A RECONNAISSANCE REPORT OF THE APRIL 5, 2017 NORTH EAST FARIMAN, KHORASAN RAZAVI EARTHQUAKE

ROAD, HOUSING & URBAN DEVELOPMENT RESEARCH CENTER, BHRC

IRAN STRONG MOTION NETWORK

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1 Introduction

On Wednesday 5 April 2016, at 06:09:08 UTC, (10: 39: 08 local time), an earthquake with Mw6.1 occurred 80 km southeast of Mashhad city. Iranian Seismological Center (IRSC) reported the epicenter coordinates of the earthquake at 35.847 N and 60.339 E with a focal depth of 6 km. This earthquake has been recorded by 19 accelerograph stations of Iran Strong Motion Network (ISMN). The maximum recorded acceleration (raw data) of this event was recorded at Nasrabad station with acceleration of about 120 cm/s^2. Main damage was mostly to the farmhouses that mud brick had been used in their construction medium. In this earthquake one person has lost her life and 40 people were injured. According to the focal mechanisms reported by various agencies (Figure 1), type of the faulting is determined as a reverse oblique fault (mostly compressional with a small strike slip component with North West-South East fault trend).

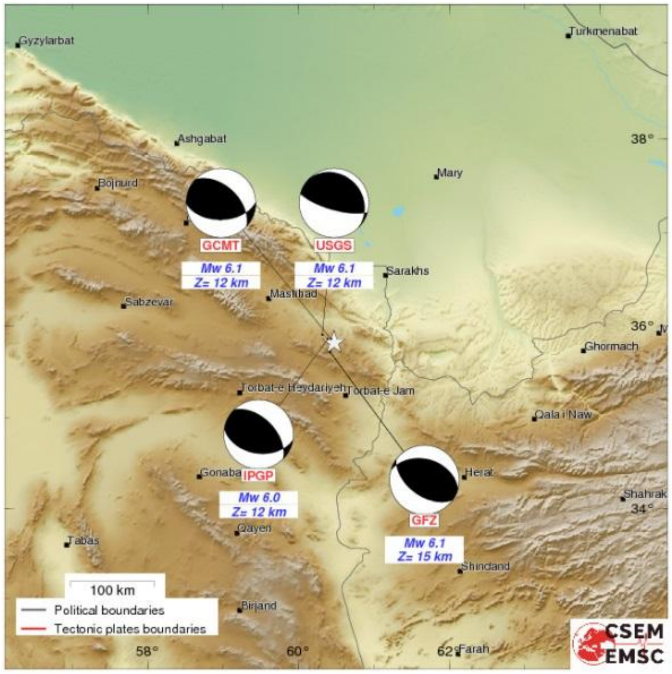


Figure 1. Focal mechanism provided by various agenises (EMSC).

2 Geological Setting of the Province

Khorasan Razavi Province consists of two different structural- sedimentary zones in terms of geological settings. Areas located at North- Northeast of the province have been called the Hezar Masjed Mountains which are part of the geological areas with rich hydrocarbons reservoirs. Central and southern areas of the province are part of the Central Iran structural unit. Regarding the structural and geological features, the province can be divided into two main units: Kopet Dagh and Central Iran structural- sedimentary zones. Kopet Dagh zone has homogeneous features, whereas Central Iran is a heterogeneous unit with different properties. The structural diversity in this region is such that the area should be divided into separate zones.

3 Regional seismicity

Historical seismicity of the Khorasan Razavi province indicates that this area has been seismically very active; therefore it is one of the most seismically active regions in the country. Study of historical and instrumental earthquakes (after 1900) suggests a high seismicity potential of the area. Many studies have been done about the earthquakes that occurred in this region. The most important researches have been done by Berberian et al [2] and Ambersis and Melville [3]. In the 20th century the instrumental recording of the earthquakes began. This has led to obtain better information about the occurrence of the earthquakes (Figure 2). Table 2 shows the occurred earthquakes with magnitude ≥6.0 in the region.

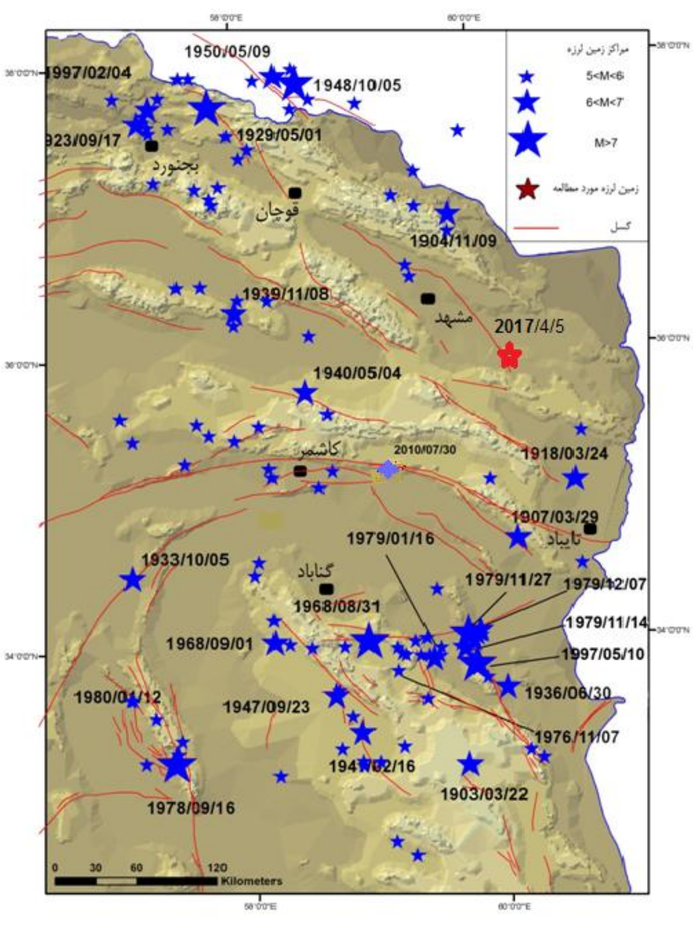


Figure 2. Approximate location of the earthquakes’ epicenter occurred in the region since 1900.

Table 1. List of earthquakes with magnitudes ≥ 6.0 in the region.

Date	Time (UTC)	Lat.	Lon.	Mag.	Depth	Reference
3/22/1903	35:00.0	33.16	59.71	Ms:6.2	0	AMB
11/9/1904	28:00.0	36.94	59.77	Ms:6.4	0	AMB
3/29/1907	57:00.0	34.7	60.2	mb:6.2	0	BER,M
3/24/1918	14:00.0	35.08	60.69	mb:6.3	0	AMB
6/30/1936	26:00.0	33.68	60.05	mb:6.2	33	AMB
11/7/1976	00:52.0	33.819	59.18	Mw:6	7	EHB
1/16/1979	50:08.0	33.904	59.471	Ms:6.7	7	EHB
11/14/1979	21:20.0	33.957	59.728	Ms:6.7	9	EHB
11/27/1979	10:34.0	34.058	59.756	Ms:7.3	7	EHB
12/7/1979	23:59.0	34.078	59.849	Mw:6.1	10	EHB
5/10/1997	57:32.0	33.848	59.809	Ms:7.3	13	EHB

4 Active Tectonics

This area is surrounded by branches of the active Kashaf Rud fault and Tus fault. The main faults of this area are described below.

4.1 Kashaf Rud Fault

Kashaf Rud fault is a reverse fault that is nearly 160 kilometers long with bending trend of NW-SE; this fault has been considered as a seismically active fault. The fault is parallel to the mountains of Kopet Dagh and northern sides of Mashhad plain and cuts the Quaternary sediments. Dip of the fault is toward the Northwest. Kashaf Rud fault caused the earthquake of 30 July 1673 with a magnitude of 6.6, and the M5.5 earthquake in April 1678 in Mashhad (Berberian, 1981).

4.2 Tus Fault

The NW-SE trending Tus fault is a branch of the Kashafrud fault. Geomorphologic evidences suggest that the Tus fault entered the Mashhad metropolitan area from the northwestern part of the city of Mashhad, near the Tus town. Tus fault, with a width of 2 - 3 km, has a reverse mechanism with dip direction to the South-West. Displaced alluvial deposits are obvious evidences that show the activity of this fault during the Quaternary period.

4.3 Daruneh Fault

The most important tectonic structure of the province is the Daruneh fault, which passes through proximity of Kashmar and Torbat Heydarieh cities. Its length is about 700 kilometers that is expanding from the eastern border to the center of Dasht-e Kavir, Iran. This fault is called Daruneh because it is located near the Daruneh village and from this location, the fault is divided to two East and west parts. This fault is also called the Great Desert fault, which is one of the most prominent structures in Iran after the Zagros main reverse fault. Daruneh fault is well known especially in places where it cuts the mountainous alluvial fans and desert sand formations. This is why Wellman (1966) considered it as an active fault [4]. Two cities in the region, Kashmar and Torbat_e_ Heydarieh, were strongly affected by devastating earthquakes caused by this fault. Also Kashmar and the villages in south of Torbat _e_ Heydarieh were destroyed in 1903 and 1923 respectively. Later, only an earthquake (1962) caused little damage to the area between the two cities [2]. It seems that the earthquake of July 30, 2010 occurred as a result of movement in some part of the Daruneh fault. Other major faults in this region are as following: Khaf, Doogh Abad, Jangal, Kashmar, and Toos fault.

5 Strong Motion Data of the NE Friman Earthquake

The main shock of the NE Fariman earthquake has been recorded by 19 digital strong motion stations in the Khorasan Razavi province (Figure 3 and Table 3). All of the SSA-2 strong motion instruments that recorded this event have the trigger threshold of 10 cm /s^2. This means that if the acceleration of the earthquake on any of the three components of the instrument reaches to this limit, the instrument starts to record the event.

