Report on Doublet Earthquakes of November 14th, 2021 – Finn, Hormozgan Province

Road, Housing & Urban Development Research Center, BHRC

Iran Strong Motion Network

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1. Introduction

Two powerful earthquakes occurred about a minute apart with epicenters around the small town of Finn, north of Bandar Abbas, Hormozgan province on November 14, 2021. IRAN Strong Motion Network (ISMN) calculated the moment magnitude (Mw) of the first and second event as 6.1 and 6.3 respectively. These two events were felt in nearby provinces as well as the countries bordering the Persian Gulf. Unfortunately, these earthquakes left one death, dozens of injurers and a lot of damage to the infrastructure of the surrounding region. ISMN recorded several records of these two events, whit the peak ground acceleration (PGA) about 567 cm/s^2 recorded at Siahoo station, 15 km from the epicenter. Several aftershocks were reported in the following hours and days, that largest one had magnitude of Mn5.0 so far (IRSC).

The first earthquake on November 14, 2021, at 12:07:04 (UTC), was reported by various agencies. The Iranian Seismological Center (IRSC), reported magnitude of this event as Mn6.4, while the US Geological Survey (USGS) and ISMN reported its moment magnitude (Mw) as 6.0 and 6.1 (Table 1).

Table 1. Earthquake information reported by various organizations (first earthquake)

Agency	**Magnitude**			**Depth (KM)**	**Epicenter Location Coordinate**		**Date**	
	Mw	**Mb**	**Mn**		**E**	**N**	**h:m:s**	**D/M/Y**
BHRC	6.1			16	56.19	27.65	12:07:04	November 14, 2021
IRSC			6.4	15	56.132	27.557	12:07:04	
USGS	6.0			6	56.06	27.71	12:07:03	

The second earthquake of November 14, 2021, Finn, which occurred at 12:08:38 (UTC), was reported by various agencies as well. The IRSC, reported its magnitude as Mn6.4, while the USGS and ISMN estimated its magnitude as Mb6.3 and Mw6.3 respectively (Table 2).

Table 2. Earthquake information reported by various organizations (second earthquake)

Agency	Magnitude			Depth (KM)	Epicenter Location Coordinate		Date	
	Mw	Mb	Mn		E	N	h:m:s	D/M/Y
BHRC	6.1			16	56.21	27.69	12:08:38	November 14, 2021
IRSC			6.3	15	56.13	27.56	12:08:38	
USGS		6.3		10	56.07	27.73	12:08:38	

Due to the seismicity, tectonic, demographic and economic characteristics of Hormozgan province, it has a special situation in Iran. For example, the city of Bandar Abbas is one of the most important economic centers in the country. Also the existence of many main ports, Bandar Abbas refinery and hundreds of other economic centers have made this city one of the most important provincial centers of the country. Currently, ISMN has 49 digital strong motion stations in this province that have been installed throughout the cities and villages of the province. 37 stations have SSA-2 (Kinemetrics) accelerometers and 12 stations have modern Fortis-Minimus (Guralp) accelerometers. A number of old instruments in Hormozgan province have been replaced with a new generation of Fortis-Minimus accelerometers in past three years, and this operation continues. These devices can send the recorded information to the central server as fast as possible using mobile communication platform (Figure 1).

Figure 1. Fortis-Minimus accelerometers used in ISMN stations.

These doublet earthquakes have been recorded by 26 SSA-2 and Guralp strong motion stations of ISMN (Figure 2).

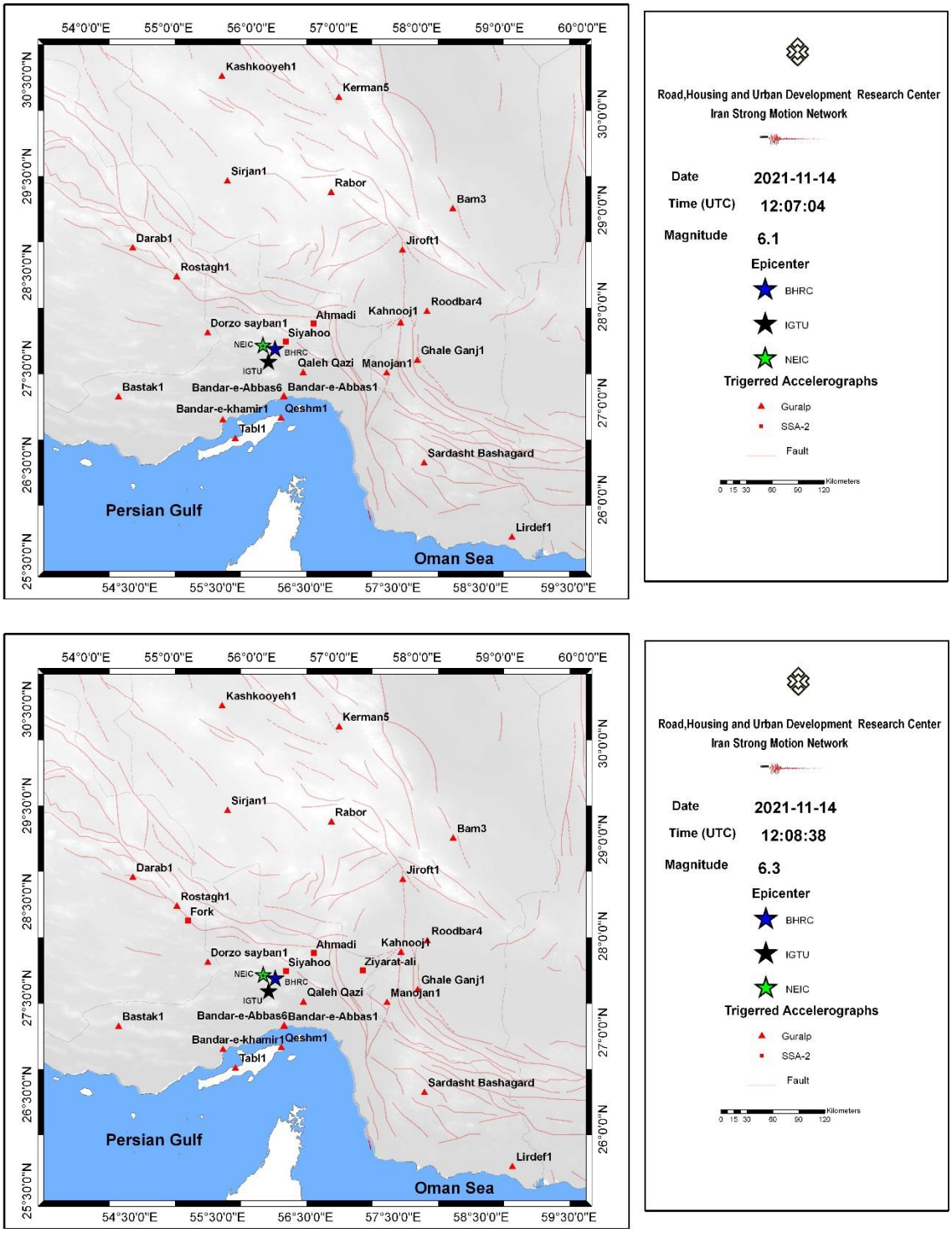


Figure 2 Map of the ISMN recording stations for the first (up) and the second (bottom) earthquake along with the epicenters reported by different agencies.

The recorded time histories along with the acceleration response spectra of these two earthquakes are presented in the Appendix.

The PGA in both earthquakes was recorded at Siahoo station as 369 cm/s^2 for the first earthquake and 565 cm/s^2 for the second earthquake respectively. Out of these 26 stations that recorded these events, 22 stations were equipped with the new generation instruments, Fortis-Minimus accelerometer (Figure 2). Due to their higher dynamic range and frequency characteristics, these new accelerometers are able to record earthquakes at a larger distance than older instruments, so as it can be seen in the Figure 2, some long-distance stations have also recorded these events (Tables 3, 4 and 5).

Table 2. List of the recording stations.

No	Station	Province	Type	Coordinate		Sea Level (m)	Azimut		Installation status
				E	N		L	T	
1	Siyahoo	Hormozgan	SSA-2	56.335	27.759	607	0	90	Free Field
2	Qaleh Qazi	Hormozgan	Guralp	56.531	27.430	42	0	90	Free Field
3	Bandar-e-Abbas1	Hormozgan	Guralp	56.300	27.191	-17	0	90	Free Field
4	Bandar-e-Abbas6	Hormozgan	Guralp	56.297	27.181	1	0	90	Free Field
5	Ahmadi	Hormozgan	SSA-2	56.666	27.939	959	0	90	Free Field
6	Fork	Fars	SSA-2	55.197	28.302	898	0	90	Free Field
7	Ziyarat Ali	Hormozgan	SSA-2	57.229	27.745	455	270	360	Ground Floor
8	Dorzo sayban1	Fars	Guralp	55.424	27.861	711	0	90	Free Field
9	Qeshm1	Hormozgan	Guralp	56.261	26.963	26	0	90	Free Field
10	Tabl1	Hormozgan	Guralp	55.727	26.759	0.8	0	90	Free Field
11	Kahnooj1	Kerman	Guralp	57.686	27.916	524	0	90	Free Field
12	Roodbar4	Kerman	Guralp	57.999	28.025	493	0	90	Free Field
13	Manojan1	Kerman	Guralp	57.502	27.400	340	0	90	Free Field
14	Ghale Ganj1	Kerman	Guralp	57.865	27.521	403	0	90	Free Field
15	Bandar-e-khamir1	Hormozgan	Guralp	55.584	26.955	20	0	90	Free Field
16	Rostagh1	Fars	Guralp	55.070	28.447	1332	0	90	Free Field
17	Sirjan1	Kerman	Guralp	55.683	29.436	1734	0	90	Free Field
18	Jiroft1	Kerman	Guralp	57.737	28.671	725	0	90	Free Field
19	Bastak1	Hormozgan	Guralp	54.378	27.204	422	0	90	Free Field
20	Kerman5	Kerman	Guralp	57.038	30.279	1773	0	90	Free Field
21	Rabor	Kerman	Guralp	56.914	29.292	2328	0	90	Free Field
22	Sardasht Bashagard	Hormozgan	Guralp	57.898	26.454	735	0	90	Free Field
23	Darab1	Fars	Guralp	54.551	28.749	1145	0	90	Free Field
24	Kashkooyeh1	Kerman	Guralp	55.638	30.525	1455	0	90	Free Field
25	Lirdef1	Hormozgan	Guralp	58.871	25.649	35	0	90	Free Field
26	Bam3	Kerman	Guralp	58.351	29.080	1034	0	90	Free Field

Table 4 Recorded accelerograms of the first earthquake.

No	Station	Record No.	E. D. (Km) (BHRC)	PGA (cm/s/s)		
				L	T	V
1	Siyahoo	9171/01	19	369	246	136
2	Qaleh Qazi	9169/01	42	51	61	41
3	Bandar-e-Abbas6	9151/01	53	35	27	25
4	Ahmadi	9146/01	57	30	28	16
5	Fork	9147	121	29	24	15
6	Bandar-e-Abbas1	9168/01	52	27	24	17
7	Qeshm1	9155/01	77	9	13	6
8	Manojan1	9161/01	132	10	11	4
9	Roodbar4	9163/01	183	11	8	3
10	Kahnooj1	9157/01	150	10	8	5
11	Tabl1	9167/01	109	7	5	3
12	Ghale Ganj1	9154/01	166	7	7	5
13	Dorzo sayban1	9153/01	79	4	6	4
14	Sirjan1	9166/01	205	4	5	3
15	Jiroft1	9156/01	189	4	4	3
16	Bandar-e-khamir1	9150/01	98	3	4	1
17	Kerman5	9158/01	304	2	3	1
18	Sardasht Bashagard	9165/01	215	3	2	2
19	Rostagh1	9164/01	141	2	2	1
20	Darab1	9152/01	202	2	2	1
21	Bam3	9148/01	265	2	2	1
22	Kashkooyeh1	9159/01	324	2	2	1
23	Rabor	9162/01	196	2	2	1
24	Lirdef1	9160/01	347	1	2	1
25	Bastak1	9149/01	186	1	1	1

Table 5. Recorded accelerograms of the second earthquake.

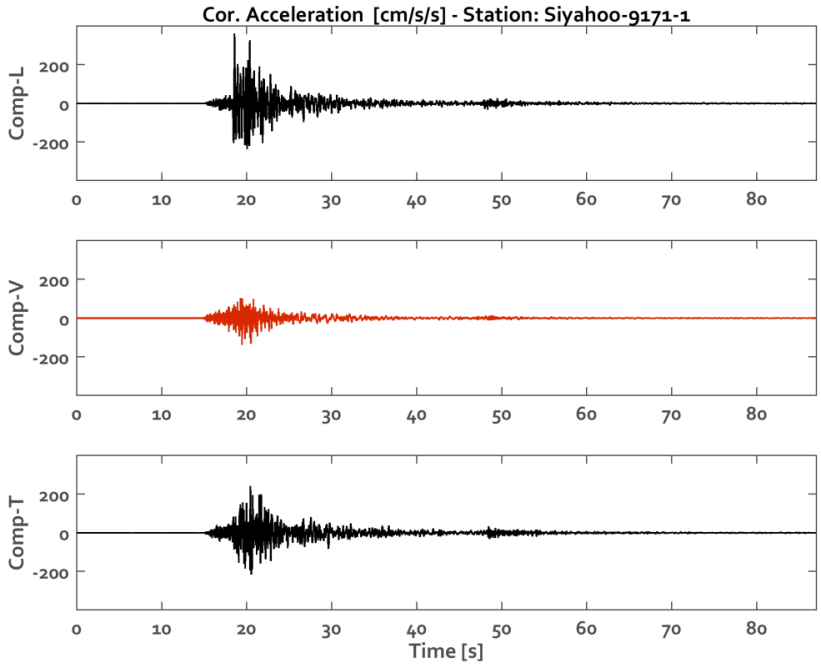
No	Station	Record No.	E. D. (Km) (BHRC)	PGA (cm/s/s)		
				L	T	V
1	Siyahoo	9171/02	15	373	565	257
2	Qaleh Qazi	9169/02	43	92	77	42
3	Bandar-e-Abbas1	9168/02	56	44	32	32
4	Bandar-e-Abbas6	9151/02	57	40	41	26
5	Ahmadi	9146/02	53	25	40	19
6	Ziyarat Ali	9145	100	8	16	4
7	Dorzo sayban1	9153/02	80	16	13	11
8	Qeshm1	9155/02	81	13	13	10
9	Tabl1	9167/02	114	9	10	5
10	Kahnooj1	9157/02	147	9	9	5
11	Roodbar4	9163/02	180	7	7	3
12	Manojan1	9161/02	131	7	7	3
13	Ghale Ganj1	9154/02	164	6	7	3
14	Bandar-e-khamir1	9150/02	103	6	7	3
15	Rostagh1	9164/02	140	6	5	3
16	Sirjan1	9166/02	201	4	5	3
17	Jiroft1	9156/02	185	4	3	2
18	Bastak1	9149/02	189	3	3	3
19	Kerman5	9158/02	299	2	3	1
20	Rabor	9162/02	191	3	2	2
21	Sardasht Bashagard	9165/02	216	2	2	2
22	Darab1	9152/02	201	2	2	1
23	Kashkooyeh1	9159/02	320	2	2	1
24	Lirdef1	9160/02	348	1	2	1
25	Bam3	9148/02	260	1	1	1

2. Recorded accelerograms at Siahoo station

Siaho station was the closest station to the epicenter of these earthquakes. It is installed as free field and is connected to the network center through a mobile communication system (Figure 3). This station is one of the active ISMN stations and has recorded 23 accelerograms since its installation until the Fin doublet earthquakes. The maximum PGA recorded at this station before these earthquakes was about 244 cm/s^2.

