SAVEZ GRAĐEVINSKIH INŽENJERA SRBIJE
ASSOCIATION OF CIVIL ENGINEERS OF SERBIA

GEOTECHNICAL ASPECTS OF CIVIL ENGINEERING AND EARTHQUAKE ENGINEERING - Vrnjačka Banja, 01-03. novembar 2023.

Svetlana Brzev[1] and Marko Marinković[2]

PERFORMANCE OF REINFORCED CONCRETE BUILDINGS IN THE FEBRUARY 6, 2023 TÜRKIYE EARTHQUAKES

Summary: *The paper discusses consequences of the February 6, 2023 earthquake sequence (a M 7.7 earthquake with epicentre in Pazarcik, followed by a M 7.5 earthquake with epicentre in Elbistan) which affected south Türkiye and northwestern part of Syria. The earthquakes caused more than 56,000 fatalities. More than 230,000 buildings experienced severe damage or collapse, while additional 40,000 buildings experienced moderate damage. The focus of the paper is on the performance of reinforced concrete buildings, which are prevalent in the affected area. The causes of structural damage are discussed in the context of the local codes, and in design and construction practices. Extensive non-structural damage was observed in these buildings, and it was caused by flexible RC frame system and inadequate amount of RC walls. The topic is relevant for Serbia since reinforced concrete is prevalent technology for buildings in our country, and some similarities in construction practices exist in Serbia and Türkiye.*

Keywords: *earthquake damage; Turkeys earthquake 2023; reinforced concrete and masonry buildings; structural damage; non-structural damage.*

PONAŠANJE ARMIRANOBETONSKIH ZGRADA U TURSKIM ZEMLJOTRESIMA OD 6. FEBRUARA 2023. GODINE

Resume: *U radu se razmatraju posledice serije zemljotresa od 6. februara 2023. godine (zemljotres magnitude 7,7 sa epicentrom u Pazarčiku, a zatim zemljotres magnitude 7,5 sa epicentrom u Elbistanu) koji su pogodili južnu Tursku i severozapadni deo Sirije. Ovi zemljotresi su prouzrokovali više od 56.000 smrtnih slučajeva. Više od 230.000 zgrada pretrpelo je tešku štetu ili se urušilo, dok je još 40.000 zgrada pretrpelo umerenu štetu. Fokus rada je na ponašanju armiranobetonskih zgrada koje su najviše zastupljene u pogođenom području. Uzroci konstruktivnih oštećenja razmatrani su u kontekstu lokalnih propisa, kao i projektovanja i izgradnje. Na ovim objektima uočena su velika nekonstruktivna oštećenja usled fleksibilnog AB okvirnog sistema i neadekvatne količine AB zidova. Tema rada je relevantna za Srbiju jer je armirani beton preovlađujuća tehnologija gradnje za zgrade u našoj zemlji, a postoje i sličnosti u građevinskoj praksi u Srbiji i Turskoj.*

Ključne reči: *Oštećenja usled zemljotresa, Turski zemljotres 2023, armiranobetonske i zidane zgrade, oštećenja konstrukcije, nekonstruktivna oštećenja*

---

[1] Adjunct Professor, Department of Civil Engineering, University of British Columbia, Canada, sbrzev@mail.ubc.ca

[2] Assistant Professor, Faculty of Civil Engineering, University of Belgrade, Serbia, mmarinkovic@grf.bg.ac.rs

1. INTRODUCTION

On February 6, 2023, Central Türkiye and northwestern part of Syria were hit by two major earthquakes, also known as "the Kahramanmaraş earthquake sequence" based on the name of the province in which the epicentres were located. The first earthquake occurred during early morning hours with the epicentre close to the town Pazarcik, it had a magnitude 7.7, at 8.6 km hypocentral depth. During early afternoon hours on the same day, another major earthquake (with magnitude 7.5 and 7.0 km hypocentral depth), occurred close to Elbistan (located at approximately 95 km distance from the epicentre of first earthquake). The chances of two major earthquakes occurring on the same day and in the same region of a country are extremely small; this is an extremely rare event in the history of past earthquakes. The epicentral region was subsequently affected by a significant number of aftershocks (more than 18,000), which kept recurring over the period of 4-5 months and caused further damage and/or collapse of previously damaged structures. A particularly strong aftershock occurred on February 20, 2023 (Mw 6.3) with the epicentre close to the Uzunbağ village (Hatay province). A map of the epicentral region is shown in Diagram 1.

