Damage Assessment of 19\textsuperscript{th} Century
Traditional Timber Framed Structures in Istanbul

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1. Introduction

Istanbul, which has been the capital city of different empires throughout history, is located in the Northern Marmara Region of Turkey. (Map 1) (Ambrasseys & Finkel, pp. 201). The Northern Anatolian fault line is the most active area of the Mediterranean Earthquake Zone, stretches from Anatolia to the Sea of Marmara (Çamlıbel, N., pp.1) (Map 2)(Ercan, A., 2001, pp. 137) and from there to Greece and Italy (Celep, Z., Kumbasar, N., pp.22, 23, 24, 35).

Due to their location, structures in this area of Turkey have historically suffered numerous intense and destructive earthquakes. Proven to be safe due to their lightness and ductile nature, wooden buildings gained importance. On the other hand, highly inflammable timber material caused several fires that have wiped out thousands of houses, even whole districts. That is why masonry buildings were made obligatory by law in the form of building regulations (Ebniye Regulations)\footnote{Ebniye Regulations: Building Construction Regulations in Ottoman Empire Period} enacted in the early 19\textsuperscript{th} century by the Ottoman government. Later however, due to many casualties and great damage caused by repeated earthquakes, timber for building was once again allowed under the law (Cezar, M., pp. 327-380).

Timber is a material which loses its resistance unless precautions against water, humidity and insects are taken. When taken together with weaknesses that occur in the carrier systems and link points, the structural problems of timber structures and chimney loads and firewalls etc., structures become less resistant to exterior effects.

This paper focuses on the inspection of the mechanical deterioration of some of the last remaining timber houses in and around Istanbul. Photographs of the structural properties of houses investigated are included to show the details of their deterioration.
1.1 The Development of Timber-Framed Structures in Istanbul

The classical Turkish house was developed (Eldem, S. H., 1984, pp. 7, 19, 83) in the cities of Istanbul and Edirne (Ahunbay, Z., pp. 269, 271, 272). In Istanbul, the construction used is known as timber framed construction with a brick filling material. Between the 15th and the 18th centuries, buildings were constructed using this system, but after the 18th century there was a decrease in the quality of work and walls with brick filling began to be plastered over (Figure 1) (Güngör, H., pp. 59, 69). The filling of timber skeletons with masonry material continued in Istanbul until the end of 18th Century. The bağdadi plaster technique was adopted in Istanbul during the 18th century (Kuban, D., pp. 245) (Figure 2), (Günay, R., pp. 146).

Timber sheathed skeleton without infill became popular at the end of 18th and 19th century Istanbul and its vicinity (Eldem, S.H., 1984, pp.7). In this system the inside of the walls were plastered with bağdadi technique, outer of the timber skeleton were sheathed with timber boarding (figure 12), (Kuban, D., pp. 245).

1.2 Structural Properties of Timber-Framed Structures in Istanbul

In the construction of these houses, different types of trees had been used, depending on their characteristics (Talât, A., v.I, pp. 4, 5). Generally trees which could be found easily around the region were preferred for construction. To ensure the consistency of main carrier system, posts, sole plates, props and joists oak and yellow pine trees were generally used; ceiling and floor coverings were of yellow or red pine, and for parts, as sheathing and windows, yellow pine was used. For balustrades and carved ceilings, red pine, walnut and linden were the preferred materials.(Günay, R., pp. 33, 34).

**Bağdadi plaster**: The plaster which is applied on the lath with dimensions 1-2cmx2cm and 1-2cmx3cm.

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Figure 2 Masonry infill timber-framed system (Güngör, H.)

Figure 2 Bağdadi lath system (Günay, R.)
These structures are composed of (Figure 3) (İzgi, U., pp.21):

- Lateral load bearing elements: Sole plates, top plates, headers, lateral connection elements, joists;
- Vertical load bearing elements: Posts and secondary posts;
- Diagonals: Diagonal props and bracings.

The elements that compose traditional timber framed structures are joined together with various combinations, either linear or at an angle (Figure 4) (Talât, A., v.II, pp. 1).

