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Feshane-i Amire Evaluation of Structural System for Adaptive Reuse

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Abstract

There are various industrial heritage buildings as reflections of the progress of industrialization in Türkiye. Especially, Istanbul has many examples of industrial heritage as it played a significant role at the beginning of Türkiye's industrialization. These buildings worth preserving can be brought back to the city through adaptive reuse. Thus, in seismic zones such as Türkiye, in addition preserving architectural values in the adaptive reuse of industrial heritage buildings, the structural system design also gains importance due to earthquakes or other structural system damages. The study analyzes the structural members of Feshane-i Amire in Istanbul before and after their adaptive reuse through architectural restoration. The study's main aim is to raise awareness of industrial heritage conservation, particularly among designers and professionals, and to emphasize discussing the structural system in adaptive reuse.

1. INTRODUCTION

Industrial structures that once reflected and functioned in the spirit of the industrial revolution could not meet the needs over time, and then they could be out of use. These structures can occur outdated because of a wide range of circumstances. Usually, industrial buildings are no more appropriate for their original use and no alternative application has been found [1]. Although industrial buildings that have become dysfunctional generally cannot be used for their original purpose due to their historical value, it is an important discussion topic to evaluate these buildings. Due to their architectural, historical, technological, and social values, structures such as factories, warehouses, energy factories, and transportation buildings built after the 18th century, which are associated with the industrial revolution and lost their function, are called 'industrial heritage' [2]. As cultural and heritage emblems, heritage structures serve as a focal point for individual and community life [3]. Any construction or intervention to modify its capability, function, and performance for arranging, reusing, or developing a building to fit novel circumstances or requirements are called adaptive reuse [4]. From the nineteenth century, conservation practices began to evolve [5]. Adaptive reuse became a topic of discussion in architecture throughout the 1960s and 1970s as environmental concerns grew [3]. Today, adaptive reuse is gaining importance in terms of social, economic, cultural, sustainability, and many other important aspects. In many research studies in recent years, sustainability, sustainable development, cultural heritage, historic preservation, and adaptive reuse have been addressed as a comprehensive approach [6, 7]. Giving heritage buildings a new way of life provides environmental and social advantages to communities while preserving national history [8].

Adaptive reuse extends the life of a building, reducing material, transportation, energy use, and pollution while contributing to sustainability [9]. In addition, the adaptive reuse approach is a type of sustainable urban transformation that extends the lifespan of the building while avoiding demolition waste, supports

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the reuse of embodied energy, and gives considerable social and economic utilities to society. As a result, it encompasses the various aspects of sustainability. Adaptive reuse avoids the wasteful demolition and reconstruction process. When combined with the energy savings, reduced carbon emissions, and social and economic benefits of recycling historically significant structures, makes reuse is a critical component of sustainable development [10].

Adaptive reuse practices of old buildings should have minimum impact on the original form [11] and offer a modern approach that adds value to the future. Instead of damaging the historic building's character, a good adaptation preserves the existing structure and its historic environment by adding a contemporary layer. The most effective adaptive reuse projects have modern annexes that add future value while respecting and preserving a building's historical relevance [10]. As people become more environmentally conscious, in addition to contributing to social status, cultural history, and local identity, historical buildings are increasingly thought to have ecological value [12]. Adaptive reuse is a better selection than demolition and replacement since it uses less energy and produces less trash. It can also serve a social aim by revitalizing recognized places [13].

Adaptive reuse is a complicated procedure that requires participants to have a thorough grasp of how to decide the building's most suited future in a location and period [14]. The material in many older structures has deteriorated and rusted, necessitating its removal and replacement [15]. Structural stability is another difficult part of any adaptive reuse project. Extensive surveys of the entire structure should be done in the planning to determine extra building loads and appropriate supports. The most probable section of the construction to be altered is the foundation system. It is not impossible to change the foundation circumstances or even reuse historical foundation conditions, although it is difficult and costly [16]. On the other hand, in adaptive reuse, structural design can also be achieved by retrofit structural members other than the foundation or adding additional elements. Considering all these challenges, there are also negative aspects of adaptive reuse. These are that the materials and techniques of the heritage building are not possible today, it is not possible to apply current building codes, and the applications are expensive [17]. Therefore, such issues should be optimized when deciding on the adaptive reuse of heritage buildings.

