Analysis of the Performance of Under Sleeper Pads- A Critical Review

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ABSTRACT: The transportation networkdirectly affectsthe economic growth of a country and a rail track network is an essential part. As a result of the increasing demand forpassenger and goods transportation, heavier freight networks and high speed rail networksare increasingly been constructed in many countries, including China, the USA, and Australia. Ballasted rail tracks are popular due their high resiliency, higher load bearing capacity, good drainage capacity, and low capital cost, and the use of geosynthetic material to improve their performance even more because under sleeper pads (USP) act as an intermediate elastic layer between the ballast and the sleeper. This paper presents a critical review of studies that primarily focused on evaluatingthe USP used in railway tracks.

1 INTRODUCTION

Owing to the growing industrial needs and higher demand for passenger transportation, heavier and faster rail traffic has been introduced in many countries(Indraratna et al., 2011).Thus, higher expenditure arises in railway tracks with frequent maintenance to maintain passenger comfort and safety levels as the track deteriorate faster with larger cyclic loading. This occurs due to uneven elastic track deflections or differential settlements.(Paixão et al., 2014).

Track substructure acting an vital role in maintaining railway geometry and ballast is the major component of it as it bears the majority of load transferred by the trains. Ballast is the most commonly used foundation material for railway tracks in many countries, but large cyclic loads subject to it causesrapid degradation that affects the longevity and stability of track, and the subsequent loss of geometric quality(Indraratna and Nimbalkar, 2013, Indraratna and Nimbalkar, 2015).Irregularities in a railway track causes trains to vibrate excessively which leads to an uncomfortable ride for passengers.(Suiker, 2002). Hence it is important to reduce stresses developed in ballast to mitigate ballast degradation. In this paper effort has been made to summarise the current knowledge on Under Sleeper Pads (USP) to improve Ballast Performances.

2 BALLAST

2.1 *Role of Ballast*

Sleepers to which rail is fastened is embedded in this granular layer. Conventionally ballast is crushed, angular rock or hardstone and it helps substructure to support against vertical, lateral and longitudinal forces from trains.(Dahlberg, 2003, Profillidis, 2014, Esveld, 2001, Feng, 2011). Mechanical behaviour of ballast is depending on aggregate characteristics (size, shape, surface roughness etc.), properties of granular assembly (gradation, density, void ratio etc.), Loading characteristics (Loading History, Current stress condition etc.) and particle degradation which is combine effect of above three. (Indraratna et al., 2011)

2.2 *Ballast Degradation*

Particle degradation directly affect to the stress strain behaviour, strength, volume change, permeability, and pore pressure development in ballast(Stewart, 1986). Particle breakage depends on the Strength of aggregates, loading amplitude, number of cycles, frequency, density of ballast, confining pressure, angularity and degree of saturation.(Indraratna and Salim, 2003)

2.3 Ballast Respond under Cyclic Loading

Stress strain behaviour of recycled ballast was observed by Indraratna and Salim using prismoidal triaxial chamber. Fig. 1 shows the stress strain plot for the ballast under repeated loading (Indraratna and Salim, 2003). At the initial stage low stiffness was witnessed as the ballast was relatively loosed and with the time stiffness has increased as the ballast layer getting denser and denser as the aggregates re-arrange themselves.

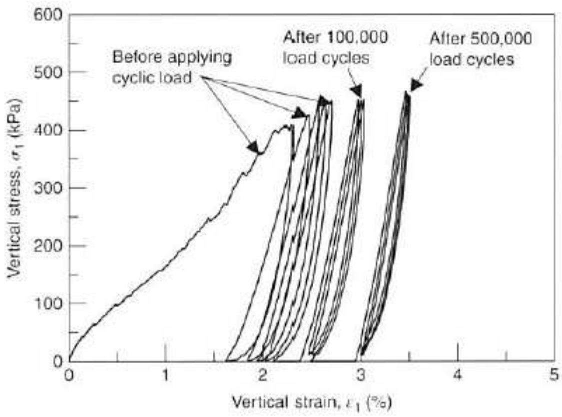

Fig. 1 Stress strain plots in repeated loading (Indraratna et al., 2011)

3 ENERGY ABSORBING MATERIALS

Under high frequency loading presence of other resilient components (Fig. 2) like rail pads, Under Sleeper Pads and Under Ballast Mats is essential to improve the ballast performance.(Esveld, 2009, Puzavac et al., 2012, Kaewunruen and Remennikov, 2008). Such elements improve the track stiffness and mitigate ballast degradation, noise emission and wave propagation.(Sol-Sánchez et al., 2015)

