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Preliminary Assessment of Building Damages in Hatay Region Based on the February 6, 2023, Earthquakes

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Abstract

Two major earthquakes struck Kahramanmaraş on February 6, 2023, with magnitudes of Mw 7.7 and Mw 7.6, resulting in both loss of life and significant economic damage. This article focuses on the results of field investigation in the Hatay region by focusing on the damage and causes of failures in reinforced concrete (RC) structures. Furthermore, pulse components of the ground motions for both earthquakes which are characterized through a multi-pulse decomposition method are presented. The results are important in terms of preventing the damage and collapse of the structures for future earthquakes.

Keywords: Kahramanmaraş earthquakes, damage, reinforced concrete, pulse characteristics.

1. Introduction

A specific number of destructive earthquakes occurred in the history of Türkiye caused loss of life and economic losses. On February 6, 2023, as reported by the Turkish Ministry of Interior Affairs, Disaster and Emergency Management Presidency (AFAD) [1], a strong earthquake with a magnitude of Mw = 7.7 struct Pazarcık, Kahramanmaraş and followed by a second earthquake occurred in Elbistan, Kahramanmaraş with a magnitude of Mw = 7.6. Both earthquakes caused damage in a large region including Kahramanmaraş, Hatay, Gaziantep, Adıyaman, Malatya, Kilis, Adana, Diyarbakır, Osmaniye and Şanlıurfa. These large earthquakes, also followed by several important aftershocks, resulted in significant damage and collapse of the variety of structures. Figure 1 illustrates the spatial distribution of the Spectral Acceleration (SA) for the Pazarcık earthquake over the Hatay region. The figure includes the simple fault lines [2], distribution of SA values according to the earthquake design level in Turkish Building Earthquake Code [3] and ArcGIS software is used to obtain the maps [4]. DD-1 earthquake corresponds to spectral quantities having a 2% probability of exceedance in 50 years, corresponding to a return period of 2,475 years, while DD-2 earthquake characterized by spectral quantities having a 10% probability of exceedance in 50 years, corresponding to a return period of 475 years. According to Figure 1a, only three of the SA values exceed the DD-1 level for SA(T=0.2s), while for SA(T=1.0s) seven SA values that are obtained from the recording stations go above the DD-1 level earthquake.

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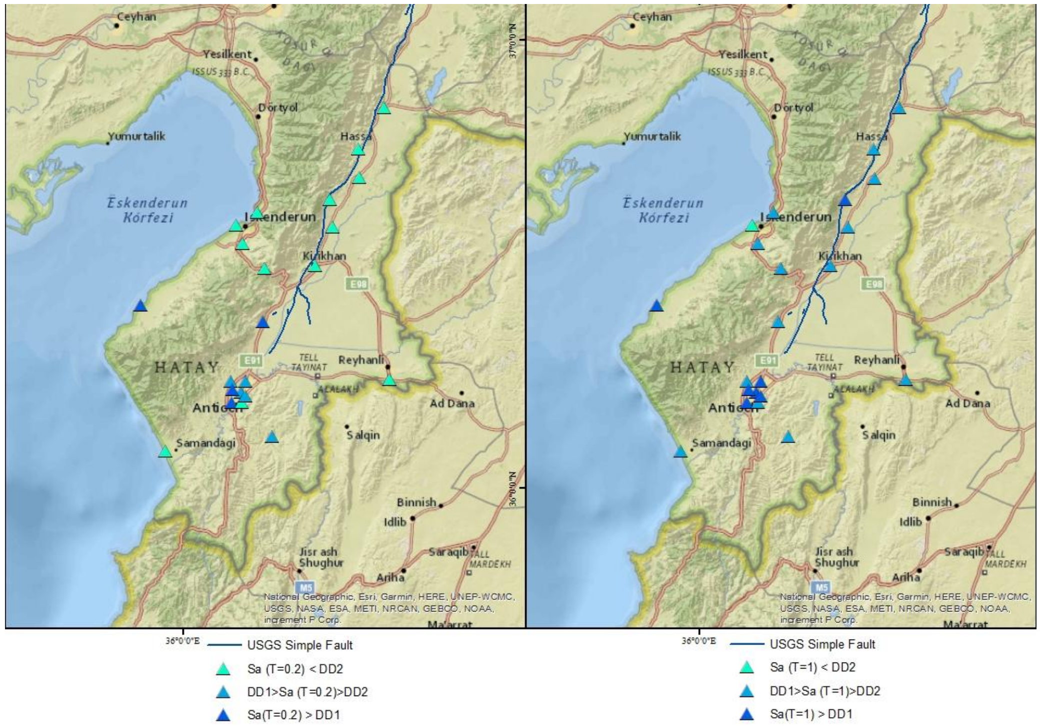


