Report of the November 12, 2017 Sarpol-e Zahab, Kermanshah Province Earthquake

Road, Housing & Urban Development Research Center, BHRC

Iran Strong Motion Network

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1 INTRODUCTION

On Sunday November 12, 2017, at 18:18:16 UTC, (21:48:16 local time), a strong earthquake with Mw7.3 occurred in the border region between Iran and Iraq in vicinity of the Sarpol-e Zahab town. This earthquake is the largest seismic event after the M7.4, 1909 AD (1287 Shamsi) Sialkhor earthquake near the Borujerd city in the Zagros region. The historical earthquake of 958 AD, with a magnitude of 6.8, caused the destruction of the Sarpol-e Zahab town and many deaths. The main earthquake of November 12, 2017 was preceded by a number of foreshocks, where the largest one was a magnitude 4.5 event 43 minutes before the mainshock that warned the local residence to leave their home and possibly reduced the number of human casualties. More than 900 aftershocks have been reported. Iranian Seismological Center (IRSC) reported the epicenter coordinates of the earthquake at 34.77 N and 45.76 E with a focal depth of 18.1 km. This earthquake has been recorded by 104 SSA-2 and CMG5TD strong motion stations of Iran Strong Motion Network (ISMN) in the western and central provinces. The maximum recorded acceleration (raw data) of this event was recorded at Sarpol-e Zahab station with acceleration of about 684 cm/s^2. Unfortunately, this catastrophic event caused 572 causalities, thousands of injured and vast amounts of damage to the buildings, houses and infrastructures in the epicentral area. The focus of the earthquake was located about 10 km south of Ezgeleh and about 35 km north of Sarpol-e Zahab and Ghasr-e Shirin towns in the Zagros seismotectonic zone. The mainshock of the event was so strong that it was felt in the entire western and central provinces of the country and in some areas such as the cities in the Lorestan, Ilam, Kurdistan and East Azarbaijan provinces, people were terrified and leaved their homes. The mainshock was fairly felt by residents on the upper floors of buildings in Tehran. Reports indicated that neighboring countries and surrounding areas have also felt this earthquake. Earthquake information reported by IRSC, the European-Mediterranean Seismological Centre (EMSC), the Geological Survey of America (USGS) and ISMN are presented in Table 1. The earthquake epicenter is located near the high Zagros fault and the main thrust of Zagros.

Table 1. Earthquake information reported by various organizations.

Agency	Epicenter Location		Magnitude			Depth (km)
	N	E	Mn	Mb	Mw	
IRSC	34.77	45.76	7.30			18.00
USGS	34.905	45.96			7.30	19.00
EMSC	34.79	45.85			7.30	24.00
ISMN	34.81	45.91			7.30	18.00

According to the focal mechanisms reported by various agencies (Figure 1), type of the faulting is determined as an oblique-thrust faulting (mostly compressional with a small strike slip component).

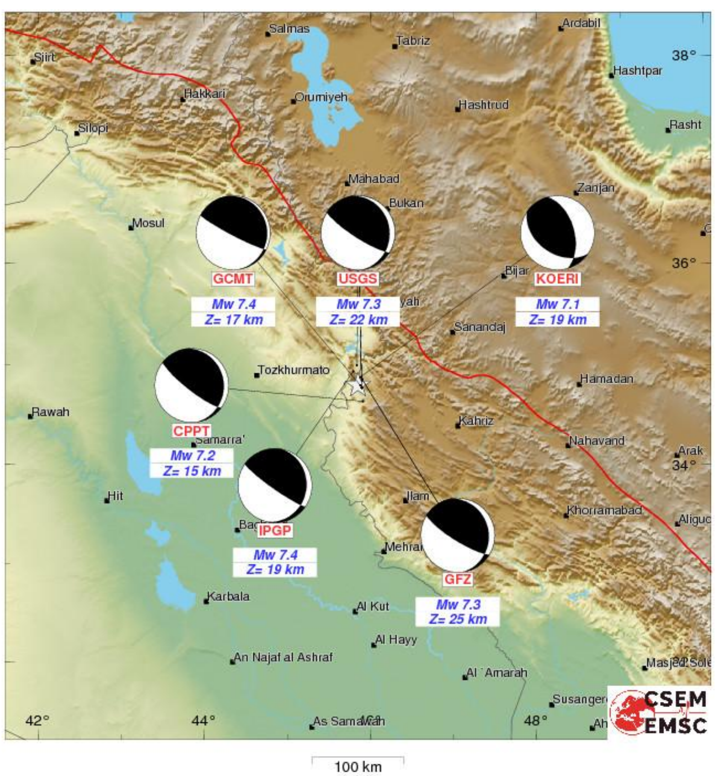

Figure 1. Focal mechanism provided by various agenesis (EMSC).

2 The Recorded Strong Motion Data of the Sarpol-e Zahab Earthquake

This earthquake has been recorded by 104 strong motion stations (SSA-2 and Guralp CMG5TD instruments) across the country. Figure 2 shows the location of the strong motion stations that recorded the mainshock and Table 2 provides the detail of the recorded accelerograms acquired from these stations. The CMG5TD accelerometers recorded this event with sampling frequency of 200 samples per second continuously, which resulted in recording of the mainshock at very long distances (such as Bojnourd University station, at distance of about 1063 km). One of the most interesting points in this event is the fact that the earthquake was felt in very large distances; therefore the majority of stations that were equipped with CMG-5TD accelerometers was triggered by this event and recorded the earthquake acceleration. Among them, we can refer to the recordings at Bojnourd station in North Khorasan and recordings registered at Damavand, Fasham, Mosha, Qom and most stations in Tehran city with a distance of more than 500 km.

Sarpol-e Zahab station was the nearest station to the epicenter of the earthquake at a distance of about 39 km. This station has been installed as a free field at the site of the Sarpol-e Zahab Governor's building (Figure 3). The peak ground acceleration (PGA) on horizontal and vertical components are about 684, 554 and 385 cm/s^2 respectively (uncorrected data). The recorded acceleration time series in Sarpol-e Zahab station were processed with a band-pass filter. The results of the filtering process indicates the maximum corrected acceleration of 681 cm/s^2 on the longitudinal component, 385 cm/s^2 on the vertical component and 554 cm/s^2 on the transverse component. The dominant period on the longitudinal, vertical and transverse components are

0.22, 0.08, and 0.3 s respectively. The significant duration of this record is about 11 second. This means the maximum energy of this earthquake has been released in 11-second in the epicentral area.

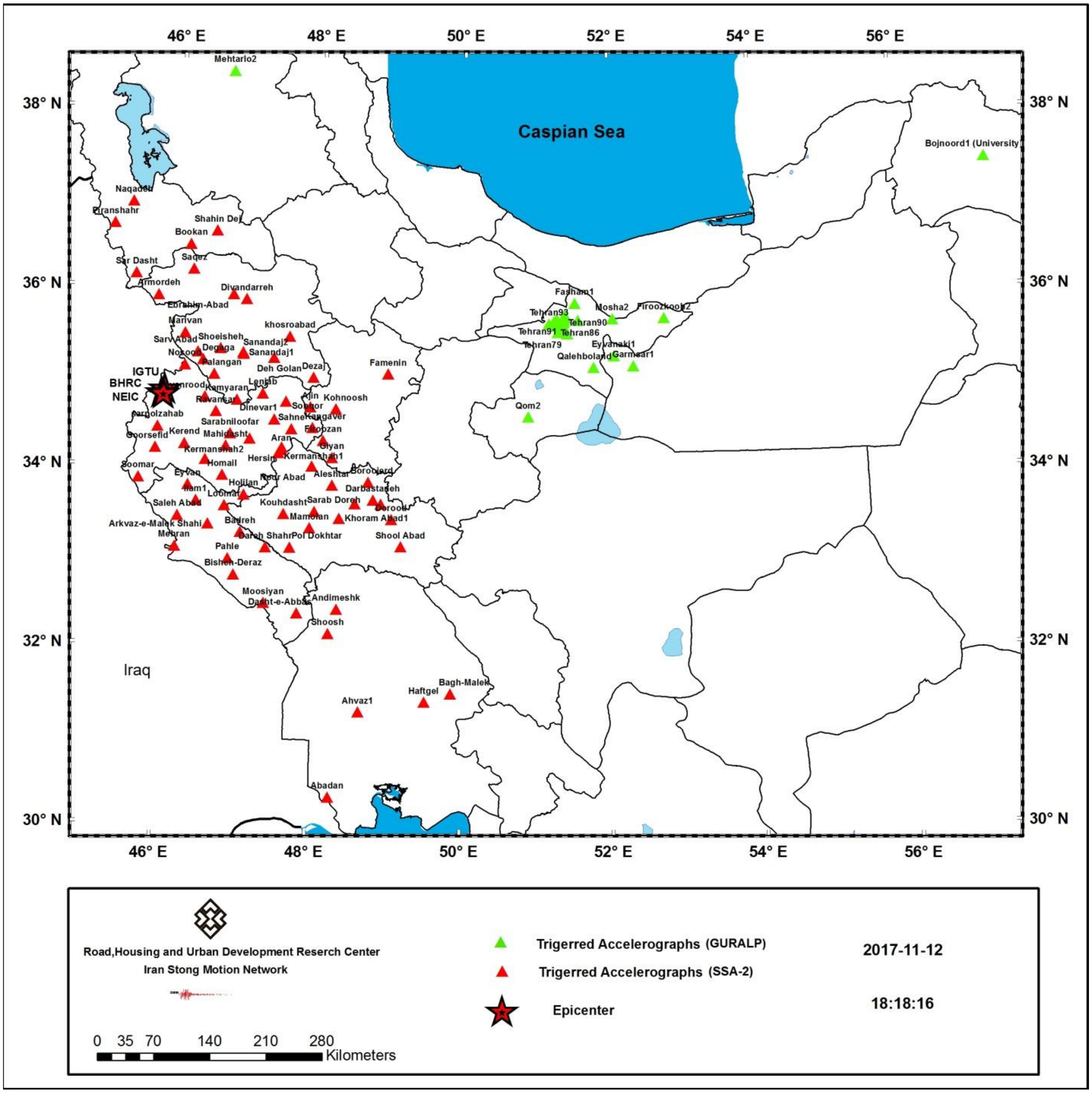

Figure 2. Map of the recording stations of the Sarpol-e Zahab earthquake along with the epicenters reported by different agencies.