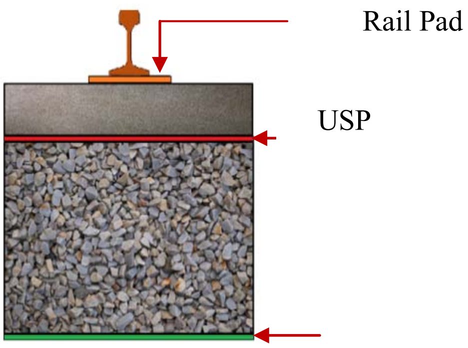

Fig. 1 Resilient Components in Railway Track

4 UNDER SLEEPER PADS

Under sleeper pads are manufactured as a foam fromRubber, Polyurethane, and EVA(Lupoien) such that it can be either glued to the hardened concrete or placed on unset concrete whileconstructing the sleepers (Johansson et al., 2008, Paixão et al., 2014). USP is a three layered structure consisting of one spring layer, one soft pad to protect the spring layer from aggregates, and one bonding layer to fix the pad onto the sleeper (Schneider et al., 2011).

The use of USP dates back over 20 years, but it has gained much more attention in central Europe in the last5-10 years. French railways were the first to introduce thin layers of polyurethane under the sleeper to reduce the contact stress(Zakeri, 2012), and since 2005 in Australia, USP is a standard component in turnouts to improve track quality. Currently in Australian railways,about 250 turnouts, 300km longtrack containUSP (Loy, 2009).

4.1 Performance of USP in Railway track.

The vertical stiffness of railway substructure can be reduced by the resilient properties of USP. As a result of deformation of USP at the contact with aggregates, contact area between sleeper and ballast increase.

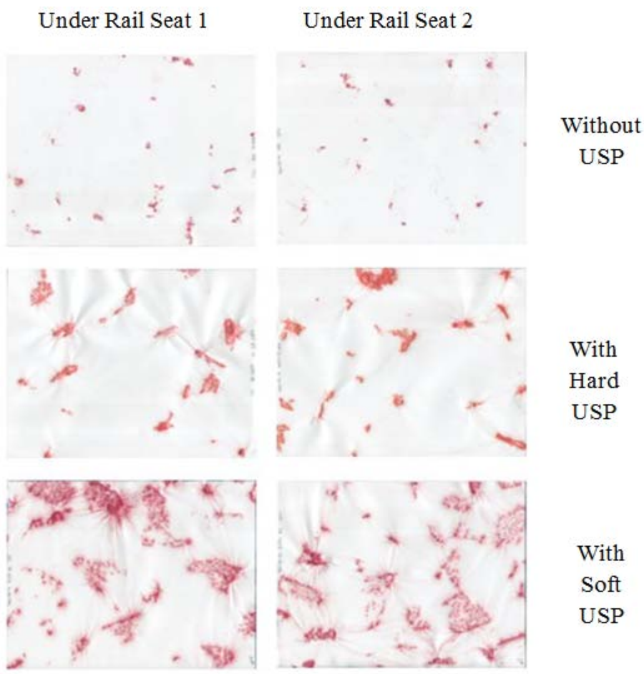

Fig. 2 Contact Area with and without USP(Abadi et al., 2015)

It has been found that normally, 3-4% of the area of a sleeper is in contact with the aggregate, but this can be increased up to 30% using USP (Witt, 2008, Johansson et al., 2008). Abadi and others conducted an experiment to measure contact area between ballast and sleeper using pressure papers and results shown(as in Fig. 3) that the contact area increase significantly with the use of USP(Abadi et al., 2015).This will reduce stress concentration in ballast and reduce particle breakage.

USP also increases the number of load bearing sleepers (Fig. 4). As the vertical stiffness reduces with the introduction of the resilient pad under the sleeper, rail tends to deflect more and hence increase the number of load bearing sleepers. That means same load is now distributing over large area and ballast will experience less stress.

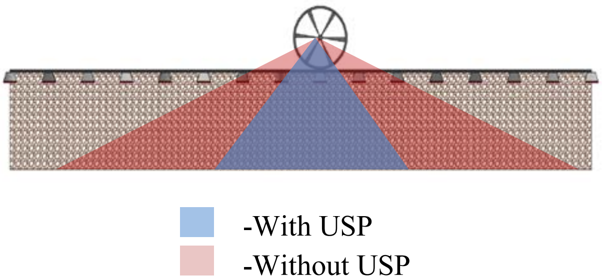

Fig. 4 Load Distribution with and without USP

Decrease in resonance frequency can be experienced by installing USP and thus reduction of vibration transmission from sleeper to ballast and track substructure can be obtained.(Lakušić et al., 2010).Recent evaluations indicated that USP is best suited to open tracks; indeed it was effective from frequencies above 40Hz while the resonance frequency was between 25Hz-40Hz, which indicated that the level of vibration emissions was higher in a track with USP than the track without USP, in that frequency limit. USP are useful in reducing ballast thickness and it is a cost effective alternative material for UBM(UIC, 2009).