Table 2. List of the recording strong motion stations that registered the event.

	Station	Epicenter coordinates		Instrument	Installation angle		Height	Shear wave
		N	E	type	L	T	(m)	Velocity (m/s)
1	Emam Taghi	35.96	59.44	SSA-2	0	90	1398	680
2	Torbat Jam	35.232	60.625	SSA-2	66	156	881	538
3	Chakhmag h	35.275	59.832	SSA-2	328	58	1544	1196
4	Khaf	34.579	60.149	SSA-2	0	90	980	414
5	Zavin-e-Sofla	36.747	59.934	SSA-2	170	260	1087	816
6	Sarakhs	36.55	61.156	SSA-2	160	250	333	498
7	Sangan	34.404	60.252	SSA-2	0	90	840	643
8	Saleh Abad	35.687	61.091	SSA-2	0	90	685	1472
9	Torghabeh	36.309	59.381	SSA-2	0	90	1302	-
10	Farmad	36.445	59.714	SSA-2	0	90	1055	-
11	Fariman	35.695	59.843	SSA-2	0	90	1404	680
12	Naderi Kalat	36.995	59.761	SSA-2	219	309	889	634
13	Gonbadli	36.387	60.859	SSA-2	4	94	451	1111
14	Mashhad 1	36.31	59.56	SSA-2	0	90	992	748
15	Mashhad 3	36.31	59.53	SSA-2	0	90	1184	676
16	Mashhad 5	36.31	59.47	SSA-2	0	90	1175	-
17	Mashhad 6	36.31	59.56	Guralp	0	90	1009	-
18	Mashhad 8	36.29	59.62	Guralp	0	90	1009	-
19	Nasr Abad	35.42	60.31	SSA-2	0	90	1095	795

When the acceleration level arrives at this limit again, and after a certain time passing, the instrument goes back to standby mode. All instruments have a pre-event memory of 15 seconds, where this feature greatly helps to record the first P-waves arrival, especially in the station that are located in large distance from the earthquake epicenter. Table 3 shows the list of recording stations that registered the main shock of this event. In most of these stations shear wave velocity have been determined by seismic refraction method. Table 3 and Figure 6 show the general characteristics of the recorded accelerograms. Fariman and Nasrabad stations were the nearest stations to the reported epicenter of the earthquake.

The time difference between P- and S- wave's arrival at Fariman and Nasrabad stations were 6.58 and 6.51seconds respectively. However, a significant difference between the recorded acceleration in the Nasrabad station (122 cm /s^2) and Freeman station (35 cm /s^2) can be seen. Since the shear wave velocities are not significantly different at these two stations, probably the differences in the recorded acceleration level can be caused by the effect of seismic directivity arising from the direction of the causative fault fracture. Unfortunately Marzdaran station along the Northern border of the earthquakes epicenter, has not recorded this event due to the technical issues.

All accelerograms were processed using a band-pass filter and the time histories of acceleration, velocity and displacement along with the response spectra were extracted. In the appendix of this reports, the history of the processed recorded accelerograms are presented along with their response spectra.

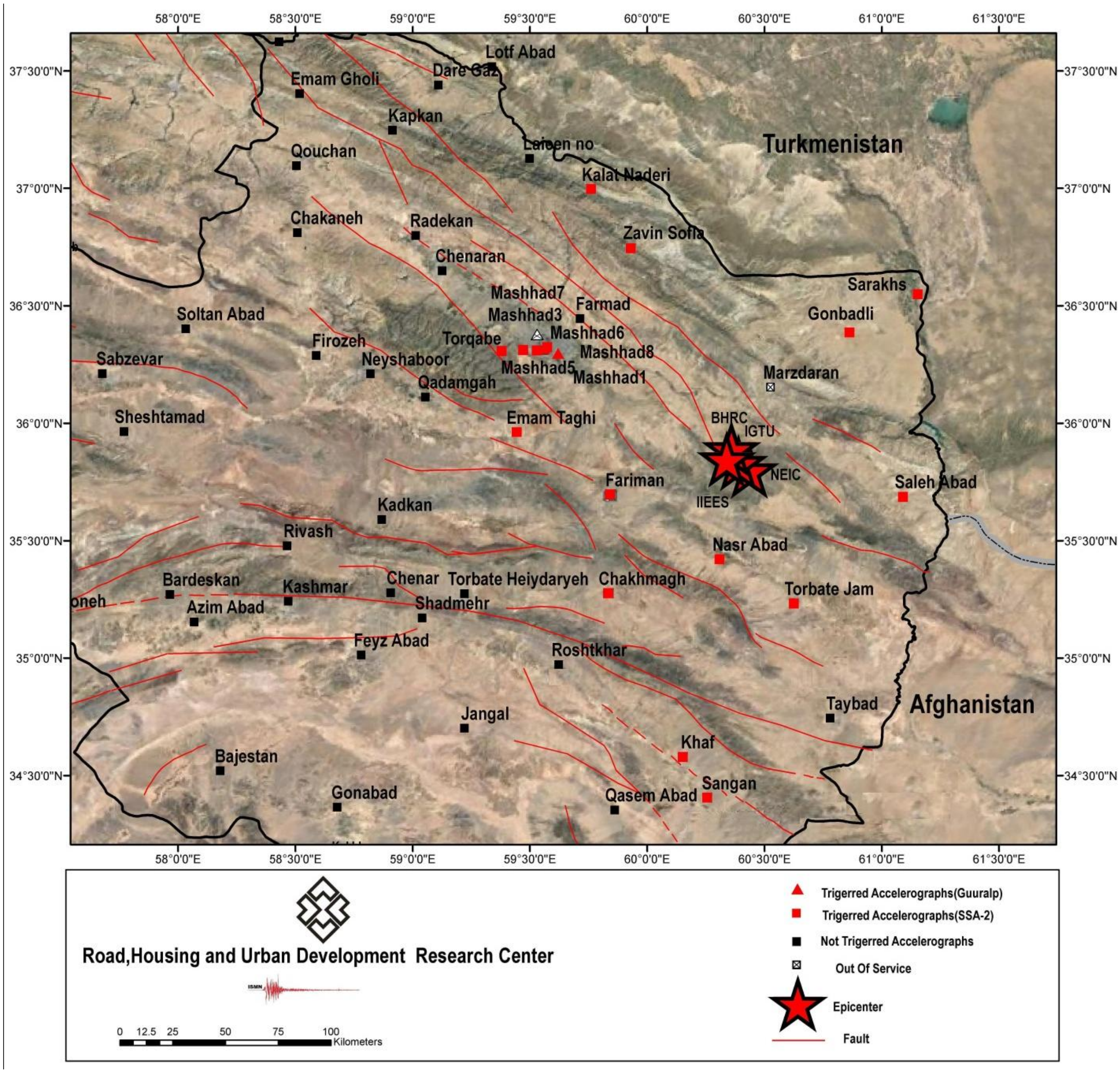


Figure 3. Recording strong motion stations.

Accelerogram registered at the Nasrabad station is one of the most important recorded accelerograms in terms of the maximum acceleration, which indicates that the effective duration of this accelerogram reached about 19 seconds and the predominant period of it is about 1.0 seconds. Regarding the fact that numbers of recorded accelerograms in this event have well registered the p-wave arrival, we were able to determine the epicenter location and moment magnitude of this event (Figure 4).

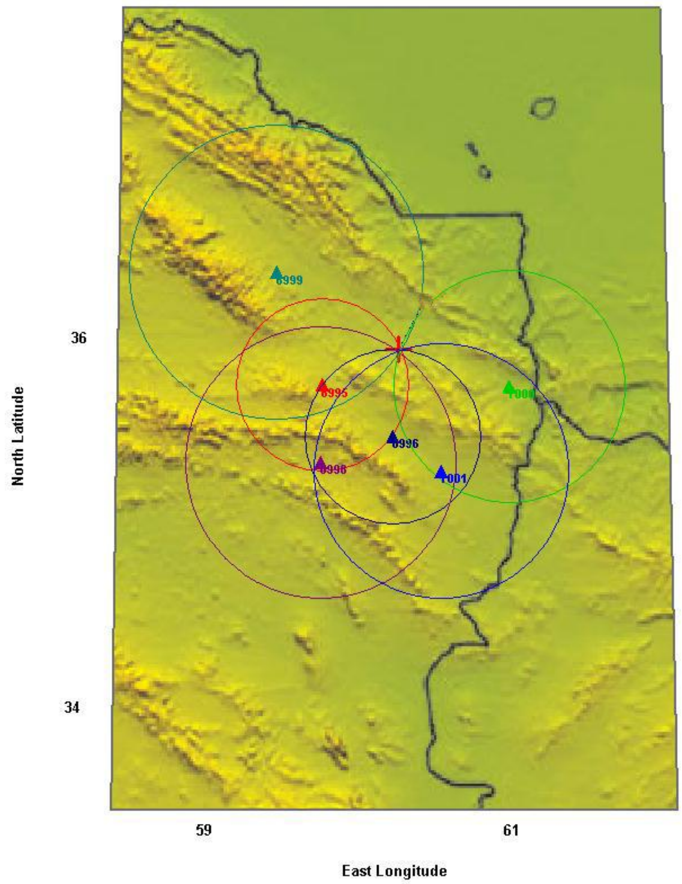


Figure 4. The earthquake' epicenter location determined by the Iran strong motion network.

