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ARAŞTIRMA MAKALESİ /**RESEARCH ARTICLE**

SEISMIC ANALYSIS OF TRADITIONAL BUILDINGS: BAGDADI AND HIMIS

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ABSTRACT

In Turkey, buildings were built with himis, bagdadi and masonry structural elements until 1950. After 1950's due to the development in reinforced concrete structures, many people who wanted to own a house, made their choices for the reinforced concrete buildings. However, himis, bagdadi and masonry structures that were constructed many years ago are still widely being used. Based on the analysis of the structure in a seismic zone for the damages after an earthquake, it has been found out that himis and bagdadi structures suffer less from the earthquake compared with other types of structures. In this study the behavior of himis and bagdadi structures under lateral loads are being analyzed. Himis and bagdadi structures are modeled and analyzed by using SAP2000. Timber structural elements such as beams and columns are modeled as framed elements. Adobe, brick and stone elements are modeled as solid, and the analysis is conducted under lateral loads. According to the analyses of these types of structures, they are found to be more ductile compared with reinforced concrete and masonry structures.

Keywords: Bagdadi structure, Himis structure, Solid, Wood frame, Seismic load, Adobe.

GELENEKSEL BAĞDADI VE HIMIŞ YAPILARIN SISMIK ANALIZI

ÖZ

Türkiye'de binalar 1950 yılına kadar hımış, bağdadi ve yığma yapı elemanlarıyla yapılmıştır. 1950'lerden sonra betonarme yapıların gelişmesiyle, ev sahibi olmak isteyen insanlar seçimlerini betonarme yapılardan yana kullanır hale gelmişlerdir. Yine de yıllar önce yapılan hımış, bağdadi ve yığma yapılar halen yaygın olarak kullanılmaktadırlar. Bir deprem bölgesindeki hasar görmüş yapılar incelendiğinde, hımış ve bağdadi yapıların diğer yapı türleri ile karşılaştırıldığında daha az hasar gördüğü gözlenmiştir. Bu çalışmada, hımış ve bağdadi yapıların yatay yükler altındaki davranışı incelenmiştir. Hımış ve bağdadi yapılar SAP2000 bilgisayar program ile modellenmiş ve çözülmüştür. Kirişler ve kolonlar gibi ahşap yapısal elemanlar çerçeve elemanı olarak modellenmiştir. Kerpiç, tuğla ve taş gibi dolgu malzemeleri katı rijit eleman olarak modellenmiştir. Bu tipte yapıların incelenmesi sonucunda, betonarme ve yığma yapılarla karşılaştırıldığında çok daha sünek oldukları sonucun da varılmıştır.

Anahtar Kelimeler: Bağdadi yapı, Hımış yapı, Katı rijit, Ahşap çerçeve, Sismik yük, Kerpiç.

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1. INTRODUCTION

Existing structures can be classified as reinforced concrete structures, steel structures, masonry structures and wood structures when considering the materials they are constructed from. Wood structures can be classified as log, bonding timber (horizontal connecting member), himis, dizeme and bagdadi (Fig.1). In this study, bagdadi structures which are mainly made up of wood and their infill material is taken as adobe, brick and stone are analysed.

In wood framed constructions, the technique of construction which is named as himis is simply described as a timber frame with masonry infill such as brick, adobe or stone (Fig. 2). Main posts, posts, tie beams, and the braces are the main parts of a himis structure. Spaces between wooden posts are filled with wall which transfers the loads from roof to the structural system. It is possible to classify traditional himis constructions into two categories depending on the structural system and masonry infill. Himis structural systems are also divided into two categories as braced and non-braced. In himis structures, vertical wood elements (main posts, posts etc.) and horizontal wood elements (girders, beams etc.) are connected to each other by nails. Wooden elements have great supporting capacity in the grain direction while this capacity is very low compared with the perpendicular direction of the grain. Wooden elements used in the structural system are very brittle under the effect of shear and tension.

In wooden framed structures, technique of construction consists of wooden strips having a width of 2-4 cm and a thickness of 2.5-3.5 cm. These wooden strips are nailed to columns horizontally in both outer and inner walls with an interval of 2-3 cm. This type of technique is named as bagdadi. If the width of these wooden strips changes between 5 to 20 cm, these structures are called dizeme. The structure that is analysed in the manuscript is a bagdadi structure. This system is widespread in areas where climate conditions are mild and wood is plentiful. In Turkey, this type of system is frequently found in various regions of Anatolia. In some regions, instead of wooden strips, reeds and rushes are used which have thinner structures.

2. SOME PROPERTIES OF HIMIS AND BAGDADI STRUCTURES

During an analysis conducted over 2000 himis and bagdadi structures in the 1950's in Eskişehir Odunpazarı quarter, it was determined that 45% of these buildings are himis, 27% of them are bagdadi and 28% of them are masonry buildings (Fig. 3). Nowadays these buildings are put under protection and by reparing them, attempt is made to ensure the survival of these buildings. Generally, they are buildings of one, two or three stories. The ground floor of these buildings is made up of natural stone and adobe, but 1st, and 2nd floors are made up of bagdadi. The reason for the ground floor being made up of stone or adobe is related to the water isolation of the building. The upper floors are bagdadi, since it is lighter compared to masonry.