Conservation and adaptive reuse of industrial heritage buildings in the world and Türkiye are limited due to the difficulties of implementing building codes and conservation decisions. However, the number of industrial heritage buildings that are adapted reuse to new functions with developing techniques and understandings is increasing. Tate Modern, Matadero Madrid, Officine Reggiane, Barth Hotel, and Liechtenstein University from the world, Santralistanbul, Museum Gasworks, Kadir Has University's Cibali Campus, and Cermodern [18] from Türkiye are important adaptive reuse projects in industrial heritage buildings.

Considering the structural interventions in adaptive reuse, the structural interventions made in the first restoration works of the Feshane-i Amire building between 1992-1998 are summarized in Table 1.

Table 1. *1992-1998 restoration interventions*

Masonry Wall	**Steel Column**	**Steel Roof**	**Roof Finishing**	**Foundation**
the masonry walls were repaired against settlement cracks and cladded	*generally preserved, only the corroded ones were repaired*	*the steel roof structure was authentically retrofitted*	*completely changed*	*structural improvements were made*

In addition, understanding the structural and material characteristics is essential for conservation practices [19]. Designers formerly had a few selections of materials, such as stone, brick, metal, and glass, and used them safely in their designs based on the material's long history and proven performance rather than the behavior of the material [20]. Therefore, structural decisions in older buildings are traditional, hence the differences with today's structural codes. Building codes, together with conservation legislation, are one of the most challenging issues to deal with while a historic building is being restored [21]. Due to changing building codes, structural issues need to be reconsidered in the adaptive reuse applications of heritage buildings.

In the context of the current building code in Türkiye [22] and the contemporary intervention approach, the structural interventions made in the current restoration works of the Feshane-i Amire building are summarized in Table 2.

Table 2. *Current restoration interventions*

Masonry Wall	Steel Column	Steel Roof	Roof Finishing	Foundation
cladding of exterior masonry walls removed and repaired where there was material damage and loss; the openings in the interior walls have been preserved	*generally preserved, only the corroded ones were repaired, and protective material applied*	*the steel roof structure was authentically reconstructed*	*completely changed, and authentically reconstructed*	*diaphragm wall was added to retrofit the ground and prevent water*

In Türkiye, it has been observed that industrial structures were not given importance until the 1970s, and there are even examples where they were removed to benefit from the lands they were located on, considering that they were not aesthetic enough. Over time, after a few pioneering projects and their discussion, the conservation of such structures began to be accepted. Today, the issue of the conservation of old industrial structures is being debated with increasing interest. Especially when it comes to buildings with industrial heritage, adaptive reuse with an appropriate function is a practiced and adopted attitude today. Adaptive reuse in industrial heritage buildings-may involve structural interventions. In this case, a balance should be established between conserving originality and providing structural comfort and safety conditions. The Feshane-i Amire industrial heritage, which will be adaptive reuse within the scope of the study, is discussed. Since the documentation of industrial buildings was considered important in the research, determination studies were conducted for the original conditions, and the interventions on the structural systems were also analyzed [23]. The structure has been evaluated in terms of structural system adequacy and intervention approaches within the scope of conservation.

2. FESHANE-I AMIRE BUILDING HISTORY AND DESCRIPTION

The Feshane-i Amire Building was established in 1833 to meet the fez and aba needs of the Ottoman army near the Golden Horn, Istanbul [24]. The remaining part was built in 1887 during the expansion of the factory. The factory was closed by Sümerbank in 1986 and the building was transferred to the Istanbul Metropolitan Municipality. The factory was evacuated within the scope of the project to organize the Golden Horn and its surroundings (Figure 1). During this period, while other industrial establishments around the Golden Horn were abolished, most of the Feshane-i Amire building part was also removed. Only the weaving workshop building of the factory has been preserved [24]. The remaining building was converted into a contemporary art museum in 1992. With the first restoration in 1992-1998, Feshane-i Amire was designed by Mehmet Ekiz to host functions such as a handicraft bazaar, exhibition, fair, and concert [25]. A new (second) restoration has been ongoing since 2018 for the currently closed building.

Figure 1. *Feshane-i Amire in 1985 [24]*

The architectural features of Feshane-i Amire, such as its large spaces with high ceilings, large windows, roof openings, and skylights, are suitable for its adaptive reuse as an exhibition hall. In this way, all the architectural features needed for an exhibition hall will be provided by an industrial building. This can be explained by the architectural/spatial sustainability of industrial heritage buildings.

