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Under sleeper pads in switches & crossings

Otto Plasek[1] and Miroslava Hruzikova[1]

[1]Brno University of Technology, Faculty of Civil Engineering, Veveri 331/95, 602 00 Brno, Czech Republic

E-mail: plasek.o@fce.vutbr.cz, hruzikova.m@fce.vutbr.cz

Abstract. Under sleeper pads (USPs) have been installed in the Czech railway lines since 2007 into two trial sections in switches and crossings and in a trial section with the aim to reduce rail pitch corrugation. The basic motivation for the construction of the trial track sections in turnouts was an evaluation of USPs' influence on improvement of track quality as a consequence of ballast bed protection against extreme stress. The paper comprises experience of USPs installation in the Czech Republic in the two trial sections with switches and crossings built in 2007 and 2014. The paper particularly provides an information about USPs applications focusing on the track settlement received by an evaluation of data from the geodetic surveying by precise levelling. Some positive influence of under sleeper pads on the track quality is observed.

1. Introduction

The increase of dynamic effects in railway track structures is connected with the train service speed and axle load increase. An increase of ballast stress is caused not only by the higher dynamic effects but also by the use of concrete sleepers and bearers which are characterized by higher bending stiffness and a relatively small contact area with ballast bed [1]. The dynamic effects occur due to imperfections of a railway track and vertical stiffness variation. The dynamic effects cause changes in sleeper or bearer support in ballast bed that unfavorably influence the quality of track geometry parameters.

A progressive deterioration of the track quality characterized by irregular supports of concrete sleepers or even by voiding sleepers which can vibrate in the ballast bed (so called dancing sleepers) as described, e.g., in [2] and [3], is a consequence of the evidence that track imperfections and higher dynamic effects are closely connected together, [4] and [5].

Under sleeper pads (USPs) which are fixed on the underneath surface of a sleeper decrease the railway track stiffness. Simultaneously the contact area between sleepers or bearers and ballast is significantly higher. Static and dynamic loads on sleepers or bearers are decreased and vehicle–track dynamic system properties are modified. Similarly, furthermore, the transfer of vibrations to a ballast bed is interrupted and damping of vibrations is moved to upper parts of a track, [6] and [7].

The first two trial sections for concrete sleepers or bearers with USPs were built in the Czech Republic in 2007 [8]. The basic motivation for the construction of the trial track section in Plana nad Luznici railway station was an evaluation of the influence of USPs on improvement of track quality as a consequence of the ballast protection against extreme stress. The second trial section was constructed in the Havlickuv Brod – Okrouhlice railway line section with the objective to reduce the rail corrugation development in the curve of small radius. This second trial section is outside of the paper scope. The third trial section with USPs was constructed in Usti nad Orlici railway station in 2014. The line tonnage is approximately 5.6 MGT per year in Plana nad Luznici, while 27,8 MGT in track No.1 and 31,8 MGT in track No.2 in Usti nad Orlici.

Usti nad Orlici station was chosen for testing of more types of the track stiffness modification in switches and crossings (S&C). S&C with special type of rail fastening as well as the USPs are investigated in the station. The variation of different properties of components should homogenize the vertical track stiffness in S&C along the track to reduce dynamic effects caused by abrupt changes of track stiffness. A special type of rail elastic fastening was installed in two selected turnouts and USPs into other two turnouts. The combined solution with the special elastic fastening together with USPs was not used since the dynamic response of such design has not been investigated yet.

Figure 1. Trial sections with under sleeper pads in the Czech Republic.

The paper comprises experience with applications of USPs in the Czech Republic from point of view of track settlement. Here published results are complementary to the evaluation of track settlement and track quality in the sections with USPs, which was published by authors in [9]. An influence of USPs on track quality and influence on sleepers or bearers deflections and vibrations has been monitored for more than nine years.

1.1. Plana nad Luznici trial section

The first trial track section was built in Plana nad Luznici railway station (the 4th Czech railway corridor: Prague – Ceske Budejovice – Linz) in the Czech Republic in 2007. The trial section comprises of a turnout J60-1:12-500-I (the rail 60 E1) with USPs and an adjacent track with and without USPs. The line tonnage ranges from 20 000 to 40 000 gross tons per day, the class of the line according to the maximum admissible axle load and load per unit length is D4 (axle load 22.5 t or load per unit length 8 t.m^{-1}).

