THE 7th INTERNATIONAL CONFERENCE
"CIVIL ENGINEERING - SCIENCE AND PRACTICE"
GNP 2020 – Kolašin, Montenegro, 10-14 March 2020

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REHABILITATION OF THE RAILWAY SECTION „KOS-TREBEŠICA“ IN MONTENEGRO

Abstract

This paper gives a brief overview of the works performed on the rehabilitation of the railway section “Kos-Trebešica”. The section extends from km 351 + 684.65 to km 358 + 428.35 for a total length of 6.75 km. The complexity of this section is essentially determined by the fact that it comprises 12 tunnels and six bridges, which is more than 50% of the whole section. During the rehabilitation, works on the substructure (landslide rehabilitation) and the superstructure, as well as some minor works on the overhead contact line and telecommunications were carried out.

Rehabilitation works with a duration of 4 hours and 30 minutes a day, were carried out in difficult working conditions. Carrying out the works so that every day after their completion, passenger and cargo traffic could proceed unhindered was a true engineering challenge. The technology of the works, the materials used, as well as problems encountered during the implementation of the project, will be described shortly. From the organizational point of view, the works on the section were made even more difficult by the fact that there are no access roads and no service.

The Contractor was a consortium of JV Strabag AG Austria and Crnagoraput AD Podgorica. The supervision of the works was carried out by the Institute of Civil Engineering Ltd. Podgorica. The Contracting Authority was the Directorate of Public Works Podgorica, and the End Recipient the Railway Infrastructure of Montenegro. The value of the works is 5,379,205.22 EUR. The contract was formed in accordance with the Fidic Red Book (1999 edition).

Key words

Railway section „Kos-Trebešica“, rehabilitation works.

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1. INTRODUCTION

The railway network of Montenegro is represented by the Vrbnica-Bar railway line. Railway line Vrbnica-Bar is a part of the International railway Belgrade – Bar and Route 4, which connects the port of Bar with trans-European corridors X and VII. The railway is 169.2 km long and extends from north to south of our country.

From a maintenance point of view, this railway line is one of the most expensive and complex in Europe and, for the Montenegrin economy, it is the most crucial line of transport.

The European Union, through the IPA funding model, granted 72.56% of the funding to Montenegro for the implementation of rehabilitation works of the "Kos-Trebešica" railway section, both for works and for supervision. The project was funded according to the rules of the Regional Development Program 2012-2013 (IPA).

The Kos-Trebešica section of the railway line extends from km 351 + 684.65 to km 358 + 428.35, and is located around 53 km north of Podgorica. The section is 6.74 km long. Its complexity is essentially determined by the fact that it comprises 12 tunnels and six bridges, which is more than 50% of the whole section.

The track was completed in 1976, when it was put into service. The axle and the vertical alignment of the reconstructed part of the track, designed for a 80 km/h speed, had to be fitted into the dimensions of existing works.

The complete superstructure was replaced (sleepers, rails, crushed stone aggregate). The rehabilitation of the landslide was carried out on a length of approximately 100 m. New drainage channels were installed, a part of the overhead contact line and telecommunications was also repaired.

Due to a short duration of daily closure of the railway and absence of access roads, the works on the construction site were additionally demanding.

The Contractor was a consortium of JV Strabag AG Austria and Crnagoraput AD Podgorica. The supervision of the works was carried out by the Institute of Civil Engineering Ltd. Podgorica. The Employer is the Directorate of Public Works Podgorica, and the End Recipient is the Railway Infrastructure of Montenegro. The value of the works was 5,379,205.22 EUR. The contract was formed in accordance with the Fidic Red Book (1999 edition). Works began in April 2019 and were completed in January 2020.

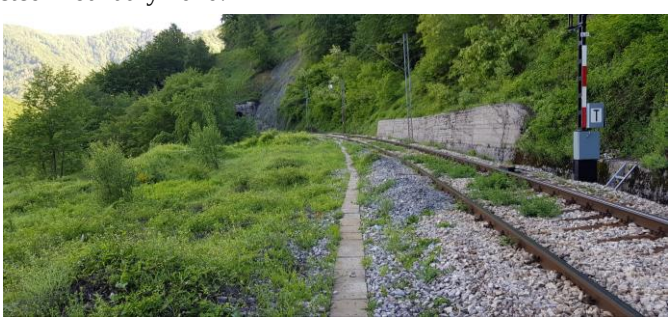

Figure 1. Section before execution of works

2. SCOPE OF WORKS

During the rehabilitation, the following works were carried out: works on the substructure (landslide rehabilitation) and the superstructure, as well as some minor works on the overhead contact line and telecommunications.