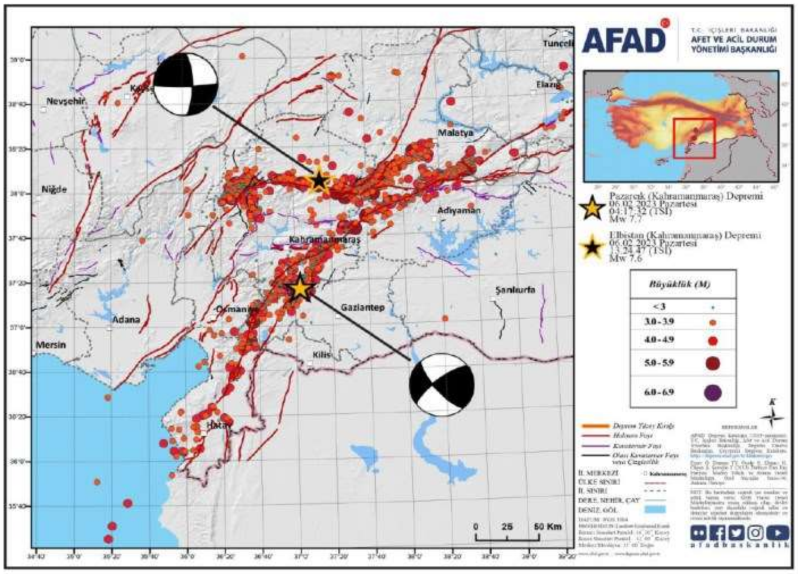


Diagram 1. Epicentral region of the February 6, 2023 earthquakes, showing the locations of epicentres of the main shocks and aftershocks (Source: AFAD)

There are three major tectonic plates within the Turkish territory - Anatolian, Arabian, and African. As a result, history of major earthquakes within the territory of contemporary Türkiye is very rich, and dates back to ancient times, i.e. the Roman Empire (400 BCE) [1]. The epicentre of the first earthquake (Pazarcik) was located at the Eastern Anatolian fault, which caused many devastating earthquakes with magnitude 7.0 and higher, particularly in the 18th and 19th centuries. A few earthquakes with magnitudes of 6.0 and higher had epicentres along this fault in the last 50 years, for example the 1971. and 2003. Bingöl earthquakes (M6.8 and Mw 6.3, respectively). More recently, in 2020. two damaging earthquakes occurred along the same fault (magnitudes 5.7 and 6.8). It is important to note that the February 6, 2023 earthquakes created an extremely long fault rupture (more than 300 kilometres), and that the effects of these earthquake are significant along the entire fault line. As a result, the extent of damage is not necessarily proportional to the distance from epicentre (which is usually the case with less severe earthquakes).

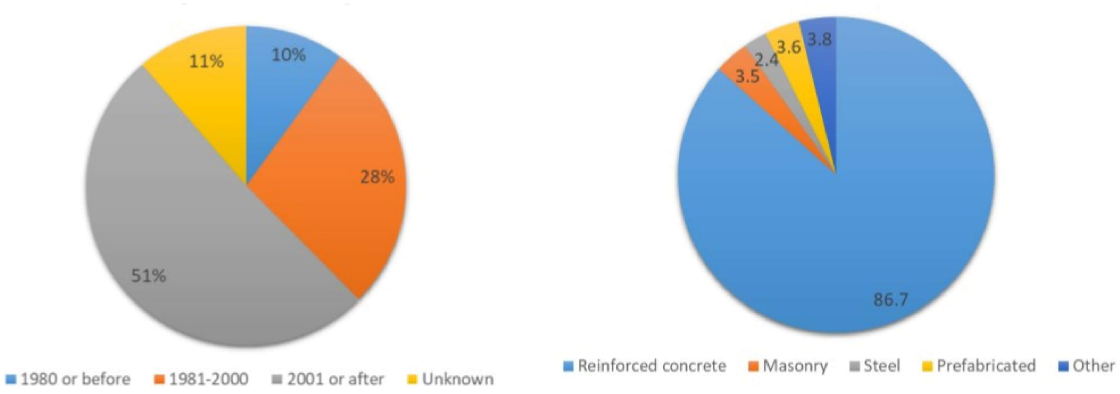
These earthquakes caused significant human and economic losses. The total number of fatalities in Türkiye and Syria was estimated to 56,000; out of this, more than 50,000 fatalities were reported in Türkiye [3]. Total economic losses (direct and indirect) in Türkiye were estimated at 96 billion euros, corresponding to approximately 9.0% of the national GDP for 2023. As expected, housing sector experienced major losses, accounting for 53% of the total amount, while buildings of other purposes account for 28% of the losses, and the infrastructure accounts for the remaining 19% [2]. The total economic losses for Syria were estimated at approximately 14 billion euros [4].

The number of affected inhabitants due to these earthquakes was estimated at 14 million in 11 provinces of Türkiye (corresponding to 16% of the total population of the country) [1]. The affected region was relatively densely populated, and encompasses numerous urban centres which experienced construction boom in the last 40 years.

