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Analysis of wooden pillar and wooden ceiling mosques of the Seljuk and principalities period

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Abstract

Mosques, as structures meticulously designed and constructed, represent the pinnacle of architectural and aesthetic solutions within Islamic civilizations. The desire for proximity to the mihrab in mosque design has necessitated the development of original and rational structural solutions, leading to significant advancements in architectural technology and technique. Mosque architecture, predominantly masonry, reflects both local architectural influences and the availability of materials, often shaped by regional traditions and construction methods specific to certain periods. A notable example of this is the wooden columned and wooden-ceilinged mosques, extensively constructed in Anatolia during the Seljuk and Principalities periods, where all elements, except for the masonry walls, were crafted from wood. This article presents a typological analysis of mosques with flat timber beams, wooden columns, and wooden ceilings, offering a comprehensive examination of their distinctive architectural features. The structural analysis encompasses all aspects from the foundation to the roof, with detailed documentation of their construction techniques. The aim of this study is to contribute to the conservation and restoration efforts of these mosques, a group of which only a few original, high-quality examples remain. Furthermore, this research is of particular significance as it represents one of the first studies to document the ceiling solutions of wooden hypostyle mosques, some of which are listed on the UNESCO World Heritage List. For the typological studies, both on-site examinations were conducted and data from previous sources were evaluated. The ceiling analysis was carried out using application photographs of a restored mosque, employing a three-dimensional modeling method.

Keywords: conservation, cultural heritage, hypostyle mosques, straight beam, wooden masjid

1. Introduction

Based on evidence gathered from scientific excavations, it is plausible to assert that wood has been employed as a construction material since the earliest stages of human civilization. Its widespread use can be attributed to its accessibility, ease of processing, and high load-bearing capacity relative to its lightness, particularly in regions where climatic conditions favor its utilization. In Anatolia, wood has been a preferred material in both civil and monumental architecture up until the mid-20th century, predominantly utilized in flooring systems, roofing structures, and as a key element in walls and architectural features, serving both structural and aesthetic functions.

The architectural evolution of mosques in Anatolia underwent significant diversification with the arrival of the Turks, who had embraced Islam, following the Battle of Manzikert in 1071. The Great Mosques constructed in the newly conquered cities and regions stand as some of the most valuable examples of Anatolian Seljuk architecture, both in terms of construction techniques and aesthetic qualities. Material selection for mosque construction typically reflects the significance of the structure itself, with wood being employed in smaller mosques, particularly in walls using timber furring or timber frame systems. In rare instances, wooden struts were used to support the roof

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structure. Mosques featuring wooden ceilings and columns represent unique examples of how wood was employed both structurally and decoratively.

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The earliest examples of mosques with wooden ceilings and columns are found in the cities of Kufa and Basra, located on the Arabian Peninsula (Öney, 2007). Consequently, such structures are often referred to in the literature as "Kufa-type mosques" in addition to terms like "wooden columned mosques" or "multi-columned mosques." The first such mosques in Anatolia date back to the late 12th and early 13th centuries. Kuran (2012) offers two hypotheses regarding the origins of these mosques in Anatolia. The first posits a connection to earlier examples of Greek temples with wooden columns and Phrygian megarons, which were characterized by their wooden columns and have a significant place in the architectural history of Anatolia. The second hypothesis suggests that the Turks, upon settling in Anatolia in the 11th century, may have brought knowledge of this building type from Central Asia, as they did not encounter similar structures in eastern and southeastern Anatolia.

Kuran further traces the origins of this architectural form to the 7th century, pointing to the canopy constructed from date palm trunks in the courtyard of the Prophet Muhammad's house in Medina as an early prototype. While mosques with wooden ceilings and columns, such as the one built by Amr Ibn al-As in Fustat, existed during this period, the influence of regional architecture, which often utilized stone and marble columns, became dominant as Islam spread into Asia. This interaction may have led to the development of wooden columned mosques, which the Turks could have introduced to Anatolia (Kuran, 2012). Aslanapa (1990) concurs with this view, suggesting that this architectural style reached Anatolia through structures like the Arus-ül Felek Mosque, built by Sultan Mahmud of Ghazni, as well as through mosques constructed by the Karakhanids in cities such as Samarkand, Bukhara, and Khiva (Aslanapa, 1990).

A second hypothesis, also advanced by Kuran (2012), emphasizes the continuous and deliberate use of wooden columns by the Turks, drawing parallels to their traditional use of wooden poles in tent structures. According to this theory, the Turkish tribes who adopted Islam in Central Asia may have worshiped in multi-columned mobile mosques, which in turn influenced the aesthetic development of mosques in settled areas (Kuran, 2012). Akok (1976), on the other hand, stresses that the use of wooden roofing systems has a long-standing tradition in Anatolian civil architecture, predating the arrival of the Seljuks. He notes that the combination of masonry walls, wooden pillars, and wooden roofs constitutes a distinct, local construction technique in Anatolia, remarking, "Masonry and wood pillars, wood, and earth roof coverings, with all their building nuances, represent an indigenous architectural style (Akok, 1976).

During the Seljuk and Principalities periods, mosques with wooden columns and ceilings continued to be constructed, especially in central Anatolia, with several high-quality examples emerging. Although their construction decreased with the rise of the Ottoman Empire, they remained a part of mosque architecture, albeit in limited numbers. Numerous studies have been conducted on the architectural, structural, and decorative aspects of these mosques. For example, the structural behavior of the Ahi Elvan (Er Akan, 2010) and Aslanhane Mosques (Çakıcı et al., 2009) has been analyzed using finite element modeling, while the material composition of mosques such as the Mahmut Bey Mosque (Akyol et al., 2006), Sivrihisar Great Mosque (Akyol, 2019), and Beyşehir Eşrefoğlu Mosque (İçel, 2020) has been examined through archaeometric analysis. In addition, mosques such as the Ayaş Great Mosque (Karaçağ, 2010), Afyon Great Mosque (Akkanat, 2010), Mahmud Bey Mosque (Akok, 1946; Yaylacıoğlu, 2010; Aydın & Perker, 2017), Eşrefoğlu Mosque (Akok, 1976; Koçu, 2014) and Arslanhane Mosque (Karaseki, 2007) have been analyzed for their architectural features, material types, and decorative elements, while Çilek (2020) focused specifically on the ornamental features of the Eşrefoğlu Mosque.