Figures 4 and 5 show the recorded acceleration time histories and the response spectra of the Sarapol-e Zahab station. The time difference between the first P- and S-wave arrivals recorded at this station is about 5.13 s, which indicates that the distance between the hypocenter and this station is about 35 to 41 km. Figures 6 and 7 show the recorded velocity and displacement time histories of the Sarapol-e Zahab station. The velocity components clearly show the existence of the long period signal, especially on the transverse component of the velocity time histories (see Figure 6). It is noteworthy that, there is two clear pack of energy in the recorded time histories of the Sarpol-e-Zahab, Kerend and some other stations (such as Noosud, Polangan and Marivan and ...) that possibly indicates two sequential failures or two simultaneous seismic events, which, of course, requires further investigations. Note that, all recordings were filtered using a band-pass filter and their acceleration, velocity and displacement time histories along with their response spectra were extracted. In the appendix of this report, the acceleration components and the response spectra of a number of stations are presented (Figures 9 to 24).

Figure 3. Sarapol-e Zahab station (SSA-2 permanent instrument along with the temporary CMG5TD instrument).

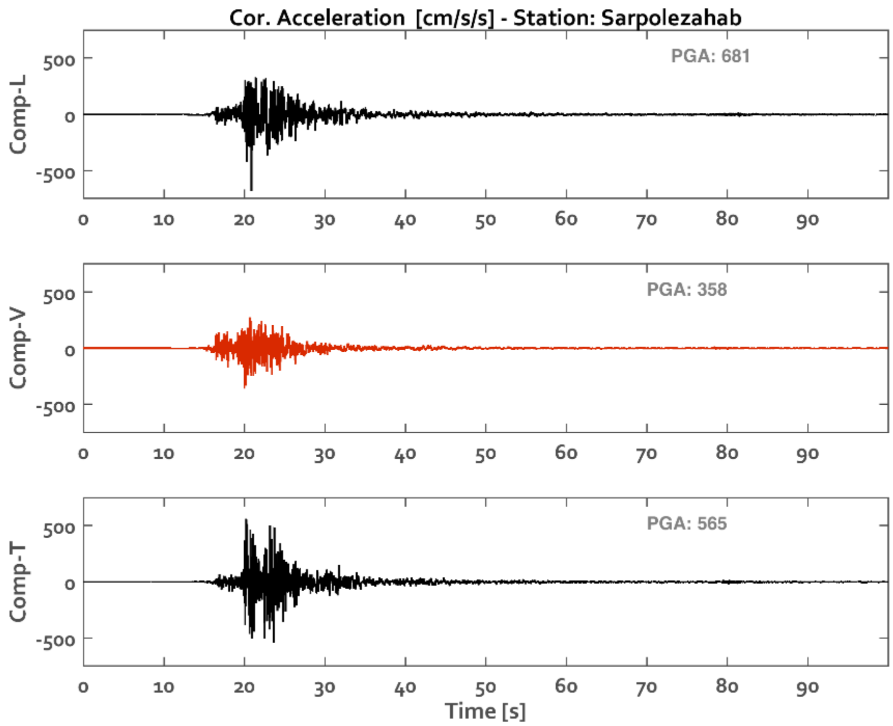

Figure 4. Recorded acceleration time history at Sarapol-e Zahab station at about 40 km epicentral distance.

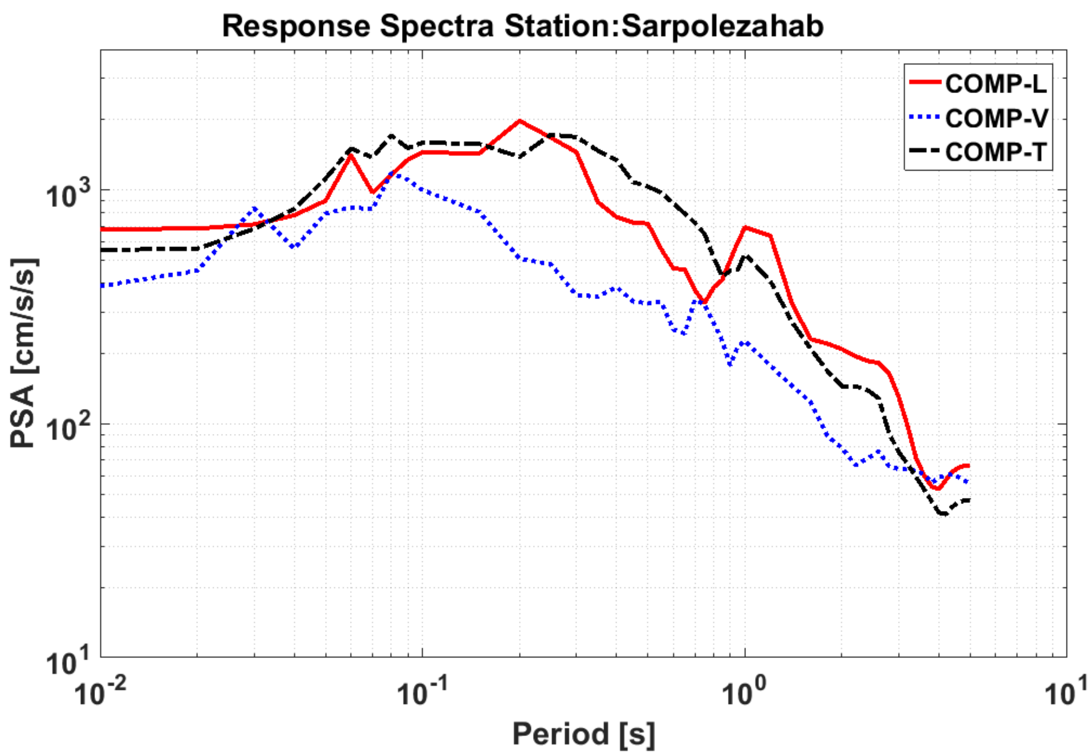

Figure 5. Acceleration response spectra at Sarapol-e Zahab station at about 40 km epicentral distance.

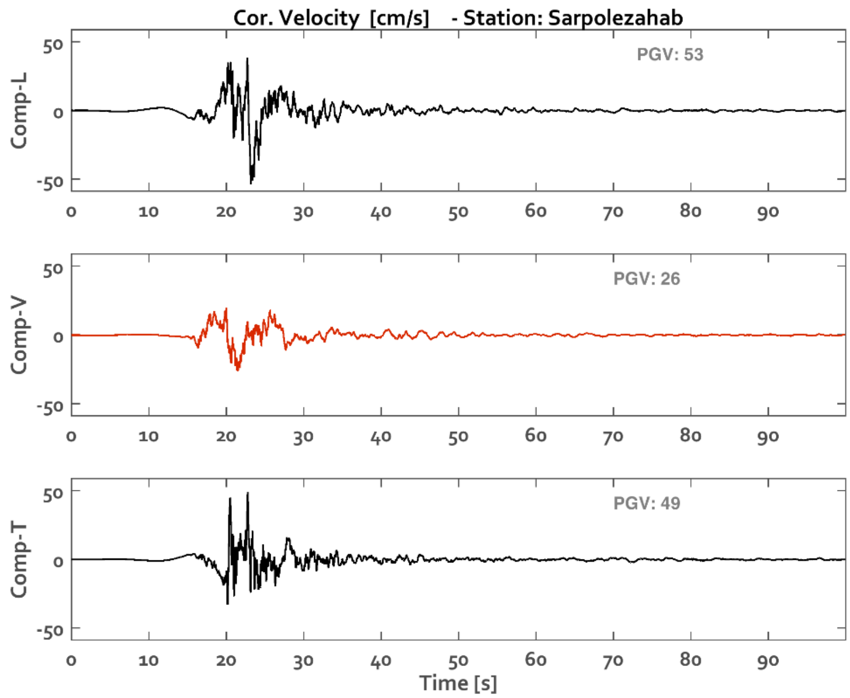

Figure 6. Recorded velocity time history at Sarpol-e Zahab station at about 40 km epicentral distance.

