THE STRUCTURAL SYSTEM AND ANALYSIS OF TIMBER CONSTRUCTION BUILT IN “GREAT MOSQUE”, TURKEY

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ABSTRACT: In Turkey a lot of wooden architectures in the Ottoman Empire are in existence. But a few wooden buildings are existence from Anatolian Seljuks Empire. Therefore, the research of the ancient Anatolian Seljuks Empire wooden buildings structure is important. The Ulu Cami (Great Mosque) is one of the most important architectural buildings in Anatolian Seljuks wooden buildings. Located in the city of Afyonkarahisar / Turkey, the great mosque was built in 1272-1277 with 40 timber columns supporting a flat ceiling. The mosque is so important for the Turkish art regarding to their plans, decorations and used materials. It will be sightseeing building for local and foreign visitors. In this paper, the structural system of this timber mosque is introduced and the connection in the timber structure is presented.

KEYWORDS: Great Mosque, Timber construction, Connection, Seljuks Empire

1 INTRODUCTION

Turkey has a long history of timber construction. Generally, the oldest existing timber buildings are mosques constructed in 12th -13th century. Many old timber buildings survived against strong wind and earthquake during centuries. Therefore the architectural and structural characteristics of the Great Mosque are presented. Unfortunately, static and dynamic analysis and experiments haven’t been performed on this building and other traditional timber structures. Taking into consideration that the structure has been built in a region exposed to strong earthquakes and owing to its public use, it was necessary to work out a study on the static and dynamic stability of the structural system, which has been prepared by experts in earthquake engineering.

Located in the city of Afyonkarahisar / Turkey (Fig.1), the great mosque was built in 1272-1277 [1] with 40 wooden columns supporting a flat ceiling. It was restored in different times; 1946-1953, 1983-1984 [2]. Great Mosque is the oldest timber building that presents the architectural style of Anatolian Seljuks periods (1040-1299).

This mosque is so important for the Turkish art regarding to their plans, decorations in the form of “kalemişi” technique and used materials. It was built by local labours and masters, and shows its artistic abilities in its geographical positions. Very few publications are available on materials and techniques used in Great Mosque. It will link Turkish historical culture and architecture. And it also will be sightseeing place for local and foreign visitors.

Figure 1: Location of Afyonkarahisar

In this paper the structural system of this mosque is introduced and the connections of the timber structure are presented.

2 STRUCTURAL SYSTEM

The Ulu Cami (Great Mosque) is one of the most important architectural buildings in Anatolian Seljuks wooden buildings, which transmit vertical load of roof from beams to a column. The building is consisted of a basement, ground floor and lower hip roof. It is founded on bedrock. Exterior masonry wall plays an important roll for lateral stability and fire proof. The main load bearing system is stone masonry wall and post and beam structural system. All external walls are load bearing.

Inside the mosque is placed on 40 timber round columns at the five nave having eight columns each. These wood columns are only one floor in height. The chief nave is higher than others.

The mosque is trapezoid planned. The architectural area is about 1050m². It has 4000cm in width, 2440-3000cm in depth and 600cm in height above the stone foundation. The plan arrangement of the Great mosque is shown as figure 2. Its sections A-A and B- B are shown in figure 3 and 4.
**Figure 2:** The plan arrangement of wooden mosque [3]

**Figure 3:** The section A-A of wooden mosque
The exterior wall is built of stone masonry and brick dust mortar (Turkish called Horasan mortar). The thickness of the wall varies from 110 to 100cm. The mosque is mainly entered from its long north wall which is constructed of cut stone. Apart from this door, a secondary door exists opening west and east walls. As shown in figure 3 and 4, the round columns are wood columns, which are only one floor in height. Their diameters are 40cm. The black elements are wood columns; blue elements are stone foundation and stone masonry walls. The main load-bearing system of this mosque is a wood structural system. The structural characteristics of this structure are that the columns support the beams. Most horizontal loads and vertical self-weight in this mosque are borne by the timber beams and columns. A lot of horizontal members (beams-joists) that go through columns are major elements to resist the lateral forces. In order to meet the requirements of whole structural rigidity and stability, joists are added between the timber beams shown in figure 5. While some of the joists are rectangular cross-section, some of them are round-section.

Identification of the joint of wooden materials is very difficult because the joint is hided under the other members (see Figure 5). So, we can identify it, when the building was assembled for the restoration. The survey was performed with measurement reports and photographs in those days of repair work. Consequently, through the documentary survey of building, the most of the column-beam joint type was identify to be corbelling joint and beam-joist joint type to be butt cog joint and corbelling (Fig. 6). The simplest joint to the craft and insert, and consequently the most common, is butt cog.

The columns are installed on a stone foundation. The wood beams connect with columns by column capitals (fig. 5). Every column has wood capitals stalactite shape or lozenge-shaped. Unfortunately, only 22 pieces of the column and capitals are original (fig 7). The others have been changed after restoration.
All beams are double row and looked as simple beams or continuous beams (Fig. 8). In the chief nave, it was used extra beams to be higher than other naves. Only the beams of chief nave are three layers (Fig. 9). Timber beams connect with timber capital by head piece. The capitals are connected with columns by corbelling technique.

Figure 8: All beams are double row.

Figure 9: The beams of chief nave are three layers

The joint of building is made with wood members and few metal fasteners (nails, bolts, etc.), so it is directly influenced by the mechanical properties of the wood members. The stiffness of joint is important at this structure.

Wooden beams and joists form of the ceiling and roof of the mosque. Originally this mosque was built a flat roof. In 1950, after the restoration a lower hip roof was build on this flat roof construction [4] (Fig 10). Lower roof is supported by whole beams and joists. We can see the ceiling structure from the bottom as no covering is applied. The timber frame has been constructed by using the well-known carpentry joints.

Figure 10: The exterior view of mosque [2].

The load bearing bases of the columns were sat on stone plates that in turn sit on the ground surface. This system isolated the wood from wet soil. Main loads considered are dead load, roof live load and wind load. Dead load includes the weight of roof, beams, columns, joists, and finishing materials. Roof live load means examination load on roof. Because the timber construction is only one floor in height, earthquake action is not the controlling load.

The women's place is the only section divider of the mosque inside. This section is along the north wall and 415 cm depth and 260cm high.

The mosque is decorated with a lot of wood members like a minbar and mihrab (Fig. 11) and glazed brick.

Figure 11: The minbar is decorated with wood members

3 CONCLUSIONS

This paper has aimed to introduce of the structural characteristics and details of traditional Great Mosque. Timber structure is a kind of traditional construction in
Turkey. Because of the lack of wood resource decades before, timber construction buildings were limited strictly. It results that our engineers are not familiar with the design and building technique of timber construction. Wood science research in Turkey is also far behind the other countries. The Great Mosque inherits the Turkish traditional culture. It is very important for an engineer and architect to timber construction technique, details, culture, art and aesthetics together.

REFERENCES
[3] The measured drawing of mosque has been drawn with the help of students who are attending at Vocational Schools of Afyon Kocatepe University