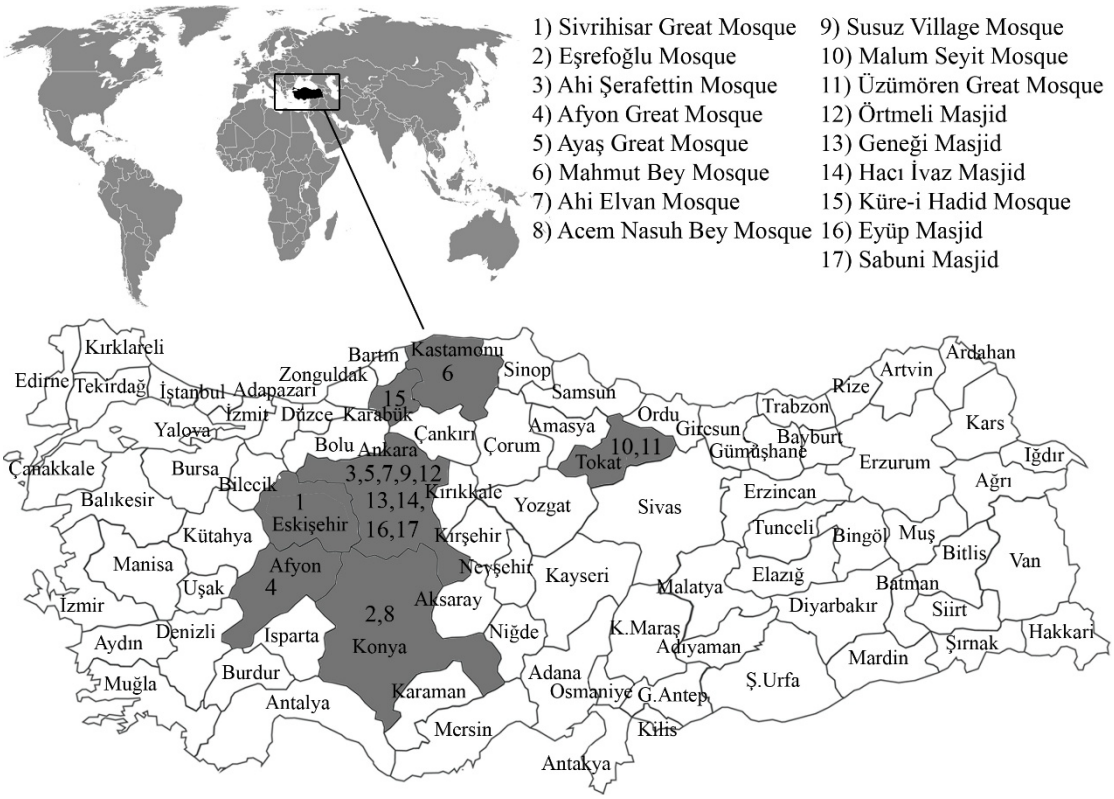


Figure 1 Location of mosques (The provinces where the structures are located are indicated by numbers)

The present study examines mosques constructed with straight beams, wooden pillars, and wooden ceilings during the Seljuk and Principalities periods (Figure 1), forming a typology with specific shared characteristics. Their structural systems have been meticulously analyzed through typological studies, with the aim of increasing awareness of their architectural composition to aid in conservation and restoration efforts. Given the limited number of surviving examples, understanding the structural configurations of these mosques is critical to ensuring their preservation. The unique contribution of this study lies in its detailed analysis of the construction systems, including the roofing structures, and the presentation of this information to the academic community for the first time. The significance of this research is further heightened by the recent inclusion of five such mosques—Eşrefoğlu Mosque, Mahmut Bey Mosque, Sivrihisar Great Mosque, Afyon Great Mosque, and Aslanhane-Ahi Şerafettin Mosque—on the UNESCO World Heritage List in 2023 under the designation "Wooden Hypostyle Mosques of Anatolia from the Medieval Pe.. Accordingly, Structure No. 1 is in Eskişehir; Structures No. 2–8 are in Konya; Structures No. 3–5–7–

9–12–13–14–16–17 are in Ankara; Structure No. 4 is in Afyon; Structure No. 6 is in Kastamonu; Structures No. 10–11 are in Tokat; and Structure No. 15 is in Karabük (Figure 1).

2. Methodology

In the scope of this study, an investigation was undertaken into the flat-roofed wooden mosques from the Seljuk and Beylik periods. A typological analysis was constructed by examining their qualitative attributes. The identification of the mosques' characteristics was informed by field observations as well as a review of prior scholarly research. In the examination of the ceiling systems, photographs from the restoration of the Aslanhane Mosque and on-site measurements of the Mahmut Bey Mosque in Kasaba Köy were synthesized and rigorously analyzed. Although photographic documentation was available for the Aslanhane Mosque, particular emphasis was placed on detailing the ceiling of the Mahmut Bey Mosque due to the distinctive nature of its ceiling system, which is characterized by unique ornamental elements.

The primary limitation of this research arises from the absence of photographic documentation regarding the ceiling repairs of the Mahmut Bey Mosque, which has hindered the comprehensive analysis of its ceiling system. Although the mosque underwent restoration, the intricate handcrafted embellishments of its ceiling and the structural relationship between the roof and ceiling could not be thoroughly examined due to the lack of repair photographs. Consequently, detailed structural data specific to this mosque were unattainable, necessitating reliance on the ceiling repair photographs of the Aslanhane Mosque.

The classification and typological delineation of culturally significant structures, particularly those designated for preservation, are critical for future academic studies. Accordingly, the proposed categorization and identification of similarities and differences among wooden-ceilinged mosques are expected to inform and guide subsequent restoration efforts. Moreover, the detailed exposition of unique construction systems will offer valuable support for restoration practices involving comparable structures in future projects.

3. The Research Findings

In the scope of this study, an investigation was undertaken into the flat-roofed wooden mosques from the Seljuk.

