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Research Paper

Site Observations on Buildings' Performance in Hatay Province After Kahramanmaraş Earthquakes

Vail KARAKALE[1a], Evren ÖZGÜR[1b*], Şenol ATAOĞLU[2c]

[1]Istanbul Medeniyet University, Faculty of Engineering and Natural Sciences, Department of Civil Engineering, 34700, Istanbul, Türkiye
[2]Istanbul Technical University, Civil Engineering Department, 34469 Maslak - Istanbul, Türkiye
evren.ozgur@medeniyet.edu.tr

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Abstract: Two major earthquakes of 7.7 and 7.6 magnitudes hit a large region east-south of Türkiye on the same day. The first 7.7 M_W earthquake occurred in Pazarcık, Kahramanmaraş on the 6th of Feb 2023 followed by an earthquake of 7.6 M_W in Elbistan, Kahramanmaraş after 9 hours. Thousands of buildings collapsed in ten provinces in Türkiye and caused thousands of life losses and injuries. More than 14 million people were affected, and a lot of people lost their homes which makes the two major events the worst natural disaster of the century. This paper presents site observations on the seismic performance of the buildings in Hatay province which was the most affected city by these earthquakes. Site observations indicate that most of the collapsed buildings are old building stocks constructed before 1999 and collapsed in a pancake failure mode which increases life losses. In general, newly constructed buildings that were designed according to the new Turkish earthquake design code show good seismic performance. Reasons for failures and failure modes of old and new buildings were investigated.

Keywords: Kahramanmaraş earthquakes, disaster, seismic, buildings, concrete

1. Introduction

Unfortunately, major earthquakes cause deaths and economic losses. In 1995 Hanshin-Awaji Earthquake hit Japan's second-largest urban area Hanshin, causing 5,000 deaths, 25,000 injured, and about 300,000 homeless [1]. More than 50,000 buildings were destroyed, and the earthquake caused economic losses of about 100 billion dollars. In 1999, a catastrophic earthquake of 7.6 magnitude hit Kocaeli Province in Turkey, causing about 18,373 deaths, 43,953 injuries, and 127,251 building damages [2, 3]. In 2004, a 9.1 Mw earthquake struck the west-northern coast of Sumatra in Indonesia. The earthquake causes massive tsunami waves up to 30 m high killing about 227,898 people in 14 countries. The earthquake damage level was very large, and it destroyed more than 220,000 human fatalities, 139,000 houses, 73,869 hectares of agricultural lands, 2,618 kilometers of roads, 3,415 schools, 13,828 fishing boats, 119 bridges, 669 government buildings, 517 health facilities, 1,089 worship places, 22 seaports, and 8 airports [4]. Furthermore, in 2011 the great east Japan Earthquake causes more than 19,729 deaths, and 6,233 injured. Approximately 122,000 buildings totally collapsed, and about one million buildings suffered severe and partial damage. The total earthquake damages cause about $154 billion in economic losses [5]. Recently in 2011, seven earthquakes with a magnitude of 7 or above occurred in Asia causing damage and life losses.

Türkiye is located in a high seismic region affected by relative motions between African, Arabian, and Eurasian tectonic plates. North Anatolian Fault Zone (NAFZ), East Anatolian Fault Zone

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ORCID: [a]0000-0002-3799-8439; [b]0000-0002-6112-4539, [c]0000-0002-6084-6353

(EAFZ), and SE Anatolian Thrust Zone are active fault segments in Türkiye as it is shown in Fig. 1 [6, 7]. All these active faults cause short time intervals of intensive damage in Türkiye earthquakes.

