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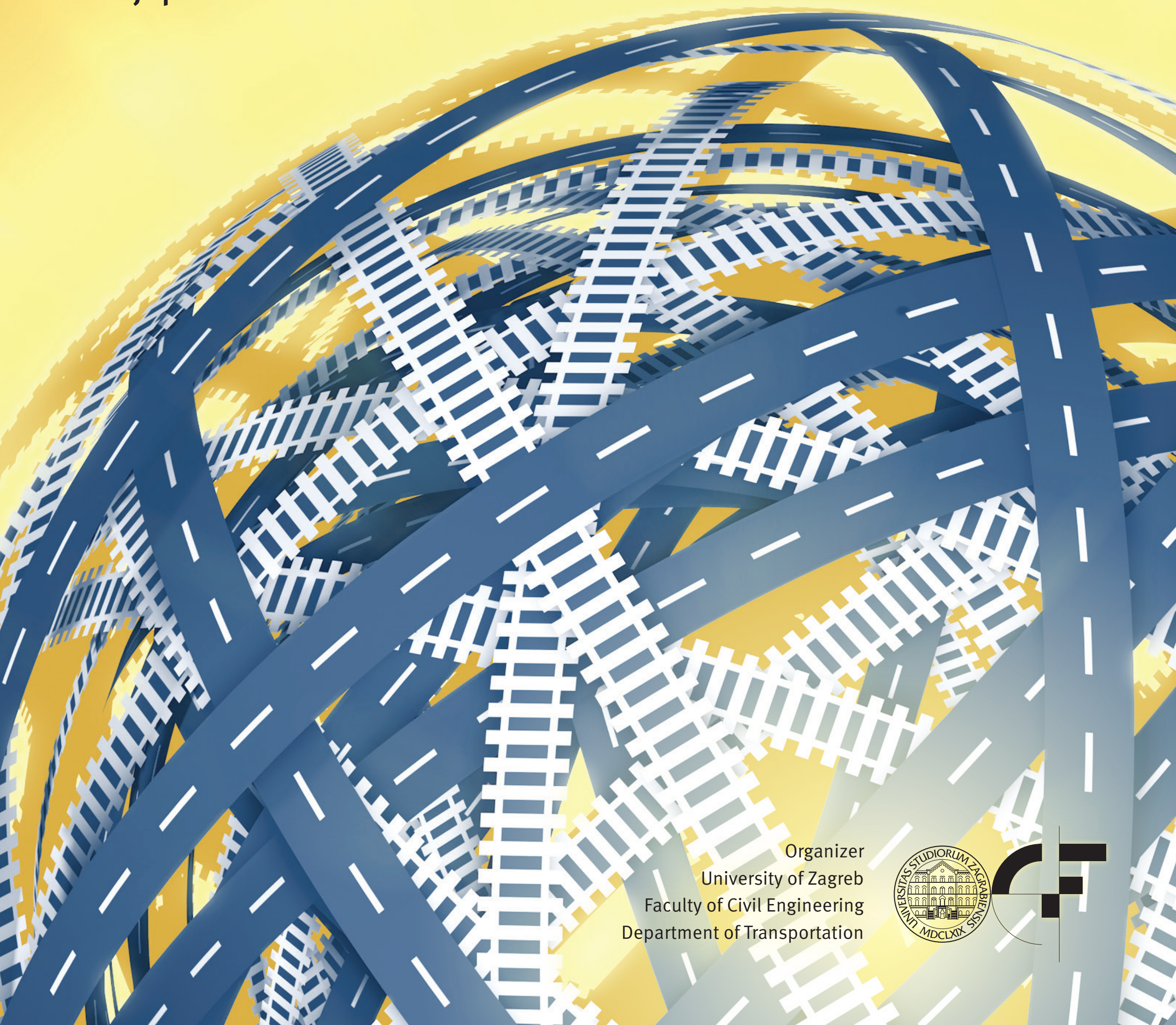
23–25 May 2016, Šibenik, Croatia

