

COMPARISON OF SEISMIC RECORDS FROM THE TURKEY EARTHQUAKES OF FEBRUARY 2023 WITH MEXICAN RECORD

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Abstract: *The study's objective was to compare seismic records from recent earthquakes in Turkey (February 2023) and historical earthquakes in Mexico. The aim is to identify if ground motions, such as the one recently recorded in Turkey, can occur in Mexico. The scope involves analyzing seismic records to obtain parameters such as Peak Ground Acceleration (PGA), response spectra, and engineering parameters like Arias intensity. The methodology includes obtaining primary seismic data for Turkey and Mexico, processing accelerograms using the Seismograms Analyzer-e program, and comparing the results. The analysis reveals significant similarities in PGA values and response spectra features between a Turkey earthquake (magnitude 7.8) and a Mexico station (Guerrero) in a rock site. For instance, a PGA value of 662.19 cm/s² in Turkey corresponds to 625.78 cm/s² in Mexico. The response spectra shapes and amplitudes also exhibit similarities, especially in structural periods between 0 and 0.25 s. These findings suggest comparable ground motions in both regions, providing valuable insights for seismic risk assessment and building design considerations.*

1 General characteristics of damaging earthquakes in Turkey

Turkey is a country that frequently faces seismic disasters, ranking third globally in terms of human losses caused by earthquakes. On average, they experience at least one earthquake each year with a magnitude ranging from 5 to 6 (AFAD, 2023a). This is due to its location in one of the most seismically active regions in the world.

Six months after the catastrophic events of February 6, 2023, according to the latest statement from the Minister of Interior, the number of people who have lost their lives because of the seismic events has reached 50,783. Of these, 7,302 were refugees (HayataDestek, 2023).

This article highlights an analysis comparing accelerograms and response spectra in the main Turkish cities affected by the magnitude Mw=7.8 earthquake on the Anatolian Fault.

On February 6, 2023, at 4:14 am local time (01:17 UTC), the Disaster and Emergency Management Authority (AFAD) reported an earthquake with a magnitude Mw of 7.7 (USGS - United States Geological Survey -

Mw=7.8) located in Pazarcık (Kahramanmaraş). The epicenter was at coordinates 37.288°N and 37.043°E with a depth of 8.6 km (AFAD, 2023b).

1.1 Historical Earthquakes in Turkey

Figure 1.1 depicts the epicenters of 1088 earthquakes with a magnitude M_w greater than 5.0, along with the depths of their hypocenters that have occurred in Turkey since 1950 (Vargas *et al.*, 2023).

It can be observed in Figure 1.1 that the western region is the area where most earthquakes in the country are located. In contrast, the other earthquakes are concentrated on the North Anatolian Fault and the East Anatolian Fault. According to seismic history, the northern zone of the Anatolian Fault is the most active of the two.

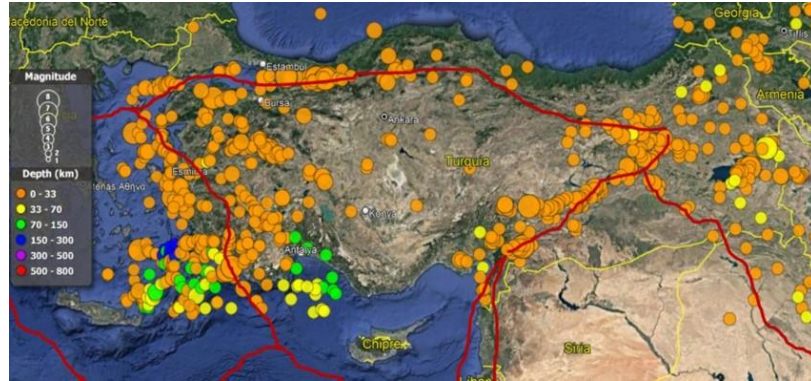


Figure 1.1 Earthquake epicenters with $M_w > 5.0$ in Turkey since 1950
(Source: Vargas *et al.*, 2023)

With information from the USGS earthquake risk program, 22 significant earthquakes equal to 7.0 or greater than 7.0 have been identified in Turkey from 1900 to 2023. Table 1 presents the primary data for these 22 earthquakes.

Table 1. Earthquakes in Turkey since 1900 with magnitude equal to or greater than 7 (USGS, 2023).

