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Üsküdar Electricity Factory - Nevmekan: Evaluation of The Structural System in The Context of Adaptive Reuse

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Abstract
Buildings in Türkiye that reflect the impact of European industrialization in the 18th century and later are now considered industrial heritage. These buildings, which are worthy of preservation, can be brought back to the city with the understanding of adaptive reuse. However, in this case, seismic loads, which pose a great risk for industrial heritage buildings, are among the important issues that need to be discussed. Therefore, the adaptive reuse of such buildings focuses on structural system design, repair, and strengthening. In evaluating the structural system, efforts are also made to establish the link between the old identities of the buildings and their present identities. In the study, the adaptive reuse process of the Üsküdar Electricity Factory (Nevmekan), an industrial heritage building located in Istanbul, is evaluated by focusing on the original architectural and structural system and the architectural and structural system design after the adaptive reuse. In the research, the survey and restoration drawings were obtained from the Üsküdar Municipality, and the original and adaptive reused structural system of the building was evaluated according to the criteria in the current earthquake code. While the Nevmekan building constitutes a positive example of social, cultural, economic, and sustainability issues with its reuse approach, the evaluation of seismic effects and their application to the building has been limited. In Türkiye, which is an earthquake zone, to preserve buildings of such high historical and industrial value and to transfer them safely to future generations, it is necessary to give importance to the improvement of the structural system in adaptive reuse projects.

Keywords: Adaptive Reuse, Industrial Heritage, Nevmekan, Structural System Intervention

1. INTRODUCTION

Industrial structures which once represented the philosophy of the Industrial Revolution and served their purpose are now out of date and frequently abandoned. Numerous factors, including population growth, altered economic and industrial practices, and elevated operating and maintenance expenditures, have an impact on this. This is mostly caused by the buildings' unsuitability for their intended purpose and the lack of an alternate usage (Orbaşlı, 2008).

According to their features, industrial structures that were constructed in Türkiye under the impact of the Industrial Revolution but lost their use over time can be recognized as industrial heritage. Buildings, such as warehouses, factories, and transportation infrastructure, constructed after the 18th century because of the Industrial Revolution, are referred to as 'industrial heritage

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buildings' because of their historical, technological, social, and aesthetic importance (TICCIH, 2003). With the urban transformations that have occurred over time, industrial structures that were originally intended for the peripheries of the city might now have a place in the urban center. On the other hand, these buildings, which represent the essence of the era, may provide the city with distinctive areas. By establishing new functions with the knowledge of adaptive reuse industrial structures that have lost their use, it is now feasible to contribute to the dynamism of the city.

Historical buildings, which are symbols of culture and heritage, function as focal points for individual and social life. It has been believed that historical buildings are important and should be protected since ancient times, but the current understanding of conservation has become a global issue in the 21st century (Orbaşlı, 2017). Therefore, historical heritage structures in Türkiye have also been affected by this conservation approach.

In terms of social, economic, cultural, environmental, and many other crucial factors, adaptive reuse is becoming more and more relevant nowadays. Sustainability, sustainable development, cultural heritage, historic preservation, and adaptive reuse have all been addressed comprehensively in several research projects in recent years (Li et al., 2021).

Adaptive reuse refers to the change, improvement or reuse applied to adapt a building to new conditions, or needs (Douglas, 2006). The adaptive reuse of historical buildings benefits the social and environmental well-being of societies while preserving the country's past (Shen and Langston, 2010). There are also environmental benefits to adaptive reuse, such as extending the life of a building and reducing pollution by using fewer resources, energy, and transportation (Bullen and Love, 2009). Recycling is a better choice than demolition or refurbishment because it consumes less energy and produces less waste. It can also benefit society by reviving well-known places (Conejos et al., 2011). The adaptive reuse of buildings avoids waste from demolition, extends their useful life, promotes the recycling of embodied energy, and provides significant social and economic benefits to society (Department of the Environment and Heritage, 2004). With increasing sensitivity, it is accepted that historical buildings have ecological importance as well as the local identity, cultural history, and socioeconomic characteristics (Cramer and Breitling, 2007).

Conservation applications require a comprehensive understanding of their structural and material properties. It is necessary to have information about the original and previous state of the building, the techniques used in its construction, the changes and their effects, the events that occurred, and finally the current situation. The intervention should be the result of an overall plan that focuses on the different dimensions of the architecture, structure, installations, and functionality (ICOMOS, 2003). According to Plevoets and Van Cleempoel (2019), adaptive reuse techniques should only slightly alter the building's original design while offering a contemporary solution that will increase its worth in the future. An ideal adaptive reuse strategy would strive to protect the current structure and its historic surroundings by incorporating more modern elements without taking away from the old structure's unique character (DEH, 2004). On the other side, there are variances from current structural rules since structural choices in older structures are conventional. So, when renovating a historic property under conservation legislation, one of the difficult challenges to handle is building structural regulations (Hein and Houck, 2008).

