Tendencies in the development of operational quality of ballasted and ballastless track superstructure and transition areas

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Abstract. Department of Railway Engineering and Track Management is cooperating with Slovak Railways (Železnice Slovenskej republiky – ŽSR) on assessment of quality of railway tracks, structures of railway tracks and parts of these structures. One of diagnostics methods is monitoring of track geometry focused on durability of ballastless track quality and its transition area to ballasted track. The diagnostics is carried out by continuous method and results are used for prediction of future degradation of construction. The first part of the paper deals with a brief recapitulation of information about the experimental sections and the methods of diagnostics of track geometry. The second part of the paper is carrying out the analysis and prognosis of development of the quality of construction of the experimental sections, which is a tool for the track superstructure maintenance planning.

1. Introduction
The ballastless track construction is on Slovak Railways network mainly used as railway superstructure construction on bridges, in tunnels and adjacent sections. Diagnostics of ballastless track sections focused on transition areas is used for monitoring of track geometry quality progress presented through quality marks of selected parameters. The quality marks and subsequently the quality numbers are for infrastructure manager useful in process of scheduling track maintenance. The early detection of track quality degradation and subsequent planning of repair interventions in the initial stage of errors in track geometry is essential precondition for achieving an extended lifetime of the structure with the required diagnostics and repair costs and also for safe operation of the railway line.

The experimental section is located near the portals of the newly built tunnel Turecký vrch. This track is a part of V. multimodal transport corridor TNT-T Venezia – Terst/Koper – Ljubljana – Budapest – Užhorod – Evov with the branch Va Bratislava – Žilina – Užhorod. The ballastless structure (system Rheda 2000®) was built within modernisation of the railway track Nové Mesto nad Váhom – Púchov, object Nové Mesto nad Váhom – Trenčianske Bohuslavice [1].

The ballastless structure passes though different types of subgrade. It starts on earthwork at the south portal and leads through the tunnel. At the north portal, the ballastless structure continues on two bridges and earthwork. The total length of the ballastless track is 2 280.145 m. A new type of transition area, which using standard superstructure components, carries out between the end of the ballastless structure and the ballasted structure. The structure consists of a longitudinal concrete bed,
20 m long. Each track has its own concrete bed. The concrete beds are dilated longitudinally. The railbed thickness under sleepers is decreasing in the direction to the ballastless track, which causes the increase of the subgrade stiffness. The bed bottom and walls are lined with elastic anti-vibration rubber mats that are supposed to simulate the earthwork soil deformation properties.

Results of the diagnostic measurements are realised until now, enable to create the global forecasting of the quality development of the monitored ballastless track – of the experimental section. The detailed information about the parameters, measuring instruments, diagnostic methods, ways of its evaluation and its partial results were published in [1, 2].

2. Methods of diagnostics

The track geometry diagnostics is carried out by the measuring trolley KRAB™ - Light. The measuring system measures the track parameters in an unloaded state. The measured parameters are [3]:

- gauge tolerance RK (after calculating the change of gauge ZR is also recorded),
- alignment of right rail SP (after calculating the alignment of left rail SL is also recorded),
- rail top level of right rail VP (after calculating the rail top level of left rail VL is also recorded),
- superelevation PK,
- quasi-twist on a short base (calculated to a quasi-twist on a base of 1.8 m long – ZK_{1.8}, 6.0 m long – ZK_{6.0} and 12.0 m long – ZK_{12.0}).