Epicenter	Year	Latitude	Longitude	Depth (km)	Magnitude
Ekinözü	2023	38.0235	37.2030	10	7.5
Nurda	2023	37.1662	37.0421	18	7.8
Karlovásion	2020	37.8973	26.7838	21	7.0
Van	2011	38.7210	43.5080	18	7.1
Düzce	1999	40.7580	31.1610	10	7.2
Derince	1999	40.7480	29.8640	17	7.6
Van	1976	39.1210	44.0290	36	7.3
Gediz	1970	39.0980	29.5700	25	7.2
Hendek	1967	40.7510	30.8000	30	7.2
Düzce	1957	40.7300	31.0900	25	7.0
Sarigerme	1957	36.4050	28.6990	35	7.3
Sarigerme	1957	36.4930	28.8290	35	7.1
Gönen	1953	40.1750	27.6480	10	7.3
Karaburun	1949	38.7180	26.4800	15	7.1
Orta	1944	40.6600	32.9980	30	7.6
Ilgaz	1943	40.8670	33.6510	20	7.5
Ordu	1942	40.9070	36.7440	10	7.0
Erzincan	1939	39.9070	39.5860	20	7.8
Soma	1919	39.1760	27.6520	10	7.0
Sivas	1916	40.2010	37.3120	15	7.0

Burdur	1914	37.6660	30.1250	15	7.0
Malkara	1912	40.7300	27.1210	15	7.2

1.2 Provinces and cities affected by the 7.8 magnitude earthquake on February 6, 2023

A devastating earthquake with $M_w=7.8$ struck southern Turkey in the early hours of February 6, with the epicenter in the Pazarcık district of Kahramanmaraş province (Figure 1.2). The earthquake impacted the neighboring provinces of Adiyaman, Kilis, Osmaniye, Gaziantep, and Malatya, as well as Şanlıurfa, Diyarbakır, Adana, Hatay, and Elazığ.

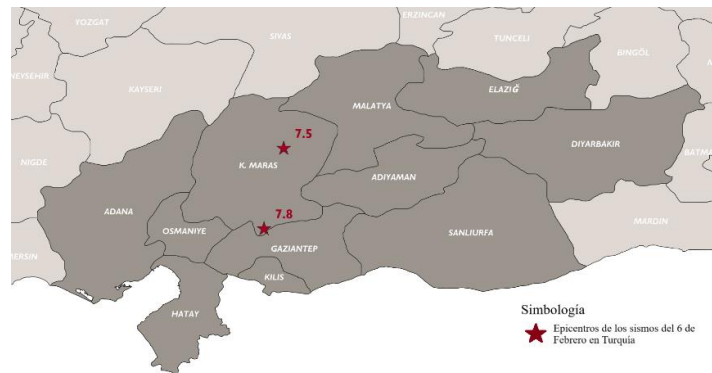


Figure 1.2 Provinces affected by earthquakes on February 6, 2023.

According to the WHO (World Health Organization), in the affected regions of Turkey and Syria, approximately 23 million people live, including 1.4 million children (Reuters, 2023). After the main earthquake, numerous aftershocks occurred, and a second major earthquake struck the region 9 hours later with a magnitude of 7.5 degrees. This second major quake caused severe additional damage and the destruction of already damaged buildings.

According to official statements from Turkey released three days after the events, precisely on February 9, 10,017 people lost their lives, and 674,072 people were injured in the earthquakes that struck 879 provinces. A total of 6,444 buildings were destroyed during the earthquake, and 11,302 buildings were reported with a "demolition notice" (BirGün, 2023).

Table 2. Assessment of the damage classification of buildings and affected population (Copernicus, 2023).

Area of interest	Recent satellite images	Affected constructions	Affected population (inhabitants)
Adiyaman (Aol-02)	9/02/2023	82.6	209250
Antiochia (Aol-11)	7/02/2023	220.1 ha	385430
Afsin (Aol-19)	7/02/2023	42*	33720
Bahce (Aol-15)	9/02/2023	2*	12460
Cumhuriyet (Aol-09)	7/02/2023	7.6 ha	16650
Diyarbarkir (Aol-03) **	9/02/2023	48 ha	562480
Duzici (Aol-14)	9/02/2023	5*	33550
Elbistan (Aol-20)	9/02/2023	289*	97650
Erdemoglu (Aol-12) **	9/02/2023	144*	12050
Gaziantep (Aol-01) **	8/02/2023	26*	1191030
Golbasi (Aol-13)	8/02/2023	57*	31430
Islahiye (Aol-10)	9/02/2023	33.5 ha	16030
Kahramanmaras (Aol-04)	8/02/2023	927*	384400
Kirikhan (Aol-18)	8/02/2023	1,593*	63530
Malatya (Aol-05)	9/02/2023	229.1 ha	423290
Nurdagi (Aol-16)	8/02/2023	63.9 ha	12250
Osmaniye (Aol-06)	7/02/2023	107.4 ha	231120
Pazarcik (Aol-08)	9/02/2023	79*	25470

Sanliurfa (Aol-07)	8/02/2023	2.7 ha	501660
Turkoglu (Aol-17)	8/02/2023	59.7 ha	36090

* In those Areas of Interest (Aol), it has been possible to assess the building-level damages.

** Consolidation is ongoing based on recently acquired satellite imagery.

2 General characteristics of damaging earthquakes in Mexico.

Mexico is one of the countries with important seismic activity in the world due to its location where three tectonic plates converge (Pacific, Cocos, and Caribbean).