Due to challenges in applying building codes and conservation choices into practice, there is a limited amount of conservation and adaptive reuse of industrial heritage structures worldwide. However, more industrial historic buildings are being renovated through adaptive reuse thanks to new structural innovations and conservation strategies. From around the globe, notable reuse projects carried out in industrial heritage buildings include Tate Modern, Matadero Madrid, Officine Reggiane, Barth Hotel, and the University of Liechtenstein (Table 1).

Table 1. Restoration interventions of Tate Modern, Matadero Madrid, Officine Reggiane, Barth Hotel, and the University of Liechtenstein

Tate Modern	Matadero Madrid	Officine Reggiane	Barth Hotel	University of Liechtenstein
The foundation system was changed to raft foundation and a steel structural system was integrated into the building.	Under foundation piles were installed, the floor slab was replaced with reinforced concrete slab, and damages to masonry load-bearing walls was retrofitted.	32 wooden modules independent of the structural system were added as support. Roof trusses and cover were renewed.	The original structural system was preserved, while the roof was completely removed and replaced with a reinforced concrete slab floor.	The roof structure and the floors on the ground floor were renovated, the steel columns were removed during this restoration and replaced after corrosion maintenance, two floors were removed in a part of the west façade and the façade was supported with steel construction.

Until the 1970s, industrial buildings were not given importance in Türkiye, and there were even instances where they were removed to utilize the land they were located on, as they were considered to be insufficiently aesthetically pleasing. Over time, following pioneering projects and their discussions, the preservation and adaptive reuse of industrial buildings began to gain acceptance. Tophane-i Amire, Hasköy Shipyard and Lengerhane, Santral Istanbul, Beykoz Leather and Shoe Factory, and Feshane-i Amire are among the pioneering projects in the field of adaptive reuse. Today, the preservation of old industrial buildings is being discussed with increasing interest. Especially in the case of buildings with industrial heritage, reuse with an appropriate function is an attitude that is practiced and adopted now. On the other hand, adaptive reuse in industrial heritage buildings may involve structural interventions. In this case, a balanced approach should be taken between preserving the authenticity and ensuring structural safety requirements.

In this study, the Üsküdar Electricity Factory, which was adaptively reused as an industrial heritage building, with its new function and name Nevmekan, is discussed. Since the research gives priority to the documentation of industrial heritage buildings, identification studies were conducted for their original conditions and the interventions made on the structural system were analyzed (Köroğlu, 2019). The survey and restoration drawings were obtained from the Üsküdar Municipality (2018), and the original and adaptive reused structural system of the building was evaluated according to the criteria in the Regulation of Building Structural Systems for Appropriate Design Under Earthquake Effects and Special Rules for the Design of Masonry Building Structural Systems Under Earthquake Effects sections of the current earthquake regulation (TBEC, 2018). These evaluation criteria include building form, building height, masonry wall cross-sectional dimensions, masonry wall gaps, steel roof system, mezzanines, and basement. As a result, the building was evaluated in terms of the adequacy of the structural system and intervention methods in the context of adaptive reuse.

The aim of this study is to examine and critique the errors and deficiencies in the existing structural system within the framework of the correct (modern) structural system design principles in the event that the industrial heritage building is reused for the same purpose or for reuse outside the original purpose, and to evaluate and critique the changes made to the existing structural system in the context of reuse within the framework of the correct (modern) structural system design principles.

2. ÜSKÜDAR ELECTRICITY FACTORY BUILDING HISTORY AND DESCRIPTION

Founded in 1911 in Üsküdar Bağlarbaşı neighborhood, Üsküdar Electricity Factory is now serving as a book cafe under the name Nevmekan. Originally an electricity factory, the building used to provide electricity for the Üsküdar Tram Line and served as a tram maintenance hangar. Serving in this function until 1965, the building lost its original function in the following years and was converted into an İETT bus garage and then vacated in 1998 (Köksal, 2005) (Figure 1). Bağlarbaşı Cultural Center was built on the land near the building in 2005. The industrial heritage building was repurposed in 2015 and adapted as a book cafe (Figure 2).

Designed by Ali Talat Bey, one of the leading architects of the period, the building has the characteristics of the 1st National Architectural Movement (Köksal, 2005). The building consists of a two-story administrative section, a five-story tower section connected to these sections, and a workshop section. The workshop section, which is the main volume of the building, is where electricity is generated and used for the tram car workshop. At the time the building was constructed, there was no nationally used earthquake regulation. Therefore, the building was constructed according to the traditional structural design approach. The first Turkish Earthquake Regulation is dated 1940 and was prepared after the Erzincan earthquake in 1939 (Tunç, 2023). The original structural system of the building consists of masonry walls and steel roof trusses. In the authentic condition, plaster and finishing damages and deterioration of the metal elements due to rusting were observed. On the other hand, the reinforced concrete supports in the basement, which are thought to have been added later, were determined.

The ground conditions on which the building is located consist of very dense sand, gravel, or hard clay layers (IBB, 2020). This situation increases the possible earthquake impact for the building ground. On the other hand, when the fault lines are examined, it is noted that the region is located in an earthquake-prone area (IBB, 2020).