3.1. Typological Classification of the Mosques

Publications concerning mosques from the Seljuk-Principalities period, particularly those featuring wooden pillars and ceilings, remain scarce. These structures are typically classified typologically and detailed according to the construction techniques of their support systems and ceilings. Öney (2007) identifies both monumental examples and smaller masjids, which she likens to tiny houses, within this group of mosques. She further notes that these structures exhibit various features depending on the number of naves, the presence of narthexes, and courtyards. However, Öney refrains from presenting a typological classification in her study (Öney, 2007).

Akok (1976) contributes to this discourse by categorizing the grand mosque types that emerged in 13th-century Anatolia into three primary groups based on their structural characteristics. The first group consists of mosques whose surrounding walls, vaults, and arches serve as load-bearing elements, without the inclusion of wooden materials in their roofs or supports. In contrast, the second and third groups, while sharing similar masonry techniques for their surrounding walls, incorporate wooden roofs. In the second group, the roof is supported by rows of stone pillars or arches, whereas in the third group, wooden pillars are employed as structural supports (Akok, 1976).

Akok's classification focuses on the use of masonry and wooden elements in roofs and supports. Meanwhile, Tuncer (1979) offers a similar typological study specifically addressing wooden roofs. He classifies wooden roofing systems of the Seljuk period into three groups: the first group includes

structures where wooden trusses are employed, with the underside either exposed (as seen in the Great Mosque of Diyarbakır) or covered with wood (such as in the Ağaçayak, Hacı İlyas, and Hacı Musa Mosques). In the second group, the wooden beams of the roof rest on rows of masonry arches. The third group features structures where stone and wooden pillars replace the series of arches supporting the roof (Tuncer, 1979).

Önge (1975) undertakes a broader typological study of wooden ceiling formations across various structures from the Seljuk and Principalities periods. Although his research encompasses all building types from this era, the typology can also be applied to mosques, as relevant examples exist for each subcategory. Önge examines examples dating from the 11th to 15th centuries of the flat beam system, commonly referred to as the 'soil roof (karadam),' which is considered the simplest form of wooden ceiling and involves a covering of earth. He identifies two types of beaming systems: straight and inclined wooden beams. Furthermore, Önge notes that flat wooden beams can be left exposed, overlapped, or used as part of vaulted or domed wooden ceilings, with three variations of coverage: uncoated, top-coated, or bottom-coated (Önge, 1975).

3.2. Architectural Elements and Scissor-Truss Wooden Ceiling Typology in Mosques

The structural pillars supporting the ceiling and forming the naves in mosques with wooden ceilings are utilized in two distinct typologies. The first method involves the use of roughly-hewn timber, wherein the tree trunk is employed after its bark has been stripped and the branches and knots have been cleaned, without further shaping or chipping of the wood (Figure 2).

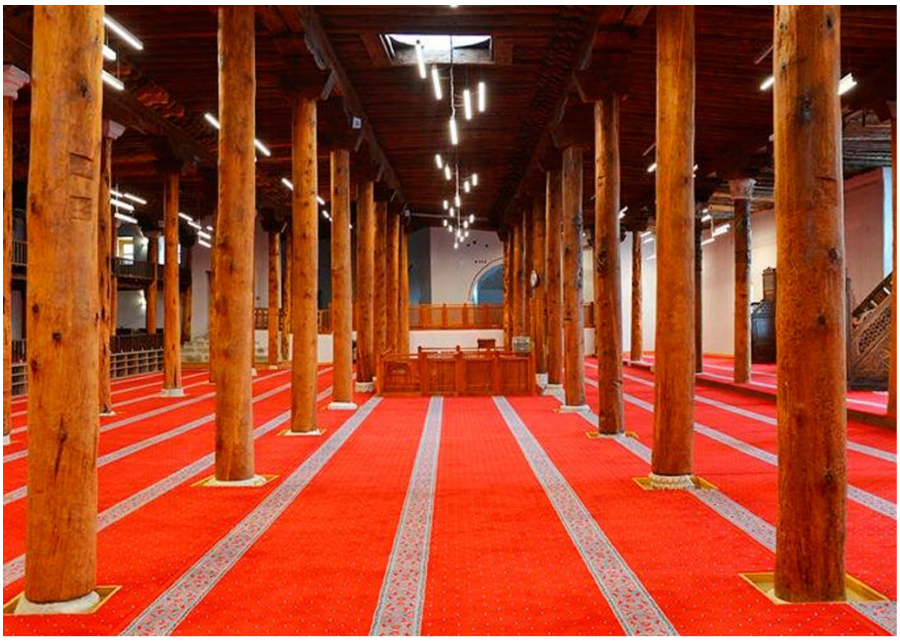


Figure 2 Sivrihisar Great Mosque wooden columns

While trees with smooth surfaces were generally selected for these circular cross-section pillars, in some instances, knotty trees with irregular surfaces were also employed, as seen in the Sivrihisar Great Mosque—though subsequent interventions over time have also contributed to this condition. Circular cross-section, unchiseled pillars are more prevalently used in mosques. Another method involves shaping the log into square, rectangular, or polygonal prisms. Notable examples of this include the polygonal prism-shaped supports surrounding the pool in the Beyşehir Eşrefoğlu Mosque (Figure 3).

Figure 3 Sivrihisar Great Mosque column capital

The art of carving and relief is observed in only a limited number of examples, such as the wooden pillars situated in front of the mihrab in the Sivrihisar Great Mosque. Similarly, hand-carved ornamental elements for aesthetic purposes can be seen in select instances, such as in the Kastamonu Mahmut Bey Mosque (Figure 4). The number and dimensions of the pillars are typically proportional to the overall size of the structure. However, it is also possible to find pillars of varying lengths and diameters within the same building. For example, in the Sivrihisar Great Mosque, pillar diameters range from 34 to 52 cm.