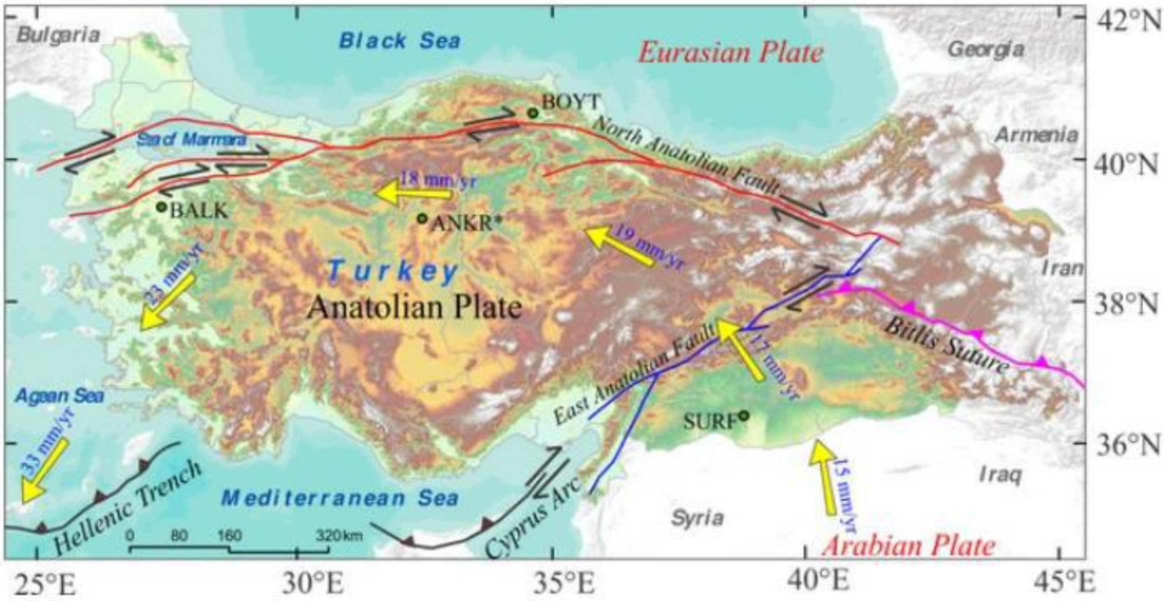

Figure 1. Active fault segments in Türkiye [7]

Figure 2. Locations of the earthquakes and the affected ten neighboring provinces [9]

For investigating and real-time monitoring of the seismic activity of Türkiye, the Turkish Ministry of Interior Disaster and Emergency Management Presidency (AFAD) operates seismic stations countrywide. Two major earthquakes of 7.7 and 7.6 magnitudes occurred in Kahramanmaraş in the east and south of Türkiye on the same day. The earthquakes were generated due to the East Anatolian Fault seismic activities and they were recorded by AFAD seismic stations. Furthermore, nine neighboring provinces of Adıyaman, Kilis, Osmaniye, Gaziantep, Malatya, Şanlıurfa, Diyarbakır, Adana, and Hatay were also highly affected by the earthquakes. The first 7.7 M_W earthquake occurred in Pazarcık, Kahramanmaraş on the 6th of Feb 2023, and after about 9 hours, an earthquake of 7.6 M_W occurred in Elbistan, Kahramanmaraş. The locations of the earthquakes and the affected ten neighboring provinces are shown in Fig. 2. Thousands of buildings collapsed in the ten Turkish provinces and caused thousands of life losses and injuries. More than 14 million people were affected and a lot of people lost their homes as a result of the two major disasters of the century. Authorities declared these earthquakes as a major disaster and call for international rescue. According to the official reports, 40,689 people have lost their lives and more than 100,000 people have been injured. 216,347 people have been evacuated from quake-hit areas. These numbers still keep increasing since the operations are being continued at full speed [8]. Hatay is one of the provinces that is most affected by earthquakes. Many buildings collapsed in Antakya. In this research site, observations and evaluation of the time history records of the earthquakes were analyzed to investigate reasons for failures and failure modes of old and new buildings in Hatay cities (i.e., Antakya and İskenderun cities).

2. Earthquake Records

At 01.17 UTC (04.17 local time), the 7.7 M_W earthquake occurred in Pazarcık, Kahramanmaraş at a depth of 8.6 km. After about nine hours, at 10.24 UTC (13.24 local time), the 7.6 M_W earthquake occurred in Elbistan, Kahramanmaraş at a depth of 7 km [9].