Road and Rail Infrastructure IV

Stjepan Lakušić – EDITOR



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VERIFICATION AND OPTIMIZATION OF TRANSITION AREAS OF BALLASTLESS TRACK IN THE TUNNEL TURECKÝ VRCH

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Abstract

The modernization of the railway infrastructure of the Slovak Republic is an ideal opportunity for verifying the applications of unconventional structures of the railway superstructure. The Department of Railway Engineering and Track Management, Faculty of Civil Engineering, University of Žilina monitors geometric parameters of experimental railway track sections in the vicinity of the portals of the tunnel Turecký vrch – sections of ballastless track Rheda® 2000, transition areas and sections of ballasted track. The preliminary results of research and experience of the infra-structure manager show that the most problematic parts of track sections are the transition areas between ballastless and ballasted track. The paper deals with the results of monitoring of the track geometry by the measuring trolley KRAB™–Light.

1 Introduction

The ballasted track superstructure is made up of rails, supporting points (sleepers), rail fastenings and rail (ballast) bed. The superstructure where the ballast function is replaced by improved materials is called ballastless track. The ballastless track has been reported as a practical and convenient structural system which resulted in its occurrence all over the world. An important reason for building ballastless tracks is the fact that by its establishment we achieve high track stability resulting in high driving comfort for passengers and lower requirements for track maintenance, possesions and financial costs.

In general, the ballastless structure is currently applied mainly in high speed lines and lines that have high line tonnage and where the costs of maintaining ballasted track grow rapidly. Furthermore, this structure becomes more common in upgraded sections of standard tracks (track speed up to 160 km/h), or high speed tracks (track speed 160 km/h $< V \leq$ 200 km/h) and mainly in the sections routed in tunnels as in these sections the subgrade properties are favourable, i.e. no settlement of foundations occurs. Besides this, ballastless track application has a positive impact on financial costs for tunnel construction, due to the smaller net tunnel cross section in case of new tunnels or excluding economically demanding reconstruction of the tunnel in case of its electrification on existing tracks. The application of ballastless structure is also possible in track sections routed on bridges due to subgrade with no settlement of foundations [1].

In the Slovak Railways network the ballastless track is currently designed and built on upgraded sections of railway tracks – as a priority in tunnels and on bridges (Fig. 1) [2]. The Department of Railway Engineering and Track Management has been involved in the diagnostics of track geometry for ballastless structure in the area of portals of the newly built tunnel Turecký vrch and after more than ten years after finishing monitoring of the prototype of ballastless structure in Lietavská Lúčka they turn their focus on the issue of ballastless track superstructure.

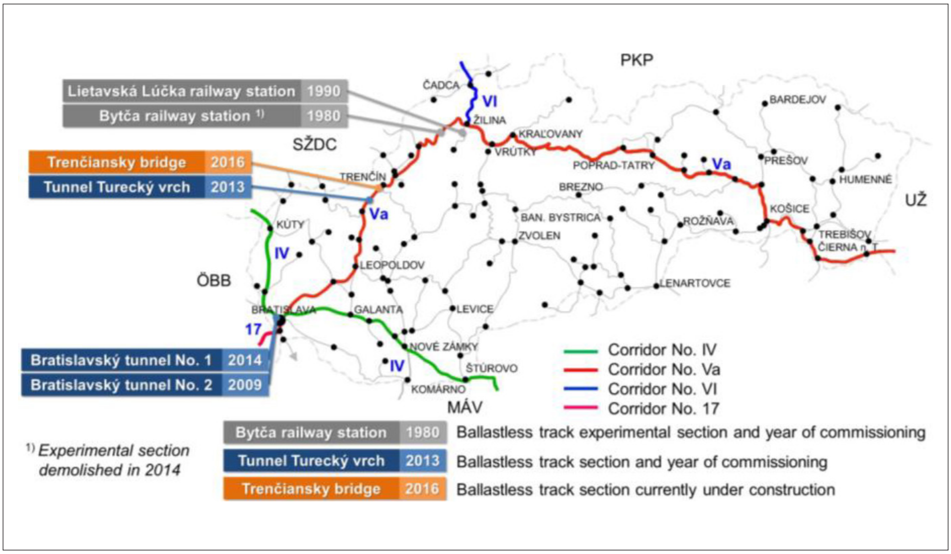

Figure 1 The ballastless track sections in the railway infrastructure of the Slovak Republic

