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STRUCTURAL TECHNICAL INSPECTION AND PROJECT PREPARATION FOR RECONSTRUCTION OF REINFORCED CONCRETE RAILWAY VIADUCT IN KRNSKO

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Abstract: *This paper describes undertaking and results of structural technical inspection of reinforced concrete railway viaduct in the Krnsko municipality and subsequent project for preparation for its reconstruction as based on the findings of this inspection.*

Keywords: Railway Viaduct, Concrete, Technical inspection, Reconstruction.

1. History of the Viaduct

The Krnsko viaduct is a railway bridge located at 67.615 km on the line no. 070, i.e. line Praha – Turnov. The bridge is a valuable historical object and is national monument since 1958. The bridge has 3 arches and spans over the valley of Strenický brook and two roads I/16 and III/27223. When this railway was opened in 1865 a steel truss bridge of the Schiffkorn cascade was here. This bridge was replaced by welded steel continuous truss bridge in 1884. This bridge did not satisfy requirements of the traffic even before the WWI and its reconstruction was thus decided after 60 years of service. The tender was won by company Ing. Hlava and Dr. Kratochvíl. They designed 3 slender concrete arches with span of 28 m and height of 12 m between the existing pillars. There are vertical walls ended with smaller arches supporting 5m wide deck. The author of this design was Ing. Stanislav Bechyně. The bridge was built in 1924 and represented the first concrete railway bridge in Czechoslovakia. This bridge was remarkable not only for the construction material but also because the continuous trackbed was used. The overall construction time was approximately 5 and half months (finished on 18th Sep. 1924). The railway traffic was closed only for 40 days. There was 90 tons of steel used for the 4097 m^3 of concrete. This makes 22.5 kg of steel per 1 m^3 of concrete. The structure was designed as under-reinforced concrete whose strength is only a little bit greater than that of a regular concrete.

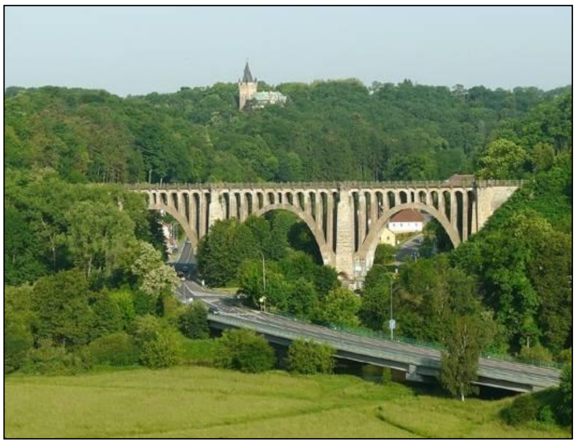

Fig. 1: General view of the Krnsko viaduct with castle Nový Stránov at the background.

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2. Construction and Technical Inspection – Used Methods

According to the task definition of the developer (TOP CON SERVIS, s.r.o.) the inspection was to assess the condition of the load-carrying mainly reinforced concrete structure. The structure was damaged by long-term leakage due to damaged hydro-insulation of the deck. The main method was a visual inspection of the surface of the load-carrying structure including acoustic tracing of the reachable surfaces, inspection was based on classical foundations (Drochytka et al., 2012; Kolisko and Rehacek, 2007). In the next phase we carried out non-destructive and destructive tests of the concrete strength in compression, determined the thickness of carbonation layer, identified and localized the reinforcement and assessed its state of corrosion. During the in-site inspection tensile strength tests of surface layers concrete were carried out. Further the chemical analyses of the concrete was done to determine the content of aggressive agents such as chloride ions. The examination works have taken place in November and December 2011 and were led by Ing. Stanislav Řeháček and Assoc. Prof. Ing. Jiří Kolísko Ph.D.