Figure 3. Siaho station with SSA2 digital accelerometer.

For first earthquake, the PGA on horizontal and vertical components are about 382 (L-component), 273 and 140 cm/s^2 respectively. The predominant period of this accelerogram on the longitudinal component was about 0.34 seconds and its significant duration was about 10 seconds. Figure 4 shows the recorded acceleration time histories and the response spectra of this record.



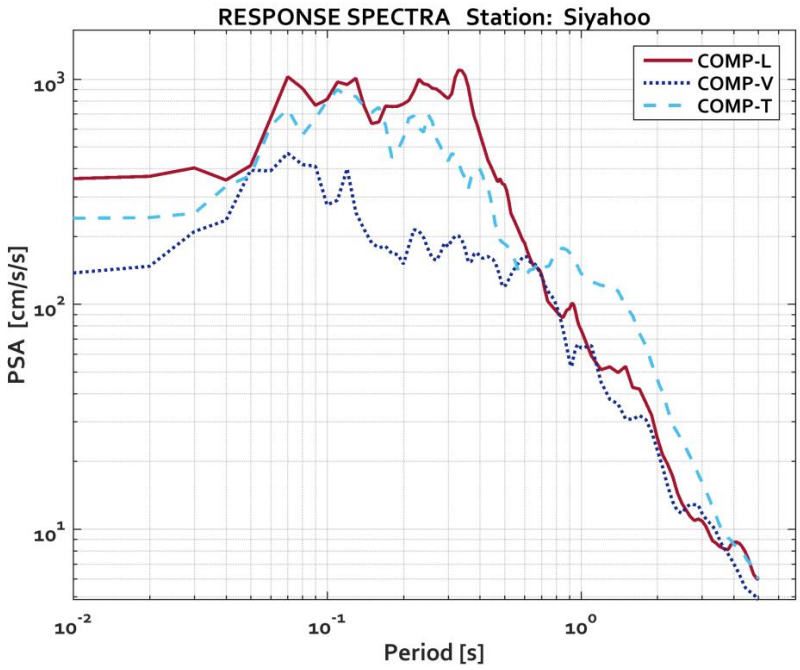


Figure 4. Recorded acceleration time histories (top) and acceleration response spectra of first earthquake at about 19 km epicentral distance.

Second earthquake at Siahoo station recorded a much higher acceleration. Record of the second earthquake at Siaho station was processed and showed a PGA value of 568 cm/s^2. This PGA was recorded on the transverse component (unlike the first record) of this station. The horizontal longitudinal, and the vertical components recorded PGAs of about 387 and 256 cm/s^2, respectively.

The predominant period of this accelerometer on the transverse component was about 0.1 second and its significant duration was about 11 seconds. Figure 5 shows the recorded acceleration time histories and the response spectra of this record.

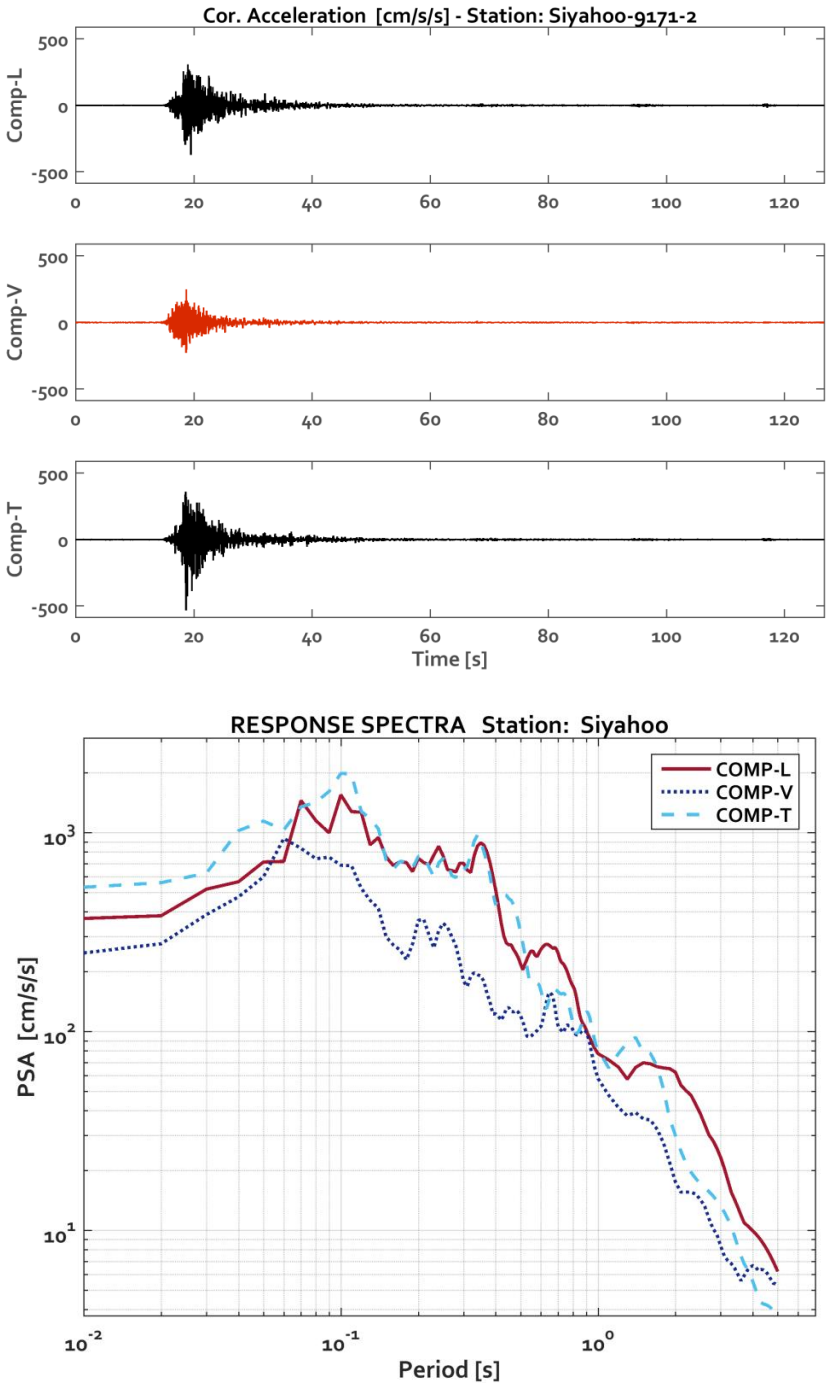


Figure 5. Recorded acceleration time histories (top) and acceleration response spectra of second earthquake at about 15 km epicentral distance.

The response spectra of the records at Siahoo station is also compared with the response spectra of national 2800 Standard in Figure 6.

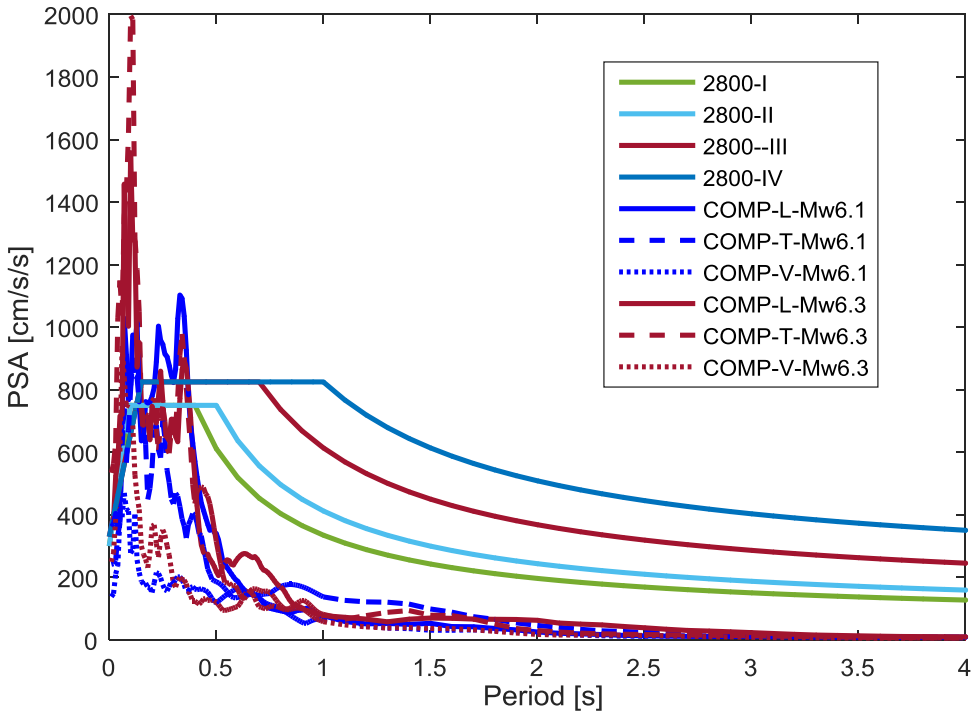


Figure 6. Comparison of the response spectra of Siahoo station with the spectra of national 2800 standard.

Obviously, the spectra at Siahoo station were equal to/or less than the values of the range of 2800 standard in the periods appropriate to the structures of Iran, which, was expected due to the magnitudes of the events.

3. Moment Magnitude Estimation

In this report the moment magnitude 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):

$$Mw = 2/3\log_{10}(M0) - 6.03 \qquad (1)$$

where the scalar moment, M0, is the seismic moment in N.m. The calculated Mw values for each station, along with other relevant records information are available in Tables 6 and 7 for the first and second earthquakes, respectively. The final estimated Mw is determined based on the

average of the Mw values at all recording stations, which are Mw6.1 and Mw6.3 for first and second earthquakes, respectively.

Table 6. The calculated Mw for each station along with other relevant record information for first earthquake.

Record No	**Station**	**Epicentral distance (km)**	**Mw**	**M0 (N.m)**	**Vs30 (m/s)**
9169-1	Qaleh Qazi	42.06	6.12	1.73E+18	not available
9168-1	Bandar-e-Abbas1	44.396	6.23	2.46E+18	not available
9151-1	Bandar-e-Abbas6	45.256	6.28	2.91E+18	not available
9146-1	Ahmadi	67.37	5.95	9.59E+17	528
9155-1	Qeshm1	67.74	6.29	3.02E+18	757
9153-1	Dorzo sayban1	77.23	6.06	1.39E+18	not available
9150-1	Bandar-e-khamir1	86.33	5.92	8.53E+17	679
9167-1	Tabl1	97.73	6.33	3.56E+18	931
9161-1	Manojan1	136.51	5.81	5.87E+17	not available
9164-1	Rostagh1	143.37	6.01	1.17E+18	514
9157-1	Kahnooj1	158.14	6.19	2.14E+18	156
9154-1	Ghale Ganj1	171.12	5.79	5.50E+17	683
9149-1	Bastak1	177.58	5.81	5.84E+17	not available
9163-1	Roodbar4	190.95	6.29	3.08E+18	not available
9156-1	Jiroft1	200.10	6.14	1.84E+18	343
9152-1	Darab1	203.57	6.39	4.35E+18	not available
9162-1	Rabor	207.25	6.42	4.91E+18	not available
9165-1	Sardasht Bashagard	214.01	6.06	1.41E+18	not available
9148-1	Bam3	275.22	5.97	1.03E+18	not available
9160-1	Lirdef1	345.61	6.11	1.65E+18	not available
Average			6.11	1.64424E+18	

Table 7. The calculated Mw for each station along with other relevant record information for second earthquake.