Figure 2.1 Tectonic plates in the region of Mexico (Mexican Geological Service, 2017).

In the last decades, Mexico has experienced significant seismic activity, leading to earthquakes with a magnitude (M) exceeding 7.0. These earthquakes have caused extensive damage in some cities across the country.

Some of the earthquakes that have caused the most damage throughout Mexico's history are as follows (Forbes staff, 2021):

- March 28, 1787, off the coast of Oaxaca with M=8.6
- November 19, 1912, Acambay, State of Mexico with M=7
- July 27, 1957, southeast of Acapulco with M=7.8
- September 19, 1985, off the coast of Michoacán with M=8.1
- April 4, 2010, Mexicali, Baja California with M=7.2
- March 20, 2012, Ometepe, Guerrero with M=7.5
- September 7, 2017, Gulf of Tehuantepec with M=8.2
- September 19, 2017, Puebla with M=7.1



Figure 2.2 Building collapse during the September 1985 earthquake. (PEINADO, 2012)

3 PGA in rock in the 7.8 magnitude earthquake in Turkey on February 6, 2023.

The seismic records were selected by considering the soil type, using the classification of the "Euro Code 8, Structural Design for Earthquake Resistance" (AENOR, 2018). Stations classified under soil types A and B, corresponding to rock or stable soil, were chosen. Additionally, stations recording accelerations greater than 200 cm/s² were selected. With these criteria, only 17 stations out of the more than 300 available for this study were utilized. Table 3 displays corrected accelerations measured in cm/s², standardized cumulative absolute velocity (CAVST) measured in cm/s, significant duration measured in seconds, and Arias intensity measured in cm/s for each horizontal component. These values were obtained using the Seismograms Analyzer-e program (Aguilar-Meléndez *et al.*, 2021).

Table 3. Accelerations greater than 200 cm/s² were recorded at stations located on rock-type soils during the Mw 7.8 earthquake on February 6, 2023, in Turkey.

No.	Station	Component	Acceleration N-S (cm/s ²)	Arias Intensity (cm/s)	Standardized Cumulative Absolute Velocity (cm/s)	Significant Duration (s)	Epicentral Distance (Km)
1	4614	N-S	1870.00	7022.00	1130.00	37.22	39.90
		E-O	2000.00		9220.00	23.83	
2	2718	N-S	654.43	421.50	2160.00	13.78	44.10
		E-O	630.31		2260.00	21.01	
3	4616	N-S	610.34	512.95	3170.00	41.80	31.30
		E-O	428.56		2510.00	41.30	
4	3123	N-S	647.00	831.75	3320.00	13.75	134.20
		E-O	593.00		3040.00	18.04	
5	4615	N-S	584.00	581.45	3160.00	47.14	24.60
		E-O	545.00		3240.00	47.13	
6	3136	N-S	508.00	368.30	2510.00	27.92	138.70
		E-O	381.00		2540.00	33.62	
7	3132	N-S	509.00	399.15	2040.00	13.52	134.20
		E-O	5.20		2290.00	18.42	
8	2715	N-S	343.00	114.05	1400.00	50.96	49.50
		E-O	238.00		1560.00	49.58	
9	3143	N-S	383.00	253.50	1810.00	25.89	58.60
		E-O	345.00		1870.00	28.98	
10	4611	N-S	343.00	261.75	2360.00	43.96	66.60
		E-O	313.00		2320.00	45.52	
11	2308	N-S	320.00	48.04	529.00	21.19	242.40
		E-O	185.00		371.00	37.95	
12	4620	N-S	295.00	240.95	2040.00	43.71	48.90
		E-O	318.00		2250.00	45.76	
13	3134	N-S	245.00	131.85	1660.00	47.23	86.70
		E-O	196.00		1550.00	46.36	
14	8002	N-S	242.95	177.50	2070.00	36.74	46.10
		E-O	202.89		1520.00	43.69	
15	213	N-S	236.00	90.99	623.00	6.42	96.48
		E-O	177.00		542.00	8.55	
16	2302	N-S	207.00	156.13	268.00	10.01	265.80
		E-O	236.00		575.00	8.52	

17	3133	N-S	140.00	44.11	1020.00	52.84	112.40
		E-O	85.80		656.00	54.64	

4 PGA in rock during seismic events in Mexico with accelerations like those recorded during the magnitude 7.8 earthquake on February 6, 2023.

The selection of seismic records was carried out, considering the type of soil, using stations with a rock-type soil classification. Stations were also chosen based on recording accelerations greater than 200 cm/s² and having an acceleration approximate to that recorded in the Mw 7.8 earthquake on February 6, 2023, in Turkey. With these criteria, only 39 records out of the 99 available in the RAII database of UNAM were used (UNAM, 2024). The provided accelerographic records are the result of the instrumentation and processing efforts of the Seismic Instrumentation Unit of the Institute of Engineering at UNAM (UNAM, 2024). Table 4 displays the maximum corrected accelerations for each horizontal component obtained from the Seismograms Analyzer-e program (Aguilar-Meléndez *et al.*, 2021).

