STRENGTHENING OF HISTORIC BUILDINGS IN POST-DISASTER CASES

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Abstract

The 96% of districts in Turkey, which includes many historical monuments, is under seismic risk. Historic buildings and monuments are an important part of our cultural heritage that we must protect and provide their sustainability.

There are many cause of decay in materials and structure of historic buildings. Earthquakes which are the external cause of damage are different from other natural disasters. The earthquakes, which we cannot predict in time and intensity, may cause major structural damage, and the collapse of historical buildings and monuments. Whenever an earthquake occurs we give more importance to the great monuments rather than the vernacular architecture which constitutes the urban fabric.

The timber and masonry buildings constitute the vernacular architecture of Turkey. However, most of the traditional wooden constructions succeed in reach our time even they are partially damaged. Timber structures are the most earthquake resistant among other traditional forms.

The aim of this paper is to show the resistance of traditional buildings, especially timber construction against the earthquakes. Unfortunately, the examples of timber construction, which constitute the biggest part of the traditional houses architecture in Turkey are decreasing. For this reason, the strategies for the preservation and strengthening of the historical timber structures should be prepared without losing time.

As a consequence, the original and damaged condition of a historical construction should be analyzed. In order to learn the values that we possess and the existing conditions of these buildings, the inventory of the whole timber construction in Turkey should be documented. Preserving and strengthening programs could be done on the basis of this documentation and conservation strategies could be developed according to them.

Key words: historic timber buildings, Turkish House, earthquake, strengthening, modern and traditional methods, Istanbul

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INTRODUCTION

Many severe earthquakes occurred during the history of Turkey and as a result of this; the major part of the historical buildings collapsed partially or have been ruined.

When we observe the history of earthquakes in Istanbul, 13 severe earthquakes happened since the year of 325. In these earthquakes, while thousands of people had lost their lives, buildings are destroyed and there occurred giant waves and clefts in the ground. According to the information taken from Turkey Earthquake Charitable Foundation (TDV), there occurred 13 important earthquakes on the years 325, 427, 478, 865, 986, 1462, 1500, 1509, 1719, 1754, 1766 and 1894. In the 1894 earthquake, which is probably 7 on the Richter scale, the clefts were formed on the seaside, some parts of the ramparts and masonry buildings are destroyed but most of the wooden buildings are succeeded in standing (Figure 1).

The history of earthquakes in Istanbul suggests that every 100-250 years there is a significant seismic event. For this reason, specialists are waiting for a major earthquake in Istanbul within 30 years. (Ahunbay, 2005)

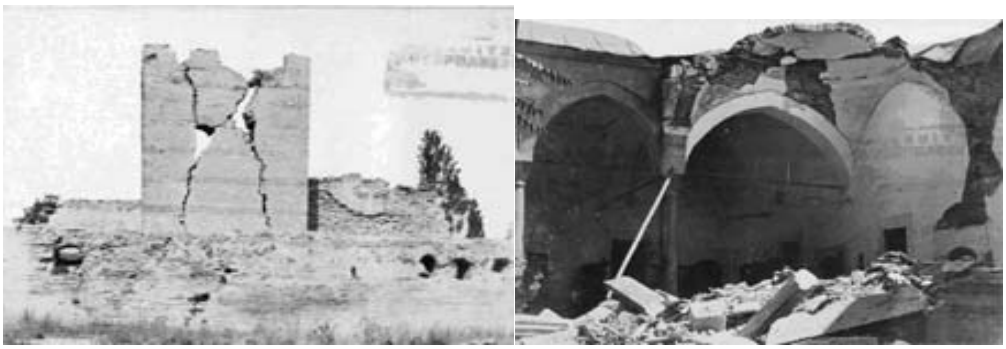

Figure 1. 1894 earthquake in Istanbul

Although the timber structures are considered to be the most earthquake resistant among other traditional forms, after a major earthquake, historical timber buildings can be seriously damaged like modern buildings. Occupiers of those buildings, also, become homeless or are obliged to repair them if they are to live in them. Unfortunately, most of the people who live in the traditional buildings are the ones, who have low incomes. In that condition, the people, whose houses are damaged or collapsed after an earthquake, have two choices. They will either be settled in the “post-disaster houses”, which are offered to them by government or they will repair their own houses with the financial support of the government.

In both of these solutions, there are many criteria that should be taken into consideration. As the homeless people are settled in the “post-disaster houses”, firstly they will encounter a cultural shock. Instead of their few storey houses, victims are obliged to live in multi-storey houses, built in reinforced concrete. People, who

live in city centers under usual conditions, have to settle outside of city centers and encounter a social environment totally unfamiliar to their life style.

