Conservation of Derince Traverse Injection Factory and Power Station in the Context of Structural Behavior

Emre Kishali1*

1* Department of Architecture, Faculty of Architecture and Design, Kocaeli University, Turkey
(emre.kishali@kocaeli.edu.tr)

Abstract — The construction of industrial buildings in Istanbul commenced during Ottoman Empire in 19th century and railway systems with the facilities were constructed in the scope of mobility of manufactures around the city afterwards spread into Anatolia. Railways, stations and subsidiary facilities were built by great significance during 19th and 20th century. In this research, Derince Traverse Injection Factory and Electric Power Building, the example of industrial heritage buildings are going to be analyzed in terms of structural safety for sustainability issues. These buildings have been abandoned due to economic developments, socio-politic influences, and health reasons. As a methodology, the damage assessment investigation done by direct investigations, infrared thermography and flat-jack test applications. Furthermore, the buildings Derince Traverse Injection Factory and Electric Power Building were analyzed with ISCARSAH principles by the help of SAP2000 analysis. Different load combinations including modal superposition (response spectrum analysis (RSA) and time history were defined in linear approach in order to analyze the structures globally in terms of deformation, internal stresses of structural elements and dynamic behavior. The program was used to assess the global dynamic behavior of the structures under the ground motions of Kocaeli earthquake occurred on 17 August 1999. The accelogram obtained from Strong Ground Motions Database of Turkey were introduced to the programs for the history – time analysis. The aim of this study is to find structural vulnerable parts of the structure considering preventive conservation approach. On the other hand, conservation issues are discussed under the integrated approach in post-earthquake damage assessment. The challenges for numeric analysis of historic buildings under strong ground motions and determination of mechanical properties are presented.

1. INTRODUCTION

In 21st century, charters for the preservation of industrial and railway heritage were constituted to promote cooperation in the decisions of the industrial heritage. The conservation of old structures and passing these values to next generations become more problematic matter where rapid manufacturing policies govern the global, national and even local economy. In Derince Railway case, conventional and scientific conservation notion is like wisely diffused since local development policies are shaped by dominantly macro economy.

National and regional developments influences the surrounding of historical centers, their surroundings and contemporary industrial heritage zones with international initiatives. Contemporary conservation activities include scientific, planned conservation and constructive conservation approaches which were raised in order to define continuous maintenance, regular monitoring in long terms via integrated conservation approaches from the site scale to users scale in the context of current preservation tools [1].

The conservation of facilities needs to be analyzed in terms of two aspects both in urban context and in single building scale. Scientific conservation approaches are required for structural safety and damage assessment under the internal and external actions. Degradations, failures, structural behavior under seismic actions, material characteristics need to be analyzed. Most vulnerable parts of structure were identified via different load combinations to provide coherent information for possible interventions.

In this paper, national, regional and city scale decisions are not mentioned – although these issues are directly related to conservation of architectural heritage - technical and structural analysis of Derince Traverse Injection Factory and Power Station were presented and discussed in the context of ICOMOS Charter – Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage (ISCARSAH Principles) principles [2]. Historical investigation, architectural – urban values, preliminary analysis and slightly and non-destructive tests were performed. Finally, global behavior of the buildings were simulated by SAP2000 with the data of 17 August 1999 earthquake logs.

2. METHODOLOGY

Structural and conservation report was requested from Kocaeli University, Department of Architecture
After 1970s, private enterprises were established, the last facility in Adana (1987) is one of the example of private enterprise. Nowadays, concrete sleepers are used in the railway constructions, especially for high-speed train; thereby, recycle of timber sleepers and conservation of the production and process facilities are current issue [5].

3.2. Historical Investigation

Derince, located 8 km west of İzmit and 90 km east of Istanbul, was established as a seaport at the end of 19th century which currently is the district of Kocaeli Province. According to the researches, Derince Seaport was constructed between 1894 – 1896 by Nagel Kaemp A.G. and Philipp Holzman Construction Company including railway facilities such as warehouse, storage buildings, lodgings and hotel structures [4][6].

Railway construction line between Haydarpaşa – İzmit was completed in 1871 – 1873. According to the research conducted by Kösebay Erkan, Derince railway facilities were completed in 1889 – 1892 [4]. In 1913, the port was used as soldier deployment spot during Balkan War. British troops reached the port, occupied the area, including Ottoman armory in the warehouses, in 1919 and then they invaded İzmit with its surroundings.