Figure 1. Üsküdar Electricity Factory old view (IETT archive, 1948)

Figure 2. Üsküdar Electricity Factory - Nevmekan current view (Torunbalcı archive, 2022)

3. EVALUATION OF THE AUTHENTIC STRUCTURAL SYSTEM FEATURES OF THE ÜSKÜDAR ELECTRICITY FACTORY

The plan geometry of the building consists of a rectangular main unit and a square tower unit connected to it. The approximate dimensions are 18 m on the narrow facade and 36 m on the wide facade. The workshop unit of the building has a basement floor and a mezzanine floor, while the office unit has 2 regular floors, and the tower unit has 5 floors (Figure 3).

The main structural masonry wall thickness is 70 cm, and the roof structure is in the form of a gable roof made of steel trusses. It was determined that the floor between the basement floor and the workshop floor has an arch flooring system, but it was supported with reinforced concrete slab flooring due to the damage caused by the load on it. In addition, reinforced concrete columns and beam supports were added at the basement floor level and steel beams and columns were used to support the slabs. In its original state, there is a mezzanine floor formed with steel profiles independent from the main structural system in the workshop area. This mezzanine floor structural system does not affect the main structural system. In the administration unit spaces, wooden flooring supported on masonry walls was used. In addition to the main structural masonry walls, there are also masonry walls as partition walls.

The triangular truss was used in the roof (Figure 4). Welding was used in the steel truss roof connections.

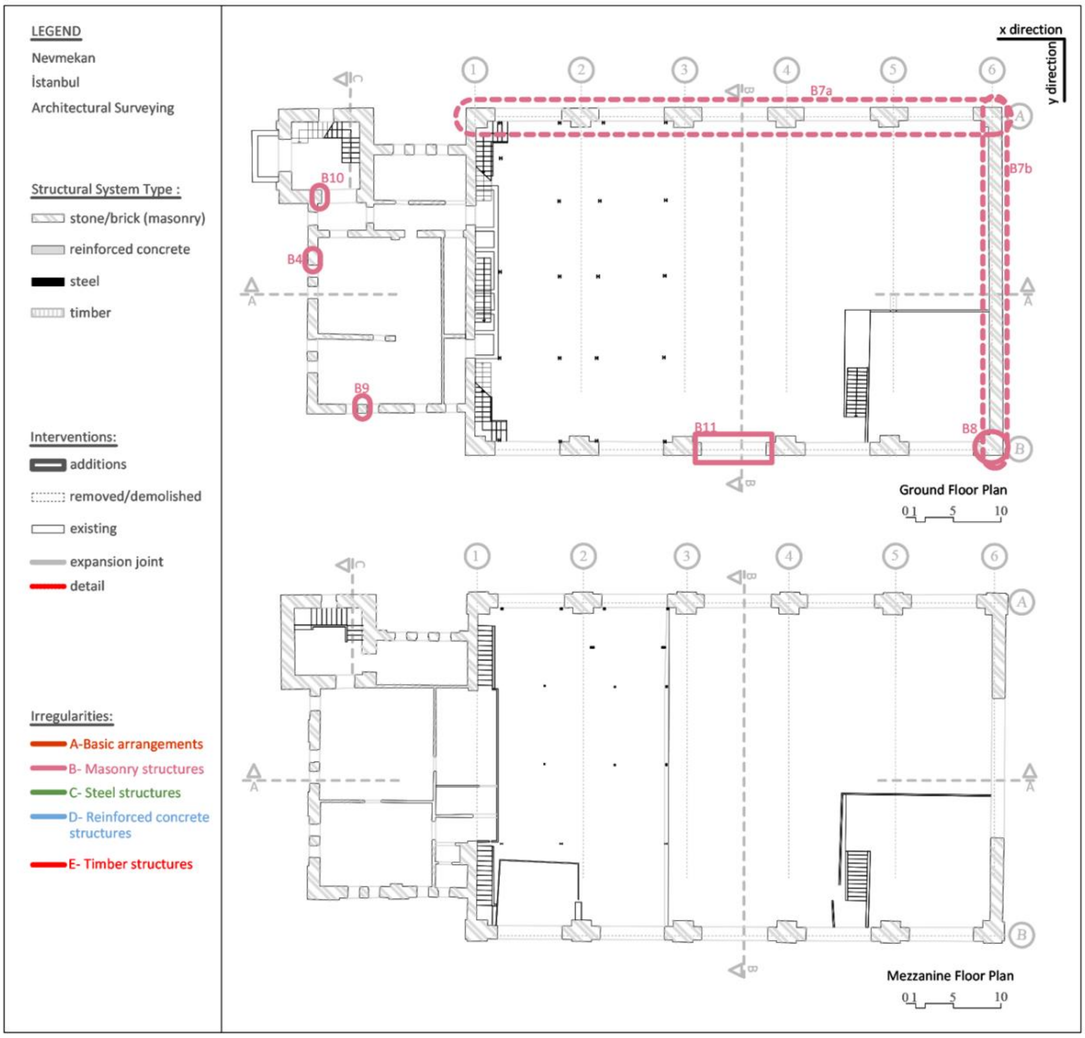

Figure 3. Üsküdar Electricity Factory architectural surveying floor plans (Adapted from Köroğlu, 2019)

The building geometry is relatively close to symmetrical. The main structural system is evaluated positively in terms of being regular, simple, and composed of a single material. The absence of protrusions in the plan, and the regular distribution of structural elements are positive features horizontally. Differences in the number of storeys, partial basement, and mezzanine in the main unit are among the negatives identified vertically. Although the tower and office unit are integrated with the main unit, the fact that it settles directly on the ground should not be ignored as it may adversely affect the behavior of the building under the influence of lateral loads. On the other hand, the continuity of the structural elements and the arrangements regarding the strengths between floors are important positive criteria for the structural system according to current earthquake code (TEBC, 2018).

