CONSERVATION OF UZUNKEMER AQUEDUCT ISTANBUL, TURKEY

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SUMMARY

Uzunkemer, a 711 meters long and 25 meters high aqueduct is part of a conveyance system supplying water to Istanbul. The remains of a Roman aqueduct were restored in mid-sixteenth century in order to provide water to the Ottoman capital . The structure has been in use ever since, but its stones have deteriorated and it is affected by environmental changes . The paper presents the project developed to ensure the long term stability of the monument.

1. INTRODUCTION

Uzunkemer aqueduct is situated to the north of Istanbul, where plenty of water springs are found. These sources must have been used since Antiquity. The Roman water supply system was probably neglected during the late Byzantine period and fell into ruin. About 1550 , the renowned Ottoman architect Sinan was commissioned to build a new water supply system for the fast growing population in the capital. Nine years of hard work resulted in the building of a nearly 50 kilometers long water conveyance system, called the *"Kirkçesme"* ; it supplied water to about three hundred public fountains in the city. *"Uzun"* means long in Turkish and Uzunkemer is the longest among the four major aqueducts within the Kirkçesme conveyance system. It spans a beautiful valley, running in the direction north-south (Fig. 1) . At its northern and southern ends , the water channel is supported by solid walls. The two-storey high middle part consists of archivolts spanning approximately 4.5- 5.35 meters. There are 47 arches in the lower and 50 arches in the upper level. The aqueduct changes direction at the

Fig. 1 : General view of Uzunkemer from southeast, showing the northern part of the aqueduct (K. Çeçen, 1987)

pier between the twenty-third and twenty-fourth openings. Historic documents supply limited information about the state of the Roman ruins at the time of the renovation ???. A careful examination of the present structure reveals evidence of the incorporation of ancient and Ottoman masonry. The date of construction is between 1554-1563. In 1564, heavy rains caused floods and Uzunkemer was damaged. In the section rebuilt immediately after the flood, the piers were strengthened by abutments.

Uzunkemer and four other aqueducts from the sixteenth century are important representatives of ancient civil engineering practice . They continue the Roman structural conception and architectural form except in the arches which are slightly pointed. The good state of preservation has been possible by the constant care of the system during the Ottoman period. The Ottoman masonry of Uzunkemer is very similar to Roman work; sixteenth century masons tried to emulate the rusticated style . Large blocks were used for the facing but the main bulk

of the piers is rubble masonry with Roman mortar. The blocks were joined with iron clamps; dowels and clamps were employed in the construction of the arches and vaults.
Some masons marks were observed on the pier blocks. Small rosettes, patterns of Catherine's wheel or Solomon's seal were carved on the pier blocks or the keystones to embellish the masonry. The beautiful rosette near the inscription block with the God's name is unfortunately vandalized, probably by treasure hunters who took it as a sign of a hidden treasure.

The property is under the custody of the Waterworks Department of Istanbul Metropolitan Municipality (**ISKI**) . It has been neglected for many years and there are serious decay problems. The Monuments Council responsible for the area recommended the preparation of a restoration project for this significant monument . ISKI was urged to start a conservation project in 1996 . During the documentation phase of the project, some of the decayed blocks were dislocated and fell on the highway . Concern for public safety prompted immediate action on the part of ISKI and at the end of 1998, a scaffolding was put up to protect the cars passing under the impaired arches.

2. METHODOLOGY FOR SURVEY AND ASSESSMENT OF DAMAGES

Uzunkemer is a famous monument attributed to Architect Sinan ; it has been studied as part of the Ottoman architecture of the sixteenth century ?2?. Professor K. Çeçen, a hydraulic engineer, studied the Kirkçesme system in the 1980's; his books provide extensive historic and technical information about this important building ?3?.

The aqueduct had been surveyed before but the drawings were not sufficient to develop a restoration project. Our first task was to produce a good survey of the present situation. The next step would be to record the damages and search for remedies to improve the stability of the vaults . The project was undertaken with a multidisciplinary approach; contribution of several experts has made it possible to investigate the different aspects of the historic structure.

2.1 Photogrammetric survey

The aqueduct is very high and the first floor level is not accessible without scaffolding. In order to attain accurate drawings in a short time, photogrammetry was preferred. The funds allocated for this project were not enough to survey the 700 meters long structure; the available budget only permitted to work on an 80 meters strip, between the arches 12- 20. The study area included the hazardous section over the highway. . To attain good images of the masonry, the vegetation covering the architectural features had to be removed . An expert team lead by Professor O. Müftüoglu from the Civil Engineering Faculty of ITU was responsible for the 1/50 scale photogrammetric survey.

2.2 Damage assessment

Natural as well as man-made damages have been active on the aqueduct for centuries. Stone surfaces have decayed; many of the joints are loose. Trees have grown on the façades and over the top of the waterway; their roots causing serious damage to the masonry.