If the project, specialist team and financial support can be provided to the victims by the government to repair their houses, the cultural heritage, that the traditional constructions formed, could be preserved and people could continue to live in their own social environments and conditions as well.

Another important point that should be taken into consideration is that the unconscious interventions, which are done by humans, destroy the structural continuity of the historical constructions. Especially in Istanbul, where the historical fabric is dense, by the increase of the commercial functions large openings are formed, the bearing components are removed or their order is changed in order to create a front for the shops on the ground floor. This intervention destroys the supporting system of the buildings and decreases its resistance against earthquake. In the upper floors, while window openings are widening, the distance between the corners of the buildings and the openings are decreased in the constructional system. Furthermore by making the distance of the spans wider, the system is changed and some of the diagonal braces and studs which are forming the timber frame are removed (Figure 2). By the way, the integrity of the construction is destroyed and it became non-resistant to the earthquake. This case suggests another point that should be cared: a control mechanism. Besides the conscientiousness of the traditional houses users, governments' supervision association should control the traditional buildings as well as the reinforced concrete buildings.

Figure 2. Examples of traditional houses that openings and construction systems have changed.

Type of building, construction and material in Turkey

The earthquake of 1999 in Adapazarı caused major losses of human life (30.000 people) and severe damage and destruction of the architectural heritage. The same earthquake had also important effects in Istanbul. Hagia Sophia, Sergius and Bacchus, Edirnekapı Mihrimah and Fatih Mosque were among the seriously affected great monuments (Figure 3). Great monuments show different problematic of their own and it is impossible to generalize strengthening methods. There are many criteria for them and each case is unique. Whenever an earthquake occurs we give more importance to the great monuments rather than the vernacular architecture which constitute the urban fabric.

Figure 3. Cracks of the dome of the church Sergius and Bacchus

Vernacular architecture affects our economic, social and cultural life. Firstly, we use these buildings as units of living. Under conditions of their being damaged or collapsed, many people will be homeless. Secondary, they help us to understand the construction techniques and materials of the past. Along with modernization and globalization, the borders of Istanbul are expanding and reinforced concrete takes the places of traditional constructions. As the traditional construction systems are not used any more, they continue to disappear and with them the appropriate craftsmanship.

The timber and masonry buildings constitute the vernacular architecture of Turkey. Choosing the timber, stone or adobe for the houses in different regions depends on the material possibilities and the climate of that region. Timber is the most common building material used in the traditional Turkish House. As it is light, easy and fast to build and especially resistant against the horizontal forces, timber has become the most continuously used material in the part of Turkey that lies on the earthquake zone. Wooden frame structures are quite ductile and able to absorb substantial movements.

In Osmaneli, a village near to Adapazarı, traditional forms of construction for dwellings are “hımış” construction. Of the few those “hımış” buildings, most appeared undamaged in the 1999 earthquake. Some damage could be found in shedding of the plaster or fall down of the infill material of the timber frame. There isn’t a major destructive crack (Figure 4).

Figure 4. The timber frame with adobe infill construction in Osmaneli.

Nevertheless, on the regions, where the forest resource is more limited, stone, brick, wood and adobe is used as the filling material of the timber frame (Figure 5).

Figure 5. The timber frame construction with masonry infill and masonry construction examples of traditional houses.

Two or three storied traditional timber constructions, are generally, formed by a timber framework building system on a stone basement wall or, a masonry ground floor. The wall of the ground floor is constructed with the rubble stone technique, which has the thickness of 60-80 cm, and is reinforced by beams (*hatıl*) placed at intervals 100-150 cm. Plaster is rarely used. The construction system of the upper floors is timber frame. Evenly spaced bearing studs are placed on the wooden beam, which is set on the basement wall or ground floor wall. On the floor level it is again linked with a beam. There are diagonal braces between the main studs. The studs are linked to each other with horizontal wooden pieces (Figure 6). This system changes according to the region and time. In the last century, thinner but more

closely spaced studs are used. Preserving the wooden framework used at the exterior surface of the building is generally provided by plastering or covering with wood clapboards. In general, wood clapboards are used in the humid and/or windy regions. (Sözen, 2001)

