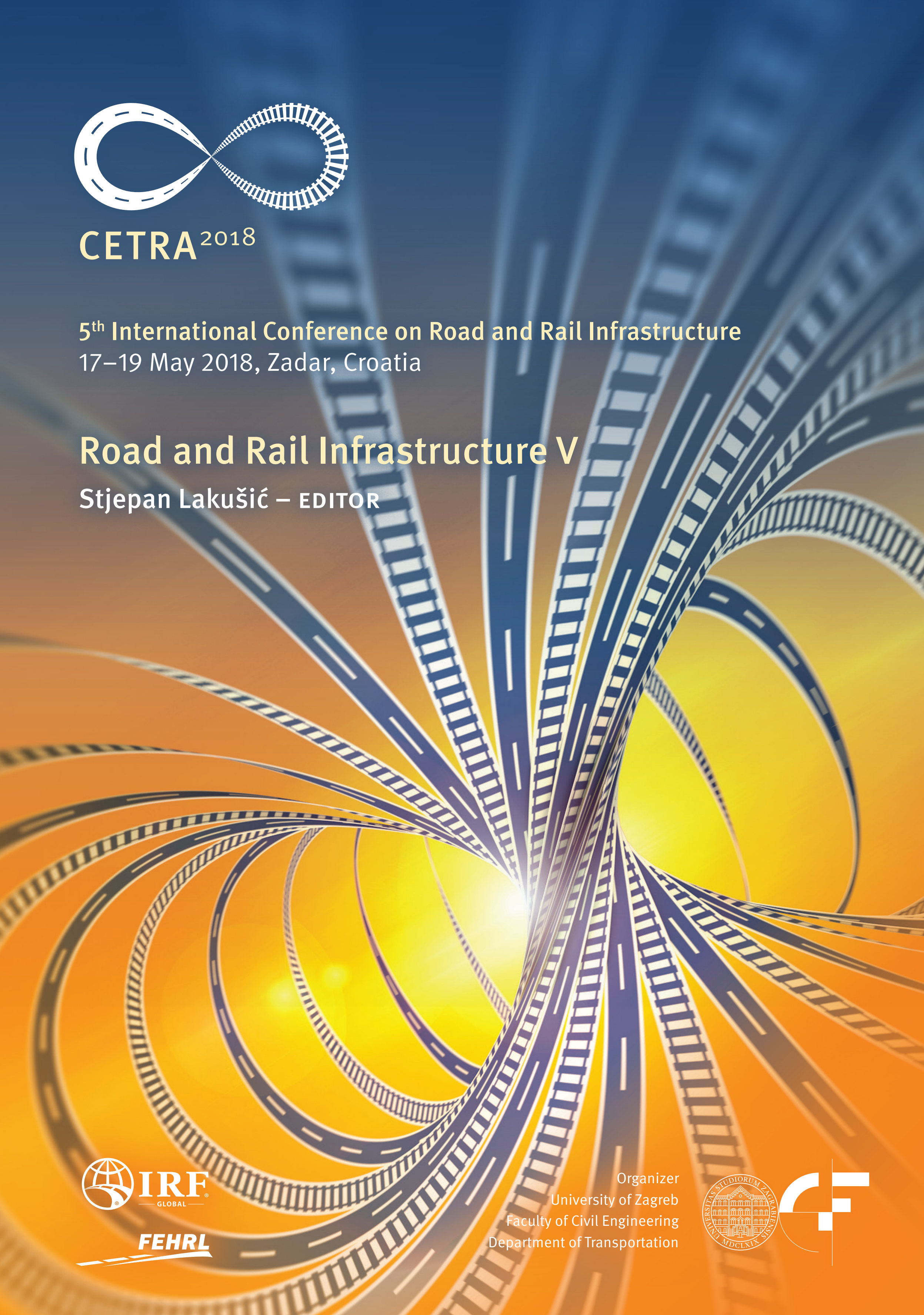

CETRA2018

5th International Conference on Road and Rail Infrastructure
17–19 May 2018, Zadar, Croatia

Road and Rail Infrastructure V

Stjepan Lakušić – **EDITOR**

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EFFECTS OF UNDER-SLEEPER-PADS ON LONG-TERM TRACK QUALITY BEHAVIOUR

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Graz University of Technology, Institute of Railway Engineering and Transport Economy, Austria