In Republican era, private companies, operating the railways, were nationalized in 1924 and General Administration of Railways and Port was established in order to integrate and centralize rail and sea transportation operations in 1927. Until 1953, the administration had functioned as supplementary budgeted public enterprise which was converted into Public Economic State Enterprise under the name of Republic of Turkey General Directorate of State Railways Administration (TCDD). In 1984, with a new constitution, TCDD was counted as Public Economic Enterprise performing economic activities by governmental organizations [7].

Carpentry Workplace was constructed as dormitory for 60 carriers, and Lodgings were constructed at the end of 19th century whereas Timber Injection Factory and Electric Power Building were established in 1930. The national government promoted the timber sleepers until 1940s. Afterwards, it was decreed that the production of timber sleepers was not economic in turn the production was highly influenced and the factory completely and officially deactivated in 2001[5].

3.3. Urban and Architectural Features of Case Studies

The area was free of built environment in late 1800s.
Natural texture has been transformed by the scattered constructions due to the industrialization. The area has been becoming denser within the course of time, thus nature and specific historic production facilities with peculiar technology have not conserved well. The sustainability of socio-economic life has been disrupted. Furthermore, the projects are related to new highway routes, transportation facilities, new industries, technology and urban zones were planned. Urban pressure on historical tissue are increasing along with population and economic growth.

On the other hand, Derince Ports have been taken into the scope of privatization. In this scope, the operation rights of some enterprises have been transferred for a period of 36 years but privatization studies had been continued for Derince Port until 2014 due to objections from non-governmental organizations [8]. Eventually, the tender for the privatization of the Derince Port was started on December 12, 2004 and completed on June 5, 2014 with a $543 million bid by Safi Solid Fuel Industry and Trade for 39 years [9]. Safi Port with the area of 396,382 m$^2$ currently provides port operation services with shore cranes and other equipment; however isolated listed railway heritage buildings stand without any active use and any integrated - participatory conservation plan.

Historical railway buildings in the area can be evaluated into two parts; first group buildings, located north of railway, were transformed to other functions. Original uses as train station building and hotels were adapted into municipality wedding ceremony hall and police station respectively. Others which are named as Derince Traverse Injection Factory, Electric Power Building, Carpenter Workplace and Lodgings, are close to Derince Port. Before privatization some important railway lodgings were standing but they were demolished in the consequence of the damages by earthquake of 17 August 1999. Currently, there is only one timber lodging standing in the area. The aforesaid four structures were abandoned in 2000s and they were listed by Conservation Board for Cultural and Natural Assets of the Ministry at the same year (Fig. 1).

Furthermore, restoration projects were prepared for these buildings considering physical degradations and structural safety; possible uses of these buildings are not defined. Due to devastating earthquake of 1999, the buildings in the port were damaged in different scale; major cracks were generated in the injection factory but structural safety of the structure was not in the level of high danger.

The building having the dimension of 43.5 x 22 m includes pressure tanks for injection; compressor room; raw material room; workplace and water tank. Construction technique is mixed structure with stone – brick masonry walls and reinforced concrete lents; the space is covered by timber trussed roof. The thickness of stone masonry load bearing walls is 60 cm. and gable walls with clay bricks stand on the stone load-bearing walls. Five spaces with the original functions are the entrance hall, it is possible to reach the large workplace area (Z02) containing four pressure tanks for the injection of timber sleepers (Z01). Compressor room having vacuuming tank (Z04) and the workplace with water tank (Z05) are located in north of Z02 (Fig. 2). The four spaces are located in one volume whereas extra impregnation facility erected in later time (Z03).

In Z02, two tanks having 2.2m diameter placed at the elevation of –1.24 m and the others are located at the elevation of +3.07 m. Besides, the ground was filled with water and the scent of creosote was still felt around and inside the building (Fig 2). The structure supply electricity for the injection of creosote into timber sleepers. The building having the dimension of 18.0 x 12.5 m. was designed as single space. Construction technique is brick masonry walls having 52 cm. covered by timber trussed roof. Vertical timber elements of roof were supported by semi heightened masonry columns so the thickness of wall is increased in these areas (Fig. 3).