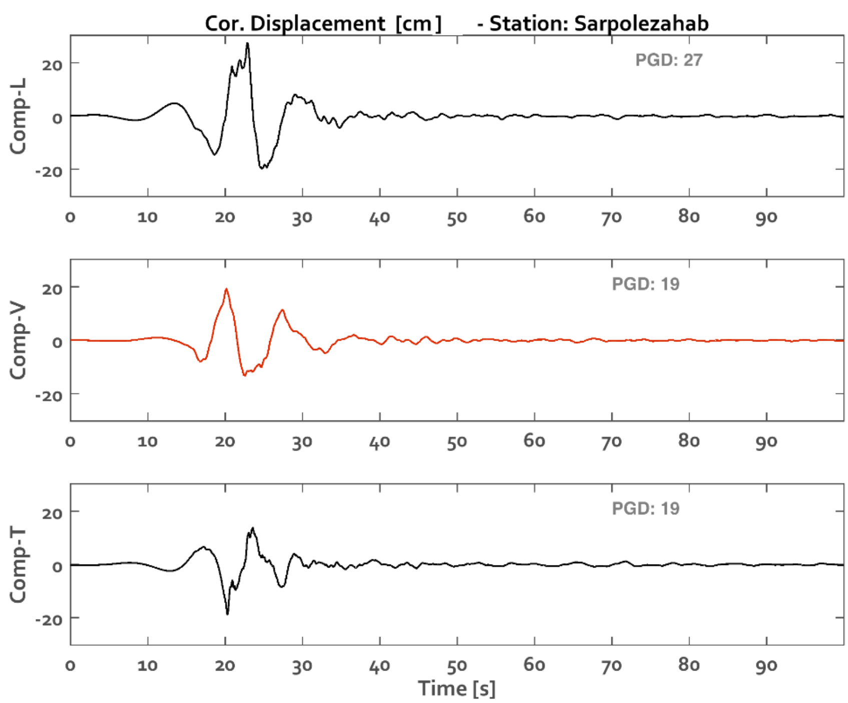

Figure 7. Recorded displacement time history at Sarpol-e Zahab station at about 40 km epicentral distance.

3 Epicenter Determination

As the number of recorded accelerograms has well registered the first P- and S-wave arrival, we were able to determine the epicenter location and the moment magnitude of this event (Figure 8). Based on the recorded accelerograms the epicenter of this earthquake is determined at 34.81 N and 45.91 E.

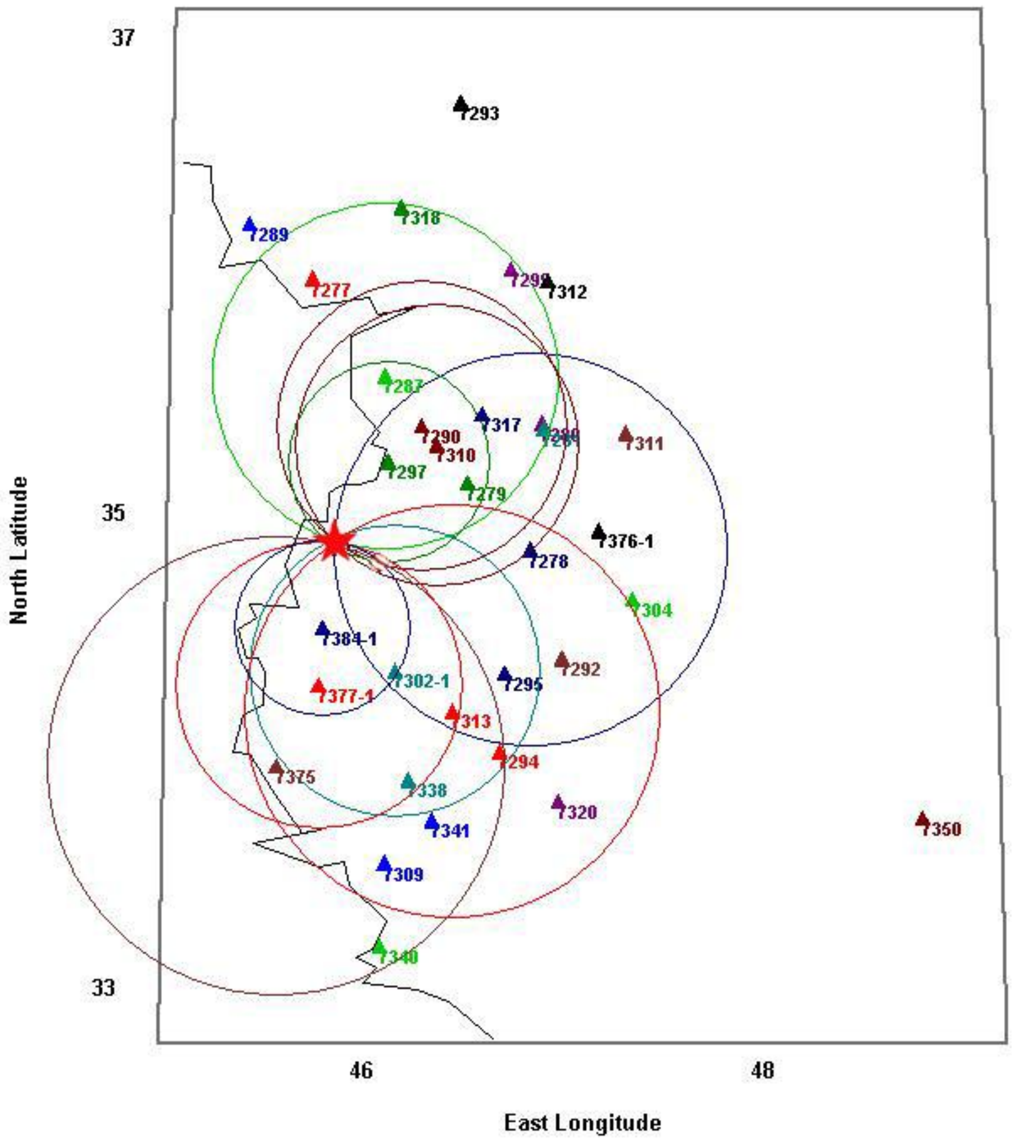

Figure 8. Epicenter location determination using the recorded accelerograms.

Table 2. Recorded accelerograms of the mainshock.

Number	Station Name	Record	Station coordinate		Vs30(m/s)	UPGA(cm/s/s)			UPGA(cm/s/s)
			N	E		L	V	T	
1	Armordeh	7277	35.93059	45.79798	484	22.07	17.7	18.64	22.07
2	Kamyaran	7278	34.7914	46.9288		32.65	15.96	35.93	35.93
3	Palangan	7279	35.0677	46.60539		45.08	50.9	37.4	50.9
4	Sanandaj1	7280	35.32268	46.99044		28.61	20.29	22.55	28.61
5	Sanandaj2	7281	35.3049	46.9995		10.84	13.22	14.03	14.03
6	Ajin	7282	34.7303	47.9301		9.89	6.51	6.98	9.89
7	Famenin	7283	35.12234	48.98154		11.43	9.22	15.44	15.44
8	Firoozan	7284	34.36079	48.11542	401	36.79	11.62	31.57	36.79
9	Kohnoosh	7285	34.71781	48.27853		8.32	7.42	10.3	10.3
10	Giyan	7286	34.17213	48.24212	731	14.45	10.34	12.97	14.45
11	Marivan	7287	35.51897	46.18358		47.12	41.27	70.09	70.09
12	Piranshahr	7288	36.70762	45.14292	577	24.1	12.13	26.95	26.95
13	Sar Dasht	7289	36.15949	45.47158	509	40.25	14.36	38.16	40.25
14	Sarv Abad	7290	35.31147	46.36972		35.01	30.95	54.35	54.35
15	Naqadeh	7291	36.9615	45.38063	209	24.4	11.6	33.23	33.23
16	Kermanshah1	7292	34.33454	47.08859		55.81	20.34	36.92	55.81
17	Shahin Dej	7293	36.67438	46.56746	415	17.88	20.3	30.41	30.41
18	Homail	7294	33.94009	46.77113	261	73.75	35.22	93.49	93.49
19	Mahidasht	7295	34.26825	46.80129	304	62.97	52.73	86.67	86.67
20	Ravansar	7296	34.652	46.652	267	102.08	38.92	120.56	120.56
21	Nosood	7297	35.16101	46.20389		45.35	53.77	44.65	53.77
22	Dareh Shahr	7298	33.14467	47.38113	413	19.95	12.53	25.48	25.48
23	Ebrahim-Abad	7299	35.97234	46.83328	466	13.19	9.6	17.38	17.38
24	Khosro Abad	7300	35.51823	47.62505		16.86	8.81	12.75	16.86
25	Aran	7301	34.24398	47.55377		35.13	12.9	19.46	35.13
26	Kerend	7302/01	34.2796	46.24026	800	195.78	180.99	261.33	261.33
27	Sahne	7303	34.48012	47.68008		45.4	19.49	24.28	45.4
28	Dinevar1	7304	34.58285	47.44624	514	81.1	22.17	76.8	81.1
29	Hersin	7305	34.27088	47.55827	530	5.32	4.9	5.02	5.32
30	Kangaver	7306	34.50021	47.96986		12.43	9.81	11.88	12.43
31	Sonqor	7307	34.78579	47.59818	1477	16.24	13.09	15.05	16.24
32	Saleh Abad	7309	33.4709	46.1894	423	15.34	12.54	17.97	17.97
33	Degaga	7310	35.22693	46.44711		70.26	47.1	65.43	70.26
34	Deh Golan	7311	35.27517	47.41527		33.55	18.58	24.96	33.55
35	Divandarreh	7312	35.92052	47.01519	455	13.17	8.72	18.34	18.34
36	Eslamabadqarb	7313	34.11009	46.52995	266	95.63	54.79	123.54	123.54
37	Pahle	7314	33.00879	46.8842	844	23.29	15.28	25.39	25.39
38	Badreh	7315	33.30706	47.03872	466	33.27	22.81	64.5	64.5