Abstract

Under-sleeper-pads (USP) are elastic elements, which are placed under concrete sleepers. The main task of USP is to decrease track ballast degradation. The aim of the present study is to analyse and compare track quality behaviour of sections with concrete sleepers and concrete sleepers equipped with USP. Around 600 km of track are investigated for the study. The initial quality after track renewal and/or tamping and also the deterioration rate are used for the analysis. Based on these results, it is possible to calculate average tamping intervals for both sleeper types and to make a comparison between them. By this means, the potential is provided for pointing out a reduction in maintenance requirements by using under sleeper pads, which results in a prolongation of service life and a reduction of life cycle costs.

Keywords: under-sleeper-pads, track, railway infrastructure, quality behaviour

1 Introduction

The ballast bed is an essential component of railway track and influences track quality and its service life. Because of increasing traffic loads, ballast is exposed to higher condition degradation, ultimately limiting the service life of track. When the threshold of ballast fouling is reached, ballast cleaning is necessary. This is a very costly measure and often equals the end of tracks service life if – depending on the track age – ballast cleaning as an additional maintenance task is no longer a reasonable option [1]. This means that ballast is a major factor for the service life of railway track.

By using under-sleeper-pads (USP) ballast condition can be improved and thus service life prolonged. The plastic properties of USP should allow a continuous embedding of ballast grains in the material. Hence, contact areas between ballast and sleeper increase and stresses on the ballast layer are reduced significantly [2].

In Austria, concrete sleepers with USP are installed in the context of the investment strategy of the Austrian Federal Railways (ÖBB) [3]: on tracks with traffic loads above 30,000 gross-tons per day (Gt/d), on lines with speeds higher than 160 km/h and in radii that are smaller than 600 m. In addition, turnouts on lines with a traffic load greater than 30,000 Gt/d and speeds higher than 160 km/h should be equipped with concrete sleepers with USP. The present study, however, focuses on plain track for reasons of comparability.

Concrete sleepers with USP have been installed in relevant quantities on the Austrian core network since 2008 (Fig. 1.) From 2008, 60 % of all newly installed sleepers have been concrete sleepers with USP. Still only about 10 % of all sleepers in the Austrian core network are concrete with USP due to the long service life of railway track.

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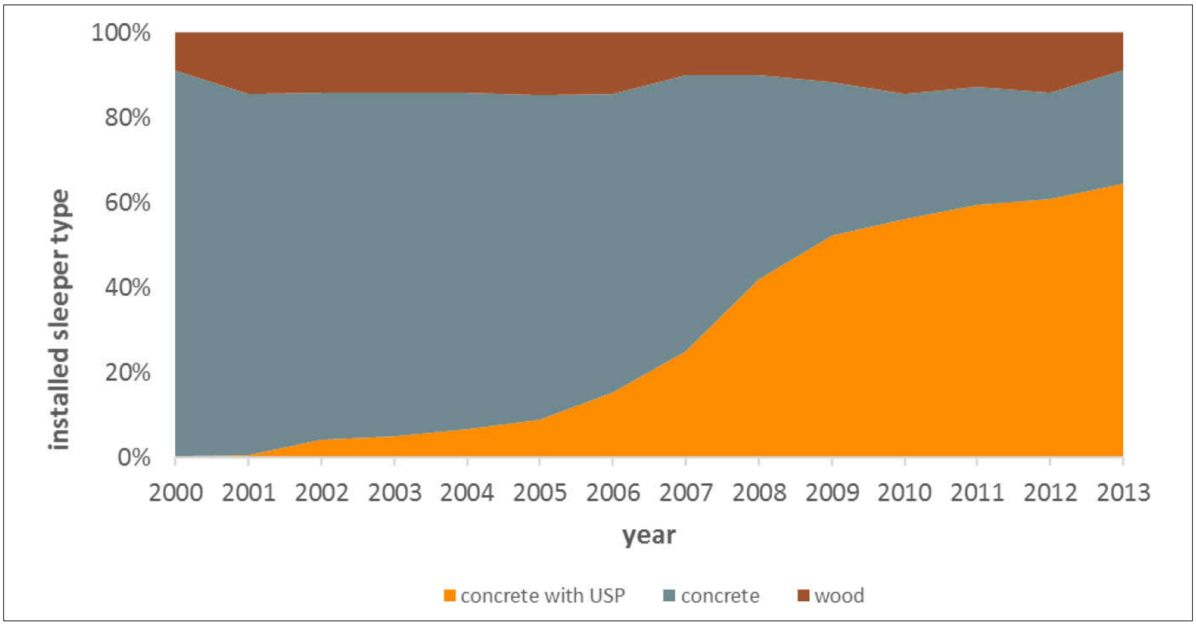

