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Adaptive Reuse of Silo Buildings as Residential Buildings

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Abstract

Aim: To increase the value of industrial buildings as part of the conservation of industrial heritage, as well as society and history, and in this context, to examine the adaptive reuse of industrial buildings on silo buildings. **Method:** First, literature research was conducted on industrial heritage, adaptive reuse, silo buildings and architectural transformation criteria. As the next step, industrial buildings in different parts of the world with adaptive reuse as residential buildings were examined and case studies on adaptive reuse of silos were selected. The properties of the selected buildings and the changes made in the structural systems were examined. In this way, it is possible to evaluate the reuse of silo buildings within the scope of industrial heritage. **Findings:** As seen in the case studies examined, no changes were made in the structural system of the buildings that would impair the stability and sustainability of the structural system. Instead, large new masses were built next to the existing building or in place of the building that was demolished due to technical inadequacies. The sense of volume in the buildings has been preserved. **Conclusion:** While transforming industrial facilities into residences, a serious analysis of all the positive and negative factors of this transformation should be made at the research and planning stage and a decision should be made accordingly. In terms of the sustainability and usefulness of the interventions, it is important to implement the interventions without damaging the structural system and to respect and protect the industrial heritage value of buildings.

1. INTRODUCTION

The concept of Industrial Heritage first emerged in the second half of the 20th century as a result of discussions on industrial buildings that lost their function as a result of technological developments. These buildings became useless and worthless over time, and were therefore under the threat of extinction. The concept of “industrial heritage” developed rapidly in industrialized countries and the subject of what would be qualified as heritage was discussed and its content was expanded over time [1].

The main factor that leads to the loss of function of industrial buildings is the inability of existing buildings to qualify to new production techniques. Apart from technological developments, there are also other factors that leads to loss of function such as difficulty in supplying raw materials, purchasing products at a lower cost from Far East countries, inability to expand the factories in the city anymore, and becoming harmful to the environment. On account of that, the existing industrial buildings have begun to be inadequate in terms of space, location or functional obsolescence. This situation resulted in the loss of function of the monumental industrial buildings that symbolize the contemporary industrial society [2].

The conservation and preservation of cultural assets has not been a subject of much attention until recently, and these buildings have been thrown into the background. However, today, a better understanding of their values, their importance in terms of cultural continuity, and their contribution

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both economically and functionally have increased the interest in the preservation of traditional structures [3].

There are two different options when discussing the adaptive reuse of a historic building. These options include maintaining the original function of the building and providing a new function of the other. Since both options will adversely affect the building, conservation principles should be taken as a basis in practice. Adaptive reuse is transformation of a building, area or land from one function to another function. If a building that is going to be reused has value of heritage, then the building should maintain its heritage value after the adaptive reuse process. Reusing keeps the existing building alive by giving a new life and function to the building instead of demolishing it [4].

1.1. Aim

This study aims to increase the value of industrial buildings as a part of the conservation of industrial heritage as well as society and history. To better understand the term adaptive reuse and its potential for the industrial heritage and in this context, to examine the adaptive reuse of industrial buildings on silo buildings.

1.2. Content

This study deals with the housing function and adaptive reuse of silo buildings, an important industrial heritage that is largely unused today. Choosing the appropriate use for the building, preserving the values of the industrial heritage buildings, meeting the needs of the new function of the building, preserving the status of the building in the social memory is a complex and important issue. In this study, the importance of these issues is emphasized and the process of refunctioning of industrial buildings as residences is examined.

1.3. Research Problems

Industrial buildings are important parts of architectural and cultural heritage. However, due to the continuous increase in industrial buildings and the fact that old industrial buildings are behind the age and technology, new buildings are being built and old industrial buildings are abandoned or even demolished over time. What can be done to protect these buildings, which are part of the industrial and cultural heritage? How can industrial buildings that have lost their function be brought back to the city, citizens and industrial heritage? Is adaptive reuse a solution to this situation?