No structural expansion joints were found in the building. In terms of today's structural design principles, the fact that the tower and office units are not built separately from the workshop unit may create additional stress in terms of torsional effects. The principle of structurally separated design to prevent such effects from creating harmful effects on the building is not a principle that is taken into consideration in buildings built in the distant past. Therefore, it is important to pay attention to this issue in adaptive reuse applications. In addition, the fact that the steel system members are partially in the form of sliding bearings enables the system to work as a kind of expansion joint, so the steel member connections can be considered within the scope of expansion joints with sliding bearings. Considering the small dimensions of the building and the fact that the main structural roof system is isostatic, the need for expansion joints in the building can be ignored.

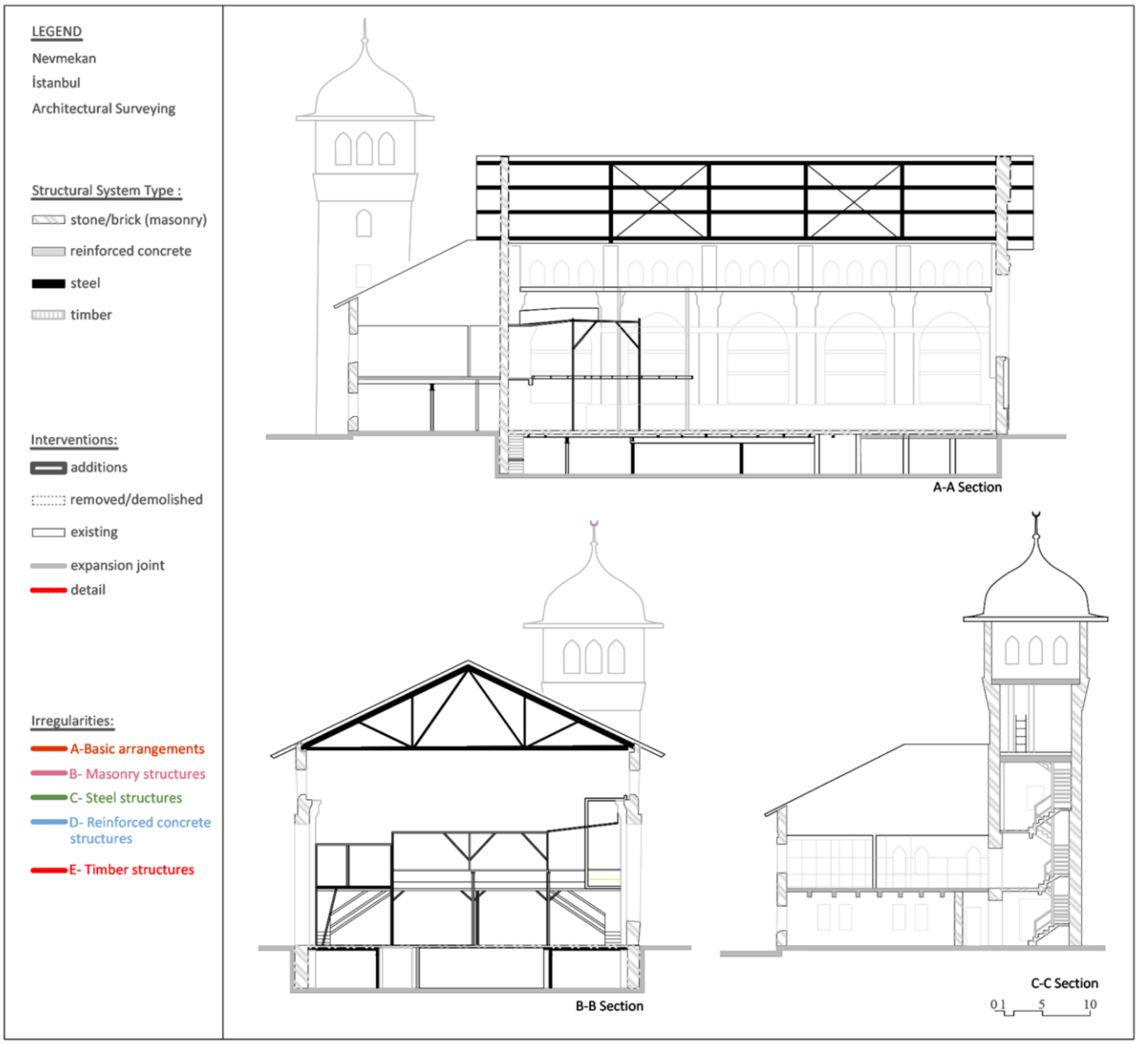

Figure 4. Architectural surveying sections of Üsküdar Electricity Factory (Adapted from Köroğlu, 2019)