39	Dezaj	7316	35.0637	47.96468	863	26.73	14.93	19.43	26.73
40	Shoeisheh	7317	35.35814	46.67753		88.39	69.52	74.84	88.39
41	Saqez	7318	36.23462	46.26379		17.11	8.55	19.05	19.05
42	Mehtarlo2	7319	38.471	46.711		3.85	1.98	3.66	3.85
43	Holilan	7320	33.72841	47.06834	413	32.24	14.73	12.35	32.24
44	Qom2	7321	34.655	50.895		8.14	3.14	6.86	8.14
45	Fasham1	7323	35.9331	51.5305		0.82	0.75	1.04	1.04
46	Chahardangeh2	7324	35.60422	51.30484		3.96	2.05	3.62	3.96
47	Mosha2	7325	35.75674	52.04981		0.86	0.75	0.84	0.86
48	Garmsar1	7326	35.225	52.331	817	1.8	1.64	2.04	2.04
49	Eyvanaki1	7327	35.34079	52.07033		1.43	1.3	1.6	1.6
50	Tehran79	7328	35.59249	51.42783		2.1	0.93	2.09	2.1
51	Tehran90	7329	35.74065	51.3637		1.34	1.09	1.36	1.36
52	Bojnoord1 (University)	7330	37.4358	57.2967		0.33	0.21	0.26	0.33
53	Boroojerd	7331	33.90435	48.73832	579	10.97	4.63	8.8	10.97
54	Dasht-e-Abbas	7332	32.41493	47.82611	342	32.36	17.47	26.92	32.36
55	Darbastaneh	7333	33.70459	48.81048	1103	15.06	9.75	15.42	15.42
56	Kouhdasht	7334	33.52368	47.61193	334	7.46	5.94	9.56	9.56
57	Khoram Abad1	7335	33.491	48.359		12.69	6.81	10.67	12.69
58	Mamolan	7336	33.37517	47.9645	986	10.69	10.25	8.97	10.69
59	Eyvan	7338	33.823	46.312	913	23.92	21.29	14.55	23.92
60	Mehran	7340	33.12376	46.16785	615	11.06	8.55	6.7	11.06
61	Ilam1	7341	33.64583	46.42801		49.78	30.28	69.82	69.82
62	Abadan	7342	30.35681	48.28999		10.93	3.88	8.42	10.93
63	Aleshtar	7343	33.86025	48.25417	621	12.44	7.97	14.54	14.54
64	Chaghalvandi	7344	33.65697	48.56156	616	23.88	8.56	28.8	28.8
65	Dorood	7345	33.48958	49.05911	771	13.85	6.3	9.13	13.85
66	Haftgel	7346	31.44193	49.529	1046	10.71	6.28	11.58	11.58
67	Noor Abad	7347	34.06972	47.96994	758	18.69	17.17	24.82	24.82
68	Sarab Doreh	7348	33.56098	48.0216	814	14.38	14.54	12.93	14.54
69	Shool Abad	7349	33.18382	49.19203	1084	14.66	5.65	10.85	14.66
70	Chalan Choolan	7350	33.65857	48.91308	428	29.13	14.87	22.57	29.13
71	Pol Dokhtar	7351	33.15152	47.70584	486	33.62	20.93	35.22	35.22
72	Bagh-Malek	7352	31.53973	49.87102	267	13.78	7.49	14.81	14.81
73	Tehran93	7353	35.70267	51.18183		1.44	0.84	1.43	1.44
74	Tehran91	7354	35.74065	51.3637		1.06	0.92	1.28	1.28
75	Tehran82	7355	35.74065	51.3637		1.34	1.09	1.36	1.36
76	Shoosh	7356	32.1937	48.24528	319	17.73	11.24	18.45	18.45
77	Tehran74	7358	35.76427	51.41016		2.73	0.98	2.88	2.88
78	Tehran76	7359	35.76364	51.39222		1.42	1.08	1.61	1.61
79	Tehran70	7360	35.73934	51.5759		1.14	1.31	1.31	1.31

80	Tehran47	7361	35.69701	51.33174		1.33	1.4	1.62	1.62
81	Tehran26	7362	35.70364	51.35109		1.67	1.19	2.24	2.24
82	Tehran73	7363	35.71982	51.38095		1.68	1.08	1.45	1.68
83	Tehran84	7364	35.75424	51.28327		1.54	1.14	1.65	1.65
84	Tehran85	7365	35.72466	51.24411		1.23	0.72	0.78	1.23
85	Tehran86	7366	35.67567	51.26155		1.45	1.4	1.52	1.52
86	Tehran69	7367	35.64722	51.39921		3.26	1.93	2.93	3.26
87	Tehran78	7368	35.73539	51.38626		1.42	1.02	1.28	1.42
88	Firoozkooh2	7369	35.75648	52.76051	883	1.4	0.83	1.47	1.47
89	Tehran71	7370	35.80054	51.39555		1.26	1.23	1.1	1.26
90	Andimeshk	7371	32.47396	48.35001		14.57	7.45	13.74	14.57
91	Bisheh-Deraz	7372	32.82531	46.97393	873	17.84	12.69	13.05	17.84
92	Soomar	7375	33.88048	45.64151	642	61.4	27.11	56.95	61.4
93	Lenjab	7376/01	34.87115	47.27785		55.83	26.06	43.57	55.83
94	Goorsefid	7377/01	34.21808	45.84572	403	309.5	233.77	277.32	309.5
95	Arkvaz-e-Malek Shahi	7378	33.39412	46.59827	325	91.95	54.78	87.12	91.95
96	Moosiyan	7381	32.51877	47.37702	472	20.37	9.59	21.26	21.26
97	Sarpolezahab	7384/01	34.45976	45.86861	619	684.42	385.24	553.62	684.42
98	Loomar	7385	33.56967	46.81593	413	139.37	41.8	73.71	139.37
99	Qalehboland	7393	35.20965	51.7868		3.93	2.58	4.74	4.74
100	Javanrood	7398	34.80999	46.48997	298	207.92	66.17	182.05	207.92
101	Kermanshah2	7410	34.36002	47.11989		124.29	33.4	68.15	124.29
102	Sarabniloofar	7411	34.40485	46.85902	323	60.35	19.49	36.25	60.35
103	Ahvaz1	7428	31.32	48.66		11	4	13	13
104	Bookan	7432	36.51	46.21		25	16	16	25

4 Moment Magnitude Estimation

In this report the moment magnitude (Mw) is determined from the seismic moment (M0), which is calculated through spectral method that is based on the Brune source model (Brune, 1970, 1971) in the frequency domain. In this method M0 is calculated based on the value of the low frequency plateau and then Mw is calculated using the following equation (Hanks and Kanamori, 1979):

$$Mw = 2/3\log10\,(M0) - 6.03 \qquad (1)$$

where the scalar moment, M0, is the seismic moment in N.m. Those strong motion data recorded by ISMN stations that are located in epicentral distance of less than 100 km were selected. The earthquake ground motion that has been recorded by these 10 closest strong motion stations provided the good quality of the recordings and all 10 three components recordings were used in the calculation of the Mw. The calculated Mw values for each station, along with other relevant records information is available in Table 3. The final estimated Mw is determined based on the average of the Mw vales at 10 closest stations (R < 100 km), which is Mw = 7.3.

Table 3. The calculated Mw for each station along with other relevant record information.

	Record Number	Station	Station Latitude	Station Longitude	Epicentral Distance (km)	Mw	M0
1	7278	Kamyaran	34.791	46.928	94.09	7.11	6.60E+19
2	7290	Sarv Abad	35.311	46.369	67.70	7.09	6.04E+19
3	7310	Degaga	35.226	46.447	65.89	7.18	8.39E+19
4	7297	Nosood	35.161	46.203	45.26	7.11	6.61E+19
5	7279	Palangan	35.067	46.605	69.16	7.09	6.03E+19
6	7384-1	Sarpolezahab	34.459	45.868	42.35	7.57	3.16E+20
7	7377-1	Goorsefid	34.218	45.845	69.23	7.48	2.38E+20
8	7302-1	Kerend	34.279	46.24	69.66	7.44	2.03E+20
9	7313	Eslamabadqarb	34.11	46.529	99.53	7.67	4.56E+20
10	7317	Shoeisheh	35.358	46.677	91.32	7.17	8.13E+19
Average						**7.30**	**1.52E+20**

5 Discussion and Conclusions

Up to the date of this report, 104 strong motion stations located in the mid-west to the center of the country have recorded the mainshock of this earthquake (Table 2). One of the significant points about this event is that the mainsock has been recorded at different stations in vast area, which indicates the uniqueness of this event and for sure requires further specialized studies. Therefore, ISMN has installed a temporary network within the macro-seismic area, and hopefully the results will be published in the near future. The important points about this earthquake are presented as following:

1- The occurrence of the November 12, 2017 Sarpol-e Zahab earthquake is the largest earthquake that rocked the Zagros area after the 1909 Silakhor Borujerd earthquake. Note that the epicenter of this earthquake is located relatively in large distance from the Silakhor earthquake. In the case of Sarpol-e Zahab region, Ambraseys mentioned an earthquake of magnitude 6.4 in 958 AD that destroyed Sarpol-e Zahab and its strong shaking was felt in large area, even in Baghdad (Ambraseys and Melville, 1973). He also mentioned another event in 1150 that destroyed the whole region, caused many dislocations in the mountains and killed many nomads. Therefore, this region has had a history of very large earthquake occurrences, but there was a seismic gap of more than 1000 years in the region.

2- Zagros region including Zagros fold belt and high Zagros with some of the most important structural faults in Iran's plateau is one of the most seismically active regions in Iran. The existence of several faults such as the Main Zagros fault, Zagros Mountain Front fault, High Zagros fault and dozens of other important and fundamental faults makes this region very seismically active. Zagros is now under the influence of a convergent pattern due to tectonic pressures with the north- northeast and south-southwest trend. This increasing tension causes the accumulation of energy in the region and consequently the occurrences of the earthquakes. Mostly these earthquakes are rather shallow events with magnitude of less than 6 that have short return period. Rarely, the depth of earthquakes in Zagros exceeds 30 kilometers.