These buildings, which are part of the architectural heritage, represent an important place in the urban fabric that can be used for the formation of new residential areas. Adaptive reuse has a great potential to prevent this. When the adaptive reuse projects are examined, it is seen that the buildings are frequently used with the housing function. Are these buildings, which are not built as residences, suitable to be used as residences? What criteria should be considered in order to function as a residence?

Does the reuse of these buildings create any problems in the structural system of the building? How should the structural system be intervened in order not to damage the building?

2. METHOD

The data collection method was used in this study. According to Mclaughlin [5], data collection is the steps of collecting and evaluating information using selected research tools; quantitative or qualitative research method. Avoiding the collection of false and misleading data, which may lead to invalid conclusions at the end of the research, is a vital step in research work. The methods applied in this study include a literature review, case studies and analysis. The following steps were followed to achieve this methodical approach.

First, a literature review was conducted on the adaptive reuse of silo buildings and industrial buildings within the scope of sustainability and protection of industrial heritage. In addition, based on previous research in this area, basic requirements and demands to be considered for reusing the building for residential purposes have been identified. Second, the multiple case study evaluation approach was used as a methodology for this paper. Silo buildings in different parts of the world with adaptive reuse as residential buildings were examined and case studies on adaptive reuse of silos were selectedThe old and new functions, building and adaptive reuse dates, designers and the architectural characteristic of the buildings were examined. Examining and assessing case studies will help to better understand the general condition and adaptive reuse of silo buildings. In this context, the reuse of silo buildings as residences, the buildings were evaluated on criteria such as structure, architectural design and installation.

3. INDUSTRIAL HERITAGE

One of the organizations working on the protection of industrial heritage is ICOMOS, which was founded in 1965. In the ICOMOS 2006 declaration [6], industrial heritage is defined as “Industrial heritage consists of the remains of industrial culture which are of historical, technological, social, architectural or scientific value. These remains consist of buildings and machinery, workshops, mills and factories, mines and sites for processing and refining, warehouses and stores, places where energy is generated, transmitted and used, transport and all its infrastructure, as well as places used for social activities related to the industry such as housing, religious worship or education.” [6-7].

In the third International Conference on Conservation of Industrial Monuments (1978) of TICCIH, which works to protect industrial heritage, the points to be considered in the evaluation of industrial heritage;

“a) that sites should be interpreted in a national or international not just a local context.

b) that the economic history and geography of the site should be explained.

c) that the site should be explained in the context of the whole industry of which it was part.

d) that remnants should be related to the production process.

e) that the interpretation of the function of a building should take precedence over a purely architectural interpretation.

f) the site should be related to other monuments in the region.

g) monuments should be explained in such a way that they can be seen in their historical perspective, with reference to the international workings of the industry of which they formed part.

h) the roles of sites as working and living places should be stressed.” [8].

3.1. Adaptive Reuse in the Scope of Industrial Heritage

The beneficial reuse of the building in all respects will create a continuity between culture and people, with good analysis of the interventions that will lead to the construction of the new function and the identification of the correct function. Adaptation to reuse arises from a combination of ensuring sustainability and protecting cultural heritage [9]

In addition to looking at the old building as a value for money, it is a more correct view to use this building as a product of cultural studies that will be passed on to future generations. The reuse project, designed by adding a new layer without deleting previous layers, becomes part of the long history of the space. The best practice for reuse of historic buildings would be that the new project can be removed at a later date and reuse will not preclude future conservation. Adaptive reuse is not just about preserving the texture or shape of buildings. It is necessary to comprehend the effect on the heritage building or area. Other considerations include spatial structures and configurations, the relationship between land and context, key insights about the land, traces and processes of activities performed there [4].

3.2. Conversion of Industrial Buildings

In recent years, globalization, which has created significant transformations in the physical and social environment with the development of technology, has also changed industrial cities to a great extent. With the transition process from the modern city to the post-modern city, one of the building groups that have undergone a transformation in the city is the "industrial buildings". Industrial buildings, which are considered "a part of the identity of the place and people because they represent multiple time layers and cultural activities" [10], have begun to be considered as 'heritage' with the understanding of conservation and heritage that developed after the second half of the 20th century. This situation brought up the reuse of industrial areas and buildings [4].