4. STRUCTURAL BEHAVIOUR

4.1. Direct Investigation

During the direct investigations, in the corners of spaces Z05 and Z04 vertical cracks exist interior surface building and at the connection of masonry
walls. On the other hand, some structural cracks are noticed in the masonry walls which can be also observed from the outside facade.

In Electric Power structural cracks, degradations and decay were not observed during direct investigations. Hair cracks, vegetation and black stain were noticed in the preliminary analysis of the structure.

4.2. Building Assessment: IRT and Flat Jack Tests

Infrared Thermography which measures infrared energy irradiated from the surface of building elements is used to detect and quantify heat losses and temperature variations through roofs and walls. Infrared thermography is applied to buildings to collect information for elements of structures, their shape, their physical characteristics, existing cracks, recently calculation of U-values and the state of decay in the structures. Due to anomalies occurred in the structures heat flux can be changed throughout the wall and IRT analysis maps localized differences in surface temperature by different heat flux from the surface [10][11][12]. In Traverse Injection Factory, existing cracks, stains due to the infiltration, rising damp, and delamination were observed via IRT technique.

Flat-jack is carried out by introducing a thin flat-jack into the mortar layer. After the test, the flat jack can easily be removed and the mortar layer restored to its original condition. The high reliability of the test is related to the undisturbed conditions of the sample on which masonry stress state, compression strength, elastic modulus are determined.

The reference field of displacements is first determined by measuring distances between gauge points fixed to the surface of the masonry. Then, a slot
is cut in a plane normal to the direction of measured stresses. Cutting the slot causes partial stress relief in masonry above and below. Afterwards, a thin flat jack is introduced into the slot. With the aid of this device, pressure (compressive stress) is applied to the masonry. In masonry, double flat jack can be applied by a second cutting, parallel to the first one, and a second jack is inserted, at a distance of about 50 cm from the other. The two jacks apply a uniaxial compression stress and deformability [13][14].

In the building three different points in various facades, close to ground level, were selected for both Traverse Injection Factory and Electric Power Station in order to perform double flat – jack tests and obtain in-situ Elastic Modulus and Poisson Ratio. ASTM C1197-14a Standard Test Method for In Situ Measurement of Masonry Deformability Properties Using the Flat jack Method was applied by KURAM Fatih Sultan Mehmet Vakaf University. As a result, average value of Elastic Modulus and Poisson ratio is found as 9520 MPa and 0.20 for rubble stone masonry of Traverse Injection Factory; 6822 MPa and 0.30 for brick masonry bounded with cement mortar of Electric Power Station [15]. The results displayed elastic regime in the stress – strain diagram.

4.3. Structural Modelling

Structural analysis is an important part of scientific and preventive conservation carried out with chemical, physical analysis and monitoring. Furthermore, global behaviors of structures under seismic actions are sought then they will be compared with the assessment results done during direct investigations. Despite the fact that technology enables the conservation experts to make realistic estimations about masonry, composition of structure, anomalies and even the chemical composition of building materials, one-to-one model which is supposed to reflect exact behavior of historical building is a complicated task. Therefore, it is necessary to generate more realistic models and make correct assumptions with specialized research questions. Realistic models are defined by exact geometry, material properties, soil conditions, connections of structural elements and current degradations. The aim of this study is to find vulnerable parts of the structures via global behavior and slightly or non-destructive methods considering preventive conservation approach. Post-earthquake damage assessment and numeric analysis under strong ground motions and mechanical properties are integrated.

In the elastic analysis of masonry structures, it is assumed that masonry units and mortar behave as a single material having unique mechanical properties. The deformations are fully recovered when the applied actions are removed [2][16]. Elastic analysis is the simplest method for the analysis and gives general information about the behavior of the structure.
Therefore the aforesaid structures were analyzed by SAP2000 program using finite element model approaches. The masonry units and mortar are considered as homogeneous material. In these study, macro – modelling, homogeneous and continuous material are assumed in models to see the global response of case studies under static and dynamic loads.

The model for the factory generated with 191 shell (thick) and 255 frame elements; that of power station includes 103 shell (thick) and 119 frames for the roof. Building and ground relation were modelled as fixed restraints for both structures.