Table 4 Accelerations greater than 200 cm/s² recorded at stations located in rock-type soils in Mexico.

No.	Station	Date	Component	Acceleration (cm/s ²)	Arias Intensity (cm/s)	Standardized Cumulative Absolute Velocity (cm/s)	Significant Duration (s)	Epicentral Distance (km)
1	SJLL	20/03/2012	N-S	1050.00	1381.50	3930.00	14.42	45.00
			E-O	1070.00		3310.00	12.82	
2	PARS	21/09/1985	N-S	604.00	95.33	706.00	7.37	153.00
			E-O	419.00		615.00	7.36	
3	JAMI	16/02/2018	N-S	555.00	302.65	1700.00	11.11	21.00
			E-O	367.00		1180.00	10.94	
4	SJLL	22/03/2012	N-S	551.00	62.42	259.00	0.81	24.00
			E-O	416.00		197.00	0.65	
5	SJLL	16/02/2018	N-S	475.00	283.15	1720.00	16.57	71.00
			E-O	465.00		1320.00	15.86	
6	PAPN	08/02/1988	N-S	428.00	67.38	514.00	3.89	22.00
			E-O	311.00		422.00	3.97	
7	SJLL	01/04/2012	N-S	432.00	34.96	237.00	2.93	22.00
			E-O	275.00		169.00	1.89	
8	SLU2	18/04/2014	N-S	413.00	191.25	1360.00	21.36	29.00
			E-O	397.00		1280.00	20.94	
9	CALE	11/01/1997	N-S	349.00	181.75	1090.00	14.21	35.00
			E-O	396.00		1180.00	13.58	
10	COMD	23/05/1994	N-S	278.00	52.29	498.00	11.14	11.00
			E-O	412.00		503.00	9.56	
11	JAMI	30/06/2010	N-S	397.00	44.96	443.00	4.33	23.00
			E-O	253.00		242.00	6.63	
12	PET2	18/04/2014	N-S	217.00	105.43	772.00	13.27	40.00
			E-O	366.00		965.00	12.88	
13	PAPN	22/12/1997	N-S	244.00	40.14	232.00	2.22	29.00
			E-O	402.00		249.00	1.63	
14	JAMI	30/09/1999	N-S	398.00	173.70	1530.00	16.16	92.00

			E-O	241.00		1060.00	15.84	
15	NILT	23/09/2017	N-S	351.00	14.09	96.10	1.29	18.00
			E-O	384.00		85.30	0.50	
16	LLAV	31/05/1990	N-S	390.00	51.17	316.00	2.71	28.00
			E-O	315.00		379.00	3.11	
17	JAMI	08/05/2016	N-S	366.00	21.44	294.00	5.15	17.00
			E-O	193.00		195.00	6.58	

5 Comparison of accelerations, standardized cumulative absolute velocities, Arias intensity, and significant duration among stations in Mexico and the 7.8 magnitude earthquake on February 6 in Turkey.

With the data obtained from the Seismogram Analyzer program, values were graphically represented to compare acceleration, absolute cumulative velocity, significant duration, and Arias intensity between the Mw 7.8 earthquake on February 6, 2023, in Turkey and seismic events in Mexico with similar accelerations.

In Figure 5.1, seismic parameters from two stations are shown, the station SJLL in Mexico and the station 4614 in Turkey. In the SJLL station, a Peak Ground Acceleration value of 1070 cm/s² was recorded during the Mw 7.4 earthquake on March 20, 2012. The data from station 4614 in Turkey showed a maximum recorded acceleration of 2,000 cm/s² during the Mw 7.8 earthquake on February 6, 2023.

Table 5 Acceleration values, CAVst, significant duration, and Arias intensity of station SJLL Mexico, seismic for the event Mw 7.4 on 20/03/12 and station 4614 Mw 7.8 on 6/02/23 Turkey.

Station	Acceleration N-S (cm/s ²)	Acceleration E-O (cm/s ²)	Arias Intensity (cm/s)	Cavst N-S (cm/s)	Cavst E-O (cm/s)	Significant Duration N-S (s)	Significant Duration E-O (s)	Epicentral Distance (km)	Depth (km)
SJLL	1050	1070	1381.5	3930	3310	14.42	12.823	45	16
4614	1870	2000	7022.0	1130	9220	37.22	23.828	39.9	20