3.3. Benefits of Adaptive Reuse

Adaptive reuse has several benefits, including social, economic and environmental benefits. The environmental advantages are the recycling of current structures and materials. The reuse of these buildings is primarily based on their high quality and potential for reuse and longer life. Reusing current structures can reduce urban sprawl and protect the nature and environment. It is also possible to increase the buildings' energy efficiency. In order to do this the heat transmittance of the wall and roof sections should be improved. It would ensure better heating and cooling [11].

Adaptive reuse extends the life of buildings, avoids demolition waste, promotes tangible energy reuse, and encompasses various aspects of sustainability including economic, social and environmental aspects.

Adaptive reuse of industrial heritage buildings revitalizes the heritage structure and its surroundings and increases their cultural and architectural emphasis. Buildings in this area from time immemorial have the ability to connect with the past and create a 'sense of place'. Therefore, upgrading and reusing industrial buildings is more valuable than demolition, allowing society to move through different eras. Reducing the number of demolished or abandoned buildings for reuse can help communities reduce crime and dangerous behavior in their neighborhoods also improves neighborhood social life [11].

3.4. Silo Buildings

Originally invented in the 1840s, the first silos were wood-frame structures, making them prone to fire. Those built in the 20th century were steel-framed structures built with concrete, many of which are a way of keeping a testament to an earlier era. With the development of technology and the economy, silos are losing their function day by day. Many silo buildings are emptying as old ports and new shipping routes change cities. In this case, adaptive reuse provides an opportunity to evaluate silo buildings and protect them as part of industrial heritage.

Countless grain elevators fall down every year. The reasons behind the fall downs are improper storage, failure to meet the codes, wear and tear. Therefore, due to the many hazards and obstacles encountered in this type of construction, all adaptive reuse projects should start with a thorough evaluation of the silo building. The evaluation should define if the structure is on the edge of collapse or if there is any havoc including acid damage. In that case, appropriate measures should be taken to keep it structurally sturdy. The silo building must undergo proper maintenance and repairs before any potential use [12].

3.5. Architectural Transformation Evaluation Criteria

Examining the architectural character of the buildings is one of the main issues to be considered before proceeding to the implementation phase of the buildings that are worth protecting to be re-functionalized. All these features contain data that can be input into the design in determining the new design, as well as showing in which direction the design can move [13]. Converting a forsaken industrial building into residences is convenient only if the resulting conversion accommodates the needs and demands of the users. Architectural standards that influence the quality of residential areas need to be defined, in order to assess their ability to meet the housing demands [14].

Housing style, dimensions, spatial and functional regulations are essential factors for each project. For this reason, the important architectural features accompanying industrial buildings should be identified and the quality of redesigned dwellings should be analyzed for the sake of adaptive reuse processes [15]. The architectural characteristics of the building can be examined spatially, functionally and structurally. In order to integrate the new function, possible spatial interventions should be made after this process [13]. In addition to these, basic requirements such as natural lighting, fire safety, ventilation, installation, energy saving and sustainable architectural criteria should be provided for the building to be used as a residence.

Based on the literature review, the evaluation criteria are grouped under 3 main headings: Architectural design, structural [14, 16] and installation [17, 20].

3.5.1. Architectural Design

Building Spatial Capacity

In buildings that are not primarily intended for housing, all amenities that characterize a traditionally built residential unit must be planned in order to achieve an adequate quality of life compared to buildings specially built for this purpose. Open spaces in the form of terraces and balconies, when properly positioned and sized properly, have a significant impact on the quality of life in the reorganized complex. To achieve this, openings can be created on the facade of the building. While this approach increases the added value of the residential area, it does not spoil the historical visual identity of the building [18].

Regarding the overall dimensions and layout of current industrial facilities, structures that do not have a very high share of construction area in the plot area are more convenient.

The built-up area of the plot has more advantages in terms of potential conversion to a residential complex, due to better utilization of sunlight and natural ventilation. According to Straton [17], the most optimal scenario is to keep the occupancy level of the built-up area under 60% of the plot area. Removal of the secondary buildings is an option to ensure this number. Nonetheless keeping the form of industrial components like entrance doors, mechanical systems or chimneys is important.