From the point of view of the diagnostics evaluation, the monitored section is divided into two subsections [4]:

- section 1.1 (line No.1, the southern portal of the Tunnel Turecký vrch) and 2.1 (line No. 2, the southern portal; both sections are 175 m long; 102.360 000 – km 102.535 000);
- section 1.2 (line No.1, northern portal of the Tunnel Turecký vrch) and 2.2 (line No.2, the northern portal); both sections are 640 m long; km 104.200 000 – km 104.840 000):

The monitoring of the experimental section is executed from July 2012 in a half-year period. By now, 9 measurements have been carried out: one before commissioning (marked as MSO) and 8 operational measurements (marked from PO1 to PO8). Within the initial measurement (MSO) were recorded 40 local faults, 30 of which in the sections with the ballasted track, 9 in the section with the ballastless track and 1 local fault was diagnosed in the transition area of the section 2.1. The contractor carried out after this measurement a repair of the track geometry and a microgeometry repair of the rail heads by grinding [5].

In the second operational measurement (PO2) were for the first time diagnosed the local faults of the vertical profile of the right (VP) and the left (VL) rail in the transition area of the section 1.1. In the following measurements – PO3 and PO4 – was diagnosed another decrease in quality of the section 1.1, which proves the increased number of the local faults, as well as the decreasing value (increasing) of the general quality number. In November 2014 the railway infrastructure manager executed the maintenance in the transition areas of the sections 1.1 and 2.1. The diagnosed local faults were removed by means of the maintenance. The complex continual diagnostics executed by the measuring trolley KRAB™ - Light and the monitoring executed by the railway infrastructure manager by means of the levelling method from December 2014 to August 2015 in the sections 1.1 and 2.1 prove other settlements of the track level. Their values do not occur as the local faults so far because the operational tolerances were not overrun. However, there is expected the formation and occurrence of the local faults within a short time period because of the proved quality decrease tendency of the particular parameters of the mentioned sections. The sections 1.2 and 2.2 in the transition areas do not prove any faults of the values. The quality development tendency of the measurements recorded so far does not imply any probability of their occurrence either in the following measurements [3].
3. The prognosis of the quality development tendency of the construction

The prognosis of the quality development tendency of the particular track geometry parameters is concentrated on the problematical section from the point of view of the track quality. As introduced in the parts 1 and 2, it concerns the transition areas from the ballastless track to the ballasted track in the subsections 1.1 and 2.1. From the data acquired by the measuring trolley were processed the graphs of the real deviations of the track axis alignment ($SK$), gauge ($RK$), gauge change ($ZR$), superelevation ($PK$), the projected value of which is in the mentioned section 0 mm, the twist fault at three measuring bases ($ZK_{1.8}, ZK_{6.0}, ZK_{12.0}$) and the rail top level of the left and the right line ($VL, VP$) in the section from km 102.454 000 to km 102.487 000. A part of this section are the transition areas in both lines from km 102.460 500 to km 102.480 500. In the paper are presented the graphs of real deviations of a selected parameter – the rail top level of the left and the right rail and the development tendencies of this parameter because it is in regard to the maintenance planning of the transition areas the most critical parameter in the long term [5].

In the transition area of the section 1.1 (Figure 1 and Figure 3) detect the tops of the right (after calculation also the left) rail a fault of this parameter on the level of the operational limit overrun defined by the values ±6 mm in PO4 for the right rail, respectively in PO3 and PO4 (the upper limit ±6 mm is overrun) and in PO2, PO3 and PO4 (the lower limit -6 mm) for the left rail. The repair of the track geometry executed in the transition area in November 2014 reduced the deviation values. However, the places with the limiting values of the deviations were remained (the contact of the transition area with the ballastless track and the ballastless track beginning).

In the transition area of the section 2.1 (Figure 5 and Figure 7) was not recorded any overrun of the operational limits of the parameters $VL, VP$ within the PO1 to PO4. However, the railway infrastructure manager carried out the maintenance in the same time at both tracks. The maintenance executed in the transition area of the track No. 2 did not improve the deviation values of the parameter. It came to the translocation of irregularities and places with the limiting values and there was recorded an increase of the deviation $VL$ from -1.5 to -3.5 mm and $VP$ from -1.0 to -3.0 mm on the contact of the conventional permanent way with the construction of the transition area.