3. THE AUTHENTIC AND INITIAL RESTORED STRUCTURAL SYSTEM FEATURES

The original structure was made of a building group (Figure 2). Feshane-i Amire is one of these buildings. The authentic structural system of the Feshane-i Amire consists of masonry and steel units. The section of the masonry walls, which are made of rubble stone and machine-made bricks forming the facade walls, is 125 cm thick. The walls have brick beams every 40 cm horizontally. The inner columns are made of cast iron and have a circular section with a diameter of 26 cm. The columns are connected using I beams and trusses, with hinge joints.

The roof is a sawtooth roof type arranging receives light from the top. On the roof, a triangular truss system is used with bolts and welding. The height of the trusses is 2 m, the span of the trusses is 5 m, and the spacing of the axis is 5,15 m. Building foundations consist of sub-wall foundations and pad foundations under columns. The plan geometry is close to rectangular, narrow facades are 63 meters and long facades are 132 meters. There is no basement or penthouse in the building, which consists of a single floor. There is no cantilever floor in the building.

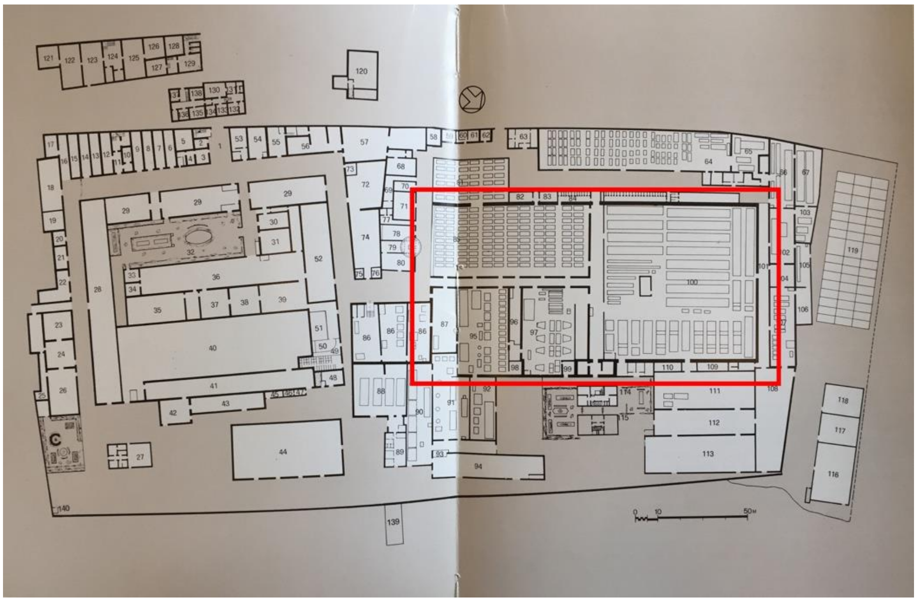

Figure 2. *Key plan of Feshane-i Amire Building [24]*

Circular cast-iron columns and roof trusses are the most significant structural members of the building and were brought from Belgium (Figure 3) [26].

Figure 3. *Feshane-i Amire before the first restoration [27]*

The dimensions of the masonry structural system are sufficient in terms of thickness, but out of limits in terms of height. During the first restoration, the increase in plan symmetry, retrofit, and repair against settlement cracks in the masonry walls, strengthening of the steel structural system members, and ground improvement works positively affected the behavior of the structural system (Figure 4).

Figure 4. *Photos from Feshane-i Amire after the first restoration [28]*

In the initial restoration, the columns were considered sufficient in terms of structural capacity. Therefore, the columns were preserved and protected without any interventions. Only the columns with corrosion damage were repaired. The roof structure was authentically preserved and retrofitted, and the roof finishing was completely reconstructed [29].

4. EVALUATION OF THE AUTHENTIC STRUCTURAL SYSTEM

The building, which has a geometric plan scheme that is very close to a rectangle, was evaluated positively in terms of the simplicity and symmetry of the structural system. The ratios of the projections in the plan are 8,5% in the x direction, and 10% in the y direction, remaining below the limit value of 20% recommended in the earthquake regulations. When the structural element distribution is examined, it has been determined that the distributions in two directions, the x and y directions, are balanced and homogeneous. The axles of the structural system are also parallel and perpendicular to each other in both directions. No arrangement has been determined in the design of the structural system as an expansion joint. However, steel structural system connections can also be considered a kind of expansion joint (Figure 5).