The negativities observed regarding the masonry structural members are that the basement floor is organized as a partial basement only under the main unit, the masonry wall height/storey height, which is limited to 3 m in structural regulation (TEBC, 2018), is 3 times higher in this building (h:10,16 m), when evaluated in the context of the condition that the free wall lengths are supported in places in the direction perpendicular to the longitudinal direction of the wall, the unsupported wall length limit values are exceeded on long facades, that is, the masonry walls are not supported along the facade, and the values obtained by dividing the total lengths of the bearing walls, which are accepted as an important criterion against lateral loads, separately for both directions except for the gaps, in one direction by the gross floor area are 0.08 in the x direction and 0.09 in the y direction, and the limit value of 0.25.I (I: Building Importance Coefficient, which for this building can be taken as 1 for its current use (TEBC, 2018)). This value is of great importance in terms of the necessity to have walls of sufficient length in both directions for the stability of the vertical structural system of masonry buildings, and it can be said that it is at a very critical level in this building. In addition, the number of storeys allowed in masonry buildings in structural-earthquake regulation (TEBC, 2018) is exceeded in this building, especially for the tower unit, and the fact that the tower unit was built adjacent to the main building can be considered as another negative situation. On the other hand, the fact that the wall section thicknesses meet the limit values specified in the earthquake code (TEBC, 2018) even in the interior walls with the lowest thickness can be evaluated as positive feature.

The ratio of the sum of the lengths of the gaps in the masonry structural walls to the lengths of the walls without gaps is variable. Especially due to the large and high windows on the facades, the ratio of the sum of the lengths of the gaps to the length of the wall without gaps is above the limit value of 0.40. This creates a weakness, especially on long facades where the main structural walls of the building are located. On the other hand, the ratio of gaps opened for circulation purposes in interior walls is appropriate. In terms of another criterion, the length of the wall without gaps between the corner of the building and the gap, no negativity was observed. The condition of the smallest length of the wall without a gap between the walls that cut each other perpendicularly and the gap is also not met. Considering that the window openings in the main unit are far above the limit value of 3 m and the height of the gap is almost competing with the height of the building, it can be said that such huge gap long directional facade walls are incompatible with today's design principles and are incomparable. Therefore, the condition of retrofit the edges of gaps larger than 3 m with vertical beams in the earthquake regulation (TEBC, 2018) cannot be met for this building.

Corrosion initiation was detected in the steel elements because of the long-term disuse of the structure. Some of the arch floorings and frame elements were found to have corrosion damages at a level that would require the replacement of the elements. On the other hand, there are no precautions applied to the steel elements against fire during the period. In the original roof truss design, it was determined that there were no joints that could cause negative effects. It has been determined that the truss-girder axis spacing provides an optimal ratio of 1/3. The ratio between the truss height and truss span was determined by the truss design principles. This is an indication that the engineering service received in the past in the design of steel trusses is to today's structural principles. Another positive criterion is that there are wind and stability connections between the roof trusses and the angles between the bars are designed to remain 30 degrees and above.

The masonry system was applied as the main vertical structural system in the building, and steel elements, which were still developing considering the years when the building was designed, were also used for support purposes. Apart from these, reinforced concrete or steel columns and beams were added to the basement floor level to support the existing slab as a period addition after the building was built. Since the studies on earthquake-resistant structural system design were limited at the time the building was built, no measures were taken against lateral loads. As a result, it was determined that most of the criteria in this direction were not met in the evaluation made by the current structural principles for masonry buildings. The fact that the steel truss elements meet the current criteria in terms of design suggests that interventions may have been made for design purposes, although not structurally. It is understood that the other members added for support purposes were added to support the slabs against the heavy wagon and crane loads, not to improve the behavior of the structural system against lateral loads.

4. EVALUATION OF THE RESTORED STRUCTURAL SYSTEM FEATURES OF NEVMEKAN

When the restoration interventions were analyzed, it was determined that the original units of the structural system were preserved. The steel truss elements were repaired and preserved in their original form. The crane structure, which will refer to the original function of the building, is connected to the roof structural system and exhibited (Figure 5, 6). The original plan geometry and the number of storeys have also been preserved. Material damages, especially plaster damage on the masonry walls, have been repaired. The most significant change observed in the structural system is that both the design of the mezzanine floor and the materials of the structural system have completely changed. The floorings have been preserved by renewing only the damaged parts. The structural additions added to the arch floorings as period additions were also preserved through corrosion modifications.

Figure 5. Restored roof structure (Torunbalcı archive, 2019)

Figure 6. The original crane (Torunbalcı archive, 2019)

The reinforced concrete support elements of the basement floor, which is thought to have been added as a period annex, have been preserved (Figure 7).

It was observed that there was no connection between the steel structural system and the masonry walls, and such a connection was not applied during the current restoration. The steel frame connections, truss type, connection elements, and dimensions of the trusses have been retained to be the same as the original design (Figure 10, Figure 11).

