



SCANNING AND THERMOGRAPHIC SURVEYING FOR NEEDS OF ELABORATION OF PROJECT FOR RAILWAY TUNNELS REHABILITATION

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Abstract

For the needs of elaboration of the project for rehabilitation of Košanski, Križiški, Jurgovski and Ležeški railway tunnels on the section of the railway between the Košana and Gornje Ležeče stations, scanning and thermographic surveying of the secondary tunnel lining was carried out. The mentioned field measurements were carried out by the SPECETES TS3 tunnel scanner which operates with a rotating laser beam and a visual field of 360 degree. Coordinates of permanent points in the tunnels set for the needs of measuring were also measured and calculated. The complete surveying equipment was installed on a railway car, which was pushed by a rail vehicle during measuring at the speed of 2 km/h. Surveying was followed by data processing and elaboration of a mathematic model of the tunnel tube, which enabled selection of the optimum position of the track route in the tunnel. From the data obtained by thermographic surveying, places with a smaller and larger quantity of seepage water were located.

Keywords: railway tunnels, thermographic surveying, clearance in tunnels, tunnel lining

1 Introduction

The railway section on which scanning and thermographic surveying was carried out is situated on the double-track railway Ljubljana – Sežana between the Košana and Gornje Ležeče stations. During exploitation, several efforts were made to increase the clearance in the tunnels, and the last correction of the track position and reprofiling of the stone lining in the three tunnels was carried out in 1996, with the goal to ensure at least the minimum clearance of the railway line in the tunnels for transport of containers from the port of Kopar. Although excellent results were achieved then, due to exploitation of the railway and penetration of water through the stone lining of the tunnel, formation of icicles and ice coatings occurs in the winter period, which considerably effects undisturbed and safe traffic flow. In order to prevent shifting of the track, it was decided that the track be executed as a ballastless track, specifically, the variant in which concrete sleepers are embedded in the reinforced-concrete slab. This technical solution of the track structure ensures stability of the track, both, by the direction, and by the height. Considering all the problems and requests of the investor, it was decided that measurements of the tunnel tube be done by using the modern technology. The technology of scanning and thermographic surveying with the scanner, carried out by the SPACETEC company from Germany, was selected.

2 Location of tunnels and description of state

Košanski (535m), Križiški (326m), Jurgovec (285m) and Ležeški (360m) tunnels are situated on the section of the railway between the Košana and Gornje Ležeče stations (Figure 1, [1]). The tunnels were built for a double-track railway within construction of the main railway line Vienna – Ljubljana – Trieste in the period from 1846 to 1857. Due to their mutual closeness, the tunnels were processed as a unique whole during measurement and designing. All the four tunnels are situated on the section of the double-track electrified railway where the greatest designed speed of trains is $V_{max}=70\text{km/h}$ and the speed is limited to 40km/h due to a very bad state of the track. The existing distance between the track axes in the tunnel amounted to 3.5m (at places, even 3.48m), whereby the track is partially a straight line, and partially curved with the curve diameter $R=260 - 275\text{m}$. In the Ležeški tunnel, the railway line is executed as a straight line, and it became deformed into several relatively mild curves with time. Deformation of the straight line in that tunnel is partially the consequence of adjustment of the track axes to deformations arisen in the tunnel tube stone lining, and partially the consequence of other conditions which made regular maintenance of the track position in the tunnel difficult.



Figure 1 Position of tunnels between Košana and Gornje Ležeče stations

3 Measuring of existing state

Before measurement itself, on the subject railway section, the training grounds were stabilized, measured and calculated, from which coordinates of permanent points in the tunnel were determined. Permanent points were stabilized in all the tunnels for the needs of directional and height securing of the tracks, and for the purpose of placing the results of detailed measurements with the laser scanner into space. Their stabilization was executed by screws attached into the secondary lining of the tunnel on yellow plastic washers with the diameter of 7cm, alternately on the left and right side of the tunnel, in cross-sections where the contact network consoles are situated (Figure 2).



Figure 2 Permanent point

For surveying needs, it was necessary to attach firmly (fix) the scanner support on a railway car. The correct position of the scanner on the railway car is the basis for surveying accuracy. Complete setting, testing of the scanner and computer equipment, and placing of a van on a railway car was done a day before surveying (Figure 3). Surveying itself was carried out during one track closing, by pushing of the railway car by a motor driven rail vehicle, which moved at the speed of 2km/h to ensure the best possible measuring accuracy.



