26.61	60.92	Sarbaz			1	41
1979 01 10	15:05:48	6.1	26.52	61.01	Sarbaz			1	69
1979 01 16	09:50:10	6.9	33.9	59.47	Korizan			12	78
1979 11 14	02:21:22	6.8	33.92	59.74	Korizan	420	Many	10	86
1979 11 27	17:10:32	7.5	33.96	59.73	Koli-Bonyabad	130	Many	14	137
1979 12 07	09:24:00	6.3	34.03	59.82	Koli-Bonyabad			2	61
1980 05 04	18:35:20	6.3	38.05	48.99	Gilvan			1	39
1981 06 11	07:24:25	6.9	29.91	57.72	Golbaf	1100	4000	2	39
1981 07 28	17:22:22	7.1	30.19	57.56	Sirch	1300	>1000	7	304
1983 04 18	10:58:51	6.5	27.79	62.05	Khash			1	30
1985 10 29	13:13:44	6	36.69	54.75	Gonabad			5	56
1988 08 11	16:04:45	6.1	29.97	51.68	Nurabad			2	105
1990 06 20	21:00:09	7.7	36.96	49.41	Rudbar	40000	Many	23	635
1990 11 06	18:45:52	6.7	28.25	55.46	Hormozgan			No	No
1991 11 04	01:50:31	5.4	30.67	50.22	Behbahan	0	50	1	23
1992 09 08	00:38:15	5.2	29.13	52.19	Dadenjan	1	11	2	52

Table 1: Continued...

Data	Time	M	N	E	Location	Dead	Injured	Record	PGA (gal)
1994 02 24	00:11:12	6.3	30.77	60.49	Sefidabeh	6	>20	No	No
1994 02 26	02:31:11	6.1	30.9	60.55	Sefidabeh			No	No
1994 03 01	03:49:00	6.1	29.1	52.62	Muk	2	50	1	119
1994 06 20	09:09:02	6.1	28.97	52.61	Zanjiran	3	100	13	1006
1997 02 04	10:37:47	7.1	37.66	57.29	Garmkhan	100	>1000	15	110
1997 02 28	12:57:18	6.1	38.07	48.05	Sarein	965	2600	21	615
1997 05 10	07:57:29	7.3	33.82	29.7	Ardakul	1560	4000	28	195
1998 03 14	19:40:27	6.9	30.15	57.6	Golbaf	5	50	5	41
1999 03 04	23:00:53	6.3	29.5	51.88	Galehganj			12	54
1999 05 06	23:01:00	5.9	29.5	51.88	Karehbas	26	100	17	423
1999 10 31	15:09:39	5.2	29.41	51.81	Polabgineh	0	28	6	100
1999 11 08	21:37:24	5.5	35.73	61.21	Salehabad	0	>50	3	333
1999 11 26	04:27:24	5.2	36.92	54.9	Aliabad	0	0		
2002 04 24	19:48:05	5.2	34.64	47.4	Dinevar	0	10	7	200
2002 06 22	02:58:21	6.5	35.63	44.05	Changureh	230	1466	65	498

7. SEISMICITY OF TEHRAN

The Greater Tehran Area is located at the foot slope area of the Alborz Mountains, which form part of the Alpine-Himalayan Orogenic Zone. The urban area of Tehran has been developed on alluvial. layers, accumulated on hard rock through complex geological formations. Seismologists believe that a strong earthquake will strike Tehran in a near future, because the city has not experienced a disastrous earthquake since 1830 (Table 2). Tehran Strong Motion Network started its activities in 1973. At present 45 accelerographs are installed in Great Tehran Area as shown in Figure 9. Tehran network recorded Rudbar-Manjil earthquake of June 20,1990 and Changureh-Avaj earthquake of June 22, 2002, and 2 earthquakes of January 1, 2002 (M=3.5), and March 9, 2003 (M=4.1) that occurred in Tehran city. The recorded accelerograms are listed in Table 3.