The 7.7 M_W earthquake time history records for 3123 Antakya and 3112 İskenderun stations are shown in Figs. 3 and 4, respectively. As it is shown in Fig. 3 for Antakya, the earthquake lasted longer than one minute, and the east-west (EW) peak ground acceleration (PGA) value reached about 800 cm/s^2 which is 0.8 g.

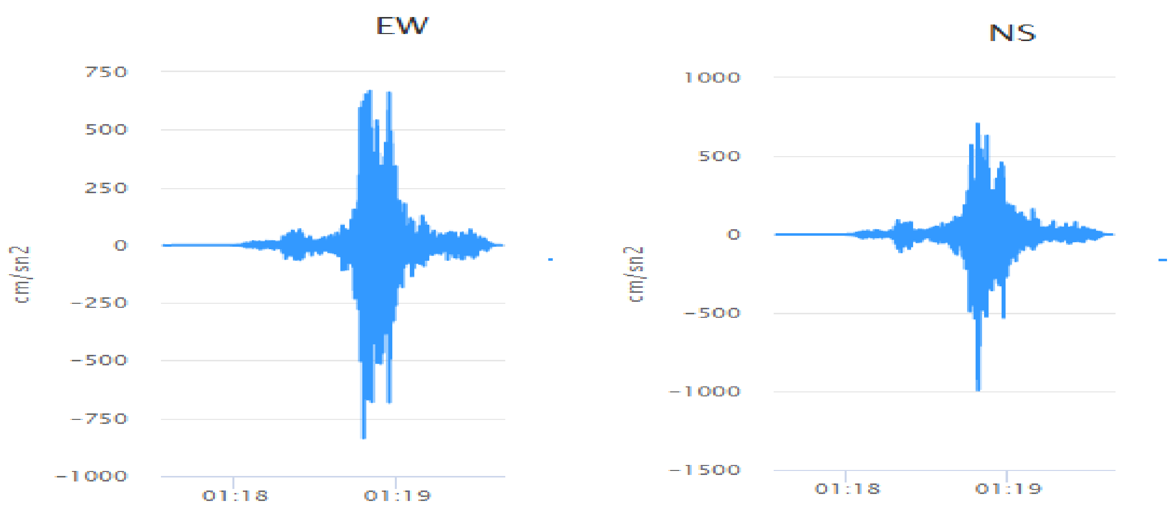

Figure 3. 7.7 M_W earthquake time history ground acceleration records at Hatay Antakya [9]

As seen in Fig. 4, the earthquake also lasted longer than one minute, and the east-west (EW) peak ground acceleration value reached approximately 200 cm/s^2 which is 0.2 g for İskenderun.

While comparing the PGA values of the earthquake for the two cities, it is clearly seen that the acceleration value of Antakya was more than 4 times higher than İskenderun.

PGA values at different locations in Antakya and İskenderun cities were measured by AFAD seismic station and presented in Fig. 5 and Table 1. It is understood from the figure that, in Antakya city center, the PGA is very high with a value more than the value of the acceleration of gravity (that is more than one g), and the average value of the PGA in Antakya is about 0.86 g. Previous studies showed that most of the settlements are located on the softest and soft soils [10]. Thus, these high PGA values occur due to the soft soil conditions which amplify the seismic waves.

