Temporary Shoring System on Masonry Buildings After an Earthquake

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Abstract. Historical masonry structures that make up the cultural assets of a country constitute the identity of the society to which it belongs. For this reason, it should be protected and should be transferred from generation to generation. Earthquakes are threatening actions to masonry structures. The force generated by the ground movement may cause shear cracks in masonry structures that may lead to fragmentation and even collapse of the structure. It is necessary to know the earthquake behavior of masonry structures to be able to apply appropriate temporary shoring systems after a damage caused by earthquake in order to prevent the future damages during aftershocks. Thus, the progress of the damages in the building is prevented and it is ensured to survive until detailed investigation or restoration. However, when the applied temporary shoring system designs were examined, the environmental conditions of the building were not taken into account in any guideline on immediate shoring. In this paper, temporary shoring system for 3 traditional houses of Bey District is designed for possible earthquake damages. This district has many registered civil architectures lined side by side along very narrow streets. Some masonry buildings were changed to reinforced concrete with multiple floors. This study includes the registration status of the buildings, their location, the number of floors to be supported, the heights between floors, the height of the forces that can be brought by the adjacent building elements, the width of the street where the facade to be supported, whether there is a window or door opening in the facade to be supported etc. If there are window or door openings, the distances of the opening to the corner points of the building and the distances between the two openings has to be recorded. According to these determinations, possible damages that may occur in the buildings are defined and a temporary shoring system is designed in accordance with the buildings and the surrounding conditions.

1. Introduction
Gaziantep, located in southeast Anatolia has hosted different cultures for centuries. Especially its location on the historical silk road has made it to be an attractive settlement area. Civilizations established in the region have contributed to the change and enrichment of the city’s urban fabric.

The first settlement of the city of Gaziantep was in the ancient city of Dülük, and it was later moved to this region with the construction of the Gaziantep Castle, which was built on a large mound (Figure 1) [1]. After 16th century, Turkmen, Kurdish and Arab tribes migrated to the city and created new neighbourhoods and carried their own cultures. This situation has changed the architectural face of the city [2].
After the Ottoman rule in the 16th century, the construction of mosques, masjids, madrasahs, inns, and baths increased in Gaziantep, and housing increased in the Bey District. These houses called Antep houses were built in accordance with the climatic conditions of the region where they are located. They are shaped around a courtyard and stone was used as construction material. Large courtyards called "Hayat" consist of areas surrounded by high walls are made of masonry stone. The windows on the façades of the buildings facing the street are high and screened by iron grillage. The residences aligned in adjacent order form narrow streets. The wall thickness of Antep houses, which are generally built with 2 or 3 floors and oriel jetting out from the first floor, varies between 50 cm and 100 cm, and the height of the garden wall varies between 300 cm and 800 cm (Figure 1). The historical Antep houses, which reflect the traditions of the society and give information about the city life of the period in which they were built, should be preserved and passed down from generation to generation [3].

![Figure 1. Street texture of Bey Neighborhood](image)

2. **Earthquake behaviour of masonry structures**

Earthquake is one of the most threatening actions that can cause damage to masonry structures. Small damages that have occurred after an earthquake can become larger with aftershocks and cause greater damage. It may even damage the load bearing system. For this reason, the historical masonry structures must be rapidly strengthened after the earthquake in order to protect them from aftershocks until the restoration process.

The forces on the walls during an earthquake act in-plane and out-of-plane of the wall. In-plane earthquake forces that act parallel to the plane of the wall may generate shear cracks while the out-of-plane forces that are perpendicular to the plane of the wall develop flexural cracks along the bed joints. Wall intersections are particularly vulnerable to earthquake effects due to significant tensile and shear stresses developed when seismic forces are transferred from walls to walls. When wall connections are inadequate or absent, vertical cracks may develop or separation may take place at wall intersections. Depending on the magnitude and duration of the earthquake, the cracks grow, intersect and become independent wall units [4] [5] (Figure 2). However, continued shaking can allow gravity to work on the independent cracked blocks and this may lead to progressive displacement and failure on the walls. It is important to make temporary support to the structure immediately before aftershocks.
3. Temporary shoring

Temporary shoring system is a system that temporarily supports a structure so that the structure stands until a permanent restoration. Before designing a temporary shoring system on a façade that is damaged by earthquake, it should be considered what kind of support is necessary for that place. Therefore, the position and the location of the building is important. The size of the street where the building is situated, if the building is on a sloped area, if there are adjacent structures to the building are important questions to be answered before designing the temporary support. A questionnaire is prepared to define such position of the structure (Figure 3).

