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Experiences from the application of remedial measures in hydrotechnical tunnel on Saska River – M. Kamenica

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Abstract. Tunnels represent significant financial investments with challenging design, construction, and operational issues. They remain in service for extended periods of time, sometime beyond their intended service life. Hydrotechnical tunnels are often prone to repairs and rehabilitation because of the devastating effect of the water. The rehabilitation of any kind of tunnel is a complex process which involves knowledge and experts from different scientific areas. In this paper some experiences from the rehabilitation of the hydrotechnical tunnel on Saska River as a part of the mine for lead and zinc Sasa are shown.

Keywords: Hydrotechnical tunnel; Rehabilitation

1 INTRODUCTION

1.1 Location

The tunnel is located in the eastern part of Macedonia, approximately 12 km from the town Makedonska Kamenica, at approximate elevation of 1000 m. This tunnel is part of the mine for lead and zinc Sasa, which is one of the most famous mines in the country.

1.2 General characteristics

The length of the tunnel is 1925 m with longitudinal slope of 5-7 %. Part of the tunnel is under the mine tailings. The cross section varies in width (~3 m) and height (~3 m) depending of the geological composition and tunnel support lining, see Figure 1.

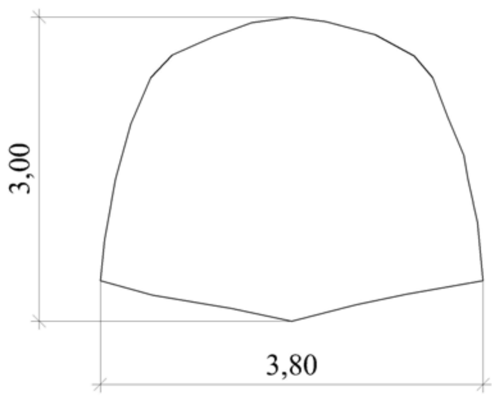

Figure 1. Typical tunnel cross section

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1.3 Previous rehabilitations

The hydrotechnical tunnel is in function since 1971. A few interventions throughout his service life have been made, for example: rehabilitation of the primary and secondary support, injection of cracks and holes in the area between the rock and the concrete support, rehabilitation of the invert etc.

2 GEOLOGICAL AND GEOTECHNICAL CHARACTERISTICS OF THE TERRAIN IN THE ZONE OF THE TUNNEL

The information about the geological and geotechnical condition of the terrain in the zone of the tunnel is gathered from a few phases of investigation, from which an adequate base of geotechnical data was created.

2.1 Lithological composition of the terrain

The following natural and artificial formations are present in the zone of the tunnel:

- Natural materials: gneiss rock, diluvial, proluvial and scree materials and aluvium (sandy gravel)
- Artificial materials: tailings sand (flotation pulp) and concrete from the tunnel support lining.

2.2 Tectonic properties of the terrain

The character of the river valley and the condition and mutual interaction of the represented rock masses indicate an intensive tectonic activity of this terrain in the geological past. The results from the investigations from which the faults and the fault zones where verified, also prove the complexed tectonic condition of the terrain.

Figure 2. Satellite view of the terrain (source: Google maps)

2.3 Engineering – geological types of rock masses

The represented rock masses in the zone of the tunnel from engineering – geological aspect can be divided into two groups:

- Strongly tied rock masses (gneisses; σ_p<50 MPa)
- Loose rock masses (alluvial sediments and flotation pulp)

2.4 Hydrogeological properties of the terrain

According to the hydrogeological function in the terrain assembly, the represented rock masses behave as collectors (alluvial sediments and flotation pulp) and isolators (gneisses).

Figure 3. Tunnel exit

3 CURRENT STATE OF THE TUNNEL

From the completely made analysis, the on-site inspection in the tunnel, and the overall results it has been noted that the hydrotechnical tunnel on Saska River can adequately perform its function. However, due to the observed irregularities along the tunnel in terms of established and identified defects, it was recommended to apply measures with which the functionality of the tunnel construction would increase, and this would result in better condition and longer exploitation period for using the tunnel. A specific defect which is present along the tunnel is the damage of the invert. Along the length of the tunnel almost the entire bottom where the water flows is eroded and is some places a channel with a depth of over 20 cm was formed.

4 REHABILITATION AND ANALYSIS OF THE TUNNEL SECTION COMPOSED SOLELY OF ROCK

The tunnel is divided in few sections:

- Parts with primary (rock bolts and reinforced shotcrete) and secondary support (reinforced concrete lining);
- Parts with only primary support (rock bolts and reinforced shotcrete);
- Parts with no support (only rock mass).