Works on the substructure included:

- mechanical excavation of the existing track ballast;
- cleaning of drainage channels;
- installation of new drainage channels;
- replacement of the substructure from km 351+800 to km 352+700;
- Main Design and execution of landslide rehabilitation from km 356 + 700 to km 356 + 900;

Works on the superstructure included the following:

- replacement of the old wooden sleepers with the new wooden sleepers (beech sleepers 2,60 m long, with KS Fastening System);
- replacement of crushed stone aggregate with a new one;
- dismantling of old rails 49 E1 and their replacement with new rails 49 E1 R350HT;
- installation of guard rails 49 E1;
- installation of anti-creep devices (MATHEE devices) for rails 49 E1;
- installation of devices against lateral movement;
- installation of track expansion devices ±150 mm, on the bridge "Vuče potok";
- welding of long welded rails;
- laying of guard rails 49E1, destressing of CWR and final welding;
- installation of posts and signs and marking of safety stripes in the tunnels.

Works on the overhead contact line and telecommunications comprised:

- Electrical works which included a continuous supervision of track reconstruction, replacement of a number of tunnel brackets, contact line wire, groundings and all electrical connections;
- Telecommunication works which included the replacement of several cable channels and their covers, telephone metal boxes and extensions on rail STA cable.

3. SHORT DESCRIPTION OF TECHNOLOGY FOR THE EXECUTION OF WORKS

The Contractor was allowed access for seven days a week, during the period of railway daily closure. This condition was particularly demanding from the organizational point of view. When performing the works in such a short time, the Contractor shall have not made any organizational mistakes. Under these limited working conditions, which also included a very narrow tunnel profile, it was very important that the Contractor proposed a fully rational technology that reduces the following parameters to a minimum: percentage of manual work, time for the execution of works and cost of works.

3.1. ORGANIZATION OF WORKS

Due to the absence of an access road with technical and operational characteristics that would satisfy the formation of a construction site on the route, the construction site (storage for new materials, storage for old sleepers and fastenings, offices for engineers, work train, main machines) was set up at the Station Kolašin. Depending on the schedule and works that were to be executed, the Contractor performed the railway track closure either from Station Kos or Station Trebešica. The closure was carried out under Traffic Instruction and Telegrams that have been issued by the End Recipient – Railway Infrastructure of Montenegro.

Before starting the works on the excavation of the track ballast, a "low speed" (20 km/h) was imposed. Low speed remained obligatory during the first and second cleaning and excavation of ballast as well as after the track was laid. The speed was increased to 50 km/h after laying and second track regulation. The design speed was introduced after the reception of the works and recording of the geometry of the track by a measurement vehicle. During the construction period, low-speed driving was properly signaled according to the terms of the valid Railway Traffic Regulations.

Landfills for disposal of the old excavated ballast were positioned along the route.

3.2. MATERIALS

For rehabilitation works on the superstructure the following main materials were used: beech sleepers l=260 cm (Hemos impregnacija d.o.o. Bijeljina), KS Fastening System (ribbed base plate b=160, synthetic pad, T head screw ϕ24 x 160 mm, washer Pp-6, double spring washer), expansion device type 300, SA 49E1 ± 150, (VEST ALPINA VAE APCAROM) Rails 49 E1 R350HT (VOESTALPINE SCHIENEN GMBH), crushed stone aggregate (Taskavac quarry, Mojkovac, Crna Gora), material for OCL (Integral doo Topola Serbia). Acceptance and Taking Over of all materials were organized in factories in the presence of Contractor and Engineer representatives.

Figure 2. a) Taking Over of fastenings for testing; b) Taking Over of rails 49 E1 R350HT, Leoben, Austria

3.3. MACHINES

For execution of the works, the Contractor used the following main machines: track motor vehicle, ballast cleaning machine, MFS wagons, ballast profiling machine, tamping machine, two way excavators, Hopper wagons, RGS wagons, gantry crane, loader, roller, truck, wrench machine, drilling machine, AT equipment, rail cutting machine, oxygen cutter, OCL TMV, Flat wagon with OCL equipment.

