Investigation and Protection Recommendations Sinan Bridges in Istanbul

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Received: 14.03.2018 Accepted:29.03.2018

Abstract- Our country is located on lands that have been home to different civilizations for centuries. For this reason, it harbors numerous movable or immovable cultural assets. Having a significant place among our immovable cultural assets, bridges are structures in which modernism and functionality are brought together by architecture and engineering disciplines by considering a sensitive balance, number of arches, arch width, arch height and construction style. Many bridges have been built across Anatolia throughout history. While a great majority of these bridges have suffered from natural disasters and human-related damages in time, today they still function.

Construction techniques and current conditions of Sinan Bridges are analyzed under the light of above-stated effects. As sample structures, survey works were performed on Mimar Sinan Bridge in Buyukcekmece and Kapuagasi Bridge over Haramidere; restitution and restoration projects were tried benefiting from written and visual sources and the traces on the structures. Structural problems within the current condition of the structures were scrutinized and intervention suggestions were made. Recommendations were made to solve protection problems arising from the location of the structures.

Keywords Survey, Restoration, Restitution, Bridge, Sinan the Architect.

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1. Introduction

Historical structures are priceless cultural assets firmly attaching the past to future. Such assets are the instruments to understand the changes and knowledge of civilizations. Historical bridges have a crucial place in every civilization [9].

There are 1499 historical bridges in our country, having hosted numerous civilizations, which were located and registered as of 2011 and had been built in Roman, East Roman (Byzantium), Sekjuqian, Ottoman and Early Republican Periods and differ in terms of location, form, construction technique, arch form, material etc. [7].

Masonry stone arch bridges are encountered in many ancient civilizations. However, Romans are known to have built the most advanced of all. Construction of masonry stone arch bridges in Anatolia particularly started in the Ottoman Period [6].

They contributed to the scientific, cultural and artistic development of societies of Anatolia civilizations and therefore a great many scientists, architectures, engineers and artists were raised. Undoubtedly, Sinan the Architect is a leading name among them. Sinan the Architect is a highly-skilled architecture and artist who signed his name in a golden age in Ottoman architecture. He executed his office as chief architect, which he was appointed in 1538, for 50 years uninterruptedly and carved his name upon more than 350 structures large and small. Among all of these structures, aqueducts, bridges and mosques have a significant place [4].

Within the study, Buyukcekmece Mimar Sinan Bridge and Kapuagasi (Haramidere) Bridge, Mimar Sinan's works, were determined as study interests. Photographs and survey drawings were used to determine existing conditions of Mimar Sinan and Kapuagasi Bridges, their architectural and structural properties, material and construction techniques were analyzed. Afterward, existing and possible damages and deformations on the bridges and out-structures were tried to be found. As a result of historical and technical researches, existing marks and comparative studies conducted so as to eliminate the damages and deformations in question and their cruxes as well, a protective approach was adopted and a restoration project was prepared.

2. Types of Deformation In Stones

2.1. Dirt Buidl-up

Accumulation of unrelated foreign materials on the surface of the stone. Inhomogeneous accumulation of dust, ash and smut particles in the atmosphere which do not have highly adhesive properties on the surface of the stone in colors from gray to black, is the most common type of pollution. Accumulation of dust, soil and mud particles by splashing on the surface of stone due to heavy rain in colors ranging from brown to gray could be an example of pollution as well [10].

2.2.Formation of Cracks and Fractures

Dislocations might occur in structures due to change of behavior as a result of exceeding of tensile or compressive strength because of degradation of materials by virtue of earthquake, subsidence and heat expansion and fractures might occur due to pressure. Concrete, losing its binding properties, cannot hold stones together and eventually disconnection starts. Other types of damage such as the formation of shell might result in fractures as well. While these fractures might be found in junctions of stones, they can occur within the stones as well [8].

2.3.Fragmentation

Main reasons of fragmentation can be listed as swelling of anchorage materials as a result of corrosion due to frost and salt effects. Furthermore, fragmentation might result from crumbling, exfoliation, erosion-like affusion, fraction etc. mechanic effects. Fragments generally break off in a parallel line with stratification [8].

2*.4. Salification*

When a stone contacts with water, the salt within its structure or the surrounding materials is activated and rises with capillary effects. White efflorescence occurs in consequence of drying that arises from the effect of rising water and evaporation, and incrustation, powdering and cavity-shaped deformations occur on the surface of the stone.

2.5. Vegetation

Vegetation occurs when seeds, carried around by winds, are placed within tiny cavities inside the wall and grow in time into plants.

Vegetation, being a type of biological deformation, might be encountered in joints, gaps inside stones or roof skin. While it might be in the form of herbs growing on the surface, trees with more than 1m. diameter might also grow if not maintained.

Growing roots are dangerous for they result in cracks, fractures and other deformations in surrounding stones.

3. Stone Bridges

Stone bridges were generally built in three types: (a) continuing arches (bridges with the same or similar arch spans and peak points); (b) single bay, rising and descending (the biggest arch bay in the middle); (c) double bay, rising and descending (the highest pier in the middle) [3]. Similar techniques are encountered in the bridges across Anatolia. However, geographical differences have resulted in differentiation the shape of the arch, and surrounding stone pits and technical knowledge in masonry techniques [2].

