Firat Univ Jour. of Exp. and Comp. Eng., 2(3), 117-123, 2023

Firat University Journal of Experimental and Computational Engineering
Fırat Üniversitesi Deneysel ve Hesaplamalı Mühendislik Dergisi

Damage Assessment of Masonry Structures in Adıyaman Province After Kahramanmaraş Earthquakes (February 6, 2023)

Kahramanmaraş Depremleri Sonrası Adıyaman İlindeki Yığma Yapıların Hasar Değerlendirmesi (6 Şubat 2023)

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Received: 01.08.2023
Accepted: 29.09.2023
Revision:15.09.2023
doi: 10.5505/fujece.2023.47955
Research Article

Citation: Çambay E. "Damage assessment of masonry structures in adıyaman province after kahramanmaraş earthquakes (February 6, 2023)". *Firat University Journal of Experimental and Computational Engineering*, 2(3), 117-123, 2023.

Abstract
According to the data of the Disaster and Emergency Management (AFAD) Earthquake Department; On February 6, 2023, at 4.17 and 13.24 Turkey time, earthquakes with magnitudes of 7.7 and 7.6 (Mw) occurred, respectively, with the epicenters in Pazarcık (Kahramanmaraş) and Elbistan (Kahramanmaraş). These earthquakes affected 11 provinces of Turkey and were recorded as the most destructive earthquakes in the last century. In the statement made by AFAD on April 20, 2023, it was reported that the number of people who lost their lives in the earthquakes centered in Kahramanmaraş was 50 thousand 96 and the number of people injured was 107 thousand 204. Adıyaman was shaken by the effects of the earthquakes and many buildings were destroyed and damaged. In this study, after the earthquakes, some damaged masonry structures, and in fill walls in Adıyaman city center; the structural irregularities, application methods and material properties used were examined on site and the causes of the damages were evaluated. The damages suffered by historical buildings in the earthquake as a result of the strengthening were discussed. After the buildings were demolished, on-site inspections were carried out.

Keywords: Earthquake, Damage evaluation, Masonry buildings

Özet
Afet ve Acil Durum Yönetimi (AFAD) Deprem Dairesi Başkanlığı verilerine göre; 6 Şubat 2023 tarihinde Türkiye saati ile 4.17 ve 13.24'te merkez üsleri Pazarcık (Kahramanmaraş) ve Elbistan (Kahramanmaraş) olan sırasıyla 7.7 ve 7.6 (Mw) büyüklüklerinde depremler meydana geldimiştir. Bu depremler Türkiye'nin 11 ilini etkilemiş ve son yüzyılın en yıkıcı depremleri olarak kayıtlara geçmiştir. AFAD tarafından 20 Nisan 2023 tarihinde yapılan açıklamalarda, Kahramanmaraş merkezli depremlerde hayatını kaybedenlerin sayısının 50 bin 96, yaralananların sayısının ise 107 bin 204 olduğu bildirilmişti. Depremlerin etkisiyle sarsılan Adıyaman'da çok sayıda bina yıkıldı ve hasar görmüştür. Bu çalışmada, depremler sonrasında Adıyaman şehir merkezinde hasar gören bazı yığma yapılar ve dolgu duvarlar; yapısal düzensizlikler, uygulama yöntemleri ve kullanılan malzeme özellikleri açısından yerinde incelenmiş ve hasarların nedenleri değerlendirilmiştir. Tarihi yapıların güçlendirme işlemi sonucunda depremden aldığı hasarlar değerlendirilmiştir. Yıkım gerçekleştikten sonar yerinde incelemelerde bulunulmuştur.

Anahtar kelimeler: Deprem, Hasar tespiti, Yığma binalar

1. Introduction

Turkey is located on the North Anatolian Fault, East Anatolian Fault, Northeast Anatolian Fault and West Anatolian Fault. North Anatolian and East Anatolian Faults are the most active faults. The earthquakes that have occurred in Turkey in recent years are caused by these two faults but have resulted in significant loss of life and high amounts of structural damage.

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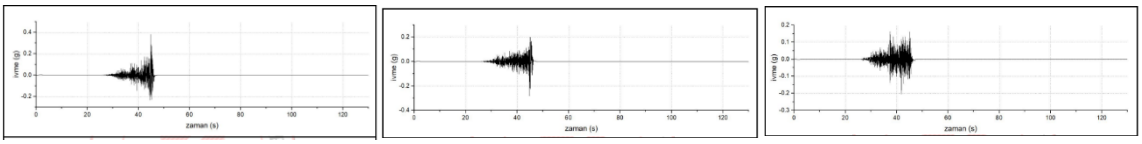
It is possible to see this situation in many historical buildings due to the major earthquakes that occurred in our country, which is the earthquake zone. Masonry structures can easily transfer their own weight and vertical forces such as dead and live loads to their foundation systems. However, they are weak in transferring tensile stresses that occur under horizontal loads such as earthquakes. Masonry building elements that exhibit brittle behavior under tensile stresses can collapse under earthquake loads and cause heavy loss of life and property [1-4].
Masonry walls are important structural elements used as carriers or as filling units in frames. In framed and/or sheared systems, masonry walls used as filling units contribute positively to the behavior of the system under earthquake loads. Since these building elements are constructed from brick/stone and binding materials, they are considered a composite material. Masonry walls, which exhibit a complex behavior with this feature, continue to exist as the most preferred building element today.