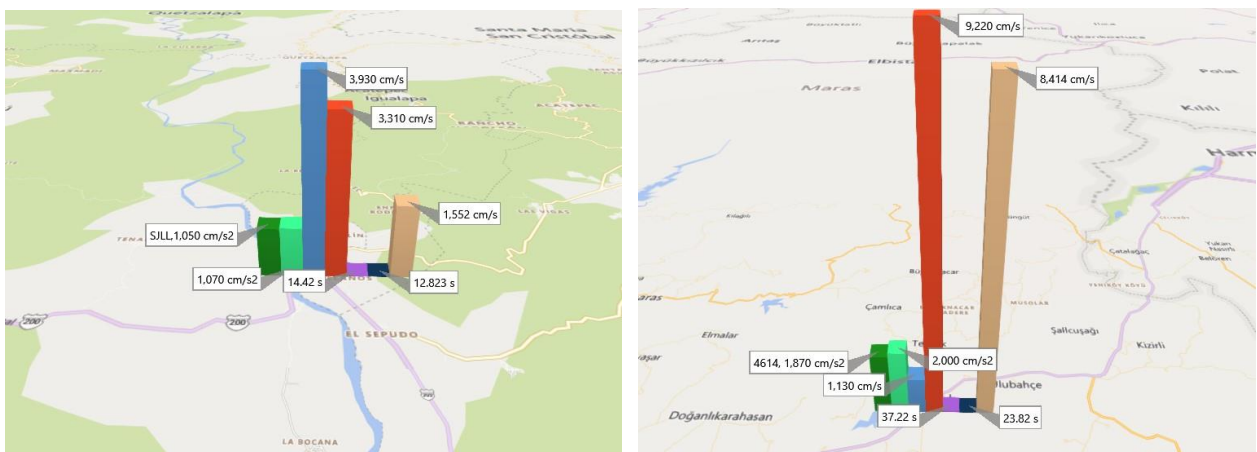


Figure 5.1 Acceleration values, CAVst, significant duration, and Arias intensity for SJLL station in Mexico from the Mw 7.4 event on March 20, 2012 (left), and station 4614 from the Mw 7.8 event on February 6, 2023, in Turkey (right)

According to data from Table 6 Figure 5.2), the PGA values of the PARS Mexican station are very similar to those of station 4616 in Turkey. However, comparing the arias intensity and the CAVstd values, we can observe that these values are significantly higher in the 4646 station than in the PARS station.

Table 6 Acceleration values, CAVst, significant duration, and Arias intensity for PARS Mexico station for the Mw 7.4 event on 21/09/85, and stations 2718, 4616, 3123 for the Mw 7.8 event on 6/02/23 in Turkey.

Station	Acceleration N-S (cm/s ²)	Acceleration E-O (cm/s ²)	Arias Intensity (cm/s)	Cavst N-S (cm/s)	Cavst E-O (cm/s)	Significant Duration N-S (s)	Significant Duration E-O (s)	Epicentral Distance	Depth (km)
PARS	604.00	419.00	95.33	706	615	7.367	7.358	153.0	15.0
2718	654.43	630.31	421.5	2160	2260	13.780	21.010	44.1	20.0
4616	610.34	428.56	512.95	3170	2510	41.802	41.302	31.3	20.0
3123	647.00	593.00	831.75	3320	3040	13.748	18.036	134.2	20.0

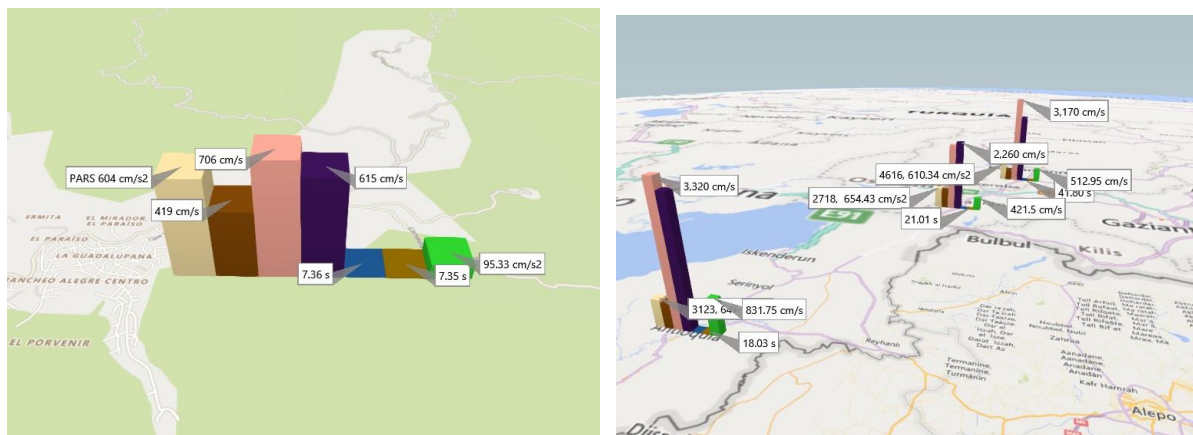


Figure 5.2 Acceleration values, CAVst, significant duration, and Arias intensity of the PARS station in Mexico for the Mw 7.4 event on 21/09/85, and the stations 2718, 4616, 3123 for the Mw 7.8 event on 6/02/23 in Turkey.