Record No	Station	Epicentral distance (km)	Mw	M0 (N.m)	Vs30 (m/s)
9169-2	Qaleh Qazi	42.06	6.24	2.55E+18	not available
9168-2	Bandar-e-Abbas1	44.40	6.10	1.61E+18	not available
9151-2	Bandar-e-Abbas6	45.25	6.33	3.51E+18	not available
9146-2	Ahmadi	67.37	6.07	1.42E+18	528
9155-2	Qeshm1	67.74	6.36	3.95E+18	757
9153-2	Dorzo sayban1	77.23	6.34	3.62E+18	not available
9150-2	Bandar-e-khamir1	86.33	6.26	2.71E+18	679
9167-2	Tabl1	97.73	6.73	1.39E+19	931
9161-2	Manojan1	136.51	5.91	8.31E+17	not available
9164-2	Rostagh1	143.37	6.31	3.33E+18	514
9157-2	Kahnooj1	158.14	6.21	2.31E+18	156
9154-2	Ghale Ganj1	171.12	5.88	7.51E+17	683
9149-2	Bastak1	177.58	6.41	4.62E+18	not available
9163-2	Roodbar4	190.95	6.39	4.34E+18	not available
9156-2	Jiroft1	200.10	6.25	2.65E+18	343
9152-2	Darab1	203.57	6.37	4.06E+18	not available
9162-2	Rabor	207.25	6.40	4.54E+18	not available
9166-2	Sirjan1	213.15	6.62	9.61E+18	355
9165-2	Sardasht Bashagard	214.01	6.03	1.26E+18	not available
9160-2	Lirdef1	345.62	6.29	3.06E+18	not available
Average			6.28	2.91151E+18	

4. Discussion and Conclusions

The Fin doublet earthquakes on November 14, 2021, in Bandar Abbas occurred in a part of the country that is seismically active and has numerous historical and recent earthquakes. Existence of many active faults such as Minab and Zagros faults in the Zagros seismic zone have made this region prone to the large earthquakes. Meanwhile, Bandar Abbas is one of the most important

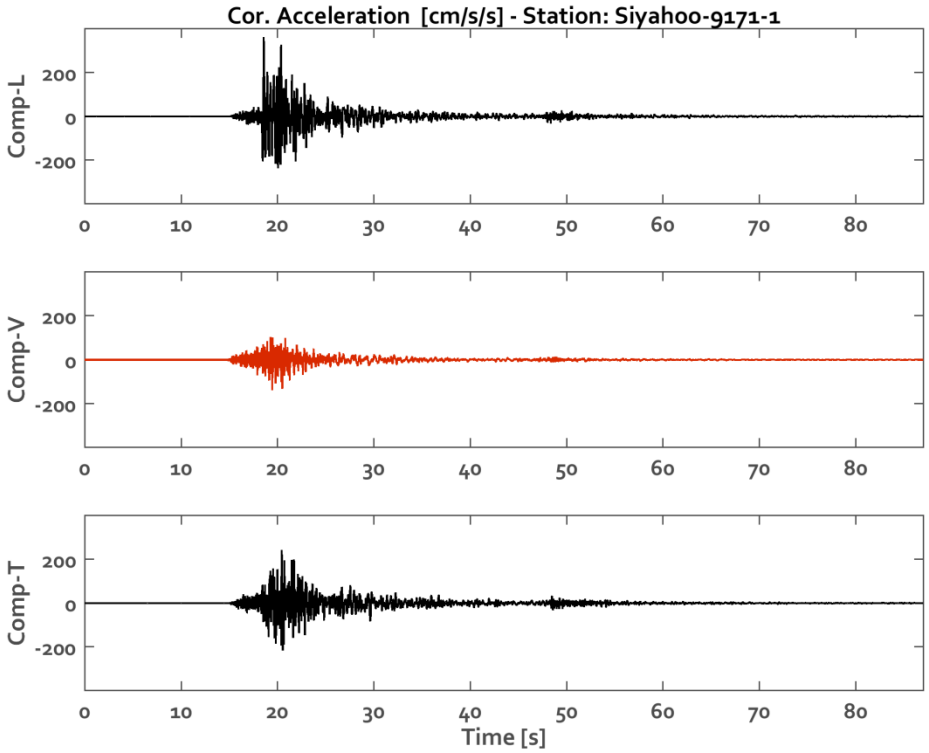
cities in the south of the country in terms of economy and population. The vulnerability of this city to large earthquakes can cause a lot of damage in probable future earthquakes.

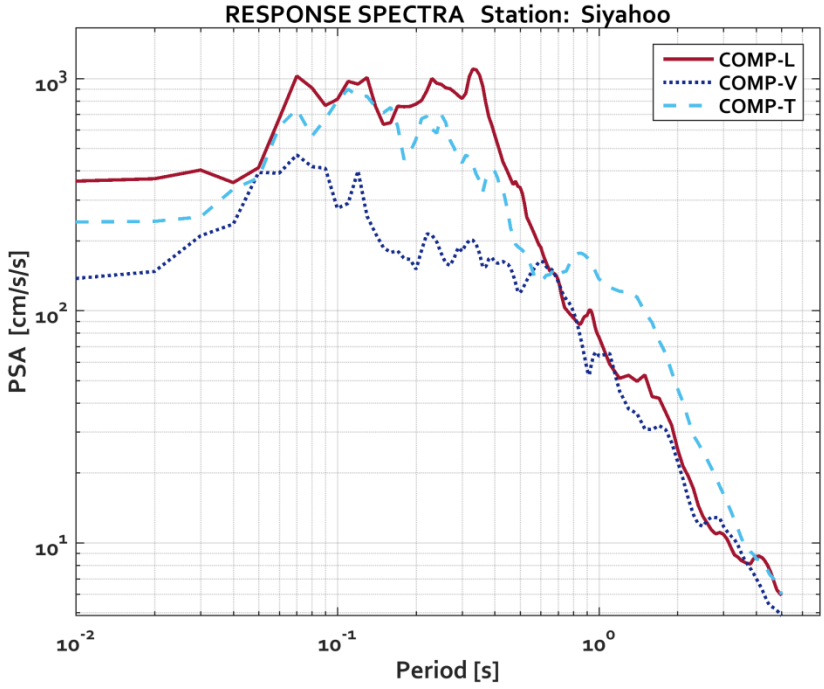
Undoubtedly, one of the main tools in earthquake risk reduction and crisis management is the design and development of the earthquake early warning (EEW) and rapid response (RR) systems. This must be done as soon as possible by allocating the appropriate budget and providing the necessary infrastructure for different seismically active regions of the country. Hormozgan province is one of the suitable options for designing the earthquake rapid response system, which can be implemented with a moderate budget and certainly, this will reduce the losses caused by the future earthquakes.

The perfect operation of the ISMN's fourth generation accelerometers in these earthquakes showed that the reconstruction and modernization of the network and the replacement of old instruments improve the recording of acceleration data from earthquakes. Furthermore, these modern instruments are vital elements for EEW and RR systems, therefore, these developing actions will lead to have a better earthquake risk reduction plans and crisis management operations in future.

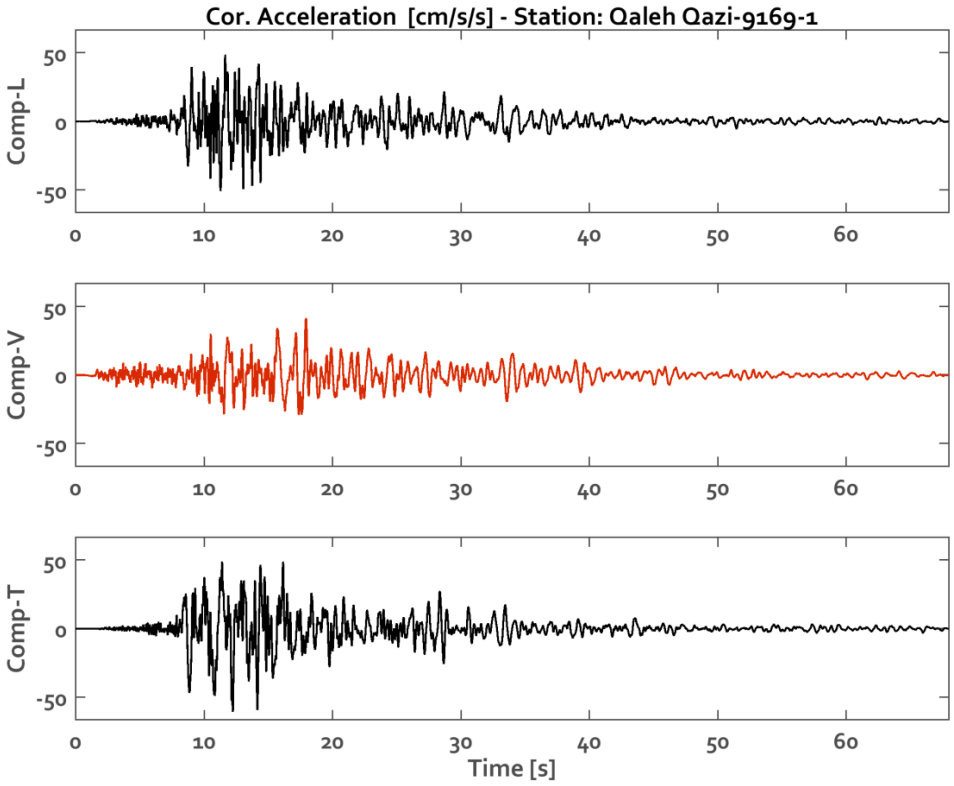
Appendix One

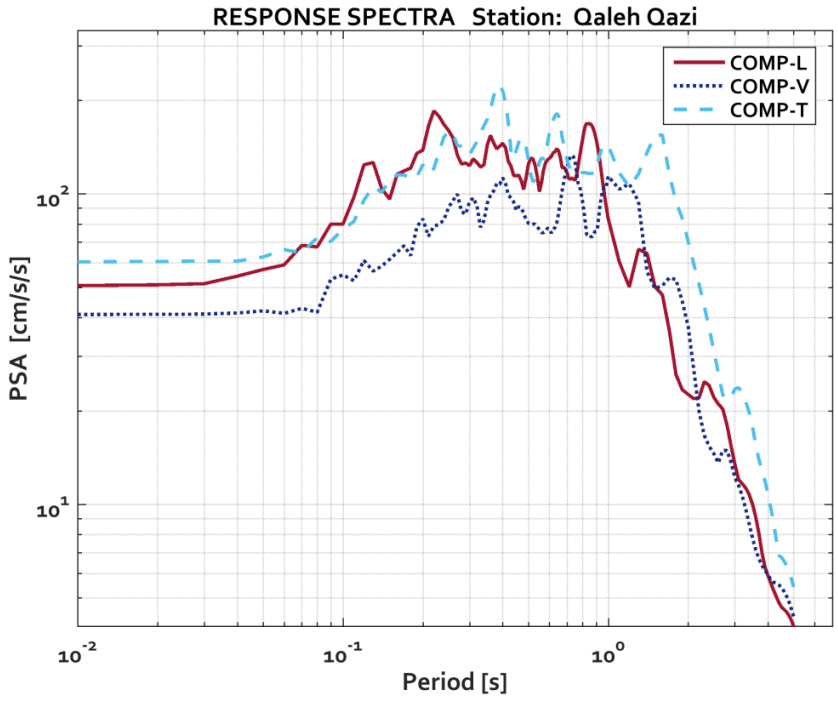
The recorded time histories along with the acceleration response spectra for the first earthquake.



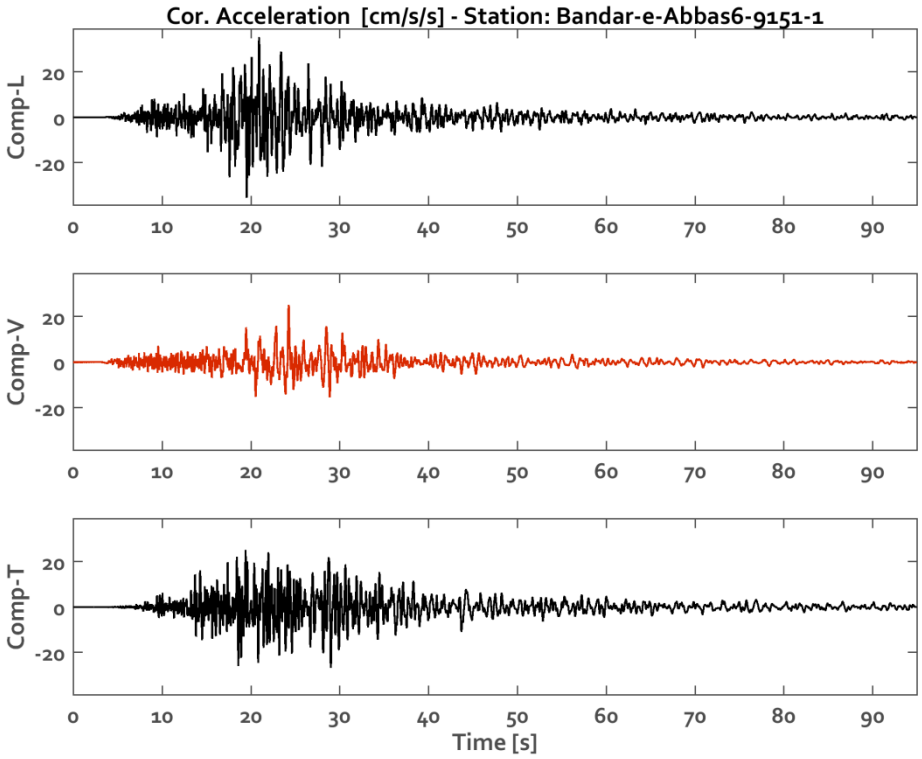


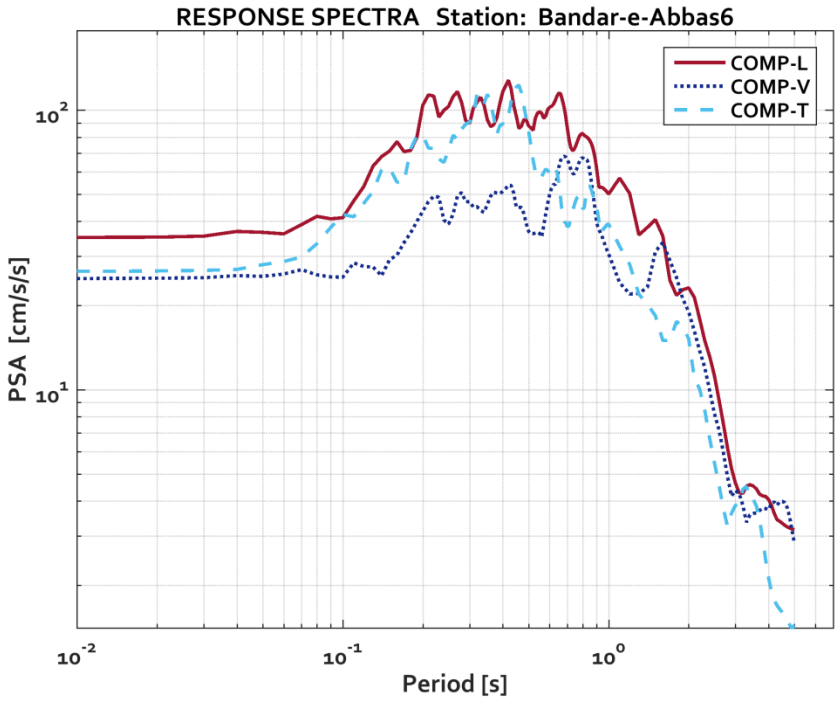
Recorded acceleration time histories and acceleration response spectra at Siyahoo station from first event.



