Surveying the railway tunnels

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Abstract: - This article presents the results of measurements made to determine the elements of real curve of the Balnaca tunnel, values of misalignment of the tunnel elements and values of assigning the structure gauge. The data obtained from the measurements are carried out by a total station and a laser scanning system. The data are used by specialists when it comes to periodical verification or rehabilitation of tunnels. Applied technology can be used by civil engineers in rehabilitation of railway tunnels.

Key-Words: - tunnel, design curve, real curve, gauge

1 Introduction

The specifics of the construction and modernization of the communication ways requires specialized surveying assistance in all phases of implementing those projects (roads, railways, water streams, artwork, etc.), both in the study phase and in the design and execution phases [1]. This applies also during the operational phase and modernization of infrastructure of communication ways.

Each stage of the development of a specific communication pathway involves surveying work, which - in the context of the design of modern communication ways - requires that the accuracy of the surveying measurements to be particularly high.

In this context, an important role lies on geodetical and topographical works required for modernization artworks for communication ways [2]. From the many types of artworks specific to communication ways are distinguished - in particular - tunnels, special constructions through the complexity of design solutions, the difficulties during construction but also by the need for special maintenance programs, time tracking and modernization during operations.

Fig.1 - Tunnel position

Based on these considerations, I realized an application regarding the contribution of geodetic and topographic works in the operational phase of a tunnel, phase which involves - in equal measure – maintenance, monitoring behavior in time and modernization such an artwork.

Surveying measurements have been made at Balnaca tunnel, located on the railway line CF Cluj - Oradea, between railway stations Bratca - Şuncuiuş, Km 598 + 930.00 m – 599 + 203.50 m, in the county of Bihor. The tunnel is located about 50 km from the city of Oradea, positioned at opening of Quick Cris valley towards the plain, in an area of contact between the Apuseni Mountains and Banato-Crisan Plain, area of transition from hills relief (Western Hills, the hills of Oradea and Gepis hills) to the plains (Fig.1).

The tunnel has a length of 273.50 m and was built by MAV (Magyar Államvasutak) hungarian railway company, between 1870-1871. In the longitudinal profile, the line in the tunnel is in: ramp 8.0‰, in plan, the tunnel is a curved line, continuous radius of 280 m, connected to the exit of the tunnel (towards Oradea) with reverse curve.

In longitudinal section: 2 portals (entrance portal L = 3.60m and exit portal L = 3.60m) and 53 rings with a length between 4.00 and 8.00 m The bridging network consists of six points: determined by GNSS technologies, for the purpose of carrying out surveying works needed for the project of modernization the railway between Braşov - Oradea. The planimetric positions of the bridging network points are defined by coordinates (X, Y) in the projection system "Stereographic 1970" (on customer request). Altimetric position of points is defined in the reference system "Black Sea 1975" and was determined through geometric levelling.

The minor control framework was designed as a traverse supported at both ends with control points, taking into account the ground conditions (tunnel in curve), restricted visibility, narrow work area, rail traffic, etc.

Measurements for the determination of the coordinates of detail points (raceway geometric elements, the upper rail level) have been carried out by a total station from Sokkia and a laser scanning system ScanStation 2 manufactured by Leica.

Fig.2 - Exit portal tunnel

2 Determining the actual curve elements of the tunnel

Tunnels in curve are exposed to changes in outlets, in particular with transverse displacements towards the inside of the curve. For the specialized designer determination of the actual curve elements and comparing them to the designed elements of the curve plays an important role in choosing the method of working for tunnel rehabilitation especially in modernization costs.

Also, the need for designing a new curve, in the case of an improper classification of the structure gauge of the real curve or redrawing existing curve are outstanding issues that must be taken into account in the procedure for modernization of tunnels.

The elements of designed curve at Balnaca tunnel, are known from design of tunnel and tunnel

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sheet, elements of real curve is calculated based on measurements made in the wheel tracks.