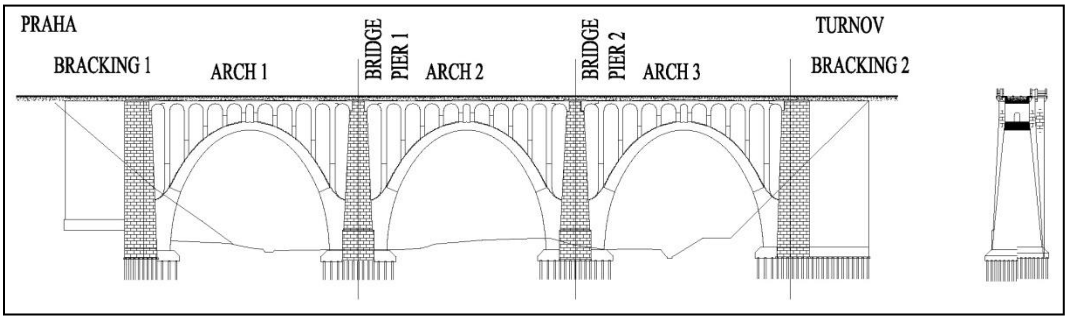

Fig. 2: Longitudinal chart and cross section of the Krnsko viaduct. The examination was carried out in indicated places.

3. Results of the Construction and Technical Inspection

The inspection found out that visible parts of the bearing structure of the bridge do not show marks of significant defects as may be excessive deformations, remarkable cracks, crashed concrete parts etc., which would signal reduced loading capacity or even loss of the whole structure stability. Basic defect of inspected concrete, caused already during initial construction is its high patchiness (Fig. 4) found by almost half of core drills and visible in the form of gravel pockets even in large area of the visible surface. The structural concrete had been further damaged mainly due to intense leakage caused by non-functional hydro-insulation of the deck and impact of weather conditions. Its classification according to currently valid standard ČSN EN 206-1 was done individually for individual structural parts and varies in the marking range C16/20 to C 25/30. Found average tensile strength of surface layers reached about 2 MPa. Content of chloride ions in the surface layer up to 30 mm was assessed as low in accordance with ČSN EN 206-1. From the aspect of conditions for reinforcement corrosion the decisive parameter is depth of carbonation which is rather variable in the inspected structure. Good situation was found in main arches, the bearing reinforcement of which is located almost all in non-carbonated part of the concrete. Markedly worse situation is on the contrary in lateral walls of arcade system. Concrete columns and abutments have such a poor steel reinforcement that it has not been reached at all in the depth of 70 mm (measured from the surface). Corrosion of reinforcement found by probes was mostly surficial but locally also extreme, with the section thinner by more than 50 % (Fig. 3). On the surface of main wall arches is degraded the original water-insulation screed failing to fulfil its function long ago. The result are massive efflorescence with leaky cracks on the bottom face and sides of vaults, areal surficial degradation of upper face with local deterioration in bigger depths, in places reaching the steel reinforcement. In parts are visible gravel pockets, mainly by working joints, caused by mixtures and technologies of compacting used during construction of the bridge. Lightened vaults arranged in upper arcade are also damaged on the surface. Larger defects of the concrete are mainly on the edges of walls and in the area of in-built drainage downcomers. Locally can be found places with covering concrete layer ripped off which is caused by the corrosion – increased volume of profile of corroded steel reinforcing bars. Reinforcement corrosion is visible mainly in areas of thin coverage. Remarkable defects were found in the place of dilatation of inserted deck fields, through which is water strongly leaking to the structures of lightening arcades. Reinforced nibs are markedly damaged, on which are set the inserted field and related stonework of columns. Damage of concrete in this area is reaching deepest. Stone parts of columns and abutments are deteriorated only surficially in very thin layer. Abutments are damaged more than columns in connection with more extensive accumulation of water behind the reverse side and also due to impact of roots of spreading vegetation including woods. Concrete parts of columns and abutments are damaged similarly to the main vault arches.

Fig. 3: Deep corrosion of the reinforcement.

Fig. 4: Detail of the drillhole – patchy concrete.

4. Concept of Solution of the Bridge Maintenance

4.1. Reconstruction of inserted fields setting

Part of the bearing structure are six inserted fields 2.8 m – 3.2 m with semicircular suspended soffit separated with dilatation joints from abutments, columns and arched parts of NK. Inserted fields will be lifted and maintained with the same procedures as other parts of reinforced bearing structures. Weight of each inserted field is about 43 t. Lifting will be done with use of pre-designed assembly tools.