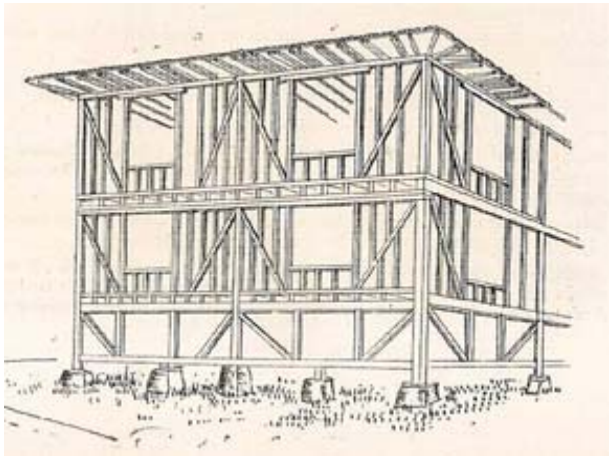

Figure 6. The timber frame of traditional house. (Kafesçioğlu, 1955)

As it is same in other regions of Turkey, the houses in Istanbul were generally plastered "*hımış"* structures until the very beginning of the 19th century. Due to industrial production of the timber and the ease of importing in Black Sea area; from the second half of the 19th century, wood clapboards buildings had taken the place of "*hımış"* structures (Figure 7). This continued until the World War I but later on, as it is the same in all over the world, the timber buildings could not be constructed in Istanbul because of the economic problems after the second half of the 1920's. (Tanyeli, 1998)

Figure 7. The examples of traditional houses with wood clapboards and "hımış" at the beginning of the 19th century in Istanbul (Eldem,1984)

Unfortunately, in Istanbul none of the examples of "*hımış"* construction could last until our time and also the wood clapboards constructions are disappearing rapidly. The urban and rural architectural heritage in Turkey is both neglected and damaged. Reinforced concrete buildings are constructed instead of the old fabric as a result of the change in the society's life style, preference of modern materials and the new construction specifications. Without registering their cultural existence and knowledge accumulation that they carry, the "hımış" buildings are disappearing. Although they survive the earthquakes with little damage, most of the traditional buildings are abandoned and they are about to disappear by being pulled down. At the end of this fast disappearance, traditional architecture would totally be lost. Because of this, without losing time, we should develop conservation strategies to preserve these traditional buildings, which form the important part of our cultural heritage.

Strengthening Historic Timber Structures

Diagnosis and Investigations

Before starting an intervention, we should analyze the social, cultural, economic and political characteristics of the building. The first step must be the examination of the structural system (effects of the horizontal loads and static study of building) and the characteristics of the wood which was used. After that, we should determine the causes of decay and previous earthquake damage in the building as the timber historic buildings still standing after earthquakes may have been weakened.

All these studies must be done by a specialist team experienced in historic conservation and strengthening. They should record structural survey results and constitute a detailed reinforcement plan. The analysis studies must provide for the structural continuity of the building and be available before starting the interventions of reinforcement. Interventions must be as little as possible but must ensure adequate continuity and connections between all the main structural elements.

Maintenance

When the historical buildings are examined after the earthquakes, most of them are seen to be abandoned or empty. The timbers of these buildings are rotten or infested by insects. The cause of this damage is lack of maintenance and regular inspections (Figure 8).

Figure 8. Lack of maintenance: case of Amcazade Yali on Bosphorus.
(Can Binan's archives)

The continuous maintenance is the main point in keeping the cultural heritage. The neglected buildings which have leaky roofs, grass growing on their walls, broken eaves, and with the access of water inside the building, are not resistant against earthquakes. For strengthening the traditional buildings that have evident structural weaknesses, we are obliged to give priorities to interventions, which does not damaged their authenticity, to choose material and techniques, which are compatible with historical constructions more than the strengthening criterion, which is based on modern technology and the calculations of new construction structures. We are obliged to make these types of interventions become widespread. Strengthening the historical buildings with proper repairs on their own will have the most successful result from the point of view of conservation principles.

Occupiers of the historic buildings should be informed and encouraged for maintenance of their houses. Government should provide permanent funds.

Traditional and Modern Techniques

The principles of conservation must always be followed. The most important purpose of conservation is to maintain the historical authenticity and integrity of the cultural heritage (Figure 9). Reinforcing a historic building with new construction methods can destroy a historic building's appearance and structural integrity. Each intervention should be follow for preference:

- Apply traditional methods
- Be reversible, if technically possible. (ICOMOS)

Figure 9. The eldest timber house on Bosphorus: Amcazade Köprülü Yali, 1699

The modern technologies should be used when the traditional methods are insufficient. Modern technologies must respect the cultural significance of the historic buildings. They should be used carefully and not cause an irreversible damage. New materials used for strengthening should be compatible with, but also distinguished from original materials of the historic building.