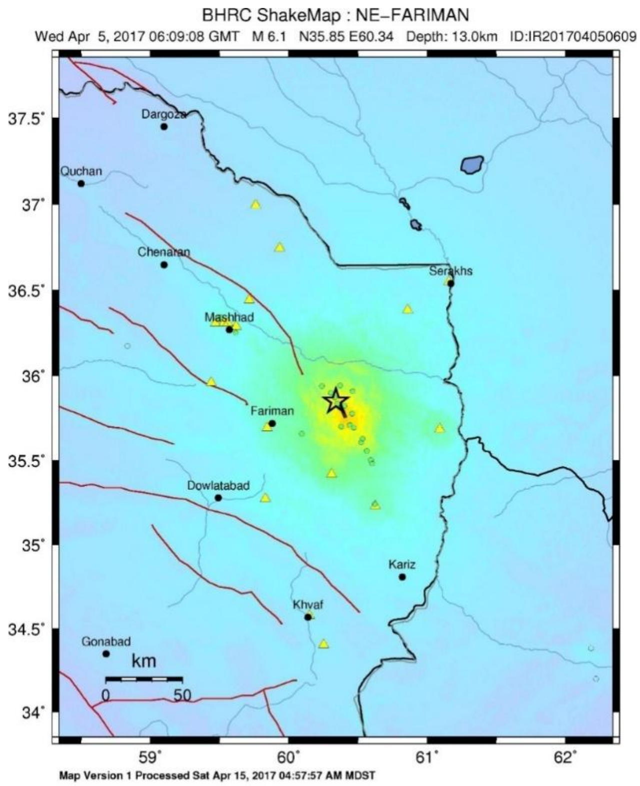
6 Field observation

6.1 Coseismic surface ruptures

There was no significant surface faulting along the region of the 2017 NE-Fariman earthquake, but there were some secondary cracks and fractures.

6.2 Intensity

Using the recorded data from this earthquake by ISMN' instruments, the intensity, acceleration, and velocity shake maps were prepared along with the uncertainty of these estimates (Figures 5 and 6). Therefore, the maximum intensity of about 7 (modified Mercalli scale) in rural areas of Doqhalee, Alghur, Kuh Sefid, Kalateh Ghadam, Sarcheshmeh Barashk, Ghaleh Sorkh and Musaabad was observed.



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17–1.4	1.4–3.9	3.9–9.2	9.2–18	18–34	34–65	65–124	>124
PEAK VEL.(cm/s)	<0.1	0.1–1.1	1.1–3.4	3.4–8.1	8.1–16	16–31	31–60	60–116	>116
INSTRUMENTAL INTENSITY	I	II–III	IV	V	VI	VII	VIII	IX	X+

Figure 5. Intensity shake map.

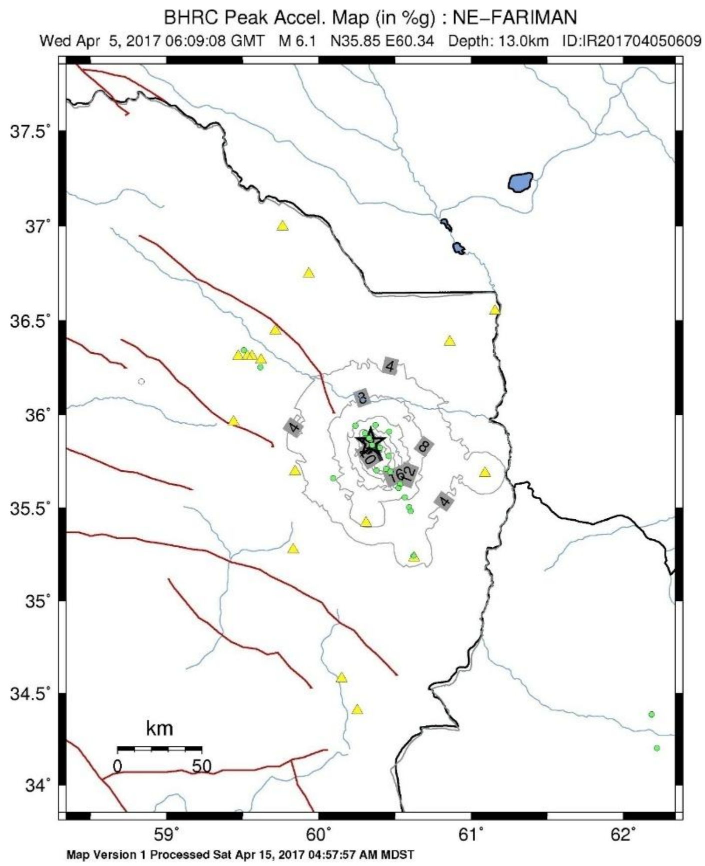


Figure 6. Acceleration shake map.

7 The Earthquake Effects

7.1 Damage to the Buildings

According to the latest official reports only one person lost her life and 40 people were injured during the NE Fariman earthquake on 5 April 2016. Field observations of the research team from ISMN indicates the limited damage to the villages of the macroseismic region and minor damage was observed in the surrounding cities such as Kuh sefid, Fariman and Nasr Abad. The main cause of damage to the buildings in the area is the poor quality of the construction, which has been seen in the other parts of the Province as well. More than 80% of the rural houses in Iran are composed of adobe or stone masonry and are constructed using only local materials and unskilled labor. The use of poor clay materials along with construction of thick walls and heavy ceiling are the main issues of the rural buildings in this area of the country. This has been observed also in the earthquake of 1378 Saleh Abad in Torbate Jam region, where the major damage to the traditional rural houses was due to the poor constructions with construction medium, such as clay and mud brick. The pictures taken from the villages of the affected region show that the buildings that comply with minimum earthquake resistant criteria set had none or minimum damage due to the earthquake. These observations confirms that the construction of earthquake resistant rural houses that can resist the moderate or even severe earthquake shaking is possible when the buildings are constructed in compliance with the principles of earthquake resistance design.

Figure 7. Destruction of the rural houses in the Doghalee village.

Figure 8. No damage to the Alghur village school building, which has been built in compliance with the principles of earthquake resistance design.

Figure 9. Demolition of farmhouse in the Doghalee village.

Figure 10. Ghale’e-Sorkh village, Council building without structural damage.

Figure 11. Collapse of the walls and demolition of the farmhouse in Ghale’e-Sorkh village.

Figure 12. Destroyed farmhouse in the Kalateh-Ghadam village.

7.2 Geotechnical phenomena

According to the ISMN expedition' report the phenomenon of the rock fall has been seen in some mountainous areas of the region. An example of this phenomenon occurred on the road between Kalateh Ghadam and Kuh Sefid, where the large boulders have fallen down by earthquakes.

Figure 13. Dimensions of the one of the fallen rocks.

8 Conclusions

Earthquakes occurrences are not a rare or abnormal phenomenon in Iran. Statistics provided by IRSC confirms the occurrences of tens of medium or small earthquakes in each year in the country. The process of these medium-sized events along with the incident of fairly large or even destructive earthquakes every so often intensely attracts the public opinion and the authorities to this specific natural hazard. In this case, for a limited time (until the large aftershock events) this issue is of great interest to the media, social networking and authorities meetings, and then it gradually forgotten, until the next big earthquake. This pattern is frequently seen in Iran earthquakes, without finding any fundamental solution to reduce the impact of this natural hazard. The recent earthquake in the southeast of Mashhad on April 5, 2017 is an interesting example of these earthquakes but the difference is that this event has happened near one of the most important cities in Iran that has high population (comparable to Tehran). After the earthquake occurrence, fear of the people in the region made them to exit and stay outdoors. Of course, one seismic event at a distance close to or even in the city of Mashhad would cause massive outflow of people from the city that will be followed by resulting chaos and anarchy. Now the basic question is that what plan authorities have thought for such a scenario in cities such as Mashhad, where almost 8 million people were staying during the New Year holidays. Unfortunately, there is no short or long term plan not only for the city of Mashhad but also for any other big or small cities in the country such as Tehran. However for what we're directly responsible, the activity of the ISMN, we should say that apart from Marzdaradn station that unfortunately was out of service (due to the technical issues) and the instrument in Mashhad Governor building (due to power outages a few days before the event), all other stations in the region have registered the major earthquake. Given that in the recent years the amount of seismic data (in terms of number and maximum acceleration) of the city of Mashhad were less compared to the rest parts of the Khorasan Razavi, this earthquake can add the richness of the data bank of this region. Definitely all stations in the city of Mashhad have recorded the main shock. Somehow the performance of the strong motion instruments despite their age, which dates back to over 24 years ago, is desirable. During the past years, some attempts have been made to renew the network, which we hope will lead to positive results. We plan to renew the ISMN in a 5-year period program along with performing other activities such as the development of earthquake early warning and rapid response systems; in advanced countries these systems are the basic solution to deal with the earthquakes along with other programs to retrofit the structures to make them earthquake resistant.

Acknowledgments

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The authors wish to express their deep gratitude to the Department of Roads and Urban Development in Khorasan Razavi province for their efforts to provide facilities for accommodation and guidance as well as providing vehicles for field trips to the affected areas and strong motion stations.