The assembly of the USPs for the turnout was designed in the finite element model [10] with the aim to reduce abrupt changes of track vertical stiffness. The basic bedding modulus of installed USPs is 0.25 N.mm^{-3} – Getzner SLB 2210. Softer USPs – Getzner SLS 1010 and SLS 1707 – were used in the crossing panel just behind a frog nose and in the area of long bearers behind the crossing. The softer USPs are only in the middle part of the bearers. Transition zones that allow smooth transition of vertical track stiffness between the track with USPs and the track without USPs were designed. The bedding modulus of USPs in the transition zones is 0.30 N.mm^{-3} – Getzner SLB 3007. The length of the transition zone in the adjacent plain track on both ends is 32.4 m, i.e., 54 sleepers. The total length of the track with USPs is 205 m. The pads were installed on the underneath surface of sleepers and bearers by gluing. The neighbouring turnout and the adjacent track were chosen as a comparative conventional section. Continuous welded rail was constructed in the whole track section including both turnouts. The review of the whole trial section is in Figure 2.

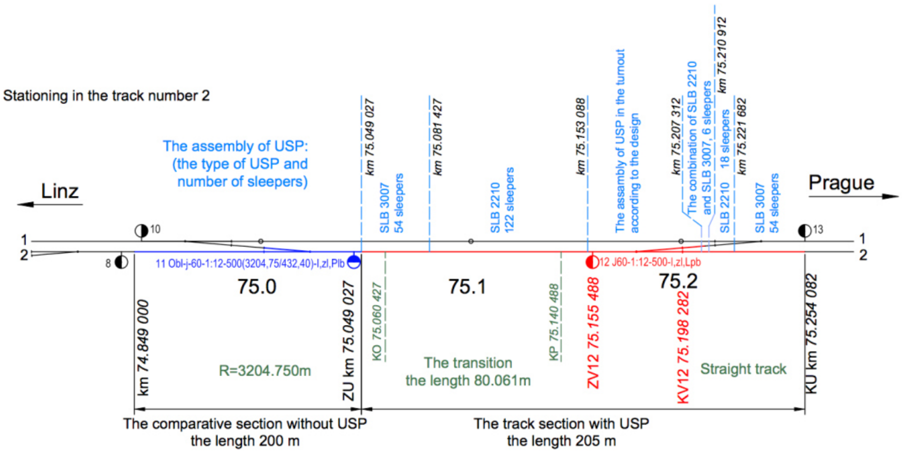

Figure 2. The scheme of the trial track section for USPs in the turnout in Plana nad Luznici railway station.

1.2. Usti nad Orlici trial section

The second trail section with S&C with USPs is located in Usti nad Orlici railway station on the main line Prague – Brno / Ostrava. The traffic load of this track ranges from 80 000 to 130 000 gross tons per day, the class of the line according to the maximum admissible axle load and load per unit length is D4. USPs are installed into two turnouts of different types – J60-1:14-760 and J60-1:12-500-I (both the rail 60 E2). Both turnouts are located on the eastern part of the railway station in the main tracks with V_{max} = 120 km.h^{-1}, for tilting trains (Pendolino CD class 680) V_{max} = 130 km.h^{-1}. The investigated turnouts are: No. 7 J60-1:14-760 in track No.1 and No. 8 J60-1:12-500-I in track No. 2, see Figure 3.