Since 1990 a garden-city type housing has been developing next to the western side of the aqueduct. This has spoiled the rural landscape; now it is impossible to perceive the aqueduct in its pure architectural form against the rural landscape. During the last ten years, the number of lorries passing under the aqueduct has increased considerably and the aqueduct is also suffering from the vibrations and pollution of heavy traffic.

Originally the façades were built of big blocks of ashlar. In some areas the stone blocks have weathered seriously. It is possible to discern different materials and techniques used to repair the damaged members or areas. Some of the recent repairs were done in a very quick and cursory way. Thin slabs of stone have been placed on the exterior surface of the arches - to make them look solid and healthy but behind the thin slabs, the voids are still visible; the cosmetic repair has not been successful. Another old repair technique is the use of small pieces of new stone blocks to repair the voussoires. These were fixed to the old masonry by means of clamps, many of which are still in good condition. These will be preserved as part of the history of the structure.

Surface erosion is a common defect; some blocks show significant signs of flaking. A more advanced form of decay is the total loss of blocks as a result of which there are lacunae in the façades. These attract birds and other animals to nestle within the masonry. Rain goes into the structure and speeds up erosion. The water conduit which runs at the top of the structure has lost its protective cover. For a long time it leaked and caused damage to the arch opening underneath. Continuous flow of water over the damaged stone blocks has aggravated the corrosion of iron clamps and dowels in the masonry and rust stains have developed .

The damages on stone blocks were surveyed and mapped on 1/50 scaled elevations. Each stone block or voussoir was examined and blocks which needed remedial treatment were identified. Direct access to the upper level of the aqueduct was only possible at the points where scaffolding was erected. The other parts were inspected with the help of binoculars or large-format photographs.

2.3 Structural assessment

Professor F. Çili, a structural engineer specialized in masonry structures, examined the piers and vaults carefully, to report on the safety of the structure. The critical points of the structure have been identified as the missing voussoires and detached blocks near the keystones. After a review of the structure, the priorities for intervention were defined. The proposal is to start the consolidation of the structure from the vaults of the fourteenth opening and to proceed with the lower vault of the eighteenth and upper vault of the nineteenth openings. All the detached stone blocks need to be secured to their positions.

2.4 Material properties

Local limestones had been used for the main structure, the piers as well as the arches. Some of the historic repairs were done with similar material. Dr. A. Gülec sampled and characterized original wall and pointing mortars were by means of laboratory research.

Fig. 2: Detail from the western façade; the first floor arch of opening 14 (Z. Ahunbay, 1999)

3. CRITERIA AND TECHNIQUES FOR CONSERVATION AND RESTORATION

Uzunkemer is a prominent feature of the local landscape and an irreplaceable treasure for Istanbul. Continued maintenance is required to ensure the preservation and safety of this significant structure. Minimum intervention is the key to remedial measures . All the original blocks should be preserved and kept by in-situ repairs. The old repairs are part of the history of the structure; they will be preserved. Small areas of lost stone can be replaced by plastic repairs. The significance of arches as the major structural safety elements makes it essential to restore them to their original form and bulk. Only the voussoires which are accessible from the facades can be repaired easily, by pushing the wedge-shaped blocks into their position. To work on damaged soffits of vaults is very difficult. The work has to be done very carefully; the quality of the execution will affect the success of the intervention.

3.1 Maintenance, preventive measures

ISKI has to establish a team of qualified masons and other craftspeople to take care of the historic aqueducts it is responsible for. The historic structure is strong and durable but constant care is essential to ensure its survival. This can only be achieved by good management of the heritage.

3.2 Stitching and stone replacements

Some of the blocks are cracked; they need to be fixed with non-corrosive clamps or synthetic resins. The totally lost stone blocks need to be replaced with stone of the same or matching quality. At present the quarries from which the original limestone was supplied are not active. For the replacement of badly damaged or lost blocks similar limestones will be provided from other quarries.

3.3 Plastic repairs and fillings

There are cavities or missing parts in the stone blocks belonging to the piers or the vaults. The simplest way to improve decayed surfaces is by plastic repair. The composition of mortar to be used for plastic repairs has been developed by Dr. A. Ersen. Stainless steel rods are to be used to improve the adhesion of the repair and to help it to resist internal and external stresses.

3.4 Injections and pointing

Injection using a lime-based mortar composed of white cement, brick powder and acrylic emulsion is recommended in areas where cavities are formed. Filling the voids in the masonry will help to establish better adhesion between surface stones and the core, strengthening the structure.

Originally the large facing blocks were joined with very thin courses and thus they were water-tight. After centuries of erosion, the arrises have lost their sharp edges and many of the joints are very wide in comparison to their original size. In order to prevent penetration of water into the masonry, all the joints need to be pointed carefully using a mortar mix compatible with the original. With this aim, he mortar mixes for repair work were designed so as to match the original *khorasan* composition. The floor of the upper level openings and the capstones of the waterway should be water proofed in order to protect the structure from rain and frost.

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