The negativities detected related to masonry elements can be summarized as follows; masonry wall heights are 5,65 meters, and this value is over 3 meters, which is the highest value determined by the earthquake regulation [22]. The maximum unsupported length of masonry walls is above the required maximum value of 5,5 meters. The values obtained by dividing the total length of the masonry walls in one direction excluding the voids by the gross floor area were found to be 0,045 for the x-direction and 0,034 for the y-direction. This value, which is accepted as an important criterion against lateral loads, is below the lower limit of 0,25. However, because the main structural system of the building is steel and the masonry walls are partially in the form of secondary structural members, the effect of not meeting this condition on the building's safety is partially negligible.

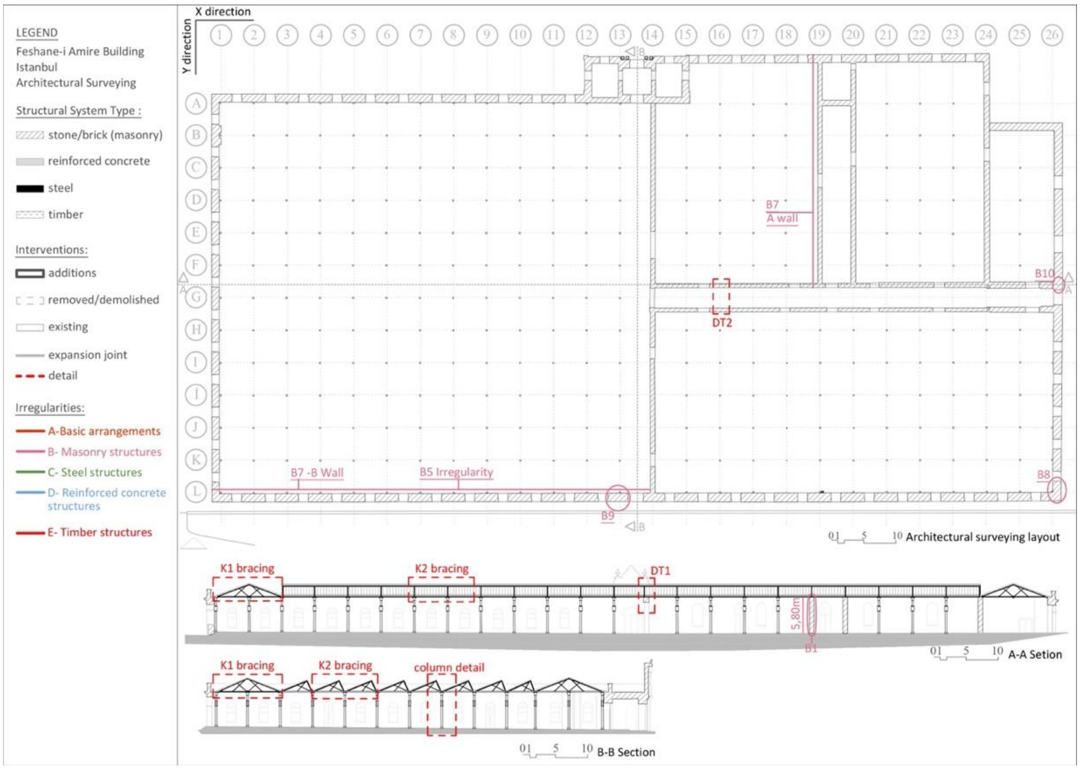

Figure 5. *The architectural surveying drawings [23]*

Although the building has a single storey, it can pose a problem in terms of the wall height allowed by the earthquake regulation [22] in masonry buildings. On the other hand, the fact that the structure has a mixed structural system in the form of steel and masonry reduces the effect of this negativity on the walls. Brick bonds on the walls are evaluated positively in terms of support. Another positive feature is that the wall thicknesses are well above the limit values. The thickness of the wall sections does not fall below 50 cm, which is the minimum value determined by the earthquake regulation [22], even on interior walls where it is the lowest, which is a positive aspect in terms of wall slenderness.

Despite the ratio of the lengths of the spaces in the masonry walls to the lengths of the filled walls being variable, it is positive in terms of masonry construction principles. Some of these values, as the most unfavorable ratio, slightly exceeds the limit value of 0,42. The minimum length of the wall between the vertically intersecting walls and the gaps is determined as 20 cm. It is recommended to be around 50 cm in the earthquake regulation [22]. The lengths of the door and window spaces in the plan level, where they are the largest, do not exceed 3 meters, which is the maximum limit value determined in the earthquake regulation [22]. On both sides of the gaps, there are no vertical bonds for retrofit.