Flood splitters were used to better bridge's drainage and to reduce the load on piers and main walls during flood. In Roman bridges, flood splitters were generally built in small, low triangular shapes and to end at the level of joist hanger. They end in a rectangular shape in the opposite direction of flow. Flood splitters can be encountered in circular shapes in certain rare examples.

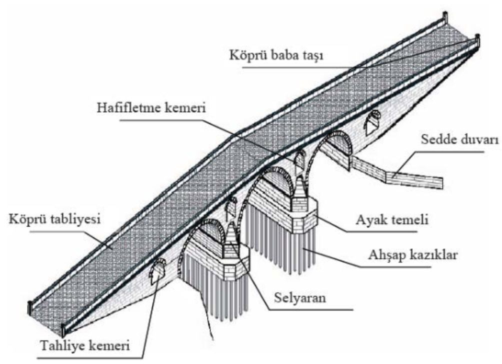


Figure: 1st Bridge Elements (Alaboz, 2008).

In Seljuqian and Ottoman period, bridges in Anatolia were built in a way to reach the maximum height and gap in the middle with narrower arch gaps and lower heights towards the end, thus having a high slope, considering the height and pressure forces the rivers would reach because of their turbulent flow. The pointed shape was particularly used in arches [2].

4.Bridges in Sinan the Architect Period

The greatest Engineer and Architecture Sinan left his mark on bridge construction in the 16th century which was the most powerful period of Ottoman Empire.

He focused these bridges in Thrace which were built to secure and facilitate military and civil transportation from Capital Istanbul to west and east. The total length of four-piece Sultan Suleyman Bridge, a work of Sinan, on Buyukcekmece Lake is 635 m. Having built nearly five hundred structures, Sinan lists Buyukcekmece Bridge among his top six works he regards the most.

4.1. Buyukcekmece Bridge

Buyukcekmece Bridge consists of four bridges constructed over three islets. Starting from the east side, I. Bridge has 7 arches and 157 m. at length, II. Bridge has 7 arches and 135 m. at length, III. Bridge has 5 arches and 101 m. at length and IV. Bridge has 9 arches and 183 m. at length. Bridges were built in two-sided slope that reaches its highest point at the top of the middle arch. Being considered among the most significant works of Sinan, the bridge is also the single structure signed by him [2].

There are two opposite observation spots in the first bridge of Buyukcekmece Bridge towards the European Side and the history spot on the fourth and the biggest bridge. History and observation spots, specific to Ottoman bridge architecture, are located in a way to stick out in the shape of cantilever.

There are king posts, found in every Turkish bridge, at the beginning and ending of every section of the bridge. Connection gaps between every section were constructed without railings so that excess water in massive floods would flow through without damaging the bridge.

Image: 1. Mimar Sinan Bridge (Buyukcekmece)

4.2. Kapuagasi Bridge in Haramidere

This bridge is located over Haramidere on 30th km. of Edirne road. Today's route to Edirne passes through the new bridge. Arch stones of the bridge are 58-59 cm. There are discharging cells in the middle piers. While the previous slope of the bridge was 9-10%, today it is 2%. The bridge consists of three arches. They are either pointed or lancet arches. Side spans are 7,37 m. middle opening is 8,79 m. Discharging cells at the sides are 2,26 m. and the ones in the middle are 1,8 m. The width of piers is 3, the width of bridge road is 6,10 m. [5].

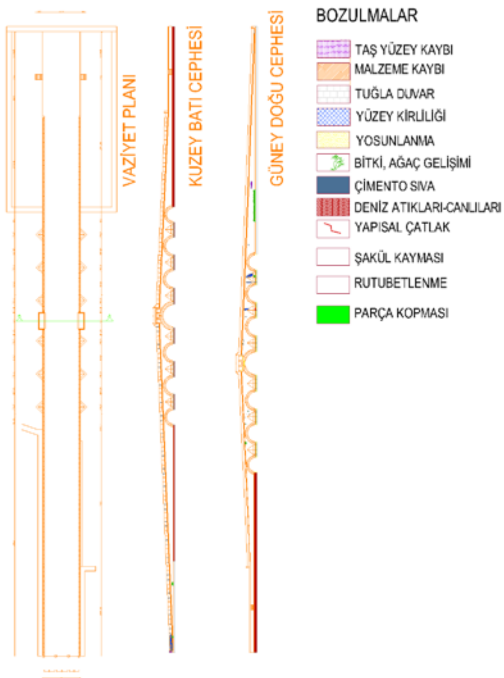
Image: 2. Kapuagasi Bridge (Haramidere)