Natural Lighting

In order to transform a building that was not primarily intended for residential use into a residential one, it is necessary to provide enough quality indoor space in terms of natural light. The major advantage of silo buildings for conversion to residential buildings is their size and convenient construction openings that allow easy conversion to a new function, but these advantages can turn into a disadvantage If we think about the amount of daylight required for the residential function [19]. In order to increase the efficiency and sustainability of the building, natural light should be allowed to enter the building.

3.5.2. Structural

As a result of the changes in the re-functioning processes of the buildings, such as structural strengthening of the buildings, making the current situation compatible with current regulations, adding vertical elements or adding new floors and buildings, which are more comprehensive; The structural elements of the building can also be interfered with.

In heritage structures, structural elements may deteriorate or rot over time. Considering the intervention to be applied to any of the structural elements and their role in the formation of the identity of the space, the characteristic feature of the building may be impaired. For this reason, the existing structural system, wall, roof flooring, etc. should be examined in detail, and the strong and weak points created by these elements in the structure should be determined before the intervention and a plan should be made accordingly [18].

3.5.3. Installation

Material Usage and Energy Saving

The construction industry takes a major place in the consumption of raw material resources and the generation of waste materials. According to a study conducted in the United States [20], the construction industry in the USA depletes a major amount of raw materials (16% of water, 40% of energy, 40% of all stone, sand and gravel and 25% of timber). Likewise, the construction industry of Canada produces 27% of all solid waste in municipal landfills, of which about 75% can be recycled or reused [21]. Based on these results, adaptive reuse is a great opportunity for a cost and energy efficient architecture. By reusing existing materials after necessary alterations and maintaining the original parts of the building during renovations, it is possible to decrease the use of new materials and to provide energy saving, sustainability and economic benefits.

Plumbing and Water Cycle

In the process of using the buildings as residences, it is necessary to review and maintain the technical infrastructures and installation systems of the buildings. If the building to be re-functionalized is too old, the installation can be completely renovated, different techniques can be used according to the conditions of the day, and in more special cases, systems such as ventilation and air conditioning must be integrated into the structure. Regardless of its first function, it is much easier to renew the installation system and integrate it with today's conditions in buildings with technical connections [18]. The pipes in the installation of an industrial building and the pipes required for a residential building are of different sizes. In order to use the space conveniently and gain space, the reorganization of the installation should also be reviewed. However, in order to preserve the identity of the building and to reflect its rawness and aesthetics, the existing installation can also be left open for display.

4. CASE STUDIES

In this section, 5 reused industrial buildings were selected for case analysis. Some of these 5 case studies which is selected according to their functions, have other functions besides the residential function. It is aimed that these studies carried out in the international arena will shed light on local and international projects. Comparison tables are made in case studies to analyze and understand the various design approaches applied in different environments.

4.1. Vienna Gasometers

Vienna Gasometers are placed in Simmering district of Vienna, the capital of Austria. The Coal Gas Factory, of which Theodor Herrman was the technical consultant, was built between 1896 and 1899. It is the largest gasometer in Europe at the time of its construction. Gasometers with very short construction times were built in groups of two. While one group was built in 84 days, the other group was completed in only 72 days [22].

The building, which is used as gas silos, is surrounded by a brick wall and the iron structure of the building is hidden inside these walls. The height of each gasometer is 72 meters and the diameter is 62 meters. When the gas need started to be met from natural gas, the gasometers that were active until 1986 were abandoned and as a result, the technical tools of the silos were dismantled. The remaining monumental structures of 90 thousand cubic meters remained only with their exteriors and were taken under protection [22]. 4 project proposals submitted by 4 different architects were selected from the suggestions received. Gasometer A - Jean Nouvel, Gasometer B - Coop Himmelblau, Gasometer C - Manfred Wehdorn, Gasometer D - Wilhelm Holzbauer were designed and the construction of the structures was completed between 1999-2001 [23].

