Timber frame system after the western influence on the houses of Istanbul

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Introduction

Wooden houses have a special significance on the Ottoman architectural heritage. Although certain characteristics and the cultural spirit were mainly preserved, various features of the houses were transmuted throughout the years. Also, the structural system of the wooden houses is varied upon the region and the period of construction. There are many studies mentioning the classifications including log houses, different kinds of "*hımış*" and "*bagdadi*" techniques [1][2][3]. The timber frame system, which is typically interconnected with *"Bagdadi"* method, is generally found in Istanbul and its spheres of influence [4]. The timber frame system without infill is a lightweight structure providing economic, practical and speedy solutions. It allows more open areas. As the structure became lighter, span lengths and spaces could be enlarged. Consequently, dimension of houses, as well as the sizes and number of the windows were increased [5]. Traditional knowledge about the material, ease of supply, economic advantages, earthquake threat and the cultural habits contributed to the intense popularity of the usage of timber structures in residential buildings. In accordance with the importance and the cosmopolitan structure of the city, there was a huge variety of houses in Istanbul. Flamboyant and eye-catching examples of timber buildings were built in different parts of the city. Wooden structures were explicitly remarkable on the urban texture of Istanbul until the mid-20th century.

This article focuses on the timber frame system of the Ottoman houses in Istanbul from period between the nineteenth century and early twentieth century. More than 750 wooden residential buildings were seen on site during the years 2014-2019 and the structural system could be observed in at least 20 of them. The statements are mainly based on the site investigation and measurements of numerous authentic elements from the timber houses built at the last period of the Ottoman Empire. As the number of the preserved buildings and original elements gradually decrease, the observations on site encompass importance. Usually structural systems are the least documented part of the structures, because they are enveloped and invisible to the users. Within this study, besides the visual and written explanations about the system, dimensions of the wooden elements and sizes of the gaps are given in tables for objective comparisons.

Lightweight system and joints

The timber frame structure of the houses of Istanbul is typically raised above a masonry ground. Thus, basements and/or ground floors are generally built in brick or stone masonry. Main load bearing elements of the timber structure are the bearers and posts, which commonly have square-like section. Floor joists sit above the bearers and the diagonal braces help to provide rigidity to the structure. Moreover, thin horizontal and vertical timber elements are placed at the gaps between the load bearing posts. Timber headings enlarge the mating surfaces and support bearers of the upper floor.

According to the application of the beams and posts, timber frame systems are categorized into four different types [6]. However, single based system is the most typical type. Therefore, all the data presented in the article mainly represents this type. In Figure 1 and 2, single based structural system can clearly be seen. In a point of fact, although it does not

reflect the traditional and common method, the exceptional type like timber grid structure can be encountered in few very late examples.

Figure 1: Single based timber frame system from a house in Sarıyer

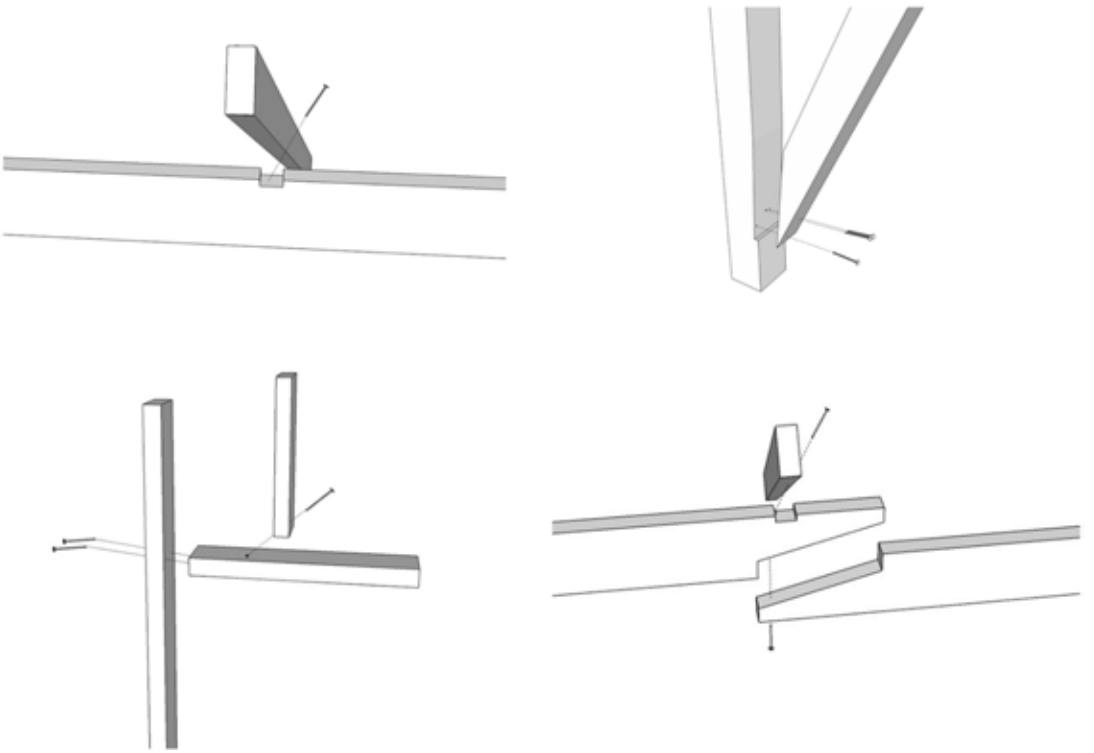
Figure 2: Timber frame system of a house in Bakırköy

