Railway Gazette
INTERNATIONAL

GERMANY

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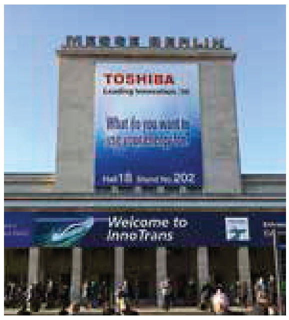

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The international railway industry comes together in Berlin this month

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September 2014

Serving the customer

PUR pads protect heavy freight corridors

The iron ore flows from Rotterdam to the Ruhr Valley in Germany are among the heaviest freight trains to use Europe's mixed-traffic network.

Increasing axleloads and tonnage are placing increasing demands on track superstructures on the busiest freight corridors. Getzner Werkstoffe has been developing its range of PUR under-sleeper pads to give an optimised combination of elastic and plastic properties designed especially for freight routes.

Following the introduction of hardened rail steels and pre-stressed concrete sleepers, ballast has arguably become the weak link in track design. Sleeper padding is a long-established practice that can offer significant ballast protection; this is essentially achieved by expanding the contact area between the sleeper bottom and the top ballast layer. This in turn requires under-sleeper pads with highly plastic properties to enable the ballast stones to be embedded as gently as possible.

On the other hand, achieving an ideal load distribution in the track by increasing its material flexibility calls for under-sleeper pads with highly-elastic properties that can be sustained over the long term, even when subjected to decades of stress. Designing pads that combine both long-term elasticity and a high degree of plasticity is a daunting task for today's material scientists.

Heavy freight challenge

The need for under-sleeper pads that combine these properties is especially acute on those railways which carry large amounts of freight, whether as part of a conventional mixed-traffic network or as dedicated heavy-haul lines serving mines and other bulk


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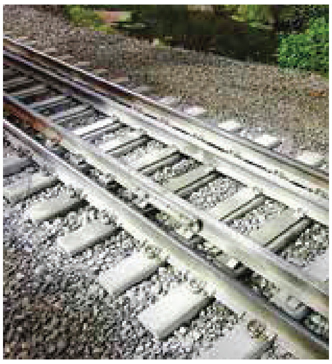
industries. Typically this definition applies to operation of 40 million gross tonnes or more over a given length of track in a year.[1] This criterion is independent of the form of traffic, whether passenger, bulk or mixed freight.

Alongside broken rail clips and sleeper cracks, the deterioration of the ballast, starting from the contact area with the sleeper, is one of the main factors that shorten the lifespan of track on these heavily-used networks. Problems can occur at transition zones from an open stretch of track to a bridge structure; such areas of discontinuity in a highly-uniform track structure can result in the exertion of a particularly intense load, leading to the fracture and pulverisation of ballast grains, of which white spotting is a clear indicator.

High-quality under-sleeper pads, often used in conjunction with suitable rail pads, can effectively counteract such effects. Under-sleeper pads are implemented as a flexible spring layer located



White spots show the destruction of ballast beneath concrete sleepers (left). Broken clips (middle) and sleeper cracks (right) result from excessive dynamic loads.

FREIGHT Track Components

underneath the sleepers, which increases the contact area with the ballast from between 2% and 8% to more than 30%. It has already been widely demonstrated that a larger contact area improves the load transmission to the ballast bed and puts less of a stress on the subgrade. The fracture of ballast grains due to overloading is prevented and settlement is minimised, while the formation of hollows and cavities can be effectively mitigated.

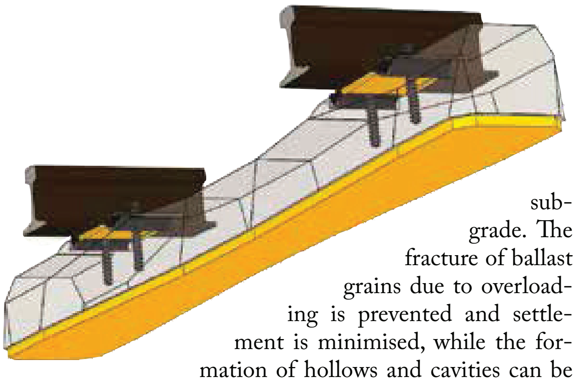


Fig. 1. Polyurethane under-sleeper pads protect the ballast layer.

To quantify the long-term effect of under-sleeper pads, extensive studies have been carried out since 2001 to measure the rate of track deterioration where they have been installed.[2] The results demonstrate a positive influence on the superstructure under different conditions, and the pads work more efficiently as the load on the track increases. All the padded areas of track show a significantly reduced deterioration rate. Even in sections with lowered ballast height, the tamping interval has been at least doubled. The use of under-sleeper pads brings about a significant reduction in maintenance requirements, thus offering life-cycle cost savings. Under-sleeper pads are commonly used today for the following applications:

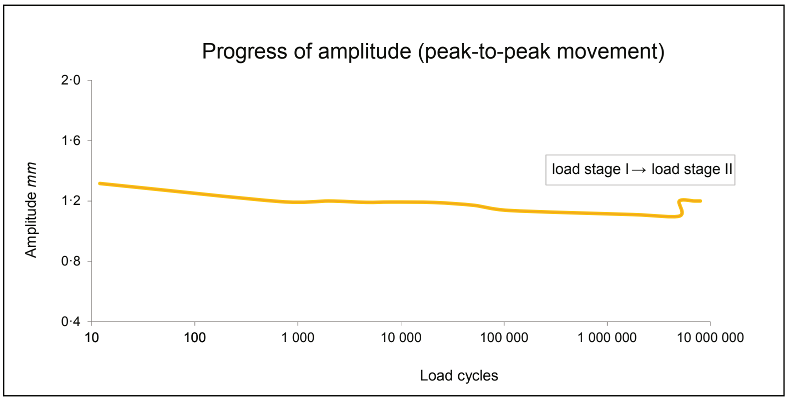
- reduction of settlement in all ballasted track structures;
- limiting propagation of rail corrugation in tight curves;
- adjustment of track stiffness in areas with reduced ballast height;
- improvement of transition zones between different types of track structure;
- mitigation of vibration;
- avoidance of hollow areas underneath sleepers;
- levelling different deflections within turnouts.

Not all materials are equally suitable for these tasks. One material that has been proven to be extremely tough and durable is Sylomer, which is made from PUR, a specialised polyurethane. In PUR production, a diverse range of properties can be adjusted to meet the desired requirements by mixing reactive ingredients. Polyol and isocyanate are the main components by proportion, having a significant impact on the mechanical properties and comparatively high tensile strength. In the development of under-sleeper pads for ballast protection, an optimum mixing ratio and the right production process are critical if a balanced ratio of elastic and plastic properties is to be achieved. As a result of many years of research, Getzner has developed a novel PUR under-sleeper pad, which aims to cushion extremely heavy loads in freight applications while maintaining high technical performance.

Fatigue strength

The fatigue strength of the newly developed pad was tested on a large rig at the Getzner Werkstoffe laboratory in Bürs, Austria.[3,4] A test rig allows the simulation of maximum track-borne loads generated by heavy freight trains, including curving forces. Other factors, such as increased train speed and overall track condition, can also be modelled. The applied static axleload of 36 tonnes was increased in line with these additional dynamics by a factor of 1·52.

For such specific fatigue tests, the under-sleeper pad is attached to the underside of a concrete slab measuring 300 mm x 300 mm, which represents the sleeper, using a plastic mesh. Half of this mesh is inserted into the concrete and the other half into the pad. The long term test was carried out in two load stages at a test frequency of 5 Hz on ballast with a height of 300 mm. The first stage saw 5 million load cycles, which was increased by a further 3 million cycles in the second phase, giving a total loading of 8 million cycles over a continuous period of about 3·5 weeks. The progression of the vibration amplitude is shown in Fig 2, reaching 1·2 mm at the end of the test. The padding exhibited no destruction from cracks, perforations



Right: Fig. 2. Recorded amplitude (peak-to-peak movement) from the long-term fatigue test in the ballast box.

Simulation of high-axleload stress in the ballast box of the large test rig (left). Following the end of the test, the ballast grains remain embedded in the PUR material (right).

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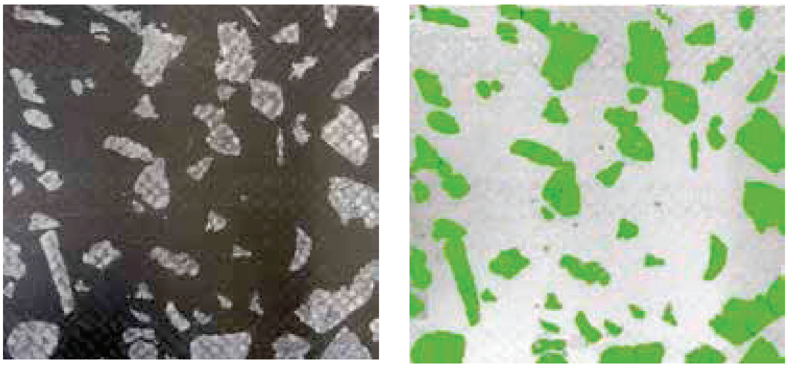


Fig 3. Digital analysis of the surface structure with ballast indentations. These are shown by chalk spray (left) and pore scan (right). The analysis showed a contact area for the PUR padding of between 25% and 33%.

or punctures, and the ballast grains embedded themselves to a maximum depth of approximately 80% of the thickness of the pad. This confirmed the satisfactory long-term behaviour of the PUR material under loading typical of heavy freight railways.