Figure 1. *Outdoor and Perspective Section Images of Gasometers [21]*

The building is functionalized in three vertical sections: the shopping center on the lowest floor, the workplaces on the middle floors and the residences on the upper floors. Each mass has become interconnected with the bridges between the shopping centers on the lowest floor (see Figure 1). The complex includes shop, restaurant, cinema, Vienna National Archive, residence, dormitory, office, etc. includes functions [23].

4.2. Grünerlokka Student House

The building is located in the Grünerlokka district of Oslo, the capital of Norway. The grain elevator built to store corn was installed in 1953 and served until the 1990s. For the building, which was closed as a result of losing its function, a project was proposed for reuse by HRTB Architecture in 1993 and the construction of the building was completed between 1999-2001 with the acceptance of the project by the local government [24].

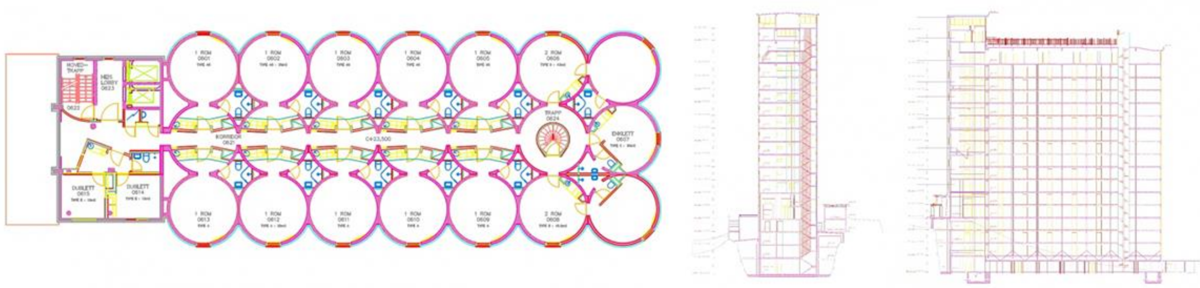

Figure 2. *Silo plan and sections [24]*

The structure, which consists of three rows (21 silos in total) in rows of 7 silos (as seen in Figure 2), is known as Grünerløkka Studenthus. The interior of the building, which is used as a student housing complex, is used and no new mass has been added to the outside of the building. Most of the building was left in its original state. In order to animate the uniform concrete walls of the building, brightly colored glass panels are used in the opening window spaces. Thus, they succeeded in adding color to the armored gray facade of the building. The building consists mostly of studios and one-bedroom apartments (see Figure 3). The building, which has become a landmark for the city, won the Oslo City Architecture Award in 2002 [24].

***Figure 3**. Indoor and Outdoor Views of Silos [22]*

4.3. The Silo

"The Silo" structure is located in the Nordhavn district of Copenhagen, the capital of Denmark. The Nordhavn district is the new city district with the original industrial buildings, which includes a significant part of the industrial buildings in Copenhagen. As part of Nordhavn's post-industrial development, the silo was completed in May 2017 by the Danish architectural firm COBE. The structure is located in Nordhavn's four million square meters post-industrial port area project, which is planned to be completed in the next 40 to 50 years, of which COBE is a part. The building, which was used as a grain silo, was abandoned and later reused as a residential structure [25]. Figure 4 shows the transformation process of the silo.

a) Before Reuse b) During Construction c) Current State

***Figure 4.** Transformation Process [25]*

The 17-floor, 62 m high and 14 m wide former grain silo is the largest industrial building in Nordhavn. The building, which has floors rising up to 7 meters, is composed of 39 different apartments. Apartments can be single or multi-story, and their sizes vary between 73 m² and 305 m². The use of the lower and upper floors of the building is open to the public. On the top floor of the building, there is a restaurant with a 360-degree view of the city and sea view [26].