2 Characteristics of the experimental section

The experimental section is situated in the vicinity of the portals of the newly built tunnel Turecký vrch. This track is a part of V. multimodal transport corridor TNT-T, so called Baltic-Adriatic corridor Venezia – Terst/Koper – Ljubljana – Budapest – Užhorod – Ľvov with the branch Va Bratislava – Žilina – Užhorod. The ballestless structure (system Rheda 2000®) was built within modernisation of the railway rack Nové Mesto nad Váhom – Púchov, km 100.500 – 159.100, object 24-32-01 Nové Mesto nad Váhom – Trenčianske Bohuslavice [1].
The ballastless structure passes though different types of subgrade. It starts on eartwork at the south portal and is routed 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. The end of the ballastless structure and the transition to the ballasted structure is carried out by a new type of transition area using standard superstructure components. The structure consists of a longitudinal concrete bed, 20 m long. Each rail has its own concrete bed and the beds are longitudinally dilated. 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.

3 Methods of diagnostics of track geometry

The diagnostics of the track geometry is carried out by the measuring trolley KRAB™–Light [3], [4]. The measuring system measures the track parameters in an unloaded state. The measured parameters are:
- gauge tolerance RK (after calculating the change of gauge ZR is also recorded),
- alignment of right rail SR (after calculating the alignment of left rail SL is also recorded),
- rail top level of right rail VR (after calculating the rail top level of left rail VL is also recorded),
- cant 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).

4 Assessment of results of track geometry diagnostics

The results of diagnostics are evaluated in accordance with valid technical ŽSR standards and regulations:

- STN 73 6360, Geometrical Position and Arrangement of 1 435 mm Gauge Railways, SÚTN Bratislava, 1999 and Amendment 1, SÚTN Bratislava, 2002 for track speeds of 120 km/h ‹ V ≤ 160 km/h (velocity zone No. 4 – RP4) [3],
- ŽSR SR regulation 103-7 (S) Measurement and Evaluation of Track Geometry by Measuring Trolley KRAB (in Slovak), GR ZSR, (2008) [4].

The experimental sections are for the sake of diagnostics marked as:

- section 1.1 (track No. 1, south portal) and 2.1 (track No. 2, south portal; both sections of length 175 m; km 102.360 000 – km 102.535 000):
- km 102.360 000 – km 102.460 500 ballasted track,
- km 102.460 500 – km 102.480 500 transition area,
- km 102.480 500 – km 102.535 000 ballastless track.
- section1.2 (track No. 1, north portal) and 2.2 (track No. 2, north portal); both sectors of length 640 m; km 104.200 000 – km 104.840 000):
- km 104.200 000 – km 104.720 500 ballastless track,
- km 104.720 500 – km 104.480 500 transition area,
- km 104.740 500 – km 104.840 000 ballasted track.

The diagnostics of the track geometry was carried out on semi-annual basis as [5]:

- measurements before putting sections into operation (MSO) 10. – 11.7.2012, 2. – 3.10.2012,
- first operational measurement (PO1) 09.04. – 10.04.2013, 21.04 – 22.04.2013,
- second operational measurement (PO2) 08. – 09.10.2013, 21. – 22.10.2013,
- third operational measurement (PO3) 25.5.2014 and 28.5.2014,
- fourth operational measurement (PO4) 29.10.2014.
- fifth operational measurement (PO5) 25.3.2015 and 17.4.2015.
- sixth operational measurement (PO6) 14. – 15.10.2015.

The measured parameters are evaluated according to the maximum input tolerance for acceptance of works with the use of new material (MSO), or according to operational tolerances and limit operational tolerances for RP4 (Table 1). The overall super evaluation of the test sections is given by:

- the quality number of the section (SQM) of each parameter (SK, RK, PK, VK),
- the quality mark (QM), as an assessment of a track geometry quality in the evaluated section,
- the tamping mark (TM), which is used to decide whether to use the tamping machine and varies from SQN by excluding the gauge tolerances (RK) which tamping machine does not maintain,
- the quality number (QN).