3- The November 12, 2017 Sarpol-e Zahab earthquake had a thrust focal mechanism. Basically, earthquakes that are caused by thrust faults generate a stronger Earth shaking compared to the earthquakes occurred as the result of the normal or strike slip faults.

4- This earthquake had a PGA of about 680 cm/s^2, duration of about 11 seconds near the focus and very wide range of frequency content. The effective design acceleration parameter that a number of researchers believe has a greater impact on the failure of the structures was around 700 in the Sarpol-e Zahab accelerogram.

5- The recorded waveforms of the event in some stations (such as Nosood, Polangan and Marivan stations) shows that at least two fractures have occurred in a very short time interval in this earthquake. In other words, this event can be interpreted as a multiple event; however, further investigations are suggested.

6- Study of the response spectra at Sarpol-e-Zahab and Islamabad stations indicates the domination of the long period components, which can amplify the damage to the multi-stories structures (from two to six floors buildings).

7- This earthquake has been felt in a very wide region, which can be a sign of its relatively high depth in comparison with the usual Zagros earthquakes. However, in this case, the data must be carefully investigated.

8- Parameters affecting the destruction of this event include high acceleration, wide range of frequency content, effect of the directivity, the earthquake duration and the effect of soil conditions; further investigation is suggested for each parameter.

9- The effect of the directivity in this earthquake is obvious. The fracture began at a region on the border between Iran and Iraq and moved along the southeast towards the cities of Sarpol-e Zahab and Islamabad. The existence of long period pulses in the record of Sarpol-e Zahab station completely confirms the directivity effect. The record of stations like Bagh-Malek, 400 km away along this path, is an indication of the directivity of the fault fracture.

10- Guralp strong motion instruments have recorded this earthquake at very large distances (about 1000 km). A number of Turkey's strong motion network stations have also recorded the earthquake.

Acknowledgments

Our colleagues at ISMN, Maryam Saadati, Khosrow Bahrami, Seyed Mehdi Hosseini, Mohammadreza Ebrahim Pour, Navid Sharifat, Vahid Abed, Shahin Borji, Alireza Dastjerdi and Mahdi Karkhaneh, are appreciated for their efforts in controlling and maintaining of the ISMN and collecting the strong motion data.

References

N. N. Ambraseys, C. P. Melville (). A History of Persian Earthquakes, Cambridge University Press, Aban 19, 1384 AP

Brune, J. N. (1970). Tectonics stress and the spectra of seismic shear waves from earthquakes, J. Geophys. Res. 75, 4997–5009.

Brune, J. N. (1971). Correction, J. Geophys. Res. 76, 4997–5009.

Hanks, T. C., and H. Kanamori (1979). A moment magnitude scale, J. Geophys. Res., 84, 2,348–2,350.

Appendix

Time histories of recorded accelerograms from main shock and the response spectra

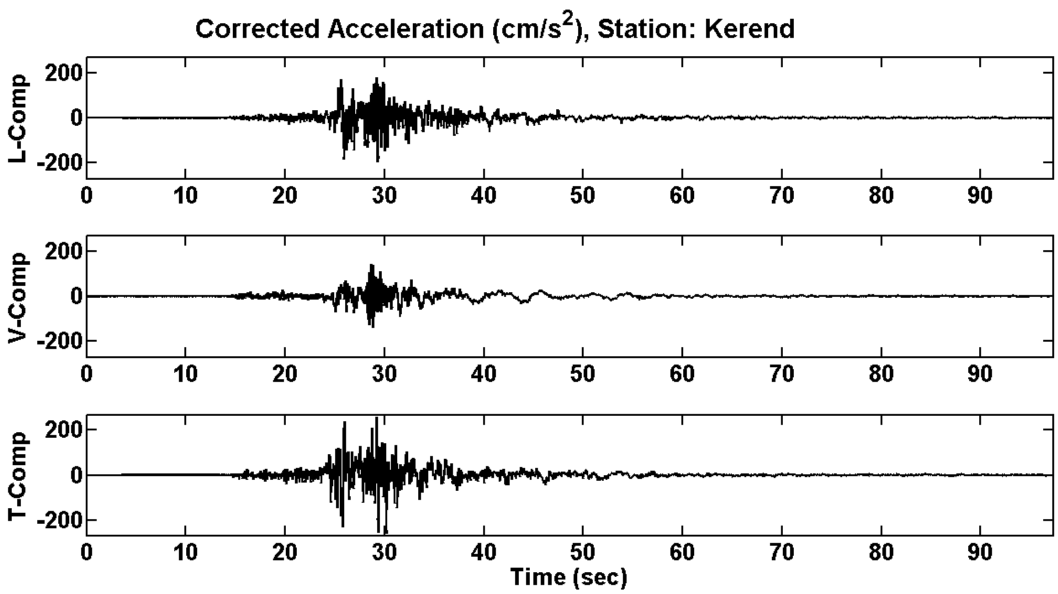

Figure 9. Recorded acceleration time history at Kerend station at about 70 km epicentral distance.

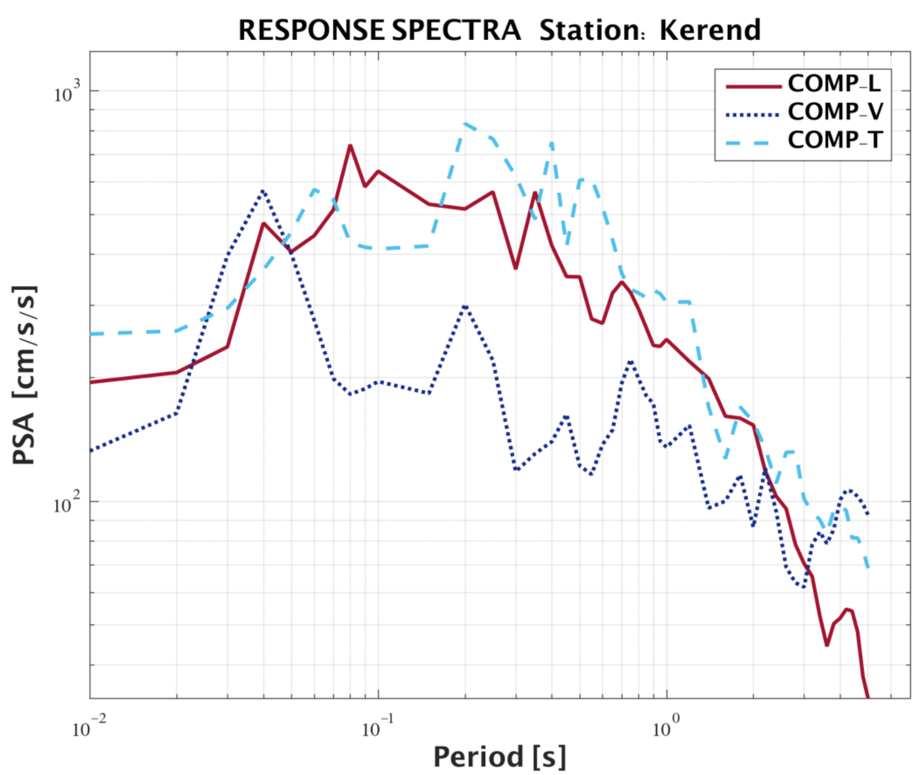

Figure 10. Acceleration response spectra at Kerend station at about 70 km epicentral distance.

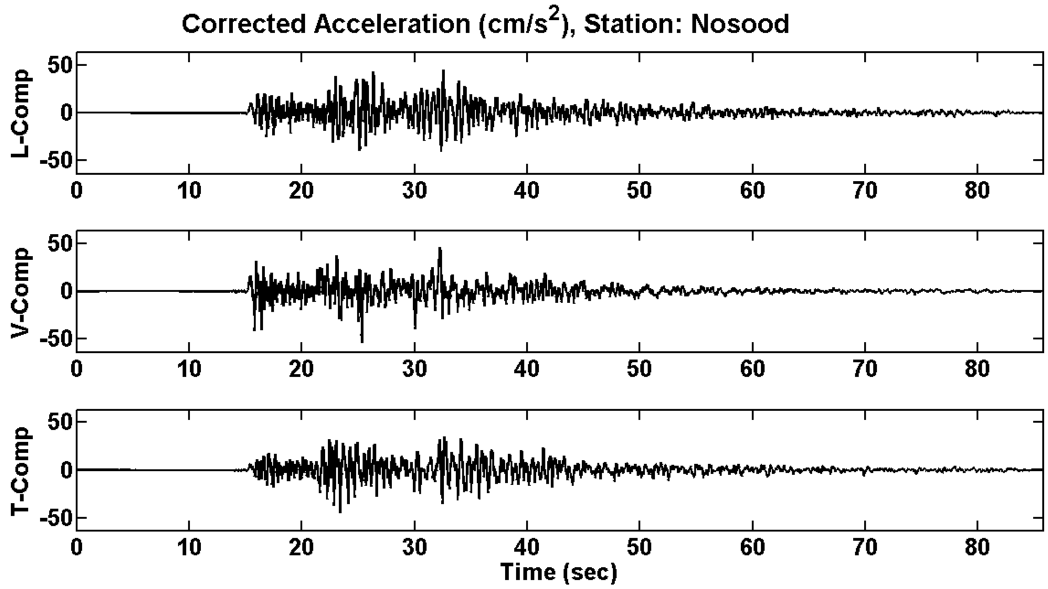

Figure 11. Recorded acceleration time history at Nosood station at about 45 km epicentral distance.