Figure 3 Mechanical ballast cleaning

3.4. SEQUENCE OF WORKS

Chronological order of main Civil Works:

1. Cutting of rails in lengths of up to 30 m,
2. Excavation of the old track ballast,
3. Cleaning of drainage channels,
4. Dismantling of the existing track and laying of the new track, loading of the new crushed stone aggregate (first) and mechanical regulation of track,
5. Dismantling of the old track and sorting of material,
6. Unloading of new crushed stone, mechanical regulation of track (second pass);
7. Installation of the device for lateral track movement;
8. Cleaning of the drainage channel in the tunnel;
9. Landslide rehabilitation;
10. Unloading of new crushed stone, mechanical regulation of track (final);
11. AT welding of the track;
12. Installation of the expansion device;
13. Installation of the device for longitudinal track movement;
14. Laying of guard rails on bridges;
15. Final profiling of the ballast prism;
16. Installation of track signs;
17. Final works.

3.5. REHABILITATION OF THE LANDSLIDE

After the railway was built, a landslide (instability) was activated on the route from km 356 + 700 to km 356 + 900. At the moment of the landslide activation, the retaining wall on the left side of the railway was damaged. The landslide was partially subsided and no significant wall and terrain displacements have been recorded since then. The manifestation that has been noticed for

the past ten years is occasional consolidation of the ballast layer, which is the reason for making a high track ballast at the above-mentioned location.

The proposed rehabilitation solution comprised passive and active remedial measures for the inactive landslide. Passive remedial measures included the installation of surface drainage, deep drainage system and weep holes. Active remedial measures included:

- Strengthening of the retaining wall above the rail by installing IBO self drilling anchors. The anchors are 8m long and have a Ø32mm diameter;
- Strengthening of the substructure by installing Tensar TriAx TX 150 geogrids.

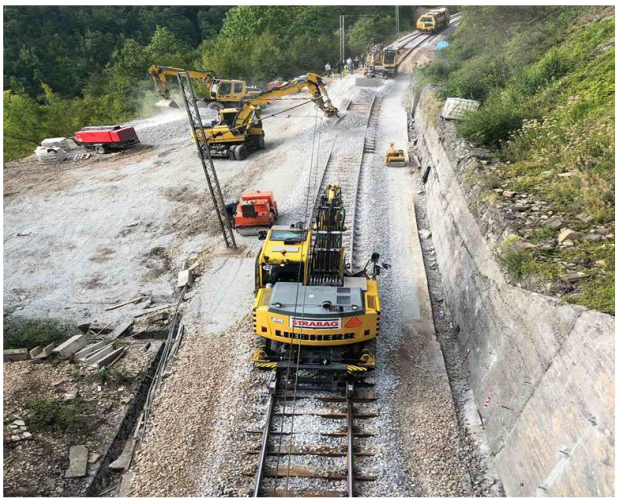

Figure 4. Final works on landslide rehabilitation

4. PROBLEMS DURING THE EXECUTION OF WORKS

4.1. SHORT RAILWAY CLOSURE TIME

The main problem on the project, which increased the price of the investment, was a very short daily period of 4 hours and 30 minutes for the execution of works. Before the commencement of the works, it was necessary to close the railway line, cut off the electrical voltage and prepare the work train. The work train came to the site, providing the part of the site where the works were performed. Only three hours and 30 minutes per day remained to perform the works. Every day after works, the passenger and cargo traffic on the section had to proceed unhindered. Considering the daily volume of goods and passengers transported from Belgrade to Bar, the attitude of the Railway Infrastructure of Montenegro for giving such a short railway closure time is understandable.

4.2. ABSENCE OF ACCESS ROADS

The absence of access roads caused the need to transport the necessary materials and equipment, as well as the workers themselves, exclusively by work train, which affected the

economy and the dynamics of works. Some of the machines had to be returned to the station Kolašin every day. Not having a network coverage caused additional difficulties in communication between the working brigades, set up at distances of even six kilometers at times.

4.3. NARROW TUNNEL AND BRIDGE PROFILES

Narrow tunnel profiles caused problems for the Contractor during the machine excavation of crushed stone aggregate, because sometimes much time was spent just in order to adjust the already shortened grid knife, which for such a short railway closure was a significant waste of time.