One of the most affected areas is the Kahramanmaraş province. An aerial view of the Kahramanmaraş city (centre of the province) before the earthquake is shown in Diagram 2. The population of the city was estimated at 385,000 in 2021.

Diagram 2. An aerial view of the Kahramanmaraş city in 2011 (source: https://commons.wikimedia.org/wiki/User:Amir_Sabbagh)

The total building stock in the affected region, including residential and other buildings, was estimated at 2.6 million buildings. Based on the statistical data it appears that more than 50% of the building stock in the affected region was constructed after 2000 [1]. It has been estimated that majority of buildings in the area were constructed using cast-in-situ reinforced concrete (RC) technology. Relevant statistical data are presented in Diagram 3.



(a) (b)

Diagram 3. Building stock in the earthquake-affected area: a) breakdown based on the construction date, and b) breakdown based on the lateral load-resisting system (based on[1], worked out by Nemanja Krtinić)

According to the reported building assessment data, more than 230,000 buildings experienced either severe damage or collapse and need to be replaced/reconstructed, while additional 40,000 buildings experienced moderate damage and could be repaired and retrofitted [1]. Many urban centres were devastated by the earthquakes, since majority of buildings collapsed and the remaining buildings had to be vacated and their inhabitants were provided temporary shelter, such as tents or containers. Antakya (also known as Hatay) was one of the most devastated cities, in which majority of inhabitants had to be relocated from their homes (Diagram 4).

Diagram 4. Ruins of Antakya (province Hatay), showing the prevalence of RC buildings (credit: SUZI-SAEE).

This paper discusses the performance of RC buildings in the February 6, 2023 Türkiye earthquakes. The focus is on cast-in-situ buildings with beam-column frame system, with masonry infills and (in some cases) structural walls. The causes of damage are discussed, and the typical damage patterns are illustrated on examples. The observations are based on the authors' reconnaissance visits to the affected areas of Türkiye from March to June 2023. Relevant lessons for the engineering practice in Serbia have been summarized. Refer to paper by Marinković et al. [5] and the seminar presentations [6] for more details on the consequences of these earthquakes.

2. DAMAGE OF REINFORCED CONCRETE BUILDINGS WITH FRAME AND DUAL FRAME-WALL SYSTEMS

The February 6, 2023 earthquake sequence caused damage and collapse of RC buildings at a very large scale, as expected given the magnitudes of these earthquakes and the high shaking intensity spread over a very large area. The affected residential buildings included both mid-rise buildings (usually up to 6-storey high) and taller, high-rise buildings (usually more than 10-storeys high). It is estimated that the majority of affected buildings were constructed after 2000, and that most of them were constructed according to the 2007 seismic design code [7], while a smaller fraction of the buildings was designed according to the 1998 and 2018 seismic design codes [8].

Majority of the affected RC buildings have a beam-column frame system, with or without structural (shear) walls, which are the main focus of this paper. A smaller fraction of RC buildings have a flat slab system, with one-way or two-way ribbed slabs supported by the columns (Diagram 5a). These slabs have „hidden“ beams, that is, shallow RC beams with the depth equal to the slab thickness. The voids in the slabs are often infilled by masonry elements (blocks). Buildings of this type were exposed to the November 26, 2019 earthquake and many of them experienced damage due to excessive flexibility of the lateral load-resisting system [9], [10].

Another RC technology used for building construction in Türkiye is tunnel form technology. These buildings are constructed by casting walls and floors in a fast manner, since the formwork is reusable for different floors. The main lateral load-resisting system consists of structural walls (shear walls). Seismic performance of these buildings has been satisfactory, with some non-structural and structural damage but collapse is rarely reported. These buildings are usually constructed in Türkiye for social housing implemented by TOKI (the Housing Development Administration of the Republic of Türkiye). Refer to [11] for examples of typical projects.

(a) (b)

Diagram 5. Typologies of RC buildings in the earthquake-affected area of Türkiye: a) building with a flat slab system, Kirikhan, and b) building with a tunnel form construction, Elbistan (credit Nemanja Krtinić).

Causes of damage in RC buildings due to the February 2023 earthquakes are very similar to those identified after the 1999 earthquakes [12] and the 2003 Bingol earthquake [13], which indicates that the deficiencies in design and construction practice have been continuously repeated, in spite of the devastating consequences of past earthquakes. The authors believe that one of the most important causes of both structural and non-structural damage in taller RC buildings is excessive flexibility of frame structures, due to either a complete absence or inadequate amount of structural walls. As a result, the capacity of structural walls in a building (e.g. elevator core) was inadequate given the high seismic demand. As a result, structural damage occurred in these walls and adjacent frame elements. On the other hand, excessive lateral drift due to a high seismic demand caused extensive damage or collapse of masonry infill walls and partitions. The authors surveyed many tall RC buildings which experienced repairable (minor or moderate) structural damage, however non-structural damage was extensive and the buildings had to be vacated.