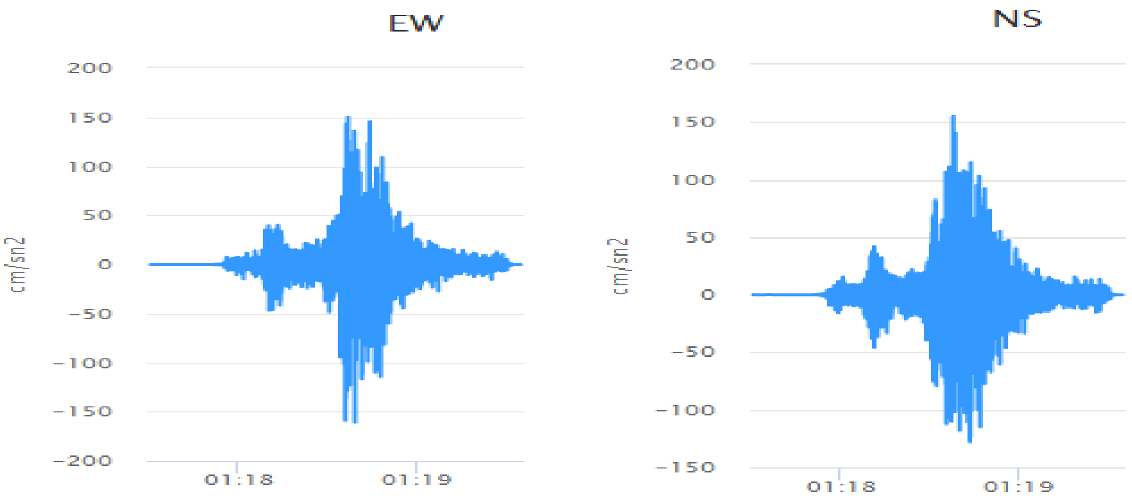

Figure 4. 7.7 M_W earthquake time history ground acceleration records at Hatay İskenderun [9]

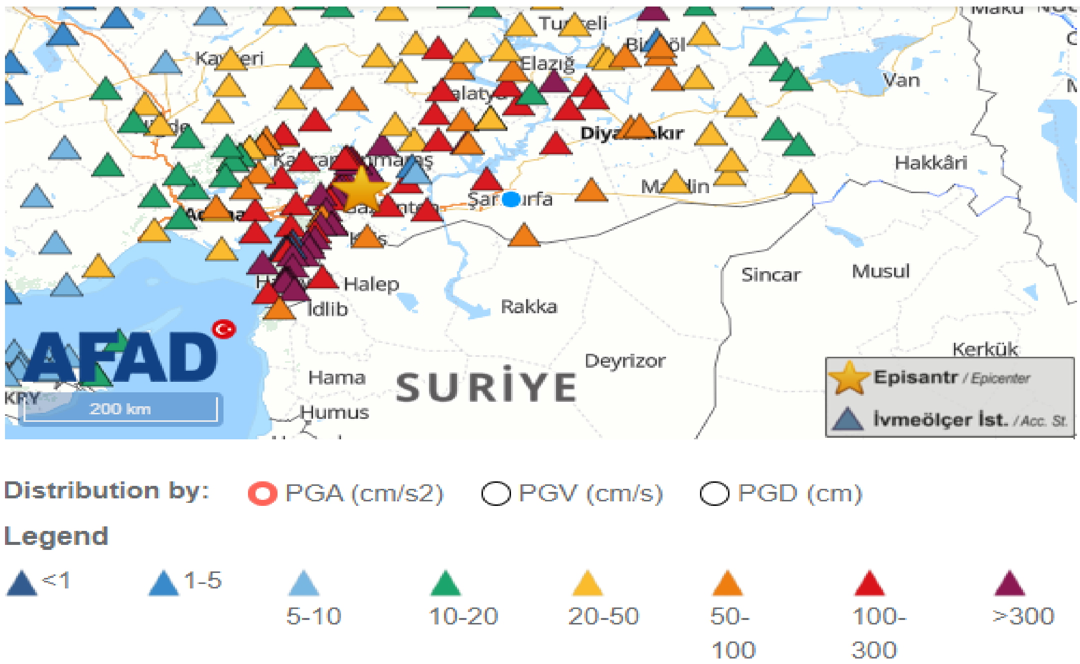

Figure 5. PGA values of all stations for 7.7 M_W earthquake (AFAD)

Table 1. PGA values of the stations located in Antakya and İskenderun for a 7.7 M_W earthquake

Antakya		İskenderun	
Station code	**PGA (cm/s^2)**	**Station code**	**PGA (cm/s^2)**
3123	868	3112	172
3126	1211	3115	286
3129	1353	3116	168
3131	366	3117	1111
3132	515	**Average**	434
Average	863		

Furthermore, in İskenderun, the average PGA value in most locations is about 0.2 g except in one location which is close to the highway road with a PGA of about 1.1 g. In addition, at this location, most of the damage occurred and this is the result of the soft soil condition there. In İskenderun, locations near the seaside have PGA with 0.17 g, and that's why there is only minor damage, or no damage appeared at the buildings.