Figure 3 Complete equipment with van on railway car

Since a double-track railway was in question, for which the most accurate data possible were to be obtained, surveying was performed twice, specifically, once along the left-hand, and once along the right-hand track. The scanner by which measuring was done operates with a circular laser beam in the 360 degree visual field, and it enables measuring of tunnel cross-sections, a visual recording of the tunnel lining and a surface thermographic recording of the tunnel, which is of importance to us for locating water behind the tunnel lining (Figures 4 and 5). The distance between individual cross-sections is several millimeters, the scanning resolution is up to 10.000 pixels on 360 degrees per a cross-section [2].

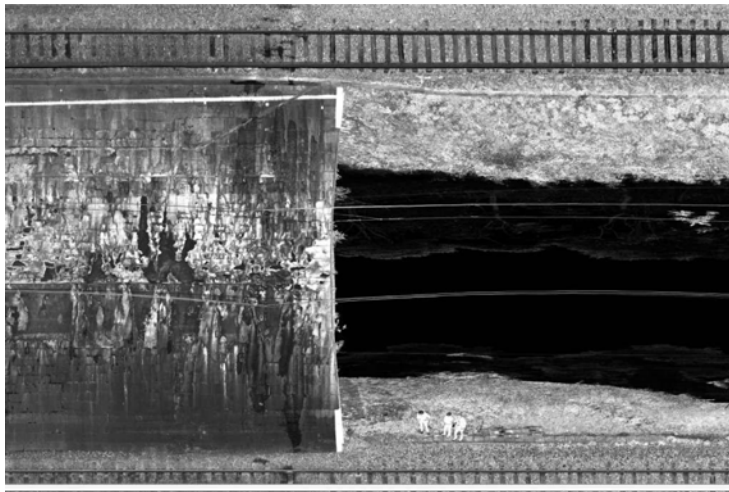


Figure 4 Scannogram, partially in tunnel, and partially outside tunnel

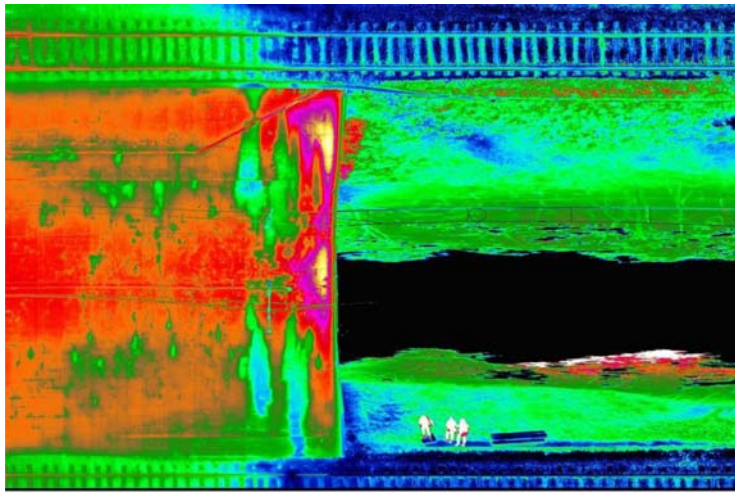


Figure 5 Thermographic survey, partially in tunnel, and partially outside tunnel

4 Processing of measured data

The results of measuring obtained by driving along the left-hand and the right-hand track were merged and transformed to the position of permanent points. Further data processing was performed by the Tu View V.8 and Tunnel – Inspektor program package, owned by the company that carried out laser measuring.

By that program, a mathematical model of the tunnel tube was elaborated, which enabled us to select and show the cross-section at any chainage. Such a procedure ensured quick control of variant solutions during optimization of the track route in the tunnel. In this actual case, the following was obtained: the distance of the track axes was increased and the curve elements were improved, which resulted in an increase of speed, and all that, with minimum interventions on the tunnel lining. After selection of the optimum position of the track in the

tunnel tube, control of cross-sections was done, and conflict points were located (Figure 6 and 7, [1]). From the data obtained by thermographic surveying, places with a smaller or larger quantity of water behind the tunnel lining were located. That data was used during determining the quantity and type of grouting mixture that will be embedded (injected) behind the tunnel lining for the purpose of preventing penetration of water per a tunnel lining.