The prognosis of the further quality development of the diagnosed parameters records various tendencies. The planning of the maintenance and repair works depends on the quality of the parameters which values are fastest impairing. In the case of the experimental sections in the area of portals of the Tunnel Turecký vrch, it is the vertical profile of the left and the right rail in the transition areas of the subsections 1.1 and 2.1. From the tendency lines created by means of the values $VL$ and $VP$ measured within PO5, PO6, PO7 and PO8 (Figures 2, 4, 6 and 8) is possible to predict that in the section 1.1 will be reached the operational limit (±6 mm) of the parameter $VL$ probably in September 2017 and the parameter $VP$ in May 2018. In the section 2.1 will the $VL$ and $VP$ reach the value of the operational limit probably in September 2017, respectively in June 2018. The overrun levels of the operational limits should be detected within the second measurement campaign of the measuring trolley of the railroads in Slovakia (in summer 2017). According to the measurement results is the railway infrastructure manager going to plan the execution of the track geometry repair in the mentioned sections.
Figure 1. The record of the deviations of the rail top level of left rail ($VL$) in the transition area of the section 1.1.

Figure 2. The development tendency of the maximum deviations of the rail top level of left rail ($VL$) in the transition area of the section 1.1.
Figure 3. The record of the deviations of the rail top level of right rail ($VP$) in the transition area of the section 1.1.

Figure 4. The development tendency of the maximum deviations of the rail top level of the right rail ($VP$) in the transition area of the section 1.1.
Figure 5. The record of the deviations of the rail top level of left rail \((VL)\) in the transition area of the section 2.1.

Figure 6. The development tendency of the maximum deviations of the rail top level of the left rail \((VL)\) in the transition area of the section 2.1.
Figure 7. The record of the deviations of the rail top level of right rail (VP) in the transition area of the section 2.1.

Figure 8. The development tendency of the maximum deviations of the rail top level of the right rail (VP) in the transition area of the section 2.1.
4. Conclusion

The monitoring of the ballasted and ballastless track construction with the centre of interest in the transition area between them has been executed for five years in the surrounding of portals of the Tunnel Turecký vrch. Within the continual diagnostics of the track geometry parameters was found out the quality decrease (represented by the increase of the value quality number – \( QN \)) in the sections 1.1 and 2.1. The quality impairment cause in the largest extent the parameters \( VL \) and \( VP \) by the overrun of the operational limits within PO2, PO3 and PO4. The repair after the measurements PO4 caused the improvement, however, it is again recorded the impairment of the measured deviations \( VL \) and \( VP \) and consequently \( QN \). With regard to the quality development of the sections 1.2 and 2.2 in the elapsed period of the monitoring it is predicted the lasting partial decrease of the construction quality responding to the railway operation without any emergency operation events.

Based on the relative and absolute construction track layout and the achieved results can be stated that the monitored sections with the ballastless track are settled and they do not show any relevant changes of the single parameters among the individual measurements. The sections with the ballasted track show changes, those ones, however, result from the character of this construction. The ballasted track sections require in certain intervals (depending on the operation loading) reparation of the track geometry: tamping and filling-in of the ballast bed and further repairs aiming at the preservation of the quality parameters during the whole lifetime of the structure. However, the measurements of the relative construction track layout have pointed at the irregularities in the transition areas between the ballasted track and the ballastless track especially in the area of the southern portal of the Tunnel Turecký vrch, in the tracks No. 1 and No. 2. These results were subsequently proved by the geodetic survey and also by the outputs of the measuring trolley of the ŽSR. The decreases recorded in these transition areas from the beginning of the measurements resulted into the limit overruns of the quality marks of the rail top level of the rails \( QM_{VK} \), as well as into the appearance of the local errors what led to the realization of the corrective action. This corrective action slightly slowed the error development tendencies, however, the quality of the track geometry of both lines continues in the degradation and the next limit overruns are to be expected already during the second half of the year 2017, out of what will result the necessity to realize another corrective action.

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