During an observation on the masonry structures that were damaged in the 1999 Izmit and 1999 Duzce earthquakes, it was observed that 40 to 80 mm sand was spread for homogenous spreading of loads in foundation hole (Fig. 3). Mostly un-reinforced and rarely reinforced concrete beams are constructed above sand (Dogan, Unluoglu, Ozbasaran, 2007). Also, there are buildings which have no foundation beams, but only brick walls above sand. Moreover, there are some natural stone foundation types in which approximately 0.5–1.0 m of the foundation lies below the ground and 0.5–1.0 m of it above the ground. These natural stones are bound together by mud or cement paste. Above the foundation (Fig. 3a-d), walls constructed using himis, brick and adobe.

Adobes' compression test results are in between 5–10 kgf/cm^2 with respect to the type of soil, additive type and construction method (Koylu 2008). All of the adobe moulds are 300–350 mm long and wide, and their height is 100–120 mm. Accordingly, half moulds are 300–350 mm long, 150–170 mm wide, and their height is 100–120 mm. Adobe on one hand creates a healthy internal place and on the other hand decreases total heat loss of the building by means of heat transfer coefficient. Adobe buildings are cool in summer and hot in winter. Briquette, brick or reinforced concrete structures are cold in the winter, but warm in the summer. Adobe protects timber better than brick and concrete (Koylu 2008).

3. DISTRIBUTION OF HIMIS AND BAGDADI STRUCTURES IN TURKEY

In Turkey, buildings were himis, bagdadi or stone structures with a structural system of wood, before the reinforced concrete system was put into operation (Fig. 4). As a wall material, adobe and natural stones were used.