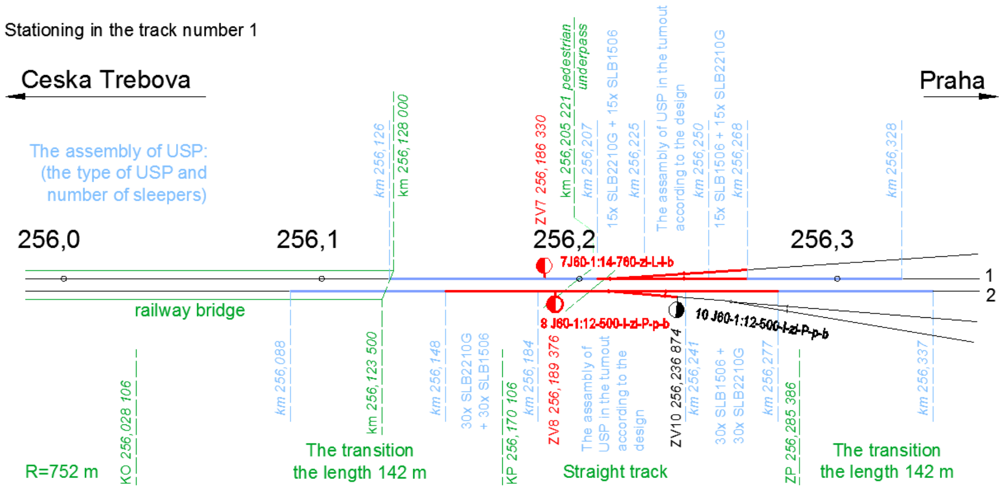

Figure 3. The scheme of the trial track section for USPs in the turnouts in Usti nad Orlici railway station.

The USPs assemblies and stiffness of USPs on particular sleepers or bearers were designed based on the numerical modelling of structures and their static and dynamic analyses. The USPs arrangement was determined regarding the vertical track stiffness homogenization but simultaneously to get the assembly design as simple as possible because of construction work procedures. USPs of 4 different types (bedding moduli) were used in the turnouts, adjacent track including transition zones. The basic bedding modulus of installed USPs is a softer than in Plana nad Luznici, i.e. 0.13 $N.mm^{-3}$ – Getzner SLS 1308G. The softest USPs were installed in the crossings just under the frog nose, the stiffest one in the transition zones between the track with and without USPs. The USPs are installed in the whole length of turnout No. 8, transition zones are located in front of and behind the turnout. The economical design of the USPs assembly was used in the turnout No. 7 where USPs were installed only in the crossing while one transition zone is located between switch and crossing, the second one in the adjacent track behind the crossing. USPs of two bedding moduli were installed into the transitions because of a gradual change of the vertical track stiffness, details of the USPs assemblies were published in [9].

The locality in which the turnouts were installed is rather complicated because of two bridges in the sections vicinity – a pedestrian tunnel and a viaduct over the rivers confluence. Both turnouts are influenced by the transitions of the track from the embankment to the bridge structures. The switch of the turnout No.7 even partially lays on the deck of the pedestrian tunnel structure.

2. Monitoring of USPs trial sections

2.1. Monitoring principles

The trial sections were built with the aim to protect permanent way elements against extremely high dynamic loading. That is why all parameters that could be influenced by the application of USPs are assessed. The following parameters are being observed in all trial sections:

- quality of track geometry parameters;
- track settlements;
- vertical deflections under a running axle;
- vibrations of railway superstructure elements;
- transfer of vibrations to a track vicinity;
- noise propagation to a track vicinity.

This article deals only with the track settlement monitoring assessed by precise levelling. The aim of this assessment is to verify the stability of the support of sleepers or the long bearers with USPs in ballast bed.

2.2. Track level and settlement

The level of running surface of both rails was monitored through geodetic surveying by precise levelling in all trial sections. Rail levels, bracket-type datum mark and other check points were monitored. The distance between the monitored cross sections in the plain track was 6.0 m; the distance between the cross sections in the turnouts and in the immediate adjacent track was 3.0 m. A total of 93 cross sections are monitored in Plana nad Luznici railway station, a total 48 cross sections in the track No.1 and 65 cross sections in the track No.2 in Usti nad Orlici railway station have been investigated.

The track level is evaluated in a relative altitude system. Relative deviations from the optimized track position, which was found out by regression in the initial observation, were calculated. Designed parameters of graduated transition curves were taken into account.