> *These specialized technologies include: vertical and center core drilling systems for unreinforced masonry buildings, base isolation at the foundations, superstructure damping systems, bonded resin coatings, and reproducing lost elements in lighter materials.* (Look et al., 2004)

A specialist team should evaluate these methods.

If the joints of the timber buildings are sound and the timbers are not attacked by insects and fungi, we can accept them, to have good earthquake resistance (Feilden, 1982). If wood element of the building is unable to continue to function as a load-bearing structural member in the building, it is a sign that there is a need of strengthening. There are many methods for reinforcement of weak timber structures. Strengthening technologies are developing all the time and they are designed to conform to the historic character of the building.

- Strapping of a building: Earthquakes, the shifting of the earth's crust, affect firstly a building through its foundations. For this reason, the analysis of soil and the foundation system should be made. The structure can be bolted to its foundation or the timber frame can be strapped together. While strapping of a building the meeting points of the cables with the building should be cared for. It is necessary to protect original elements to prevent the cable cutting into them. Using wooden angle plates at the meeting points of metal materials and structure is suitable. It is very important how the turnbuckles which provide the tension of strapping cable will be used. The walls must be connected to each other with using braces made from timber, steel, synthetic fibers, etc (Figure 10). We can give additional strength by using plywood stiffeners between the building and strapping cables. By the way, this provides the

structural continuity of a building, and also be used as a plate. Strapping of a building is probably the most common reinforcement method and can be applied to masonry buildings as well. Strapping provides for the building to perform structurally as a whole.

Figure 10. Temporary consolidation of the timber frame structures (Can Binan's archives)

- Infill openings: Another method of providing the structural continuity is to fill in openings. As it effects on the appearance of the historical building, it is not much preferred. In order to infill the openings masonry or timber framing are used. But costs are very high. This method also provides for the building to move as a single unit.

- Repair weakened wooden structural systems by bracing existing members: Interior bracing system is always better than exterior ones as they do not ruin the original appearance of the building (Figure 11). Bracing system aim for emergency consolidation after a disaster and must be integrate with the existing structural system of the building. Reinforced bracing should be added in order to have minimal impact and not overload the structural system. The compatible materials should be selected in this system. Timber braces are usually used in historical buildings. Another point that should be cared for is to provide a strong ground as the system transfers the loads to the soil.

Figure 11. Interior and exterior bracing systems (Can Binan's archives)

- Reinforcing the joints of the timber buildings between floor, wall and roof connections, column and beam ties using mechanical fasteners like anchor ties or bolts, metal straps, dowels or pegs of wood, metal or glass fiber reinforced plastic, etc (Figure 12). Care should be taken while using these fasteners as the timber elements shrink and expand because of the humidity and the temperature differences. Missing areas of wood can be filled with epoxy resins or other filling materials compatible with the historic character of the building.

Figure 12. Reinforcing the joints of the timber buildings using mechanical fasteners (Can Binan's archives)

CONCLUSION

The historical buildings and monuments are an important link between our time and history. They reflect the social, cultural and economic experiences of the past. Unfortunately, most of the historical buildings are generally neglected in our times. They are damaged or have collapsed because of the interior factors such as their ground features and location, and the exterior factors such as earthquakes, other natural disasters and vandalism. For this reason, it is very important to protect them by taking measures from structural aspect without loosing time. But, it is harmful rather than being useful to apply misguided repairs without determining the reasons for the damage and analyzing the structure of the buildings.

First of all, the original and damaged condition of a historical construction should be analyzed. The applied intervention and strengthening should be determined respecting the results to the integrity and authenticity of the historical building.

The work of analysis and evaluation should be done as a result of the cooperation of the specialists, who are from different disciplines like earthquake specialists, architects, engineers and art historians. Besides, it is necessary for these specialists to have common knowledge on the subject of conserving and strengthening the historical buildings.

In 2001, Turkish Academy of Sciences (TÜBA) has started the “Cultural Inventory of Turkey” in order to label the cultural possessions of the country systematically. A similar work has been done on the extent of the project of Turkey Archeological Settlements (TAY) since 1994. In this project the aim is to make the inventory of the whole archeological existence of Turkey. These inventory studies are made on the scale of a region and a house. The earthquake factor should also be added to these studies and should constitute a whole by combining them with the studies of analysis and evaluation.

Thanks to these inventory studies, we will both learn the values that we possess and the existing conditions of these buildings will be documented. Preserving and strengthening programs could be done on the basis of this documentation and conservation strategies could be developed according to them. By examining and researching earthquake-resistant historical constructions, and their details, we can adopt them for modern buildings in earthquake zones.

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