In the case of the data in Table 7 (Figure 5.3), it is possible to observe that the data reported from the JAMI station in Mexico has significant similarities with the data from the 3132 station in Turkey.

Table 7 Acceleration values, CAVst, significant duration, and Arias intensity from the JAMI station Mw 7.2 on 16/02/18, SJLL Mw 4.8 on 22/03/12, Mw 7.2 on 16/02/18 in Mexico, and the stations 4615, 3136, 3132 Mw 7.8 on 6/02/23 in Turkey.

Station	Acceleration N-S (cm/s ²)	Acceleration E-O (cm/s ²)	Arias Intensity (cm/s)	Cavst N-S (cm/s)	Cavst E-O (cm/s)	Duración Significativa N-S (s)	Significant Duration E-O (s)	Epicentral Distance	Depth (km)
JAMI	555	367	302.65	1700	1180	11.107	10.942	21.0	16.0
SJLL	551	416	62.415	259	197	0.811	0.654	24.0	24.0
SJLL	475	465	283.15	1720	1320	16.570	15.862	71.0	16.0
4615	584	545	581.45	3160	3240	47.143	47.130	24.6	20.0
3136	508	381	368.30	2510	2540	27.924	33.616	138.7	20.0
3132	509	512	399.15	2040	2290	13.519	18.418	134.2	20.0

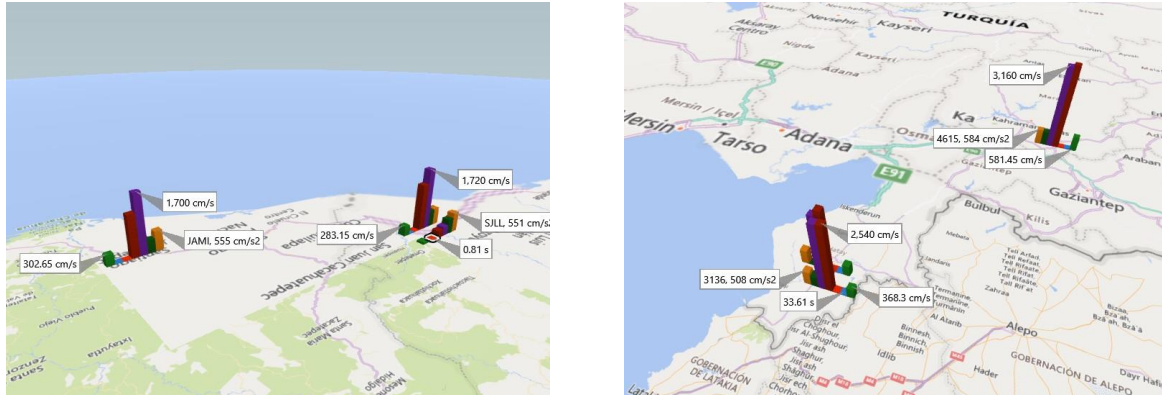


Figure 5.3 Acceleration values, CAVst, significant duration, and Arias intensity of station JAMI Mw 7.2 16/02/18, SJLL Mw 4.8 22/03/12, Mw 7.2 16/02/18 Mexico, and stations 4615, 3136, 3132 Mw 7.8 6/02/23 Turkey.

With the Seismogram Analyzer-e program, response spectra were generated for various stations and plotted simultaneously to observe the similarities and differences between each of them. In Figures 5.4 and 5.5, we can observe this comparison of response spectra for each horizontal component.

According to Figure 5.4, seismic records in Mexico triggered greater values of spectral accelerations than the accelerations triggered by the Turkey earthquakes. For instance, for a structural period of 0.2, the higher values of spectral acceleration were produced from the seismic record of the SJLL station in Mexico. Therefore, for some kinds of structures the potential of damage in Mexico was higher in the SJLL station than the potential of damage in Turkey. Similar behavior occurs in the response spectra of Figure 5.5.