Due to the narrow profile it was not possible to place the grid knife on the three bridges, so the excavation of the track ballast was carried out using rail-road excavators and manually. All of the above led to a slowdown in the execution of works and to an increase in the percentage of manual work. The rehabilitation of tunnels and bridges wasn't a part of the Contract, which was not a good decision. During the execution of the works, there were many structural damages in a form of cracks in the tunnel lining, as well as water leaks from the tunnel. In the case of bridges, the damage was inflicted on the waterproofing, footpaths, etc. Most of these tunnels and bridges will have to be reconstructed in the near future; thus, their eventual rehabilitation will inevitably require repetition of many activities already covered by this rehabilitation. The true problem here lies in the fact that tunnels and bridges make up more than 50% of the section.

4.4. CHANGES OF THE REVIEWED MAIN DESIGN

During the execution of the works, it was found that the geodetic surveys weren't compatible with the actual site conditions. The Contractor submitted the corrected geodetic surveys and modifications of the layout drawing and longitudinal profile compatible with the new geodetic records. This modification was not accepted as the transitional curves were designed in the form of a clotoide rather than a modified cubic parabola, by the use of which the complete Belgrade-Bar railway line was designed. In order to overcome this problem, and using the newly recorded geodetic surveys as a basis, the Designer carried out the necessary modifications, and the Resident Engineer ordered the Contractor to perform the works according to the corrected drawings.

4.5. DISCREPANCY BETWEEN THE NEWLY DESIGNED RAILWAY AXIS AND THE EXISTING RAILWAY AXIS WITH AN OVERHEAD CONTACT LINE

During the execution of the works, an incompatibility between the new railway axis and the existing railway axis with an overhead contact line emerged (change of the position of the OCL is not covered by the contract for the execution of works). The incompatibilities were noticeable in tunnels No. 185, 187, 193. The problem was solved by the replacement and installation of new brackets. Thus, the existing brackets in tunnel No. 185, installed at 35 m intervals, were replaced by 11 new brackets installed at 30 m intervals. It was necessary to dismantle the already installed grounding and install it in a new position. In the tunnel No. 187 two brackets had to be replaced, and a longer steady arm had to be installed on one bracket. In the tunnel No. 193, a longer steady arm was required for one bracket. Therefore, it was necessary to replace and install a total of 17 new brackets instead of the expected 4.

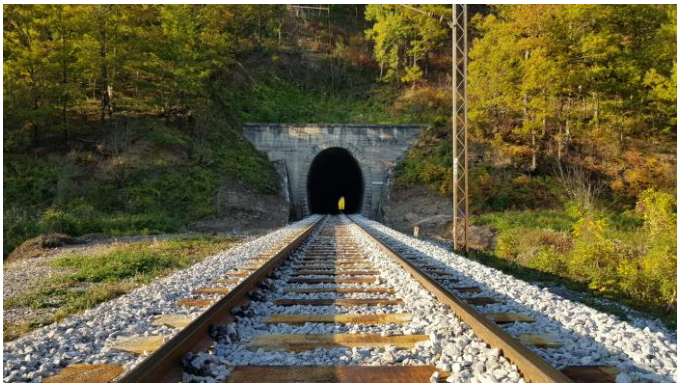

Figure 5. The route after completion of works

5. CONCLUSION

This project confirmed that the dictum "A job well planned is a job half-finished" is true. With very good organization, the Contractor shortened the time necessary for the execution of works from 15 to 11 months, which is a great success. Also, this project is a lesson to the Contracting Authority that scope of works should be carefully selected before the tendering process. During the selection of scope of works it is very important to coordinate different types of works, for example the substructure (bridges, tunnels, landslides etc.) and the superstructure. Most of the tunnels and bridges located at the rehabilitated section Kos-Trebešica have to be rehabilitated in the near future, which will inevitably entail the need to repeat many activities already covered by this rehabilitation Contract.

Also, this project is yet another proof that the problem does not exist if all participants in the process: Contractor, Engineer, Client and End Recipient, want to solve the problem and have the same goal which is successful completion of the project. Of course, the occurrence of problems is normal, but problems should be coped with, not increased or created.

LITERATURE

[1] " Main design for railway line track for Section Kos-Trebesica (km 351+684,65 – km 358+428,35)", Italferr S.p.a., Roma, Institut za istraživanja i projektovanje u privredi d.o.o. Budva, Institut za građevinarstvo d.o.o. Podgorica, Podgorica, 2011;

[2] "Contract Agreement between Directorate of Public Works and JV Strabag AG Austria and Crnagoraput AD Podgorica", Podgorica, 2018.

[3] "Rekonstrukcija pruge Kos-Trbešica", Kemal Abdić, Podgorica, 2019.