Deformation Measurement of the City Tunnel Sitina in Bratislava

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Key words: deformation measurement, tunnel construction and operation, control network

SUMMARY

The new highway ring was built in Bratislava, which included 2 bridges and one new tunnel. The tunnel Sitina build in 2003-2007 designed with two pipes covers the planned traffic load in time of launching operation is 20 000 vehicles / 24 hours in both directions. The tunnel was driven with New Austrian Tunnelling Method (NATM).

According the requirements defined by the tunnel designer were control measurements done in the tunnel. These were needed due to bad geological conditions and the small deepness of the tunnel. Control profiles and their continual measurement were required by the designer during the first 5 year of the tunnel operation. Using the results of geodetic measurements will be decided about the requirement (need) of next measurement epochs.

ZUSAMMENFASSUNG

Neu Autobahnring wurde in Bratislava gebaut, mit zwei Brücken und einem neunen Tunnel. Das Tunnel Sitina war im 2003-2007 gebaut, wurde mit seinem zwei Röhren führ eine Belastung von mehr als 20 000 Autos / 24 Stunden geplant. Führ Aufbau des Tunnels war die Neue Österreichische Tunnel Methode verwendet.

Aufgrund der Forderungen der Tunneldesigner wurden Kontrollmessungen aufgesetzt. Diese sind wichtig wegen der schlechte Geologie und der kleine Tiefe der Tunnellage. Kontrollprofile wurden definiert und deren permanente Messung vorgeschrieben in lange von 5 Jahre. Nach Ergebnisse dieser Messungen wurde die Entscheidung über die Durchführung nächste Messungen getroffen.

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1. INTRODUCTION

Tunnel Sitina is part of the highway D2 structure in Bratislava, was designed for separate bidirectional operation, which is covered by two tunnel pipes (the west tunnel pipe length is 1440 m, the length of east tunnel pipe is 1415 m). The planned traffic load in time of launching operation is 20 000 vehicles / 24 hours in both directions. The tunnel was driven with New Austrian Tunnelling Method (NATM).

Roadway width in the tunnel between curbs is 7.5 m, on both sides are footpaths 1.0 m wide. Distance between both tunnel pipe centre lines is changeable and reach maximal value approximately 47.0 m (Fig. 1). Mentioned offset of the tunnel pipes was needed for minimization of relative negative influence of tunnel constructions during diving, and also for adequate dead capacity of rock column between both pipes.

The tunnel pipes are connected with exit corridors on five places (EXIT 1 to EXIT5), one of that is enlarged for the emergency vehicle transit. In each tunnel pipe is placed one emergency bay with length of 40.0 m. Normally each 150 m are placed big SOS inspection chambers and each 90 m fire inspection chambers. Ventilation is longitudinal, with use of flow ventilators.

2. THE AIM OF THE MEASUREMENTS

Geodetic measurements were realised for purpose of estimation of:

- parameters of the control network points to control their stability,
- vertical displacements of bottom points stabilised on control profiles and points stabilized in exit corridors,
- absolute and relative 3D deformation of control profile points.

For all parameters are needed to be estimated with their accuracy characteristics, which are limited by extreme values defined by the designer.

With the aim of long-term stability control of secondary tunnel ceiling were in the tunnel defined 17 control profiles – 8 profiles in the east tunnel pipe and 9 profiles in the west tunnel pipe. Each control profile consist of point triplet, which are placed in profile – point No.1 in midpoint of arc near vertical axe of tunnel pipe, points No.2 and 3 are placed in side part of ceiling approximately 1.0 m above roadway level in the tunnel (Fig. 2). Points are stabilized in ceiling with cadmium anchors with possibility of reduction element adjoining for fixation of reflected prisms or foil reflector (system Leica).