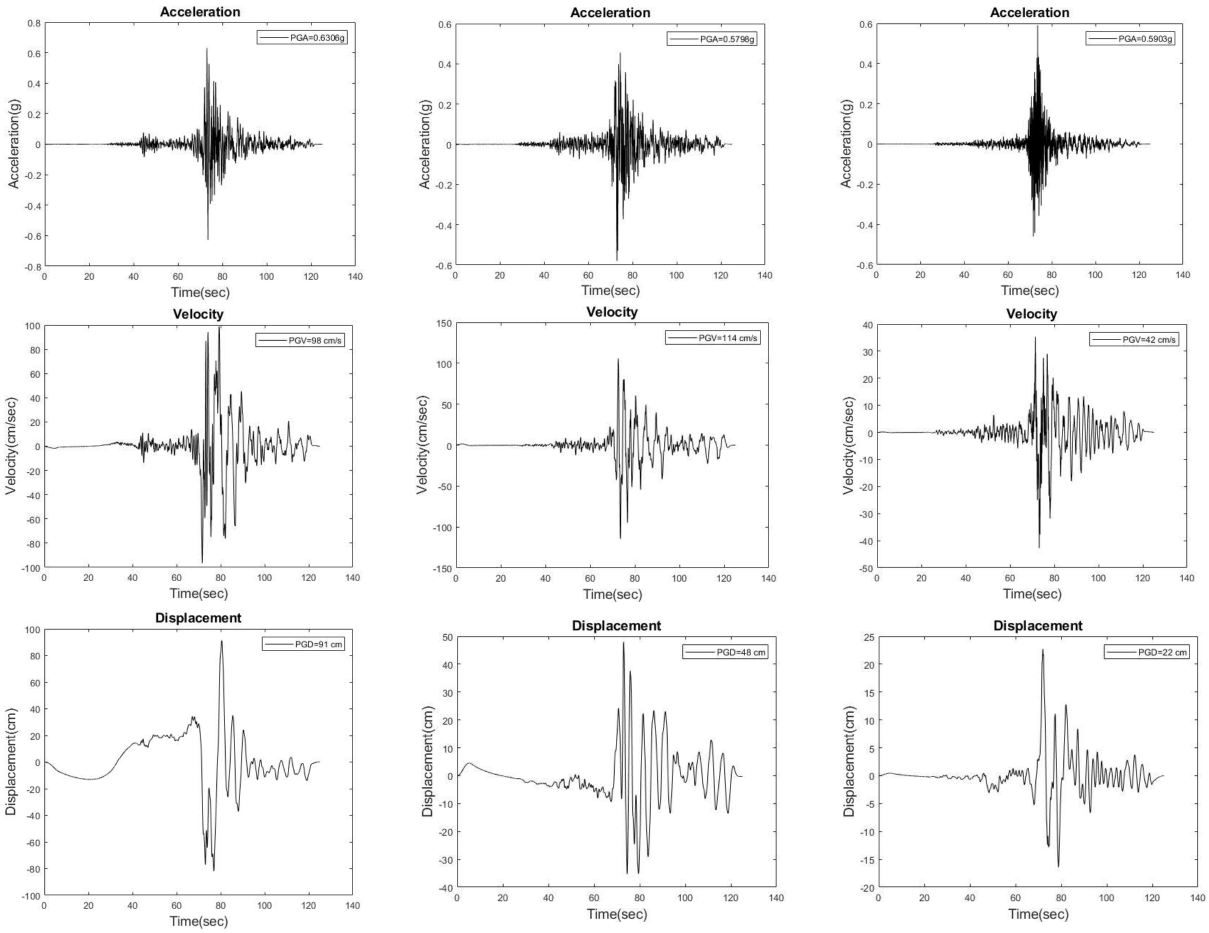
Figure 1. Spatial distribution of Spectral Acceleration (SA) for Pazarcık earthquake (a) SA (T=0.2), and (b) SA (T=1).