4.1 Rehabilitation of the tunnel section composed solely of rock

A segment of the tunnel has only invert and pillars with no primary or secondary support in the upper part. For this segment multiple variant solutions where considered:

- Solution 1: Primary support from reinforced shotcrete (d=20 cm) and rock bolts with length of 3 m placed at 1,5 m;
- Solution 2: Primary and secondary support (reinforced concrete d=30 cm);
- Solution 3: Rehabilitation of the invert with anchors, new reinforcement and new layer of concrete.

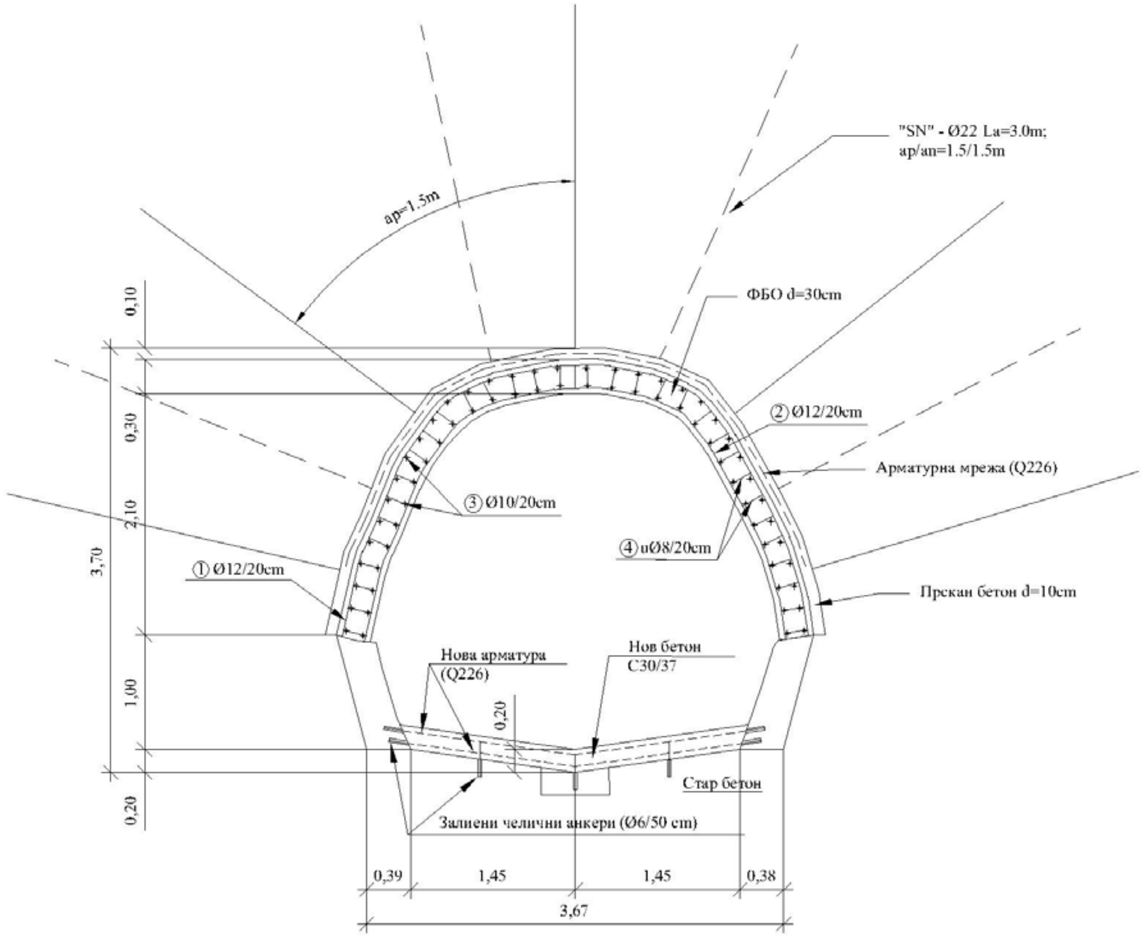

Figure 4. Tunnel cross section with primary and secondary support

4.2 Analysis of the tunnel section composed solely of rock

The analysis was made for multiple variant solutions covering several stages:

- Solution 1: Analysis of the tunnel with the invert and pillars from reinforced concrete (for stability control);
- Solution 2: Analysis of the tunnel with the invert and pillars, as well as primary support from reinforced shotcrete and rock bolts with length of 3 m;
- Solution 3: Analysis of the tunnel with primary and secondary support (d=30 cm);
- Solution 4: Analysis of the tunnel with primary and secondary support, without the invert.

The analysis process was simulated in the numerical model in multiple phases:

- Phase 1: Initial stress condition in the massif before construction;
- Phase 2: Excavation of the tunnel and construction of the invert with the pillars;
- Phase 3: Pseudo-static analysis.

