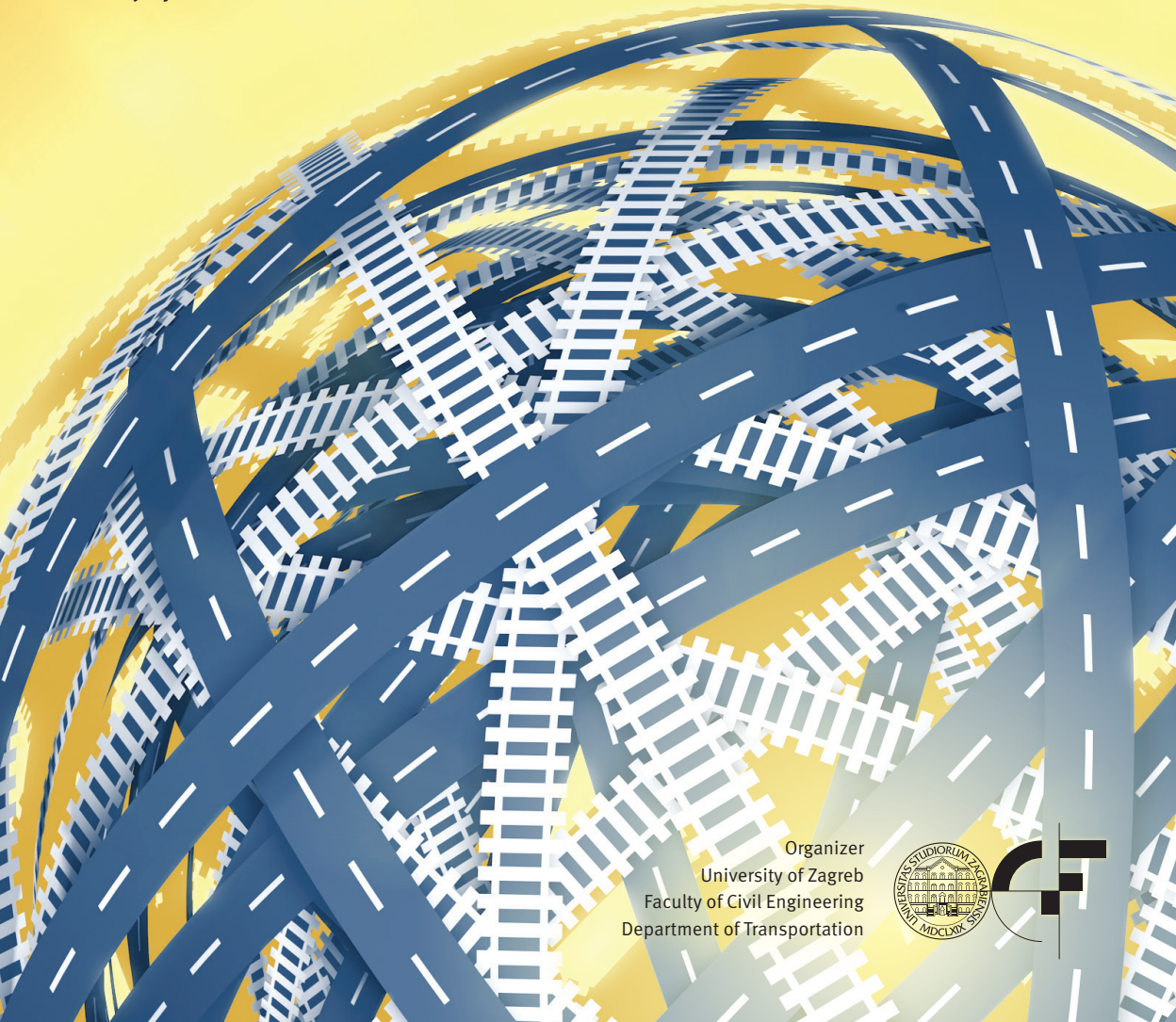


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4th International Conference on Road and Rail Infrastructure
23-25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