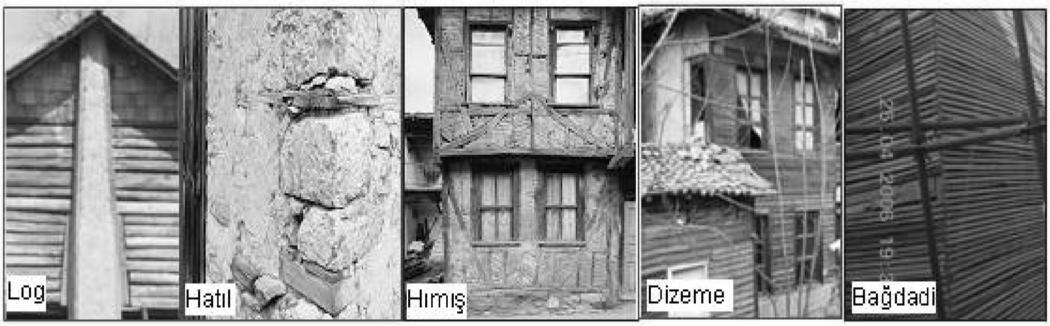

Figure 1. Types of wooden structures

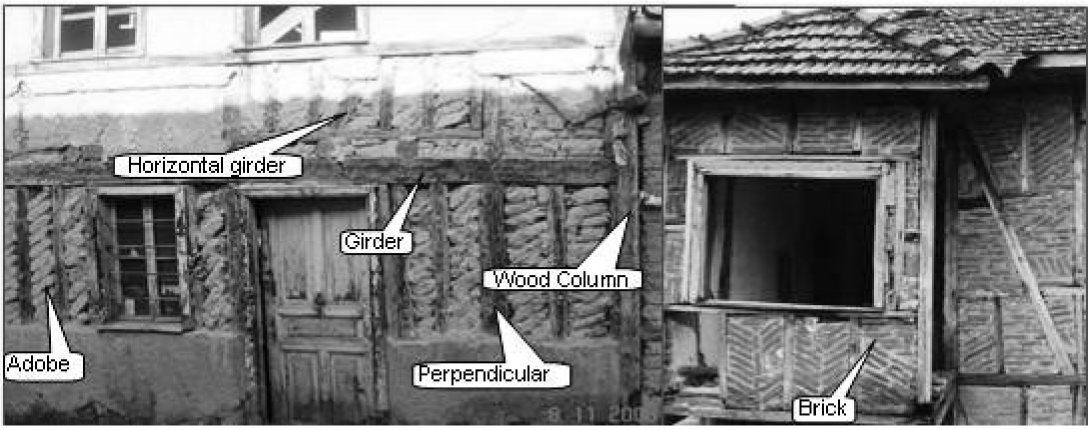

Figure 2. Details of a himis structure

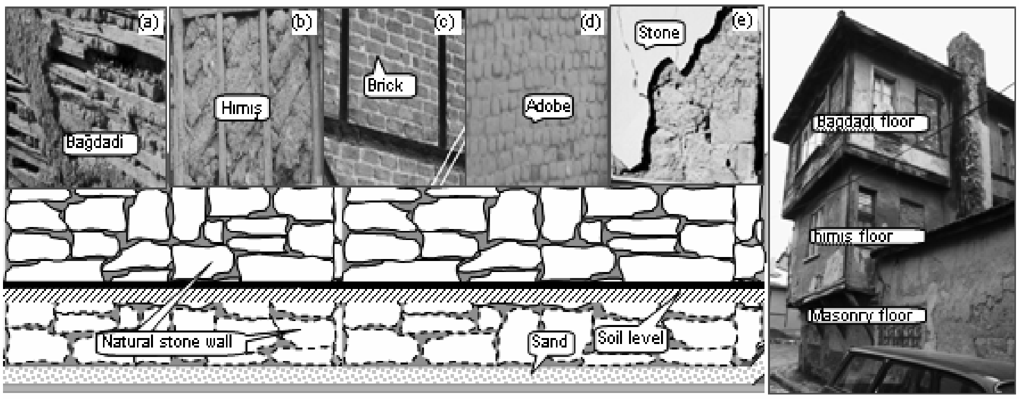

Figure 3. Systems of foundation and kinds of wall

Bagdadi structures consisting of timber are preferred in the seaside regions where the forests are located, whereas piled structures made up of less wood, himis or adobe and stones are preferred in the inner regions. Climate and forest area had considerable impact on the distribution of such buildings.

Currently, people in Turkey generally, prefer reinforced concrete or masonry buildings. Buildings with wooden structural systems used to be the most preferred ones before 1950, but now these structures are rarely preferred and are being forgotten (Fig. 4) (Aslı 2004). However in developed countries such as USA, Canada, Japan and Australia, such method is not only followed for wooden buildings, but also is getting use of opportunities granted by technology. New details and techniques are developed and construction of these wooden buildings is continued. Today wooden buildings in general constitute 80%-90% of all buildings and in residences, in location areas, In earthquake zones such as California, this rate reaches up to 99% (Çobanoğlu 2001).

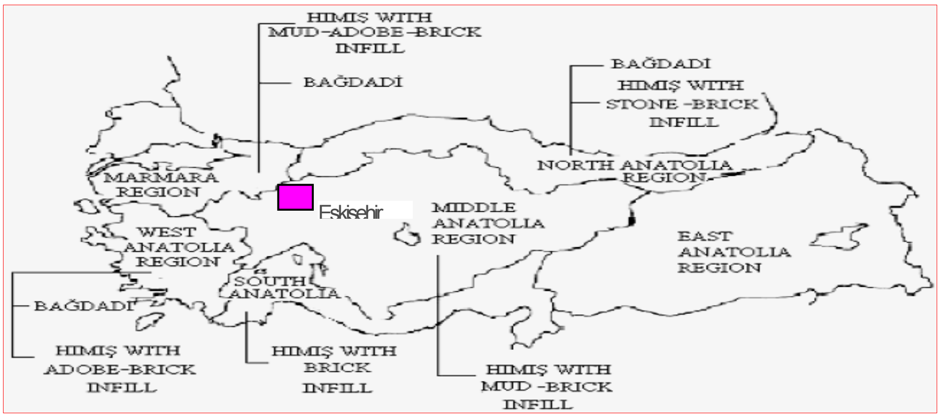

Figure 4. Use of himis and bagdadi structures in different zones of Turkey (Aslı 2004)

4. SEISMIC ACTIVITIES OF TURKEY

Turkey lies on one of the world's seismically most active regions. In Turkey, due to the 130 damaging earthquakes in the last 98 years (1900–2005), about 67,000 people died (700 on averages per year), 200,000 were injured, and 600,000 structures were destroyed or heavily damaged. According to the seismic map of Turkey (Fig. 5), 92% of the Turkish land, 95% of the population, and 98% of the industry lies on the seismically active ground (in Seismic Zones 1 to 4) (Dogan 2008).

The earthquake in Izmit (on 17 August 1999 at 03:01:37 local time, Marmara Sea region, North Western Anatolia, epicentre 40.702N–29.987E, M_w=7.4) caused extensive damage in a wide area of about 300 km^2. In total, there were 77,342 buildings severely damaged or collapsed, 77,169 with moderate damage and 89,872 lightly damaged. The official death toll is 17,322 in the Izmit earthquake. In a study conducted in a zone that was deeply affected by Izmit earthquake, it was seen that reinforced concrete buildings had more damage than the traditional buildings known as himis, bagdadi and masonry buildings (Fig. 6) (Aksoy, Ahubay, 2006).

5. EARTHQUAKE DAMAGES OF HIMIS AND BAGDADI

In addition to the intensive seismic activity of Turkey, the use of himis and bagdadi structures is very wide (Fig. 4-5). Consecutive earthquakes and such structures require investigation of these structures. In analyzing the earthquake hazards, it has been observed that reinforced concrete and wooden buildings suffer damages due to their irregularities. If reinforced concrete structures, himis and bagdadi structures with same stories are located in the same earthquake zone, it is seen that reinforced concrete structures are more damaged by the earthquake than himis and bagdadi structures.Irregularities such as soft layer, short column, asymmetric overhang, torsion, plan irregularity and crashes present in himis and bagdadi structures cause them to suffer from damages in case of any earthquake (Fig. 7). These irregularities are the ones for which measures should also be taken for reinforced concrete buildings (TEC, 2007). Buildings damaged due to soft irregularities are stated below.