In the steel frame structural system, there are no braces or masonry walls to meet the horizontal loads. However, in the original steel roof construction, the trusses were connected to steel diagonal bracing members for the horizontal loads. Steel structural system member sections are at a sufficient level if there are no problems with the material. Because it was detected the beginning of corrosion in some steel components. There is no protection against fire in steel members. On the other hand, although the building remained empty for a long time, no big problems such as loss or damage were detected in the steel structural system. In addition, it was determined that welding and bolt joints, which may show negative behavior, were not used together in steel members.

Figure 6. *Status before the current (second) architectural restoration [30]*

When the original system is examined in terms of truss properties, the ratio of axis spacing to truss openings is almost 1, well above the optimum value expected to be between 1/3 and 1/4. The ratio between the height of the truss and the span of the truss is 1/3, which is still much higher than the value of 1/8 determined in the principles. Although these rates are not considered economical in terms of material consumption and therefore labor, they show that the truss design is quite safe. The horizontal wind and stability rods on the roof are positive for safety. The fact that the angles between the rods are generally designed to remain at 30 degrees and above has been identified as a positive feature.

There is no partial basement, and all foundations are at the same level. This feature is considered positive in terms of the behavior of the structural system.

Considering the period when the building was designed, it can be said that it was not designed within the framework of certain regulations, but within the framework of knowledge passed down from generation to generation such as mastery. Due to the knowledge of the period, the principles of design according to lateral loads were naturally not taken into consideration in the design of the structural system. The structural design was generally made by considering the vertical load-bearing system. In this respect, it can be said that the requirements were adequately met. On the other hand, since the steel structural system of the building was a newly developed structural system style and material at that time, it is thought that it was designed using technology and various calculation methods within the framework of certain scientific knowledge, rather than traditional methods. An example of this is that the columns were pre-produced in the factory and then assembled on-site.

5. THE NEW AND RESTORED STRUCTURAL SYSTEM FEATURES

The original masonry and steel components of the structural system have been protected. In this context, the materials and sections of the facade walls have been preserved following their original form, and the parts that were damaged in the masonry wall and the joint material that has been emptied were repaired with the original material (Figure 7). The cast-iron columns, I-beams, and trusses have been maintained and preserved in their original form. It was determined that a diaphragm wall was added to retrofit the ground and prevent water from coming from the sea / Golden Horn side. While the number of floors has not been changed, only a mezzanine floor with an independent structural system will be added to the office unit.

Figure 7. *Currently exterior masonry wall*

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 reconstructed to be the same as the original design (Figure 9, Figure 11).