Table 2: The earthquakes occured in Greated Tehran Area

Year	**Month**	**Day**	**Mw**	**Latitude (degrees)**	**Longitude (degrees)**	**Epicentral Distance (km)**	**Assumed PGA (gal)**
743			7.1	35.30	52.50	81	49
855			7.0	35.60	51.50	12	412
855	12	22	7.9	35.20	54.30	263	17
854	1		5.4	35.70	51.00	41	34
958	2	23	7.7	36.00	51.10	46	161
1119	12	10	6.4	35.70	49.90	140	13
1177	5		7.1	35.70	50.70	68	63
1301			6.6	36.10	53.20	164	12
1485	8	15	7.1	36.70	50.50	140	23
1608	4	20	7.6	36.40	50.50	116	44
1665			6.4	35.70	52.10	59	44
1687			6.4	36.30	52.60	123	15
1809			6.4	36.30	52.50	116	17
1825			6.6	36.10	52.60	113	21

Year	Month	Day	Mw	Latitude (degrees)	Longitude (degrees)	Epicentral Distance (km)	Assumed PGA (gal)
1830	3	27	7.0	35.80	51.70	25	208

Table 2: Continued...

Year	Month	Day	Mw	Latitude (degrees)	Longitude (degrees)	Epicentral Distance (km)	Assumed PGA (gal)
1869	8	1	6.3	34.90	52.50	130	13
1930	10	2	5.4	35.78	52.02	52	24
1957	7	2	6.7	36.20	52.60	118	21
1962	9	1	7.1	35.54	49.39	187	15
1983	3	26	5.3	36.12	52.21	83	10
1990	6	20	7.4	36.96	49.39	232	14
1994	11	21	4.5	35.90	51.88	45	14