The evaluation of relative geometry parameters was chosen for two reasons. The first reason is the fact that a printing of absolute track level in a chart does not provide an evidence of the track level deviation which is relatively small to the absolute track level. An expression of the deviation relative to the designed track level is influenced by overall changes of the track level in the whole section - settlement or tamping of the track – which is the second reason.

The longitudinal level of the track in both trial track sections was measured twice or occasionally three times every year after the trial sections had been put into operation. If a track geometry correction by tamping procedure had been planned, the levelling was carried out of the track a few days before and after the maintenance work.

Due to a weak subsoil the track sections in the plain track behind the turnouts in Usti nad Orlici had to be tamped in March 2015 in both tracks and in November 2015 in track No.2. In the period between both tamping non-specific maintenance was carried out in track No.1 so this period was removed from the numerical evaluation. Next tamping of both tracks and turnouts is planned for March of 2017. Such maintenance makes the evaluation difficult since only measurements between two consecutive tamping can be taken into account.

The charts in Figure 4 and Figure 5 provide an impression of qualitative assessment of the track settlement in the particular sections. The small and homogeneous settlement is evident in the turnout regions in both tracks in comparison with the adjacent track sections.

The level deterioration and variation is evident in both track behind the turnouts, which is caused by the weak subsoil in this area. The information about the weak subsoil was provided by railway infrastructure manager based on data from the construction work acceptance process (these data are confidential and not available for the research team). Unfortunately, this fact also influences an evaluation of behavior of the track with USPs since the track level in the transition zones follows the level of the adjacent track on the weak subsoil.

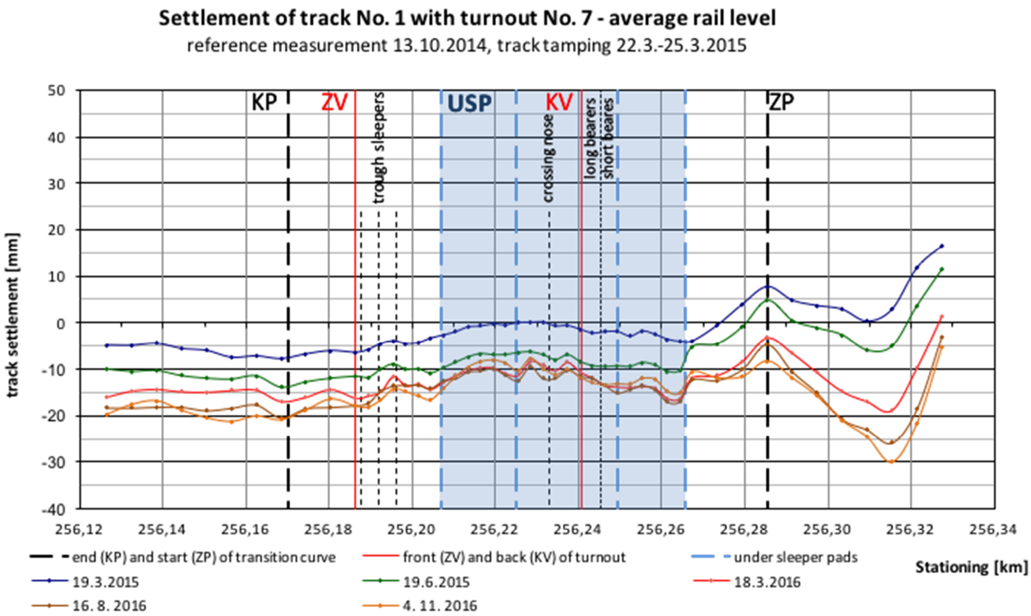

Figure 4. The track settlement in track No.1 Usti nad Orlici after track tamping (March 2015).