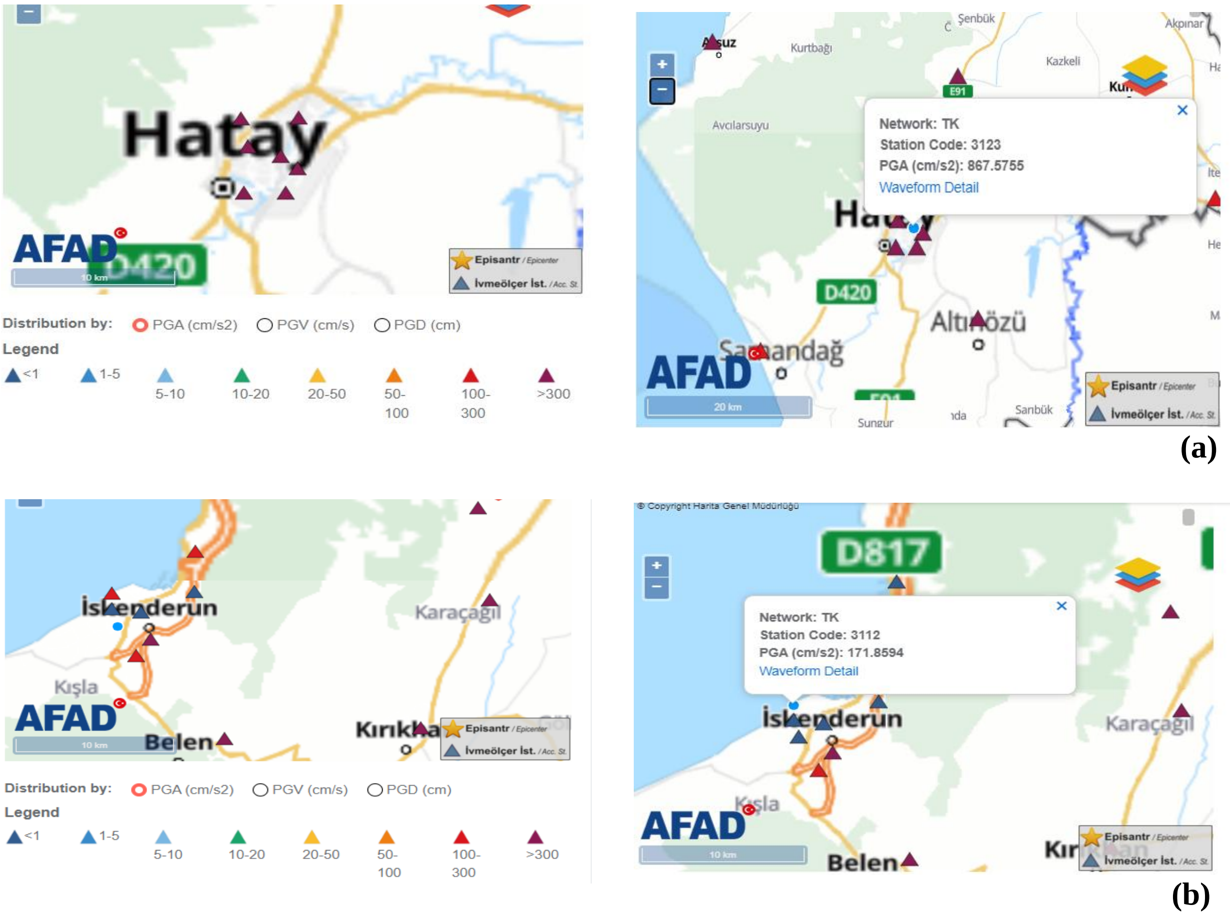

Figure 6. Two examples of PGA values, (a) 3123 Antakya and (b) 3112 İskenderun stations

Fig. 7 shows the PGA values of all stations for the second earthquake which occurred at 13.24 local time. The fault line of that earthquake does not pass from Antakya. Therefore, the PGA value in Antakya is very low, measuring about 26 cm/s^2.