The section evaluation is carried out according to [4] using:

- the quality number of the evaluated section, which is used to assess the quality of track geometry and is calculated from the standard tolerances of the measured parameters of the evaluated section (SK, RK, PK, VK); to evaluate the quality of track geometry are set recommended standard tolerances values of each parameter and quality number values for RP4 are listed in Table 2,
- the quality marks of each parameter (SK, RK, PK, VK); the results of evaluation by the quality marks are indicative and additional and are not binding for the evaluation of track geometry; assessments that are defined at various intervals of the quality marks are only recommendatory (Table 3).

Table 1 The tolerances of relative geometric parameters of the track for RP4 [3]

Measured parameter	Limit input tolerances		Operational tolerances		Limit operational tolerances		Note
RK (mm)	-2	2	-3	5	-5	10	–
ZR (mm/m)	2		3		4		–
PK (mm)	-3	3	-6	6	-8	8	–
Measured parameter	**Limit value**		**Operational value**		**Limit opera-tional value**		**Note**
ZK (1:n) (mm/base)	1:250 (7.2; 4.0)		1:250 (7.2; 4.0)		1:167 (10.8; 5.99)		on measuring base 1.8 m
	1:832 (7.2; 1.20)		not evaluated		1:250 (24.0; 4.0)		on measuring base 6.0 m
	not evaluated		not evaluated		1:333 (36.0; 3.0)		on measuring base 12.0 m
Measured parameter	**Limit input relative tolerances**		**Relative operational tolerances**		**Limit operational relative tolerances**		**Note**
VL, VP (mm)	-3	3	-6	6	-8	8	–
SL, SP (mm)	-3	3	-6	6	-8	8	–

Table 2 The limit values of respective tolerances of geometric quantities (SDV) and quality numbers (CK) for RP4 [4]

Limit input tolerances				Limit operational tolerances			
SDV_{SK}	SDV_{RK}	SDV_{PK}	SDV_{VK}	SDV_{SK}	SDV_{RK}	SDV_{PK}	SDV_{VK}
0.7	0.8	0.7	0.8	0.9	1.0	1.1	1.5
QN				**QN**			
1.8				2.5			

Table 3 The scale of quality marks according to quality section evaluation [4]

Interval of quality marks	Verbal assessment of the section according to the quality mark	Color of the quality mark in printed output
0 ‹ QM ≤ 2	the state of track geometry is satisfactory in the section evaluated	no color marking
2 ‹ QM ≤ 3	it is recommended to design the repair of track geometry in the section evaluated in the maintenance work plan	green color
3 ‹ QM ‹ 4	it is recommended to perform the repair of the track geometry in the section evaluated before the nearest inspection	violet color
4 ≤ QM ≤ 6	it is recommended to perform immediate measures in the section evaluated to ensure the safety of operation	red color

5 Quality assessment of diagnosed sections

The quality development of the track geometry quality diagnosed by the measuring trolley KRAB™–Light is shown by Fig. 2 to Fig. 6. The evaluation of tolerances of track geometry in RP4 includes evaluation of straight track, track in curve or in transition curve. As a part of the input measurement (MSO), 40 local errors were found, 30 of them in the section with ballasted track, 9 in the section with ballastless track and 1 in the transition area in the south portal area (rail no. 2). After this measurement, the contractor carried out the repair of track geometry and the repair of microgeometry of rail heads by grinding in the diagnosed sections. Unfortunatelly, the contractor did not provide the details of this intervention. In the second operational measurement (PO2) there were for the first time diagnosed local errors of alignment of right (VP) and left rail (VL) in the transition area of the south portal (rail no.1) that confirm the results of the measurements by measuring vehicle of ŽSR. In the following measurements – in the third and fourth operational measurement (PO3 and PO4), further quality degradation of this track section was diagnosed, confirmed by the increased number of local errors and lower value of quality number (Fig. 2). In November 2014, there were done maintenance interventions in transition areas near south portal. The interventions also significantly decreased the value of quality numbers of sections, from the value 2.36 (PO4) to the value 1.31 (PO5) in the section 1.1 and from the value 1.86 (PO4) to the value 1.59 (PO5) in the section 2.1. The levelling in both transition areas of the south portal (sections 1.1 and 2.1) from December 2014 to August 2015 showed further decline in vertical alignment of the track. With regard to their size these values cannot be at present considered as local errors but in relation to qualitative decrease of other parameters of sections, incidence of local errors can be expected in the near future. The transition sections of the north portal do not show any decrease of these values and the trends based on measurements do not indicate probability of their incidence in further measurements [5].