Consequences of excessive structural flexibility on the seismic performance of a building will be illustrated on an example of a RC building located in Kahramanmaraş, one of the largest cities in the earthquake-affected area. Although the recorded accelerations in the area were lower compared to other locations (PGA values for the stations TK4617, TK4620, and TK4624 located in the city ranged from 0.12 to 0.36g) [14], many taller RC buildings experienced either extensive damage or collapse. Diagram 6 shows elastic acceleration response spectrum for the station TK 4620 located in Kahramanmaraş, and the corresponding design spectra for 475-year return period earthquake, indicating that the recorded spectral accelerations are within the design range (for elastic response). The design spectra for 2475-year return period earthquake are significantly higher than the spectra obtained from the recorded accelerations.

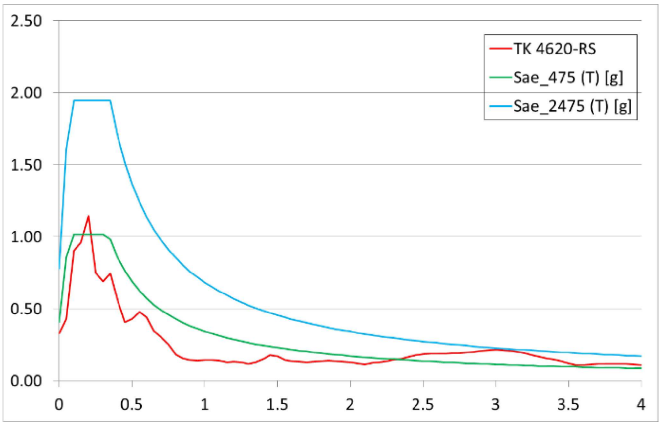


Diagram 6. Elastic acceleration response spectra for station TK4620 located at Kahramanmaraş (red line shows the spectra based on the recorded accelerations, while green and blue lines show design elastic spectra for the earthquake with return period of 475 years and 2475 years, respectively).

A few design- and construction-related deficiencies were observed in the buildings which were surveyed by the authors. The buildings were designed in 2016 as a part of the building complex consisting of four building blocks (A, B, C, and D) - see exterior view in Diagram 7a. The building has 11 floor levels, out of which the bottom 4 levels have a larger plan shape and there are no masonry infills, therefore the bottom portion acts like a podium that supports the more narrow upper portion of the building (Diagram 7b). It should be noted that podium portion of the building was laterally supported in the E-W direction on each side by the adjacent structures (seismic gaps between the building blocks were specified by the construction drawings but were not implemented). Also, the bottom two storeys of the podium were buried (earth-supported) on the north side.

(a) (b)

Diagram 7. An example of a high-rise RC building, Kahramanmaraş: a) exterior view, north façade, and b) an elevation showing N-S direction (note the podium).

Typical floor plan for the upper portion of the building (above the podium) is shown in Diagram 8. Based on the information provided on the construction drawings, the building was designed as a dual frame-wall structure for seismic design purposes. However, besides the C-shaped elevator core which acted like a complex structural wall, there were no additional walls in E-W direction, and only 6 short structural walls (25 cm x 175 cm thickness x length) were constructed in the N-S direction. The 2007 seismic design code did not clearly prescribe the minimum amount of walls and their contribution to the overall lateral load resistance, which is believed to be an omission in the code.

An additional factor contributing to excessive lateral flexibility of the structure, particularly in the E-W direction, was an asymmetrical column layout. It can be seen from the floor plan (Diagram 8) that majority of the columns were aligned in the N-S direction, but only 4 columns along the exterior gridline on the north side plus two additional interior columns were aligned in the E-W direction. The columns have an elongated rectangular shape, with 25 cm width and the depth ranging from 60 to 100 cm. It is expected that majority of the columns resist seismic effects in E-W direction by weak axis bending, which is undesirable.