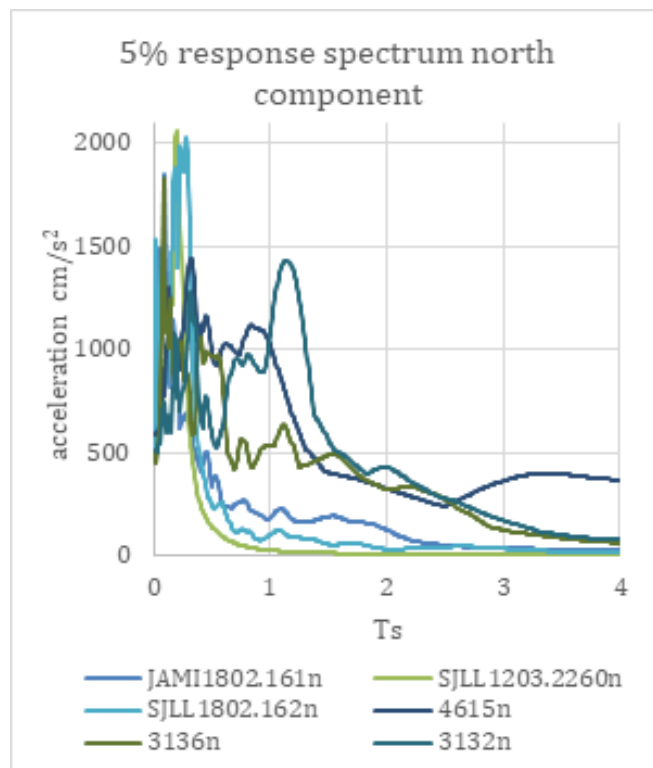


Figure 5.4 Response spectrum with 5% critical damping, from the JAMI Mw 7.2 16/02/18, SJLL Mw 4.8 22/03/12, Mw 7.2 16/02/18 Mexico stations, and stations 4615, 3136, 3132 Mw 7.8 6/02/23 Turkey.

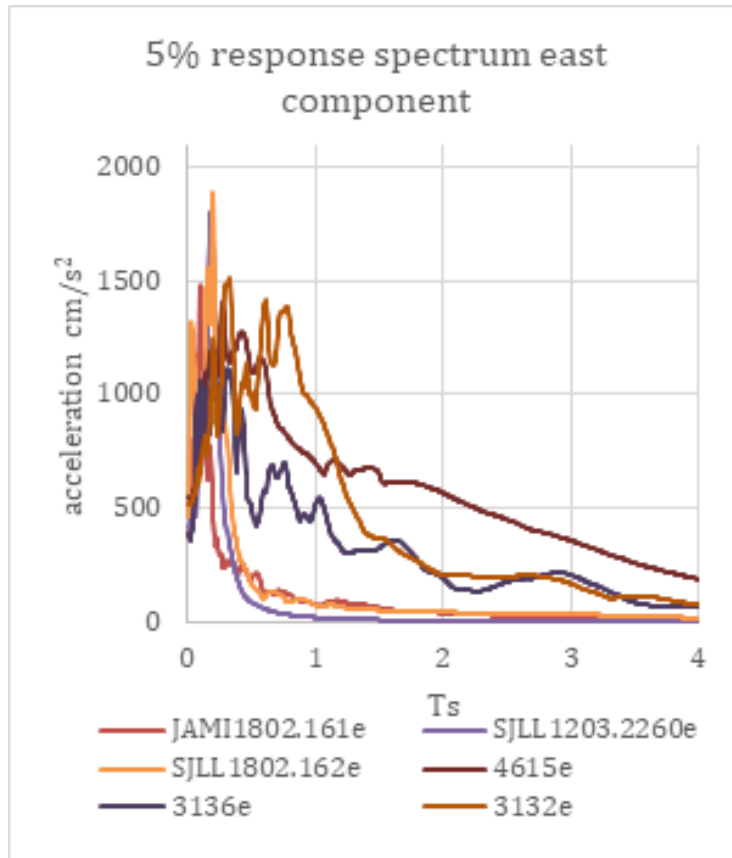


Figure 5.5 Response spectrum with 5% critical damping from the JAMI Mw 7.2 16/02/18, SJLL Mw 4.8 22/03/12, Mw 7.2 16/02/18 Mexico stations, and stations 4615, 3136, 3132 Mw 7.8 6/02/23 Turkey.

In figures 5.6 and 5.7, it is also possible to observe similitude between the response spectra of Mexican earthquakes and the response spectra of Turkey earthquakes.