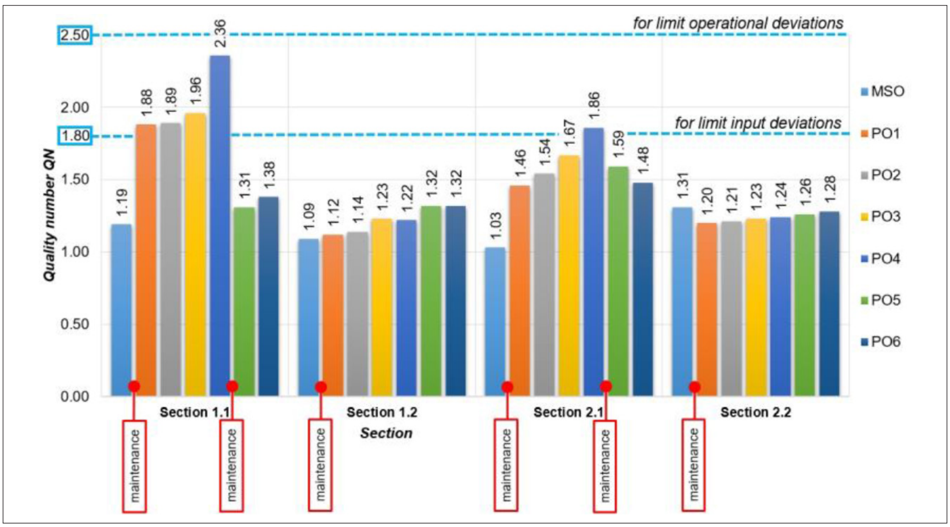

Figure 2 Overall quality numbers in the monitored sections

The quality marks of alignment of right (after calculation also left) rail QM_{SK} (Fig. 3) were in the input (MSO), first (PO1), second (PO2) and third operational measurement (PO3) in the interval $2 < QM_{SK} \leq 3$. The quality marks in the interval $3 < QM_{SK} \leq 4$ were achieved in the sections 1.1 and 2.1 (both rails of the south portal) in the fourth operational measurement (PO4). After interventions the values of quality marks decreased to the interval $0 < QM_{SK} \leq 2$ in the section 1.1 (rail no. 1, south portal), or $2 < QM_{SK} \leq 3$ in the section 2.1 (rail no. 2, south portal).