Figure 1 Distribution of new installed sleeper types in the core network of ÖBB

2 Previous studies

Various studies have already demonstrated the positive effects of USP. One investigation [2] could show that using USP increases the contact areas between sleeper and ballast. This leads to a significant decrease of stresses between the sleeper and ballast grains and to an improved load distribution. Another examination [4] reveals that using USP increases the resistance against lateral movements. Within the project "Load Labs" the effects of different ballast types with and without USP were analysed [5]. Moreover, this project could show the increased contact areas between sleeper and ballast for concrete sleepers equipped with USP. Furthermore, it turned out that sleepers with USP show a more favourable behaviour regarding settlements and in case of impact stresses. Under certain conditions, it is also possible to reduce the wear of rail pads and corrugation on the inner rail in small radii [6].

Another possibility for evaluating the behaviour of concrete sleepers with USP offers fractal analysis of vertical track geometry [7]. This analysis allows the determining of the specific wavelength range that is responsible for track geometry failures. It is thus possible to evaluate whether a track irregularity is mainly caused by poor ballast (mid-waved-range) or substructure (long-waved-range) condition. The usability of this method was confirmed in the course of an extensive evaluation process [8]. Fig 2 shows an evaluation of the mid-waved range of fractal analysis, which describes the ballast condition. This evaluation contains 4,000 km of track of the Austrian main network. In the course of this, the ballast condition of tracks with conventional concrete sleepers and concrete sleepers equipped with USP are compared over the track service life (in the form of cumulated traffic load). The result was that concrete sleepers with USP show a much better ballast condition in general together with a lower degradation of ballast condition. Hence, this result means a further evidence for the improved load distribution and a positive impact on track ballast of concrete sleepers with USP.

Proving the positive effects of USP was already possible on test track sections in Austria in 2007 [9]. First analyses of these track sections in terms of track quality behaviour were carried out within the project "Wirtschaftlicher Nutzen von Schwellenbesohlungen" (WINS) [10]. The investigation shows, that using USP leads to a significant improvement of track quality after tamping and a decreasing deterioration of track quality. Within the economic analysis, it turned out that the life cycle costs can be significantly reduced, although the investment costs for sleepers with USP are slightly higher [11].