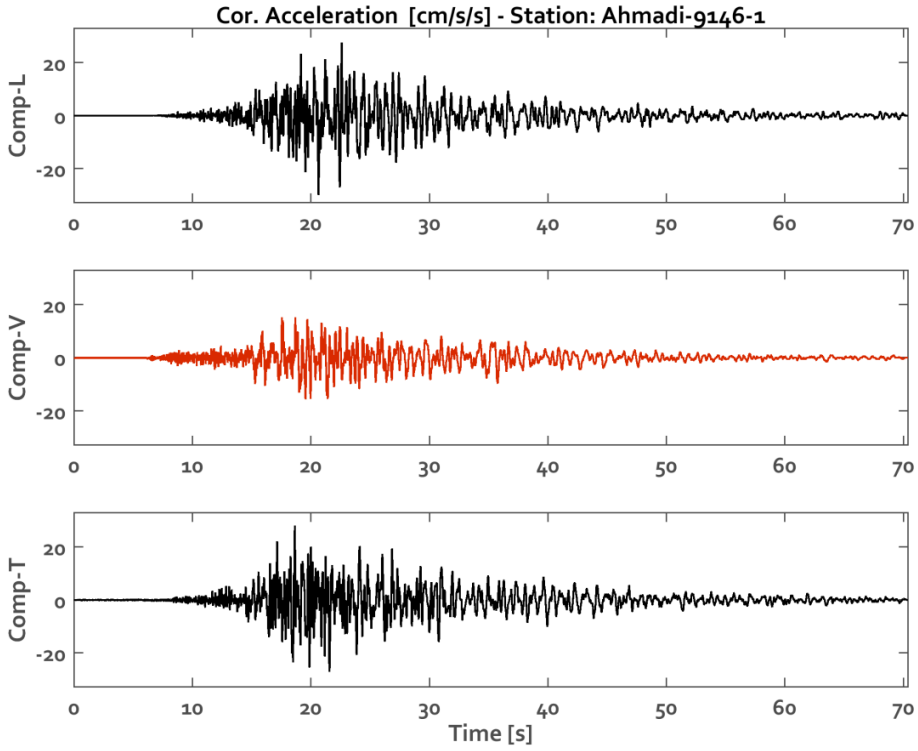


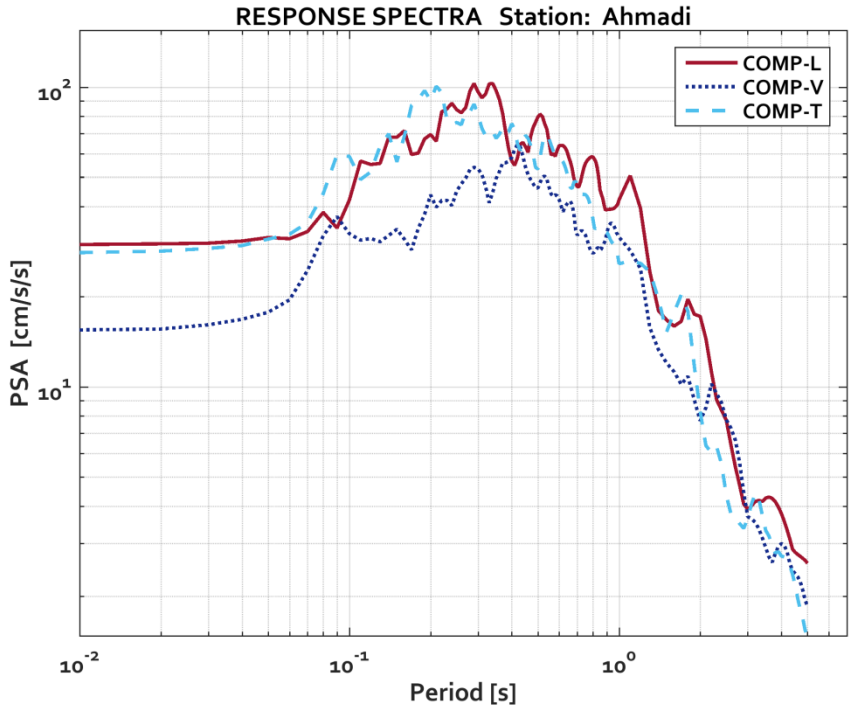
Recorded acceleration time histories and acceleration response spectra at Qaleh Qazi station from first event.



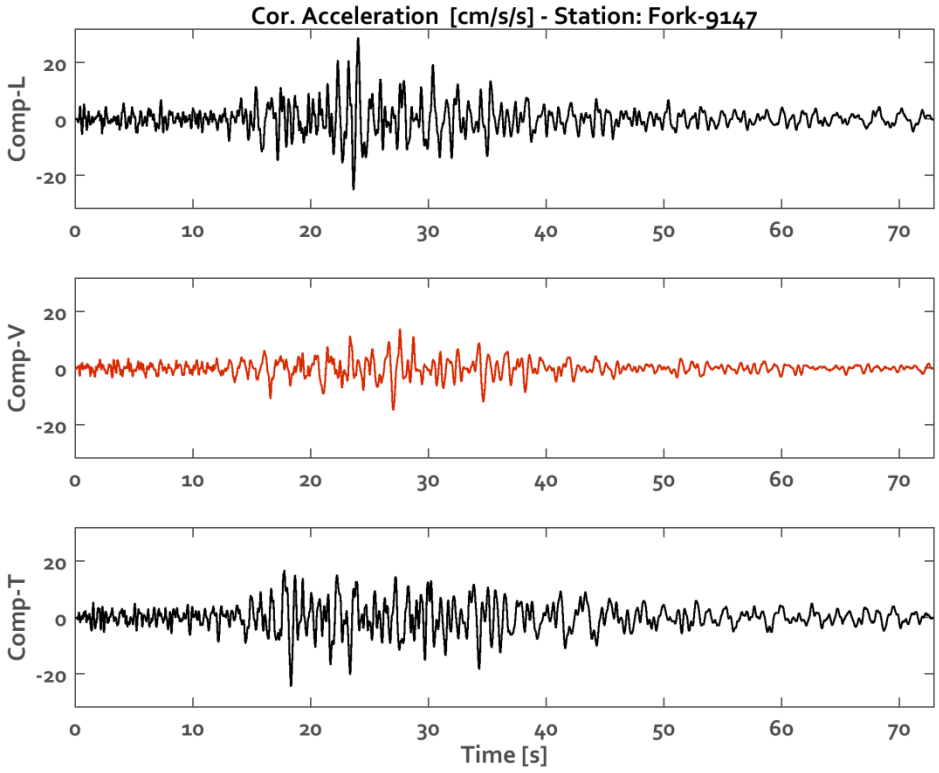


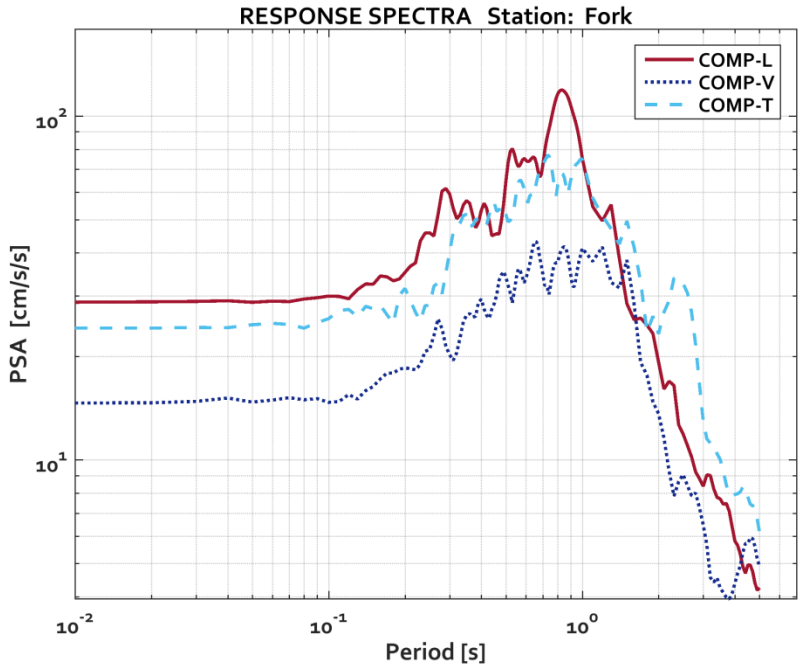
Recorded acceleration time histories and acceleration response spectra at Bandar-e-Abbas6 station from first event.



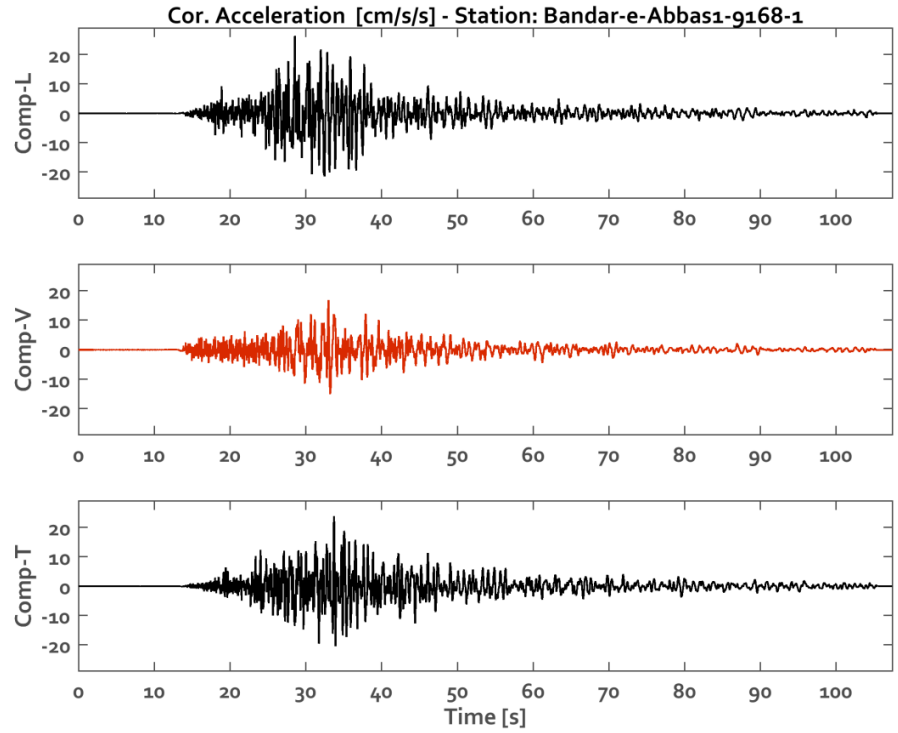


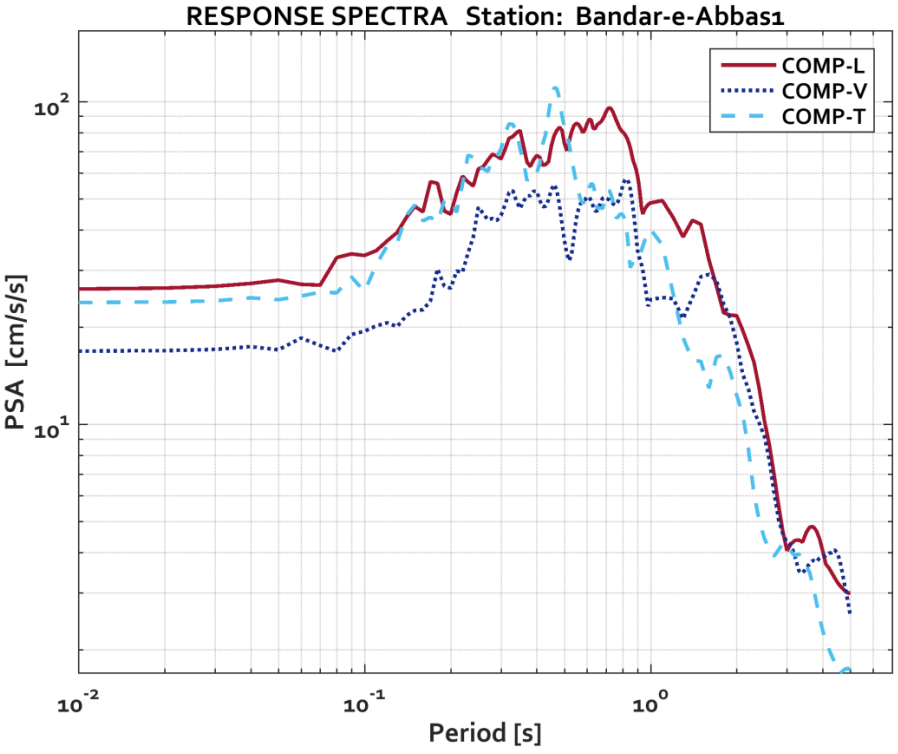
Recorded acceleration time histories and acceleration response spectra at Ahmadi station from first event.



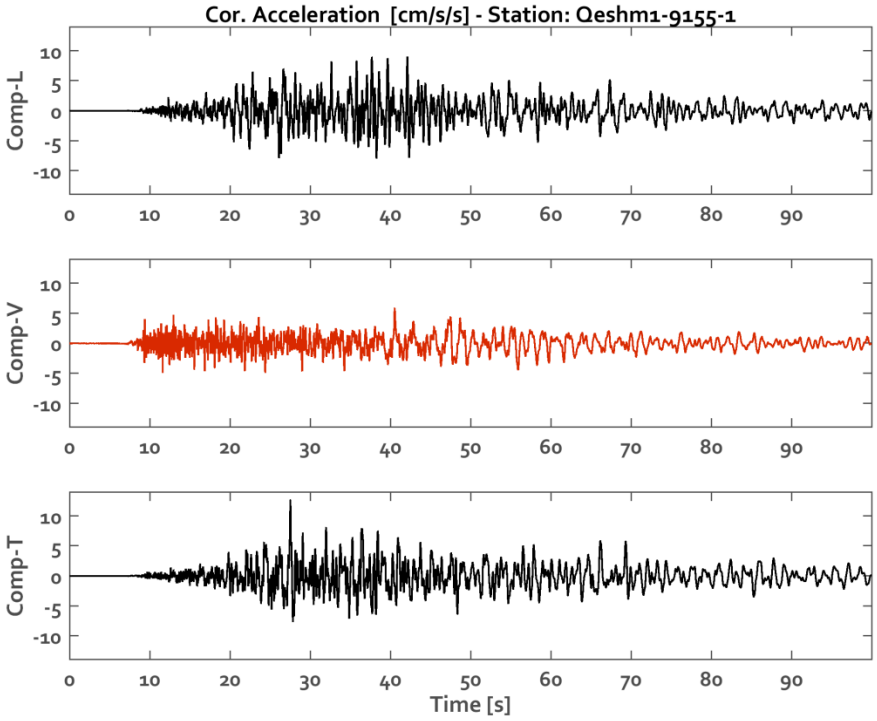


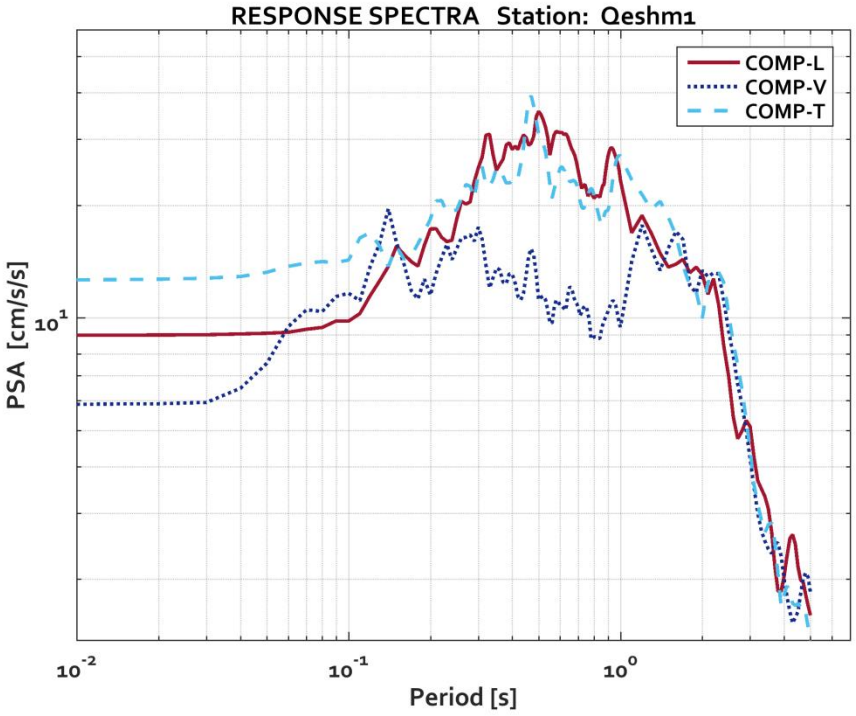
Recorded acceleration time histories and acceleration response spectra at Fork station from first event.