The measures required to be taken for preventing X cracks on walls after the earthquakes is the subject of laboratory studies and regulations for the last 20 years (Fig. 8) (Frosch, 2005). Frosh reached a solution for buildings which are newly built; however, it continues to be a problem for present buildings which were previously built. It shall not be wrong to say from the analysis of traditional himis and bagdadi structures that mentioned X crack problem was solved long years ago. Even though the construction date of such structures is old, the fact that they are not provided with any technical service, gives us some insights.

6. PROPERTIES OF ANALYZED MODEL

A model was formed representing the structures widely used in Eskişehir and Turkey. The model consists of two different constructions that are most common: overhang and without overhang (Fig.9). In addition, it included two different types of construction as himis and bagdadi. These two types of construction were analyzed by modeling them with different filling material.

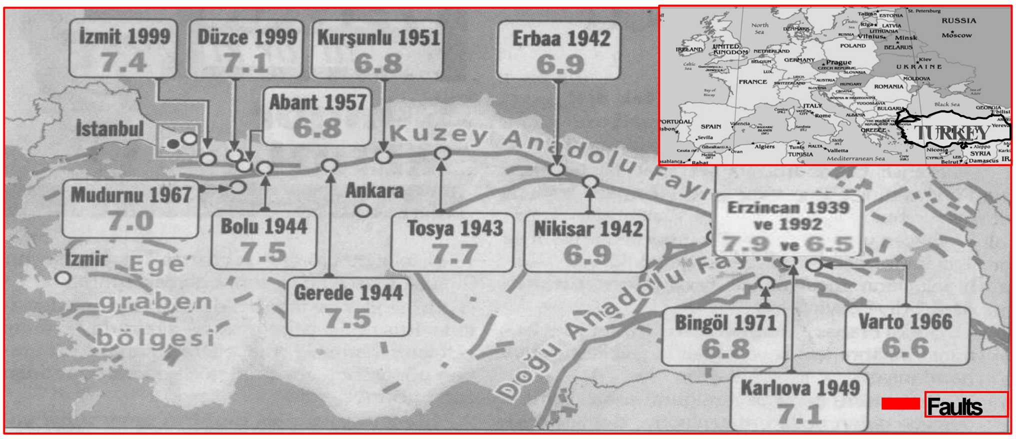

Figure 5. Severe earthquakes of Turkey (Dogan 2007)

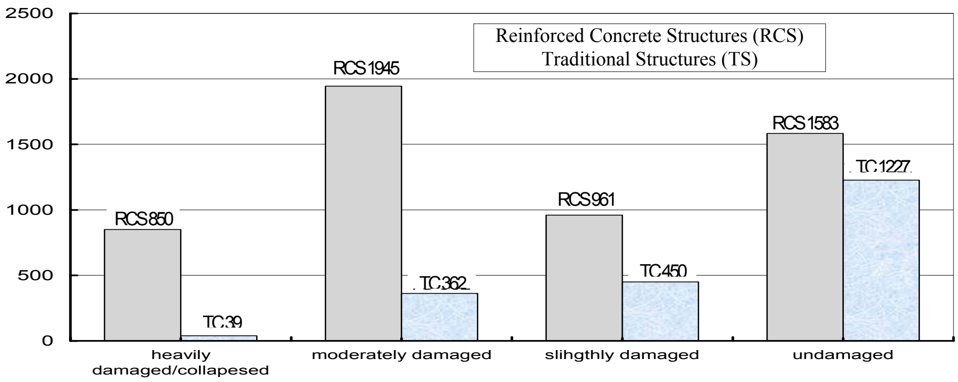

Figure 6. Izmit Earthquake damages of RCS and TS building (Aksoy, Ahubay 2006)

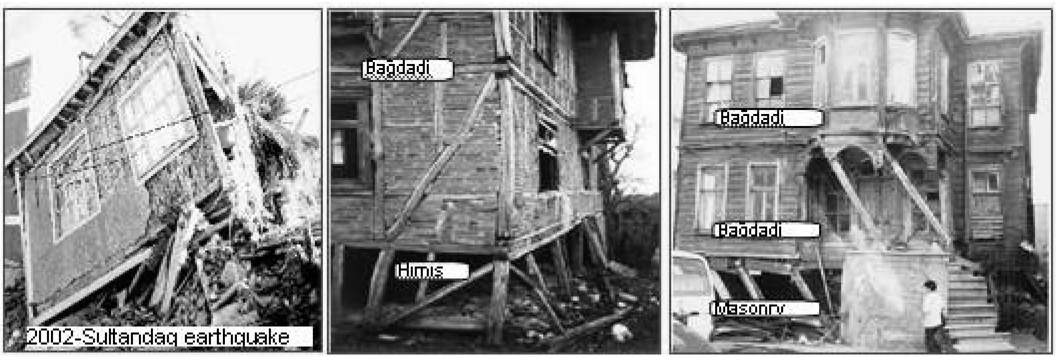

Figure 7. Earthquake damage at soft stories (Dogan 2007)