Figure 4 Kastamonu Mahmutbey Mosque wooden columns

Pedestals were typically employed beneath the pillars at their junction with the ground. These pedestals primarily served to prevent deterioration by protecting the pillars from moisture absorption from the ground, while also facilitating the even distribution of the roof's load across a

broader surface area. Additionally, pedestals were used to bridge the gap between the ground and pillars of varying heights, thus equalizing the upper elevations. The use of pedestals of different heights within the same structure, as seen in the Sivrihisar Great Mosque and Ankara Hacı İvaz Masjid, supports this functional intent. These pedestals could be crafted from smoothed stone blocks, intricately worked stone blocks, or spolia from ancient civilizations (Figure 5). Pedestals were positioned either above or beneath the floor slab. In many existing examples, the pedestal remains visible on the ground. Önge (1975) cites the Great Mosque of Afyon as an example of pedestals located beneath the floor slab. However, during restoration work in 1952-53, the original spolia pedestals were removed and replaced with the plain stone pedestals seen today (Önge, 1975). Additional examples of sub-floor pedestals include the pillars in the Hacı İvaz Masjid and those situated in front of the mihrab in the Mahmut Bey Mosque in Kastamonu.

Figure 5 Sivrihisar Great Mosque pedestals

Column capitals are generally employed to connect the pillars to the ceiling. In addition to their aesthetic function, these capitals facilitate the smooth transfer of the load from the main ceiling beam to the column and help align the struts to the appropriate height with surrounding elements. Capitals were crafted from either wood or stone. Önge (1975) classifies wooden column capitals into three types: wooden beams with profiles at both ends, and wooden pieces shaped as inverted truncated cones or pyramids (Önge, 1975). Önge interprets these capitals as 'beam headers with wooden profiles at both ends,' which function more as cushions to prevent the struts from exerting excessive pressure on the beam, rather than acting as traditional capital heads. These components are often found atop other wooden capitals, serving as sleeper beams (Figure 6). As these parts are referred to as sleeper beams in other literature (Akok, 1976; Tuncer, 1979), this article classifies them as 'pillars without capitals' and organizes them accordingly in the typology. Examples of pillared mosques without capitals include the Beyşehir Çavuş Village Mosque and the Karaman Hoca Mahmud Mosque. Mosques with inverted truncated cone or pyramid-shaped capitals, such as the Sivrihisar and Ayaş Great Mosques (Figure 6), exemplify this architectural feature. Among pyramid-shaped capitals, those with muqarnas (stalactite) decoration stand out for their aesthetic and technical qualities. Önge (1968) identifies two types of muqarnas capitals. The first type, carved from solid wood, is rare today, with one of the finest examples found in the Mahmud Bey Mosque in Kasabaköy, where these capitals were intricately carved and embellished with decorative patterns (Önge, 1968).

Figure 6 Beyşehir Çavuş Village Mosque column capital

Another technique for creating this type of capital involves manufacturing the components separately and affixing them to the pillar by nailing. Examples of this technique, referred to in the literature as 'nailed stalactite wooden capitals,' include the Genegi Masjid, Eşrefoğlu Mosque, and Afyon Great Mosque (Önge, 1968). These capitals are non-structural, serving purely decorative purposes. According to Önge (1968), these capitals are typically arranged in octagonal or polygonal compositions on wooden pillars with circular, octagonal, or polygonal cross-sections. After the first 4-5 rows, the top of the capital generally takes the form of a star, polygon, or square and fits securely beneath the ceiling beam. A flat wooden platform, composed of boards placed side by side, supports the beam on top of the capital. Önge also notes a distinctive tapering at the end of the inverted cone or pyramid-shaped struts near the head, referring to these shorter, thinner sections as the 'neck' (Figure 3), with the Beyşehir Eşrefoğlu Mosque cited as a prime example (Önge, 1968; Önge, 1975). Additionally, some of these wooden capitals feature hand-drawn ornaments, created using madder dye. In some instances, such as the Beyşehir Çavuş Village Mosque, Beyşehir Eşrefoğlu Mosque (Figure 7), or Kastamonu Mahmut Bey Mosque, these ornamental designs extend to the ceiling, while in others, they are confined to specific areas.

Figure 7 Beyşehir Çavuş Village Mosque column capital

Non-wooden capitals, in contrast, were often repurposed from the architectural remnants of earlier civilizations, such as spolia, and incorporated into mosque structures. These spolia capitals can be found in simple linear forms (Figure 8) or adorned with floral motifs (Figure 9), typically following the Corinthian order with acanthus leaf decorations (Table 1).

Figure 8 Sivrihisar Great Mosque column capital

Figure 9 Ahi Şerafeddin Mosque column capital

Table 1 The Features of Pillars, Pedestals and Column Caps in Mosques with Wooden Ceilings

Mosques with wooden pillars and wooden ceilings	Pillars					Pedestal			Capitals					
	Section		Ornament			Available		Non. Ava.	Spolia		Not spolia			
	Circular	Angular	Carving	Relief	Hand-drawn	Simple	Ornamental		Simple	Ornamental	Without capital	Muqarnas	Conical	Hand-drawn
Sivrihisar Great Mosque	●		●	●		●	●		●	●			●	
Eşrefoğlu Mosque	●	●			●	●						●		●
Ahi Şerafettin Mosque	●					●			●	●	●			
Afyon Great Mosque	●					●						●		
Ayaş Great Mosque	●					●						●	●	
Mahmut Bey Mosque		●			●			●			●	●		●
Ahi Elvan Mosque	●	●				●			●	●	●			
Acem Nasuh Bey Mosque	●					●						●		●
Susuz Village Mosque	●	●						●			●			
Malum Seyit Mosque	●	●	●			●							●	
Üzümören Great Mosque	●							●			●		●	
Örtmeli Masjid	●							●		●				
Geneği Masjid	●					●						●		●
Hacı İvaz Masjid	●							●	●					
Küre-i Hadid Mosque	●				●			●			●			●
Eyüp Masjid	●					●					●			
Sabuni Masjid		●				●			●					

Profiled wooden sleepers, aligned parallel to the pillars, are positioned beneath them at the junctions where the primary load-bearing beams connect to the pillar capitals. These sleepers are composed of one or two sections, depending on the thickness of the main upper carrier beam. By distributing the point pressure exerted by the pillars across a broader surface, the sleepers help to prevent damage to the beams. These wooden sleepers are typically employed in either a flat form (uncarved), with minimal carving (Figure 10), or with intricate carvings (Figure 11), depending on the design profile.

Figure 10 Üzümören Great Mosque wooden sleepers and wooden column capitals

Figure 11 Malum Seyit Mosque wooden sleepers and wooden column capitals

Some of these elements, utilized in various mosques with differing profiles, have been transformed into aesthetic features through the addition of hand-drawn ornamental decorations (Figure 12), similar to those found in other parts of the mosque.