Combinations of traditional timber framed structural elements have been carried out, directly or with supplementary elements, in these houses. Direct joints are generally mortise and tenon joints, using supplementary elements such as wrought iron nails (picture 1).
When surviving artifacts are investigated, it is obvious that the traditional timber skeleton house is generally composed of 2 or 3 storeys - a wooden frame structure settled on a masonry foundation as seen in figure 3, basement or first floor, from 1 to 1.5 meters above the ground see in figure 5 (Çobancaoğlu, T., pp. 323). The sole plates are half-overlapped at the corners and the posts are mounted on these sole plates leaving spaces of 1 or 2 meters. The posts are generally supported by the diagonal props in the corners or at the centre (Eldem, S. H., 1987, pp. 168). The secondary posts are placed between the main ones every 60 to 70 centimeters (Eldem, S. H., 1987, pp. 180). The posts, props and the secondary posts are tied together with the lintels (kuşak). The joists are placed on the soles as their sections become upright to the front of the structure (Eldem, S. H. 1987, pp. 170). The heights of structures was determined by building regulations (ebniye nizamnameleri) and the height of each storey was 3.50 to 3.70 meters.

![Figure 6](image1.png)

**Figure 6** Timber-Framed Structure Setting on Masonry Foundation (Çobancaoğlu, T.)

**Figure 6** Rubble Stone wall with wooden joists (Eldem, S. H.)

In order to stabilize the basement or first floor walls, wooden joists (hatıl) needed to be installed at 1-meter intervals along the height of the wall. These joists are placed on both sides of the wall and are connected to each other by the use of perpendicular joists (Eldem, S. H., 1987, pp. 174), see in Figure 6, (Eldem, S.H., pp.B2, 3).

If the buildings were semidetached there are masonry fire walls approximately 50~60 cm in width between them and two types of joists are placed on these walls:

1. Direct placement: In this type of construction the joists are inserted about 20~35 cm into the wall. The disadvantage of this connection is that the end parts of the joists can decay in time due to humidity. For this reason, joists may lose their carrying capacity (figure 7), (Talât A., pp. 35).

2. Placing on a wall project: The decay is not as likely as in the direct placement technique (figure 8), (Güngör, İ. H.).
Connection of joists with iron clamps into the wall makes floor more rigid so load bearing capacity is increased (figure 9) (Güngör, İ. H., pp.70).

Structural projections consist of prop, console with joist and overlapped console joists. After the 18th century the console joists were mounted on the sole plate which was placed on the curved brackets (furuş) (Figure 10), (Eldem, S. H., 1987, pp.170, 235, 284). In the 19th century curvalinear props, known as paraçol (timberknee) or eliböprdne (diagonal braces) were covered with laths or timber planks and produced in various forms (Çobancaoğlu, T., pp. 214) see in figure 11(Günay, R., pp.115).

The building’s internal skeleton system is generally enclosed by başdadi laths; see in Figure 12a (Güngör, İ. H., 1969); on the outside of the building boarding planks 2-2,5 cm in thickness were used, see in Figure 12b, (Günay, R., 2002). This boarding system wraps around the building and acts like a curtain wall.

The roof is purely structural. Construction of the roof is simply analyzed as a setting roof because it doesn’t cover an important inner aperture of the house (figure 13) (Eldem, S. H., V.3, pp. 170,172). The components of the roof consist of binding, a middle roof pole, bracings, purlins and rafters.
The joists of the roof floor are placed on the top plate of the timber skeleton system and the rafters are placed on the purlins which are placed on flooring joists (figure 13) (Günay, R., pp.115).

**Figure 10** Projection samples from Cerrahpaşa and Büyükdere (Eldem, S.H.)

**Figure 11** Projection sample from Suleymaniye (Günay, R.)
Figure 12 a) Outer wall with timber sheathing (Güngör, İ. H.)

Figure 12 b) Different types of boarding (Günay, R.)

Figure 14 The traditional connection of timber skeleton and timber roof (Eldem, S. H.)