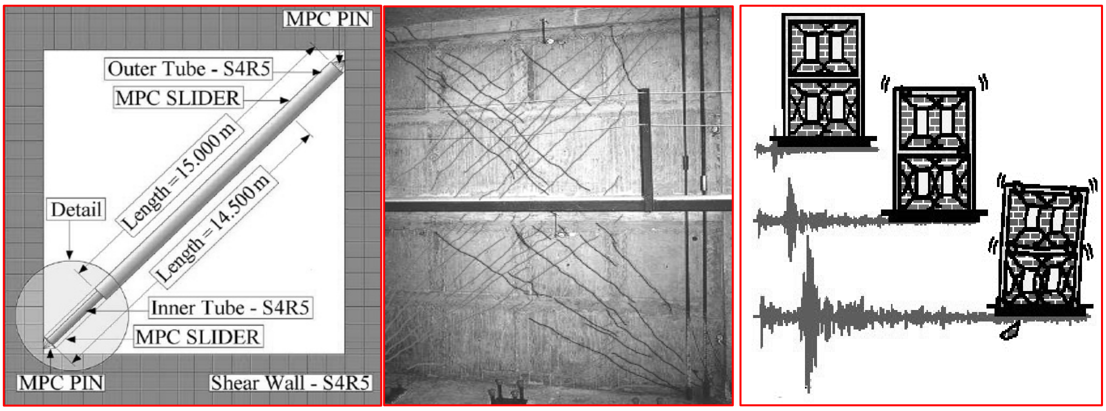

Figure 8. Experimental study of wall behaviour (Frosch, 2005)

Figure 9. Plan with overhang and without overhang

In these analyses, wooden components are modelled as frame and filling components are modeled as solid and SAP2000 program is used for the analyses (Wilson, Habibullah, 2000). Dimensions of building without overhang are 7.20x8.40 m. and with overhang has 1 m. overhang in both directions as shown in Figure 9.

In himis and bagdadi structures, the structural system is formed by connecting wooden frame with nails and rivets (Fig. 10). Adobe, natural stone, briquette, bims and ytong (kind of gas concrete) are used as filling materials. When the filling materials are examined, , it is generally seen that adobe is used in 70% of them. In new constructions, brick and ytong which are lighter are used.

While constructing himis and bagdadi buildings, initially a wooden bearing system is formed for each floor (Fig. 11). In the wood frame, buttresses (diagonal post) should be carefully placed. Using fitting methods at connections of wood components as well as nails increases resistance of the building against earthquake.

Gaps between wooden structural systems are filled with wall material. Afterwards, a plaster is covered on it. Floors of these types of structures are obtained by arranging the beams initially with a gap of 0.5-1m. between each other, and then by putting woods on previously arranged wooden beams in a reverse way. A roof system is constructed on the roof floor. Roof coating material can be roof tile, soil or reed.

The wooden structure form that is mostly used in Turkey is the himis structure constructed with diagonals. For this reason, such a structure is analysed in line with different materials and results are presented and compared in the graphics below (Fig. 12).

The properties of used materials were given in the table below (Table 1.).

The analysis regarding himis and bagdadi structures is initially started by only taking a plane frame which was modeled as a present structure. This frame was analyzed for the status of wood components and filler materials consisting of adobe, brick, bims, natural stone, ytong and briquette under horizontal loads by SAP2000 program (Fig. 13). In the analysis, wooden elements are modeled as frame elements and filling materials are modeled as solid elements.

Figure 10. Frames of himis and bagdadi structures

Figure 11. Wooden bearing system and its overhangs.