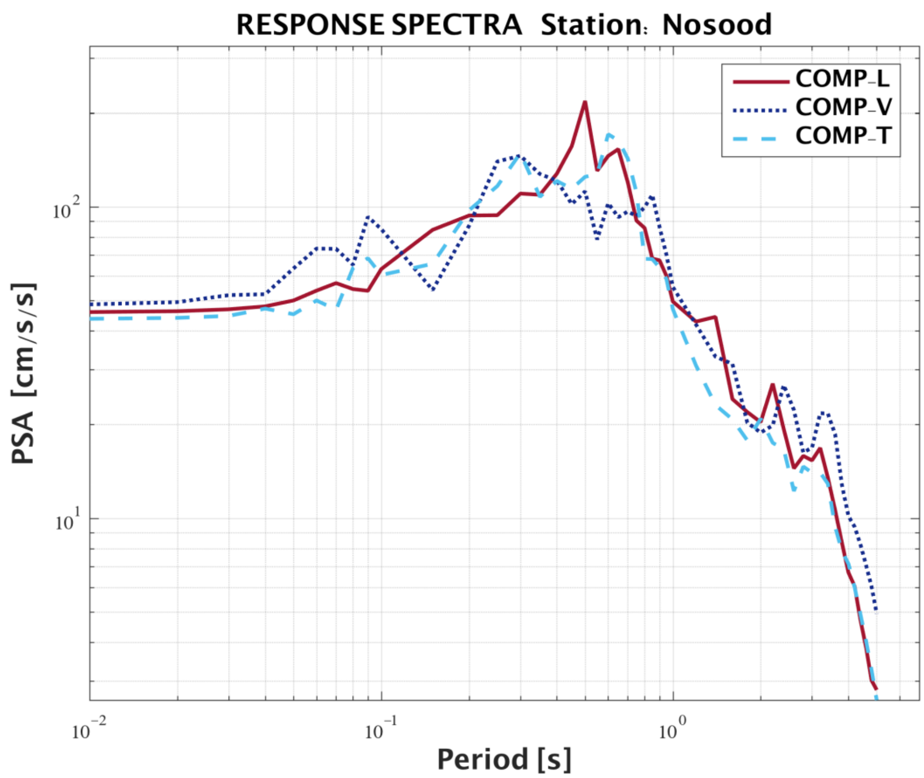

Figure 12. Acceleration response spectra at Nosood station at about 45 km epicentral distance.

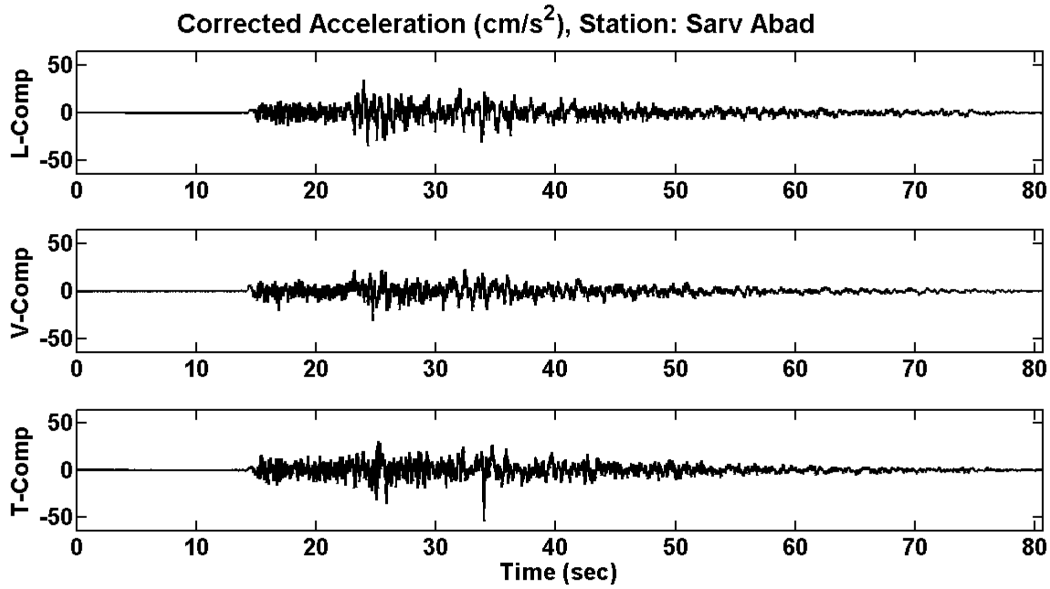

Figure 13. Recorded acceleration time history at Sarv Abad station at about 68 km epicentral distance.

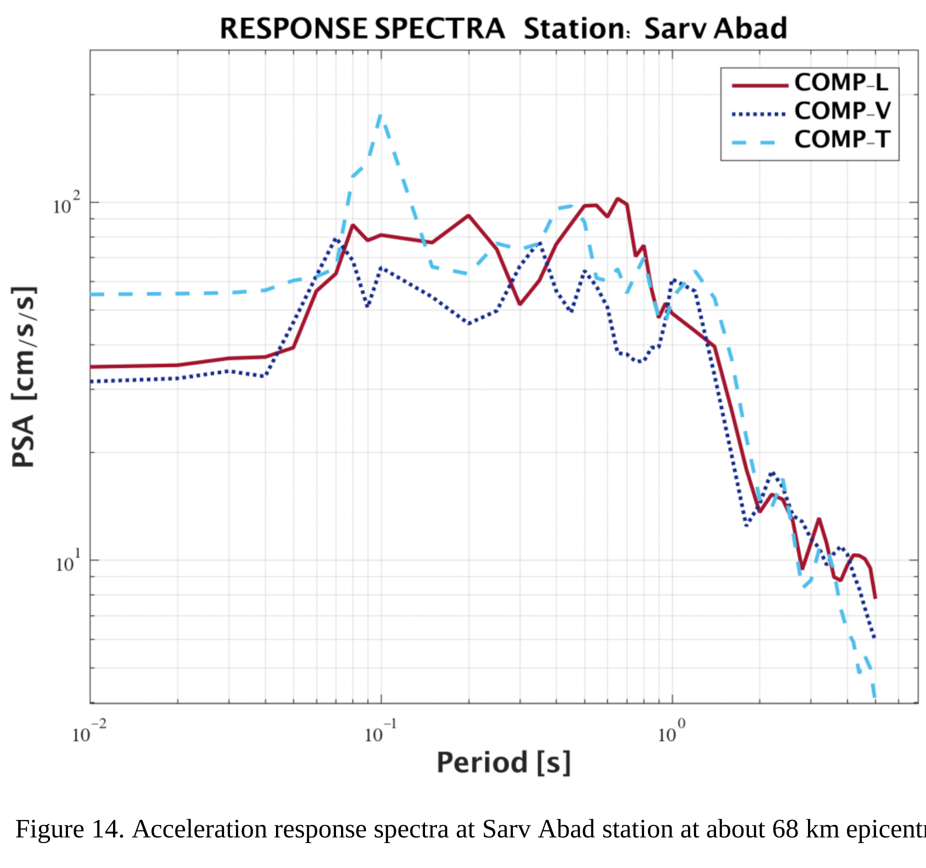

Figure 14. Acceleration response spectra at Sarv Abad station at about 68 km epicentral distance.

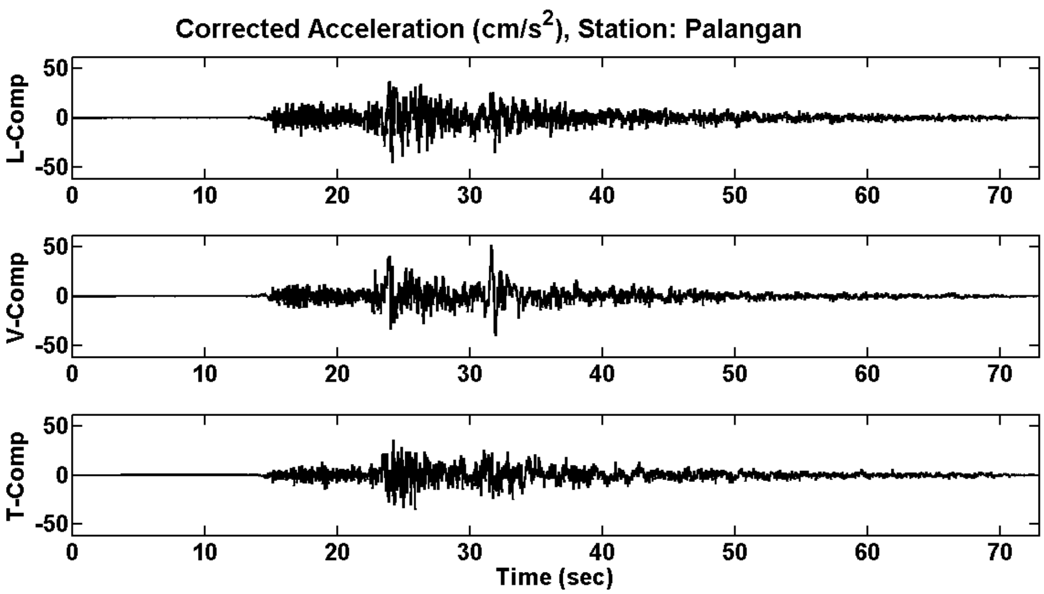

Figure 15. Recorded acceleration time history at Palangan station at about 69 km epicentral distance.