Figure 14 Eave detail of a timber framed building (Günay, R.)
2. Reasons for the Deterioration of Timber Framed Constructions in Istanbul

Few timber framed structures from the 19th century remain today. There are many reasons for their diminishment in numbers. From a historical or social point of view, the effects of the Industrial Revolution on cities (Toffler, A., pp. XX) and life styles, as in many countries, showed themselves in 19th century Istanbul. With the migration of the people from villages to the city the population of the cities increased (Küntay, E., pp. 125, 126). The construction of reinforced concrete multi-storey apartment houses decreased the production of timber buildings. The owners of these timber buildings moved to new settlements and rented their houses to people who migrated from villages and with this new way of life, houses that were abandoned to their fate, became neglected and began to deteriorate due to atmospheric conditions (Ahunbay, Z. pp.125, 126).

The main reasons for deterioration of these houses were:

1. Natural reasons such as earthquake (Picture 2), water and humidity, atmospheric conditions: long term outer effects like ultraviolet light, frost and wind, weak timber sections, fungus and the invasion of insects (Picture 8).
2. Man-made reasons including abandonment, fire (Picture 3, 4a, 4b, 5), incorrect methods of construction, wrong choice of materials (Ahunbay, Z., pp. 42), fatigued materials (loss of resistance over time because of the continuous effect of weight) (Picture 18), defective workmanship, incorrect attempts at restoration (Picture 6, 7), economic insufficiency, traffic, air pollution, lack of laws to protect these structures, municipal indifference, and vandalism (Çobancaoğlu, Ç., pp. 272, 273).

2.1 Structural Deterioration of Timber Framed Structures in Istanbul

For the reasons mentioned in section 2, deterioration of timber structures starts from the components meant to protect the structure from exterior damage, i.e. masonry foundations, roofs and sheathings. The deterioration is concentrated on main carrier components and their link points, unstable chimneys and fire walls (Dışkaya, H., pp. 146, 177) (Picture 11, 12) and result in decreased carrying capacity of the timber sections, causing contortion, breaking and collapse of the system (Dowrick, D., pp. 402) (Picture 22, 25).

The main structural deterioration can be seen on:

a. The carrying system: masonry wall timber frame system connections (Picture 8); roofs and eaves (Picture17, Picture 18); projections (Picture 13, 14, 15, 16) and diagonal braces (Picture 9, 10); posts (Picture 33b, c) and beams (Picture 24).

b. Exterior deterioration: sheathings (Picture 20, 21, 22), windows (Picture 23, 24), tiles (Picture 19).

c. Interior deterioration and building components: doors, stairs (Picture 34, 35), bağdadi plaster (Picture 24, 25, 26, 27, 28), ceiling and floor decks (Picture 29, 30, 31, 32, 33a), (Çobancaoğlu, T., pp. 280-283).

3. Observations And Examples Showing the Mechanical Condition of Existing Buildings

Today only a handful of timber framed constructions bearing witness to past lives have been restored - many of them are still waiting for restoration. The photographs present observations and examples showing the mechanical condition of existing buildings which have been damaged over time.

Deteriorations in traditional timber framed structures of 19th century depend on the origin of the damage:
3. A. Deteriorations by Natural Origin:

3. A.1 Earthquakes

Picture 2 shows the effect of earthquake momentum on construction. Although analysis of this effect depends on inadequate structural connections, it can be seen clearly in the photograph of the Mürefte Earthquake in 1912 (Cogito, pp.58).

![Picture 2](image)

3. B Deteriorations Caused by Man

3. B.1 Fire

Although a few fires originate from lightning, most are caused by humans.

![Picture 3](image)
3. B. 2 Incorrect Attempts at Restoration

*Picture 5 a, b,* Some carrier system details after a fire from the same house, in Kuzguncuk (Photographs: Dişkaya, H.)

*Picture 5* A house in Süleymaniye after fire (Photograph: Dişkaya, H.)

*Picture 6* Incorrect sheathing restoration, a house in Topkapı (Photograph: Dişkaya, H.)

*Picture 7* A house in Zeyrek (Photograph: Dişkaya, H.)
3. C Carrier System Deterioration

3. C. 1 Masonry wall timber structure connections

The effects of water, humidity and exterior effects such as ultraviolet light cause the timber sheathing to decay and soak up water inside of the main carrier system, causing deterioration of the main carrier structure. See the picture 8 and 9.