Figure 12 Eşrefoğlu Mosque wooden sleepers and wooden column capitals

3.3. Ceiling System

The pillars supporting the main beams, positioned on wooden sleepers, are carved into square or rectangular prisms. This design ensures that the upper (intermediate) beams make full contact with the pillar heads or sleepers, allowing the load to be evenly distributed across the entire surface. These beams extend continuously across the pillars, with the joints between beam sections aligned with the central axis of the pillars. The main load-bearing beams, spanning between the pillars and the masonry walls, create long, rectangular naves (Figure 13). In mosques with this architectural layout, the width of the naves can reach up to 4.5 to 5 meters in the axial arrangement formed by the wooden posts. The number of naves, determined by the spacing between the pillar axes, is a defining characteristic of this type of mosque (Table 2, Table 3). Typically, the central nave is higher than the lateral naves in this architectural form. The increased height of the central nave is achieved through a stepped construction of wooden elements extending from the console. In some buildings, the lateral naves are sloped to provide the necessary gradient for the upper cover, while in others, the slope is achieved by progressively raising the height of each nave towards the center. Depending on the size of the structure, mosques are typically designed with an odd number of naves—3, 5, 7, or 9. The central nave is often wider and/or higher than the others, contributing to the distinctive sanctuary space created by this layout.

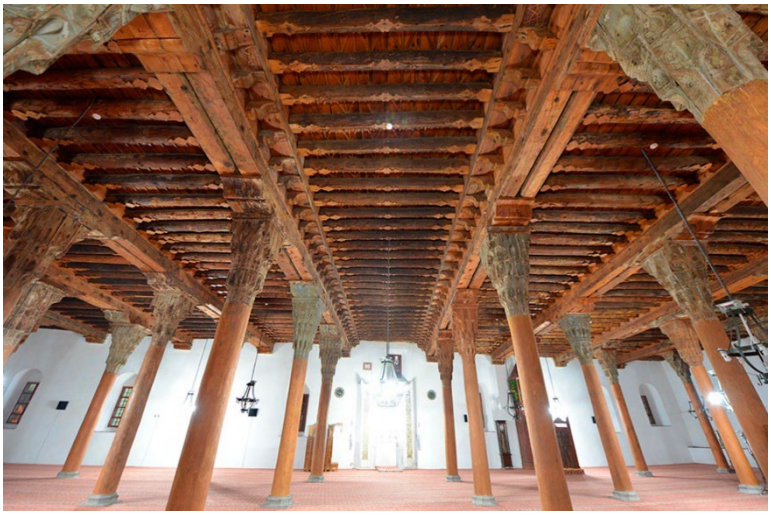


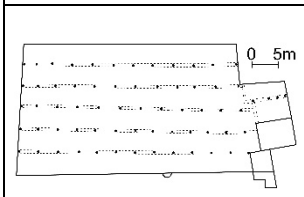
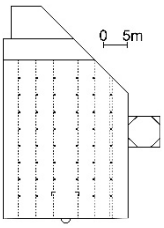
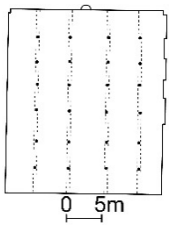
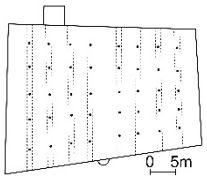
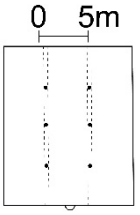
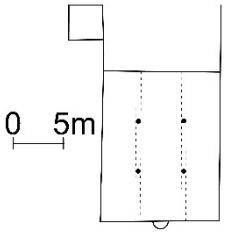
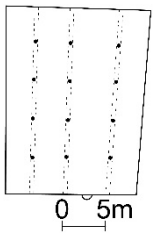
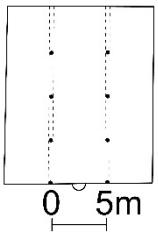
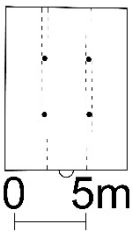
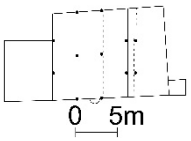
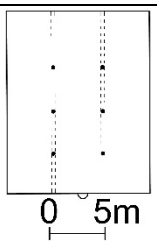
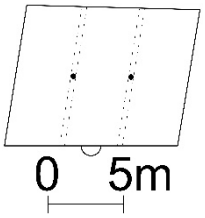
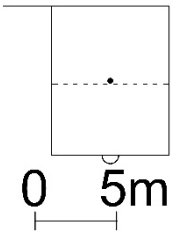
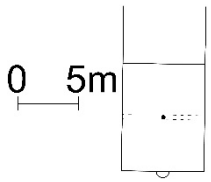
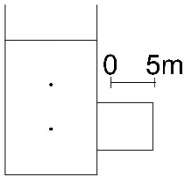
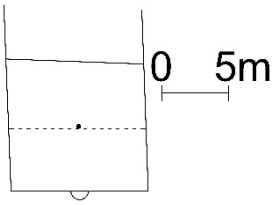
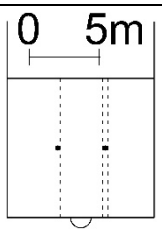
Figure 13 The naves in Afyon Great Mosque

The main beams that define the naves are extended along the pillars, positioned to form the long sides of the naves. When upper (intermediate) beams of the same or occasionally varying heights are placed on these beams from both directions, two main carrier beams are positioned side by side on each pillar without any gaps (Figure 13). Tuncer (1979) notes that the decision to use single or double beams depends on the span and cross-sectional dimensions, as double main beams provide a more secure fit for the upper (intermediate) beams and are more suitable for muqarnas capitals. Additionally, it is known that beams parallel to the walls are integrated into the masonry walls, corresponding to the wooden beams supported by rows of pillars. These wall-mounted beams align with the main beams in the structure, taking on the role of primary load-bearing elements along the walls.