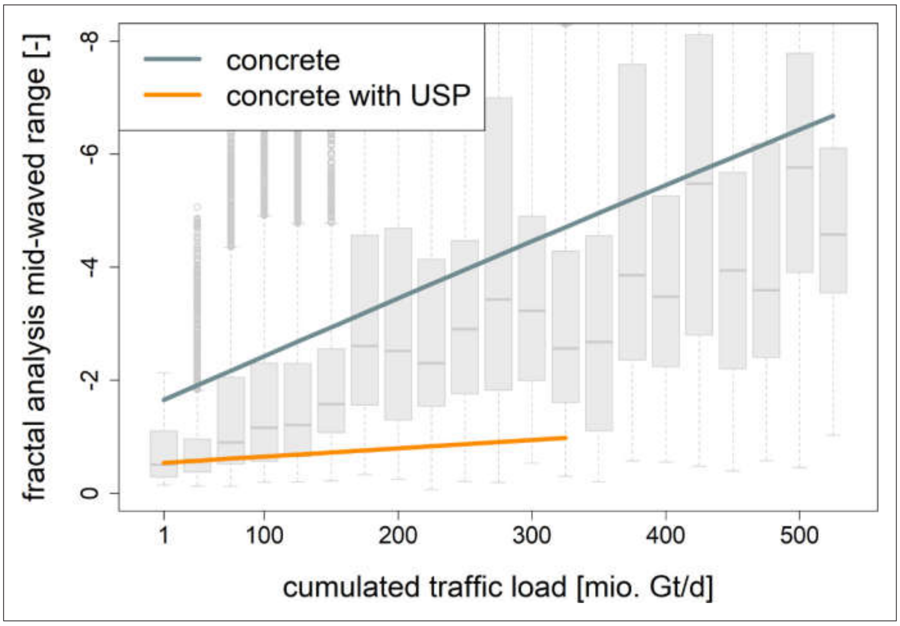

Figure 2 Fractal analysis (mid-waved-range) confirm track ballast protection by using USP

The evaluations for the project WINS were made at the point in time, when concrete sleepers with USP had started to become a standard component. Thus, only a low volume of data and a short time series were available for the analysis. Because of the implementation of the investment strategy of the Austrian Federal Railways, the present study can refer to a much higher data-volume. The goal of the current investigation is to evaluate, whether the promising results from former studies can be confirmed with long-term experiences regarding USP.

3 Track quality behaviour

The Institute of Railway Engineering and Transport Economy at Graz University of Technology focuses on the topic of track quality and its development over time during a period of many years. A comprehensive data warehouse has been established in the course of this including measurement data from the measuring car, asset information, constraint points, line parameters and executed maintenance tasks. The information is stored every 5 m and denoted as a cross section, [12].

For the present study, the modified standard deviation of the vertical track geometry [13] is used to describe track quality. Between two maintenance tasks – in most cases tamping – track quality can be described by means of a regression function. A linear function is thus used, that shows track quality in dependency of time as follows:

$$Q(t) = Q_n + b{*}t \tag{1}$$

In Eq. (1) Q(t) describes the quality level at time t, Q_n the initial quality after tamping, b the deterioration rate and t the elapsed time.

If a specific quality threshold is reached, it is necessary to carry out a maintenance task for guaranteeing safe and comfortable railway operation. In order to keep track quality on a high level, it is necessary to obtain a good initial quality plus a low deterioration rate. The service life of track is extended by these means and life cycle costs are reduced.

Fig 3 shows the deterioration process of a railway track in one cross section. The black points represent quality figures (SigmaH) that are calculated out of data from the measuring car. The vertical lines illustrate maintenance tasks. The red line between two maintenance actions is calculated based on the quality figures and by means of the linear regression function in Eq. (1).

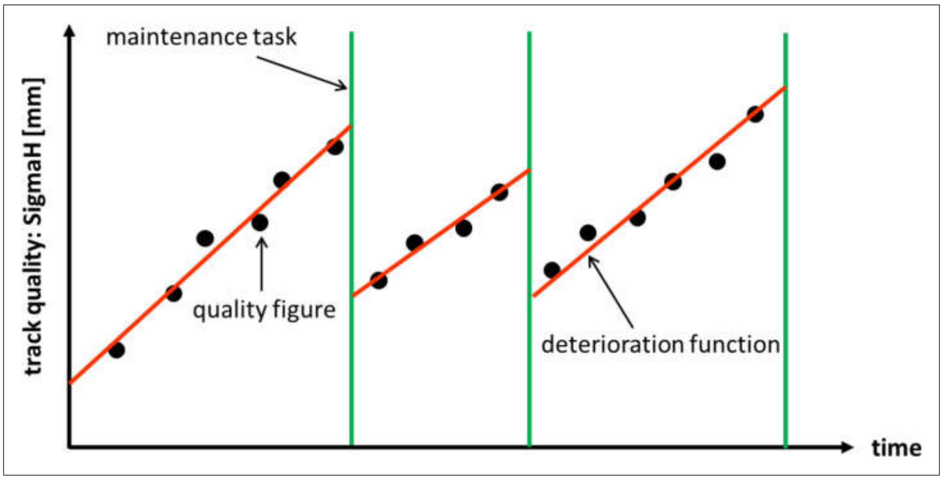

Figure 3 Deterioration process of track quality

The present analyses contain cross sections with sleepers installed in the year 2005 or later, since sleepers with USP have been installed in reasonable amounts since then. Based on correlation analysis, the result emerge that there is no general trend for the deterioration process in dependency on line speeds or radii. By contrast, however, traffic load shows a significant influence on deterioration and is therefore clustered separately. Altogether, about 120,000 cross sections (equals 600 track-km) can be evaluated within the present examination.