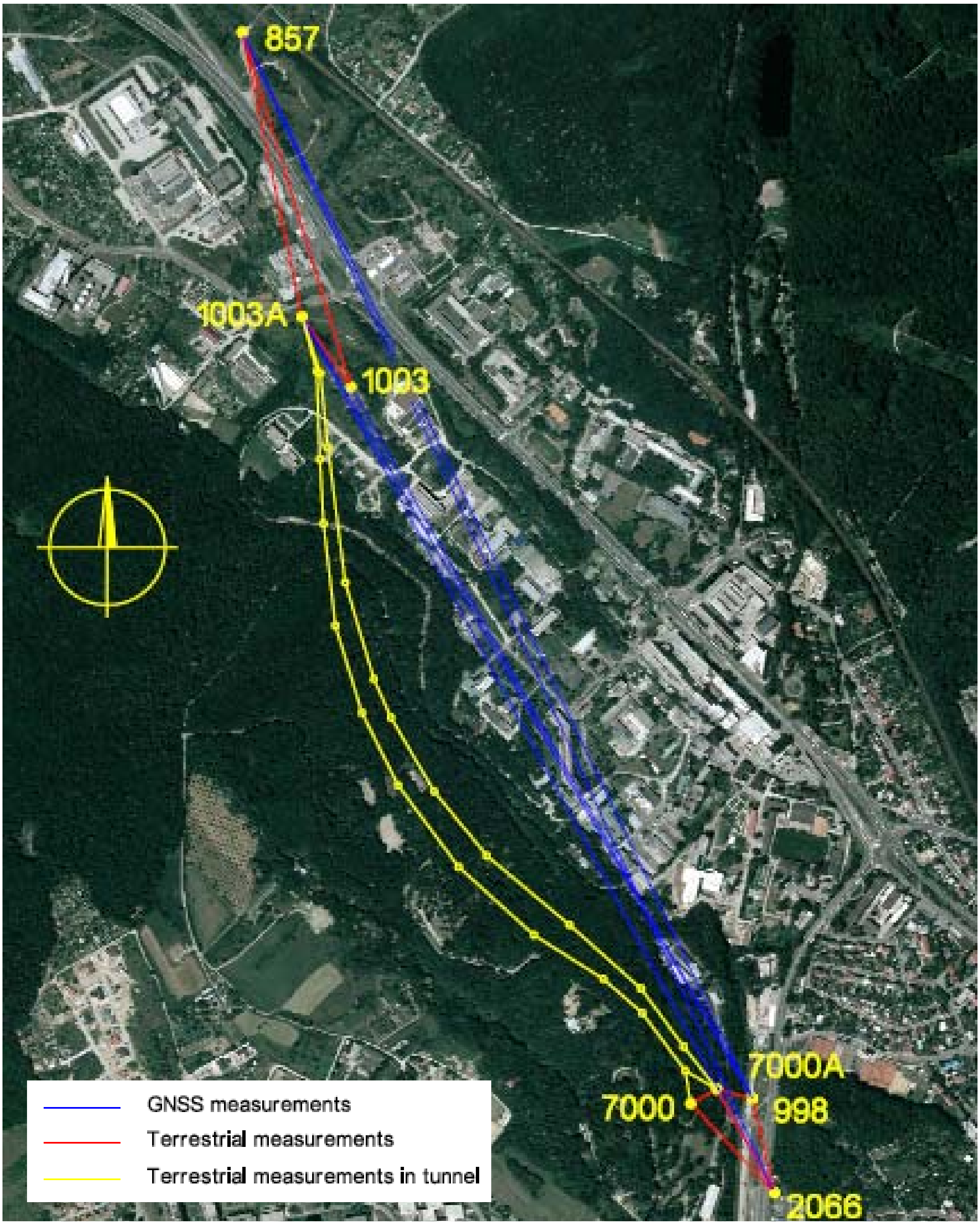

Fig. 1 Location of tunnel Sitina with net points

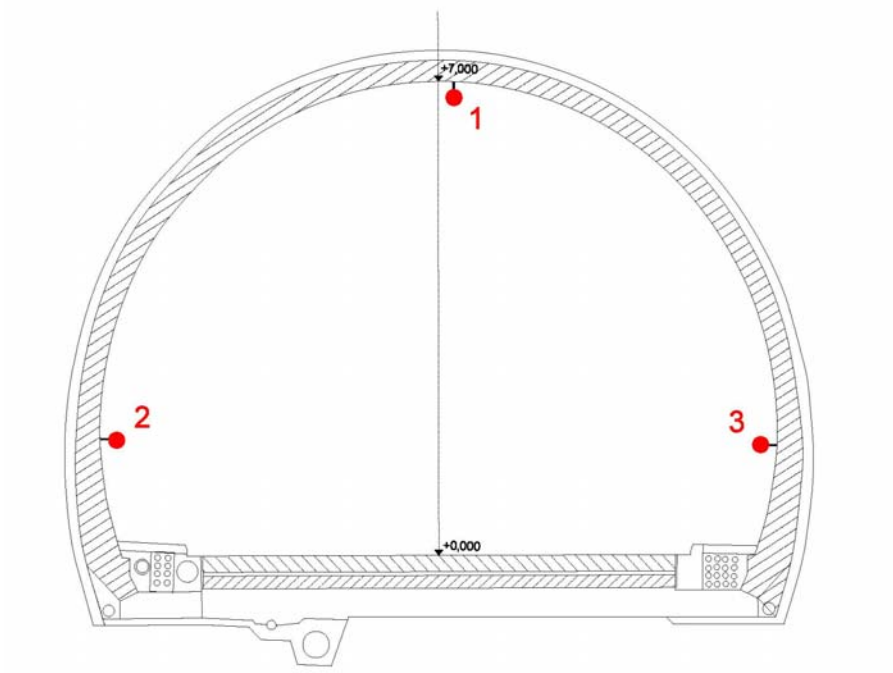

Fig. 2 Control profile

2.1 Verification of the control network stability

Stability control of all net points was done by terrestrial and GNSS measurements (on north and south portal). Together were on all positions measured zenith angles, which were used for computing of vertical height differences between network points. The GNSS measurement was realised together on the base points 857, 1003 and 1003A on north portal and base points 998 and 2066 on south portal (Fig. 1). All base points are stabilised with measuring columns. For measuring were used dual-frequency receivers Trimble 5700 with Trimble Zephyr Geodetic antenna (2 pieces), Leica 503 with Leica AT502 antenna (2 pieces) and Trimble R6 with Trimble R6 Internal antenna (1 piece). Length of observation was minimum 3 hours with average 7 to 9 satellites on particular points.

Terrestrial measurements were realised by Leica TCA1201 with automatic data recognition. Producer specifies accuracy of horizontal direction $\sigma_\alpha \leq 3^{cc}$, length $\sigma_d \leq (1 + 2.10^{-6}.d)$ mm and zenith angle $\sigma_z \leq 3^{cc}$. The angles (horizontal and vertical) were measured in 3 sets, lengths duplex. During the time of the control measurement realization was near the south portal established new portal point 7000A, which supply the missing collimation between points 7000 and 998, which was cancelled by construction of noise reduction barrier. Point 7000A is situated on abutment wall above reserve power located right to the roadway near entrance to the east tunnel pipe from south. In region of north portal was cancelled collimation from point 1003 to spotted points after build of cut and portal parts of both tunnel pipes built in excavation. Establishing of new portal point 1003A near south bridge abutment in front of entrance to the west tunnel pipe from north solved this situation.

Spatial lengths between network base points No.998, 2066, 857, 1003 and 1003A were measured with GNSS technology. Base points coordinates, estimated in coordinate system ETRS89, were transformed into system JTSK with local transformation key LGO without using quasi geoid.

The adjusted values of coordinates of existing and also new designated base points, was done by mean square method in free network configuration. The network structure, composed from lengths estimated with GNSS technology, was supplemented with terrestrial measurements. To the list of network base points are supplemented new points – the point No.7000A (portal point near the south portal) and the point No.1003A (portal point near the north portal), with coordinates estimated during the base (zero epoch) measurement.

The most probable (adjusted) values of coordinates of measured (profile) points was done by mean square method too, like second stage (step) network with adjoining to the base point network (first stage network), with reflection on uncertainty of the first stage points position estimation and without effect of second stage points on the first stage points.