5. Building Techniques of Mimar Sinan Bridge

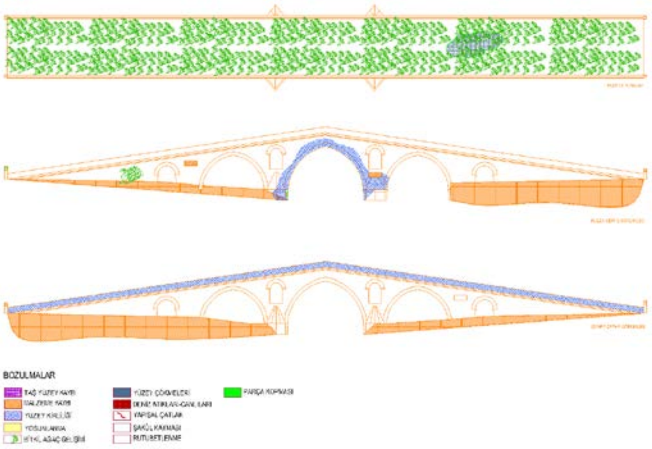
Bridges are located over bridges, lakes by driving piles into the ground and placing footings over piles for stabilization. According to the statement in Tezkiret-ul Bunyan, having started to build Buyukcekmece bridge upon the order of Suleiman the Magnificent, Sinan first analyzed the floor and chose to build on a shallow, solid place close to sea rather than building on the swampy side. The spots to drive piers were surrounded by cofferdams; after the water inside was discharged, piers were driven by rammers and stone footing was built over the piers. Massive blocks of stones constituting the footing were connected to each other by iron clamps and stabilized by pouring lead in between. The length of piers was reported in Tezkiret-ul Bunyan as "*as tall as two or three persons*" [1]

6. System Analyses of Bridges of Sinan the Architect

Survey studies were conducted in Mimar Sinan (Buyukcekmece) and Kapuagasi (Haramidere) bridges of Sinan the Architect within the study and it was focused on the similarities in terms of construction techniques and deformations in the bridges of Sinan the Architect. First surveys were conducted in both of the bridges within the study and then damages due to natural disasters and human effects were analyzed. Damage types determined in the study were explained to make recommendations of intervention in regard to restoration of damages.



Drawing: 1. Mimar Sinan (Buyukcekmece) Bridge



Drawing: 2. Kapuagasi (Haramidere) Bridge

Photo: 1. Buyukcekmece Bridge (Surface Accumulation)

Photo: 2. Buyukcekmece Bridge (Vegetation)

Photo: 3. Buyukcekmece Bridge (Damages)

Photo: 4. Buyukcekmece Bridge (Fragmentation)

Photo: 5. Buyukcekmece Bridge (Salification)

Photo: 6. Buyukcekmece Bridge (Cracks and Fractures)

Photo: 7. Kapuagasi Bridge (Surface Accumulation)

Photo: 8. Kapuagasi Bridge (Surface Accumulation)

Photo: 9. Kapuagasi Bridge (Damages)

Photo: 10. Kapuagasi Bridge (Fragmentation)

7.Assessment And Conclusıon

Turkey is a rich country in terms of immovable cultural assets. Black incrustation is frequently encountered on the surface of these immovable cultural assets because of air pollution, atmospheric effects, traffic, ways of use and material degradation factor (salts, acid rain etc). The goal of cleaning is to remove insoluble or poorly soluble shells, soluble salts, various layers of restoration, smut, dust, microorganisms, parasite plants and bird or animal wastes. Deformation of historical artifacts which bear utmost importance not only in terms of tourism but also of handing down the next generations our history, culture and traditions is a problem not to be neglected both for the sake of humanity and our country. In order for our historical structures to be preserved for future generations, it is necessary to determine the causes of the deterioration that arise in these artifacts correctly and to take appropriate precautions.

Deteriorations observed in Mimar Sinan and Kapuagasi Bridges, analyzed within the study, and solution offers were established.

7.1. Buyukcekmece (Mimar Sinan Bridge)

The differences in texture, size and type of concrete used in the bridge cover indicate various repairs. These repair traces can be specified as the explanation of the absence of a structural damage on a large part of the structure. However, it provides information on what kind of damage the structure was exposed to prior to repair.

- Deformed arch forms have been observed and the arch forms must be restored in order to correct the unbalanced load distribution on the structure.

- Stream rehabilitation studies should be done to regulate the stream regime, and possible damages to the structure due to unbalanced loads on the piers should be prevented.

- Previous interventions on the bridge are observed. The parts repaired with cement mortar should be renewed with a mortar suitable for the original mortar composition.

- Arch should be renewed with a mortar suitable for the original mortar composition by discharging the joints in the areas repaired with concrete.

- Scour and fractures in flood splitters and piers should be repaired.

- Plants that damage the building physically and visually should be cleaned.

7.2. Haramidere (Kapuagasi Bridge)

When considered in general, there is not any structural damage requiring immediate precaution. However, as stated in the studies;

- It is required to remove negative effects on the structure such as dirt on the facade and inside the arches, use of cement mortar in joints and rise of soil level.

- The paving stones used in the bridge pavement should be removed and returned to original

- The accumulations of environmental wastes and the dirt build-up brought by the changes in the regime flow must be removed

- Missing and deteriorated king piers should be renewed staying true to the texture of the structure.

- Surface cleaning is required in facade stones and arch interior with an appropriate method.

- It is suggested to repair the deteriorations in the discharging cells, built with bricks, and relieving arches in a method suitable for the construction technique.

- Plants that damage the building physically and visually should be cleaned.

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