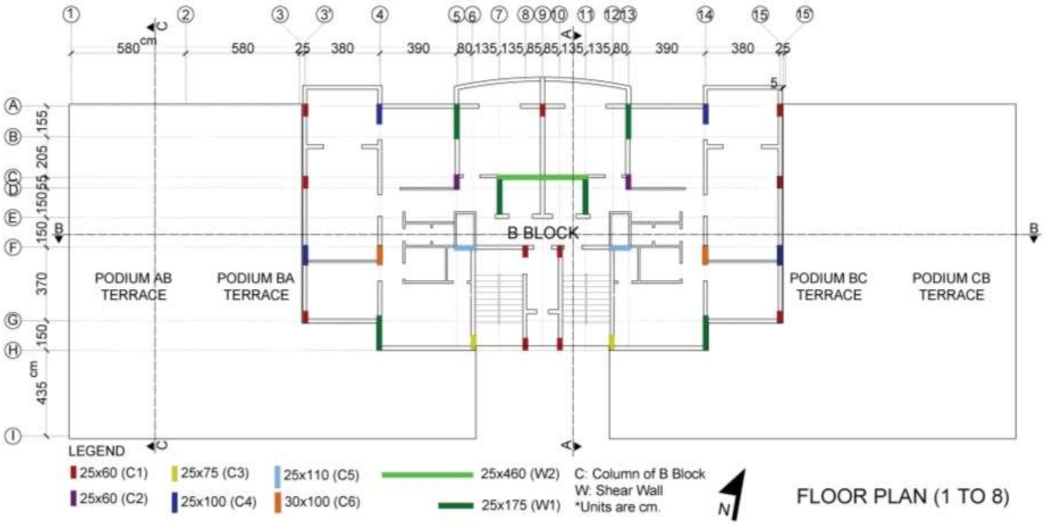


Diagram 8. An example of a RC building, Kahramanmaraş – typical floor plan for the floor levels above the podium (credit: Şerife Özata).

These buildings experienced only moderate structural damage, however non-structural damage was extensive. Structural damage in the elevator cores, as observed at the ground floor level, was mostly in the form of shear cracking or damage due to the combined axial load and flexure, as illustrated in Diagram 9.

(a) (b)

Diagram 9. Structural damage in an elevator core: a) shear cracks (Block C) and b) damage at the base of the wall due to buckling of longitudinal reinforcement caused by overturning moment (note absence of cross-ties)

It should be noted that the detailing of reinforcement for the elevator core was not implemented according to the construction drawings. One of the important deficiencies is related to the absence of cross-ties, which have important role in preserving the integrity of reinforcement cage in shear walls and columns. Absence of cross-ties in RC shear walls and columns was observed in many surveyed buildings. Reinforcement detailing for the elevator core (as specified on the construction drawings) is shown in Diagram 10.

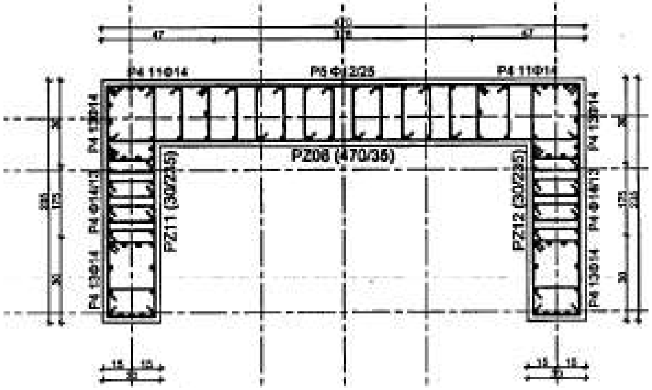


Diagram 10. Reinforcement details for the elevator core (note closely spaced cross-ties indicated on the drawing)

The most significant consequence of excessive structural flexibility was a non-structural damage of infill walls and partitions. In particular, exterior infill panels on the south façade of the building experienced significant damage, and many infills entirely collapsed (Diagram 11). Many interior infills and partitions experienced cracking, and/or portions of the infills fell out of the frame (Diagrams 12a and b). The infills were made of lightweight concrete blocks (known as bimsblock or bricket in Türkiye), and the extent of damage could be partially attributed to their low compressive strength (on the order of 2MPa). A typical masonry element (block) is shown in Diagram 12c.

Diagram 11. Failure of exterior masonry infills was observed in all building blocks

(a)

(b)

(c)

Diagram 12. Non-structural damage of masonry infill walls and partitions; a) extensive cracking of exterior masonry infills and separation from the frame – ground floor level; b) failure of both interior and exterior infills at the upper floors, and c) a typical masonry block.

Another cause of non-structural damage in RC buildings was related to overhangs, that is, an increase of the floor area above the ground floor level (see Diagram 13). Overhangs at the upper floors are created when floor slabs project outwards from the exterior column axes. These overhangs cause a difference is stiffness and mass between the ground floor and upper floors (a vertical irregularity). Post-earthquake reconnaissance studies in Türkiye showed that buildings with significant overhangs sustained heavier damage compared to regular buildings. In many cases, exterior walls within the overhang portion either partially or completely collapsed, see Diagram 14. These walls were not connected to exterior columns and there were no means of providing attachment to the structure, neither in vertical nor horizontal plane. As a result, these walls were extremely vulnerable to out-of-plane seismic actions. Damaged overhangs were observed at various localities throughout the earthquake-affected area.