According to the data of the Disaster and Emergency Management (AFAD) Earthquake Department; On February 6, 2023, earthquakes with magnitudes of 7.7 and 7.6 (Mw) occurred at 4.17 and 13.24 Turkey time, with the epicenters in Pazarcık (Kahramanmaraş) and Elbistan (Kahramanmaraş), respectively. These earthquakes affected 11 provinces of Turkey and were recorded as the most destructive earthquakes in the last century. In the statement made by AFAD on April 20, 2023, it was reported that the number of people who lost their lives in the earthquakes centered in Kahramanmaraş was 50 thousand 96 and the number of people injured was 107 thousand 204.

In this study, damage assessment studies were carried out in Adıyaman city center between February 10-17, 2023, and the effects of the earthquake forces on the masonry structures in the region were examined on-site. According to the data taken from the seismometers at the central station no 0201 in Adıyaman province during the first earthquake, the largest ground acceleration values were obtained as 0.383 g in the east-west direction and 0.281 g in the North-South direction. Acceleration-time graphs of the stations in question are given in Fig 1.

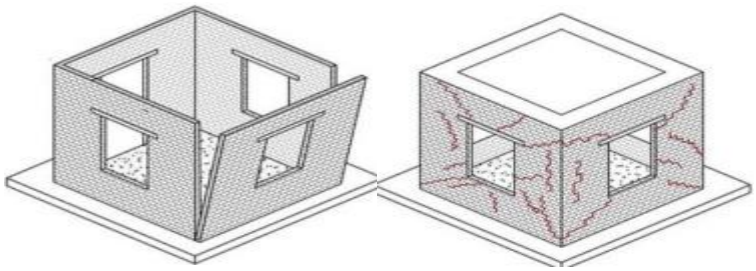


a) East-west (0.383g) b) North-South (0.281g) c) Up-down (0.206g)

Figure 1. Acceleration graphs of Adıyaman Central Station No. 0201 [5]

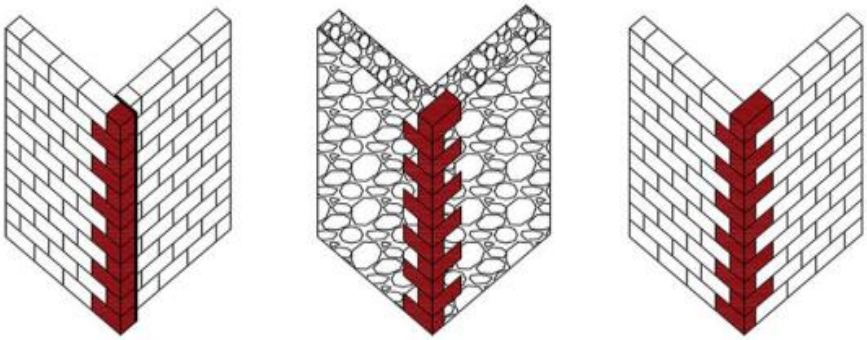
2. Behavior of masonry structures

It was determined that the most damage in masonry structures in the earthquake zone occurs out of the plane, or in other words, as a result of the first damage mode (Fig 2). It was also observed that beam connection elements are missing in the majority of damaged structures. Şenol [6] damage assessment studies were carried out in Antakya and İskenderun districts of Hatay province between 20-23 February 2023, and the structures in the region; It was examined on-site in terms of structural irregularities, materials used and the effect of earthquake forces. Tomazevic [7] pointed out that as a result of the out-of-plane behavior of masonry walls, cracks may occur in the regions where stress concentrations are most intense and, as a result, collapses in the direction perpendicular to the direction of seismic movement. Subsequently, Ayala and Speranza [8] concluded that the out-of-plane behavior of walls and the collapses that occur as a result of this behavior are directly proportional to the quality and strength of the connections and wall elements.



a) b)

Figure 2. a) Out-of-plane behavior b) In-plane behavior [9]



a) b) c)

Figure 3. Corner details: (a) Lack of keystone, (b) Insufficient support c) a sufficient combination. [9]

Corner joint damages were frequently encountered in studies carried out in the earthquake zone. roper wall-to-wall and wall-to-floor connections this construction increases the strength of the corners under the influence of earthquakes (Fig 3).