Organizer
University of Zagreb
Faculty of Civil Engineering
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RECONSTRUCTION OF THE RAILWAY TUNNELS TIČEVO, KLOŠTAR AND RESNJAK

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Abstract

The reconstruction of the railway tunnels Tičevo, Kloštar and Resnjak was carried out as a part of the reconstruction and modernization of the RH2 corridor railway line M202 Zagreb Main Railway Station – Rijeka. Reconstruction of the railway tunnels Tičevo, Kloštar and Resnjak, each of which is characteristic in its own right, entailed the reconstruction of the tunnels, tunnel portals, approach cuttings at the tunnel entrance and exit, by installation of the state-of-the-art materials, using the specific technology of execution of works, and respecting the defined railway line closures to ensure railway transport safety, and reconstruction of the civil-engineering, power-electric, control-command and signaling and interlocking subsystems as a single unit.

Keywords: reconstruction of the railway tunnels Tičevo, Kloštar and Resnjak

1 Introduction

Railway corridor RH2 stretches from the state border with Hungary through Botovo – Koprivnica – Dugo Selo – Karlovac – Rijeka – Šapjane and ends at the state border with Slovenia. Railway line M202 Zagreb Main Railway Station – Rijeka is one of the railway lines which are situated on that Corridor alignment. Because of the detected instabilities in the approach cuttings (the geo-technical structure in front of the entrance portal) and exit cuttings (geo-technical structure after the exit portals), and in the tunnels, such as the rockslide of the stone blocks, raised shotcrete on the rings in the tunnels, appearance of stalactites in the winter period on the contact wire and track, which jeopardized the safety of the railway transport, people and material goods, it was necessary to start the reconstruction works, which, in addition to the works of track reconstruction, contributed to improvement of the technical conditions of the civil-engineering infrastructure subsystem.

2 The initial condition and reconstruction requirements

During maintenance of the tunnel, the instabilities on the approach and exit cuttings of the tunnel were detected, reflected in of falling out of stone blocks of various sizes due to deterioration of the rock mass; rockfalls due to flushing of soil and loss of retaining capacity; sliding i.e. uncontrolled slipping of the material onto the railway line, while in the tunnel in the winter period the appearance of stalactites on the contact wire and the track in the structure gauge of the rolling stock were detected, causing disturbances on the overhead line equipment and the danger of breaking, but also the danger of the train damage and derailing.

The reconstruction was aimed at providing safety of the railway transport, people and material goods by providing permanent stability of the approach cuttings, exit cuttings and tunnels, in order to ensure the conditions in which the key properties of the structure are provided,

which in turn would enable performance of the regular maintenance cycles without major financial spending.

In selection of the solution of reconstruction it was necessary to take into consideration the height of the overhead line equipment and its minimum distance from the tunnel vault, meeting of conditions of the GB structure gauge, and in the approach and exit cuttings, for the sake of integration into the natural surroundings and preservation of the original configuration, the technical solution should be such to let it blend into the natural surrounding and retain its authentic configuration and appearance, and at the same time to be in line with the technology of works on the railway lines (carrying out of works at a fast pace within a short period). All railway tunnels are constructed without hydro-insulation which protects from penetration of water, and the rings of dressed stones are at the same time their primary and secondary lining. Tunnel Tičevo, 173 m long, was constructed in 1872 for two tracks. It is situated between the stations Ogulinski Hreljin and Gomirje and consists of 19 tunnel liners, rings of dressed stones with the interspace of the live rock, and the overburden of ca. 10 m, on which here and there is shotcrete. The entrance portal has already been reconstructed with shotcrete and exit portals are situated in the live rock. The approach cutting and exit cutting are also in the live rock.



Figure 1 Entrance portal of tunnel Tičevo and the exit cutting

Tunnel Kloštar, 248,40 m long is situated between stations Gomirje – Vrbovsko. It was constructed in 1872 in the limestone rock with the overburden of ca. 7 m. It has five tunnel liners, i.e. rings of dressed stones with the interspace of the non-lined rock. Its width accommodates two tracks. On all five rings there is shotcrete of questionable stability. The entry and exit portals are of the live rock above which there is the earth mass underpinned by the mass of the trees. The approach and exit cutting are in the live rock.