The most essential aspect of the numeric analysis is that flat jack tests are applied on the structures for the input of material during simulation processes. Density, the property of material, Young’s Modulus and Poisson ratio is used for the definition in model. They are obtained from flat-jack tests so that model becomes more realistic. It is aimed to determine the most vulnerable parts of structures by calculating direct stress (force per unit area) and out of plane shears stresses acting on the positive and negative faces in each direction. The values were compared to the allowable ones obtained from literature considering limestone masonry behavior as a result vulnerable parts of structure can be interpreted.

Allowable compression strength, allowable tensile strength and shear strength are obtained as 18 MPa, 2 MPa and 6 MPa respectively [19]. The values for timber structural elements are obtained from UNI 11119 as 7.5 MPa for allowable compressive strength and 6 MPa for allowable tensile strength. Main load bearing material is taken as oak for timber-framed walls as shell elements and selected as 3rd class. They are the lowest timber class in order to address the worst scenario [20].

Live loads for snow in the roof (0.47 KN/m2) are calculated from Turkish Standards 498 [21]. Load combinations are defined to analyze the response of structures under different possible loads. In the SAP2000 analysis, different load combinations including modal superposition (response spectrum analysis (RSA) and time history are defined in order to analyze the structures in terms of deformation, internal stresses of structural elements and dynamic actions. In this study two combinations are represented to assess the dynamic behavior of the structures under the ground motions of Kocaeli earthquake occurred on 17 August 1999. The accelogram data of the earthquake, obtained from Strong Ground Motions Database of Turkey, are introduced to the programs for the history – time analysis. Load combinations defined in model are;

- $1.0G + 1.0Q + 1.0Tx$ (COMB1)
- $1.0G + 1.0Q + 1.0Ty$ (COMB2)

Where G, Q and E are dead load, live load and time – history earthquake loads respectively.
4.4. Explanatory Results

According to the simulations, the most vulnerable parts are the connections of roof construction and load bearing masonry walls in Derince Traverse Injection Factory. Compression and tensile stresses are higher than the assumed allowable strengths in southwest façade and in the partition wall which is perpendicular to it. Direct investigation with damage assessment results match the results deduced from the simulation. On the other hand, structural cracks in Z03 are not detected in the numerical model. It can be explained that these cracks are caused by previous soil settlements and/or seismic actions. Moreover, the connection of stone masonry walls with partition walls are found as vulnerable zones as indicated during direct investigations (Fig 6.)

Considering Electric Power Building, the weak points are listed as the connection between vertical elements of roof and short masonry columns in the corners and along the façades considering allowable compression and shear strength and the calculated ones. These values do not exceed the assumed allowable stresses but they are close to these values. Tensile stresses may create critical areas only in northeast façade.

5. CONCLUSION

The railway heritage structures were faced privatization, abandonment and lack of conservation maintenance in Derince. The macro impacts on buildings are complicated to provide consistent maintenance and preservation program. Furthermore, the buildings display structural problems that need to be investigated in the context of scientific conservation approach. In this research, ISCARSAH recommendations were followed to find the structural anomalies, degradations, global structural behaviors and remedial measure if needed.

The historical, architectural, geometrical and contextual analysis of structures were carried out. Linear analysis was performed via SAP2000 program to reveal the global behavior of structure and vulnerability under seismic data of 17 August 1999. The load distribution schemes and high values show good agreements with the detected failure analysis. Especially in the north and west façade of Injection Factory existing cracks were not detected. Structures have gone through strong earthquake and still standing with some structural cracks; no partial and heavy damage observed. Therefore, these structures can be rehabilitated by minimum interventions. Furthermore, nonlinear behavior of material is not considered which means structural modeling and analysis need further investigations. More detailed analysis nonlinear pushover and detailed micro modeling for vulnerable areas are suggested. In the model, connection of timber roof with structure was assumed as fully connected, these situation should be checked by in-situ investigations. Furthermore, the structures should be inspected by other non-destructive tests such as...
ultrasonic velocity tests, Schmidt hammer, georadar, and metal detector etc. and laboratory chemical tests for more data. They also need to be monitored in order to support conservation acts and structural behavior.

Last but not least, regional and national conservation vision is very essential for the protection of the assets. Demolishment and reconstruction issues are discussed for these buildings; unplanned conservation plan creates uncertain conditions for the sustainability. Therefore, macro and micro conservation activities should be consistent to have holistic approach.

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