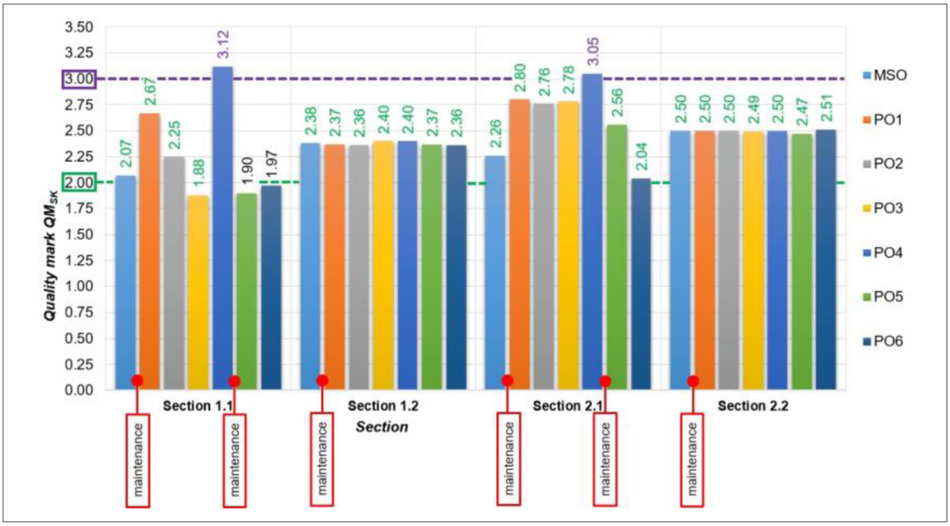

Figure 3 Quality marks of track alignment in the monitored sections

The quality marks of gauge tolerance in all the sections and measurements were in the value interval $0 < QM_{RK} \leq 2$ (Fig. 4). The higher values of quality marks QM_{RK} of sections 1.1 and 2.1 are related to the higher share of sections with ballasted track compared to the sections in the north portal area where ballastless construction is prevailing. It fixes gauge in much better quality than ballasted track.

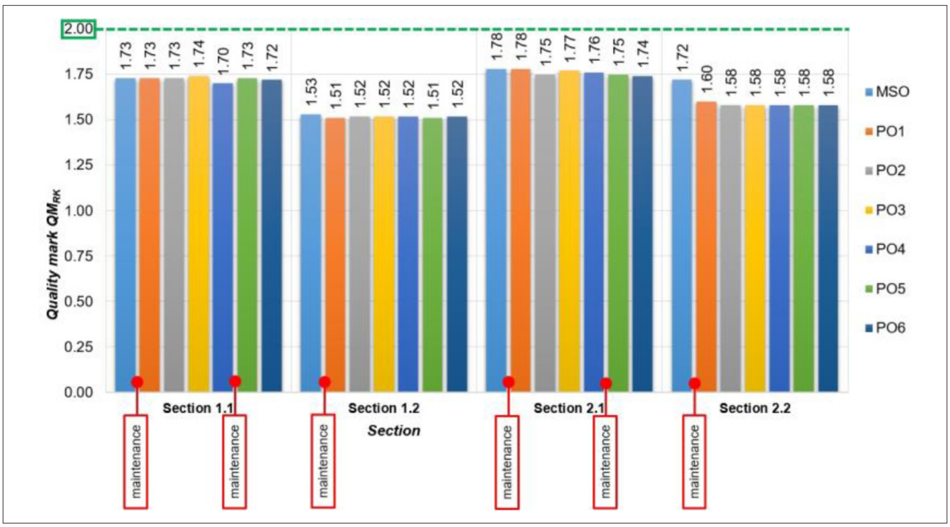

Figure 4 Quality marks of gauge in the monitored sections

The quality marks of cant QM_{PK} are in the value intervals $0 < QM_{PK} \leq 2$ and $2 < QM_{PK} \leq 3$ in the second, third and fourth operational measurement (PO2, PO3 and PO4) in the section (rail no. 1 at the south tunnel portal). After corrective interventions the values got back to the interval $0 < QM_{PK} \leq 2$. The increasing trend of quality mark of cant QM_{PK} in this section indicates that in one of the following measurements the value will again reach the interval $2 < QM_{PK} \leq 3$ (Fig. 5).