Figure 5. *Indoor and Outdoor Views [25]*

The structural system of the building was preserved as much as possible and door and window openings were designed only in the outer part of the building (as seen in Figure 5) as long as the load-bearing system allowed. The new facade of the building was designed in harmony with the original concrete structure, ensuring continuity between the old and the new. An angled insulation layer made of galvanized steel was added to the exterior as the new building cladding. Thus, it was possible to preserve the elongated shape of the silo. While the exterior of the silo was covered with a new façade, the interior was preserved as much as possible and left untouched (see Figure 5 and Figure 6). The spatial diversity reflected in the housing units arises from the functional differences in the processing and storage stages of the grain in the silo. All apartments have floor-to-ceiling panoramic windows and balconies (see Figure 5). The frames of the windows, which offer sweeping views of the city skyline and the port area, are hidden outside the existing concrete walls [25].

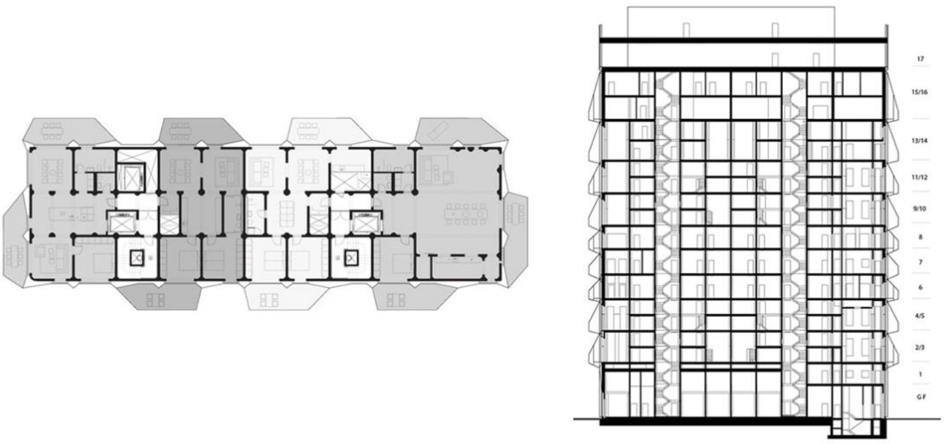

Figure 6. *Plan and Section [25]*

4.4. Frosilo

The Frosilo structure is located in the port area of Copenhagen, the capital of Denmark, known as Brygge. The project includes the adaptive reuse of soybean processing plant silos built in the 1960s. Abandoned in the 1990s, the twin silos were put into use as a residential building in 2005 within the framework of the Frosilo project. It was MVRDV's responsibility to transform the buildings into apartment blocks. Unlike warehouse conversions common in a historic district, silos were viewed by MVRDV as a bare structure that could easily accommodate "futuristic" homes [27].

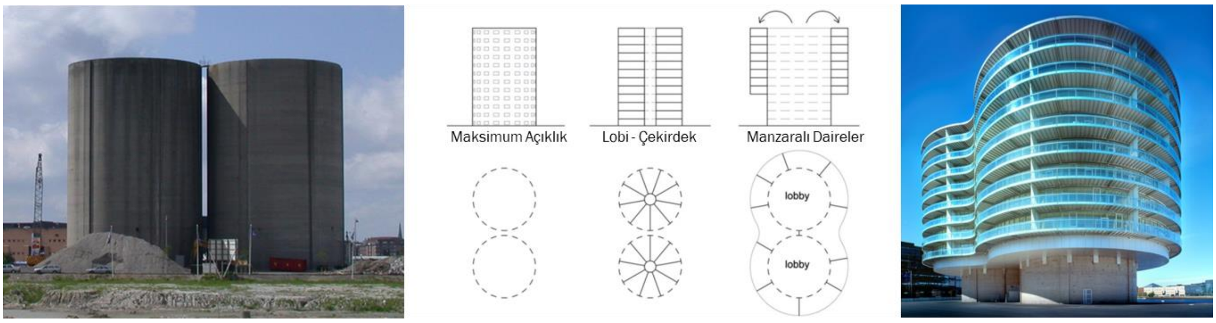

Figure 7. *Building Transformation Diagram [27]*

Silo structural constraints were the solution to the design. The unique circular structure and location of the silo is utilized. Silo shapes are noticeable from the outside and the design reflects itself (see Figure 7). The silo acts as a core for the project. The futuristic lobby of the silo is covered with a glass roof. It is difficult and complex to make large openings in the external concrete walls that form the structural system of the silo. As many openings as possible were made in the walls and then residential blocks were added.