4 Results

The most important results are illustrated and described in the following section.

4.1 General results

Fig. 4 shows a comparison of initial quality and deterioration rate of concrete sleepers and concrete sleepers equipped with USP. The results show, that the usage of conventional concrete sleepers leads to an initial quality (quality after tamping) of 0.5 mm and to a deterioration rate of 0.14. Concrete sleepers with USP display an initial quality of 0.3 mm and a degradation rate of 0.07 in average. Hence, initial quality can be improved significantly by using USP.

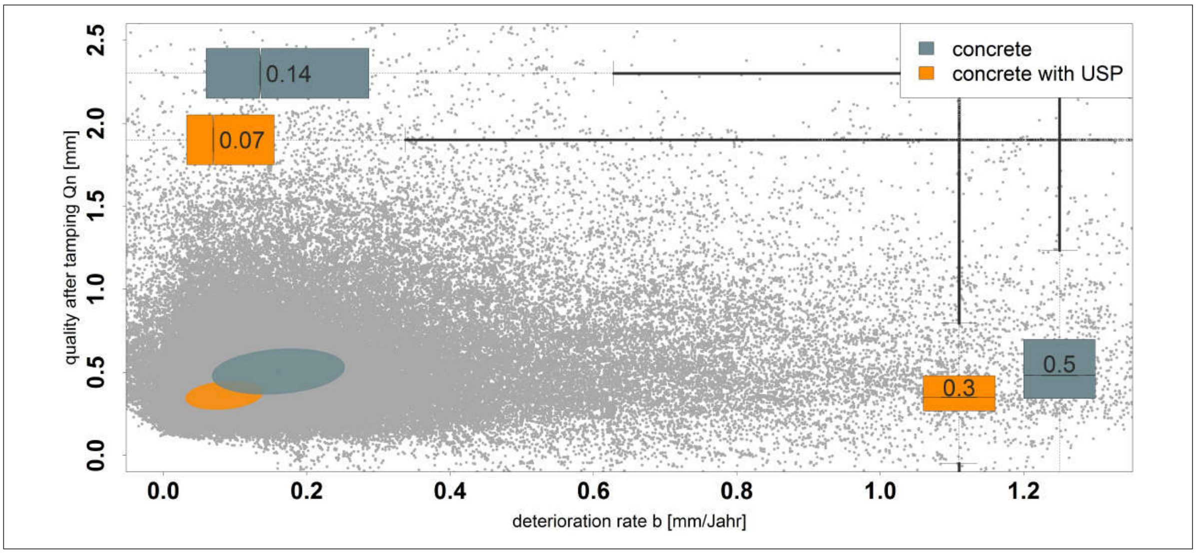

Figure 4 Comparison of quality after tamping and deterioration rate for concrete sleepers and concrete sleepers with USP

This effect can be observed independently of the traffic loads. The higher initial quality is caused by the increased contact area between sleeper and ballast, which leads to an enhanced load distribution. Thus, breaking of ballast grains and subsequently initial settlements are reduced [2]. Furthermore, the investigation shows that the application of USP reduces the deterioration rate of track quality significantly. This effect can also be confirmed for all ranges of traffic loads. Within higher traffic loads the positive effect is even greater.

4.2 Resulting tamping-coefficient

What are known as “tamping-coefficients” are calculated for examining the impact of USP on the maintenance demand during the life cycle of the track. These factors represent the prolongation of the tamping interval due to the installation of USP. A prolongation of maintenance intervals is achieved by improved initial track quality and reduced degradation rates (based on SigmaH). The calculation of such a coefficient is explained by the example of cross sections for traffic loads between 45,000 and 70,000 Gt/d.

An intervention limit for tamping must first be defined. This intervention limit depends on line speed. The higher the line speed, the stricter are the requirements on track quality for safety reasons. Furthermore, the intervention limit depends on track age, because a younger track should be maintained earlier than a track at the end of its service life, [13].