This study presents the strong ground motion records obtained from AFAD stations, time-domain pulse characteristics and the distribution of damage observed in buildings and the characteristic features of the damage are presented based on the field observations focusing on the Hatay region. The field observations were performed only from the outside of the structures due to safety considerations. To achieve the aim of the paper, first recorded ground motions and the corresponding acceleration response spectrum were presented and followed by the analysis of time-domain pulse characterization of the ground motions specifically for Hatay. Field observations in the same region are presented in Section 4. Finally, the last section describes the conclusions of the study.

2. Recorded Ground Motions and Acceleration Response Spectrum

2.1. Acceleration, velocity, displacement

The recordings of the earthquakes are available for an extensive region and published in Turkish Accelerometric Database and Analysis System (TADAS) [5]. Figure 2 illustrates the details of time histories of station 3124 for Pazarcık earthquake. Peak ground acceleration (PGA) and peak ground velocity (PGV) and peak ground displacement (PGD) are also included in the figures. PGA values are important for the low-rise structures, while PGV values are mostly related with the mid-rise structures as observed RC buildings in the Hatay region.

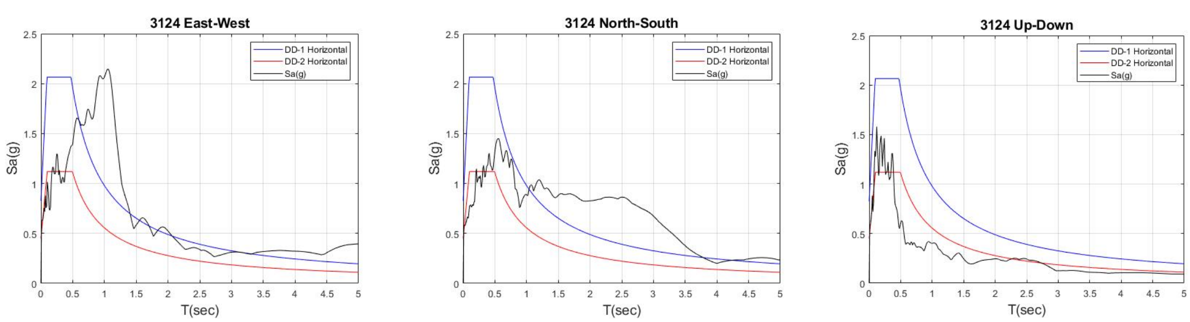


(a) (b) (c)

Figure 2. Acceleration, velocity and displacement time history of Station 3124 for (a) East-West, (b) North-South, and (c) up-down directions.

2.2. Response spectrum

The elastic response spectra for the station 3124 is presented in Figure 3 for the Pazarcık earthquake. For east-west and north-south directions, the SA values exceed the elastic response spectrum for a return period of 475 years (DD-1).



(a) (b) (c)

Figure 3. The elastic response spectra for station 3124.