The main elements of circular curve are:

- U (or φ) - bending angle of the rays is given in the project;
- R - curve radius is chosen or imposed by traffic conditions;
- β - bending angle of alignment I şi II:

$$\beta = 200g - \varphi \qquad (1)$$

- T- Tangent length:

$$T = VT_i = R*tg\varphi/2 \text{ or } T = R*ctg\beta/2 \qquad (2)$$

- b - Bisector length:

$$b = VO - BO = R*(sec\varphi/2- 1) \qquad (3)$$

- lc -Length of curve:

$$l_c = \pi R\varphi/200^g \qquad (4)$$

- DT - Overcoming tangent:

$$DT = 2T - l_c \qquad (5)$$

- c - chord length:

$$2c = T_iT_e, \rightarrow c = R*\sin\varphi/2 \qquad (6)$$

- f – the arrow of curve:

$$f = R - OG = R - R\cos\varphi/2 = 2R\sin^2\varphi/2 \qquad (7)$$

Main points of the circular curve are:

- Ti - entry point into the curve;
- Te - exit point from curve
- V - point of intersection of the alignments I and II
- B - bisecting point of the curve

The designed elements of Balnaca tunnel, a curve in circular arc, are shown in Fig.3 in red and in Table 1.

The real curve elements have been determined from measurements made with the Scanstation2.

The Cyclone software, based on several selected points on the axis of runways, generates with the command "Create object" / "From pick points" / "Arc", the arc closest to the center of the track line. Real curve elements are presented in Fig.3 in blue and in Table 1 [3].

For a good outlining the differences, Table 1 presents the main elements of the projected curve values and the main elements of the actual curve values.