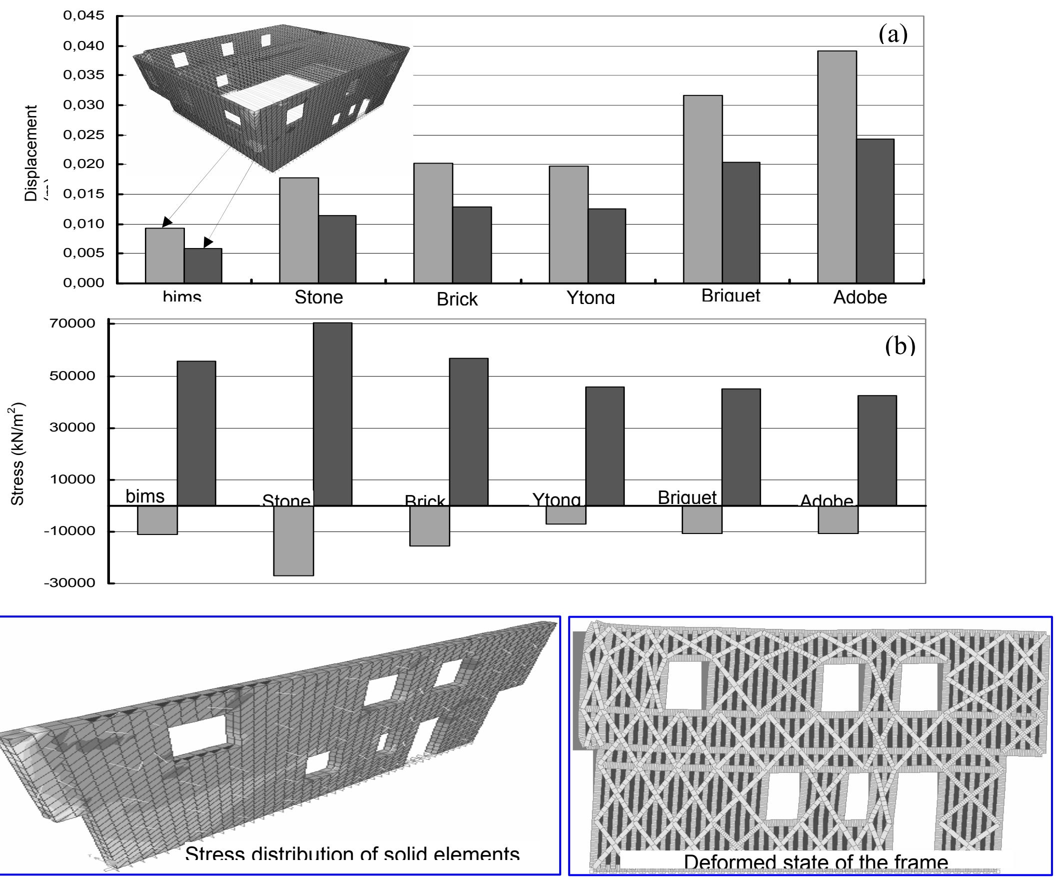

Figure 12. Results of the analyses of Himis frame

Table 1. Properties of materials used in walls (Koylu, 2008)

Wall materials	Unit weight (kN/m^2)	Modulus of elasticity (kN/m^2)	ν poisson rate	α thermal expansion coefficient (1/C)
Wood (lateral)	0,7	600000		2,2x10^{-5}
Wood (vertical)	0,7	12500000		2,2x10^{-5}
Adobe	1,7	1400000	0,3	7x10^{-8}
Brick	1,92	3000000	0,35	1,134x10^{-5}
Stone	2,4	3500000	0,4	1,14x10^{-5}
Bims	0,8	7000000	0,3	8x10^{-6}
Ytong	0,6	2050000	0,25	1,45x10^{-5}
Briquiet	1,6	1800000	0,3	6x10^{-6}

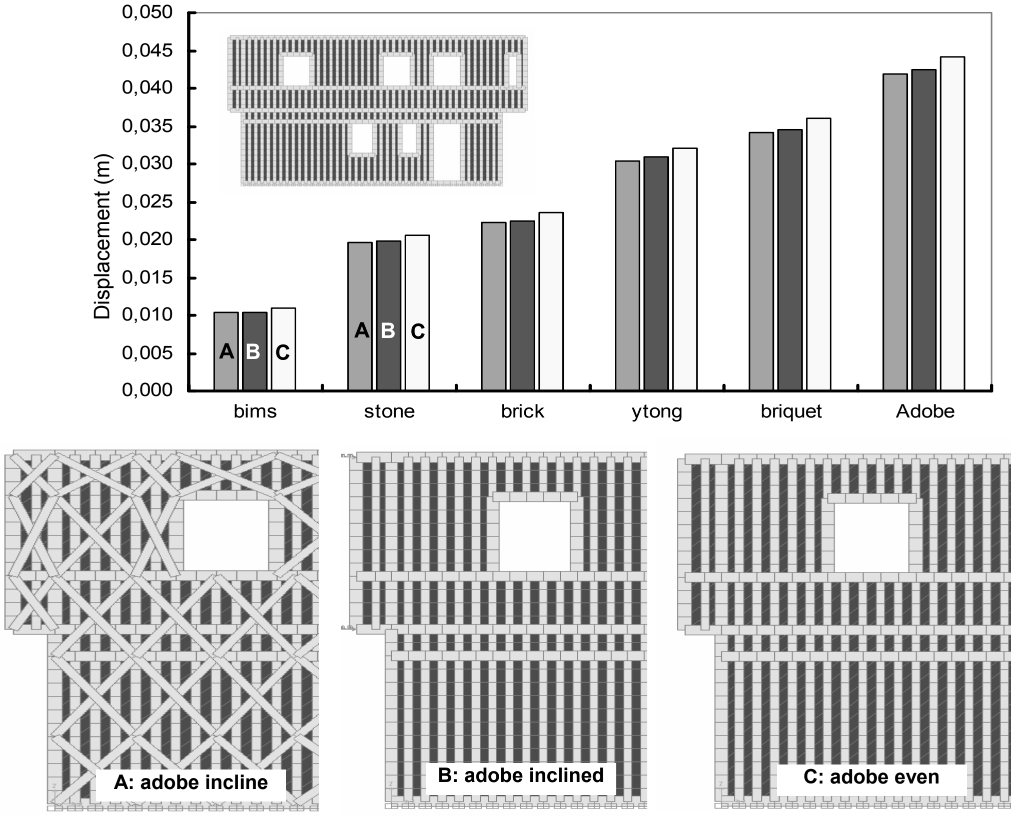

Figure 13. Different himis structures

The stress values of filler materials considered as solid are shown in Fig. 13. As the strength of adobe is low due to the fact that adobe is made up of earth, the biggest displacement and stress occured in this material. Analyses were conducted regarding the structure type seen in Fig. 13 below in connection with frame taken from structure which was arranged as a model. As a result of the analyses, the graphics of displacements formed on frame, and maximum and minimum stresses which occurred on the solid elements are illustrated in Fig.14.

Based on the analyses graphics of displacements which are formed on the frame and maximum and minimum tensions which occurred on solid elements are shown in Fig. 15.