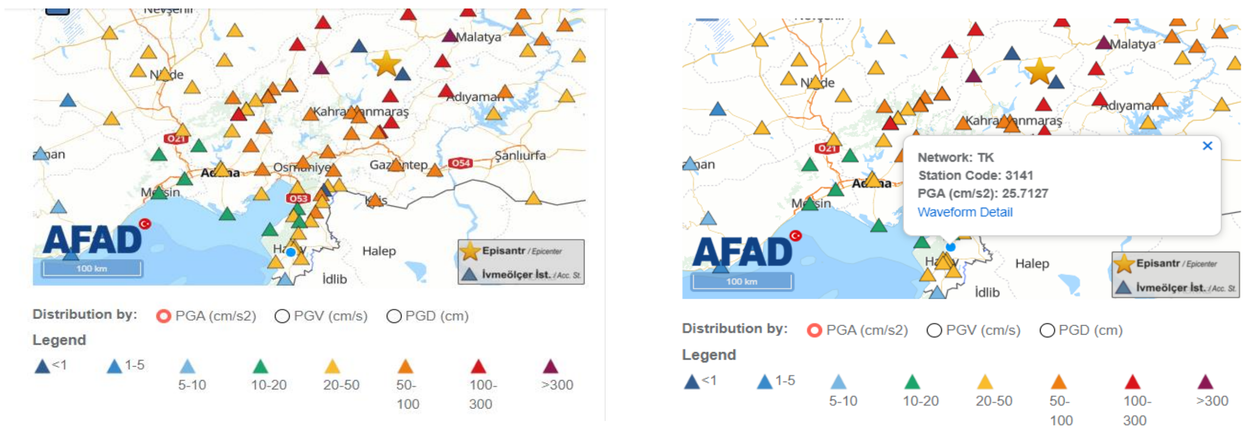

Figure. 7. PGA values of all stations for 7.6 M_W earthquake (AFAD)

Fig. 6 shows the PGA values for 3123 Antakya and 3112 İskenderun stations. It can be said that PGA values at Antakya are about four times higher than PGA values in İskenderun. Thus, the level of damage and number of buildings that collapsed in Antakya is about three or four times higher than the level of damage in İskenderun.

3. Site Observations and Buildings Damages

Site observations show that the most damaged buildings are two to five stories old RC buildings constructed before 1999 as it is shown in Fig. 8.

a) soft story, low concrete quality and poor reinforced detailing

b) floors with different levels, pounding, and loss of bond between concrete and reinforcement bars

Figure 8. An example of old buildings with severe damage or totally collapsed

The main causes of earthquake damage to these old buildings are having very low-quality concrete, poor reinforcement detailing, poor workmanship in concrete work, and deficiencies in the structural system (Figs. 8a and 8b). Some of these old buildings were constructed very close to each other without paying attention to floor diaphragm levels even for adjacent buildings, that's why they suffered pounding as it is shown in Fig. 8b. The lateral load structural systems of these buildings are generally RC frames with very low rotational ductility. Brittle partitioning walls in these buildings were damaged during the earthquake because they are not flexible to match the relatively big story drifts. Furthermore, local failures in beam-column connections and buckling of reinforcement bars, lack of adequate development lengths, and loss of bond between concrete and reinforcement bars were observed in these buildings (Fig. 8b).

Fig. 9 shows a comparison of old and new buildings at the same site under the same soil condition. While old buildings collapsed, minor damage was observed in the new buildings in some areas.