Figure 2 Entrance portal of tunnel Kloštar and tunnel's interior

Tunnel Resnjak, 197,72 m long, is situated between the stations Zalesina and Delnice. The tunnel was constructed in 1873 for one track of the GB structure gauge (basic). It consists of seven niches which are situated at every 25 m. It is clad with the dressed stones in 34 tunnel liners, and here and there, there is shotcrete. The entrance portals, frontal walls and the wing walls in the approach cutting and exit cutting are also made of dressed stones, above which there is very unstable soil with tendency of sliding and rockslides. From the last niche before the exit portal, the material has been falling onto the track; therefore for safety reasons the slow running of trains of 20 km/h is introduced in the tunnel.



Figure 3 Entrance portal of the tunnel Resnjak, interior of the tunnel and the niche from which the material is falling

3 Project documentation

Based on the Contract for the service of external consultant for special inspections of the track structures, the Main civil-engineering design of reconstruction of the tunnels and approach cuttings between the consortium of bidders, IGH d.d., ŽPD d.d. Geotehnički studij d.o.o., and the customer, HŽ Infrastruktura LLC, the following project documentation was prepared:

- 1) Project of reconstruction of tunnel Tičevo, the main and the detailed civil-engineering design of reconstruction, project reference 23-001/13, Institut IGH d.d., May 2013.
- 2) Project of reconstruction of the cutting approaches of tunnel Tičevo, the main and the detailed civil-engineering design of reconstruction, project reference 23-001/13, Geotehnički studio d.o.o., May 2013.
- 3) The geodetic survey of tunnel Tičevo, project reference 23-001/13, ŽPD d.o.o., 2013.
- 4) Project of reconstruction of tunnel Kloštar; the main and the detailed civil-engineering design of reconstruction, project reference 23-002/13, Institut IGH d.d., July 2013.
- 5) Project of reconstruction of the tunnel cutting approaches of tunnel Kloštar, the main and the detailed civil-engineering design of reconstruction, project reference 23-002/13, Geotehnički studio d.o.o., June 2013.
- 6) Geo-technical survey of instability of the cutting approaches of the tunnel Kloštar, project reference 23-002/13, Geotehnički studio d.o.o., June 2013.
- 7) Geodetic survey of the tunnel Kloštar, project reference 23-002/13, ŽPD d.o.o., 2013.
- 8) Project of reconstruction of tunnel Resnjak, the main and the detailed civil-engineering design of reconstruction, project reference 23-003/13, Institut IGH d.d., July 2013.
- 9) Project of reconstruction of the tunnel cutting approaches of tunnel Resnjak, the main and the detailed civil-engineering design of reconstruction, project reference 23-003/13, Institut IGH d.d., November 2013
- 10) Geo-technical survey of instabilities of the tunnel cutting approaches of the tunnel Resnjak, registration number 4110-36/13, Institut IGH d.d., July 2013.

4 Reconstruction works

Works of reconstruction in all three tunnels are performed in phases according to the approved railway line closures (on weekdays an 8-hour closure; on weekends the 36 and 72 hour- non stop- closure), with switching off of the contact wire and with earthing with the protection rod outside the boundary of the works operations on both sides of the tunnel cutting approaches and cutting exits. Protection of the track and of the signalling and interlocking lines of the power electric infrastructure subsystems was carried out using geo-textile, civil-engineering nylon, board formwork, while the optic cable was inserted into the plastic tube and buried into ground, and after completion of works it was returned to the girders in the tunnels.