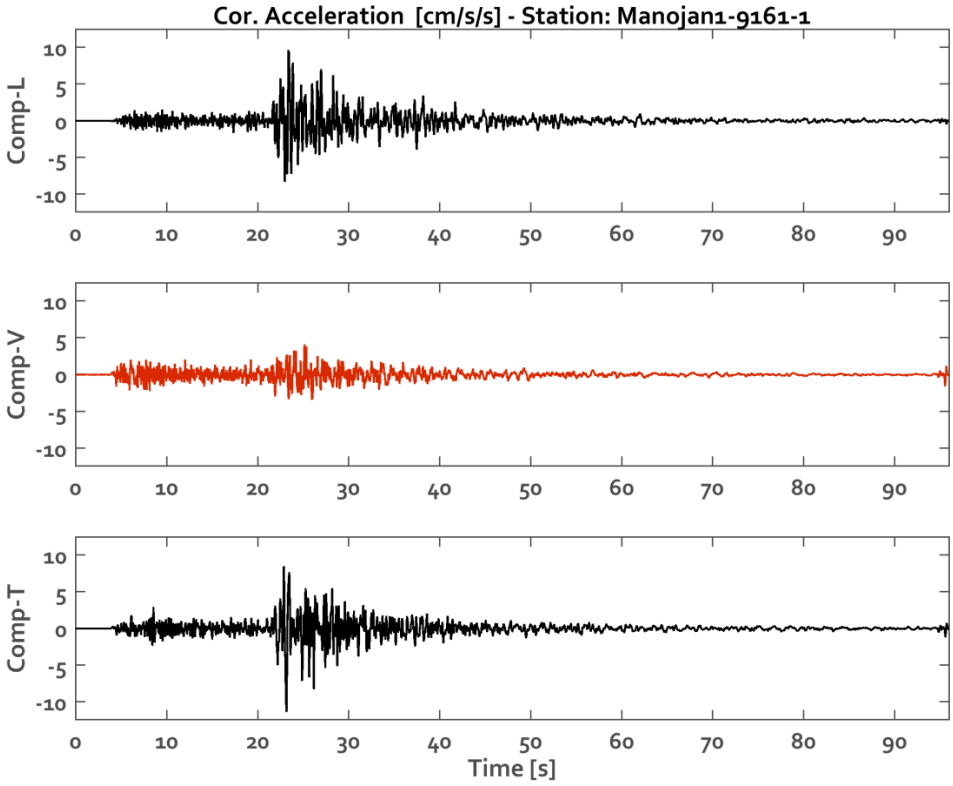


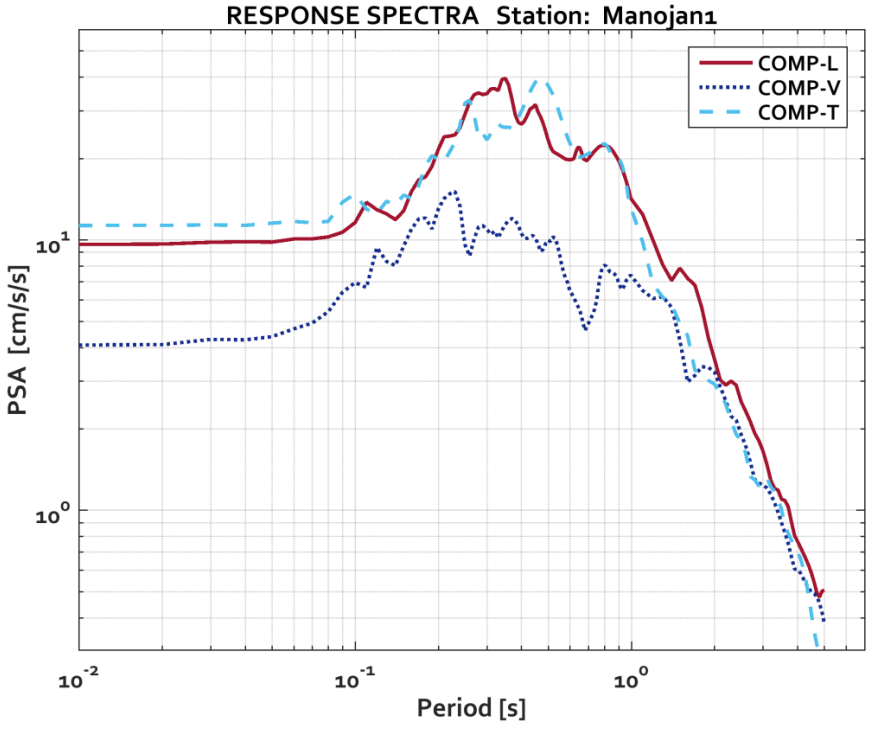
Recorded acceleration time histories and acceleration response spectra at Bandar Abbas1 station from first event.



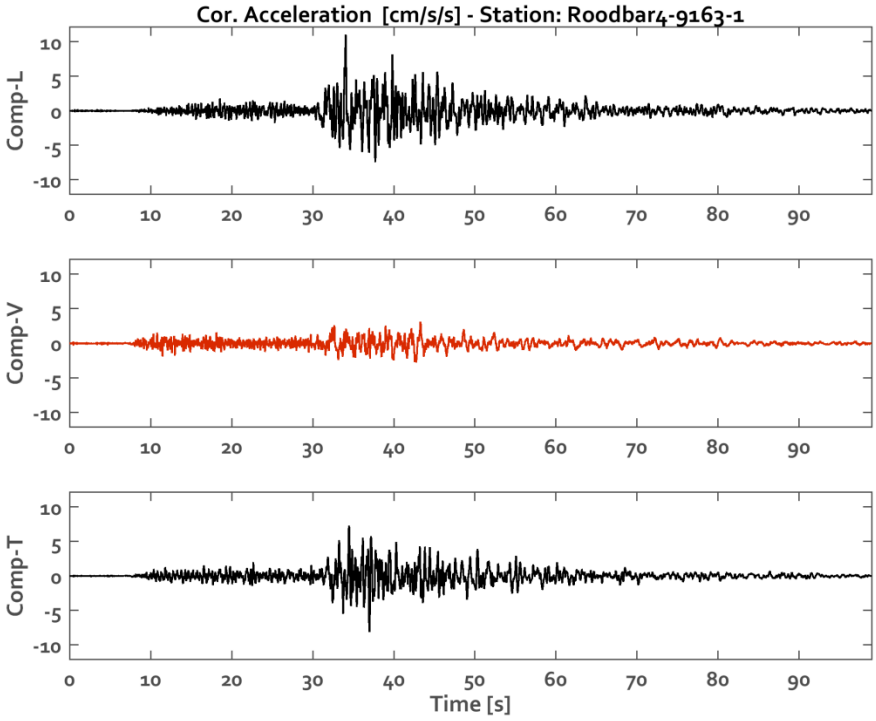


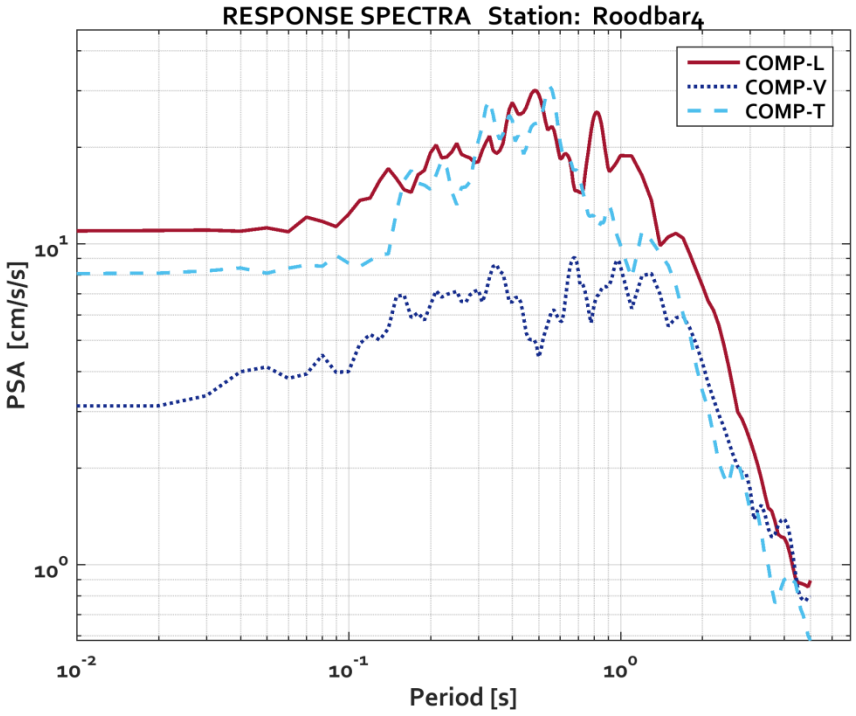
Recorded acceleration time histories and acceleration response spectra at Qeshm1 station from first event.



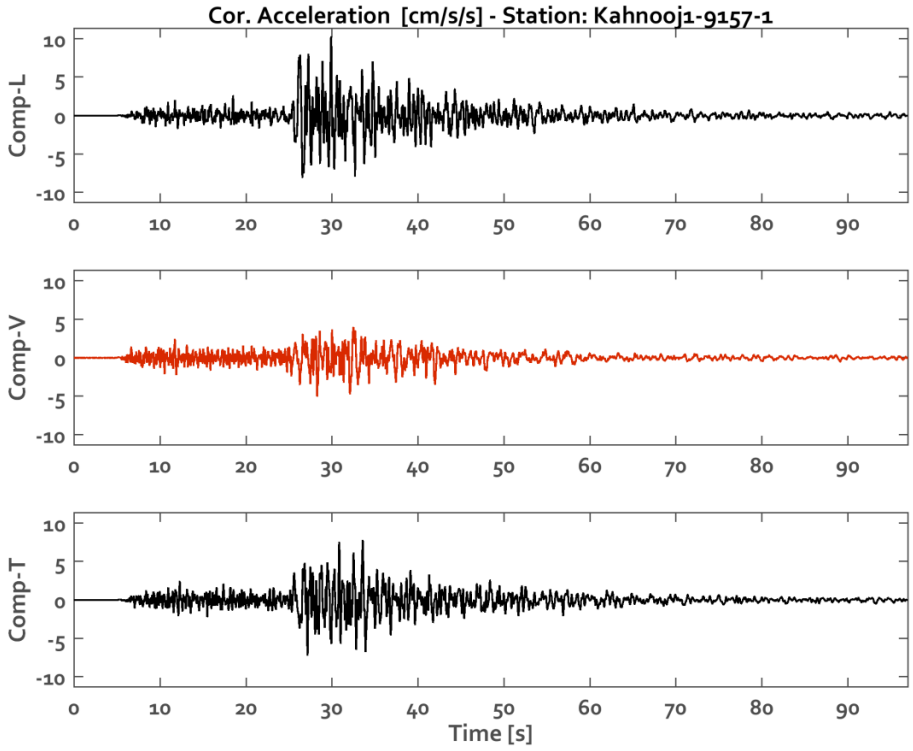


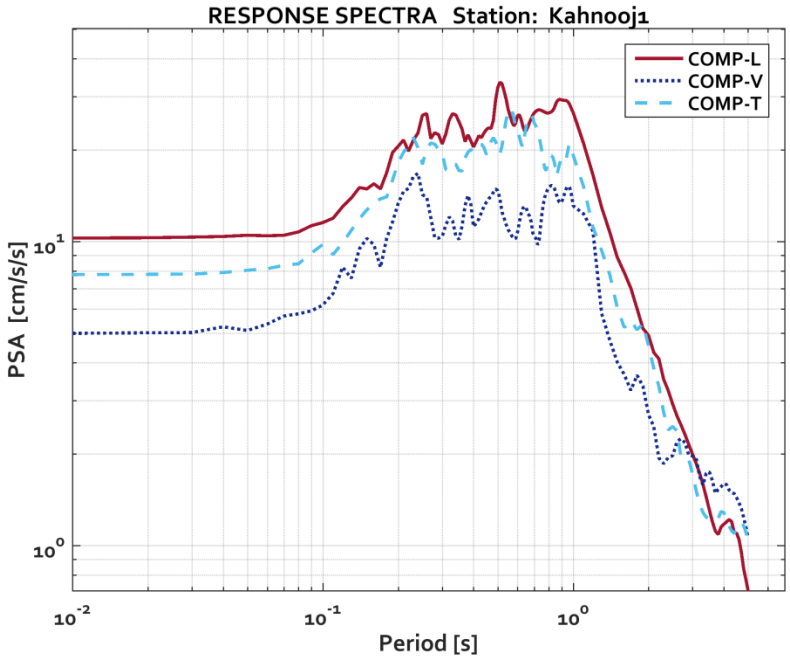
Recorded acceleration time histories and acceleration response spectra at Manojan1 station from first event.





Recorded acceleration time histories and acceleration response spectra at Roodbar4 station from first event.