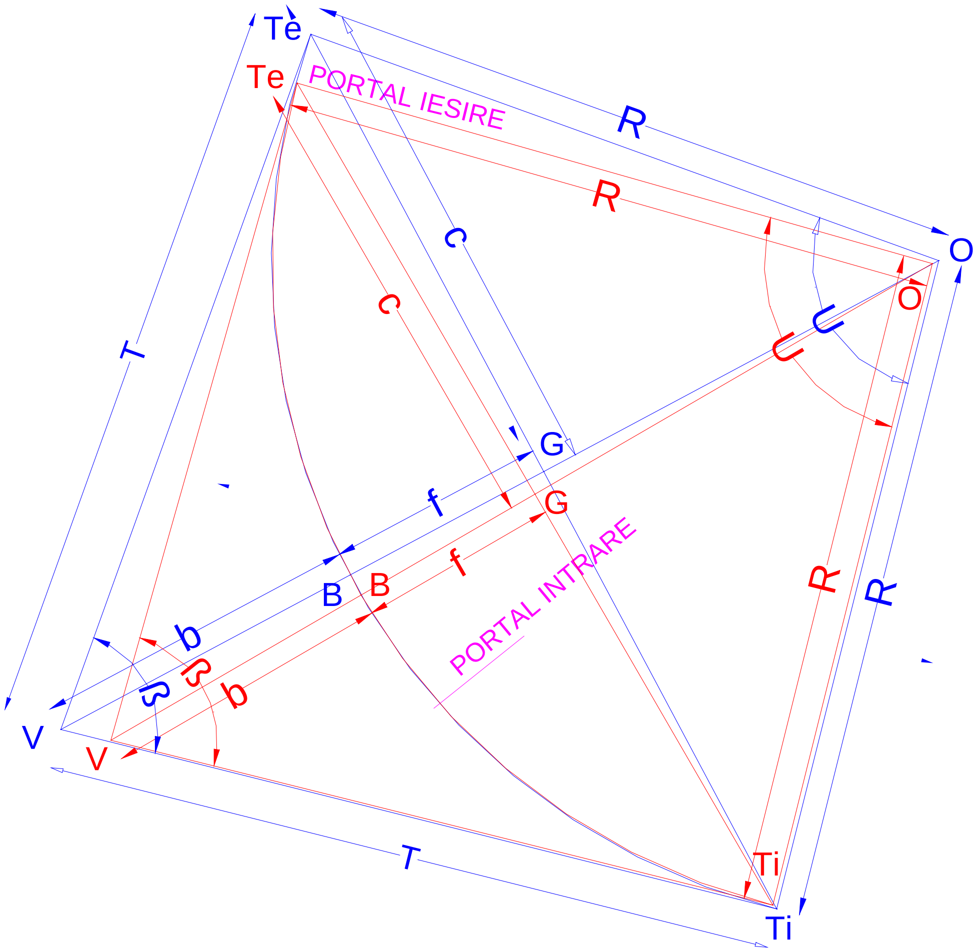

Fig.3 - Elements of designed curve and actual curve

Table 1-Designed curved and real curve elements

The main element of the curve	Projected curve	Actual curve
U	106.3854g	102.0740g
R	280.000m	277.000m
β	93.6146g	97.9263g
T	309.593m	286.174m
b	137.430m	121.277m
lc	467.907m	444.134m
DT	151.279m	128.214m
c	207.666m	199.033m
f	92.184m	84.347m
V	X= 607133.288m Y= 313550.901m	X= 607128.787m Y= 313571.918m
Ti	X= 607058.816m Y= 313853.099m	X= 607059.681m Y=313849.622 m
Te	X= 607424.579m Y= 313655.772m	X=607404.094 m Y= 313650.032m
B	X= 607197.964m Y= 313672.162m	X= 607189.595m Y= 313676.848m
O	X= 607329.732m Y= 313919.219m	X=607328.483 m Y= 313916.513m

3 Calculation of misalignment values of the tunnel elements and values of assigning the structure gauge

In order for the specialized designer to be able to establish a viable solution for the need of re-setting out the real curve on the projected position from measurements, the following elements are calculated:

- Δt - misalignment between the axis of the shaft and runways tunnel;
- ΔCFp existing misalignment between the existing tread axis and design tread exis.;
- minimum horizontal distances separating gauge tunnel soffit, Gd (right gauge), Gs (left gauge)

Data obtained for Δt misalignment and ΔCFp misalignment were measured by superimposing real curve over the projected and over the tunnel axis at each point of the tunnel rings (Fig.4). The resulted dimensions are centralized in the tables (Table 