Minimum displacement and stresses are obtained in the cases where the frame is made up of reinforced concrete,. Displacements become almost 2.4 times more than the reinforced concrete if the frame is arranged as himis or bagdadi. This situation shows that himis and bagdadi structures are more ductile than reinforced concrete, structures stresses reach to highly big values compared with the reinforced concrete structures. However, masonry frame which is modeled as a monolithic structure is made up of only bricks and does not have columns.

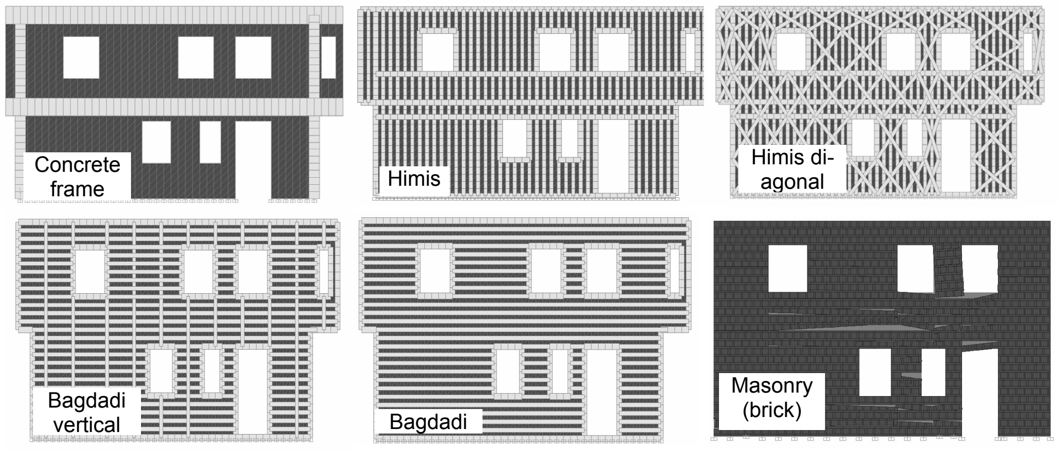

Figure 14. Types of modeled structures

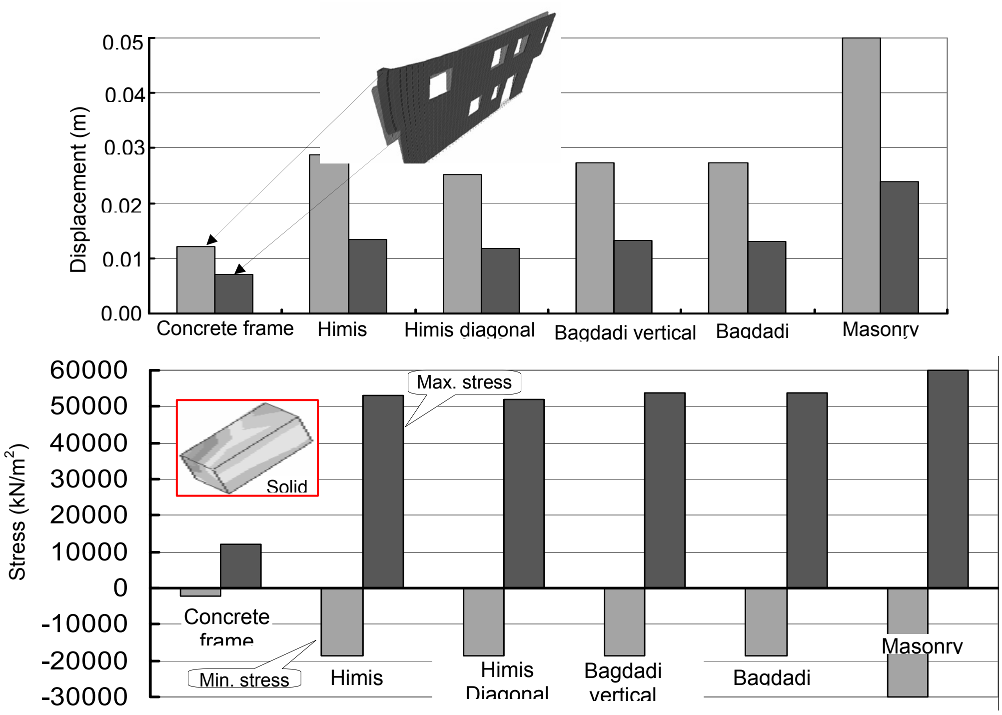

Figure 15. Displacements and stresses according to different types of structures

For this reason, displacement and stress values reach to highly big values for this type of structure.

Fig. 16 illustrates the changes in frame and solid components when the frame is made up of adobe or bricks with filling material for a himis structure without overhang.

In the buildings without overhang, the structure, in which adobe is used, creates more displacement than the structure in which brick is used (Fig. 16). For the solid material, less stresses occur in adobe, whereas, more stresses occur in brick. In case of using the filler material in an inclined way, displacements and stresses increase in solid components compared using filler material in a straight way. Using the filler material in an inclined way is due to little contact surface with wooden components.

When there is an overhang in himis or bagdadi structures, it changes the internal forces on solid and frame elements since the overhang destroys symmetry of the structure (Fig. 17). This change forms extra internal forces in structural elements.