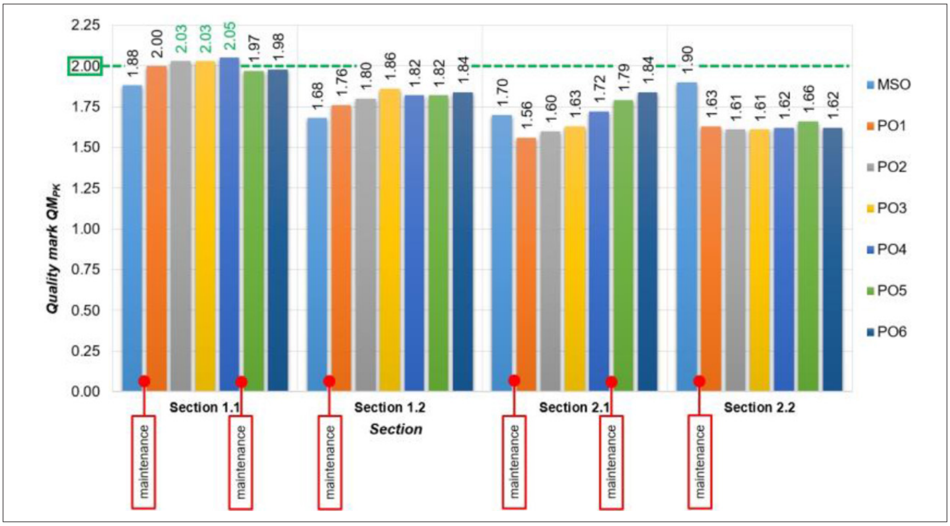

Figure 5 Quality marks of cant in the monitored sections

The worst quality mark, based on so far carried out measurements, seems to be the quality mark of rail top level of the right (after calculation also the left) rail QM_{VK} (Fig. 6). The defects of rail top level tolerance of rail are the most frequently occurring defects resulting from the evaluation of measurements by the measuring vehicle ŽSR. With the exception of the section 2.1 (rail no. 2 in the south portal), in all the sections and measurements there were reached values $2 < QM_{VK} \leq 3$ and values $3 < QM_{VK} < 4$ in the first to fourth operational measurement (PO1 to PO4). The corrective intervention carried out before the fifth operational measurement (PO5) decreased the values of quality marks QM_{VK} that were in the fifth and sixth operational measurement (PO5, PO6) again in the interval $2 < QM_{VK} \leq 3$. The growing trend indicates that in the following measurements the quality mark of value QM_{VK} in the interval $3 < QM_{VK} < 4$ can be achieved.

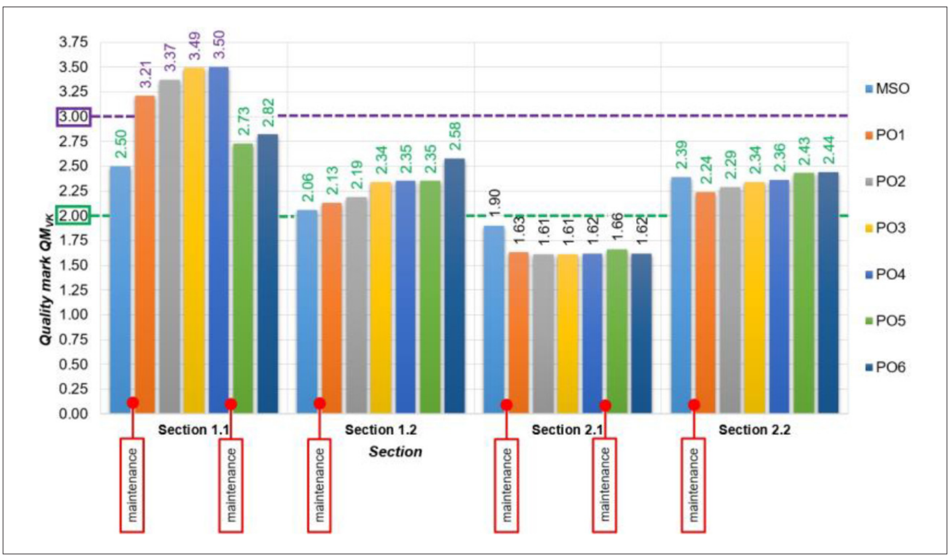

Figure 6 Quality marks of rail top level of right rail in the monitored sections

6 Conclusion

The results show that the critical point of ballastless sections are the transition areas from this type of construction to the ballasted superstructure. The current problem in this field is optimization of design of transition areas. Its solution can be found important by infrastructure operators in relation to corridor track modernisation where construction of more ballastless sections is planned. The paper contains results of the grant VEGA 1/0597/14 "Analysis of methods used to measure the unconventional railway track construction from the point of view of accuracy and reliability".

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