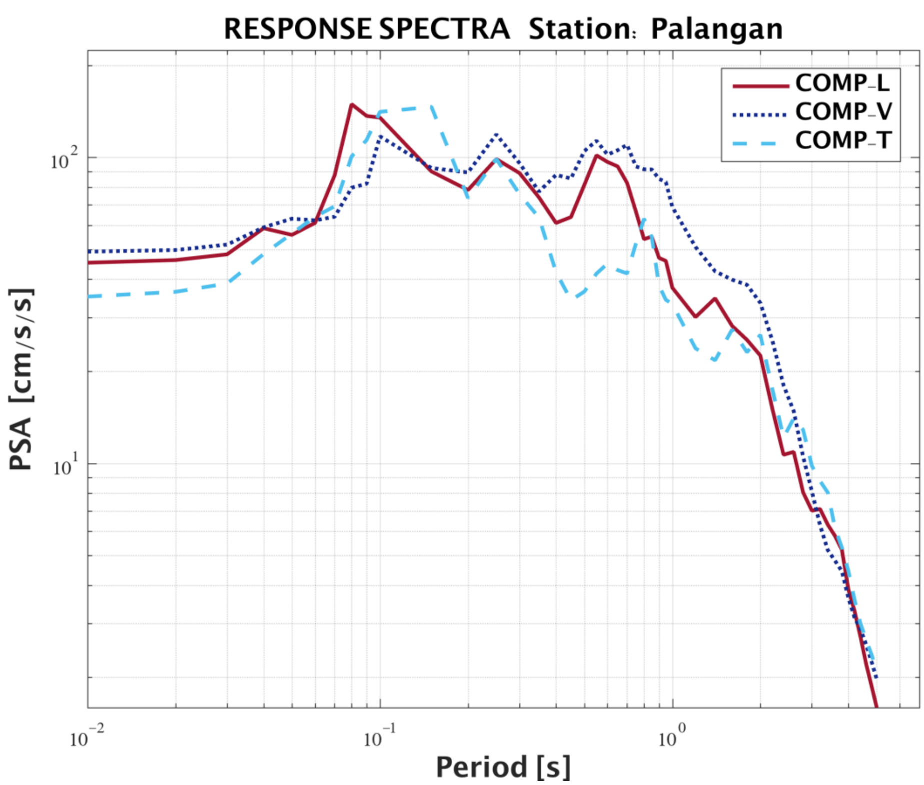

Figure 16. Acceleration response spectra at Palangan station at about 69 km epicentral distance.

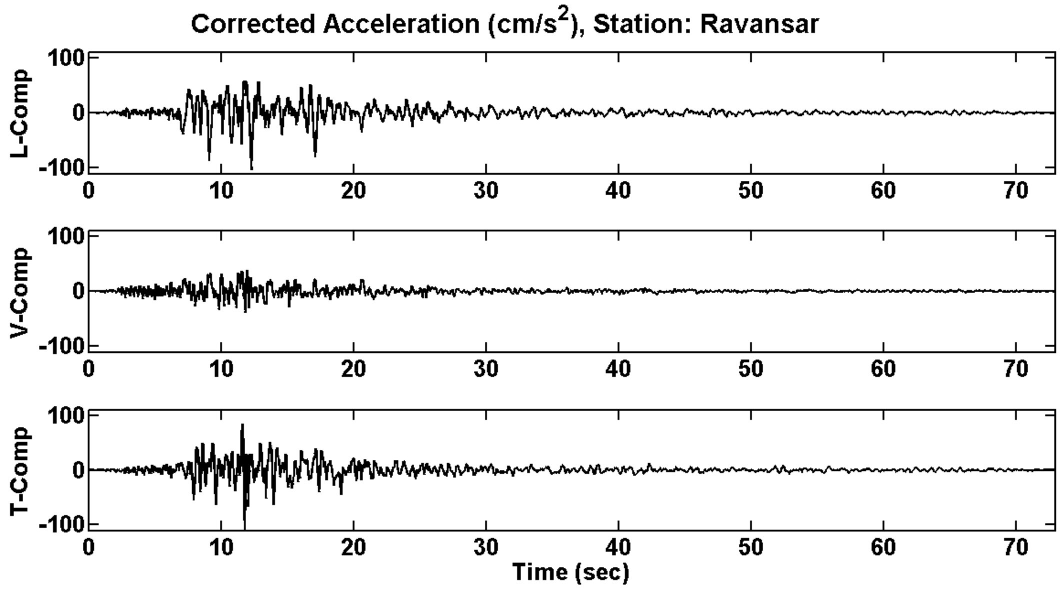

Figure 17. Recorded acceleration time history at Ravansar station at about 72 km epicentral distance.

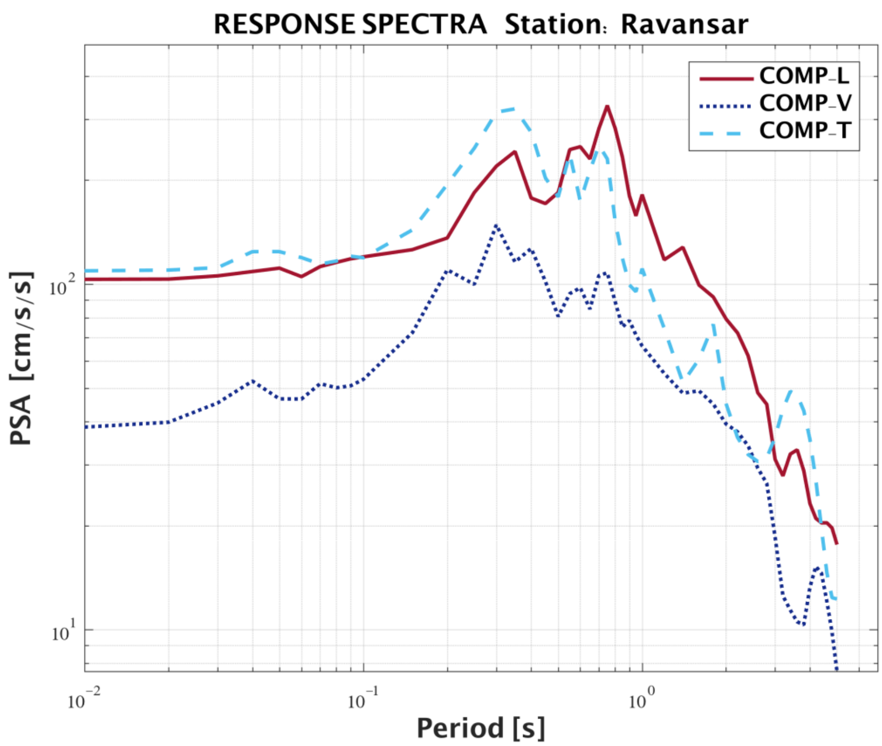

Figure 18. Acceleration response spectra at Ravansar station at about 72 km epicentral distance.

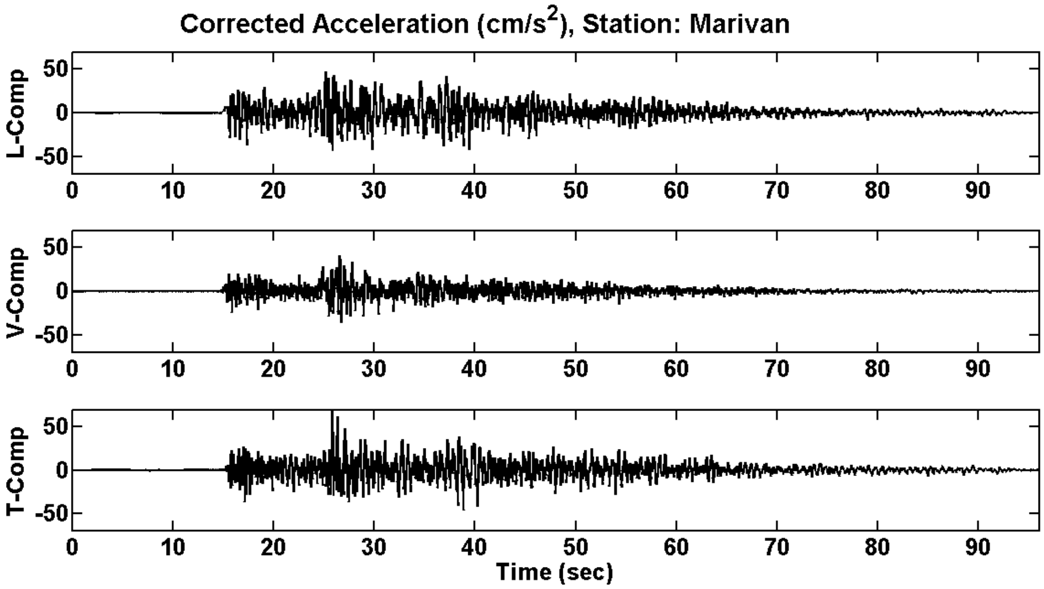

Figure 19. Recorded acceleration time history at Marivan station at about 80 km epicentral distance.

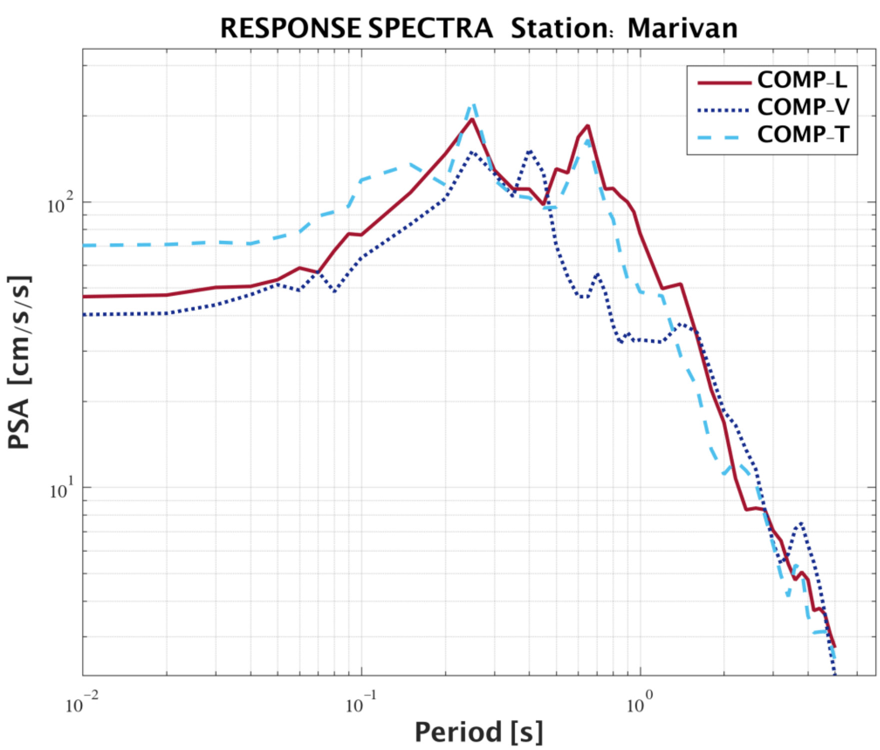

Figure 20. Acceleration response spectra at Marivan station at about 80 km epicentral distance.