Table 2 Wooden Beams, Nave and Roof Elements in Wooden Ceiling Mosques

Mosques with wooden pillars and wooden ceilings	Wooden Beams		Nave Setup											Roof Elements			
	Side naves		Axis direction		Height		Number of naves							Snow well		Lighting lantern	
	Straight	Sloping	Mihrab axle	Parallel to the mihrab axis	Rising towards the center	All naves are equal	2	3	4	5	6	7	9	Available	Nope	Available	Nope
Sivrihisar Great Mosque		●		●	●						●				●	●	
Eşrefoğlu Mosque		●	●		●							●		●		●	
Ahi Şerafettin Mosque	●		●		●					●					●		●
Afyon Great Mosque	●		●		●								●		●		●
Ayaş Great Mosque	●		●		●			●							●		●
Mahmut Bey Mosque	●		●		●			●							●		●
Ahi Elvan Mosque	●		●		●				●						●		●
Acem Nasuh Bey Mosque	●		●		●			●							●		●
Susuz Village Mosque	●		●		●			●							●		●
Malum Seyit Mosque	●		●		●			●							●		●
Üzümören Great Mosque	●		●		●			●							●		●
Örtmeli Masjid	●		●		●			●							●		●
Geneği Masjid	●			●	●		●								●		●
Hacı İvaz Masjid	●			●	●		●								●		●
Küre-i Hadid Mosque	●		●			●	●								●		●
Eyüp Masjid	●			●		●	●								●		●
Sabuni Masjid	●		●		●			●							●		●

Table 3 Plans of Wooden Ceiling Mosques

Plans				
Sivrihisar Great Mosque	Eşrefoğlu Mosque	Ahi Şerafettin Mosque	Afyon Great Mosque	Ayaş Great Mosque
				
Mahmut Bey Mosque	Ahi Elvan Mosque	Acem Nasuh Bey Mosque	Susuz Village Mosque	Malum Seyit Mosque
				
Üzümören Great Mosque	Örtmeli Masjid	Geneği Masjid	Hacı İvaz Masjid	Küre-i Hadid Mosque
				
Eyüp Masjid	Sabuni Masjid			
				

The naves are covered by upper (intermediate) beams placed parallel to the shorter sides of the structure. The spacing between these beams is approximately 1 to 1.5 times the width of the beam, and they are secured to the masonry walls either by resting on the main beams extended over the pillars or by being embedded within the wall itself. Önge (1975) notes that these beams typically penetrate 20-30 cm into the masonry wall. Consoles are created by extending the upper (intermediate) beams into the nave, forming profiled consoles. The ends of these consoles are profiled and support a secondary beam placed above them. The upper (intermediate) beams resting on this secondary beam are used to cover the elevated central nave (Figure 14). This method, which involves the use of multiple rows of consoles to raise the central nave, is exemplified in structures such as the Sivas Grand Mosque, Beyşehir Eşrefoğlu Mosque, Kastamonu Mahmut Bey Mosque, and Aslanhane Mosque. This elevation not only resolves the issue of roof slope but also enhances the aesthetic value of the interior.

The openings at the points where the upper (intermediate) beams rest on the main beams are covered with flat wooden boards, approximately 1 cm thick. These boards are inserted into specially carved grooves along the side faces of the beams by sliding them from above (Figure 15). Typically, the boards are inclined toward the ceiling. In some instances, moldings have been observed, particularly on the upper sections of these boards. Additionally, decorative wooden boards are incorporated into the ceiling system for aesthetic purposes. These boards are affixed either beneath

both ends of the beams or above the joints where paired main beams are used, and they are often carved with motifs and embellished with hand-drawn decorations. These decorative boards are referred to as 'sayvan' (Önge, 1975) or 'lambriken' (Tuncer, 1979) (Figure 14).

Figure 14 The canopy/lambricanes in Afyon Great Mosque

Figure 15 Photos taken during the restoration of the Arslanhane Mosque

To prevent soil from falling into the mosque, an insulating layer is placed on top of the upper (intermediate) beams (Figure 16). Tuncer (1979) explains that this insulating layer consists of wooden plates, upon which a mixture of barren clay (with added salt) and straw or tow is applied to prevent cracking. Önge (1975), on the other hand, suggests that this layer may be composed of reed, mat, or plate-shaped boards. He further notes that after this layer is plastered with mud, it is covered with 30-40 cm of salty soil, a traditional covering known among the people as 'karadam' or 'soil roof'.

Tuncer (1979) notes that while the ceilings of mosques can be ventilated from below, the presence of a top soil covering prevents ventilation from above. To address the risk of decay, a secondary ceiling was introduced in the restoration of the Konya Doğanhisar Grand Mosque, built in 1548, and the Konya Ilgın Yukarı Çiğil Village Mosque, which dates back to before the first quarter of the 18th century. This secondary ceiling was created by placing an additional main beam over the original beams. However, no such secondary ceiling was found in the Ankara Aslanhane Mosque (Directorate General of Foundations, 2023) (Figure 17).

Figure 16 Photos taken during the restoration of the Aslanhane Mosque

Figure 17 Photos taken during the restoration of the Aslanhane Mosque.

The 'Karadam' soil roof covering was a common feature in rural Anatolian architecture. This covering was created by laying a layer of stones, reeds, wicker mats, or thin branches to prevent soil from falling onto the wooden beams, followed by a 10-30 cm thick layer of soil. Research has also been conducted on the composition of the soil used in this covering. Bulut Karaca (2021) indicates that the soil consists of two layers: a 3-4 cm layer of impermeable clay and a high-salt-

content soil referred to as 'barren' or 'trim' (Bulut Karaca, 2021). In contrast, İner and Çağlarer (2013) describe the second layer of mud, called 'bişirik,' as being composed of clay-rich soil mixed with straw.

In subsequent years, the roofs of many mosques from this period were restored or altered to feature fitted roofs covered with tiles. However, various researchers assert that these roofs were originally covered with soil. For instance, Akok (1976) notes that, despite the Beyşehir Eşrefoğlu Mosque's new wooden roof with copper plates, it was originally covered with soil, like other structures from this period. Similarly, Tükel Yavuz (2002) suggests that most buildings of this era, excluding conical tombs and baths, originally had flat roofs, many of which were earthen, though this is not always certain. She identifies cut stone slabs as the roofing material for some structures, such as the Karatay Inn. Kuran (1995) also observes that the flat earthen roof of the Niksar Great Mosque was later protected with a tiled, sloped roof.