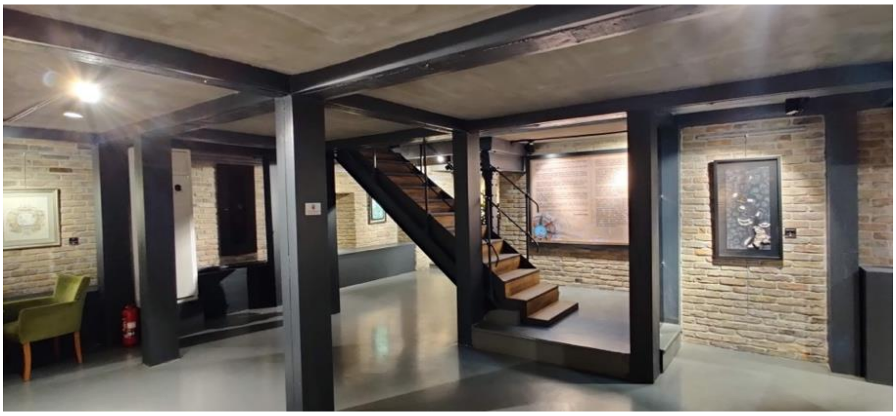

Figure 7. Status of the basement floor (Torunbalcı archive, 2019)

It is observed that the restoration interventions were carried out without a major impact on the original plan scheme of the building. The floors have been preserved to a great extent by their original state. The mezzanine floor was demolished and rebuilt. In the original state, the mezzanine floor structural members were made of steel elements, whereas in the new state, they were constructed with wood materials. The lower floor of the mezzanine floor, which was rebuilt wider than its original plan dimensions, was re-functionalized as a library. In the last case, the structural members of the mezzanine floor were arranged to be independent of the original structure (Figure 8, Figure 9, Figure 10).

Figure 8. Status of the mezzanine floor (Torunbalcı archive, 2022)

After the restoration, no arrangement could be identified to improve the horizontal loads on the masonry structural walls. The steel roof trusses were improved by the original by corrosion maintenance (Figure 11). On the other hand, the masonry and steel members were not changed in terms of material and design. Although architectural interventions for the new function were observed, structural concerns remained in the background.

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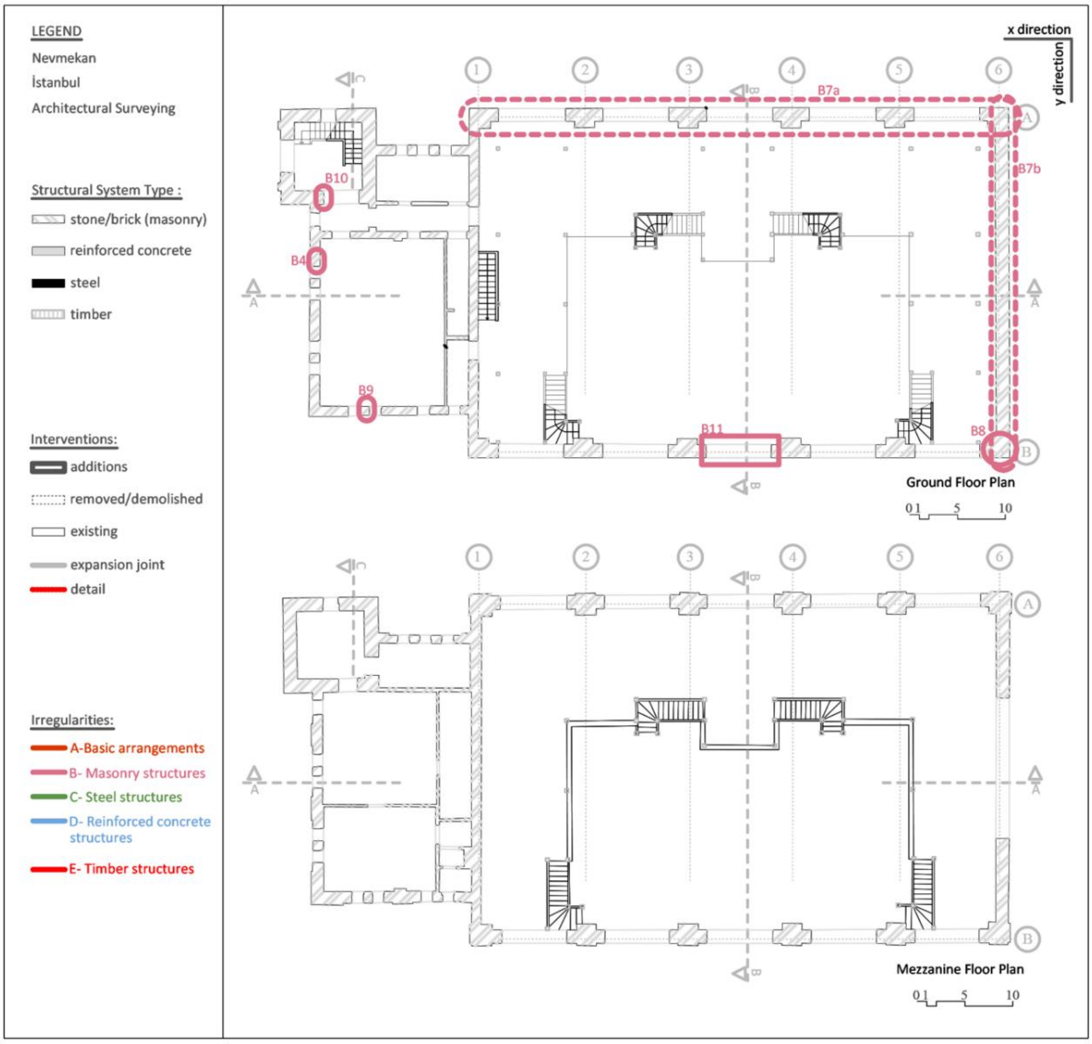