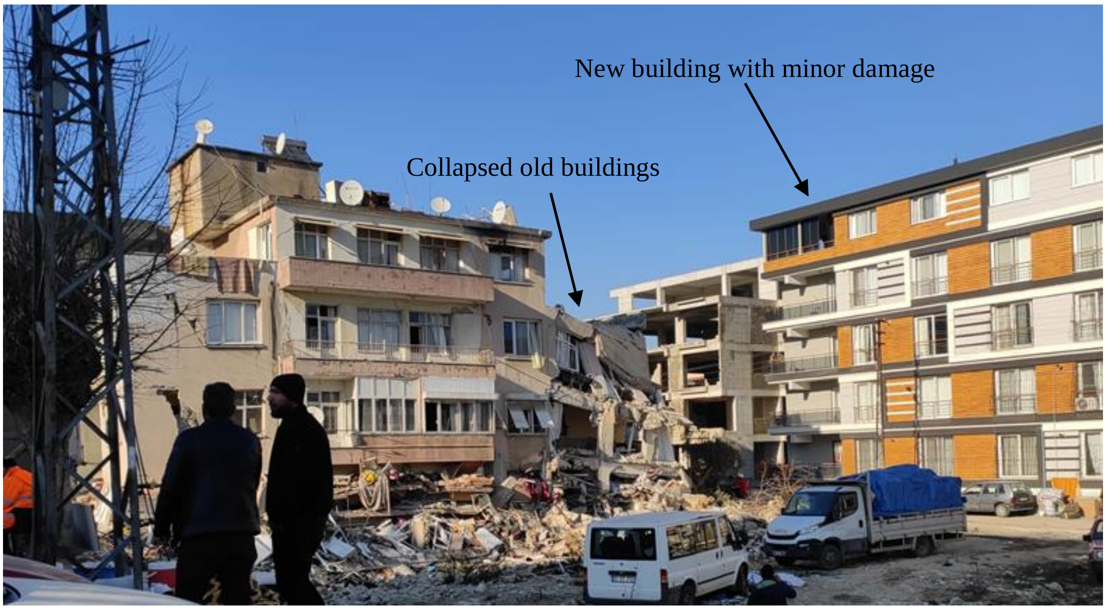

Figure 9. The newly constructed buildings compared to the old buildings

Some examples of new buildings are shown in Fig. 10. Most of the new buildings show good seismic performance with no damage or minor damage as seen in Fig. 10.

Fig. 11 shows examples of some new buildings with moderate and severe damage. Although these buildings have moderate and severe damage, they did not have pancake failure mode as it is shown in Fig. 11.

Figure 10. Good seismic performance of some new buildings

Figure 11. Damaged new buildings without pancake failure mode

Buildings with RC shear walls show good performance even if they are old buildings as it is shown in Fig. 12.

Figure 12. An example of a building with RC shear walls

TOKI buildings constructed by the "Ministry of Environment, Urbanization, and Climate Change" in İskenderun show good seismic performance with minor or no damage. The structural system of TOKI company buildings is RC shear walls system, and the buildings were constructed on regions of stiff soils or rock soils (Fig. 13).

Figure 13. TOKI buildings in İskenderun without damage

In some locations in İskenderun city, the earthquake causes soil liquidation which leads to buildings and road settlements as in is shown in Fig. 14.

Figure 14. Examples of soil liquefaction in İskenderun city

4. Conclusions and Discussion

In accordance with the site observations in İskenderun, about 25% of the buildings get moderate and severe damage and 75% of them survive with minor damage. Most damaged buildings are old buildings and 15% of the damaged buildings were newly constructed and they get failure. The cause of failure of these new buildings has occurred due to design mistakes or poor control of construction materials and construction details. Old hospitals without seismic isolation systems got damaged, and newly constructed hospitals with seismic isolation systems survive without any damage.

According to the PGA values observed in Antakya and İskenderun, the following results can be obtained:

- PGA average value in Antakya is about 0.86 g. These high PGA values occurred due to the soft soil conditions which amplify the seismic waves.
- In İskenderun, the average PGA value in most locations is about 0.2 g except in one location which is close to the highway road with PGA about 1.1 g. At this location, most damage happened due to the soft soil conditions.
- Only minor damage or no damage was observed on buildings located near the sea cost in İskenderun is related to the considerably low PGA value of 0.17 g at that location.
- PGA values at Antakya are about four times higher than PGA values in İskenderun. It explains the higher level of damage in Antakya compared with İskenderun.

