BALLASTED RAILWAY TRACK: REDUCING MAINTENANCE NEEDS

William Powrie, professor of geotechnical engineering and dean of the Faculty of Engineering and the Environment at the University of Southampton, and **Louis Le Pen**, senior research fellow in rail infrastructure, consider the ways through which the economic and operational performance of ballasted track could be improved.

On conventional railways, and on high-speed lines that are not heavily trafficked, ballasted track is attractive in terms of its economy and adjustability. However, this strength is also a weakness; with trafficking, ballast gradually settles and may lose its horizontal alignment, so that the design geometry must periodically be restored through maintenance. Differential settlement along the length of the track can be particularly damaging; it leads to variations in dynamic load that exacerbate the problem, so that the rate of geometry deterioration gradually increases.

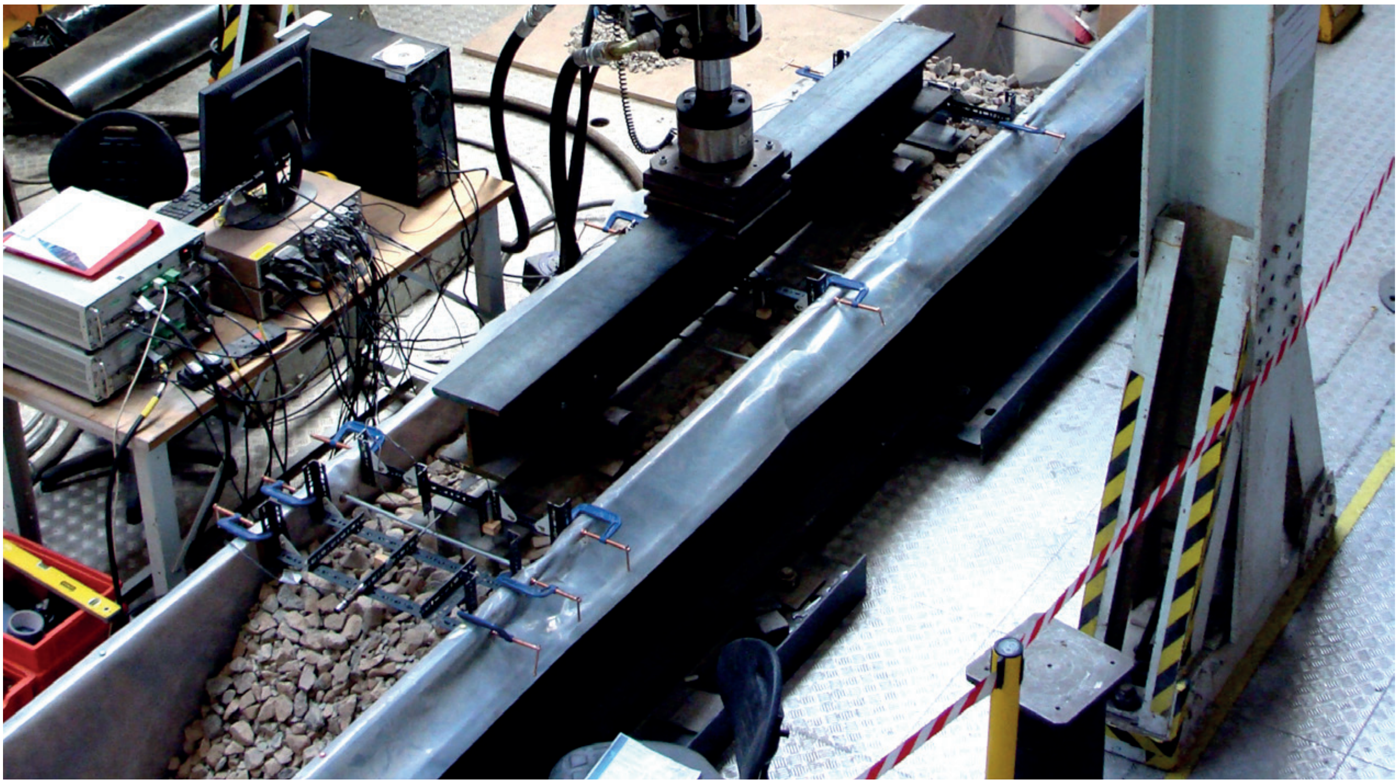
Maintenance to restore the design level is usually by tamping. In this process, the track is raised and vibrating tines inserted into the ballast to squeeze it horizontally in the direction of the track, raising the level of the ballast surface. This reduces the density and disturbs the structure of the ballast, which has become established over hundreds of thousands or even millions of cycles of train loading to carry essentially vertical loads.