For the boundary conditions within the present analyses (average line speed of 140 km/h), the intervention limit for the modified standard deviation of vertical track geometry is 1.2 mm. Using the median values of initial track quality and deterioration rate, it is possible to calculate the behaviour of track quality over time for different traffic loads. This calculation is made for conventional sleepers (Fig. 5, grey line) as also for concrete sleepers equipped with USP (Fig. 5, orange line). The result is a time interval (tamping interval) for both sleeper types until the intervention limit is reached. Afterwards, the tamping intervals of both sleeper types can be related to each other, which results in the tamping coefficient.

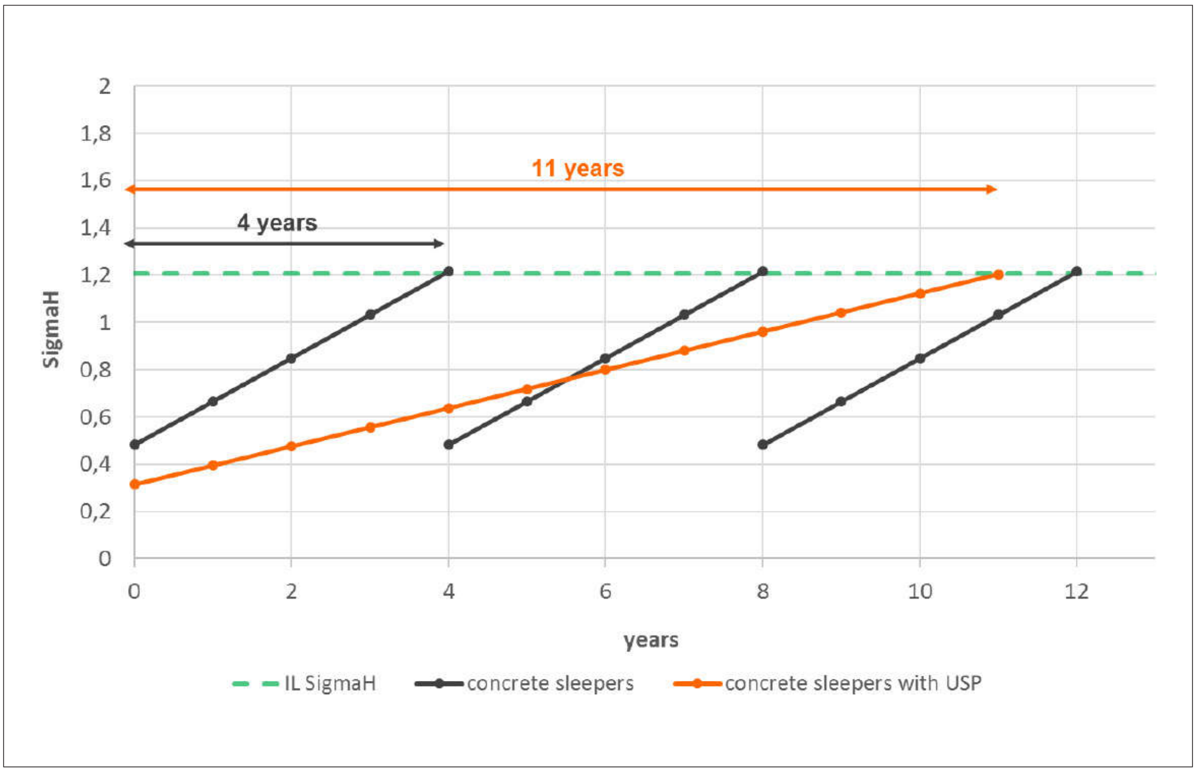

Figure 5 Behaviour of track quality (SigmaH) over time; 45,000 – 70,000 Gt/d

Fig. 5 shows the development of SigmaH over time for traffic loads between 45,000 and 70,000 Gt/d. Conventional concrete sleepers reach the intervention limit of 1.2 mm after 4 years. Concrete sleepers equipped with USP exceed this intervention limit after 11 years. This means that the use of USP leads to a prolongation of the tamping interval by a factor of 2.8. In Fig. 6, all tamping intervals for concrete sleepers with and without USP for different traffic loads as also the related tamping coefficients are illustrated.