At least one post is placed on each corner of a building. The number of vertical posts depends on the number of floors, all of them are positioned on the same vertical line. Distances between the parallel elements, such as posts, studs and noggings can vary depending on the project. In general, posts are placed on the line through the walls and their array with gaps is arranged based on the durability of the system and the design of the structure. Noggings and studs were added in anywhere needed as their place was probably decided on site by the rule of thumb. Timber is also used for the structural system of the roofs. Timber rafters are nailed to the ridge beam and often supported by the purlins. Thus, the load is distributed always toward the plates. Through the extension of the rafters, eaves are generated. The wooden roof structure is covered with boards both inside and outside. The upper boards create a suitable surface under the final covering and also help to protect the structure from the weather. Under boards provide clear finishing for the interior and enable decorative ceilings. Unlike many European examples, the wooden roof structure is invisible to the users. While the upper boards are nailed directly above the rafters, the interior boards are nailed down to the additional horizontal timber elements (Fig.4). The spaces, where the roof structure is observable, are mainly structured to be used as a repair room or as a warehouse.

Figure 3: Structural system inside the walls

Figure 4: Roof structure and the plates

Joinery methods of the timber structural system are mainly simple and all the joints are nailed. As the flexibilty had a great significance to the structures in the city with a threat of earthquake, nailed connections were preferred. Although several other techniques are mentioned in literature, basic nailed joinery is the most popular and common method applied for the houses. Probably locked joinery was used in rather small architectural elements. In the structural system, even the most basic form of connections, such as bringing elements together just with small notch or without any chipping can be encountered. Moreover, several types of lap joints, basic butt and beveled pieces are often found. At the joints, where more than two elements are connected, combinations of the traditional simple methods are used. Several examples of the joints are given in Figures 5-8.



Figures 5-8: Example of a joint bringing two elements together

It has to be underlined that the nails play an important role in timber houses. They are not only used for strengthening the connections of the structural parts, but also in small decoration elements. Therefore, different sized nails are utilized associating with their purpose. All nails are made of metal. Both wrought iron and also factory produced small wires were found on the researched sites. Reused timber pieces and later renovations might also have introduced older or newer types of the nails into the structure. As a general rule, thick and strong nails were used for the load bearing elements and tiny as almost invisible ones were kept for the façade ornaments. To avoid the risk of danger, any kind of exposed nail end was twisted. Furthermore, the role of the craftsman on the decisions for the nailed joints has to be emphasized. There were no standardized systems for the application of the connections and usage of the nails. They were mainly decided on site and formed by hand tools. The number or direction of the nails used in the same type of joint can vary. Thus, it is quite obvious that function, visual quality, safety and playing by ear through the knowledge of the craftsmen have played important roles on the nailing tradition [7].