Speed restrictions are usually applied to newly-tamped track, until the first few trains to pass over it have caused some degree of recompaction. This implies the need for a degree of overlift above the final required level, which involves a degree of informed guesswork and is a further undesirable aspect of tamping.

There are two ways in which the economic and operational performance of ballasted railway track could be improved. The first is to reduce the rate at which permanent settlement accumulates under traffic loading, so that the track needs to be maintained and adjusted less frequently. The second involves the application of alternative maintenance and adjustment techniques, which utilise rather than destroy the ballast structure that develops with traffic over time.

Laboratory tests carried out on a single sleeper bay in the Southampton Railway Testing Facility (SRTF) at the University of Southampton's National Infrastructure Laboratory have demonstrated the reductions in permanent settlement that can be achieved by four specific modifications to the ballast or to the sleeper/ballast interface. These are:

- Changing the ballast grading (particle size distribution);
- Fixing resilient pads (under sleeper



pads, or USPs) to the underside of a hard sleeper;
- Adding fibre reinforcement to the ballast;
- Reducing the slope of the ballast shoulder.

Ballast is generally specified as an essentially single-sized granular material. This means that the opportunity to develop interlocking between differently-sized grains (with smaller grains fitting snugly in the voids between larger grains, as in a traditional road base material) is at best limited. The reason for this is that historically, railway ballast had to be able to absorb relatively large quantities of fine fouling materials (e.g. coal dust from wagons and train toilet waste) while remaining highly permeable to water to allow it to drain freely. On a modern railway the sources of such fines are much reduced, meaning that the ballast specification could be altered to include a wider range of grain sizes without dramatically affecting its long-term permeability (after allowing for a degree of fouling). This approach has been adopted successfully by Australian railways.

Traditional timber sleepers provided a relatively soft interface with the ballast. When the track was loaded, ballast grains would indent the underside of the sleeper; this increased the contact area, reduced contact stresses and generally provided a more stable interface. Modern reinforced concrete sleepers are hard. As a result there is no indentation by the ballast, the sleeper rests on relatively few ballast grains, the stresses on individual grains are high (potentially leading to damage), and the sleeper to ballast interface may be generally less stable. These effects can be mitigated by attaching a resilient pad (known as a USP) to the underside of the sleeper. Experience in Europe, particularly in Austria and Sweden, has demonstrated the benefits of USPs.

The addition of a small proportion (up to about 0.6% by volume) of suitably-sized polyethylene fibres to the ballast was also beneficial in reducing permanent settlement. This is because as the ballast layer tends to deform, the grains are restrained by tension generated within the fibres.

However, the biggest benefit in the tests carried out in the SRTF was obtained by reducing the slope at the edge of the mound of ballast on which the track sits (termed the "ballast shoulder"). Reducing this slope from 1:1 to 1:2 halved the rate of development of permanent settlement. This is because a significant amount of ballast settlement (after initial densification) is due to lateral movement outward, towards and down the shoulder slope. While it might be difficult to reduce the shoulder slope in practice, lateral restraint to the ballast bed – for example, by means of wire gabions or proprietary signal cable duct manufactured for that purpose – would give similar benefits.

Alternative maintenance techniques

The principal options for alternative, improved maintenance techniques are stoneblowing, dynamic track stabilisation, and targeted repair of specific defects – rather than general or continuous tamping.

Stoneblowing involves the introduction of smaller stones, through placement tubes, directly between the sleeper and the surface of the compacted ballast bed. In this way, sub-sleeper voids are filled and sleepers can be raised to the desired level without disturbing the structure of the existing ballast.

Dynamic track stabilisation is a process by which newly-placed ballast is prepared using a machine that simulates the loading effect of train passage to achieve the densification normally associated with the first few trains to pass over the track after the line is re-opened. The technique enables the line to be handed back with the correct vertical alignment and no speed restriction. Neither technique is new – both were developed in the days of British Rail, but have remained relatively underused on the UK network.

The targeted repair of specific defects, based on raising poorly supported sleepers by the amount of deflection during train passage measured by lineside instrumentation (geophones, digital analysis of video images or accelerometers), has been shown to be effective when general or continuous tamping had failed at problem locations (often associated with transitions between different track forms or under track crossings) on HS1.

Separately or together, improvements in ballasted track performance and maintenance/adjustment techniques have the potential to increase the time interval between required maintenance interventions substantially. In terms of the 2012 Rail Technical Strategy priority areas of cost, carbon, capacity and customer experience, that could be a game changer.

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