Figure 8. *Plan, Section and Indoor Images [27]*

The houses were built outside the silo in order to benefit from the view and the circulation was solved inside the silo as seen in Figure 8. Housing masses adhere to the structure like a parasite and are carried by the walls of the silo. Thus, in order to preserve the silo atmosphere, instead of covering the inside of the silo with a wall, it was ensured that it was only circulation (see Figure 8) [27].

4.5. Kanaal in Wijnegem

The building is located in an important 19th century industrial area in the Albert Canal nearby Antwerp, Belgium, which has been converted into a contemporary space for mixed use. As part of the Kanaal project, art dealer Alex Vervoordt has taken over a former malt distillery, grain storage silos and red brick warehouses, a total area of 55,000 square meters. The silos were built in 1857. The conversion process was executed by Stephane Beel Architects. A large part of the area is used as a residential building, in addition to this, it contains many functions such as offices, museum space, workshops and a parking lot [28].

Figure 9. *Before and After Adaptive Reuse [26]*

Within the scope of the project, there are 8 gray and 15 white silos. Two silos, 31 and 28 meters high, were removed from the gray concrete silos and replaced with new transparent silo masses. A new residential volume was built in place of the white silos, which were removed due to technical problems. In contradistinction to the current gray silos, the structure is clad with white wood and the structural system is formed by steel (see Figure 9). Traces of the existing silos along the ground level were preserved in the newly constructed masses. Small openings for windows and doors were created in the walls of the remaining six gray silos (see Figure 10). Openings that reflect the appearance of certain landscapes have a structural logic. The gray silos, which are connected to each other by bridges, are positioned separately from each other. The connection of gray and white silos is provided by identical type of bridges [28].

Figure 10. *Outdoor Images [28]*

5. EVALUATION AND CONCLUSION

5 adaptive reuse projects of silos were examined as an example. The silos' main functions were to store gas, grain, seed and malt. Silos, which were previously used for storage purposes, were used as offices, art, commercial, restaurant, public etc. in addition to their residential function as seen in Table 1. In this way, industrial heritage buildings were opened to the use of the public. The transformed silos were built in the 19^{th} and 20th centuries and adaptive reuse processes were completed in the 21st century (see Table 1). The transformation process was planned by architects Jean Nouvel, Coop Himmelblau, Manfred Wehdorn,

Wilhelm Holzbauer (Vienna Gasometers) and companies HRTB (Grünerlokka Student House), COBE (The Silo), MVRDV (Frosilo) and Stéphane Beel Architects (Kanaal).

Table 1. *List of Projects and Project Information*

Building Name	Architect/ Company	City	Country	Building Date	Adaptive Reuse Date	Old Function	New Function	Height	Width
Vienna Gasometers	Jean Nouvel	Vienna	Austuria	1899	2001	Gas Silos	Residence Office Mall	72	62
Grünerlokka Student House	HRTB	Oslo	Norway	1953	2001	Grain Silos	Residence	54	5,3
The Silo	COBE	Copenhagen	Denmark	1960	2017	Grain Silo	Residence Office Art	62	14
Frosilo	MVRDV	Copenhagen	Denmark	1960’s	2005	Seed Silos	Residence	42	25
Kanaal	Stéphane Beel	Antwerp	Belgium	1857	2015	Malt Silos	Residence Office Museum	31	7,5

To examine the buildings, there has been made an assessment over criteria which includes structure, architectural design, and installation. According to the evaluation criteria, the results in Table 2 were reached. While executing adaptive reuse of the silo buildings examined, it has been tried to intervene with the least damage to the structural system of the buildings. The structural system of 4 buildings was preserved, and some masses of the kanaal building which is the oldest building among them (see Table 1) were demolished due to the unsuitable load-bearing system. In place of the destroyed building block, a new building block was built based on the mass of the collapsed building. In 2 buildings, new structural components have been added in addition to the existing structural system. Thus, it became possible to create housing programs. In four of the silo buildings, openings have been created as much as the structural system allows. Large openings were avoided in the buildings and maximum door and window openings were created to the extent allowed by the structure. Thus, the structural system of the buildings was preserved, circulation was created in the building and natural light was allowed to enter the building. The plumbing arrangement of the buildings was reconstructed according to the given functions. The plans and spatial volume of the buildings are arranged according to the requirements of the housing program and the changes made are clearly distinguishable from the existing (old) structure.