2), the last column is calculated by the designer specialist if the modernization solution requires a different axis of the track from the designed axis, where ΔCFa is misalignment between existing tread axis and the new proposed tread axis.

Determine the minimum horizontal distance separating gauge tunnel soffit, Gd (right gauge), Gs (left gauge), structure gauge was done according to STAS 4392 (Fig.5), depending on the radius of the curve R, over-expansion to the outside of the curve Se, over-expansion towards the inside of the curve Si, over-exaltation outer rail h and increase the distance between track centers Sc. The values of these elements are extracted from tables: R = 277m, Si = Se = 131.5mm, Sc = 17.3mm, H = 150mm.

Calculated structure gauge (Fig.5) was superimposed on each profile performed at joints between rings (Fig. 6), measuring values, Gd (right gauge) and Gs (left gauge). Extracted gauges are centralized in the same tables with misalignments (Table 2), the values entered in the table are minimum values measured in a section gauge, both the left and the right gauge. The minimum value accepted by standards for difference in gauge - soffit is 220 mm.

As shown in Table 2, the minimum value is exceeded for some gaps on the inside of the curve due to the misalignment of the running axis to the designed axis. In this case, usually it retraces circular curve on the design position.

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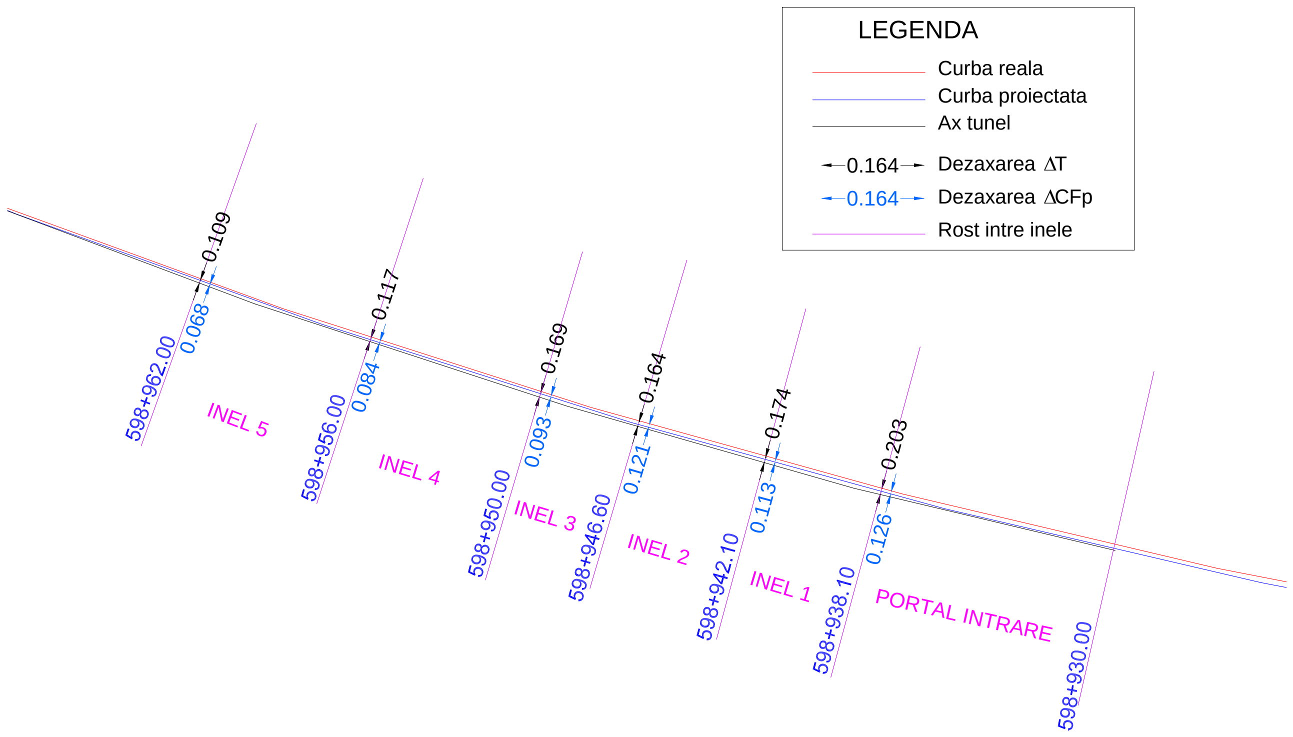