Figure 8. *Currently steel structural system members*

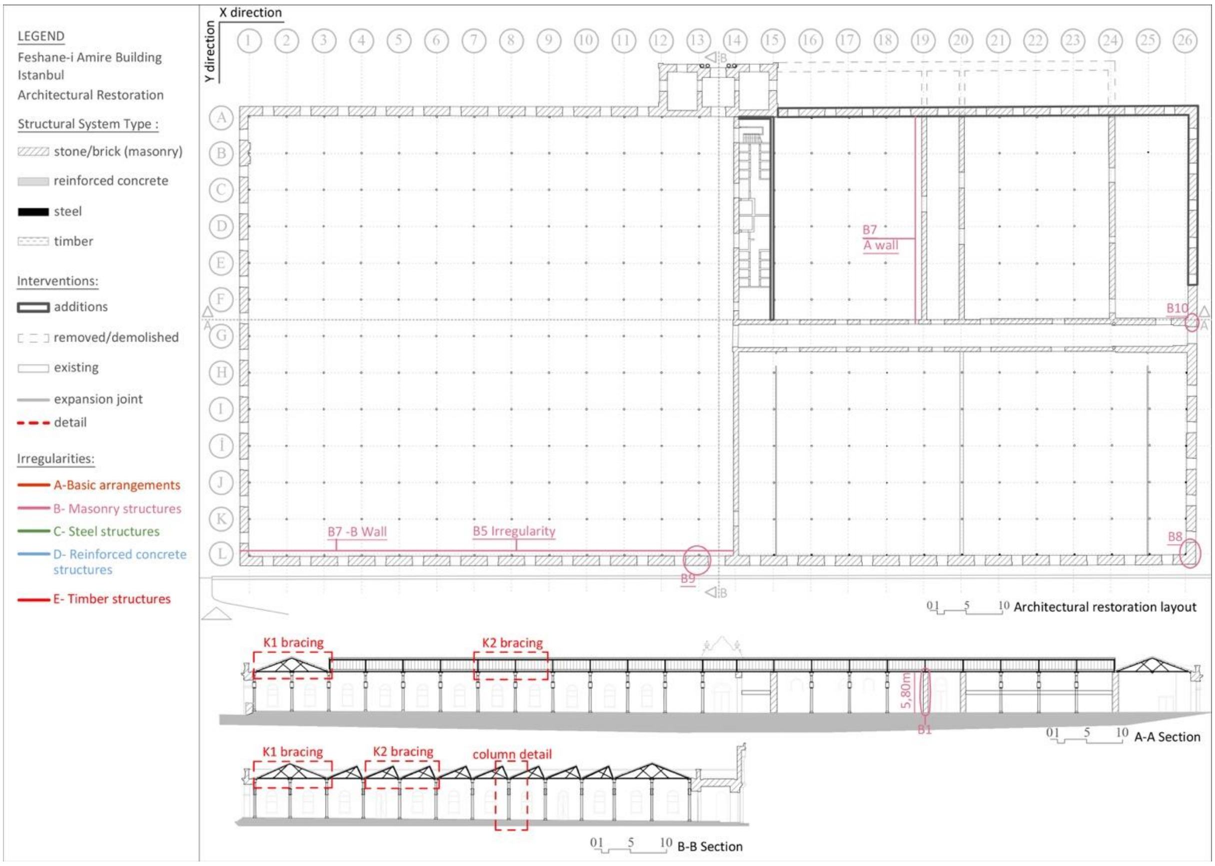

Figure 9. *Current architectural restoration drawings [23]*

Figure 10. *Currently roof trusses and braces*

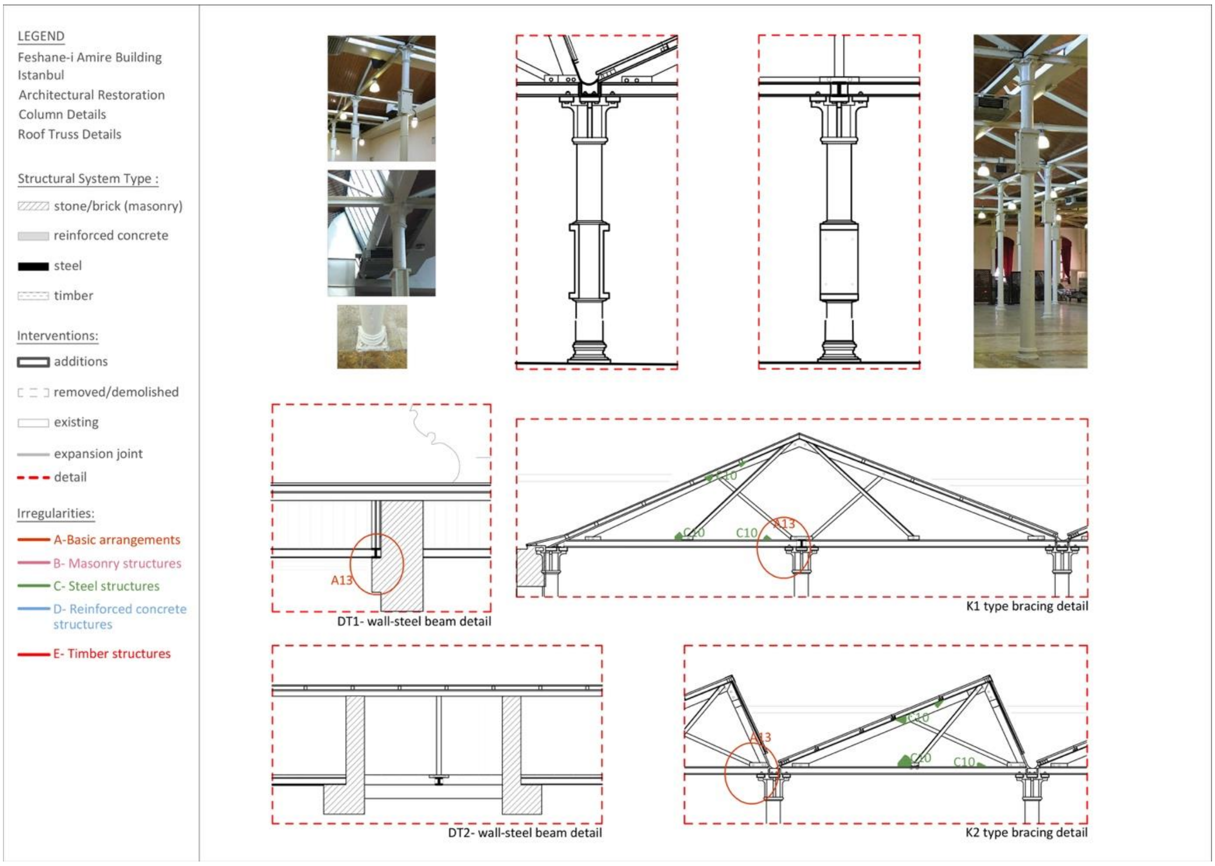

Figure 11. *Steel column and roof truss details [23]*

The Belgian precast steel columns have been used as the most suitable solution for the drainage of water to be collected on the sawtooth roof since its construction (Figure 12). The water taken from the columns with circular pipe cross-sections was conveyed to the Golden Horn through channels at the foundation level. During the current restoration, this channel system will be preserved and covered with a proper cover system.

Figure 12. *Detail of the column drainage system before it was covered*

6. EVALUATION OF THE NEW AND RESTORED STRUCTURAL SYSTEM AND CONCLUSION

While the other units of the factory, which was organized as a building group according to its original function, were demolished, the symmetry of the building was increased by completing the demolished walls with original materials and techniques. In the final state, the plan geometry of the building was completed in rectangular form and there is no projection in the plan. The distribution of the vertical structural system members in the plan is regular and by the original design. During the current restoration, no additional arrangement was made for an expansion joint, and for the reasons explained in detail above, there is no need for this due to the characteristics of the system.

Concerning the masonry structural members, no intervention was found to cause a positive change in the maximum unsupported lengths of the masonry walls. In the values obtained by dividing the total lengths of the masonry walls in one direction excluding openings by the total floor area, the relocated walls did not cause a significant change. The retrofit and repair of the masonry walls were conducted with the original materials and design, without any change in the cross-sectional dimensions.

As the mezzanine floor, which will be added to a part of the building, will be supported by a structural system independent, it does not have any negative impact on the behavior of the main structural system.