Masonry of abutments and columns will be unpieced in the place of setting of inserted fields up to the height of 0.5 m and replaced with new reinforced bearing sills made from concrete C30/37 - XF3. Couple of bearing sills on the columns will be fastened together with steel bars set in the drills in original pier cap. Anchoring of bars will be hidden in the bearing sill. New reinforced bearing sills will connect the upper part of the column in the area of setting of inserted fields thus allowing fitting of Teflon ledgement bearing and would improve distribution of horizontal forces caused by the transportation to stone parts of the substructures and exclude transmission of horizontal forces originated in temperatures caused by non-functional sliding bearing and causing degradation of upper parts of stone abutments and columns. Degraded concrete of nibs of bearing structures will be demolished, remaining parts will be cleaned and possible damaged reinforcement will be completed and nibs will be re-profiled or completed with concrete into the original shape. Refurbished original inserted fields will be set on Teflon ledgements.

4.2. Refurbishment of reinforced bearing structure

The whole original reinforced structure will be refurbished including inserted fields, which will be refurbished after their getting down. With exception of inserted fields all works will be performed under operation on the bridge after setting up of new waterproof insulation.

Proposed procedure of refurbishment works includes the following:

- preparation of the base with silica sand blasting,
- removal of damaged covering layers in parts of corroded reinforcement, stripping, cleaning and passivation of corroding reinforcement or its completion, if necessary,
- grouting of the whole structure with micro-fine-cement (MFC),
- filling of gravel pockets and caverns,
- re-profilation,
- allover consolidation screed,
- protective paint.

4.3. Refurbishment of functional layers of ledges

In areas where the functional layer is not cohesive with the base, mainly in wall niches on abutments or where it is damaged, it will be removed. Subsequently the functional layers of ledges, depending on the grade of damage in individual areas will be concreted with the layer reinforced with mash or re-profiled. Dilatation joints in parts of ends of inserted fields will be sealed or covered.

4.4. Refurbishment of stone walls of the substructure

Walling of the substructure will be rid of remains of vegetation, cleaned by jet water, deeply re-jointed and based on results of water pressure tests it will be grouted with cement mixture. Individual weathered stones will be replaced, faces of abutments will be locally re-masoned.

4.5. Waterproof insulation

Bearing structure of the bridge will be insulated with system of waterproof insulation (SVI) against descending water with asphalt double-strip waterproof layer, fully connected with the base, on horizontal areas with hard protective layer from cast asphalt 30 mm thick, on vertical areas with soft protective layer.

Functional area of ledges will be insulated with directly-functional screed with coarsening pour pulled over the strip of anchoring of the insulation on the side of rail bed.

4.6. Drainage

Current concept of bridge drainage will be kept, only cross drains will be added in the place of termination of the insulation behind ends of wing walls.

Original layer of cambered concrete thickness of 0 to 170 mm in the bridge axis will be demolished and replaced with new cambered concrete layer C30/37 - XF3 reinforced with mesh, thickness 50 - 220 mm in the bridge axis. Original drains of the insulation surface will be replaced. Original downtakes of drainage will have replaced the pipes from rustproof steel. In the area of entries of revision staircases through walls will be connected downcomers made from HDPE pipes running on internal side of walls, except concrete section, from the top directly to original concrete drains, running along revision staircases on the upper surfaces of vaults.

4.7. Handrailing

With regards to national heritage protection the original reinforced handrailing columns will be preserved on the bridge. Original couple of pipe rails will be replaced with triplet of rails on the elevations of pipe rails axis 150 mm, 650 mm and 1150 mm above functional layer of the ledge. Concrete columns will be redeveloped.

5. Conclusion

Reconstruction of the bridge showing constant defects has in majority two steps. First is to stop degradation of concrete and second is to reinforce the concrete. Taking into consideration that this bridge has necessary ability of passage, all financial means will be used for complete redevelopment and water insulation of the whole building thus extending its life for another decades.

Acknowledgements

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