One of the most important factors to be taken into account when designing temporary shoring is the physical condition of the building’s surroundings. For example, in Bey District, except for the streets less than 1.5 m wide, there is a 20 cm wide and 10 cm high trottoir in front of the building façade. In addition, there is a 20 cm wide and 5 cm high gutter in front of the trottoir. Thus, there is a 5 cm elevation difference between the ground elevation in front of the building façade and the road elevation. So, temporary shoring should be designed considering the elevation difference.

Figure 2. Examples of cracks that can cause dangerous damage
While designing temporary shoring, the width of the street where the facade to be supported has to be taken into account. It is dangerous to do any support in the building for some parts may fall down. Therefore, the temporary supports have to be constructed on facades. During and after earthquakes, the streets should serve for any kind of passage or transportation to help people. Therefore, the temporary shoring has to let this passage. If possible, the system should be designed to allow passing vehicles as fire brigade from the street.

Temporary shoring is made by wrapping the structure partially or all around, by frame system, by raking shore system (Figure 4). Wrapping of the structure is applied to support the building elements at the upper elevations that can’t be supported by frame system and raking shore system. With this support, it is ensured that the building walls connected to each other with bands or rods move together. The frame system allows the load to be transferred to the ground by supporting structure with one frame. Besides, it is connected to another frame designed so that it doesn’t prevent the passage. It is more appropriate to construct the frame system for narrow streets where the raking shore system can’t be constructed. Raking shore system, is the system that consists of triangulations to transfers the load from the building wall to the ground.

Figure 3. The questionnaire that defines position of the structure
Figure 4. a) Wrapping of the structure partially or all around, b) Supporting of the structure with frame system c) Supporting of the structure with raking shore

4. Case work: Temporary shoring for possible damages

The 3 traditional houses of Bey District where the temporary supports are designed for possible earthquake damages are on Hanifioğlu Street, on Eski Sinema Street, and on Kayacık Ara Street (Figure 5).

Figure 5. The structures observed and relations to each other

The 3 floored house on Hanifioğlu Street is situated at the corner and also has façade on Hanifioğlu dead-end street. The width of the Hanifioğlu street is 347 cm. and the width of the dead-end street is 179 cm. While the facade facing the Hanifioğlu dead-end street is on a flat ground, the facade facing Hanifioğlu street is on a ground with a slope less than 30°. On both facades to be supported, the ground floor height is 290 cm, the second floor height is 313 cm, and the third floor height is 255 cm (Figure 6).

Figure 6. The location and photos of observed structure
On the facade facing Hanifioğlu dead-end street, there are 3 openings on the 2nd floor and 2 openings on the 3rd floor. Besides, the distances of the leftmost openings to the corner of the building are 23 cm on the 2nd floor and 67 cm on the 3rd floor. The rightmost opening of the 2nd floor at the corner and the rightmost opening of the 3rd floor is 58 cm to the corner. On 2nd floor, the distance between the left opening and middle opening is 130 cm and the distance between middle opening and the right opening is 50 cm. The distance between the two openings on 3rd floor is 165 cm. The adjacent building is a three-storey masonry stone structure. Assuming that the lowest level is "0", the heights of the forces that can be transmitted by the masonry wall on the left are respectively 81 cm and 606 cm. The type of temporary shoring shown in Figure 7, is suggested for possible damages to the facade of the observed building.

![Figure 7](image1.png)

**Figure 7. Possible damages and method of temporary shoring**

On the facade facing Hanifioğlu street, there is 1 opening on the ground floor, 4 openings on the 2nd floor, and 3 openings on the 3rd floor. Besides, the distances of the leftmost openings to the corner of the building are 274 cm on the ground floor. The leftmost opening of the 2nd floor at the corner and the leftmost opening of the 3rd floor is 163 cm to the corner. The distances of the rightmost openings to the building corner are 224 cm on the ground floor, 69 cm on the 2nd floor, and 79 cm on the 3rd floor. On 2nd floor, the distance between the left opening and middle opening is 59 cm and the distance between middle openings is 69 cm. Besides, on the 3rd floor, the distances between openings are 69 cm too. The adjacent building element is a masonry stone wall. Assuming that the lowest level is "0", the height of the force that can be transmitted by the masonry wall is 363 cm. The type of temporary shoring shown in Figure 8, is suggested for possible damages to the facade of the observed building.