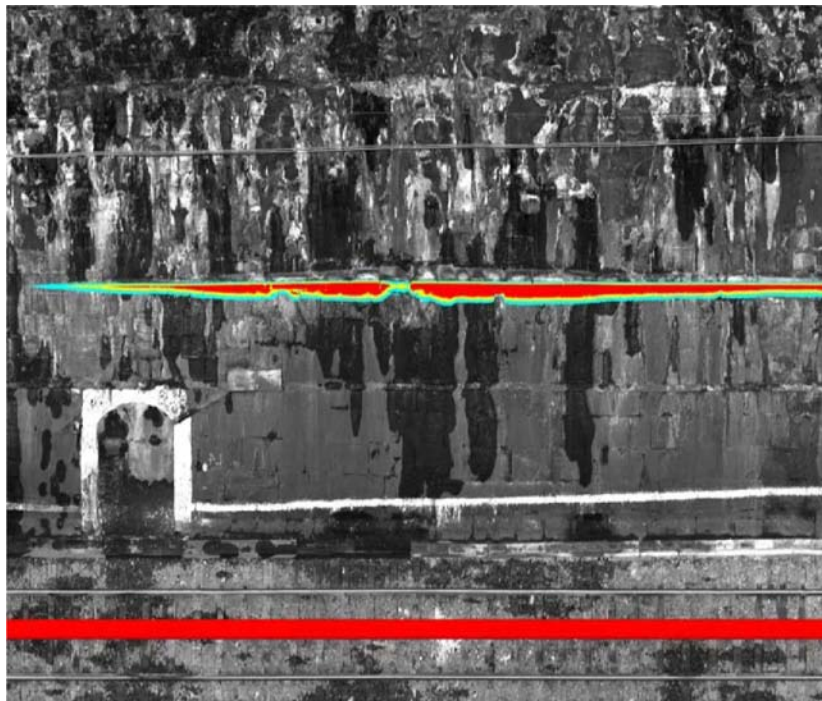


Figure 6 Scannogram with marked places of intervention of selected cross-section into tunnel lining

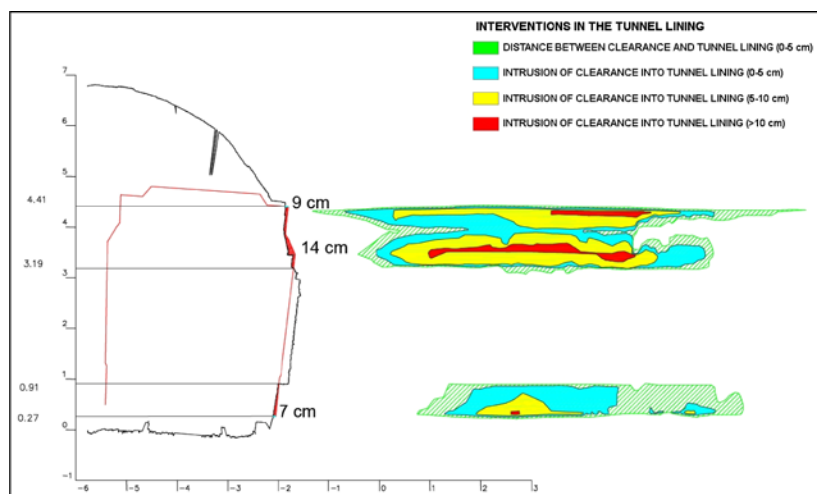


Figure 7 Size of intervention in tunnel lining

5 Conclusion

Optimization of the track position in tunnels and size of intervention in tunnel stone linings with the purpose of securing the requested clearance in the tunnel was done on the basis of accurate scannograms for the first time in Slovenia. A scannogram gives us a complete image of the actual state of the tunnel lining and offers us a possibility of selecting the truly optimum position of the track in space.

Since the new technology has its specific characteristics, during the analysis of interventions in space, which we verified in several classical ways by topographic surveys, we could not have determined the amount of the tolerance that should be taken into account during execution of interventions in the tunnel tube with 100-percent certainty.

We estimate that the tolerance that should be taken into consideration is 2–3 cm. Regardless of specific problems in analyzing of measurements and the expected tolerance during execution of the works, we believe that using of such data in designing of the spatial position of the track is a big step forward towards better technical solutions in very demanding spatial dimensions, such as tunnels in curves, particularly if the tunnel tube is partially deformed, as was the case in the mentioned tunnels described in the paper.

References

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