During this period, smooth, knot-free trees with minimal branching and cracks were selected for construction. Tuncer (1979) states that these woods were kiln-dried and treated with insect repellent. While tree species varied, juniper and yellow pine were used for the construction of the Sivrihisar Great Mosque (Sivrihisar Municipality, 2024), and it is known that all the timber elements of the Beyşehir Eşrefoğlu Mosque were made from pine (Akok, 1976). Tuncer (1979) also notes the use of fine-fiber spruce, cedar, and fir in such mosques. Notably, nails were not used in the assembly of the timber structures. Instead, joints were crafted by inserting wedges between the wooden elements, using various techniques to fit the pieces together.

3.4. Analysis of Scissor-Truss Ceiling System in the Context of Kasabaköy Mahmut Bey Mosque

Although mosques with scissor-trussed ceiling systems exhibit various typologies, they are fundamentally constructed using the same structural principles. In this regard, the ceiling system of the Kasabaköy Mahmut Bey Mosque has been analyzed, with restoration images from the Aslanhane Mosque providing further support, leading to conclusive insights. As a result, the restoration of structures employing similar systems can be effectively undertaken by understanding these ceiling formations.

Following the construction of the stone walls, the first step in the ceiling assembly involves the placement of vertical posts. In the Mahmut Bey Mosque, the columns are octagonal, measuring 35 cm at the base and 26 cm at the top. The detailed column under examination features a muqarnas-style capital, with the widest section having a diameter of 58 cm. To evenly distribute the load between the column and the main beams, a simple, flat cushion is placed parallel to and 3.5 cm beneath the main beam. The main beam is then positioned atop this cushion, extending in the same direction. To elevate the ceiling system, profiled small beams, approximately 1 meter long and 17 cm wide, are vertically placed on the main beam at 40 cm intervals. These beams are adorned with decorative penwork on both the lower and side surfaces.

The connection between these beams is achieved by inserting approximately 2 cm thick boards into grooves cut into the beams. The rigidity of the structure is further reinforced by the placement of long beams vertically over the upper part. The final support beams for the side aisles are placed vertically on top of these two beams, with one end embedded in the stone wall and the other extending outward by approximately 28 cm. Three grooves are carved into this beam to close gaps and ensure the connection of beams, with two grooves accommodating boards for the side aisles and one for the main aisle.

Additionally, to reinforce the connection between the beams and prevent any slippage, a vertically oriented beam is placed over the profiled sections. The area between this beam and the wall is covered with wood, enclosing the side aisles. The ceiling of the main aisle is formed by positioning beams vertically and in alignment with the final beam, with evenly spaced intervals. The final layer of beams also features grooves at both ends, into which boards are inserted to close the gaps between them.

In this section, decorative elements are introduced by vertically mounting star-shaped carved boards between the beams, over which flat, uncarved wooden boards are placed. To stabilize both the wood and the ceiling structure, the entire ceiling is filled with soil. While the original design involved a soil-filled roof, subsequent interventions replaced this with a pitched roof. Roof beams were placed on top of the soil layer, completing the roof system (Figure 18).