Exterior and interior spaces

Facade claddings are among the very specific characteristics of wooden houses of Istanbul from the last period of the Ottoman Empire. Horizontal timber elements differentiate them from many Anatolian and European houses. The tradition of the horizontally placed hand-cut timber boards dates back to the beginning of the eighteenth century and because it was only used for the seaside mansions, this specific type is known as *"yalı baskısı"* meaning the stamp of the seaside mansion. The facades were protected from water leakage by the nailed overlapped boards. *"Yalı baskısı"* was broadly used between late 18th century and early 19th century [8]. In the second half of the 19th century, timber boards with half grooved connections and tenon mortises appeared in the architectural atmosphere of Istanbul. Moreover, establishment of a timber factory in Istanbul enabled the production of machined claddings by the end of the 19th century.

Different types of boards including *"yalı baskisi"* or machine shaped claddings can be still seen in Istanbul. In addition to characteristic horizontal boards, with the influence of European architecture vertically placed claddings are found. However, they are always combined with horizontal ones and are usually incorporated for decoration at the upper part of the facade. The horizontal timber claddings are approximately 1-3 cm thick, however, their width varied in a wider range between 10 and 32cm. With increased width, commonly over 20-24cm, lines were printed to convey the impression of narrow cut boards [9]. Timber planks were always protected from fast deterioration by the application of a coating. Besides, their visual perception was remarkable with vivid colors. Colors like red, yellow, blue, white or beige were frequently used. Even on the neglected houses, which are remained in original wood color, traces of vivid paint from early days can be observed.

Interior sides of the walls are covered with the *Bagdadi* laths, plaster and color, while timber cladding boards are applied on the exterior side. *Bagdadi* is the name of a common technique, which enables the creation of a suitable surface for plaster and paint above the timber framed walls. The elements of the timber structure provide a base whereon thin laths are placed horizontally and nailed. This surface is then coated with 1-3 cm thick plaster. The Bagdadi technique can be categorized in two distinctive types by observing the separation of the laths. The first type shows evenly cut thin elements which are separated by small gaps and nailed regularly. The second type, however, shows irregularly split timber laths with varying gaps and fractures. Although rather uncommon, both types are sometimes observed within the same room or even on different parts of the same single wall. In these rare cases at the specific areas, a probability of a previous restoration work has to be kept in mind.

Although Bagdadi method is dominantly found on the timber frame structures, another similar application method can be occasionally encountered. In this method, which came in after the end of the 19th century, galvanized wires were used instead of timber laths. They were nailed to the timber structural elements for the same purpose of the *Bagdadi* laths [10].

Dimensions

After a comprehensive investigation on site and measurements with traditional methods, a general dimensional range has been found. All the measurements including the extreme bounds were taken into consideration and counted in the research rather than recording only the average numbers. Besides the gaps between the same types of elements (Table 1), short and long edges of the various structural timber elements are presented (Table 2 and 3).

The distance between main posts was stated between 1.5 and 2.0 meter on the published lecture notes of Ali Talat from 1911, while it was found at the range 96-239 cm on the site measurements [11]. Furthermore, the same source claims that the studs were placed with 20-30 cm gaps, but they are measured between 16 and 50 cm on the preserved authentic examples. Published data reflects a narrow scale than the actual findings, but it probably reflects the most common or the ideal numbers.

	Rafters	**Posts**	**Floor Joists**	**Studs**
Distance in cm:	29-53	91-239	28-50	16-50

Table 1: Gaps between the same types of elements [12].

In Table 2, width and height the original timber elements are presented. As the length of the elements vary in a wide range up to the span size and also design of the dwelling, they were not added to the classifications. All the sizes were measured on site with the metric system, but it should be emphasized that old unit system was still being used at the time those buildings were constructed. Although the metric system was first approved in 1869 at the Ottoman Empire period, the old system was not totally left. Both types of measurement system can be encountered, under different laws from different years until the permanent reform at the year 1931. Cross-section sizes of the timber elements became smaller after the mid-19th century. As an example, it is reported that the king posts were minimum 30 x 30 cm and the posts of a seaside mansion in Boyacikoy were 40 x 40 cm [13]. Nevertheless, among the researched objects any structural element in such a big size was not seen.

Timber Elements	**Short Edge (cm)**	**Long Edge (cm)**
Posts	8-14	10-16
Braces	8-12	9-15
Bearers	7-13	11-15
Floor joists	3-6	12-22
Noggings and Studs	3-5	7-15
Bagdadi laths	0,5-1,5	1-4

Table 2: Sizes from the cross-sections of the timber elements according to the on-site measurements [14].

Width and height of the timber elements of the roof structure are given in Table 3. Although hip rafters are put in a separate classification, sizes of the jack rafters and king commons are given under the group of "common rafters", because their character and dimensions are very similar.

