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# Vibration attenuation at rail joints through under sleeper pads

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**Abstract**

Modern railway tracks require electrification to power the trains and signaling systems to detect near real-time location of trains on railway networks. Such systems require the rail to carry and return the residual electricity back to substation, while enable signals to transfer within a track circuit. This track circuit requires rail joints to divide and insulate each loop of the circuit. Such the rail joints often generate impact transient dynamics to track systems. This paper presents the filed investigation into the vibration attenuation characteristic of under sleeper pads (USPs), which are the component installed under the concrete sleepers generally to improve railway track resilience. The field trial is aimed at mitigating rail joint impacts in a heavy haul track under mixed traffics. 'Big Data', obtained from both the track inspection vehicle and the sensors installed on tracks, demonstrate that track surface quality (top) of the section was improved after the track reconstruction. Fourier analysis results showed that the track surface (or vertical deviation) tends to deform at larger displacement amplitude and resonates at a lower wavelength of track roughness. Interestingly, the operational pass-by vibration measurements show that the USPs has resulted in an increased vibration of both rail and sleeper with USPs. Although the studies have found that the sleepers with USPs tend to have lesser flexures, the field data also confirms that a railway track with USPs could experience a large amplitude vibration, especially when excited by a high-frequency impact force. These dynamic behaviours imply that the use of soft to moderate USP could potentially induce dilation of ballast whilst the use of hard USP may reduce sleeper-ballast friction. In the end, these could then weaken lateral track stability over time.


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## 1. Introduction

Ballasted railway tracks are popularly built for traditional suburban and urban rail networks globally. Its benefits include low capital investment, high resilience, high maintainability and constructability, high level of vibration absorption and so on. There are two groups of track components: superstructure and substructure. Superstructure components include rail, fastening system, sleeper, under sleeper pad, ballast and ballast mat; while substructure counterparts are subballast, formation, geotextiles and foundation. Under sleeper pads (USP) are resilient pads installed on the soffit of sleepers as an attachment to provide additional track resiliency between the sleepers and ballast. Fig. 1 shows a typical cross section of the ballasted railway track with under sleeper pad. In recent years, USP has been used widely and heavily in central Europe such as in Austria, Czech Republic and Germany. Additionally, several counties have carried out pilot trials such as in Sweden, Australia, and China. USP is made of polyurethane elastomer with a foam structure including encapsulated air voids. Three common objectives for installing USP are to moderate track stiffness; to reduce ground vibrations; and to reduce ballast breakage. USPs could reduce track stiffness in special areas such as turnout systems (switches and crossings) or tracks on bridge viaducts. The vibration of sleepers could also be isolated by the USP so that the ballast and formation are uncoupled from the wheel/rail interaction, reducing the ground vibrations affecting surrounding buildings and structures. The reduced ballast damage is accomplished by a reduction of contact pressure, and thus wears, in the sleeper/ballast interface. A more uniform load distribution is achieved by the use of USP, resulting in the reduction of the contact pressure and the smaller variations of support stiffness along the track. An application of USPs in Australia was initially trailed back in 1980s on open plain tracks. The outcome showed little improvement at the time whilst the delamination and degradation of the USP material were the key negative issues found in the field [1-6].

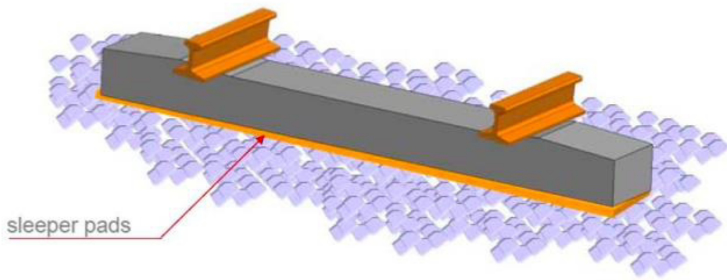


Fig. 1. Under sleeper pads [7].

**Nomenclature**

| | |
|---|---|
| $2\alpha$ | Total joint angle or equivalent dip angle (radian) |
| $C_t$ | Equivalent track damping (kNs/m) |
| $K_t$ | Equivalent track stiffness (MN/m) |
| $M_t$ | Equivalent track mass (kg) |
| $P_0$ | Static vehicle wheel force (kN) |
| $P_2$ | Dynamic vertical force (kN) |
| $M_u$ | Vehicle unsprung mass per wheel (kg) |
| $v$ | Train velocity (m/s) |
| UBM | Under ballast mat |
| USP | Under sleeper pad |