3. Damage Observations

After the restoration process in 2021, the Adıyaman Tuz Hanı, built in the 1800s, was observed to have suffered major damage as a result of the 6 February Pazarcık earthquake. As a result of on-site inspections, damage occurred due to out-of-plane behavior. In particular, it has been determined that the masonry units were built using randomly placed stones with irregular shapes. The lack of sufficient connections between stones has resulted in poor earthquake performance of such structures. TDY [10], to increase the lateral resistance of masonry structures against earthquakes, it is mandatory to use reinforced beam systems called both horizontal and vertical beams. However, no reinforced concrete beams were seen on the exterior of this building (Fig. 4). As a result of the restoration, careless workmanship and random placement of stones were also determined as a result of the examinations.

Figure 4. Tuz Hanı in the center of Adıyaman

As a result of field studies carried out in the region, it was observed that most of the masonry structures were built using a mixture of natural stone and perforated clay bricks. Due to the weakness and brittleness of the perforated clay brick material, it has been concluded that the seismic behavior of masonry structures built using this type of material is weak. In many cases, it has been found that under the influence of earthquakes, clay elements lose their strength before mortar. Generally, it has been found that clay bricks are crushed as soon as masonry walls begin to lose their strength due to shearing. This loss in the connection between masonry materials can lead to collapse following the initiation of cracks. The fact that the infill wall of the reinforced concrete building was manufactured without being compressed between columns caused both in-plane and out-of-plane behavior (Fig 5).

Figure 5. Damaged masonry walls in Adıyaman city center

Figure 6. Kap mosque in the center of Adıyaman

It was observed that the lack of connection between the roof and walls in the mosque under investigation increased the earthquake damage. In many historical buildings in the region, the roofs are made of wooden beams and are supported directly on the load-bearing walls. Failure to install beam systems at the roof level disrupts the box behavior of the masonry structure, causing masonry walls to collapse in out-of-plane directions. Fig-6 shows the earthquake damages observed as a result of the roof system not being supported correctly to the walls.

In addition, corner joint damages were frequently encountered in studies carried out in the earthquake zone. It has been shown in the literature that lateral stresses caused by the roof increase the damage. Improper wall-to-wall and wall-to-floor connections reduce the strength of corners under earthquake effects. In particular, incorrect support of corner joints causes them to become unstable. In case of roof damage, non-deformed walls usually topple over, causing major damage. The quality of the wall is determined by the effectiveness of the keystones used. Fig. 7 shows the corner joint damages observed in the region.

Figure 7. Damaged masonry walls in Adıyaman city center

Although some of the reinforced concrete buildings in the region survived this devastating earthquake with little or no damage, it is possible to observe wall damage in most of these structures [11]. They are generally detected as diagonal shear cracks. Walls moving out of the plane and walls detached from the frame system have also been observed. Due to the weakness and brittleness of the perforated brick material, it has been concluded that the seismic behavior of masonry structures built using this type of material is weak. In many cases, it has been found that under the influence of earthquakes, clay elements lose their strength before mortar. Generally, it has been found that clay bricks are crushed as soon as masonry walls begin to lose their strength due to shearing. This loss in the connection between masonry materials can lead to collapse following the initiation of cracks. Perforated clay brick elements were used and infill walls that were damaged because adherence could not be achieved with the missing mortar are shown in Fig. 8.

Figure 8. Ulu mosque in the center of Adıyaman

Adıyaman Ulu Mosque, which is estimated to have been built in the 16th century, was destroyed except for its north-west walls by the February 6 earthquake. The mosque was determined that additional loads were placed on the structure as a result of the restoration work carried out in 2016. The mosque lost its historical texture.

4. Results

Disaster and Emergency Management (AFAD) Earthquake Department; On February 6, 2023, at 4.17 and 13.24 Turkey time, earthquakes with magnitudes of 7.7 and 7.6 (Mw) occurred, respectively, with the epicenters in Pazarcık (Kahramanmaraş) and Elbistan (Kahramanmaraş). Adıyaman was shaken by the effects of the earthquakes and many buildings were destroyed and damaged. After the earthquakes, some damaged masonry structures and infill walls in Adıyaman city center. Within this framework, the structural irregularities, application methods and material properties used were examined on site and the causes of the damages were evaluated.
According to the results obtained from the observations:

- It was concluded that the seismic behavior of unreinforced masonry structures exposed to horizontal and vertical load combinations depends on many parameters.
- As a result of the restoration, poor workmanship and the use of low-strength materials are the primary causes of the damages observed.
- In addition, it was observed that the mechanical properties of the material used for the restoration, loading conditions, the way the nodes are formed, construction technology and site conditions have direct effects on the seismic performance of the structure.
- It was also observed that building load-bearing walls without using beams and placing roofs directly on the walls makes the structures in the region prone to out-of-plane behavior.

5. Credit Authorship Contribution Statement

Ertuğrul ÇAMBAY: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing - review & editing.

6. Ethics Committee Approval and Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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