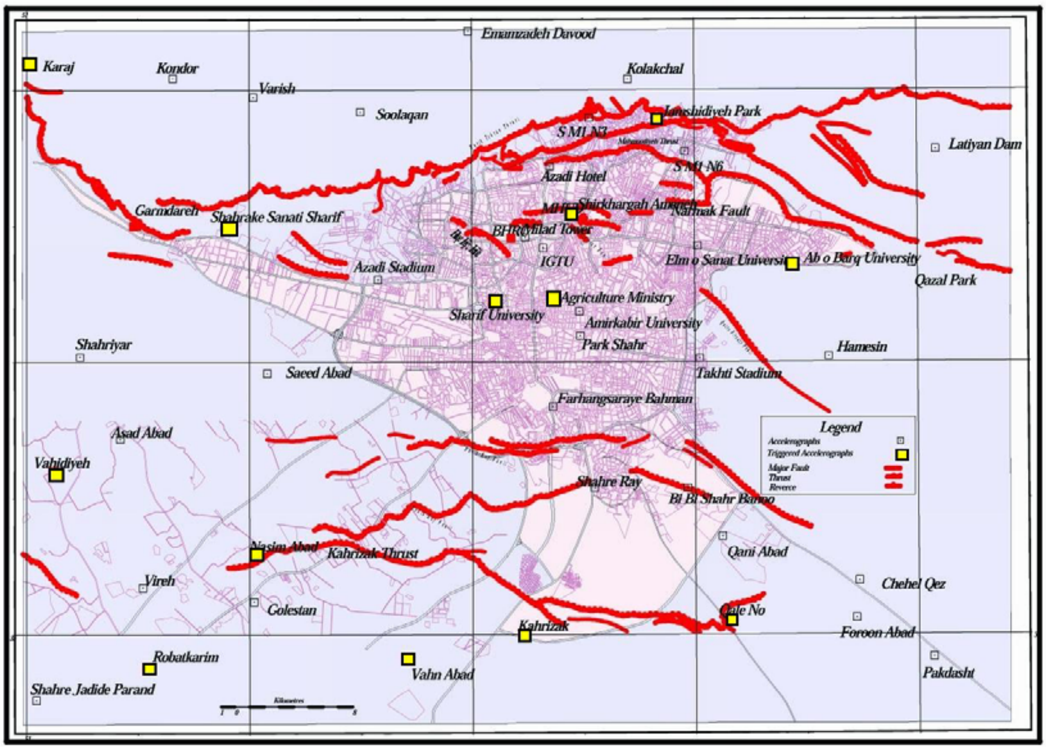


Figure 9. The map of Greater Tehran Area strong motion network

Table 3: The list of accelerograms recorded in Greater Tehran area

Station	Geo. Coord.		Origin Time		Epicenter		E.D.	Magnitude		U.P.G.A (cm/s/s)		
	E	N	D-M-Y	h:m:s	E	N	(km)	mb	Ms	L	V	T
Geological survey	51.32	35.69	21/01/1990	13:39:41	51.38	35.92	26			28.01	8.86	30.58
Kahrizak*	51.35	35.52	20/06/1990	20:59:00						40.34	24.59	39.52
Sharif university	51.48	35.70	20/06/1990	21:00:11	49.41	36.96	232	6.4	7.7	10.95	29.24	12.52
BHRC	51.37	35.73	20/06/1990	21:00:11	49.41	36.96	223	6.4	7.7	31.13	15.85	35.16
Geological survey	51.32	35.69	20/06/1990	21:00:11	49.41	36.96	222	6.4	7.7	9.76	12.49	13.34
Kahrizak*	51.35	35.52	20/06/1990	21:00:11	49.41	36.96	236	6.4	7.7	47.68	29.46	34.59
Chizar	51.42	35.77	20/06/1990	21:00:11	49.41	36.96	223	6.4	7.7	15.82	21.45	12.71
Robat Karim*	51.08	35.47	20/06/1990	21:00:11	49.41	36.96	223	6.4	7.7	13.60	22.80	20.60
Karaj*	51.00	35.85	20/06/1990	21:00:11	49.41	36.96	188	6.4	7.7	40.67	14.84	14.57
Eshtehard*	50.37	35.71	20/06/1990	21:00:11	49.41	36.96	163	6.4	7.7	70.59	45.96	76.92
Agricultur Ministry	51.39	35.71	20/06/1990	21:00:11	49.41	36.96	225	6.4	7.7	53.24	28.34	60.41
Agricultur Ministry	51.39	35.71	20/06/1990	21:00:11	49.41	36.96	225	6.4	7.7	53.90	30.79	51.28
Nasim Abad	51.17	35.55	12/01/2002	05:18:18						11.27	6.86	9.38
Vahidiyeh	51.02	35.60	12/01/2002	05:19:21						7.67	12.01	14.74
Agricultur Ministry	51.39	35.71	22/06/2002	02:58:20	48.93	35.67	222	6.2	6.4	13.67	3.77	9.78
Urban Ministry	51.40	35.72	22/06/2002	02:58:20	48.93	35.67	223	6.2	6.4	9.84	5.02	14.32
Urban Ministry	51.40	35.75	22/06/2002	02:58:20	48.93	35.67	223	6.2	6.4	22.86	5.02	17.34
Urban Ministry	51.40	35.72	22/06/2002	02:58:20	48.93	35.67	223	6.2	6.4	4.35	2.11	5.23
Vahidiyeh	51.02	35.60	22/06/2002	02:58:20	48.93	35.67	189	6.2	6.4	14.32	5.76	15.40
Vahn Abad	51.17	35.45	22/06/2002	02:58:20	48.93	35.67	204	6.2	6.4	12.82	6.12	10.84
Kahrizak	51.37	35.50	22/06/2002	02:58:20	48.93	35.67	221	6.2	6.4	13.09	4.22	10.88
Garmdarreh	51.08	35.75	22/06/2002	02:58:20	48.93	35.67	194	6.2	6.4	11.70	5.65	9.46
Shahrak Sharif	51.15	35.75	22/06/2002	02:58:20	48.93	35.67	201	6.2	6.4	16.40	6.74	13.25
Ghaleno	51.52	35.51	22/06/2002	02:58:20	48.93	35.67	235	6.2	6.4	7.38	4.22	11.24
Jamshidiyeh park	51.47	35.82	09/03/2003	22:50:23	51.46	35.74				4.63	4.84	18.08
Agricultur Ministry	51.39	35.71	09/03/2003	22:50:23	51.46	35.74				3.93	11.35	2.40
Abbaspur university	51.57	35.73	09/03/2003	22:50:23	51.46	35.74				55.91	12.64	29.87

8. CONCLUSIONS

The Iran Strong Motion Network (ISMN) is the greatest regional accelerographic network in the Middle East, but also one of the greatest in the world. In recent years, Iran Strong Motion Network has been consistently upgraded, and increased emphasis has been put on making it more reliable and automatic. The most important projects of ISMN are studying the site effect using geophysical and geotechnical investigations as well as earthquake and aftershock studies. A project that is currently under way is the implementation of a strong motion database that allows the user to consult the strong motion cataloug through the internet.

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