Reconstruction in all three tunnels consisted in removal of the existing shotcrete, washing and cleaning of the surfaces to be reconstructed, of contact injecting (injecting of the grooves between the dressed stones) and binding injecting (injecting of the space of the dressed stone and the ground behind in order to statically reinforce the dressed stones) by the cement injection mixture with addition of bentonite and superplasticizer; installation of 0.7 to 1,0 m long soakways of 7 cm in diameter, installation of the steel welded net Q-188 and sprayed mortar R4, 3 to 10 cm thick, depending on the condition of meeting the structure gauge GB; installation of the bar and cable anchors 500/550 N/mm², 1,5 cm to 3,0 cm in diameter, 1 to 3 m long, at the distance of 2,5 m to 4 m; and application of the permanent elastic poly-cement coating in three layers, ca 0,15 cm thick each with the net where the flatness of the base allows. Tunnel cutting approaches and exits, due to their specific qualities in providing stability, were constructed by the system of anchors and various pre-stressed protection nets, depending on the conditions on the site, structure and characteristics of the soil, type and character of the load.

In tunnel Tičevo reconstruction works are divided into three groups: reconstruction of the unstable zones of the stone lining, reconstruction of the unstable zones of the stone lining and reconstruction of the rock mass. The reconstruction of the unstable zones of the stone lining comprised the stretches in the tunnel vault of the stone blocks “wedged” by the small wooden wedges which protected the stone blocks from the loss of stability, and the reconstruction of the site where stone blocks started protruding towards the tunnel gauge. After the machine and manual removal of the shotcrete from the surfaces where it was placed, the surface was washed and cleaned. Since the dressed stones in the vault visually pointed to the questionable stability, the next step was installation of the steel fabric and application of the sprayed mortar, so that the outlines of the steel fabric were visible, and that the dressed stones could bind and harden. The contact and binding injection was followed by the drilling of the holes and installation of the adhesion bar anchors, their injection, fastening and application of the 5 cm thick sprayed mortar. Into the tunnel flanks at the top of the tunnel wall, the soakways were installed, and where it proved necessary to channel the line in order to reduce the seeping of water and pressure on the tunnel lining, the number of the installed soakways was increased. The last phase was application of the permanent elastic poly-cement coating in three layers which, due to rugged base, was applied without net. The caverns in the tunnel were reconstructed by the steel fabric and sprayed mortar. The zones of the entrance and exit portals were protected by the steel fabric, sprayed mortar and soakways.

The cutting approach and exit of the tunnel were reconstructed by manual and machine removal of the unstable stone blocks. The stability of the cutting approaches and exits was provided by the system of the hexagonal, double-twisted protection nets Pr 400/550 MPa by the fixed bar anchors, system of the bar anchors and protective pre-stressed retaining net type TECCO of high tensile strength of 1770 N/mm². On both sides of the cutting approach and exit, in the entire length because to the cable of the signalling and interlocking electric power infrastructure subsystem, and the proximity of the foundation of the contact wire and the cutting exit, instead of the concrete channels type II, the drainage pipes are installed.



Figure 4 Reconstructed vault of the tunnel Tičevo and cutting exit of the tunnel

Reconstruction of tunnel Kloštar was carried out in two ways: by reconstruction of the rings of the dressed stones and reconstruction of the rock mass. From the dressed stones first the old shotcrete was removed manually and by hydro-demolition. When the works began, one part of the shotcrete fell off by itself. After removal of shotcrete, the washing was carried out, as well as the contact and binding injection along the entire length of the ring from the foot to the crown. At the frontlines of the rings the steel fabric and sprayed mortar were installed, and as the final phase, the permanent elastic coating in three layers, with the net, was applied. After cleaning and washing, in the rock mass the micro-cracks were detected, from which the seeping of water onto the track was visible. In line with the project supervision, due to large-scale roughness in the tunnel vault, instead of sprayed mortar, the sprayed concrete with fibres was installed, so that the steel fabric could be installed, to be protected by the sprayed mortar in the following phase. Water which was seeping from the vault was channeled by the small pipes before installation of the steel fabric into the flanks of the tunnel by the rock wall. The permanent elastic coating in three layers without net was the last phase of the works on the rock. During execution of works, after injection of the second ring, in the period of heavy rainfalls, through the soakways of the second ring, a large quantity of water seeped along the front of the track wooden sleepers, so the channels which were installed to channel the water towards the channels in the cutting approach. The entrance and exit portals were protected by the protective pre-stressed net type TECCO G65/3 of high tensile hardness of 1770 N/mm² and by the system of the bar and cable anchors. The caverns at the entrance and exit portal where reconstructed by channeling the water through the drainage into the corners of the portals outside the structure gauge zone, and the cracks were filled by the sprayed concrete.