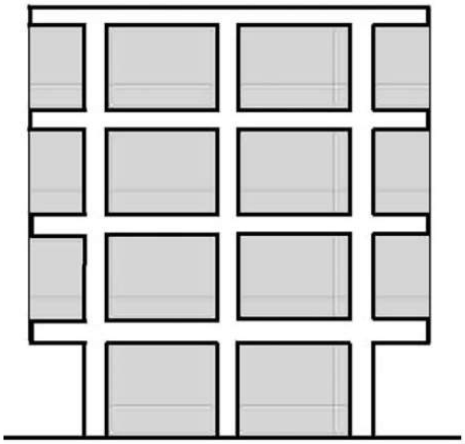
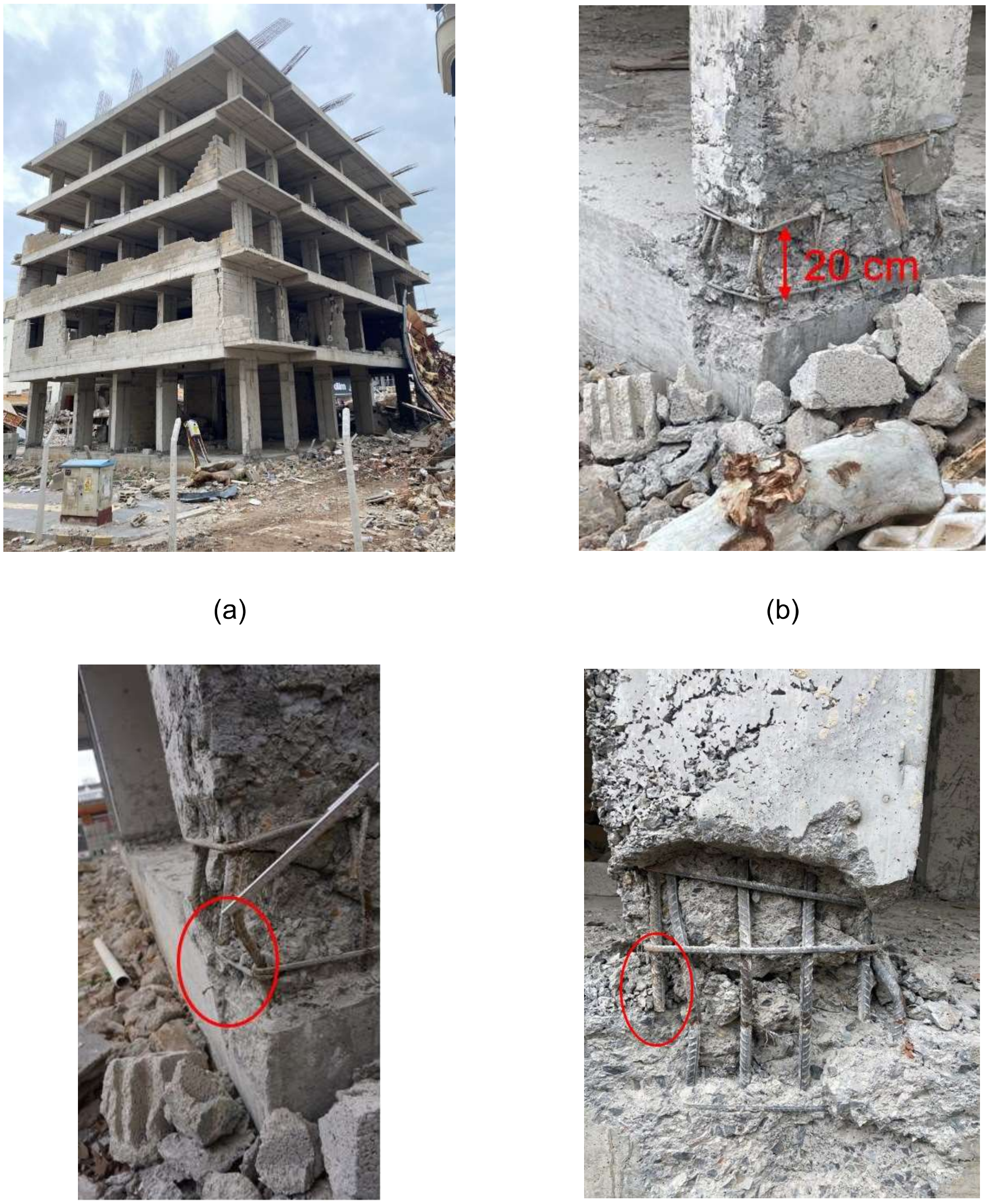


Diagram 13. An elevation of a building with overhangs [13].

