Restoration of masonry arch bridge over Venta River in Kuldiga

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Introduction

Even the clay bricks had been known since the 12th century, the use of them for bridge structures actually started only in the 19th century. In a very short period (from the middle until the end of the 19th century) had been built several significant bridges (Glotch and Elstertahl Bridges in Germant [1] and other). Bridge over Venta River in Kuldiga built in 1874 belongs to the longest clay brick masonry highway bridges in Europe. The bridge consist of seven 17 m long arched spans with total length of 164 m (Fig.1). The historians say that the construction was carried out on a very high level the best construction materials were used. The evidence is that bricks and cement for mortar were chosen after careful tests in labs of Riga Politechnicum. The bridge was open for transport on 2nd of November 1874. German troupes blew two arches at Riga side up during the World War I. Temporary constructions were built over the demolished arches. They were renewed in 1926. The destroyed brick structures were replaced by reinforced concrete structures. The facade was painted in red in order it looked the same as the rest of the bridge.

Fig.1: View of the bridge after renovation

Nevertheless during the long lifetime the bridge had a lot of damages that could influence the further service life.

The clay brick masonry bridges in Europe that have been built 130 and more years ago deteriorated with the time due to environmental impact or due to pro-active maintenance approaches. Often these bridges are historical heritage therefore many European countries perform investigations about the favorable restoration methods, including investigation of building materials and calculation methods of load carrying capacity.

The aim of this work is to analyze and evaluate the investigation results of historical clay brick and connective mortar properties and provide the recommendations for reconstruction of bridge.

Inspection of bridge structures

Historically the bridge consist of two parts – the 133 years old initial part and 81 year old restored part. Consequently it is possible to analyze “old” and “new” part separately. Already the inspection carried out in 1926 discovered serious problems in waterproofing and water drainage. In the pictures of archives can be clearly seen signs of water filtration with mineral undermine in both facades as well as in the arch surfaces.

The inspection carried out in 2006 showed several deteriorations in masonry wall and arch structures. There were found in bricks, some stones had crumbled away in piers, cracks in reinforced concrete (Fig. 2).

Fig. 2: View of the fifth arch in 2006 inspection

During the inspection was found that hydro insulation and drainage of surface water had been damaged due to long term use, and it had caused crumbling of water filtration in bricks through the surface of arches and side facades. Brick corrosion, crumbling of joint materials due to long-term water filtration could cause the loss of bridge’s carrying capacity.

Historical clay brick and mortar properties

During lifetime the clay brick masonry deteriorated and lose his initial qualities. An important task therefore becomes the preservation and restoration of clay bricks in the existing masonry bridge structures.

The use of soft bricks with lime based mortar (as in structure from 1874) allow the water migrate in masonry and did not rise the damages. The use of cement based mortar for joints with soft bricks (as in structure from 1925) accumulate the water in bricks and the frozen water destroys the brick from inside (Fig.3). The obtained results allow taking right decisions by restoration and upgrading.

Fig.3: View of new parapet built in 1926

It is important to ensure the natural water migration in historical masonry.

When working out the restoration project, very careful research had been done on the bridge. Stone Conservation and Restoration Center (Dr. Inta Vitina) of Riga Technical University was asked to research bricks and mortar. Tests of physical features of stones showed that all historic bricks had a high level of porosity and water absorption. The reinforced concrete tests had considerably lower quality. It is important to show that indicators of porosity of dolomites and water absorption are similar to brick indicators. It means that dolomite is compatible with bricks and ensures the right *breathing* to the brick wall. But the brick wall fixed with cement mortar and ferocious concrete are not compatible with historic bricks and historic dolomite grout, because it makes exudation of dampness and *breathing* of the brick wall harder. Such combination of materials stimulates corrosion of bricks especially in places where the stone wall of 1926 had been renovated with the cement mortar. It is clearly visible when compare the technical condition of original and renovated in 1926 parapets (Fig.4).

Fig. 4: Bridge parapet (on the left side the one built in 1926 and on the right old one)

Chemical tests of salt pollution of bricks, reinforced concrete, dolomite stone and the old dolomite grout indicate that the level of the salt soluble in water is very low and does not correspond to criteria of unsalted brick walls although before the cleaning of the bridge in 2001 signs of white salt could be found. The reason for that might have been Calcium Carbonate ($CaCO3$) that usually appears on historic monuments because of water migration through bricks, undermining Calcium Hydroxide out of grout and mortar. When the drying Calcium Carbonate carbonizes on the brick surface it creates insoluble Calcium Carbonate that can be cleaned by heavy water or sand jet only thus increasing the brick corrosion because the natural protection layer is getting damaged. The pH level that was found in reinforced concrete is 8.5 and 9.3 thus showing signs of corrosion created by carbonization(Fig.5).

Fig.5: View of reinforced concrete arch

The research allowed working out renovation tasks of the bridge – the damaged bricks should be changed with bricks of the same quality utilizing the cleaned old bricks from buildings of the same time or making use of the brick *Sencis* that is produced in factory Lode after the old mixing formulae. Disintegrated and mechanically weak brick surface should be cemented and wholes should be filled with special restoration mortar. Cement mortar should not be used for brick joints. The best one is dolomite grout with 5-10% Portland cement as a binding material.

Reconstruction design

The first thing to do is to dismantle the road surface and to dig out the filling of arches in order to see the technical condition of the bridge. After the digging up of the filling had been done it was possible to see that the bridge is in good condition – the surface of reinforced concrete did not have big damage or cracks. But for our traffic intensity the carrying capacity was not good enough, therefore it was planned to reinforce it by building steel framework for arches 6 and 7(Fig.6).

Fig.6: View of concrete arches

The surface of brick arches was in good condition, old waterproofing and protection layers where still partly there. Therefore the most necessary tasks were to restore waterproofing (Fig.7) and fill the arches with draining soil.

Fig.7: New waterproofing

For the bridge to be able to carry the transport capacity provided by transport rules, a reinforced concrete slab resting on a ground filling of arches will be put on the top of brick arches. This slab provides not only some bearing capacity and load distribution but also helps to collects and drains water from the deck (Fig.8). Side and piers of arches will also get restored. It is planned to renew the present electricity poles, to make four new ones (the analogues), as well to reconstruct the system of technical support system. A very modern lighting system will be built.

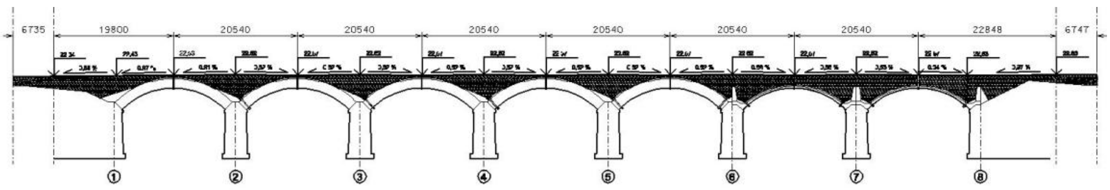

Fig.8: Longitudinal section of the bridge

After renovation it will be possible to use the bridge over the River Venta for everyday traffic capacity provided by transport rules (Fig.8).

Fig.8: Bridge deck after renovation

Conclusions

The renovation of masonry arch bridge over Venta River in Kuldiga has been a successful project that proves the importance of material and structural resource. Using data from these researches it was possible to ensure the natural water migration in this historical masonry bridge as well as protect the bearing contractures from farther deterioration.

Literture

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