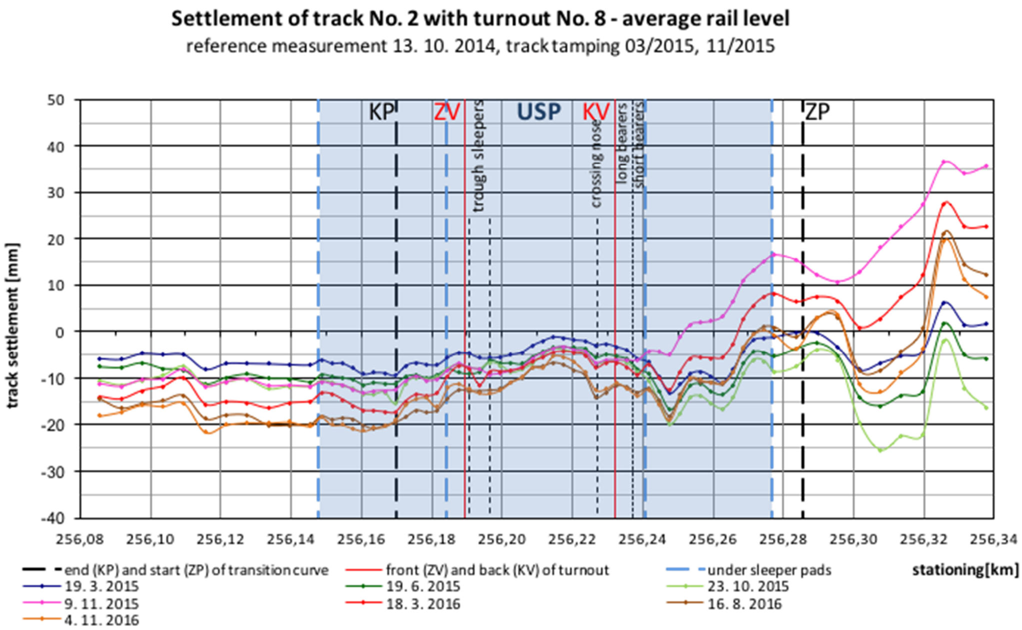

Figure 5. The track settlement in track No.2 in Usti nad Orlici after track tamping (22–25th March 2015).

2.3. Numerical evaluation of track settlement

The settlement progress analysis against line tonnage in both sections for plain track with and without USPs was carried out. The exponential regression of settlement curves was calculated by least square method following the formula:

$$S(l) = L \cdot \left(1 - e^{-\frac{k}{L} \cdot l}\right) \tag{1}$$

in which symbols mean:

S(l) … function of settlement [mm];
l … line tonnage [MGT … million gross tons];
L … limit of settlement [mm];
k … slope of tangent at $l = 0$ [mm.MGT^{-1}].

The regression parameters used in the formula (1) were calculated by the Newton iterative method using the least square method. The detailed description of a numerical calculation of parameters is provided in [11].

The track settlement in Usti nad Orlici was evaluated in both tracks since November 2015 after the last tamping in track No.2 because no maintenance has not been carried out in both tracks. The evaluation of the track settlement including nonlinear regression is presented on charts in Figure 6 and Figure 7.

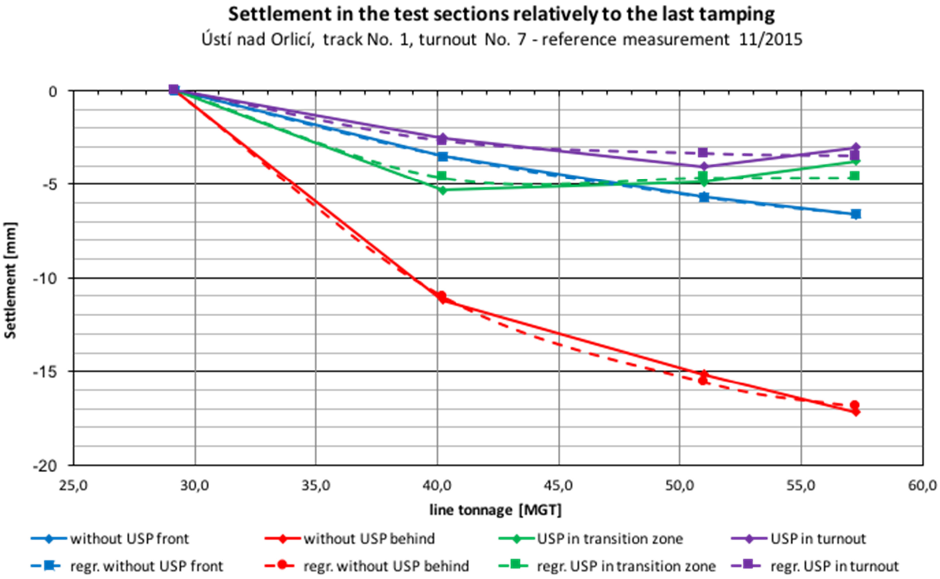

Figure 6. The track settlement progress in Usti nad Orlici after the track tamping 11/2015.