Table 2. *Intervention Typologies and Structural System Status in Projects*

Evaluation Criteria		Building Name				
		Vienna Gasometers	**Grünerløkka studenthus**	**The Silo**	**Frosilo**	**Kanaal**
	Are there any openings in the facade?	-	+	+	+	+
	Is the existing structural system preserved?	+	+	+	+	+,—

Structure	**Are there any destroyed load-bearing element?**	-	-	-	-	+
	Have any new structural elements been added?	+	-	-	+	+
Architectural Design	**Is the plan, spatial volume of the building arranged in accordance with the housing space?**	+	+	+	+	+
	Have necessary arrangements been made to ensure the natural lighting of the building?	+,—	+	+	+	+
	Are the applications made to the building distinguishable from the old building?	+	+	+	+	+
Installation	**Have arrangements been made for the ventilation of the building (openings in the façade, ventilation spaces inside the building, addition of ventilation systems, etc.)?**	+	+	+	+	+
	Have the building's plumbing and water cycle been rescheduled according to the housing program?	+	+	+	+	+

From the information obtained from the reviewed projects and literature research, the following conclusions were reached: In order to reuse the silo buildings as residential buildings, the silos and other surrounding industrial elements must provide the general requirements designed for the residential area. In this phase, first of all, it is necessary to explore the spatial potential of industrial facilities and to define housing needs and potential requirements. Based on the research made in this area, some common demands have been identified to reuse for residential purposes. If the transformation process is approached and implemented appropriately, there is a higher chance of obtaining sustainable and functional results. Large dimensions of industrial premises affect the interior space quality. In order for these buildings to be converted into residences, the necessary basic requirements such as natural lighting of the area, providing the water cycle and ventilation must be fulfilled. These requirements are fulfilled in the examined buildings. The requirements of the housing unit such as ventilation, openings, water cycle etc. are fully met.

As a result of the literature research, it has been seen that the residential function is frequently used as a new function in the adaptive reuse of industrial buildings. Adaptive reuse is a solution to loss of function of industrial buildings. Adaptive reuse gives the existing industrial building a new life with a new function. Residential function is a good way for it. In addition to the residential function, giving public functions to the building ensured the integration of the citizens into the building. The buildings were brought back to the city with a new function.

One of the factors that has a critical impact on the success of the conversion process is the special architectural expression conveyed by these buildings. It is important to preserve the buildings in memory of the urban-public identity. It should be carefully planned and designed so that the size, shape and location of the intervention applied in the building do not compete with the historical building. The building should be part of the new whole and the architectural expression of the existing building should be preserved. These issues are taken into account in the projects examined, but the size of the intervention in the Frosilo building precludes the old structure. However, since the intervention is made as a continuation of the silo building and based on the silo lines, this does not spoil the architectural expression of the silo buildings.

The planned interventions to the structural system of the building should be analyzed in order to maintain the sustainability and strength of the structural system. No intervention should be made that would impair the strength of the structural system of the building. If necessary, new load-bearing elements should be added to strengthen the structural system.

As seen in the case studies examined, no changes were made in the structural system of the buildings that would impair the stability and sustainability of the structural system. Instead, large new masses were built next to the existing building or in place of the building that was demolished due to technical inadequacies. The sense of volume in the buildings has been preserved. As a result, while converting industrial buildings to residences, it is necessary to seriously analyze and determine the positive and negative factors of the conversion during the research and design stage. In terms of the sustainability and usefulness of the interventions, it is important to implement the interventions without damaging the structural system and to respect and protect the industrial heritage value of buildings.

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