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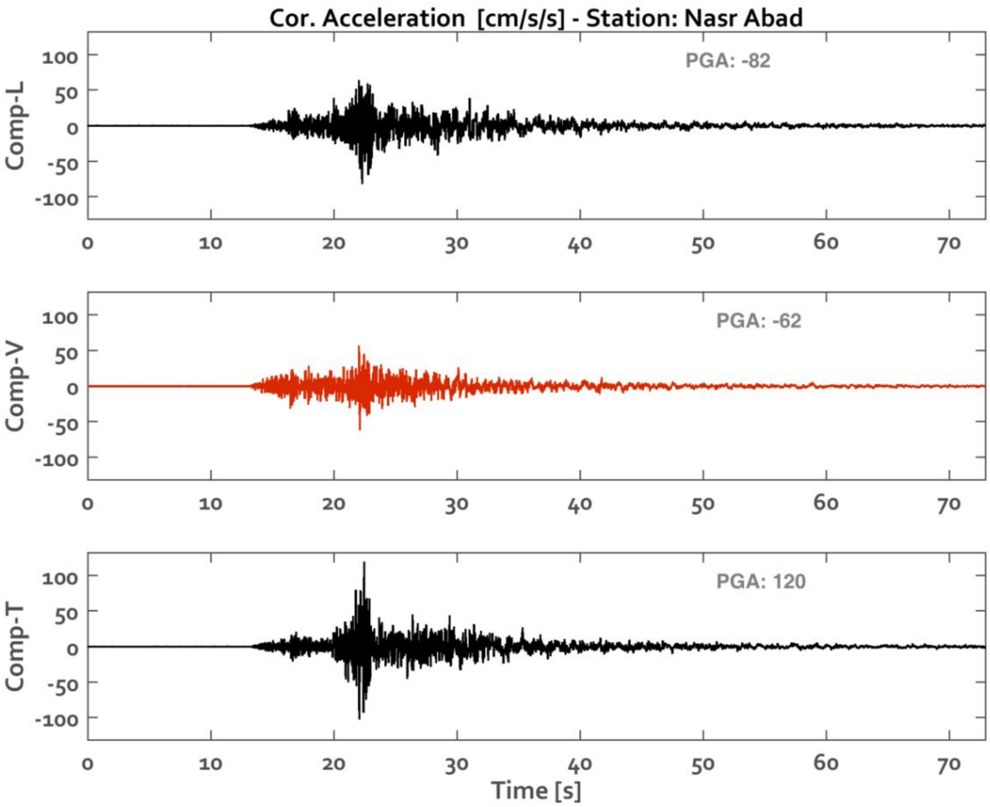
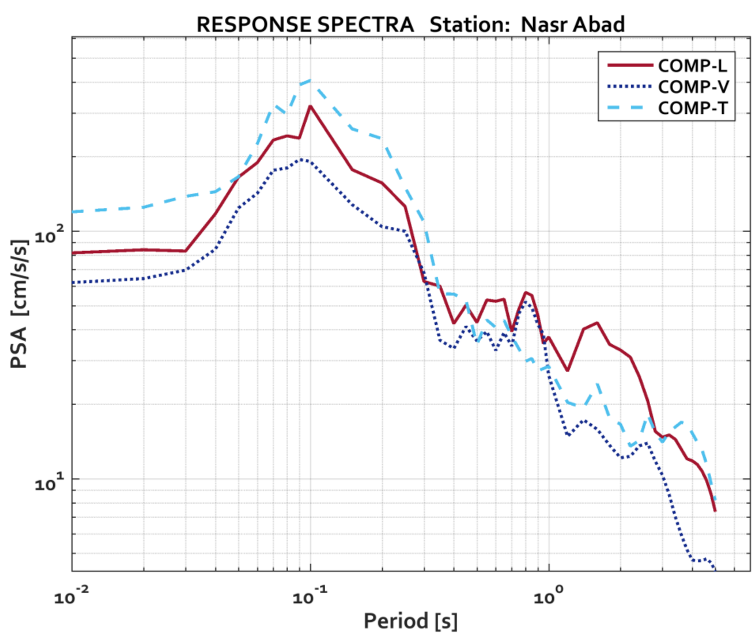
Appendix

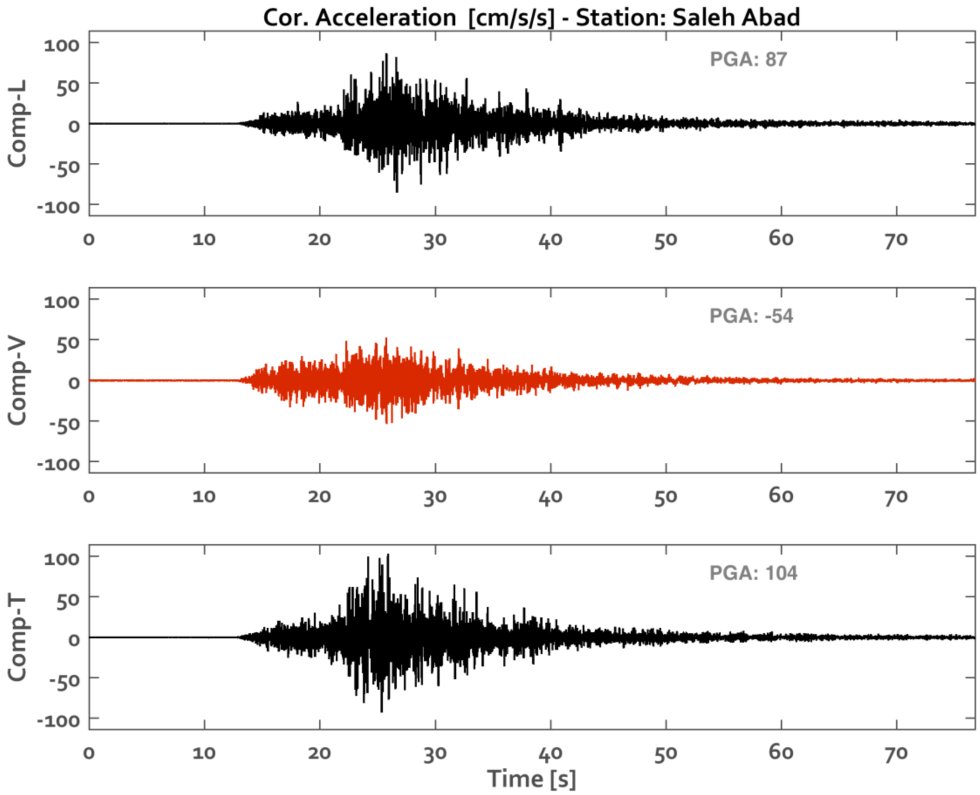
Time histories of recorded accelerograms from main shock and the response spectra



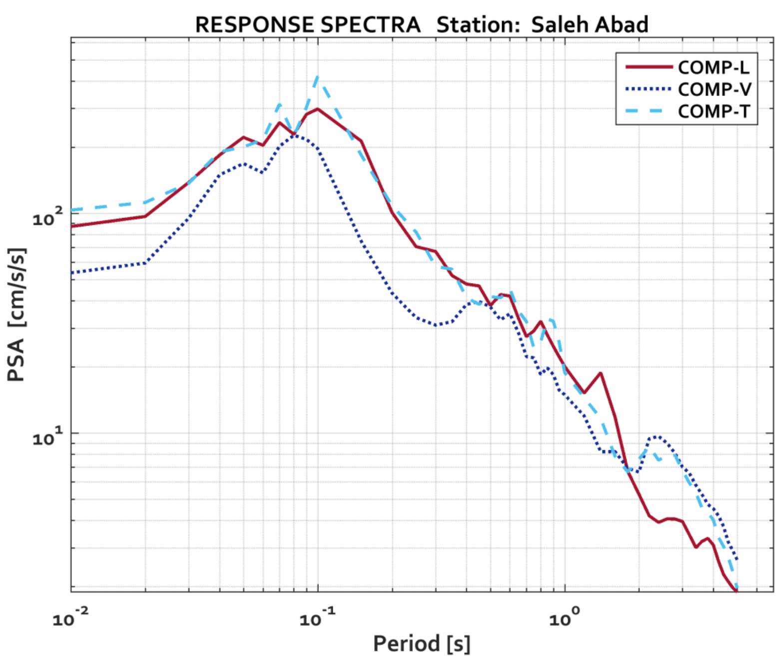
Corrected acceleration time history at Nasrabad station.



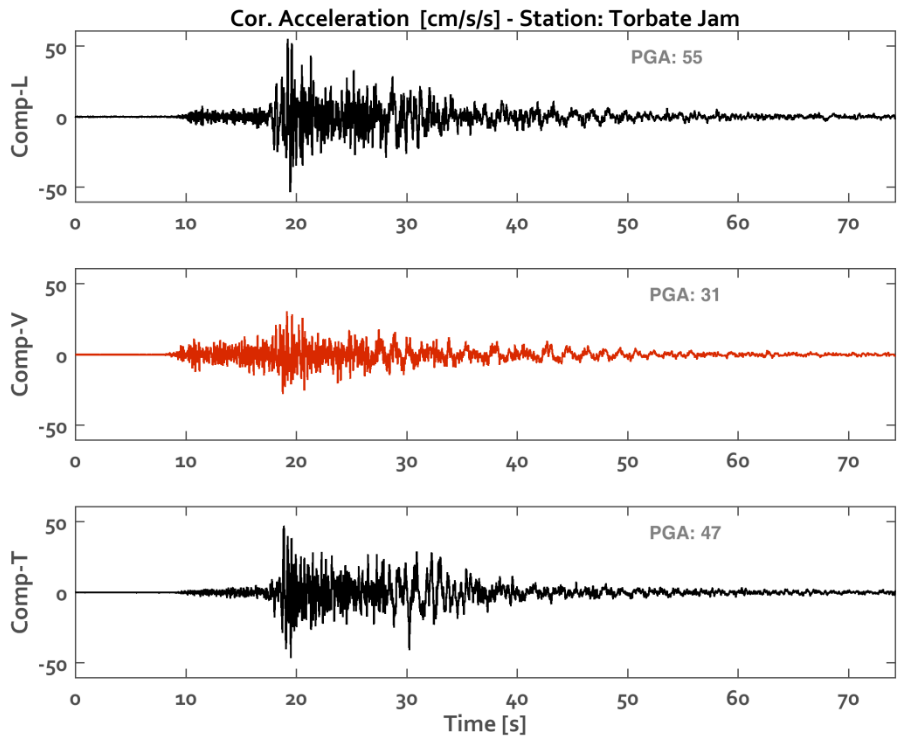
Acceleration response spectra at Nasrabad station.