![Figure 8](image2.png)

**Figure 8. Possible damages and method of temporary shoring**

The 2 floored house on Eski Sinema street is located on the ground with slope less than 30°. The width of the Eski Sinema street is 342 cm. This building has one facade that is necessary to be supported. The ground floor height of the building is 291 cm, and the second floor height is 303 cm (Figure 9).
Figure 9. The location and photos of observed structure

On the façade facing Eski Sinema street, there are 5 openings on the ground floor and 6 openings on the 2nd floor. Besides, the distances of the leftmost spaces to the building corner: 66 cm on the ground floor and 75 cm on the 2nd floor. The distances of the rightmost openings to the building corner are 84 cm on the ground floor and 77 cm on the 2nd floor. On the ground floor, the distance between the left opening and next middle opening is 106 cm. Besides, the distances between middle openings are respectively are 120 cm, 104 cm and 303 cm. At the 2nd floor, the distance between the left opening and next middle opening is 89 cm. In addition, the distances between middle openings are respectively are 93 cm, 81 cm, 99 cm and 114 cm. The adjacent building on both the left and right of the façade to be supported is a two-storey masonry stone building. Assuming that the lowest level is "0", the height of the force that can be transmitted by the adjacent building on the left is 87 cm. The height of the force that can be transmitted by the adjacent building on the right respectively are 209 cm and 556 cm. The type of temporary shoring shown in Figure 10, is suggested for possible damages to the facade of the observed building.

Figure 10. Possible damages and method of temporary shoring
The 3 floored house on Kayacık Ara street is located on a flat ground. The width of the Kayacık Ara street is 315 cm. The ground floor height of the building is 367 cm, the second floor height is 372 cm, and the third floor height is 278 cm (Figure 11).

**Figure 11.** The location and photos of observed structure

On the façade facing Kayacık Ara Street, there are 3 openings on the ground floor, 3 openings on the 2nd floor and 3 openings on the 3rd floor. Besides, the distances of the leftmost openings to the building corner are 52 cm on the ground floor, 53 cm on the 2nd floor and 64 cm on the 3rd floor. The distances of the rightmost openings to the building corner are 87 cm on the ground floor, 83 cm on the 2nd floor and 90 cm on the 3rd floor. On the ground floor, the distance between the left opening and the middle opening is 86 cm and the distance between middle openings is 51. On the 2nd ground, the distance between the left opening and the next middle opening is 80 cm and the distance between middle openings is 46 cm. In addition, on the 3rd floor, the distance between the left opening and the next middle opening is 62 cm and the distance between middle openings is 62 cm too. The adjacent building on the left of the facade to be supported is a two-storey masonry building, and the adjacent building on the right is a 3-storey masonry stone building. Assuming that the lowest level is "0", the heights of the force that can be transmitted by the adjacent building on the left respectively are 219 cm and 713 cm. In addition, the heights of the force that can be transmitted by the adjacent building on the right respectively are 501 cm and 873 cm. The type of temporary shoring shown in Figure 12. is suggested for possible damages to the facade of the observed building.
5. Conclusions

Bey District is one of the first residential areas of Gaziantep and is very rich in terms of historical buildings. Although most of the buildings in the region have been restored, many buildings have also been destroyed by natural events such as fire, earthquake or vandalism.

Earthquake is one of the factors that cause great damage to buildings. Earthquake forces consist of forces parallel to the building wall and perpendicular to the building wall. Forces parallel to the building wall create diagonal cracks in masonry structures during earthquake. These cracks grow and create independent units on the building facade and cause ruptures in the building element with aftershocks. If traditional masonry structures, which constitute the cultural properties of the society, are supported by using temporary shoring system after the earthquake, the progression of the existing damages is prevented and the structures remain standing until the restoration.

There are 3 types of temporary shoring system. These are wrapping the structure partially or all around, frame system, and raking shore system. Street use is very important for first aid after an earthquake. The most important thing when choosing the temporary shoring type is that the passages are not prevented. So, it is significant to design suitable for the street.

In this paper, 3 buildings in Bey District with facade to Hanifioğlu street, Eski Sinema street and Kayacık Ara street were chosen and their surroundings were observed. Possible damages in the
structures after the earthquake were determined. Temporary shoring systems have been designed in accordance with environmental conditions for these damages. In this way, the structures will be supported quickly after the earthquake, the destruction of the aftershocks will be prevented.

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