Project B	**Under Sleeper Pads (USP)**
Part of	**Research Challenge 1, TRACK4LIFE**
Project timing	Started June 2015
More information from	Dr Louis Le Pen
Project partner	Network Rail (NR)
Associated projects	EU project In2Rail, H2020-MG-2014: Grant agreement 635900. WP3, Deliverable 3.3: T2F researchers wrote section 4.4.2 on USPs.

Project aims

Previous work had identified the potential benefits of under-sleeper pads (USPs) in reducing long-term (plastic) settlements of railway tracks, improving the stability of the sleeper-ballast interface and reducing contact stresses [B4]. This project aims to explore the potential benefits of USPs and understand the reasons for them, with a particular emphasis on "difficult" areas such as S&C and transitions:

1. field monitoring to assess the benefits of under sleeper pads at potential problem locations
2. discrete element method (DEM) analyses to clarify the mechanisms involved.

Progress to date

Project aim 1. Measurements of track deflection during train passage have been carried out to assess the benefits of under sleeper pads at two sites (Fig.B1). These are (a) a typical S&C at Wooden Gates on the East Coast Main Line [B5], and (b) over a concreted under track crossing (UTX) on HS1 at Crissmill.

Fig.B1. USP field monitoring sites: (a) Wooden Gates S&C; and (b) Crissmill, HS1

Data from Wooden Gates ([B5], Fig.B2) show that

- soft USPs caused a large (>40%) increase in vertical movement as trains pass
- movements with medium stiffness USPs were similar to those with no USPs
- medium USP reduced the variability in movement between sleepers
- installation of USPs on long bearers exacerbated rocking (see Project F).

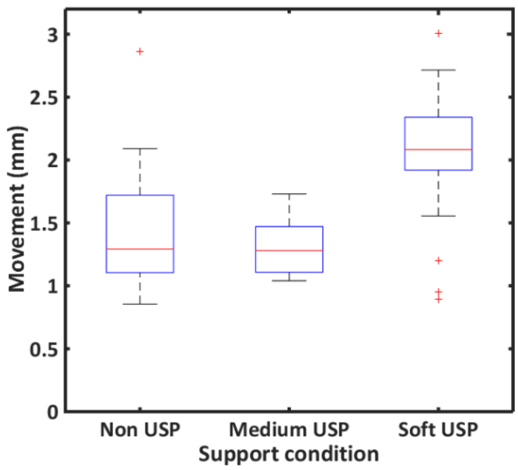


Fig.B2: Mean, standard deviation and range of sleeper movements with and without USPs; Wooden Gates, ECML

Data from Crissmill (Fig.B3) show that

- installation of USPs over the UTX and for a short distance on either side prevented voiding, maintained a more uniform support modulus and reduced deflections to those on plain line
- informed, targeted packing at defects were much more effective than generic tamping.

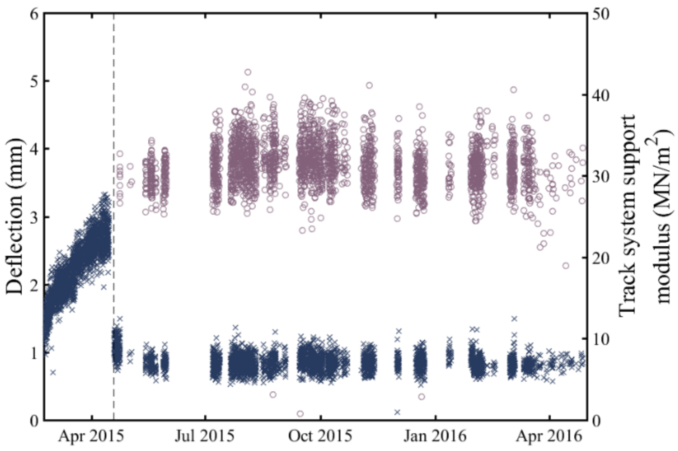


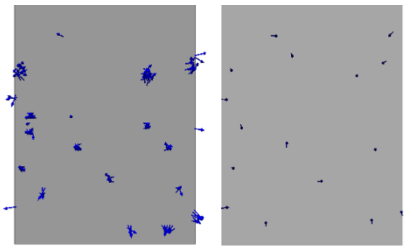
Fig.B3: Dynamic deflection (blue) and track support stiffness (mauve) before and after USP installation; Crissmill, HS1

Project aim 2. Discrete element method (DEM) analyses have confirmed the mechanisms of improvement (increased contact area, reduced contact stresses and improved stability at the sleeper soffit / ballast interface) [B6] previously demonstrated in the Southampton Railway Testing Facility (Fig.B4) [B4].

Planned further work (Programme objectives in brackets)

- Further field monitoring in collaboration with Network Rail, to establish (i) the typical range of transient deflections of the track as trains pass and how these change over time, and (ii) the development of long-term permanent settlements and the associated loss in geometry (1A.1, 1B.2)
- FE and DEM analyses to establish the fundamental mechanisms operational in the field (1A.3, 1B.3)
- Use of data to optimise track system performance (1A.4)
- Incorporation of results into integrated performance and maintenance models (1A.5).

Experimental contact history (L) with and (R) without USP



DEM ballast / sleeper contacts (L) with and (R) without USP

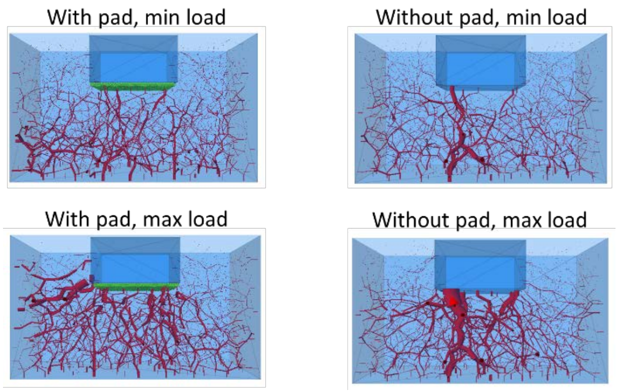


Fig.B4: Experimental contact history and DEM ballast / under sleeper contacts at minimum and maximum loading with and without USPs present, and DEM force chains

Journal papers

[B4] Abadi, T., Le Pen, L., Zervos, A., & Powrie, W. (2015). Measuring the area and number of ballast particle contacts at sleeper/ballast and ballast/subgrade interfaces. *The International Journal of Railway Technology* **4** No.2, 45-72. doi:10.4203/ijrt.4.2.3
[B5] Le Pen, L, Watson, G, Hudson, A & Powrie, W. (2017). Behaviour of under sleeper pads at switches and crossings – Field measurements. *Proceedings of the Institution of Mechanical Engineers Part F, Journal of Rail and Rapid Transit* (AOP). doi:10.1177/0954409717707400
[B6] Li, H and McDowell, G R (2017). Discrete element modelling of under sleeper pads using a box test. *Granular Matter* (in review)

Related publications

Milne, D, et al (2016). Proving MEMS technologies for smarter railway infrastructure
Cross Industry Track Stiffness Working Group (2016) A Guide to Track Stiffness pp34f, 42f,
Powrie, W (2017). Article, "Ballast or slab?" Rail Technology Magazine