Diagram 14. Non-structural damage of exterior partition walls in buildings with overhangs

Damage of RC columns in frame systems was also observed in the affected area. The damage was often caused by excessive axial and flexural demand and was observed at the base of the columns which did not have adequate capacity. Damage at the base of the columns could be also attributed to the formation of "strong beam - weak column" mechanism, which is characterized by plastic hinging at the column base and can ultimately lead to a soft storey collapse. This type of damage was observed in a 5-storey building in Nurdagi which was under construction at the time of the earthquakes (Diagram 15). A plastic hinge was formed at the base of a column at the ground floor level. A few detailing deficiencies were also observed in this building; for example, the ties within the critical zone were provided at 20 cm spacing, and 90 degree hooks were used for the anchorage (as opposed to 135 degree hooks which are prescribed for ductile columns). Additional detailing deficiencies included absence of cross-ties which are prescribed by the 2007 seismic design code, at the maximum spacing of 25 times the tie diameter (corresponding to 20 cm spacing for 8 mm diameter ties). Buckling of longitudinal reinforcement took place as a result of the excessive tie spacing and absence of cross-ties. It was observed that lap splice length for longitudinal reinforcement was very short, and the location coincided with the maximum seismic demand (this observation is common for the columns and structural walls). In some cases it was observed that the ties were not provided in the critical column zones, as observed in a 4-storey residential building in Antakya (Diagram 16).



(a) (b)

(c) (d)

Diagram 15. Structural damage of an RC building under construction in Nurdağı: a) an exterior view; b) and c) inadequate reinforcement detailing within a critical zone of RC column, and d) *inadequate anchorage of longitudinal reinforcement, and inadequate concrete construction practice (segregation) in RC column*

Diagram 16. Damage of an RC column without ties in the critical zone at the top of the first floor level, a low-rise residential building in Antakya (Hatay)

3. LESSONS FOR THE SERBIAN DESIGN AND CONSTRUCTION PRACTICE

The February 6, 2023 Türkiye earthquakes caused significant human and economic losses, and affected 14 million people in 11 provinces. Although the territory of Serbia does not have history of major earthquakes similar to those that recently occurred in Türkiye, it is important to highlight the lessons relevant for engineers responsible for design and construction of RC buildings in Serbia. These lessons are summarized below:

1. An appropriate layout of structural members and a sound structural concept are most important; this means an adequate amount of vertical structural elements (walls and columns) with adequate size and reinforcement details. A special attention should be paid to the concept and layout of structural elements in a building. A design concept must be communicated to and agreed by the architects, designers and investors.
2. Larger number of RC shear walls with adequate size and reinforcement details is needed in majority of surveyed RC high-rise buildings in the earthquake-affected area of Türkiye.
3. Reinforcement detailing should be implemented according to the seismic design code provisions. It is particularly important to ensure adequate stirrup spacing, hooks are at 135° and not 90°, and that the spice length is sufficient.

4. "Weak column-strong beam" failure mechanism should be avoided. Special attention is required for the design of flat-slab systems in order to avoid a "pancake"-type failure.
5. Quality of the construction materials (concrete and reinforcing bars) should be in line with the technical standards.
6. Quality of the execution and workmanship should be controlled – construction assurance is an important aspect of the implementation.
7. Vertical extension of buildings should be avoided, especially without the input by qualified design engineers.
8. A sudden change of stiffness in elevation should be avoided, e.g. buildings with an open ground floor and stiff upper floors, because this often causes a "soft storey" failure mechanism, which is in some cases followed by overturning of entire buildings.
9. Special attention should be paid to the design of non-structural elements (infills and partitions). Their interaction with the structural elements should be either taken into account in design, or avoided by separating the infill walls from the adjacent frame elements.

The earthquake sequence that occurred in Kahramanmaraş, Türkiye in February 2023 represents an example of extremely strong ground shaking, which at many sites may have exceeded the design intensity according to the Turkish technical regulations. Unfortunately, the extent of destruction and loss of life is not completely surprising. Omissions in the design, construction, and inspection of buildings, and general enforcement of regulations in Türkiye were identified after previous earthquakes and confirmed in these recent events. All these factors affected the seismic behaviour of RC buildings in the region. Based on the survey of damaged buildings the authors had an impression that these buildings were not designed and/or constructed according to the requirements of the Turkish technical regulations. The authors believe that the compliance of building projects with the technical regulations related to the design and construction of buildings would certainly result in fewer fatalities and less damage. Also, in many cases, the design concept and layout of structural elements in a building was selected to pay more attention to the requirements of investors and functionality, than to the basic seismic design concepts.