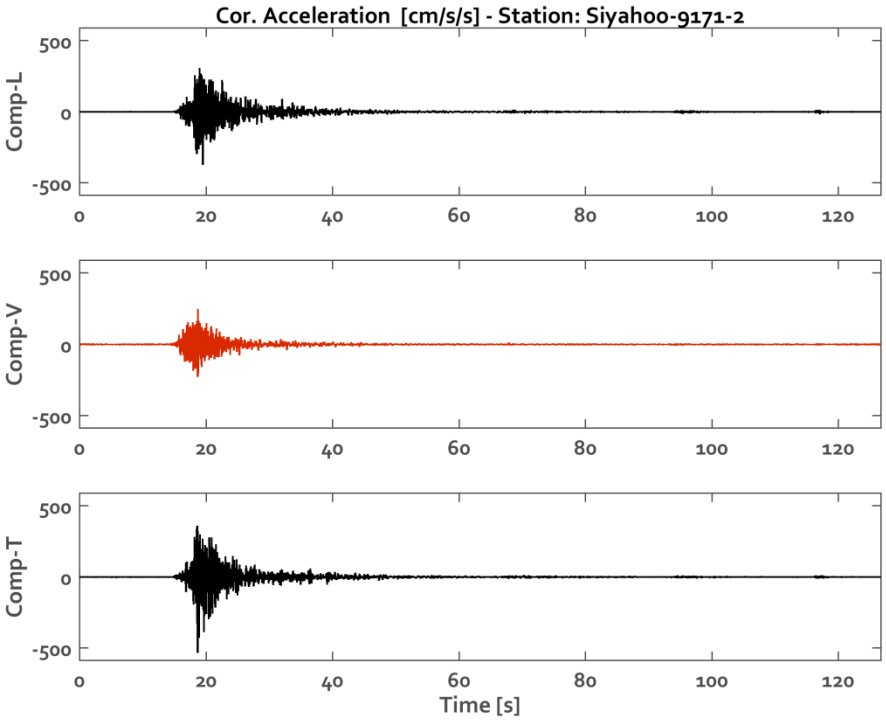


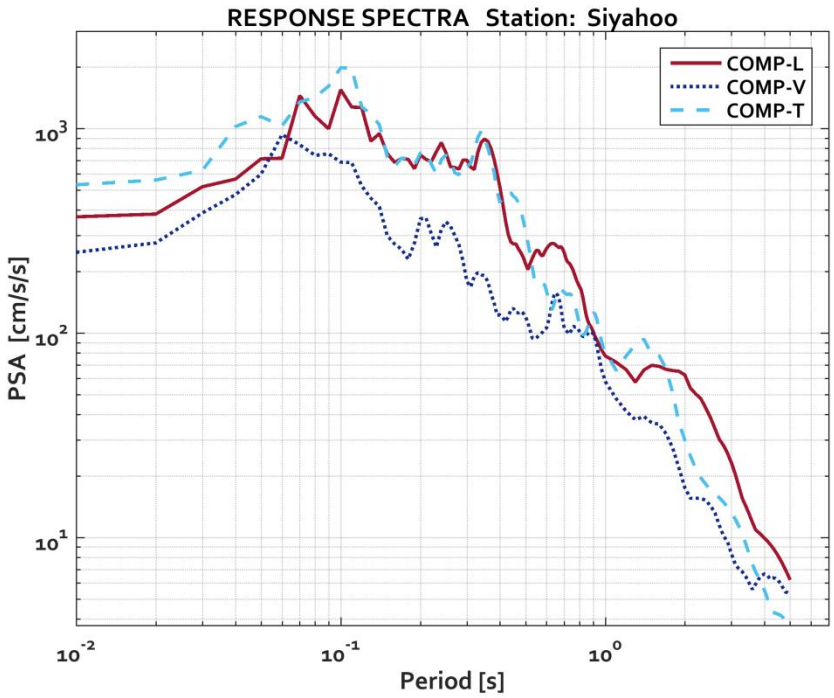


Recorded acceleration time histories and acceleration response spectra at Kahnooj1 station from first event.

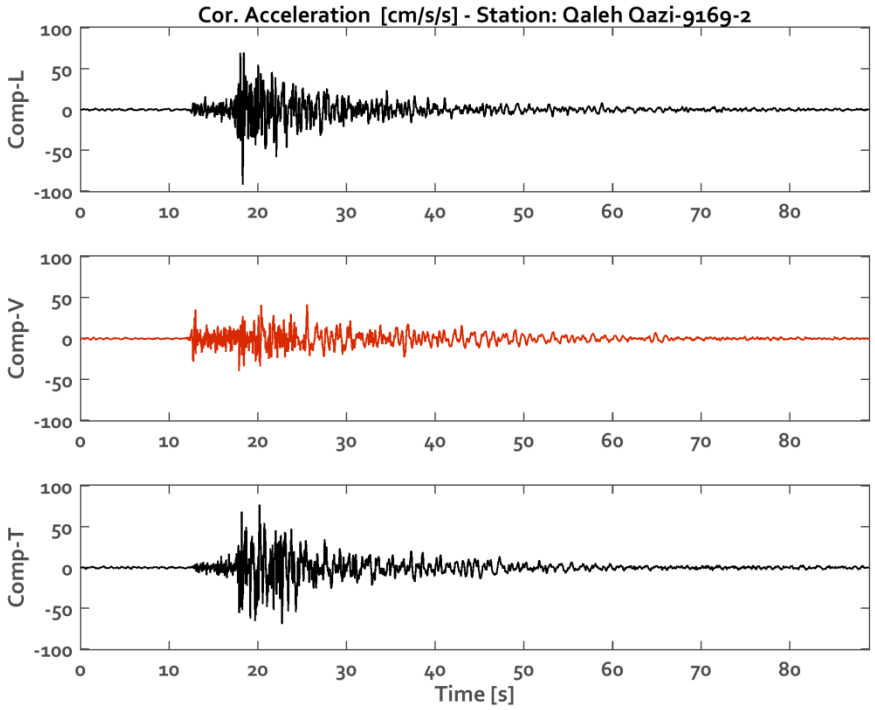
Appendix two

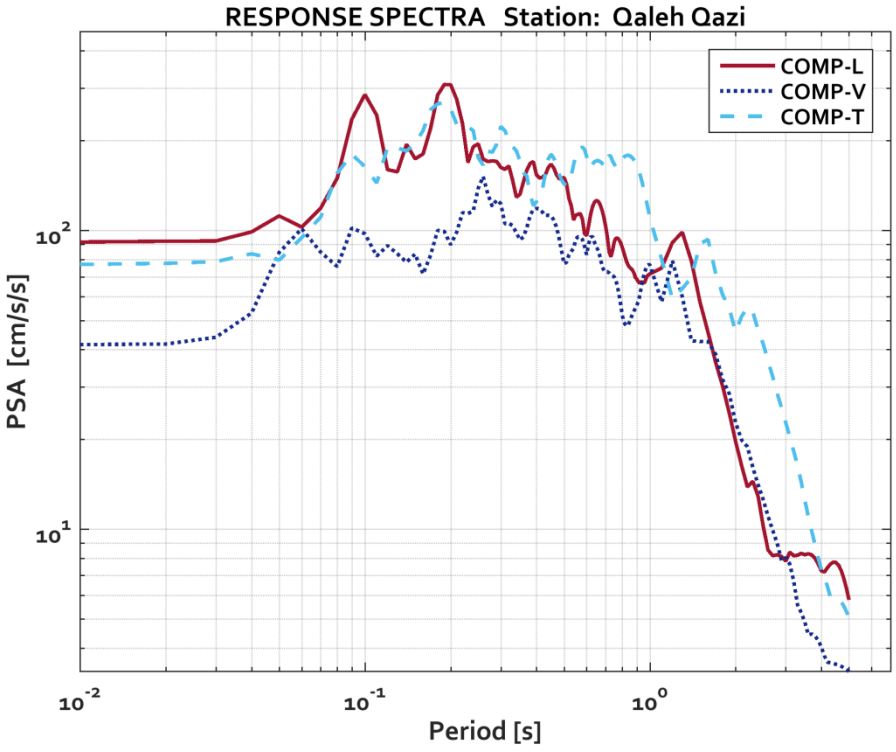
The recorded time histories along with the acceleration response spectra for the second earthquake.



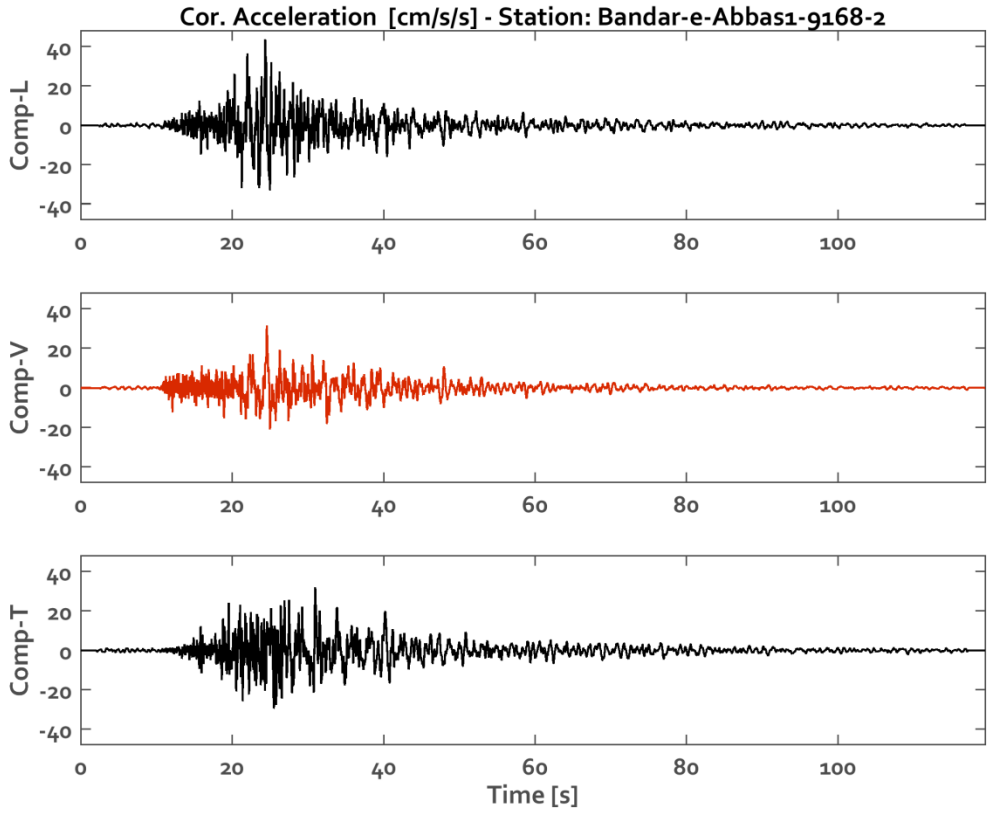


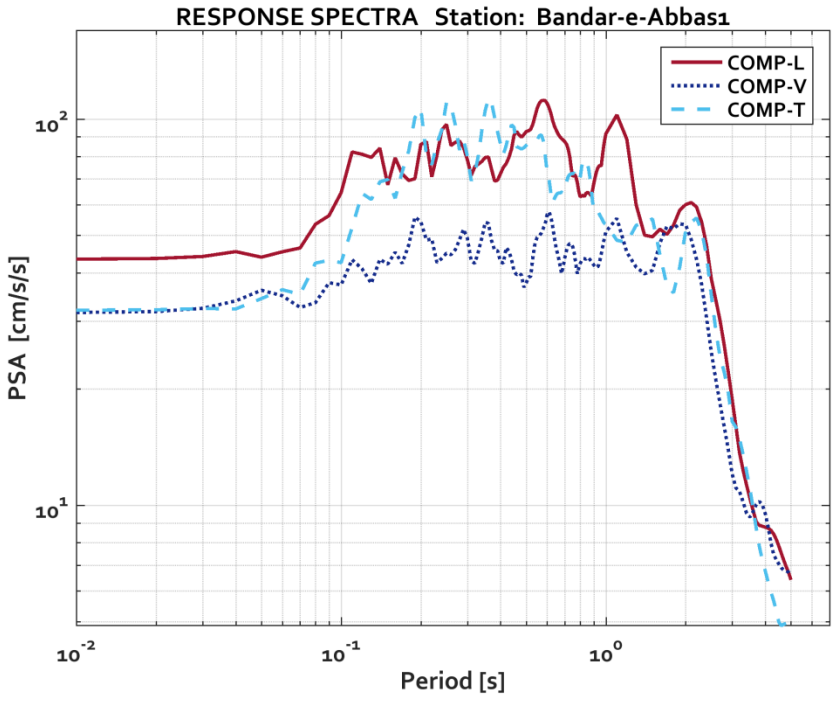
Recorded acceleration time histories and acceleration response spectra at Siyahoo station from second event.