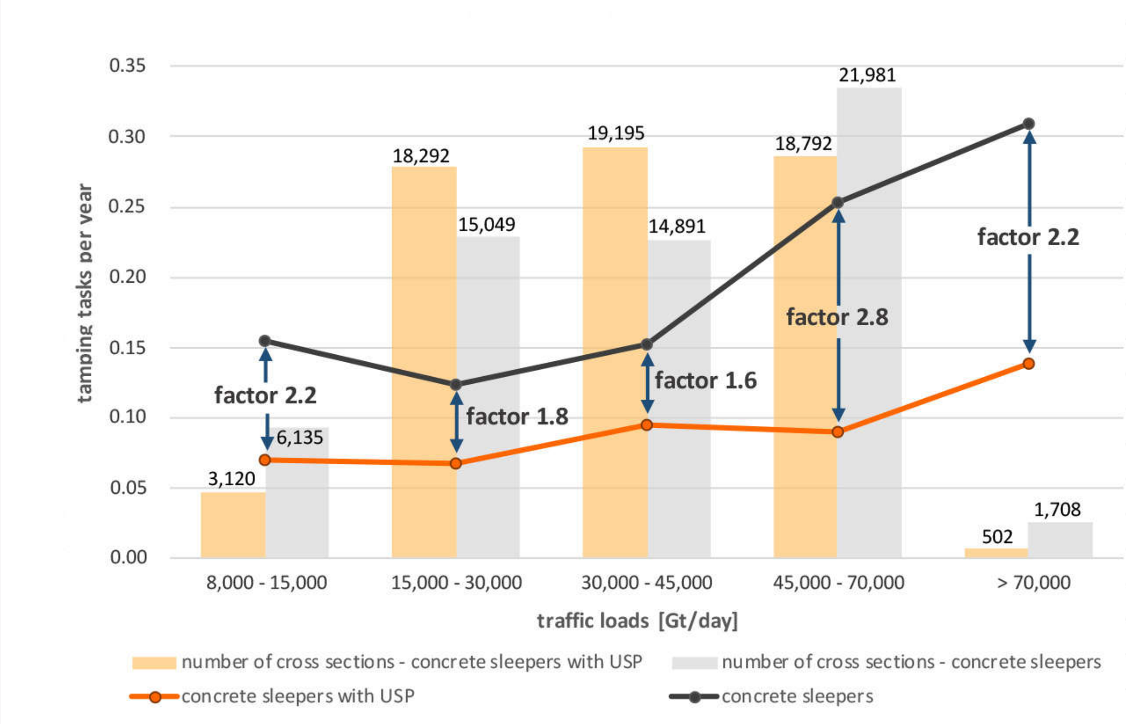

Figure 6 Tamping coefficients for different traffic loads.

The investigation reveals that in general the tamping interval decreases for higher traffic loads. This means tracks with higher traffic loads must be maintained more frequently. The tamping coefficient shows in all traffic-load-ranges values of 1.6 or higher. Hence, it is possible to extend the tamping interval by at least 60 % by using USP. The biggest impact of USP can be seen at traffic loads between 45,000 and 70,000 Gt/d with a tamping coefficient of 2.8. Former studies [10, 11] based on a much lower cross section volume and short-term analyses, showed prolongations of tamping intervals by factors of 2 – 3 (depending on traffic loads). This means the results of former studies can be confirmed by the current investigation.

5 Conclusion

The goal of the present study is to investigate long-term track quality behaviour of track sections with conventional concrete sleepers and concrete sleepers equipped with under-sleeper-pads. For this purpose 120,000 cross sections (equals 600 km of track) are available. The results show, that it is possible to improve quality after tamping, as well as the deterioration rate of track quality significantly by using USP. It turns out, that the application of USP prolongs the time period between necessary tamping measures by a factor of 2. For lower traffic loads, the tamping interval can be extended by 60 %. For higher traffic loads, it is possible to almost triple the tamping interval. The extended maintenance interval also leads to an increased service life of the whole track. These results confirm the expectation of a significant reduction in life cycle costs, although the investment costs of concrete sleepers with USP are slightly higher. In conclusion, it can be stated that using under-sleeper-pads should be an important part of a sustainable investment strategy of a railway infrastructure manager.

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