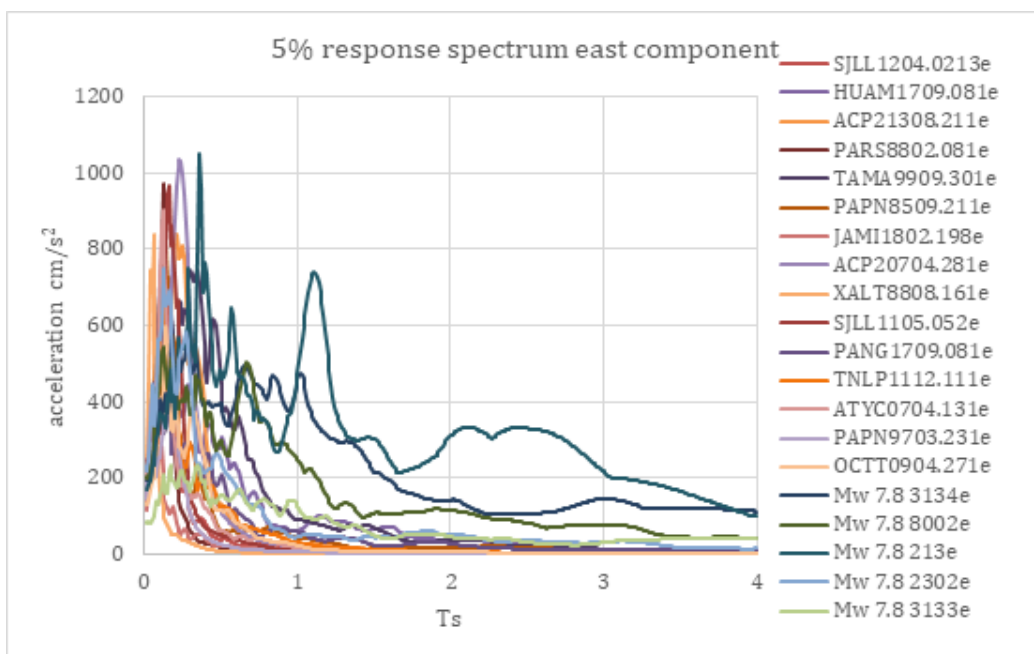


Figure 5.6 Response spectrum with 5% critical damping, from the stations JAMI Mw 7.2 19/02/18, SJLL Mw 4.8 02/04/12, 2/18 Mexico, and stations 4615, 3136, 3132 Mw 7.8 6/02/23 Turkey.

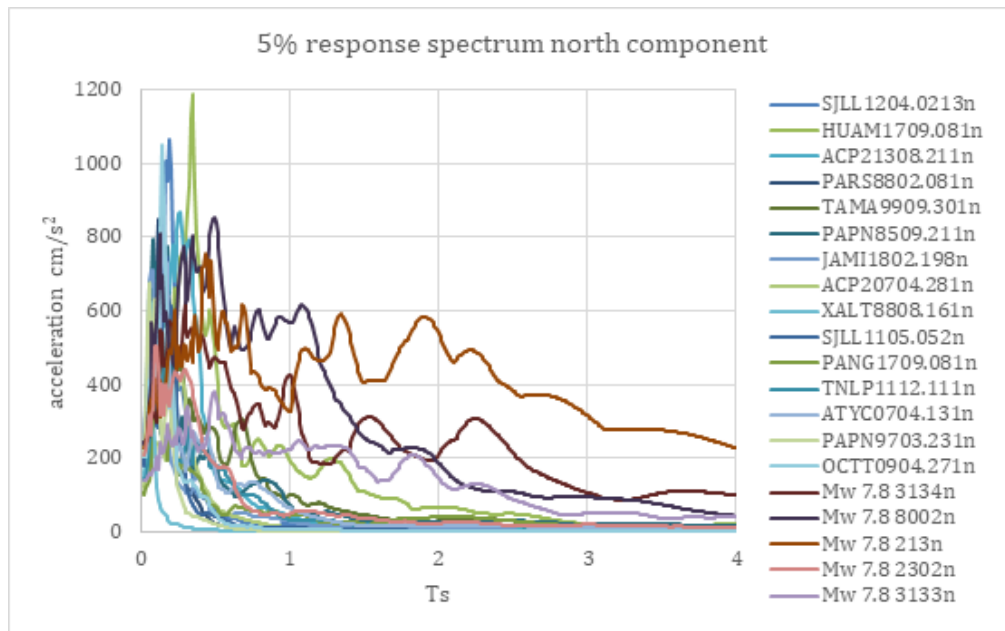


Figure 5.7 Response spectrum with 5% critical damping, from the stations JAMI Mw 7.2 19/02/18, SJLL Mw 4.8 02/04/12, 2/18 Mexico, and stations 4615, 3136, 3132 Mw 7.8 6/02/23 Turkey.

6 Conclusions

The data analyzed in this article were selected considering the classification of rock or firm soil type and the maximum accelerations recorded during the seismic event. With these two pieces of information, a data selection was made for Mexico and Turkey. In Mexico, the maximum recorded acceleration identified in this study was 1070 cm/s^2 , which was recorded during an earthquake with a magnitude of 7.4 on 20/03/12. This represents half of the acceleration recorded during the earthquake on February 6th in Turkey.

One of the main objectives of this article is to identify whether similarities in seismic ground motions between Mexico and Turkey can be found. To achieve this, comparisons of CAVst, Arias Intensity, Significant Duration among seismic events were made. Response spectra for these seismic events were generated using the Seismogram Analyzer program. The data obtained reveals a significant similarity in the first 2 s in the shape of some response spectra analyzed in the present work. Also, we observed that some values of response spectra from Mexico earthquakes have spectral acceleration values higher than the Turkey earthquakes analyzed. Therefore, according to the results, in Mexico have occurred seismic ground motions with higher levels of potential of damage than the earthquakes of February of 2023 in Turkey.

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