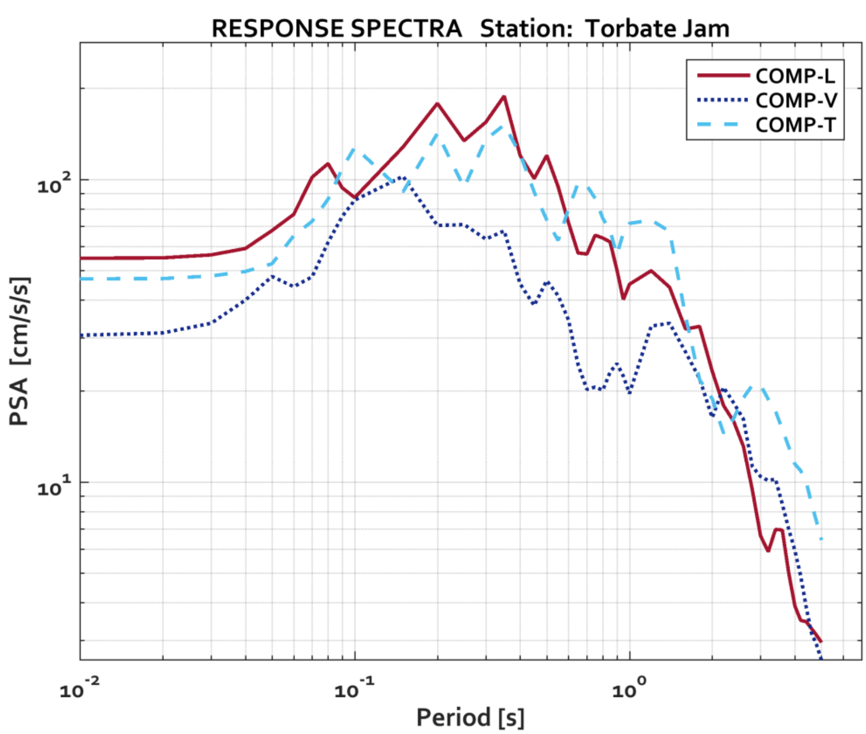
Corrected acceleration time history at Saleh Abad station.



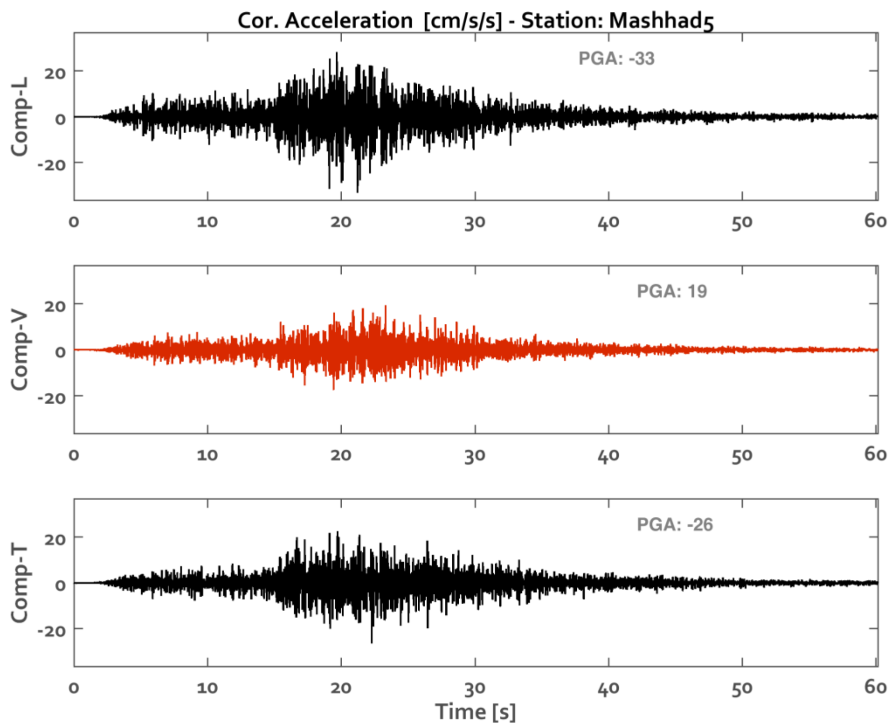
Acceleration response spectra at Saleh Abad station.



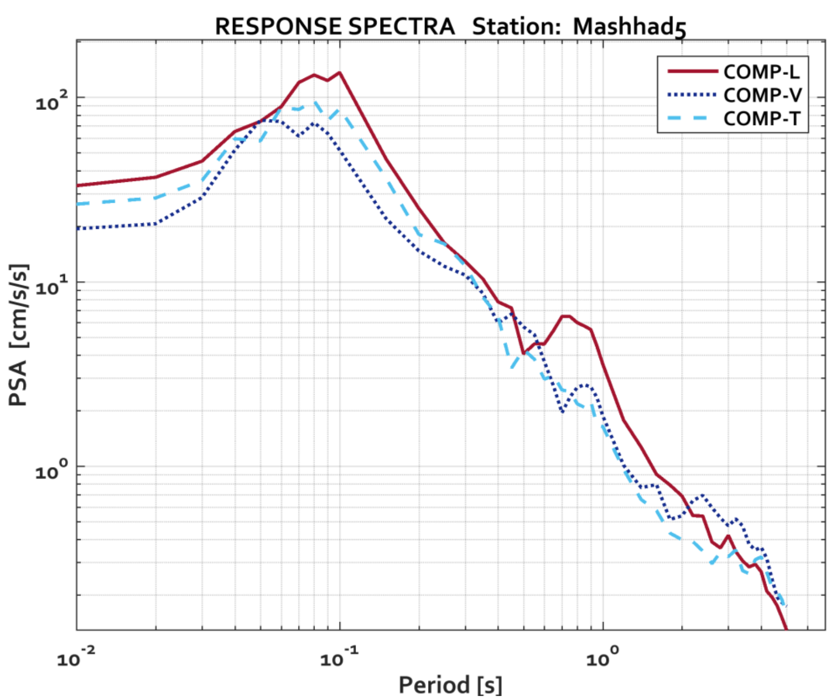
Corrected acceleration time history at Torbate Jam station.



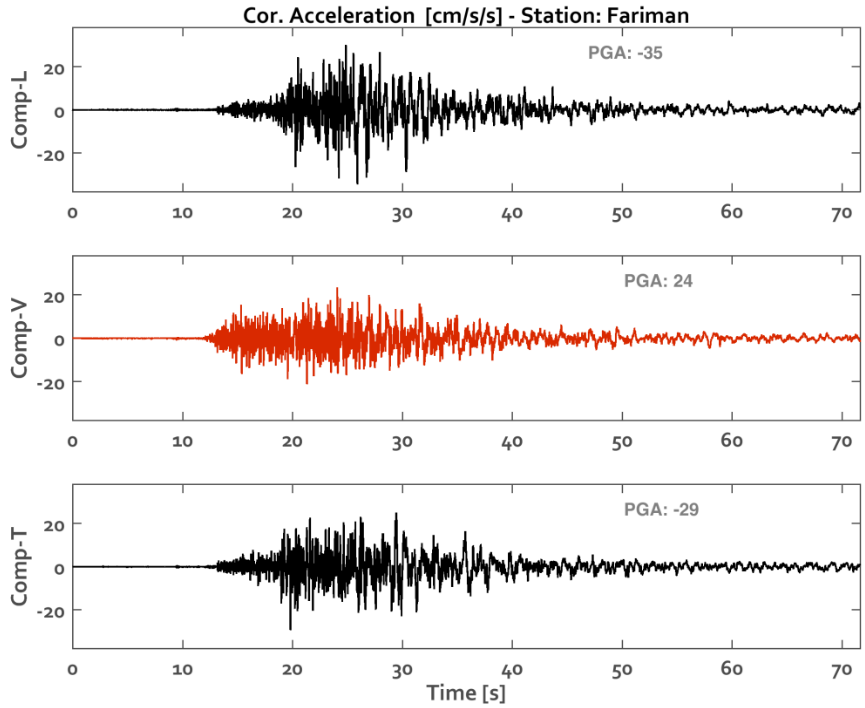
Acceleration response spectra at Torbate Jam station.



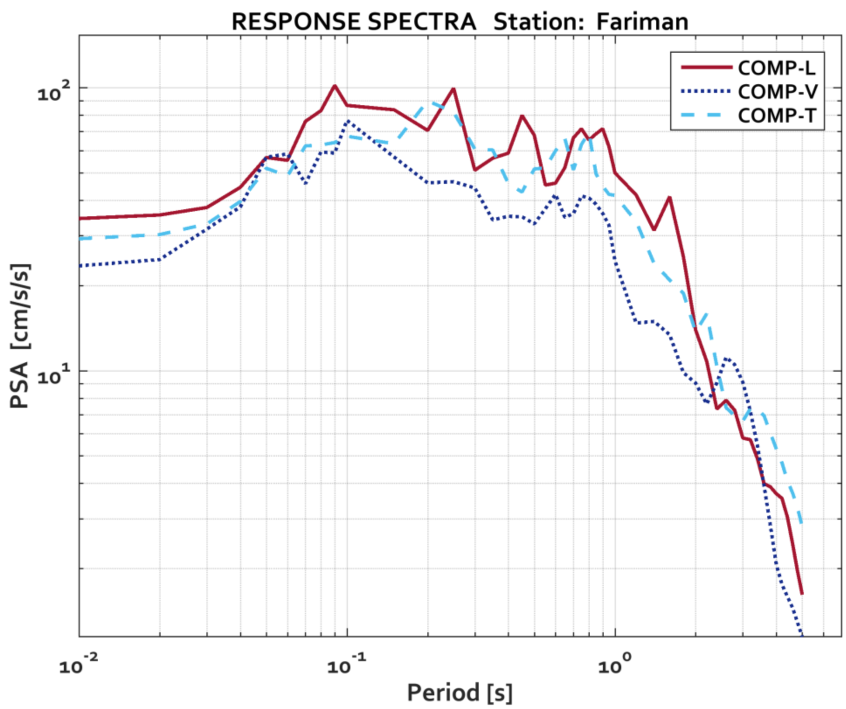
Corrected acceleration time history at Mashhad station.