Figure 9. Nevmekan restoration project floor plans (Adapted from Köroğlu, 2019)

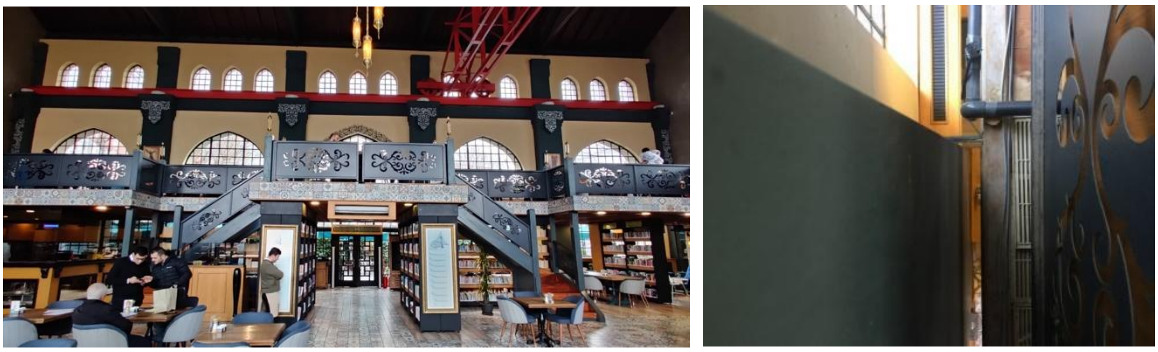

Figure 10. Mezzanine floor and masonry structural wall (Torunbalcı archive, 2019)