Accordingly, stakeholders in the Serbian construction practice (architects, engineers, and investors) should consider this series of unfortunate events in Türkiye as a warning that the rules of the construction profession must not be put aside but must be placed at the top of the priority ladder. It is important that these lessons will be taken into account at the stage of planning recovery after future earthquakes in Serbia. The inclusion of technical experts, public institutions, local communities, and general public in the planning and decision-making process should contribute to efficient and transparent reconstruction process after an earthquake.

Acknowledgments

The authors are grateful to the Serbian Association for Earthquake Engineering (SUZI-SAEE) for the support to visit earthquake-affected areas in Türkiye and gain valuable experience regarding the building damage and other earthquake consequences.

The team members from the Republic of Serbia are especially grateful to the colleagues from Türkiye, for cooperation during and after the visits. Their knowledge and experience significantly contributed to the quality of the visits and this publication. Special thanks are due to Nemanja Krtinić and Şerife Özata for the photos and drawings included in this paper.

4. REFERENCES

[1] SBB (2023). 2023 Kahramanmaraş and Hatay earthquakes report. Presidency of Strategy and Budget, Government of Türkiye. https://www.sbb.gov.tr/wp-content/uploads/2023/03/2023-Kahramanmaras-and-Hatay-Earthquakes-Report.pdf

[2] World Bank (2023). Global Rapid Post-Disaster Damage Estimation (GRADE) Report, February 6, 2023 Kahramanmaraş Earthquakes, Türkiye Report. Global Facility for Disaster Reduction and Recovery (GFDRR). https://documents1.worldbank.org/curated/en/099022723021250141/pdf/P1788430aeb62f08009b2302bd4074030fb.pdf

[3] AFP (2023). Topshots of the Week (25-31 March, 2023). Agence France-Presse. https://www.afp.com/en/inside-afp/topshots-week-25-31-march-2023

[4] Mondesert, A., Delany, M. (2023). Donors Vow 7 Bn Euros For Turkey, Syria Quake Aid. From AFP News. https://www.barrons.com/news/donor-conference-seeks-to-rally-quake-aid-for-turkey-syria-bce11409

[5] Marinković,M., Blagojević,N., Krtinić,N. and Brzev,S. (2023). Posledice zemljotresa u Turskoj u februaru 2023 godine i pouke za Srbiju. SUZI eGlasnik. 6 (1), p.2-16.

[6] SUZI&ETH (2023). SUZI&ETH seminar u vezi zemljotresa u Turskoj - 29. maj 2023. https://suzi-saee.rs/akcije/online-suzieth-seminar-u-vezi-zemljotresa-u-turskoj

[7] 2007 - Regulation on buildings in earthquake zones (DBYBHY)

[8] Türkiye Bina Deprem Yönetmeliği, Afet ve Acil Durum Yönetimi Başkanlığı, Resmi Gazete, Sayı: 30364 (Mükerrer), 18 Mart 2018.

[9] Marinković, M., Baballëku, M., Isufi, B., Blagojević, N., Milićević, I., & Brzev, S. (2022). Performance of RC cast-in-place buildings during the November 26, 2019 Albania earthquake. Bulletin of Earthquake Engineering, 1-54.

[10] Nikolić-Brzev, S., Marinković, M., Milicević, I., Blagojević, N. (2020). Posledice zemljotresa u Albaniji od 26.11.2019. na objekte i infrastrukturu (Consequences of the November 26, 2019 Albania earthquake on the buildings and infrastructure). Serbian Association for earthquake engineering (SUZI-SAEE), Serbia (in Serbian).

[11] TRT Haber.<https://www.trthaber.com/foto-galeri/deprem-bolgesine-yapilan-evler-nasil-olacak-iste-ornek-proje-gorselleri/54328/sayfa-2.html>

[12] Sucuoğlu H, Yazgan U, Yakut A. A Screening Procedure for Seismic Risk Assessment in Urban Building Stocks. Earthquake Spectra. 2007;23(2):441-458. doi:10.1193/1.2720931

[13] Özhendekci N, Özhendekci D. Rapid Seismic Vulnerability Assessment of Low- to Mid-Rise Reinforced Concrete Buildings Using Bingöl's Regional Data. Earthquake Spectra. 2012;28(3):1165-1187. doi:10.1193/1.4000065

[14] Çetin, K.O., Ilgaç, M., Can, G. and Çakır, E. (2023). Preliminary Reconnaissance Report on February 6, 2023 Kahramanmaraş-Pazarcık (Mw=7.7) and Elbistan (Mw=7.6) Earthquakes. Middle East Technical University, Report METU/EERC 2023-01, Ankara, Türkiye.