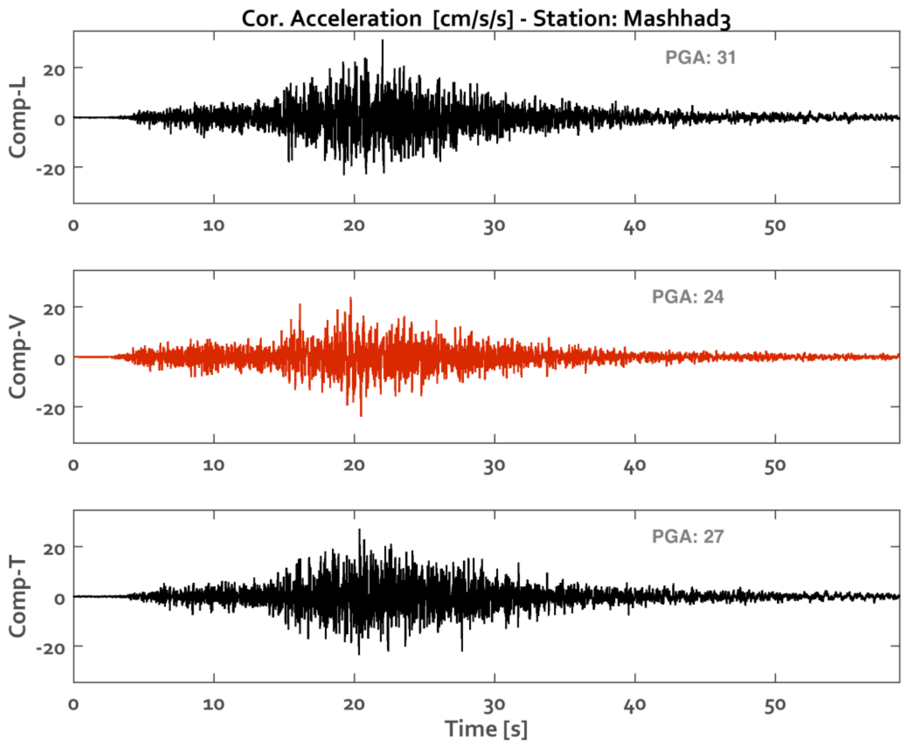
Acceleration response spectra at Mashhad station.



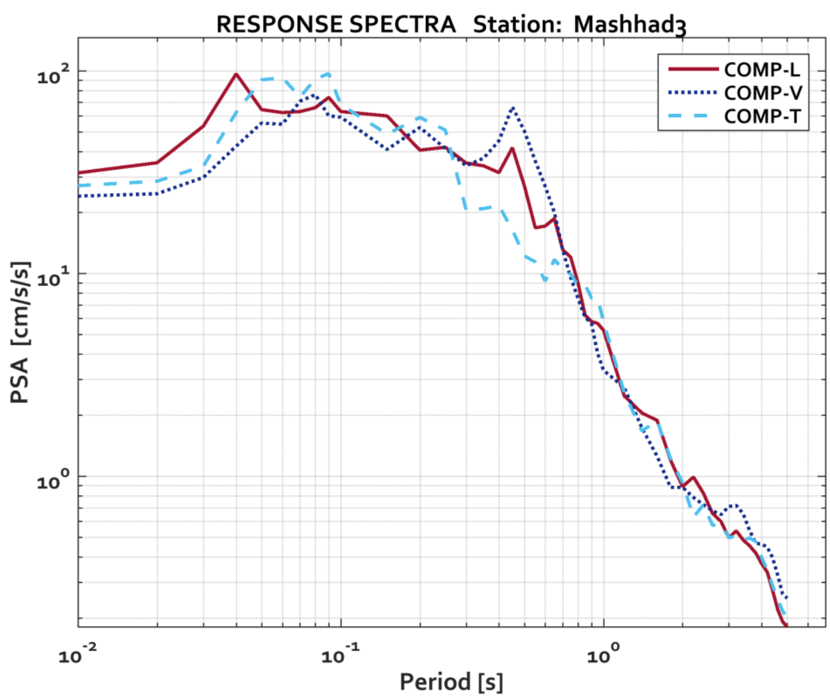
Corrected acceleration time history at Fariman station.



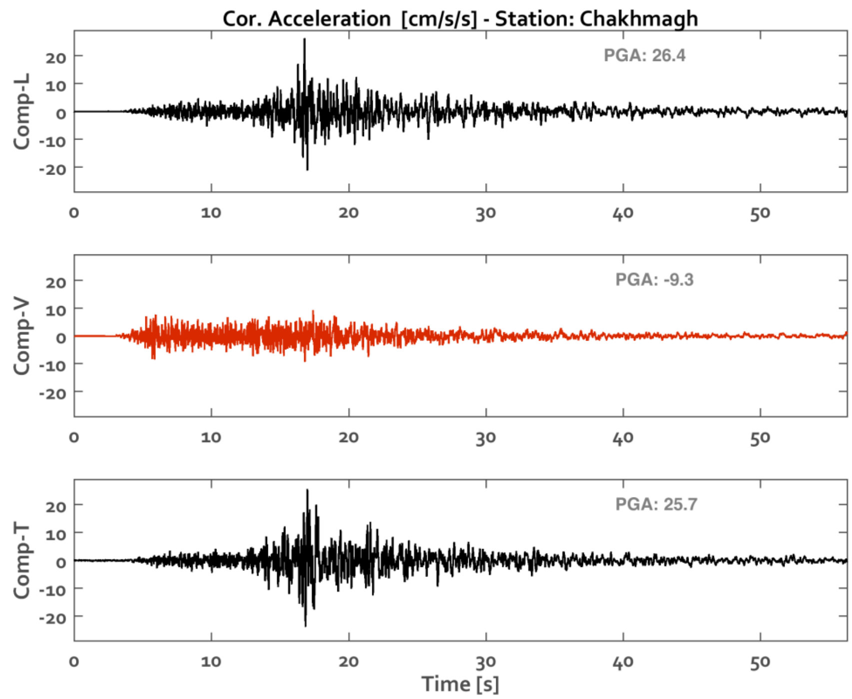
Acceleration response spectra at Fariman station.



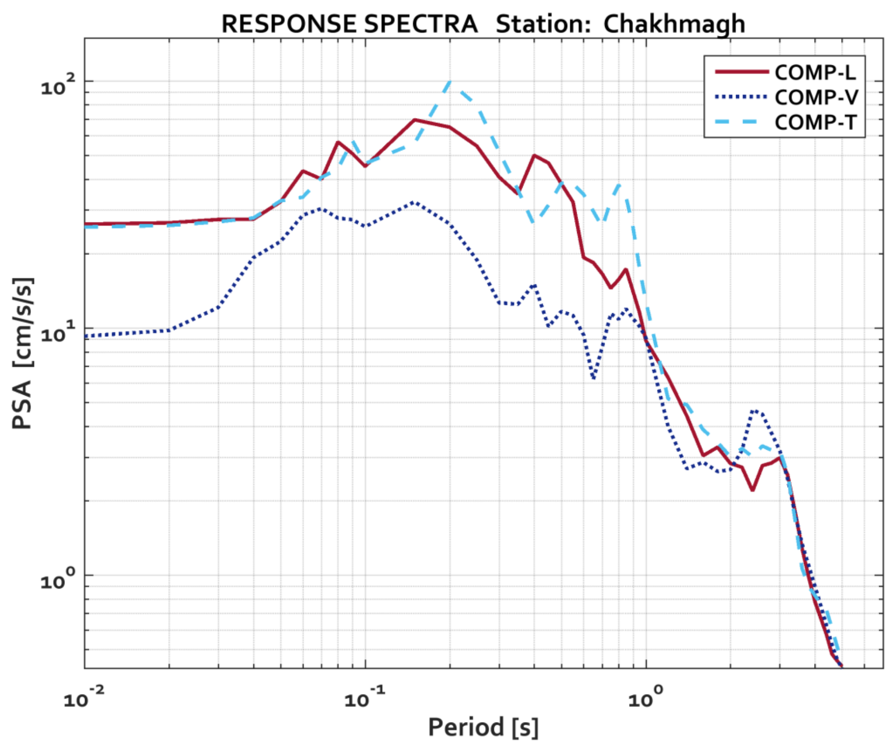
Corrected acceleration time history at Mashhad3 station.