Fig.4 –Misaligments Δt and ΔCFp

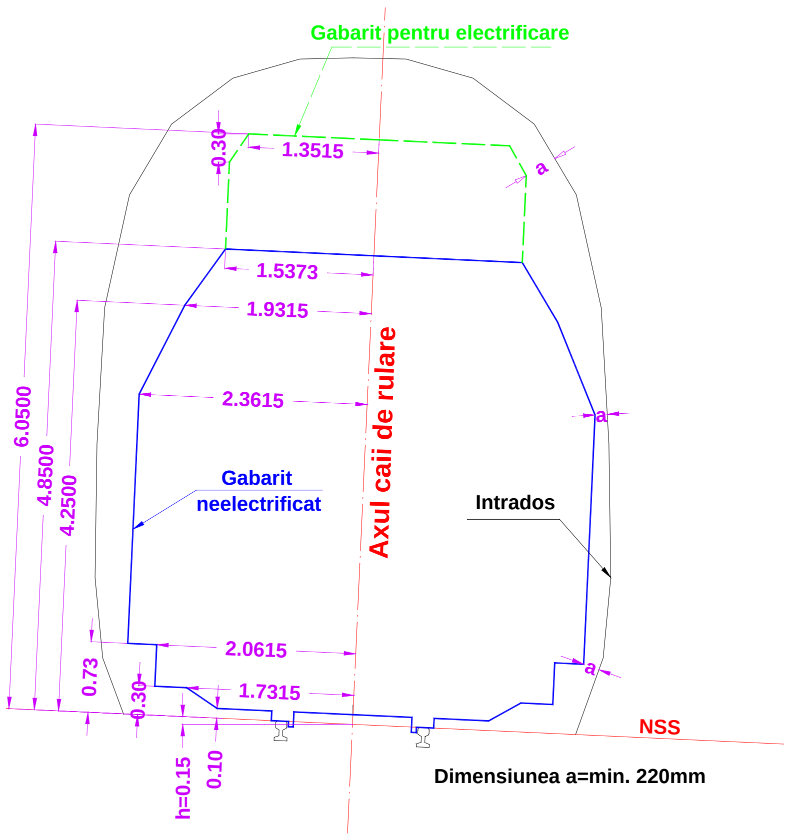

Fig.5 – The standard gauge for curve tunnels

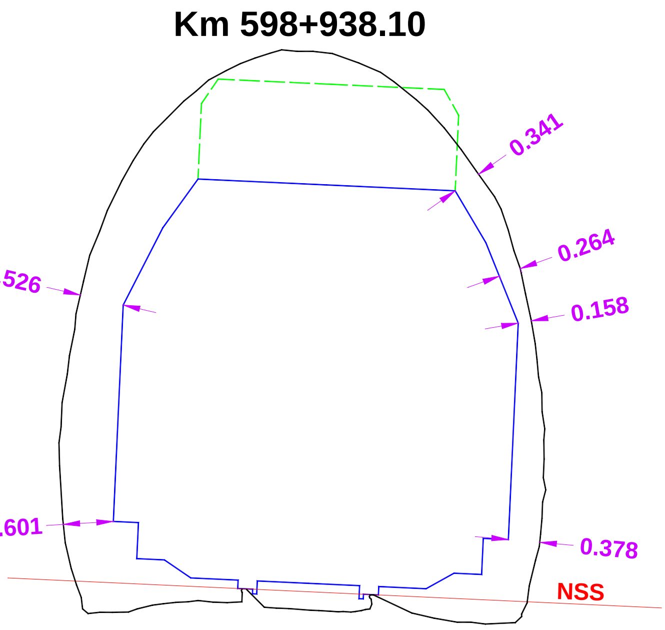

Fig.6 – Calculation value of the gauge

Tabel 2 - Misalignments and gauges

Km	Rost rings	ΔT [mm]	Gd [mm]	Gs [mm]	ΔCFp [mm]
598+938.10	PI/1	203	158	526	126
598+942.10	1/2	174	205	508	113
598+946.60	2/3	164	158	526	121
598+950.00	3/4	169	293	569	93
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599+018.50	15/16	282	269	1262	21
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599+038.50	20/21	188	294	1277	34
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4 Conclusion

The specific difficulty for tunnels is the knowledge of the real technical condition of them, due to the following factors: we can observe and trace only the elements of soffit and track elements, the archive documents, particularly for old tunnels, not contain many relevant technical data.

The modernization works of the tunnels also have their own specific because their importance can not be accurately estimated only on the basis of preliminary studies, their implementation is difficult, due to the nature and conditions of realization.

Topographic measurements with different instruments, the results obtained after processing the measurements, allow the extraction of vital information for specialized designer. Depending on these results are proposed specific rehabilitation and modernization works of tunnels.

New technology total stations (Sokkia Set 650X) fig.7, digital levels (Leica DNA03) fig.8, GNSS technologies (GPS Topcon/ Hiper Pro) fig.9, dynamic scanning systems (L-KOPIA/LKO) fig.10 [4], static scanning systems (Leica ScanStation2) fig.11, allow obtaining final specific and needed products to modernize the designs tunneling from: site location plans and 3D coordinates of detail characteristic points of tunnel, continuing with: longitudinal and cross sections profiles, calculation of volumes, surfaces, excavation anf filling volumes, generating terrain models until framing the gauge freedom of movement, elaborating the tunnel sheet and mapping defects tunnel soffit.

Fig.7 - Sokkia Set 650X total station

Fig.8 - Leica DNA03

Fig.9 - GPS Topcon/ Hiper Pro

Fig.10 - System L-KOPIA/LKO

Fig.11 - System Leica ScanStation2

Also new measurement technologies allow analysis of the possibilities of obtaining the geometric elements of the tread and the tunnel (main elements of curve, raceway shaft, tunnel shaft, gauges) and comparing them with projected elements. It can calculate the specific misalignment of tunnels geometric elements and values for gauge admission, which are imposed by the specialized designer, solutions to modernize the tunnel in the redrawing the path axis and retrace other specific factors, opportunities for electrification, etc.

Using laser scanning measurement systems reduces the time to perform measurements, this benefit is reflected in the cost of the work, the

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number of points acquired in a short time is very high, this help in the correct interpretation of scanned objects even with very small dimensions fig.12 [5].

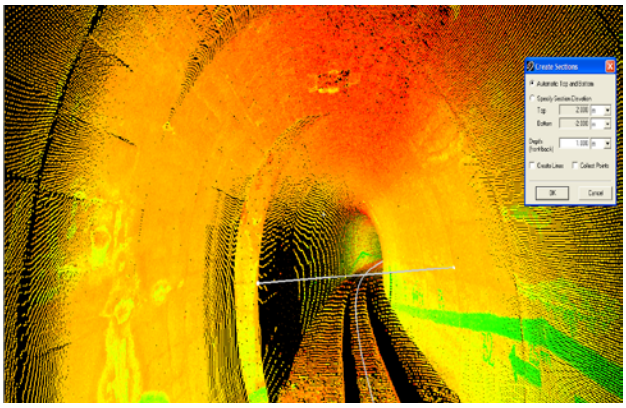

Fig.12 - The laser scanner point cloud

As perspectives can be taken into account and analyzed opportunities for performance monitoring and evolution deformations in tunnels using laser scanning technology.

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