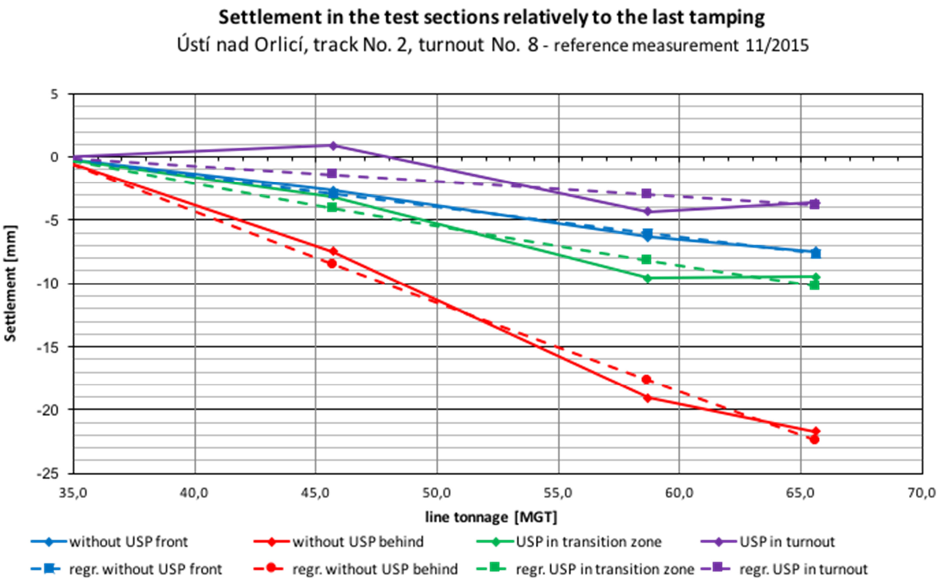

Figure 7. The track settlement in Usti nad Orlici after track tamping (22–25th March 2015).

Table 1. Results of numerical evaluation of the track settlement.

	Usti nad Orlici track No.1, turnout No.7		Usti nad Orlici track No.2, turnout No.8		Plana nad Luznici [11]	
	L [mm]	k [mm.MGT^{-1}]	L [mm]	k [mm.MGT^{-1}]	L [mm]	k [mm.MGT^{-1}]
without USPs front	9.9	0.4	63.3	0.3	10.62	0.02
without USPs behind	19.0	1.5	260	0.7		
USPs in transition zone	4.6	7.7	43.5	0.4	-	-
USPs in turnout	3.6	0.5	95 700	0.1	10.47	0.02

3. Conclusion

Based on the numerical evaluation (Table 1, Figure 6, Figure 7) following facts can be stated:

- the biggest track settlement caused by weak subsoil occurs behind both turnouts in Usti nad Orlici (red lines in Figure 6 and Figure 7);
- the dependence of track settlement on line tonnage is untypically almost linear in track No.2 in Usti nad Orlici so a relatively fast settlement can be expected in this track;
- the track settlement in the track section with USPs in Plana nad Luznici is approximately twice bigger than in the track section with USPs in Usti nad Orlici.

A negative relative settlement (uplift) has been identified in the track sections with USPs, although it is very small, up to 1 mm. This effect has not been completely explained yet. The reason can be the limited precision of measurement and evaluation methods. Because this effect has not been identified for the first time, authors consider also other factors, which could cause this effect, e.g. climate influence on ballast bed and substructure layers. Generally, the conclusion is that USPs in the turnouts in Usti nad Orlici positively influence the track settlement, consequently the track quality, i.e. the main objective for USPs installation is satisfied.

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