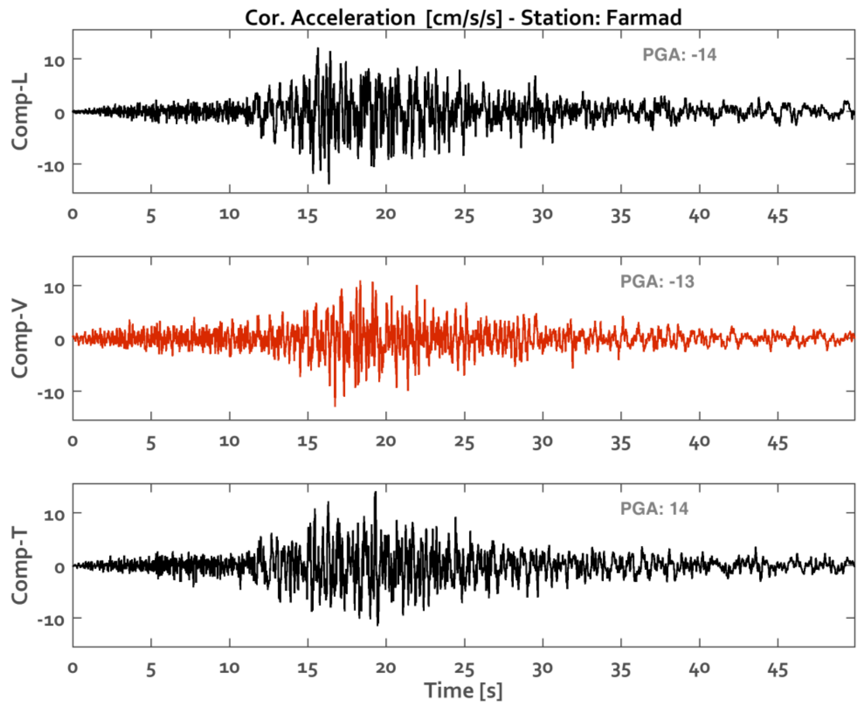
Acceleration response spectra at Mashhad3 station.



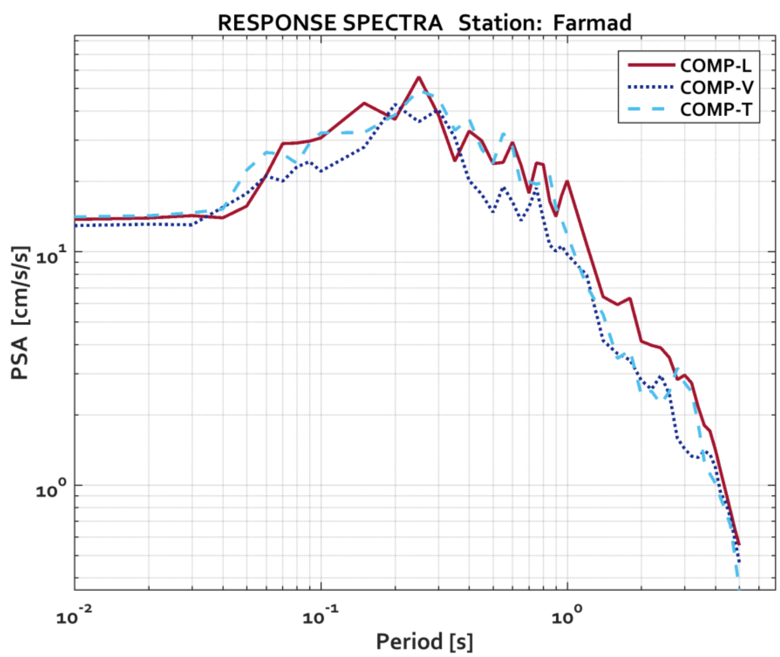
Corrected acceleration time history at Chakhmagh station.



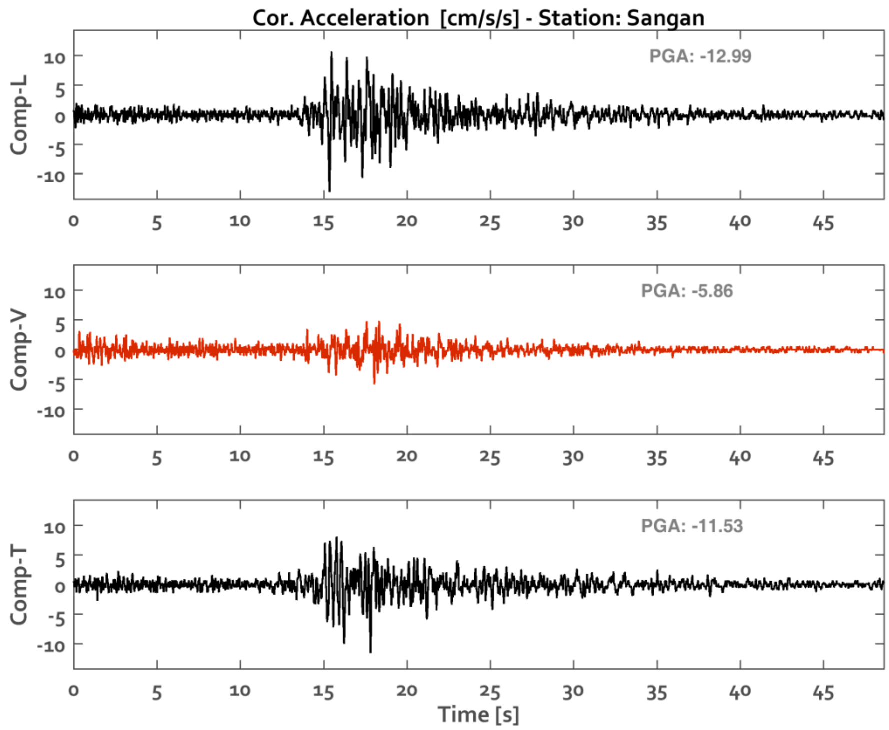
Acceleration response spectra at Chakhmagh station.



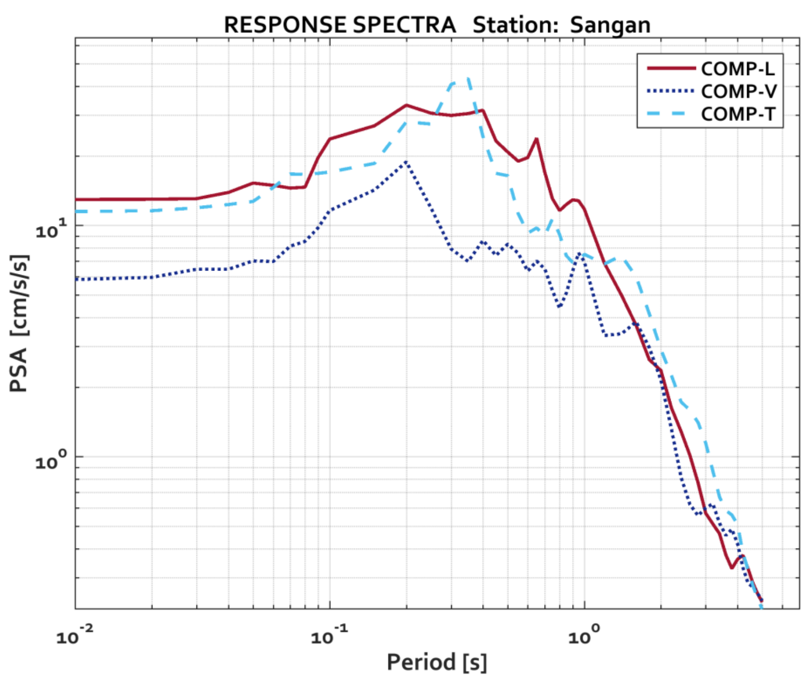
Corrected acceleration time history at Farmad station.



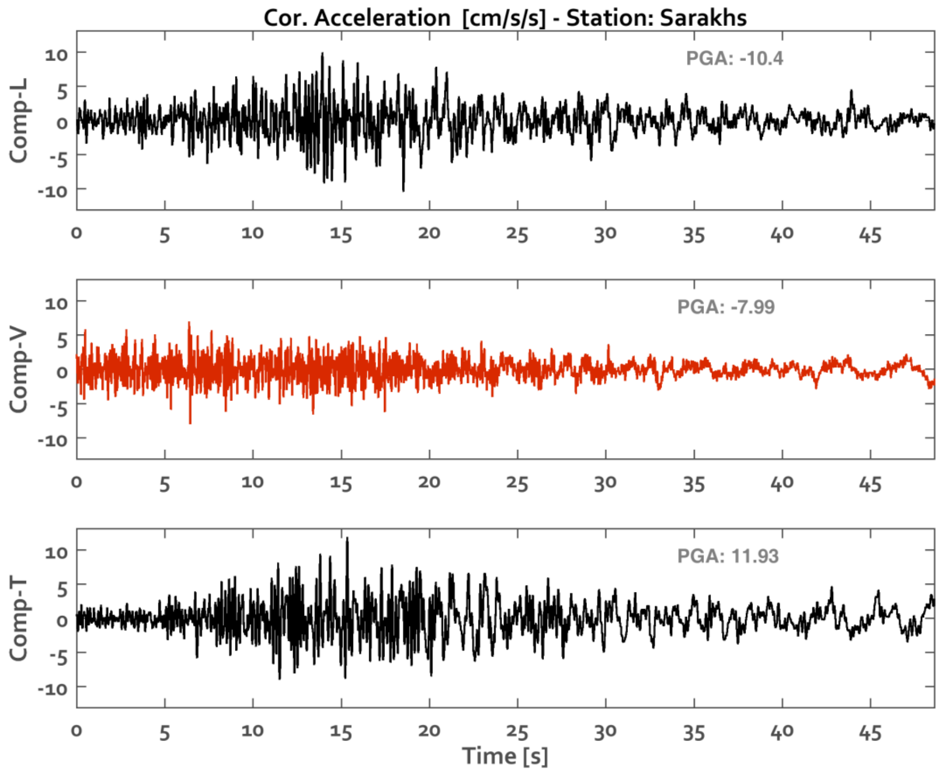
Acceleration response spectra at Farmad station.