In addition to the results obtained from PGA values, it is observed that most of the collapsed buildings during the Kahramanmaraş earthquakes are old building stocks constructed before 1999. Most of the collapsed old buildings collapsed in a pancake failure mode and this caused thousands of life losses and injuries. The reasons for failures are having very low concrete quality, buckling of reinforcement bars, lack of development lengths, and loss of bond between concrete and reinforcement bars.
Buildings with RC frames and shear wall structural systems withstand earthquake effects with minor or moderate damage. It is related to the existence of RC shear walls with good concrete quality. New buildings constructed after 1999 and designed according to the new Turkish seismic code [11] show good seismic performance and withstand earthquake effects with minor or moderate damage.

However, some of these buildings also collapsed. The collapsed new buildings should be investigated in detail in order to understand the reason for the collapse. Hospitals with seismic isolation systems show good performance during the Kahramanmaraş earthquakes with no damage. The region was hit by two major earthquakes on the same day. Hence, it is fair to say that some of the collapsed buildings withstand the first earthquake, then collapsed in the second earthquake. To prevent loss of lives and injuries in future earthquakes, there is an urgent need to strengthen or renew all existing old building stocks in Türkiye. On this issue, it is recommended that administrative authorities should cooperate and take all precautions to develop regulations between the counterparts of the problem.

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Author(s) Contributions

All the authors contributed to this site research and approved the final version of the manuscript.

Competing Interests

The authors declare that they have no competing interests.

References

[1]. "Natural Disaster Databook 2021 An Analytical Overview" Asian Disaster Reduction Center (ADRC) Higasjhikan 5F., 1-5-2 Wakinohamakaigan-dori Chuo-ku, Kobe 651-0073, Japan.

[2]. A. Barka, "The August 1999 Izmit Earthquake" *Science*, 285(5435), 1858-1859. DOI:10.1126/science.285.5435.1858, 1999.

[3]. OCHA (15 September 1999), "Turkey – Earthquake OCHA Situation Report No. 21". ReliefWeb. Retrieved 12 May 2023. https://reliefweb.int/report/turkey/turkey-earthquake-ocha-situation-report-no-21.

[4]. S. Nazara and B. P. Resosudarmo, "Aceh-Nias Reconstruction and Rehabilitation: Progress and Challenges at the End of 2006," ADB Institute Discussion Paper No. 70, Asian Development Bank Institute, Kasumigaseki Building 8F, 3-2-5 Kasumigaseki, Chiyoda-ku, Tokyo 100-6008, Japan

[5]. T. Miyazaki, "Impact of Socioeconomic Status and Demographic Composition on Disaster Mortality: Community-Level Analysis for the 2011 Tohoku Tsunami," *Int J Disaster Risk Sci* vol. 13, pp. 913-924, 2022. https://doi.org/10.1007/s13753-022-00454-x

[6]. D. Kalafat, A. C. Zülfikar, and S. O. Akcan, "Seismicity of Turkey and real-time seismology applications in determining earthquake hazard," *Academic Platform Journal of Natural Hazards and Disaster Management*, vol. 2, no. 2, pp. 96-111, 2021. doi:10.52114/apjhad.1039670

[7]. K. Ansari, O. Corumluoglu, and S. K. Sharma, "Numerical simulation of crustal strain in Turkey from continuous GNSS measurements in the interval 2009-2017," *Journal of Geodetic Science*, vol. 7, no. 1, pp. 113-129, 2017.

[8]. "Kahramanmaraş Depremi", https://www.trthaber.com/haber/gundem/asrin-felaketinde-can-kaybi-40-bin-689a-yukseldi-747421.html (Accessed Feb. 19, 2023)

[9]. "Last Earthquakes", https://deprem.afad.gov.tr/last-earthquakes (Accessed Feb. 19, 2023)

[10]. H. Korkmaz, "The relationship between ground conditions and earthquake effect in Antakya," *Turkish Journal of Geographical Sciences*, vol. 4, no. 2, pp. 49-66, 2006 (in Turkish).

[11]. TBSC, "Türkiye Building Seismic Code", AFAD, Official Gazetta, (in Turkish). Ankara: 416 pages, 2018.