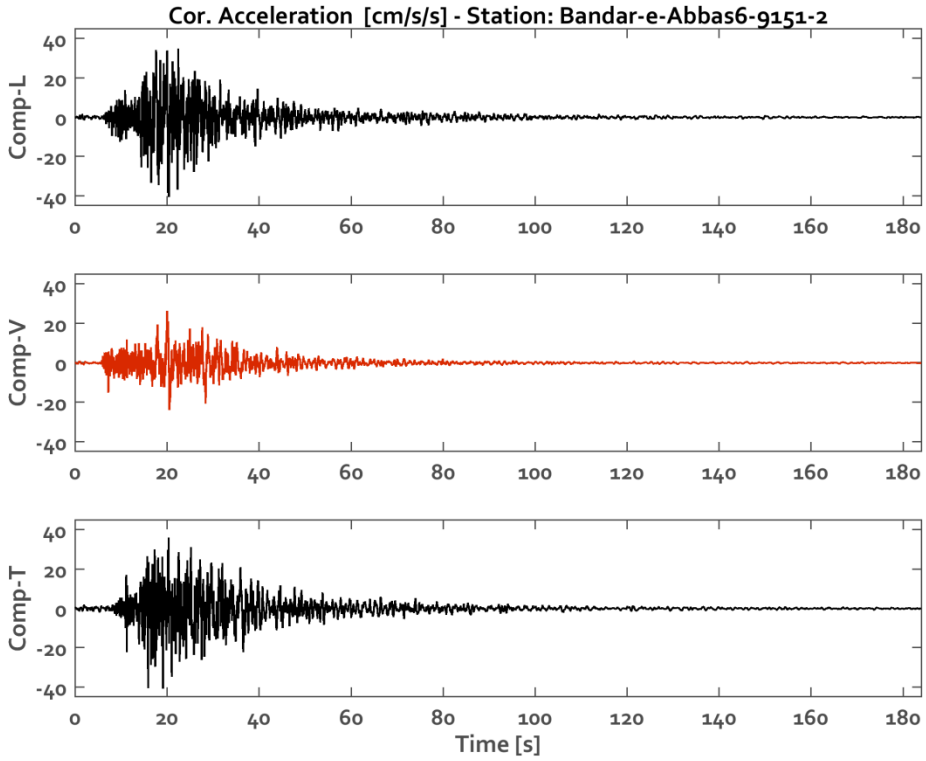


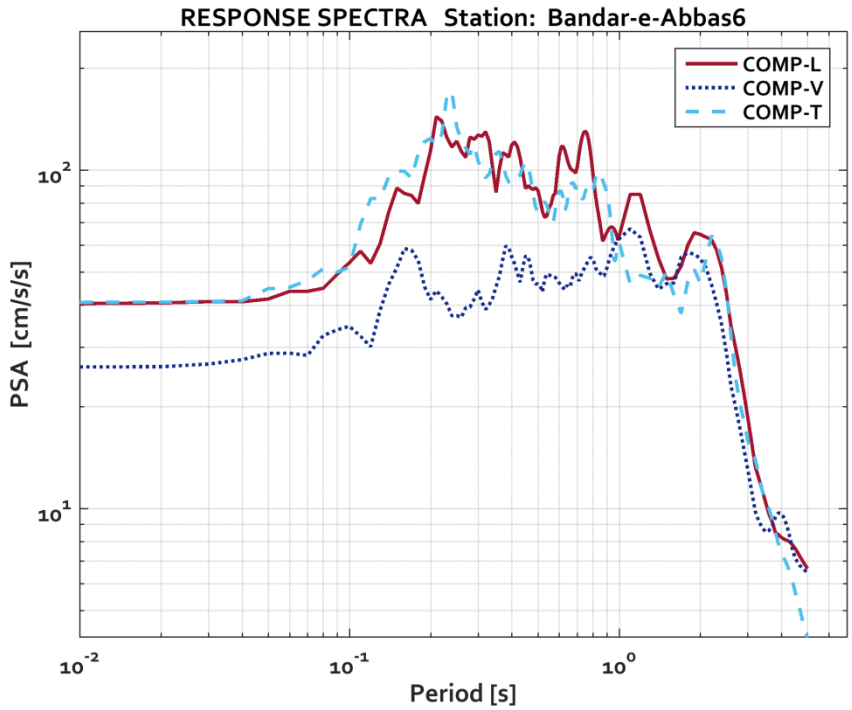
Recorded acceleration time histories and acceleration response spectra at Qaleh Qazi station from second event.



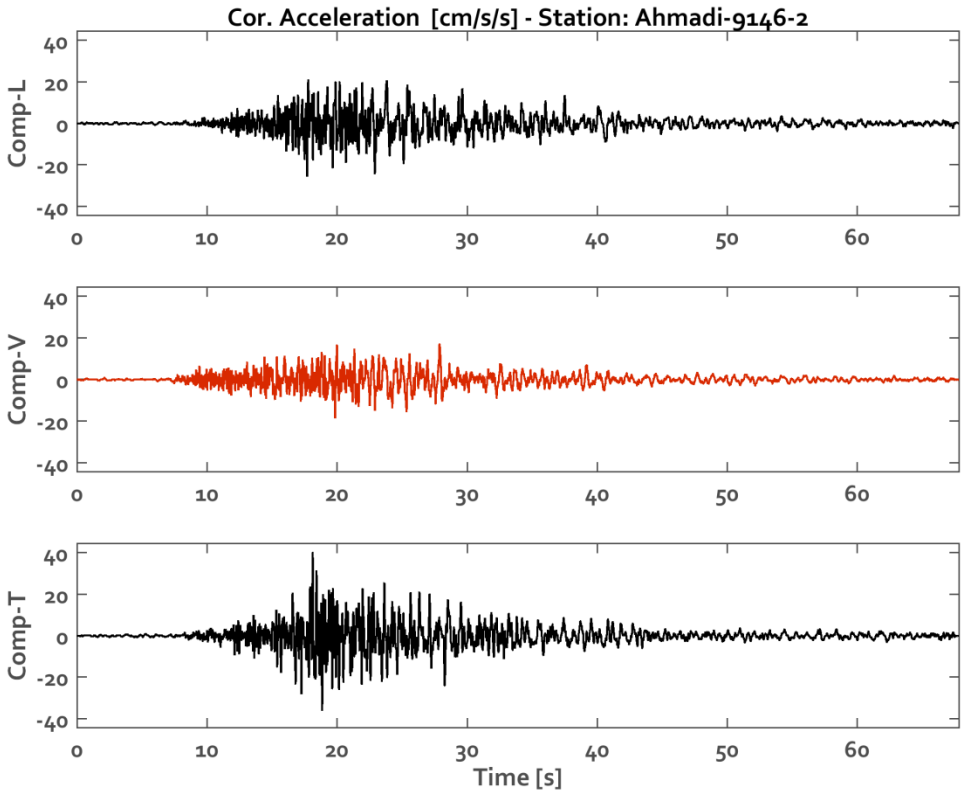


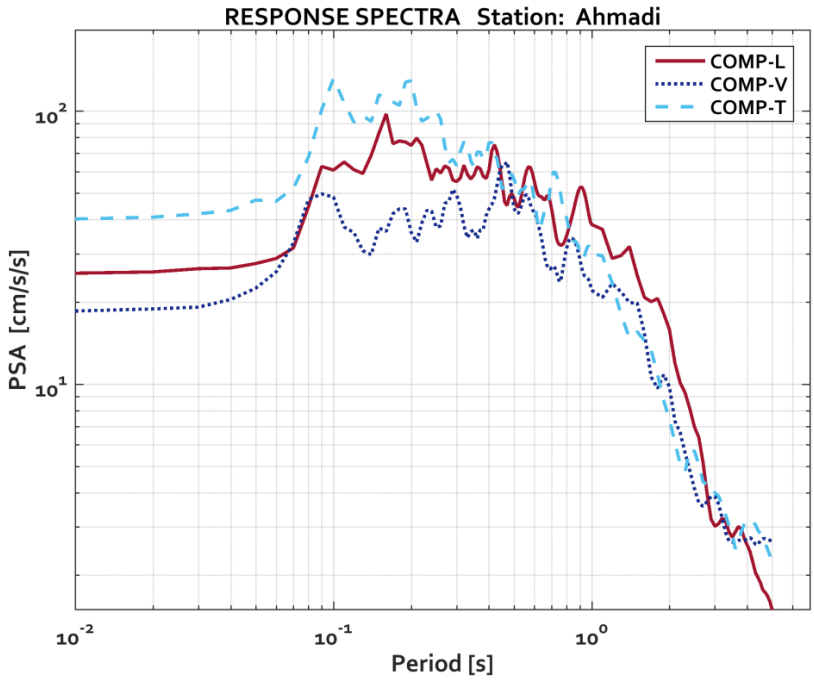
Recorded acceleration time histories and acceleration response spectra at Bandar Abbas1 station from second event.



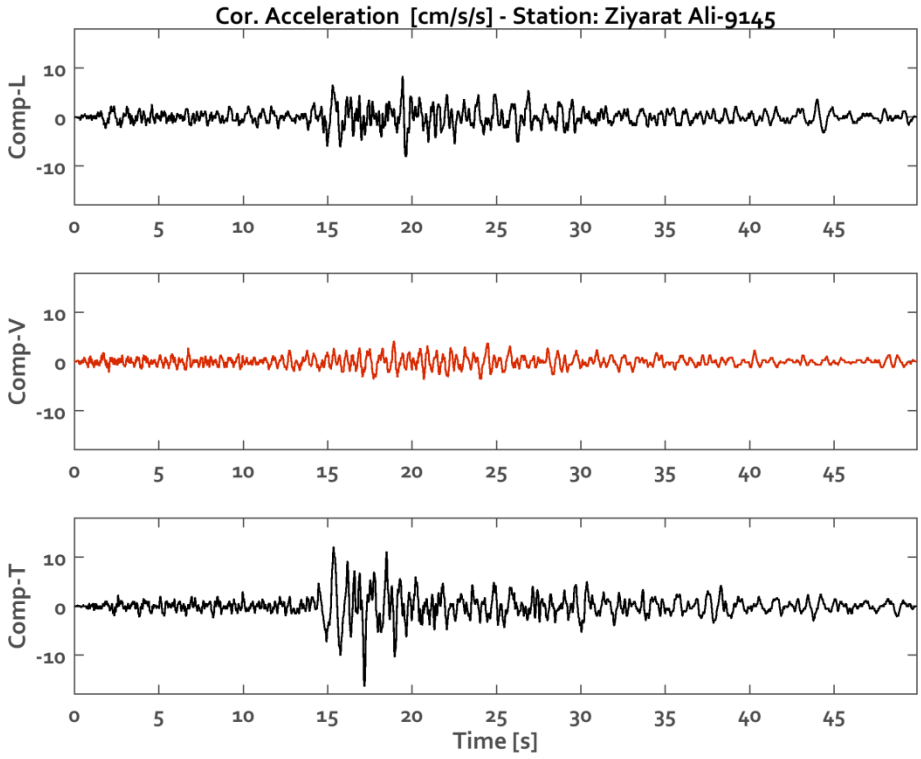


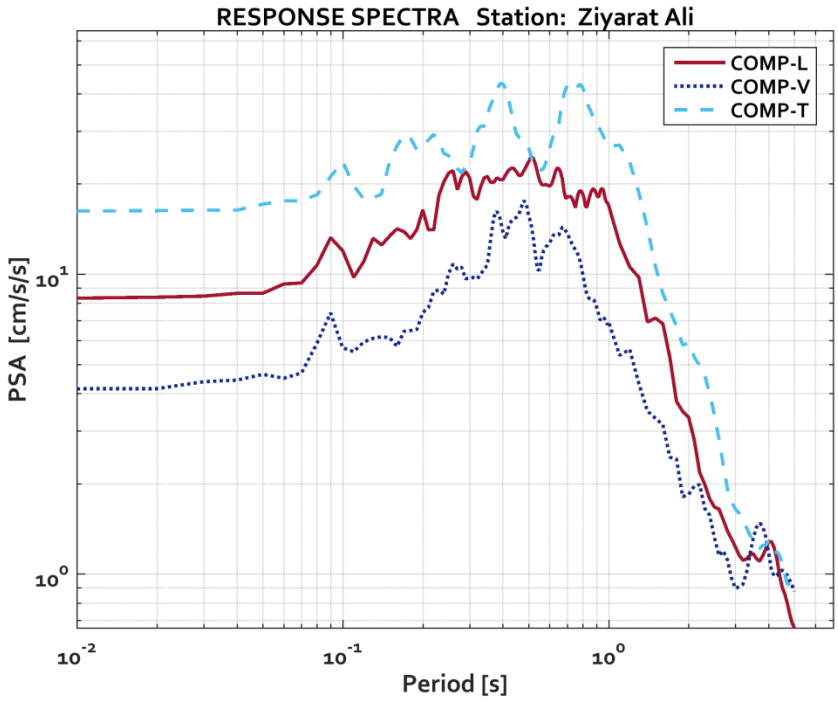
Recorded acceleration time histories and acceleration response spectra at Bandar Abbas6 station from second event.



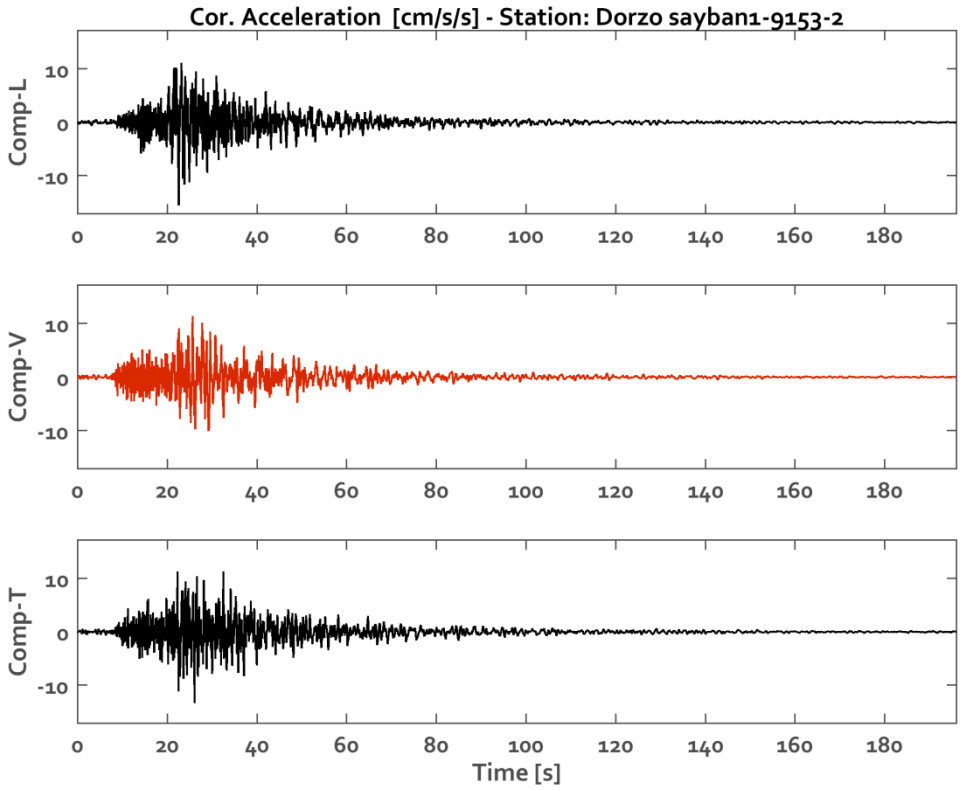


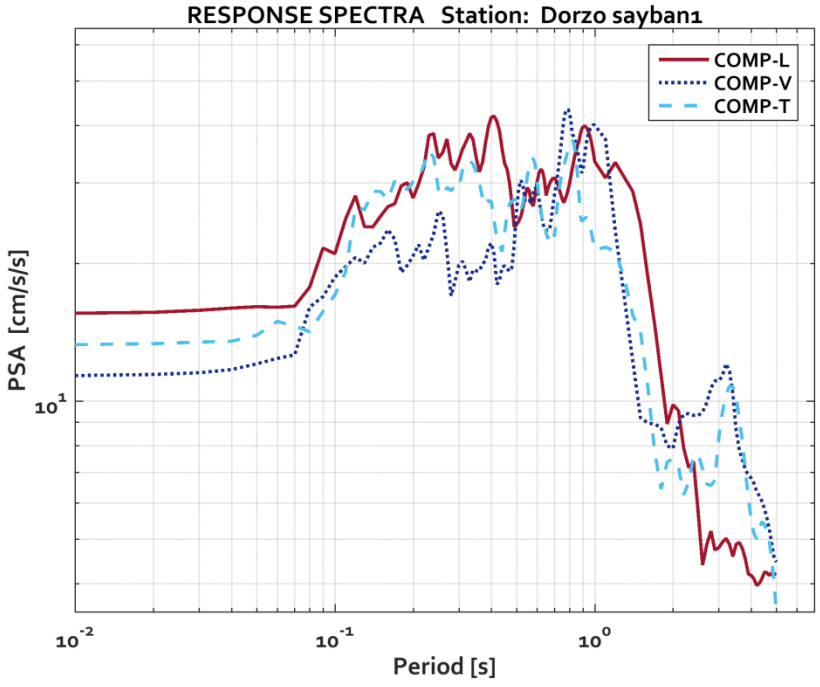
Recorded acceleration time histories and acceleration response spectra at Ahmadi station from second event.