3. Time-Domain Pulse Characterizations

The multi-pulse decomposition method developed by Ahmadi et al. [6] is employed to extract primary pulse components for the ground motions of the Kahramanmaraş earthquakes in Hatay region; therefore, one ensemble of 23 ground motion from the Pazarcık earthquake (See *Appendix* Table A.1) and one ensemble of 18 ground motions for the Elbistan earthquake (See *Appendix* Table A.2) are used. For the pulse characteristics of the earthquake effected region considering the eleven cities' readers are referred to the research conducted by Sezgin et al. [7]. The developed method by Ahmadi et al. [6] effectively used a Gaussian-Fourier series to precisely approximate the original ground motion. The approach allows for the extraction of key parameters of pulse components, such as period and amplitude, which can provide valuable insights into the extent of damage caused by ground motions. In this method, the original ground motion is approximated by *n* components using Gaussian-Fourier function. Figure 4 illustrates k-mean clustering analysis [8,9] of the component period for the extracted first component and the energy ratio for the corresponding components. The ground motions are separated into three clusters: short (0.1-1.2s), medium (1.2-3.5 s) and long (3.5-5.0s) period pulses. The buildings in the Hatay region primarily consist of two- to eight-story residential structures, with a period range approximately between 0.5 and 1.5 seconds. As a result, short-period pulses are highly likely to excite higher modes, which largely contributed to the significant damage and collapse following both earthquakes.

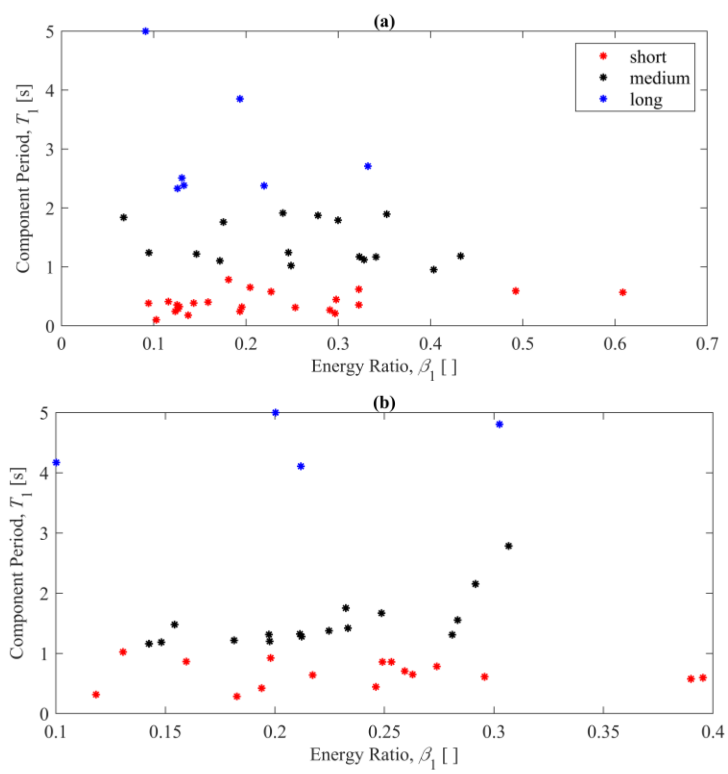


Figure 4. The properties of the first components for the: (a) Pazarcık earthquake, and (b) Elbistan earthquake in Hatay.

4. Observations on Building Damages

According to The Republic of Türkiye Ministry of Environment, Urbanization, and Climate Change [10], 10,991 buildings were heavily damaged and collapsed in Hatay. The primary causes of the observed damage and failures in reinforced concrete (RC) buildings were attributed to the quality of construction materials, improper reinforcement placement, corrosion of reinforcing bars, as well as poor design and implementation practices. In several buildings, it was observed that columns and shear walls were arranged only in one direction, limiting the structure's earthquake resistance in the perpendicular direction. However, the presence of shear walls in some buildings helped to prevent failure or damage in other load-bearing elements.

Due to the limited space, only specific damages are included in this paper. Figure 5 illustrates the example of heavily damaged totally collapsed buildings in Iskenderun and Antakya. The use of plain reinforcement can be seen in Figure 5b.

(a) (b)

Figure 5. Heavy damage and collapsed RC buildings in (a) Iskenderun, and (b) Antakya.

(a) (b)

Figure 6. Damage due to soft story (a) Iskenderun, and (b) Antakya

Another frequently observed type of damage in the region is the failure caused by the presence of soft stories referred to as system level damage. Figure 6 provides two examples of such failures. The use of glass windows instead of infill walls on the street-facing façade of commercial shops, combined with the increased floor height at this level compared to others, increases deformation demands, which ultimately contributes to the damage in these buildings.