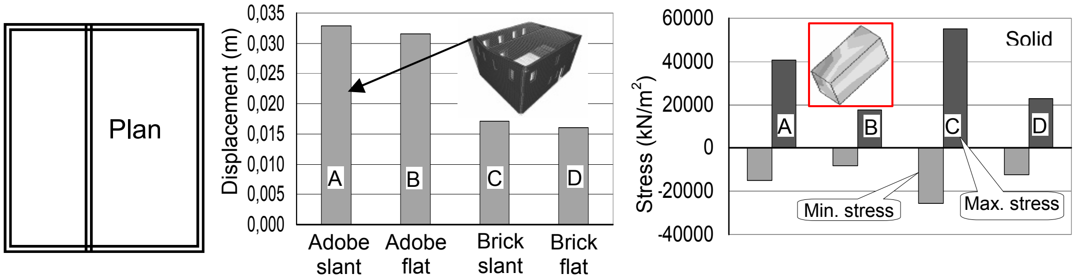

Figure 16. Displacements and stress positions for himis structures without overhang

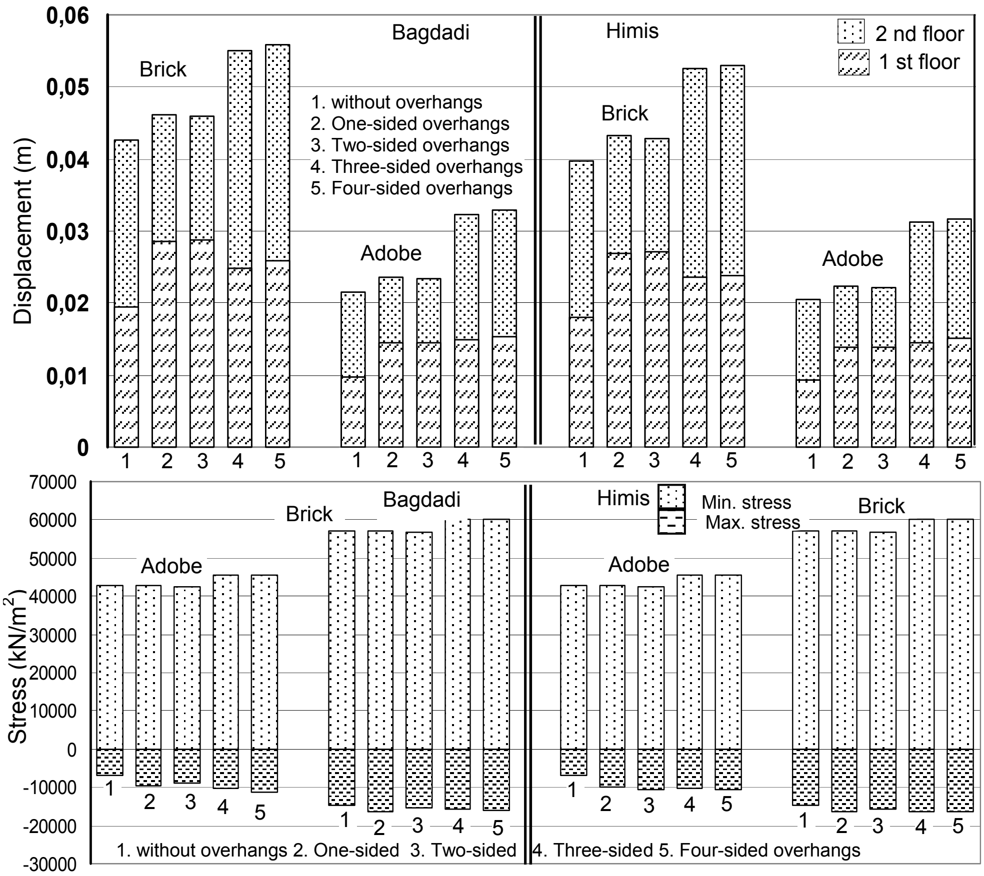

Figure 17. Comparison of non-overhang (1) and overhang two side (2) to bagdadi structures

7. CONCLUSIONS

From the analyses and investigations of earthquake damages of present himis and bagdadi buildings, it has been seen that these types of structures are more ductile compared to reinforced concrete structures. It was observed from the analyses that reinforced concrete and wooden buildings suffer from damages due to their irregularities. When reinforced concrete structures and himis-bagdadi structures are located in the same earthquake zone, it is seen that under same earthquake loading reinforced concrete structures with the same number of floors is more damaged than himis-bagdadi structures. It is also observed that the bagdadi structures are more ductile than himis structures, so that the earthquake damages of bagdadi structures are less than himis structures with the same plan. Beside that as can be seen from the analyses results, when adobe is used as a filling material it has more displacement capacity than other filling materials, and it also has the greatest stress values as a solid element. For this reason, adobe having the provided properties is the most proper element as a filling material. Moment, shear force and axial force on frame elements of bagdadi structures are greater than himis struc tures. After 1960's the construction of these types of structures are getting less and less even it might be said that there is none constructed. However previously constructed buildings in urban areas are still in use, considering the fact that materials that they have been built up of is worn out, they need to be strengthened.

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