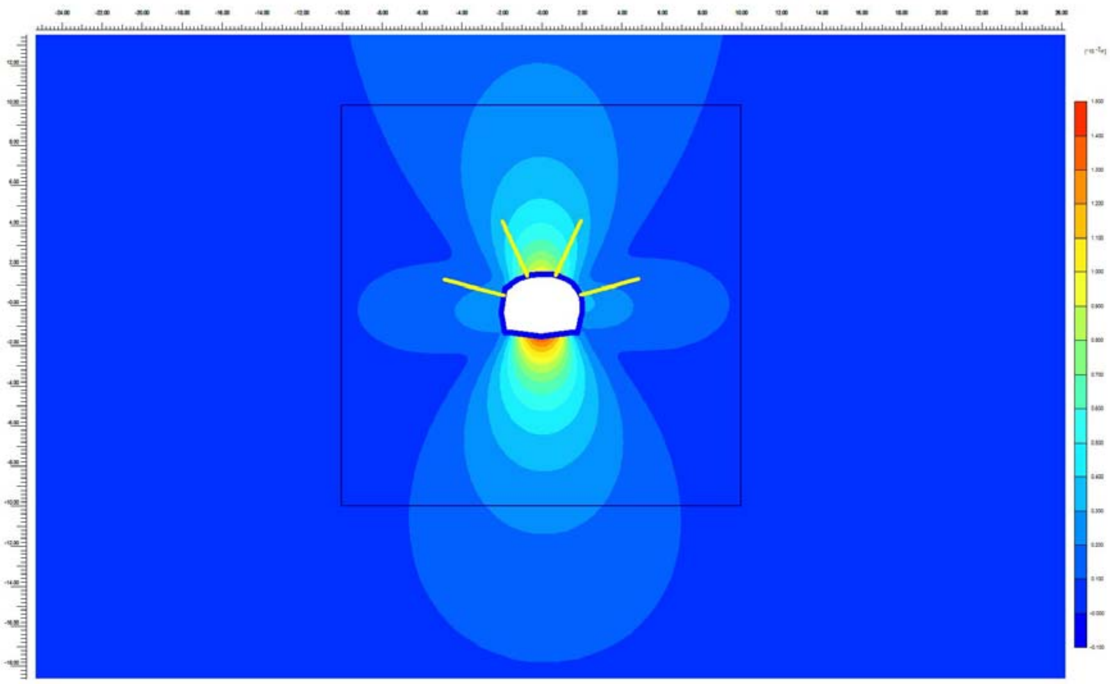

Figure 5. Deformations of the local environment and the lining

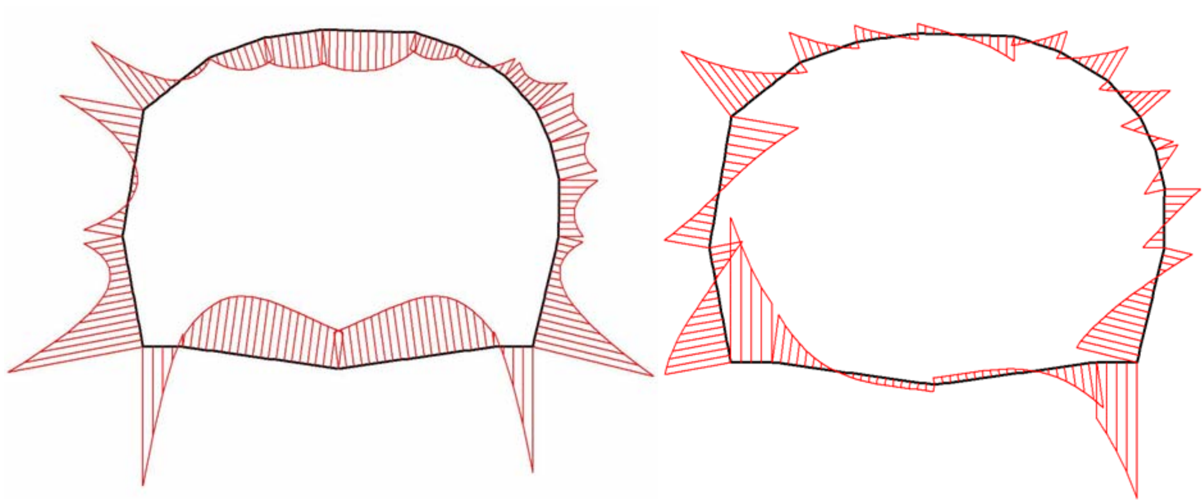

Figure 6. Diagrams of bending moments (left) and transversal forces (right)

5 CONCLUSIONS

The rehabilitation of tunnels is inevitable process throughout the service life of the structure, especially with hydrotechnical tunnels. From detailed analysis and observation the stability and rehabilitation solutions have been determinated for the tunnel on Saska River, which is part of the mine for lead and zinc Sasa. The rehabilitation solutions enable the improvement of the tunnel construction bearing capacity and functionality in phase of longtime exploitation.

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