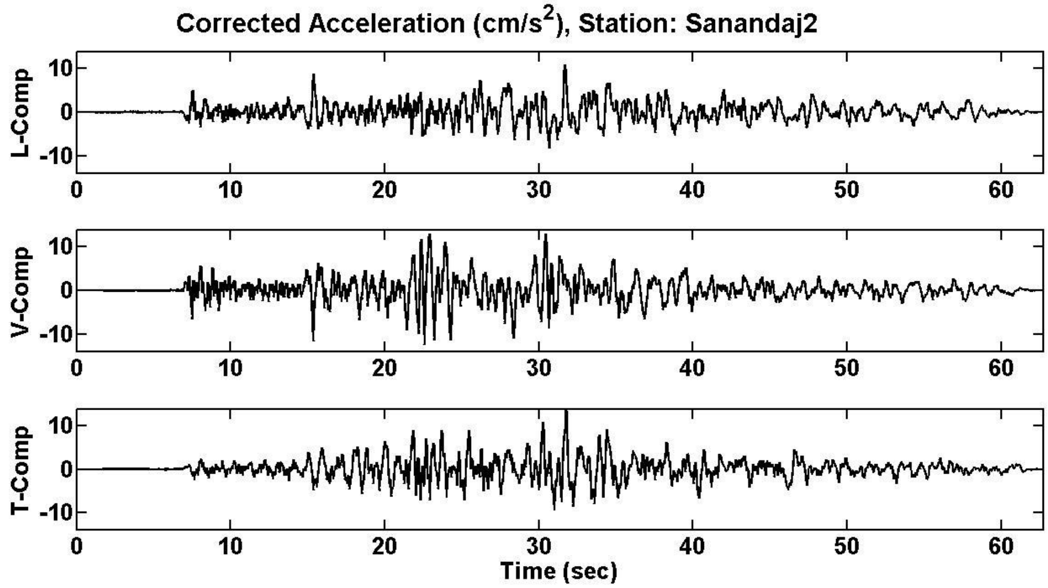

Figure 21. Recorded acceleration time history at Sanandaj2 station at about 113 km epicentral distance.

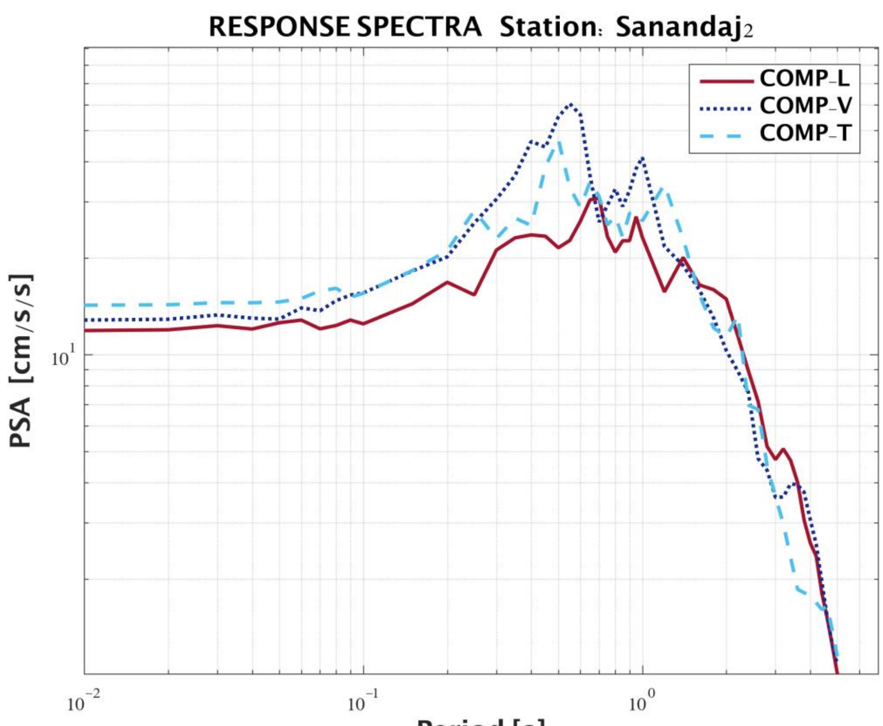

Figure 22. Acceleration response spectra at Sanandaj2 station at about 113 km epicentral distance.

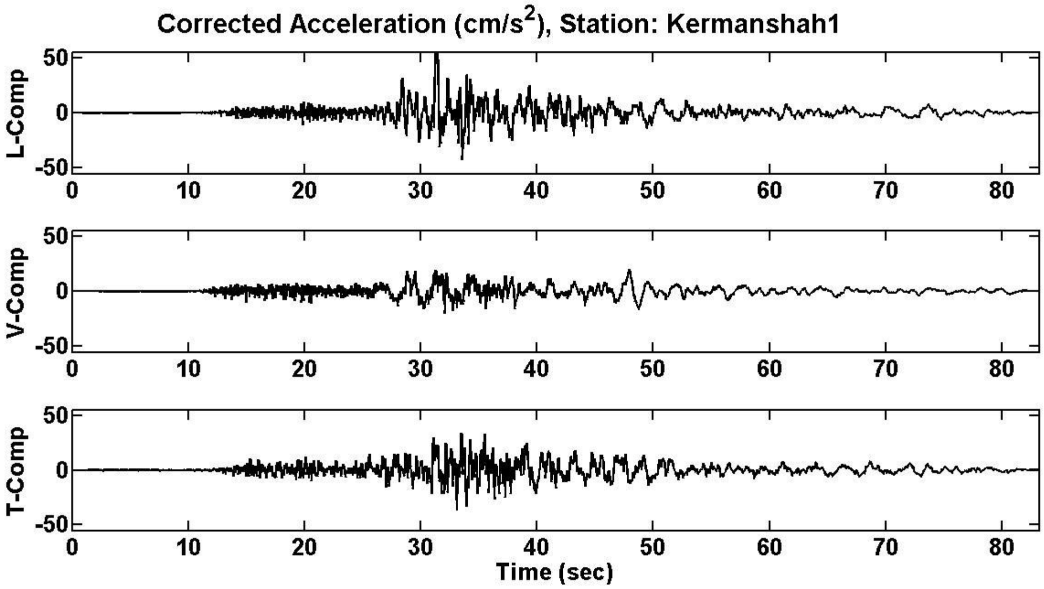

Figure 23. Recorded acceleration time history at Kermanshahe1 station at about 122 km epicentral distance.

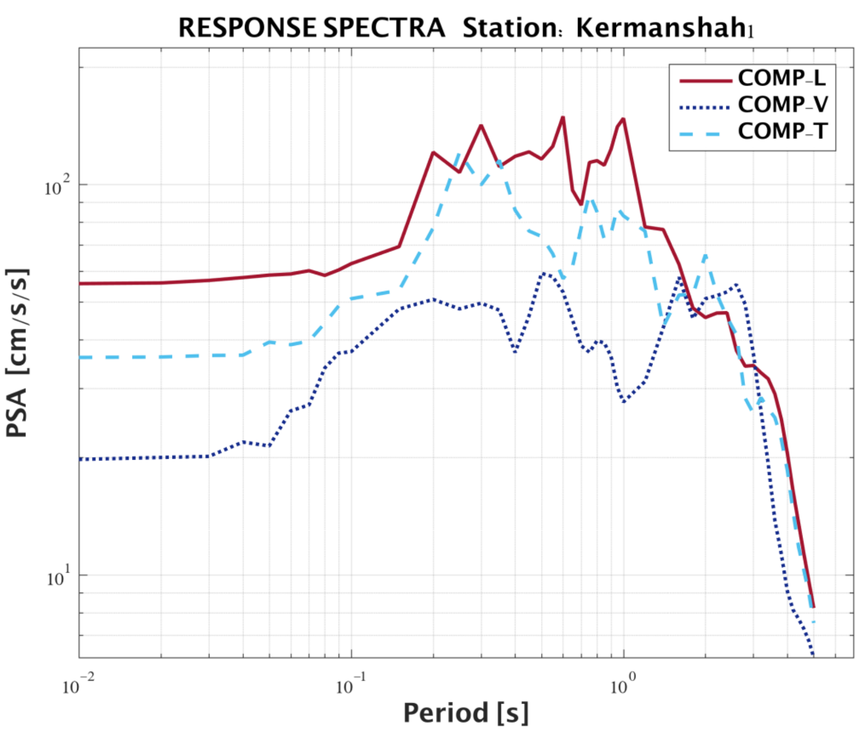

Figure 24. Acceleration response spectra at Kermashah1 station at about 122 km epicentral distance.