This causes decay in sheathings and sole plates and eventually the bağdadi plaster, posts, joists and bracings, see picture 10.
3. C. 2 Firewall effect

Picture 12 Instability of firewall attached houses in Zeyrek (Photograph: Dişkaya, H.)

3. C. 3 Deterioration of projections

Picture 13 A house in Zeyrek (Photograph: Ersertel, Y.)
Picture 14 A house in Zeyrek (Photograph: Dişkaya, H.)
3. C. 4 Deterioration of eaves

Picture 16 A house in Üsküdar (Photograph: Dışkaya, H.)

Picture 17 Deterioration in eave, a house in Mimar Sinan (Photograph: Dışkaya, H.)

3. C. 5 Deterioration of the roof support system

Picture 18 Damage from humidity and bending deformation of purlin and rafters, a house in Fatih (Photograph: Dışkaya, H.)
3. D Outer Deteriorations

3. D. 1 Deteriorations in roof tiles

Picture 19 Deterioration in roof and tiles, a house in Fatih (Photograph: Dişkaya, H.)

3. D. 2 Deteriorations in sheathings

Picture 22 Deteriorations in roofs, eaves, sheathings, projections and windows, a house in Celaliye (Photograph: Dişkaya, N.)

Picture 22 A house in Zeyrek (Photograph: Dişkaya, H.)

Picture 22 A house in Zeyrek (Photograph: Dişkaya, H.)
3. D. 3 Deteriorations in windows

**Picture 23** Changing the structural system by changing the sizes of windows, a house in Zeyrek (Photograph: Dişkaya, H.)

**Picture 24** Damage from humidity and water from windows with broken glasses, a house in Zeyrek (Photograph: Erser, Y.)

3. F Interior Deterioration

3. F. 1 Deterioration in bağdadi laths and walls

**Picture 24** Inside deterioration of a house in Zeyrek (Photograph: Erser, Y.)

**Picture 25** Deterioration of walls in a house in Süleymaniye (Photograph: Dişkaya, H.)

**Picture 26** Deterioration of a wall of bağdadi laths, a house in Zeyrek (Photograph: Dişkaya, H.)

**Picture 27** Deteriorations in bağdadi laths and plaster, a house in Celâliye (Photograph: Dişkaya, H.)
3. F. 2 Deterioration of ceilings and floor decks

Picture 28 Deterioration of the wall and bağdadi plaster, a house in Zeyrek (Photograph: Dişkaya, H.)

Picture 29 Deterioration in ceiling and floor deck, a house in Celâliye (Photograph: Dişkaya, H)

Picture 30 Ceiling deformation caused by humidity, a house in Ortaköy (Photograph: Dişkaya, H)

Picture 31 Deterioration of ceiling, window and wall, a house in Süleymaniye (Photograph: Dişkaya, H)

Picture 32 Deterioration in ceiling and floor deck, a house in Zeyrek, (Photograph: Dişkaya, H.)

Picture 33 a, b, c, Humidity effects on a ceiling, propped up with beams and posts to halt its bending, but the lower part of the prop has decayed, a house in Topkapı (Photograph: Dişkaya, H.)
3. F. 4 Deterioration of stairs

Picture 34 Deterioration in stairs, a house in Celaliye, (Photograph: Dişkaya, H.)
Picture 35 Deterioration of a staircase, a house in Celaliye, (Photograph: Dişkaya, H.)

4. Conclusion

This report has dealt with conditions of timber framed structures in Istanbul, which, over time, have deteriorated for various reasons. Istanbul was once the capital city of the Ottoman Empire and is filled with a lot of beautiful timber skeleton houses bearing the memories of past life styles and examples of historical construction techniques. Most of these buildings are at risk of disappearing because of lack of care and restoration. They must be restored with much care and many precautions to prevent their collapsing under climatic and physical effects.

The main objective for producing this study is based on hope to preserve these houses for future generations. In this study, the general construction properties of these houses have been discussed and the reasons for their deterioration have been analyzed. Photographs to illustrate their present conditions have also been provided.

Bibliographical References:

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- Kuban, D., 1995, Turkish House with Hayat, İstanbul: Eren, pp. 245.