The apriori characteristics of the measured quantities in second stage network was estimated on the level of

$$\sigma_{\omega} = 1 \text{ mgon} \quad \text{and } \sigma_{d} = (2 + 2.10^{-6}.d) \text{ mm.}$$

Aposteriori characteristics of measured quantities in second stage network estimated during adjustment process indicated high precision and quality of realised measurements:

East tunnel pipe	$\sigma\hat{}_{\omega} = 0.6$ mgon	$\sigma\hat{}_{d} = (1.2 + 1.2.10^{-6}.d)$ mm,
West tunnel pipe	$\sigma\hat{}_{\omega} = 0.6$ mgon	$\sigma\hat{}_{d} = (1.2 + 1.2.10^{-6}.d)$ mm.

Heights estimation of chosen (existed) and new established base points on surface was realised by precise levelling method. Measurements were done by compensator levelling instrument Zeiss NI 007, whose apriori accuracy is given by standard deviation for 1 km levelling σ_0 = 0.7 mm. For measuring were used compared levelling rods with invar stripe. Levelling courses were adjoined to points of the State levelling net No.503 (net point No.998), 504 and 505 (net point No.2066) near south portal and No.507.02 (wall plug of point No.1003) near north portal. Vertical net of base points were supplemented by new stabilised points VB1 to VB9. New points are stabilised by spiked levelling mark on ground of portal variable road sign construction near south portal (points VB1 to VB4) and north portal (points VB5 to VB8). Point VB9 is stabilised with wall plug on point No.1003A.

2.2 Verification of the control profiles stability

Stability control of the secondary tunnel ceiling were realised by spatial coordinates estimation of measured points on selected control profiles, which were designated for tunnel pipes deformation measuring. They were stabilised by reflected prisms and foil reflectors Leica in defined tunnel control profiles. Measurements in underground were realised by combination of polygonal course method and temporary stations and measuring of horizontal directions, zenith angles and slope distances to each measured points. During measuring was used automatic target recognition function (ATR), to each point was aimed repeatedly and minimum from two stations.

Heights of measured points in particular control tunnel profiles marked with No.2 and 3 were designated by precise levelling method, using compensator levelling instrument Zeiss NI 007 with adjoining to height base points near portals. Heights of all measured points on control profiles were determined also with trigonometric method with UMS Leica TCA 1201.

Together were stabilised new measuring points in exit corridors EXIT 1 to EXIT 5 – two points in each corridor. These points were stabilised by spiked levelling marks in the floor of corridors near doors (E1V, E1Z, E2V, E2Z to E5V and E5Z).

During control measurement were heights of base and measuring points designated with two method combination – geometric levelling method and trigonometric method. On chosen base points (998, 1003, 1003A and 2066) on the surface and on all measuring points in underground marked with No.2 and 3 were heights designated with both methods. On profile points in underground stabilised in roof part of secondary ceiling marked No.1 in each profile were heights designated only by trigonometric method.

For computing adjusted values of height differences were measurements arranged to closed courses, which can be closed through exit corridors (EXIT1 to EXIT 5). Heights of profile points designated with geometric levelling and trigonometric method can allocate certain discordance because of preparations are not stocked in ideal horizontal position and are not settled with height mark. This discordance didn't exceed value of two-times of standard deviation established for trigonometric method on all points.

3. CONCLUSION

According the requirements defined by the tunnel designer were control measurements done in the tunnel. These were needed due to bad geological conditions and the small deepness of the tunnel. Control profiles and their continual measurement were required by the designer during the first 5 year of the tunnel operation. Using the results of geodetic measurements will be decided about the requirement (need) of next measurement epochs.

REFERENCES

Kopáčik, A. et al., (2008) Deformation measurement of the D2 highway tunnel Sitina in Bratislava. Slovakia, Bratislava, Slovak university of technology, Department of Surveying.

BIOGRAPHICAL NOTES

Alojz Kopáčik is Professor at the Slovak University of Technology.
Study Geodesy and Cartography SUT Bratislava 1977-82. Doctor studies at the Department of Surveying the SUT Bratislava in 1982-85. Senior lecturer 1985-1998, 1998-2004 Assoc. Professor, since 2004 Professor at the Department of Surveying. Lecture from Geodesy for CE, the Underground and Mine Surveying and Engineering Surveying, Measurement systems in engineering surveying and Surveying for Civil Engineering (in English).
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