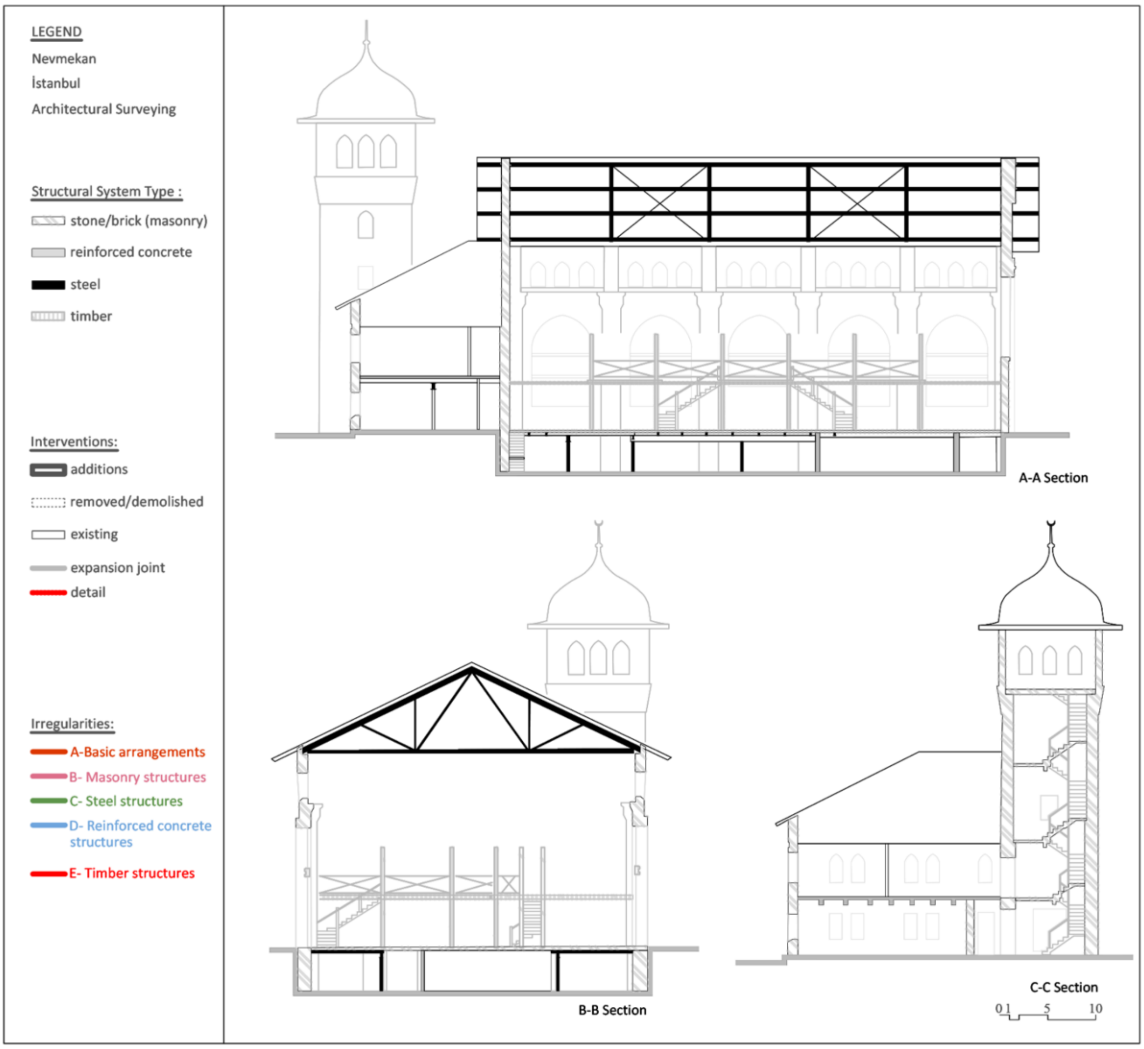

Figure 11. Nevmekan restoration project sections (Adapted from Köroğlu, 2019)

5. DISCUSSION AND CONCLUSION

During the adaptive reuse of the Üsküdar Electricity Factory and its change to Nevmekan, several restoration interventions were made to the structural and non-structural (architectural) system members (Table 2).

The original plan geometry of the building, which was close to symmetrical and regular, and the number of storeys were preserved.

After the restoration, no strengthening was found to reduce the horizontal loads on the masonry walls. On the other hand, plaster damages and other non-structural (architectural) damages on the masonry walls were repaired.

Steel roof trusses were maintained for corrosion. Steel frame connections, truss type, connecting elements and dimensions of the trusses were kept the same as the original design. It was observed that there was no connection between the steel roof structural system and the masonry walls, and no connection was designed during the restoration process. Therefore, the masonry and steel members were not changed in terms of material and design.

The most important change observed in the structural system is the complete change of both the design of the mezzanine and the materials of the structural system of the mezzanine. The mezzanine floor, which currently has a steel structural system, was re-designed, and constructed in timber and separately from the main structural system during the restoration works. The floor slabs were preserved only by renovating the damaged parts. Steel structural inserts added to the arch slabs as period additions were also preserved by making corrosion modifications.

The reinforced concrete support elements of the basement floor, which is thought to have been added as a period addition, have been preserved.

Table 2. Restoration interventions of Nevmekan

plan geometry & storeys	masonry walls	steel roof	masonry walls & steel roof connection	floor slab & mezzanine floor	basement
The original plan geometry and the number of storeys of the building were preserved.	Plaster damages and other non-structural (architectural) damages on the masonry walls were repaired.	Generally, the design and materials have been preserved, only the corroded ones have been repaired.	Any connection between the steel roof structural system and the masonry walls is not designed, as it was.	Floor slabs have been preserved, with only the damaged parts were renewed, mezzanine floor was re-designed and constructed in timber and separately from the main structural system.	The reinforced concrete support elements of the basement floor were preserved.

It is observed that the restoration approach is based on preserving the architectural values of the building with minimum intervention. Repairs to the masonry wall plaster and finishings, improvements to the corrosion damage on the steel roof elements, and reconstruction of the mezzanine floor with lighter structural members explain this situation. It should not be neglected here that while working towards the preservation of architectural values, it is sometimes possible to make a comprehensive intervention to the original structural system and even change the materials. If such radical decisions can be taken, some decisions can also be taken in the context of building safety. In this building, it is seen that the works conducted for the safety of the structural system remained only in the form of repair. Although it is not expected that the restoration interventions applied in such registered buildings of historical value will meet the current earthquake regulation (TEBC, 2018), it should be expected that at least the structural system arrangements that will show better behavior under the earthquake effect of masonry structures should made in a way that will minimally affect the original architecture or better yet not affect it at all. However, in the adaptive reuse and restoration of this building, it has been observed that the restoration approach has been based on architectural protection with minimal intervention, and interventions in the context of experiential contribution to the safety of the building and safer delivery to future generations have been missed. Cermodern and Feshane-i Amire buildings, which are Industrial Heritage buildings and have recently been adaptive reuse, have been restored with a similar approach (Torunbalcı et al., 2022; Günay et al., 2023). As can be seen from the studies evaluating the interventions to the structural systems in the adaptive reuse of these buildings, it is seen that this approach is generally dominant and like this example.

The Nevmekan building has provided a positive example in terms of social, cultural, economic, and sustainability issues with its adaptive reuse approach. On the other hand, the evaluation of seismic effects and their application to the building was limited. During the restoration, no additional structural work was carried out to improve the behavior of the structural system of the building under the influence of horizontal loads and to increase the safety level of the building. In Türkiye, which is an earthquake zone, the preservation of buildings with such high historical and industrial value and their safe transfer to future generations will only be possible with the importance and inclusion of structural system studies in adaptive reuse projects.

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