The beam-column joints in the earthquake-affected region were found to be highly susceptible to damage. Seismic codes for ductile design impose strict guidelines for the design and detailing of these confinement zones. However, in many buildings in the Hatay region, column overlap joints were improperly placed within the beam or floor, making it easier for columns to pull out from the joints as seen in Figure 7.

(a) (b)

Figure 7. Damage observed in beam-column joints in Antakya.

Conclusions

February 6, 2023, Kahramanmaraş earthquakes caused significant damage in a large region including Kahramanmaraş, Hatay, Gaziantep, Adıyaman, Malatya, Kilis, Adana, Diyarbakır, Osmaniye and Şanlıurfa. These large earthquakes, also followed by several important aftershocks, resulted in significant damage and collapse of the variety of structures. This study reports on field reconnaissance efforts and the properties of the recorded ground motions in the Hatay region. SA values at 0.2s and 1s exceed the DD-1 level at several recording stations. Additionally, the spectral acceleration values indicate that the recorded values for mid-periods are higher than both the DD-1 and DD-2 elastic response spectra. Time-domain pulse characterization results indicate that 54% of the first components of the recordings from the Pazarcık earthquake produced short-period pulses, while 55% of the first components from the Elbistan earthquake showed similar short-period pulses. During the field reconnaissance results showed that, the primary causes of the observed damage and failures in reinforced concrete (RC) buildings were attributed to the quality of construction materials, improper reinforcement placement, corrosion of reinforcing bars, as well as poor design and implementation practices.

Appendix A

Table A.1. Pazarcık earthquake ground motion ensemble.

No	Station	Repi (km)	Rrup (km)	PGA(g)	No	Station	Repi (km)	Rrup (km)	PGA(g)
1,2	3143	65.13	0.4	0.388607	25, 26	3124	140.11	11.7	0.65
3,4	3144	77.04	2.1	0.778413	27,28	3125	142.15	14.6	1.14
5,6	3137	82.48	1	0.683379	29,30	3135	142.15	36.4	1.40
7,8	3134	90.29	28.2	0.250959	31,32	3123	143.00	14.4	0.67
9,10	3145	91.13	3.7	0.705939	33,34	3132	143.12	14.4	0.53
11,12	3139	96.19	0.3	0.588509	35,36	3126	143.54	15.4	1.20
13,14	3116	105.38	18.7	0.172192	37,38	3131	144.98	16.2	0.37
15,16	3142	106.49	0.4	0.75387	39,40	3129	146.39	17.9	1.38
17,18	3115	113.57	19.1	0.292376	41,42	3136	148.39	21.6	0.54
19,20	3146	114.57	11.5	0.493385	43,44	3140	165.82	38.3	0.22
21,22	3133	123.47	27.9	0.23	45,46	3147	177.12	48.8	0.06
23,24	3141	125.42	6.9	0.98					

Table A.2. Elbistan earthquake ground motion ensemble.

No	Station	Repi (km)	Rrup (km)	PGA(g)	No	Station	Repi (km)	Rrup (km)	PGA(g)
1,2	3115	196.09	178.0	0.028069	19,20	3135	222.04	192.0	0.018159
3,4	3116	187.47	158.0	0.019264	21,22	3136	236.36	225.0	0.022538
5,6	3123	229.36	205.0	0.024253	23,24	3137	168.8	157.0	0.02541
7,8	3124	226.42	205.0	0.032043	25, 26	3139	182.55	163.0	0.058285
9,10	3125	227.96	205.0	0.020823	27,28	3140	250.8	222.0	0.030651
11,12	3129	232.64	210.0	0.026752	29,30	3141	211.11	191.0	0.026146
13,14	3132	229.68	215.0	0.023506	31,32	3144	162.37	145.0	0.079064
15,16	3133	213.54	201.0	0.020122	33,34	3147	264.57	247.0	0.007311
17,18	3134	167.34	142.0	0.040182	35,36	3138	156.81	139.0	0.070202

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