While UIC summarising report for USP investigating the behaviour of Under Sleeper Pads, they tested 21 combinations of stiffness for the rail pad and USP with four different soil conditions and found that the damping effect of a rail pad and USP reduced the stress level on the ballast. However, the introduction of USP leads to an increment in the vertical acceleration of the sleeper and rail while increasing the vertical displacement.(UIC, 2009)It has been found that ballast degradation in tracks with USP is lower than tacks without USP, which in turn reduced the cost of maintenance. Combination of rail pad and USP also impacts on track performance; for instance, a soft USP with Stiff Rail Pad creates the worst situation and may cause the sleepers to crack.

4.2 USP in Transition Zones

Transition zones are the most critical areas of high speed rail tracks due to differential settlement between the stretch over the embankment and the abutment of a bridge or tunnel. As a result, huge vertical dynamic forces can be created and such discontinuities need continuous maintenance. Furthermore, there is a transition region between these two structures because the vertical stiffness varies gradually (Insa et al., 2011). The increment in the dynamic forces depends on the speed of the train, the ratio between stiffness, the length of transition and soil damping. The increment in vertical acceleration caused by differential settlement adversely affects the level of passenger comfort and safety. (Esveld, 2001, Paixão et al., 2014).

A study conducted by Insa et al., 2011 showed that USP had no significant influence on the deflection and reduction of stress in the layers of track below the ballast, even when the stiffness and thickness varied. Furthermore they found that USP cannot smooth out the vertical acceleration at transition zones (Insa et al., 2011).

However, the experiments carried by Anders et al (2008) showed that the vertical displacement and vertical acceleration of the sleepers increased after USP was used the increased more as the stiffness of the USP decreased (Figs. 5 & 6). But at the same time they show thatthe load transferred to the ballast decreased after USP was introduced, and reduced even further as the stiffness of USP

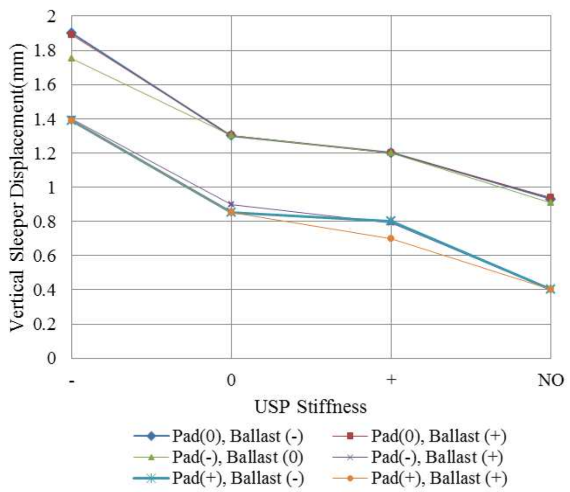

Fig. 5 Vertical Sleeper Displacement on the sleeper for different combinations of USP. Rail Pad & Ballast Stiffness

decreased. Even though it increased the vertical deflection, USP helped to reduce the stress level in that ballast. Thisresult indicated that the USP parameters must be selected very carefully.

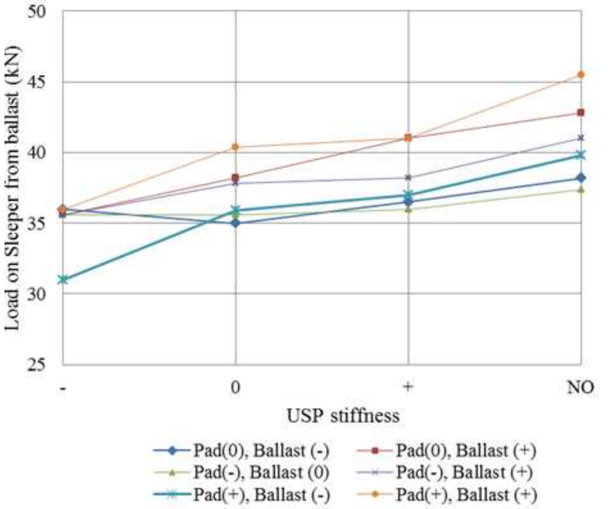

Fig. 6 Maximum Load on Sleeper from Ballast (Johansson et al., 2008)

5 CONCLUSIONS

USP can be used to reduce the stress level in the railway substructure, but the parameter selection depends on the characteristics of the particular railway track. Sometimes tracks without USP performed better than tracks with USP. The properties of USP and combined characteristics of rail pads will determine the overall performance of the track, but improving railway geometry is still a question because USP increases the vertical deformation and acceleration(UIC, 2009).

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