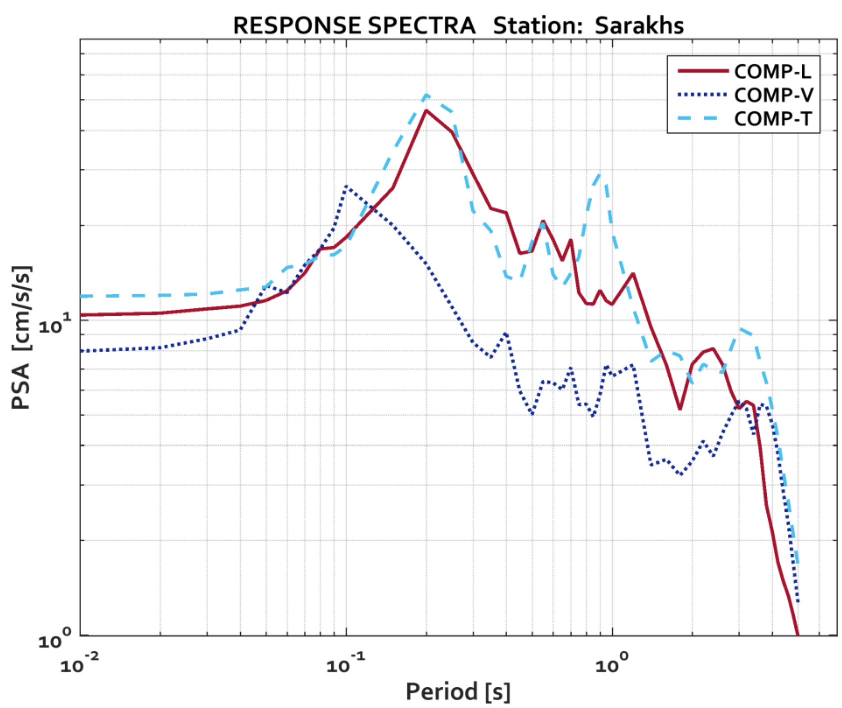
Acceleration response spectra at Sangan station.



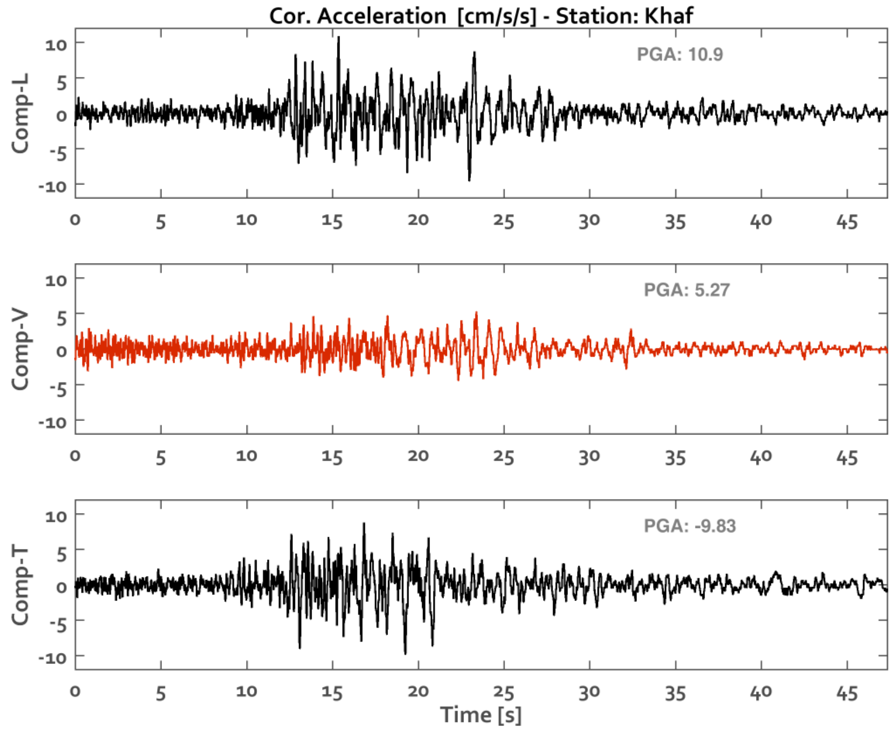
Acceleration response spectra at Sangan station.



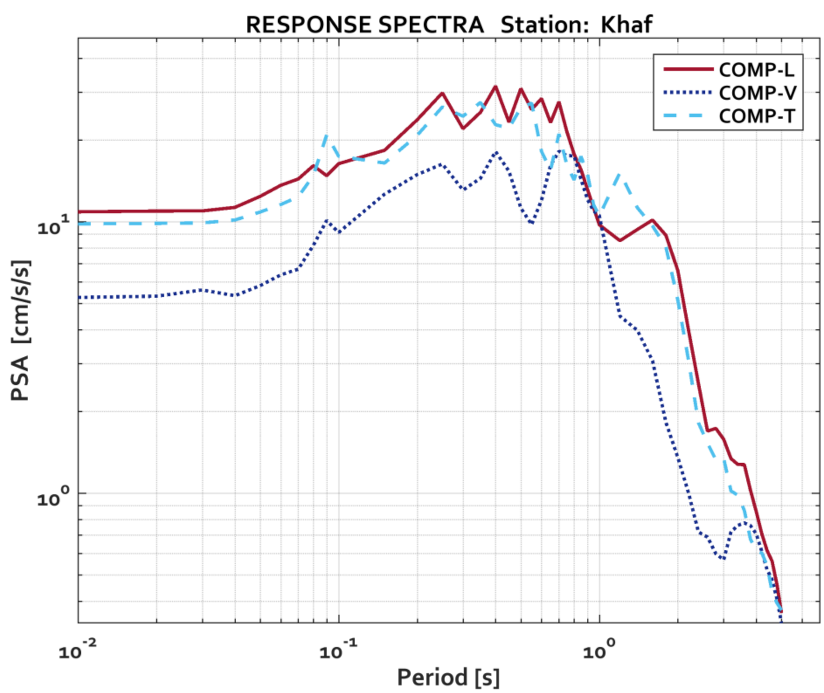
Acceleration response spectra at Sarakhs station.



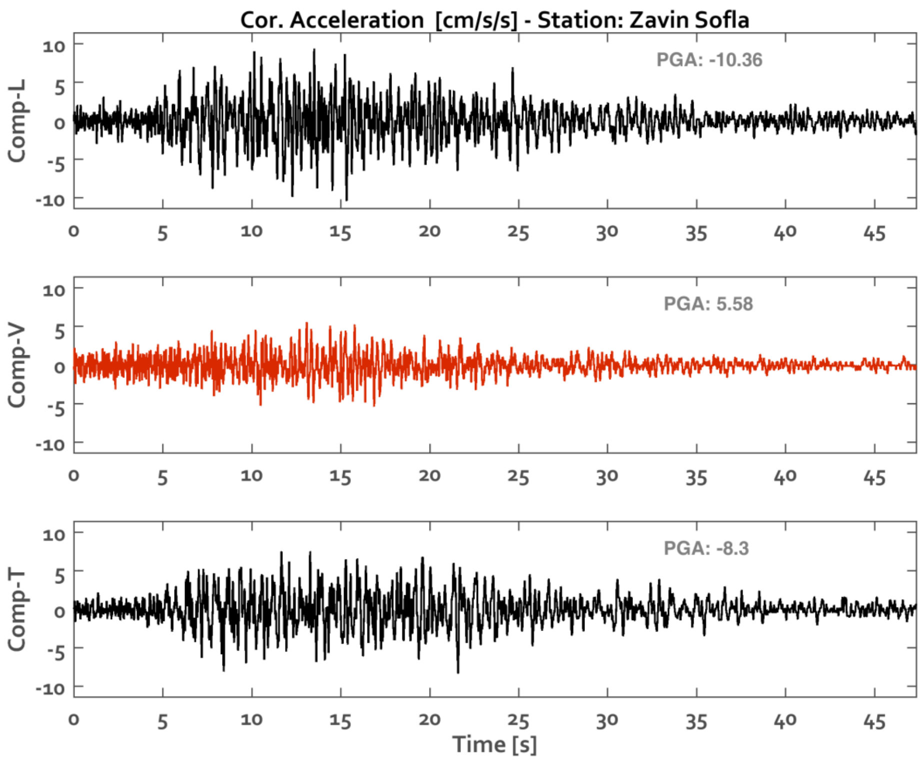
Acceleration response spectra at Sarakhs station.



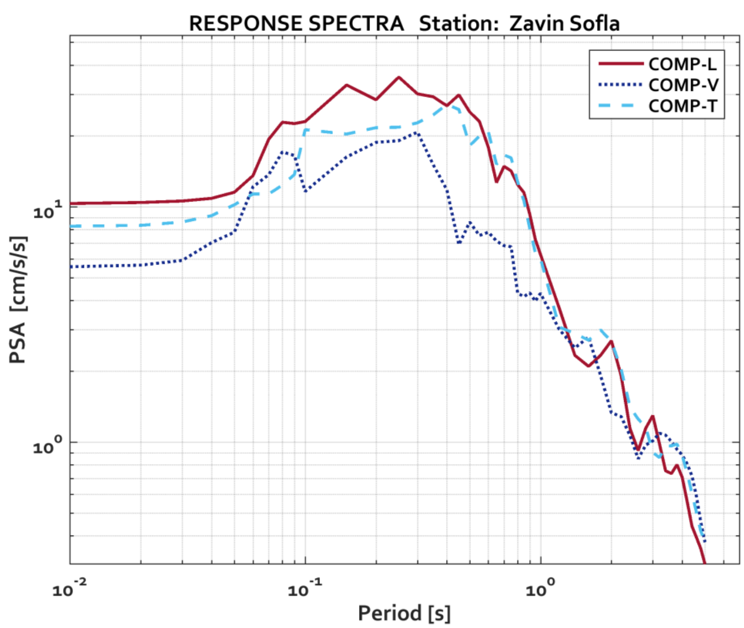
Acceleration response spectra at Khaf station.



Acceleration response spectra at Khaf station.



Acceleration response spectra at Zavin Sofla station.



Acceleration response spectra at Zavin Sofla station.