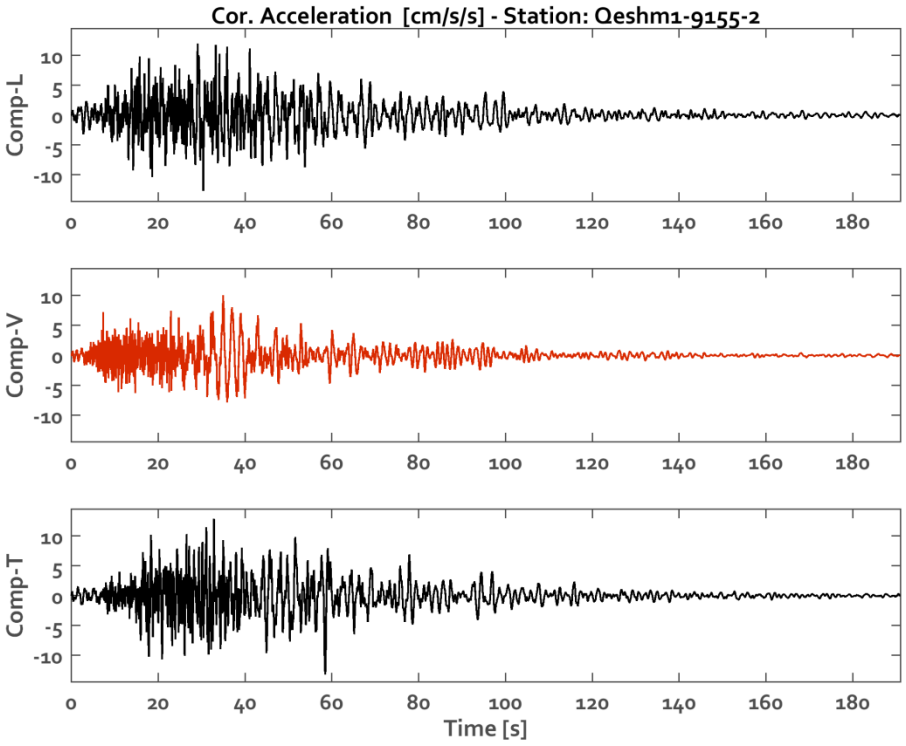


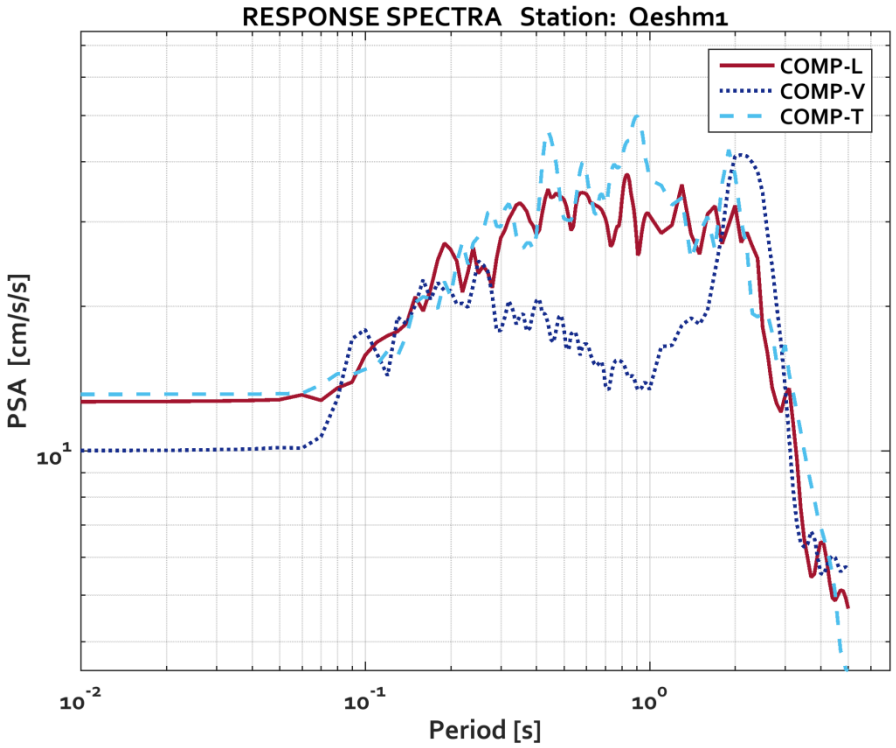
Recorded acceleration time histories and acceleration response spectra at Ziyarat Ali station from second event.



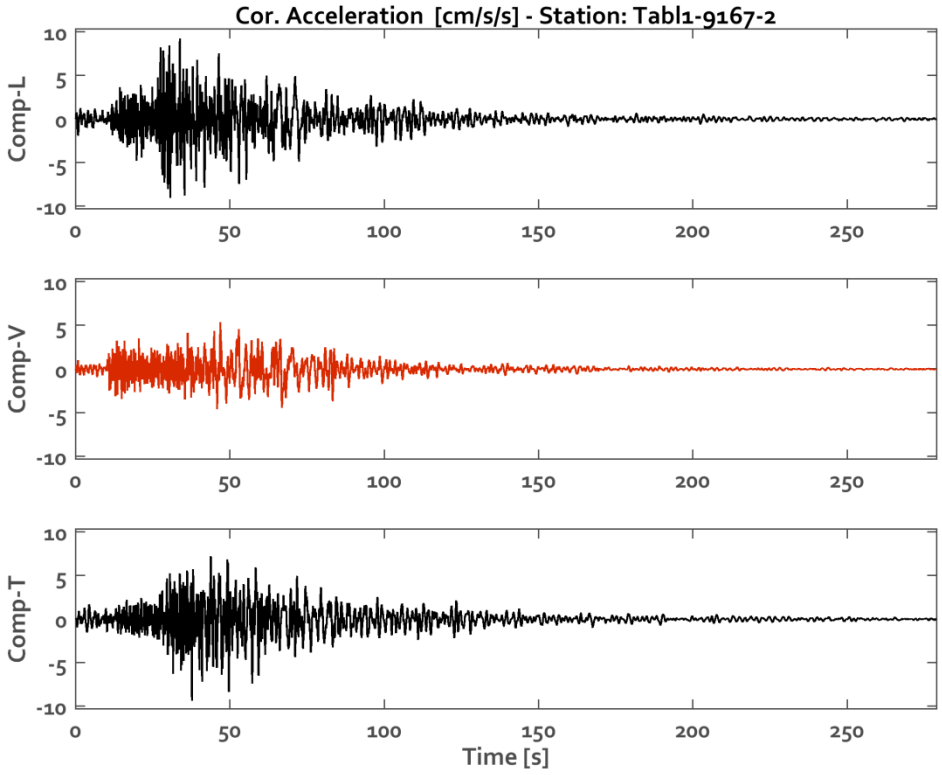


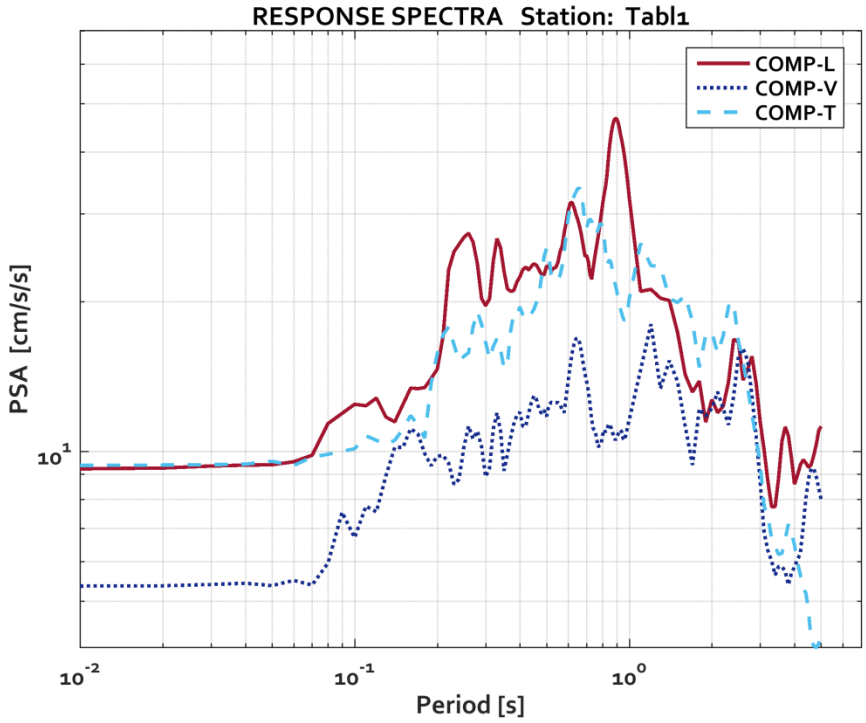
Recorded acceleration time histories and acceleration response spectra at Dorzo Sayban station from second event.



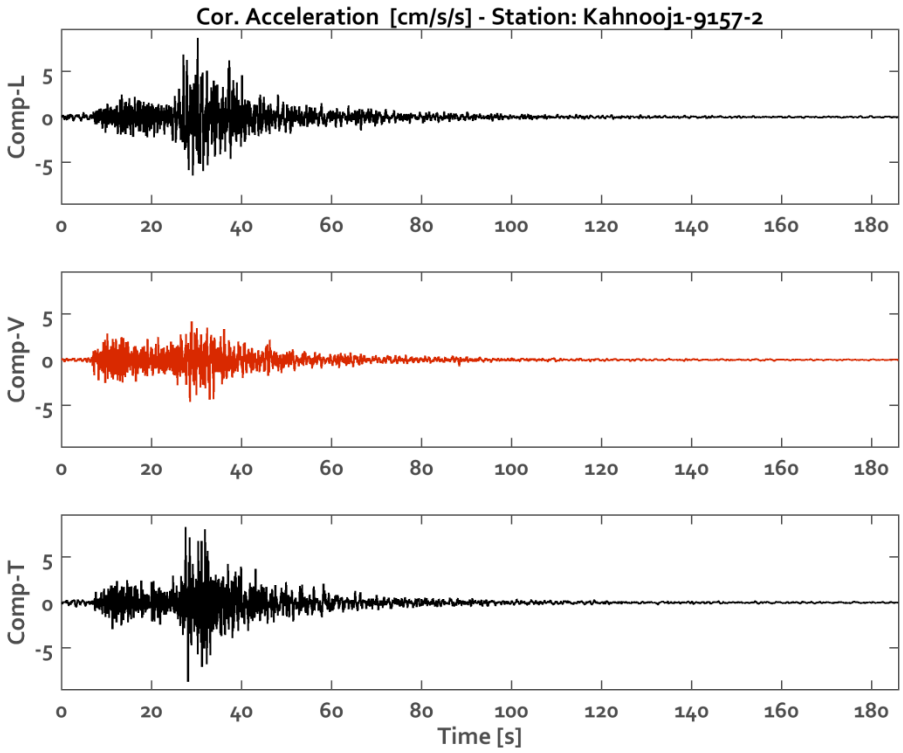


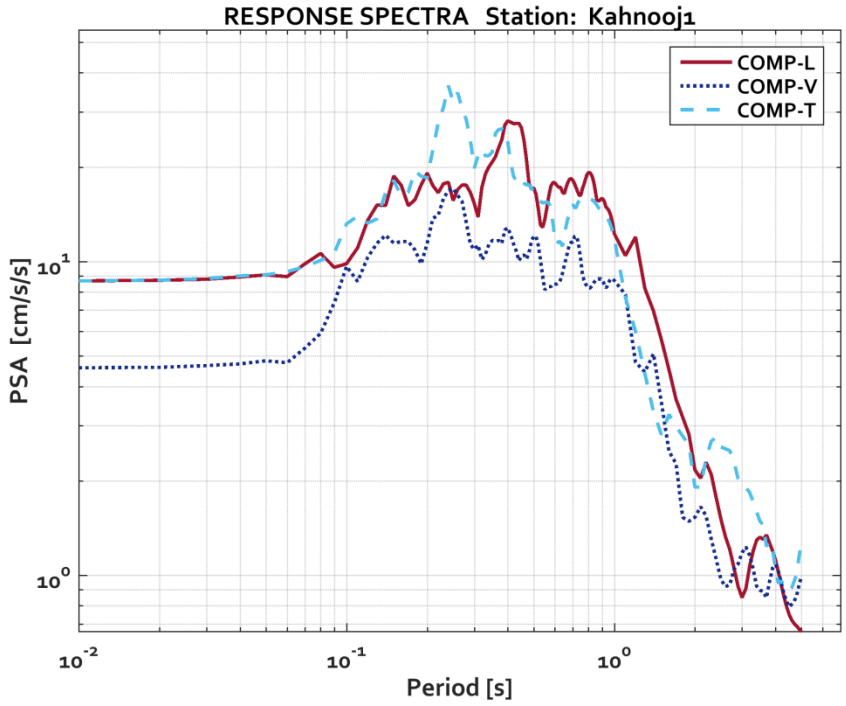
Recorded acceleration time histories and acceleration response spectra at Qeshm1 station from second event.





Recorded acceleration time histories and acceleration response spectra at Tabl1 station from second event.





Recorded acceleration time histories and acceleration response spectra at Kahnooj1 station from second event.