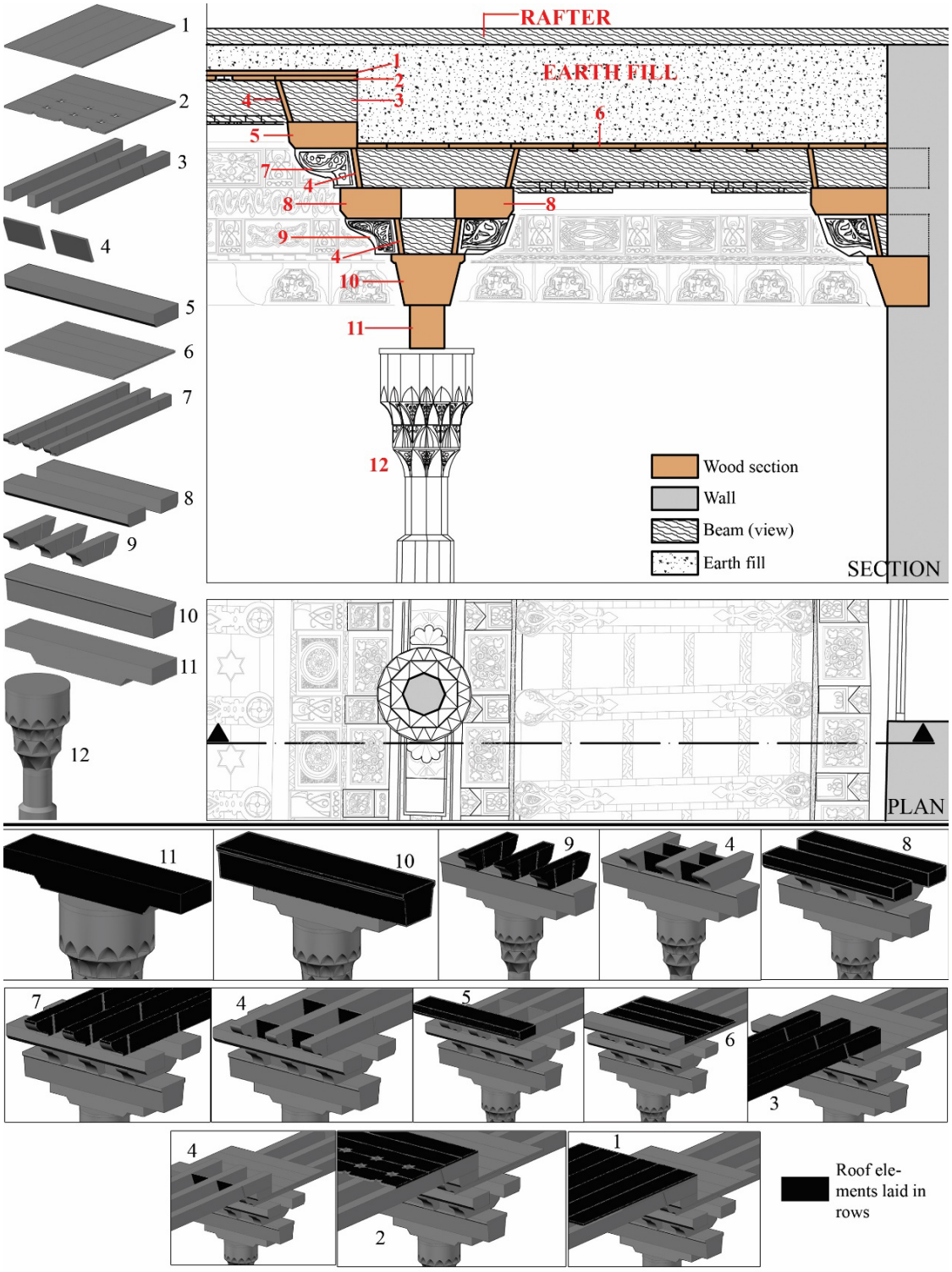


Figure 18 Carrier system analysis of Kasabaköy Mahmud Bey Mosque

4. Results and Discussion

Scholarly opinions differ regarding the origins and development of mosques with wooden pillars and ceilings. These structures, which were built during the Anatolian Seljuk and Principalities

periods, continued to be constructed gradually over time. However, the mosques featuring superior wood craftsmanship and aesthetic sensibilities—characterized by wooden pillars, ceilings, and flat weft-beam roof systems—represent a distinct architectural typology. These mosques are differentiated from those with domes, overlapping ceilings, or vaulted systems. Within the scope of this study, these structures were examined within the context of the Seljuk and Principalities periods. Nevertheless, many mosques, particularly those in regions where timber is abundant, were constructed using wood as a primary or sole material, often in conjunction with masonry structures.

Many mosques, particularly those in regions abundant with timber, were constructed using wood either as the primary or a significant building material, often alongside masonry. The mosques analyzed in this study are characterized by masonry walls, while all other elements, including the roof, are made entirely of wood. In these buildings, wooden pillars, arranged in rows, support the ceiling. These pillars rest on original or repurposed stone plinths or foundations, which may be visible either above or below ground. Most of the pillars feature capitals made of either spolia or wood. Above these capitals, wooden sleepers were placed to distribute the load, supporting the primary beams, which run continuously across the structure and define the naves. The naves are covered by beams laid perpendicular to the main beam. Restoration data and surviving original examples indicate that the roofs of these buildings were originally flat. A key structural detail is the arrangement of the naves at progressively lower levels relative to one another, which facilitates water drainage from the roof. In this typological study, system details such as the number of naves, their height and orientation, as well as key elements like column capitals, pedestals, and pillars, were identified and analyzed. The analysis was further supported by restoration photographs from the Aslanhane Mosque, providing, for the first time in the literature, comprehensive and detailed information on the structural characteristics of these buildings (Figure 18).

In addition to the qualitative assessments provided in the discussion, the tabulated data further illuminate the structural and stylistic diversity among the examined mosques. Table 1 reveals that approximately two-thirds of the surveyed examples incorporate circular-section pillars, while the remaining third employ angular or polygonal forms. The presence of hand-carved ornamentation on pillars is relatively rare, observed in fewer than 20% of the cases, which underscores the functional priority of these elements over decorative concerns. However, in certain examples such as the Mahmut Bey Mosque and Eşrefoğlu Mosque, ornamentation extends beyond the pillars to encompass capitals, pedestals, and even sleeper beams, reflecting a more elaborate artistic program.

A comparative reading of Table 1 also indicates that spolia usage in capitals remains a significant feature: nearly half of the mosques examined reuse stone capitals from earlier civilizations, frequently of Corinthian inspiration with acanthus leaf motifs. This practice not only reflects the pragmatic reuse of available materials but also the aesthetic integration of pre-Islamic architectural vocabulary into Seljuk and Beylik period religious structures. Wooden muqarnas capitals, by contrast, occur in roughly one-quarter of the cases, often in the most architecturally refined examples. Their concentration in prominent mosques—such as those of Sivrihisar, Beyşehir, and Kasabaköy—suggests an intentional association between this decorative form and high-status commissions.

The analysis of Table 2 demonstrates that the majority of mosques employ a three- or five-nave arrangement, accounting for almost 70% of the dataset. Wider central naves, either elevated or flanked by lower side naves, appear in over half of the examples, highlighting a spatial hierarchy directed towards the mihrab axis. Snow wells and lighting lanterns are comparatively scarce—present in less than one-third of the mosques—which may relate to regional climatic variations and construction traditions. The data also reveal that straight-beam configurations dominate, while sloping side naves are less common, suggesting a persistence of flat-roof construction methods consistent with the traditional “karadam” soil roof typology.

From a typological standpoint, as summarized in Tables 1–3, the co-occurrence of certain features points to regionally influenced design patterns. For example, the combination of circular-section pillars with stone spolia capitals and flat beam ceilings predominates in central Anatolia, whereas polygonal pillars with elaborately carved wooden muqarnas capitals are more frequent in the western examples. Quantitatively, these stylistic combinations account for nearly 80% of the surveyed corpus, reinforcing the notion that while individual mosques exhibit unique craftsmanship, they remain anchored within well-defined architectural traditions of the Seljuk and Principalities periods.

5. Conclusions

The present study represents the first comprehensive analysis of the ceilings and detailed architectural drawings of the 'Wooden Hypostyle Mosques of Anatolia from the Medieval Period,' which are listed on the UNESCO World Heritage List. The construction details of the wooden ceiling analyzed in this study are based on the Kasabaköy Mahmutbey Mosque, selected for its highly authentic ceiling, preserved with intricate pen work decorations.

The findings from this research are crucial for identifying and anticipating potential issues in similar structures, particularly in the context of conservation and restoration efforts. These insights will inform decision-making processes in conservation applications. As additional fine details are identified and incorporated over time, the data generated from this study will further contribute to the advancement of preservation practices.

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CRediT Authorship Contribution Statement

Ercan Aksoy: Writing – review &editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization, Resource, Writing – original draft. Özlem Sağıroğlu Demirci: Writing – review &editing, Methodology, Data curation, Conceptualization, Resource.

Declaration of Competing Interest

No conflict of interest was declared by the author.

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Ethics Committee Approval

Ethics committee approval was not required for this study.

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