Contact area and contact pressure

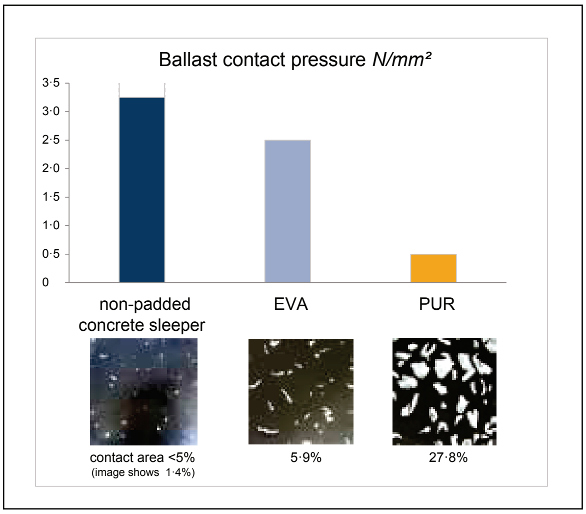
The plasticity of the under-sleeper pad enables the uppermost layer of ballast to embed in the padding material. This is an important safety feature, as it ensures a greater degree of lateral track resistance; lateral resistance is generally higher for concrete sleepers equipped with pads than those without.[5] From the outset, it was a requirement of the product development process that there should be no negative impact on track stability, and this objective was confirmed in testing undertaken by TU München.[6]

However, the main benefit afforded by the flexibility of the padding material is that the forces are transmitted to the ballast superstructure more homogeneously. Getzner has developed a proprietary method for quantifying the contact area quickly and very precisely (Fig 3). This post-test analysis showed a contact area for the PUR padding of between 25% and 33% — Fig 4 shows the contact areas under a concrete sleeper without padding, with EVA ethylene vinyl acetate padding and with PUR padding, all at the same stiffness.

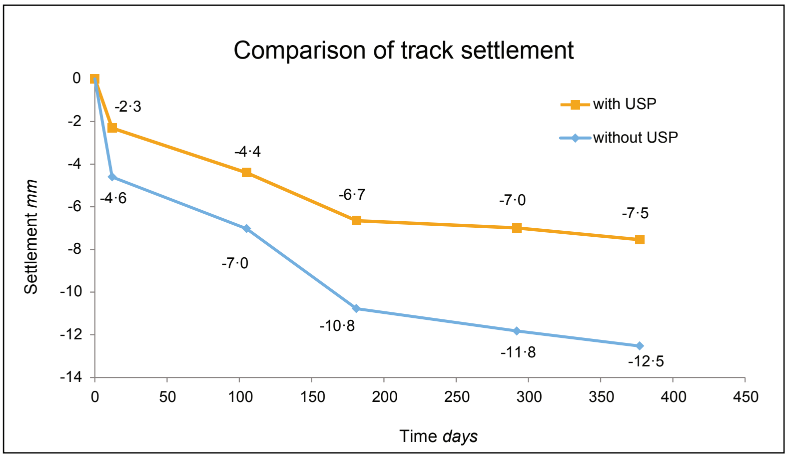
As expected, the contact area with non-padded sleepers is the smallest (generally <5%), the EVA padding material is in the middle (5·9%), while the PUR material demonstrates the largest contact area (27·8%). The test procedure for each material was identical, including the identical nominal material bedding modulus. The larger the effective contact area of the ballast, the more uniform the load transmission, with a consequent reduction in ballast contact pressure.

The effectiveness of using Sylomer as a material for under-sleeper pads has been demonstrated in numerous field tests.[7] Individual sections have been equipped with semi-plastic PUR pads for comparison against sections with no padding. Track settlement behaviour was recorded by means of precision levelling. Fig 5 shows the average settlement progression; trends were clearly visible after just 377 days. The average track settlement in the unpadded zone was 12·5 mm, while in the padded zone the track had only settled by an average of 7·5 mm. So the settlement of the unpadded ballast superstructure was more than 65% greater, reflecting the positive results seen in other installations, despite the relatively short observation period. Indeed, the greater homogeneity of the padded trackform can in some case be discerned by the naked eye. ■

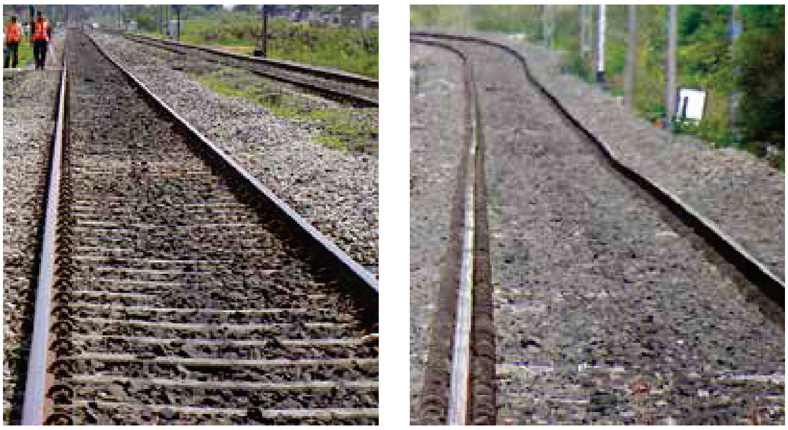
Fig. 4. Average ballast contact pressures underneath sleepers. Comparison of an unpadded concrete sleeper with EVA and PUR padded sleepers.



Below: **Fig. 5. Settlement progression with and without under-sleeper pads after 377 days of operation.**



Bottom: **The different quality of track is evident by comparing track sections with pads (left) and without (right).**



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