Timber Elements of the Roof Structure	**Short Edge (cm)**	**Long Edge (cm)**
Roof Studs	5-12	10-15
Hip rafters	5-6	15-22
Common rafters	3,5-6	10-14
Purlins	4-11	14-22
Ridge Boards	5-6	16-21

Table 3: Sizes from the cross-sections of the timber roof elements according to the on-site measurements [15].

Sizes of lumber with the types of the wood used in the second half of the 19th century are published in a text book named "Usul-I Kesf-I Mimari" [16]. They are given below in Table 4 to provide another comparison. However, it has to be kept

in mind that the names of the elements on the published data are different from current usages. The lumber was identified in detail closely related to the sizes and the original meaning was lost after the change in the measurement system. Direct translation of the data may cause confusion. Therefore, the data was regrouped and simplified. As an example, nearly 5-10 different sizes of lumber of the same usage were put under the same group. Moreover, although the metric system was already approved at that time, "zira" and "parmak" are the units of measurement on the published data. Zira is equal to 0,758 m and parmak is 3,1582 cm. They were converted to the metric system in Table 4 for better understanding and original units were also presented for exact accuracy.

When the results of the Table 2 are compared with the lecture notes (Table 4), the cross-section sizes of the lumbers appear in a wider range. As the onsite measurements reflect the end sizes of the timber pieces, having sizes smaller than the uncut lumber is an expected result.

Usage	**Type of Wood**	**Length**		**Width**		**Height**	
		Zira	meter	Parmak	cm	Parmak	cm
Corner post and buttress	Oak	5-12	**3,8-9,1**	3-12	**9,5-37,8**	6-12	**19-37,8**
Bearer (horizontal element)	Oak	6-12	**4,6-9,1**	3-5	**9,5-15,8**	1-4	**3,2-12,6**
Brace (diagonal element)	Pine	6-15	**4,6-11,4**	3-12	**9,5-37,8**	1-12	**3,2-37,8**
Floor joists and bearers	Hornbeam or oak	5-10	**3,8-7,6**	3-8	**9,5-25,3**	1-3	**3,2-9,5**
Bagdadi laths, Ceiling and the rooftile underlayment	Pitch pine or other kinds of pine	2-5	**1,5-3,8**	3-7	**9,5-22,1**	1/6-1/2	**0,5-1,8**

Table 4: Types and sizes of the lumbers used during the second half of the 19th century. The data is generalized and the size ranges correspond to the data from various pieces [17].

Role of the influences

The influence of the European styles was mainly realized at first view on the façade layout and ornaments. However, there is an indirect impact of the westernization on the structural system. It is quite obvious that after the 19th century, a special importance was devoted to the exterior decoration of the houses in accordance with the increased popularity of the western styles. The visual meaning of the structural system lost its significance especially in Istanbul, because they were enveloped and became non-visible to the users. Gradually, the system became lighter. On the other hand, the transformations always trigger another issue. The effects were bidirectional. As the structure became lighter, it enabled the creation of more open spaces. In this way, bigger houses with larger windows could be constructed. As the freedom on the design and façade surfaces increased with the lightweight structure, architectural environment became more suitable for applying new trends.

Furthermore, the timber frame structural system of houses in Istanbul has several similarities with the balloon frame and platform frame. Although they were applied in almost at the same period of time in USA and Ottoman Empire (or maybe earlier in Ottoman Empire), the distances between the geographical locations reduce the probability of an interaction. There may be some coincidences, as the timber is one of the oldest and basic construction materials of humanity. But, also a kind of interaction has to be thought. At this point, it needs independent detailed research for clarification.

Conclusion

Authentic timber elements of houses of Istanbul are gradually disappearing. Not only the urban metropolitan conditions and changed lifestyles, but also through deterioration through lack of maintenance and wrong interventions he loss of

their original form. Visual documentation of the houses is rather easy with various techniques, but the structural system is the least documented part. Within this paper, timber frame structure without infill and the Bagdadi method is explained in detail. Moreover, dimensions of the structural elements, distances between the same type of elements on the frame system and joint techniques are presented. Quantitative findings on site are compared with the published data. Role of the influences are discussed. Observations from hundreds of houses were used for the statements made in the article. To sum up, it is aimed to shed a light to the present status that may lead to further studies on timber structures.

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