During the current restoration, positive interventions such as concentric or eccentric steel braces or adding a masonry wall inside the frame were not applied to meet the horizontal loads in the steel members. Except for the fact that the roof trusses of the building are connected with steel braces at the top of the column, no other arrangement has been made that will contribute positively to the lateral strength. And the existing structural system has been preferred to be used only by repairing it.

Maintenance against corrosion in the steel structural system members was conducted in the form of sandblasting-2 layers of zinga-plaster-paint. It is planned to provide fire prevention in steel members with a sprinkler system to be added to the entire structure, and it is preferred not to apply a chemical application to the steel member surfaces in a way that will increase the fire resistance. On the other hand, it has been determined that the continuity of the frame in the original structure was ensured properly during the current restoration, and the truss's features were preserved in a way that was exactly the original design. Since the sandwich panels in the roof system used as finishing in the first restoration are not suitable for the authentic roof, it is planned to replace them with a titanium clamp system roof finishing.

A positive structural system intervention was achieved in the Feshane-i Amire building, which will be adaptive reuse for the exhibition hall after the current restoration. It can be stated that it will be an example in terms of structural design for future projects with works such as the changing roof, the protection of structures, control of masonry sections, and filling of missing masonry according to the original. In addition, during the current restoration works, tests were carried out for the appropriate mortar and the authentic mortar was applied. In contrast, considering the earthquake loads, the high masonry walls were not supported with steel lateral supports or other retrofit methods.

The building analyzed in terms of structural interventions also has positive characteristics mentioned in the literature for adaptive reuse. The Feshane-i Amire building, which will be adaptive reuse for art projects, will become a social and cultural focal point in the city. On the other hand, using the existing building instead of building a new one will contribute to sustainability in terms of decreasing materials, transportation, energy use, and pollution. In this way, sustainability in spatial, structural, cultural, social, and environmental issues has been considered in the adaptive reuse of the Feshane-i Amire building.

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