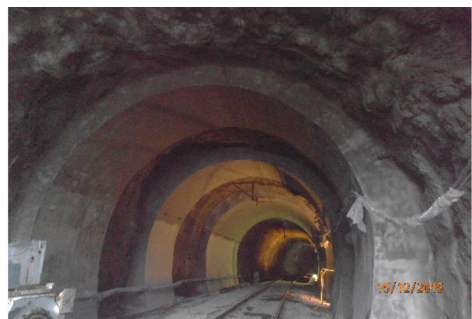


Figure 5 Cutting approach and entrance portal of the tunnel Kloštar and the rings at the exit part of the tunnel after reconstruction

Reconstruction of the cutting approaches and exits was carried out by the manual and machine cleaning of the slopes, installation of the pre-stressed protection net DELTAX of

high tensile hardness of 1770 N/mm^2 which was fixed by the system of anchors. On the left side of the cutting approach and exit, the channels type II were installed, which channel the accumulated water.

Reconstruction of the tunnel Resnjak due to the critical structure gauge also differed in the reconstruction of the last niche before the exit portal from which the material was uncontrollably slipping onto the track. The first activity in execution of the reconstruction works was to identify places where the shotcrete of weak adhesion capacity, deteriorated and broken, and to remove it. In order to carry this out, the entire tunnel was “knocked” mechanically by the hammer (the adhesion capacity was checked by the hammer, and the sound provided the information of the adhesion of the shotcrete onto the base). Removal of the shotcrete was carried out in some places, manually and with machines along the entire tunnel. Those places for which it was found to have good adhesion, the pull-off method was made, which confirmed it. After washing and cleaning, the holes for the bar anchors were drilled into the broken parts of the stone blocks, the anchors were installed and injected. Sporadic injecting was carried out in the tunnel vault, and binding injection in the tunnel wall, followed by installation of the steel fabric and 3 cm thick sprayed mortar. During works of shotcrete removal in the tunnel vault, several yellow plastic half-pipes were found, which were channeling water into the flanks, and they were situated under the shotcrete. Since during the summer time period a large quantity of water was seeping onto the track, twelve half-pipes were installed in the tunnel, some of which were visible, and some where protected by the sprayed mortar, since the structure gauge allowed that. The last phase of works was application of the permanent elastic coating. Reconstruction of the last niche before the exit portal of the tunnel entailed the removal of the unbound parts of the rock mass, construction of the reinforced concrete pillow with the armature, drilling of the anchors and injecting above the niche vault. In the niche the soakways were drilled, the niche was clad and protected by the sprayed mortar and permanent coating. All other niches in the tunnel were reconstructed by washing, cleaning, underpinned and protected by the sprayed mortar and permanent elastic coating. After completion of works, the marks of the niches in the tunnel were outlined too.



Figure 6 Cutting exit of tunnel Resnjak and interior of the tunnel after reconstruction

Reconstruction of the cutting approaches and exit cuttings of the tunnel was carried out by construction of the anchors, hexagonal double-twisted net of the cords and before their installations the drains were drilled and the dressed stones were bound by injection including the leveling of the grooves. Above the entrance and exit portal the barrier of posts, net and steel cords was constructed. The posts are constructed of the steel profiles NPI-20 and NPI-16, anchored into the concrete foundations at the distance of 3 m. The net of the barrier is hexagonal, double-twisted and galvanized. On the left and right side of the cutting exit and above the entrance portal, the concrete channels with descent were installed.

5 Conclusion

Reconstruction of the tunnels Tičevo, Kloštar and Resnjak, each of which is specific in its own right, using the state-of-the-art materials of similar properties and specific technology, within a short period of time provided the permanent stability of the cutting approaches, cutting exits and tunnels, providing essential qualities to the structure, which contributed to the safety of the railway system, people, material goods, and partial reconstruction and modernization of one of the segments of the RH2 corridor.

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