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Use of a bituminous mixture layer in high-speed line trackbeds

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HIGHLIGHTS

- Observed improvements in track performance with sub-ballast bituminous layer.
- Lower maintenance needs for the track section with sub-ballast bituminous layer.
- Linear viscoelastic behaviour of bituminous mixture was characterized and modelled.
- Grain indentation into the bituminous layer could be related to better performance.

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ABSTRACT

Feedback on the use of a sub-ballast bituminous layer in a ballasted high-speed line (HSL) is evaluated in this paper. Conclusions are drawn on the relation between the thermo-viscoelastic behaviour of bituminous materials and the improvement in maintenance needs observed on the studied HSL. The case study is a 3 km long experimental zone of the French East-European high-speed line (EE HSL) built with a bituminous mixture sub-ballast layer. In service since 2007, the EE HSL test section has required fewer maintenance operations compared to adjacent sections with conventional structure. Thermo-viscoelastic properties of a bituminous mixture were characterized to understand and explain the contribution of a bituminous sub-ballast layer to the track behaviour. Improved 3D complex modulus tests were performed on laboratory-compacted cylindrical specimens using sinusoidal loading. A constitutive model, called 2S2P1D (2 Springs, 2 Parabolic, 1 Dashpot), developed in the LTDS/ENTPE Laboratory, University of Lyon, was used to simulate the linear viscoelastic (LVE) behaviour of the tested material. The results were analysed in the light of the working conditions and typical loadings of the EE HSL. The results of this study contribute to the definition of an optimal design method for ballasted HSL tracks with bituminous sub-ballast layers.

1. Introduction

The development of the railway transportation industry comes with an increase in traffic speeds, freight loads and traffic volume. Improvements in the track structure are then necessary in order to cope with the increasing demands and to ensure low railway operating costs and high passenger comfort and safety during the design life. In the case of ballasted tracks, sub-ballast layers are determining elements in the mechanical performance of the track and for the protection of the ballast. Using bituminous mixtures for sub-ballast layers has been identified as a possible solution for the necessary enhancement of the track structure. This applies for both passenger and freight traffic lines. Indeed, in the past decade over 322 km of bituminous sub-ballast layers have been built for new projects in the mid-west area of the United States; mostly for heavy freight traffic [36]. Studies and field experiences have identified some advantages of sub-ballast bituminous layers including vibration damping, reducing stress levels on the subgrade and constituting a low permeability layer over the soil layers, which leads to a reduction in the maintenance needs. In addition, constructive advantages have also been observed such as allowing the engines to circulate onto the trackbed during the construction phase [15,16,21,35,37].

In 2004, the French National Railway Company (SNCF) designed a 3 km long experimental zone with a bituminous mixture sub-ballast layer in the East-European High-Speed Line (EE HSL) that connects Paris to eastern France. This HSL has been in service since 2007 with trafficking by French TGV and German ICE passenger trains at a commercial speed of 320 km/h. By 2013, its average

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annual daily traffic (AADT) was estimated at 112 trains per track. So far, the test section has shown very good behaviour and, most interestingly, a significant reduction and a better efficiency of the maintenance operations compared to the surrounding sections made with conventional granular materials. The success of the EE HSL test section encouraged the use of bituminous sub-ballast layers. As a result, at this moment, four new major HSL projects are being built, partially or completely, with bituminous mixtures in France and another one in Morocco. These projects are:

– The East-European HSL (phase 2) – 55 km (52%) of sub-ballast bituminous layer. In service by mid-2016.
– The Brittany-Loire (BPL) HSL – 105 km (58%) of sub-ballast bituminous layer. In service by 2017.
– The Southern Europe-Atlantic (SEA) HSL – 43 km (14%) of sub-ballast bituminous layer. In service by 2017.
– The Nimes-Montpellier (CNM) HSL bypass – 80 km (100%) of sub-ballast bituminous layer. In service by 2017.
– The Tangier – Kenitra HSL – 200 km (100%) of sub-ballast bituminous layer. In service by 2018.

This paper focuses on the feedback on maintenance needs from the EE HSL test zone and the influence of the thermo-mechanical properties of the bituminous mixture on the observed improvements. Regarding geometry degradation of ballasted tracks, several authors highlight the need to understand the ballast and subgrade deterioration mechanisms in order to improve maintenance efficiency while preserving the viability, comfort and safety of railway transport. A necessary step to understand the degradation process of tracks with a bituminous sub-ballast layer is to characterise the mechanical behaviour of bituminous mixtures under railway traffic loading conditions. These materials are mostly developed for highway pavement loading conditions, which differ significantly from those of HSL trackbeds. The main differences are the constant compression effort due to the ballast and the superstructure weight; the dynamic phenomena due to higher traffic speeds and the greater axle loads, amongst others. Moreover, bituminous sub-ballast layers are based on highway pavement design methods, using road base-course mixtures. Unlike in highway pavements, as a sub-ballast layer, these mixtures are exposed to weather conditions (mainly moisture) during their service life. Taking into account all of these factors when characterizing the mechanical behaviour of bituminous mixtures is crucial for drawing conclusions on its performance as a sub-ballast layer and, therefore, its role in the degradation process of the track structure.

In the first part of this paper, the EE HSL test section is described and the feedback on performance and maintenance is presented and analysed. In the second part, the mechanical performance of bituminous mixtures is addressed by characterizing the linear viscoelastic (LVE) behaviour of a mixture of the same characteristics as the one used to build the EE HSL test zone. The complex modulus test was used to characterise the LVE behaviour. Test results are presented. A rheological model called 2S2P1D (2 springs, 2 parabolic elements, 1 dashpot), developed at the Laboratory of Civil Engineering and Construction (LGCB) of ENTPE-University of Lyon, was used to model the experimental results. Finally, the analysis of experimental and modelling results in the light of EE HSL experience allowed conclusions to be drawn on the benefit of viscoelastic properties of bituminous materials on the maintenance of ballasted high-speed lines.

2. Feedback on maintenance needs from the East-European high-speed line test zone

The East-European high-speed line is a ballasted track that links Paris to the French city of Strasbourg, on the German border. It is part of the railway network that connects France with Germany, Luxembourg and Switzerland. French TGV-R, TGV-POS and German ICE3 trains traffic this line at commercial speeds up to 320 km/h. The EE HSL project has two phases. The first one, 300 km long from Paris to Baudrecourt, has been in service at high speed since June 2007. The second one, a 106 km long extension to Strasbourg, has just been completed and will soon come into service. The test zone addressed in this paper was built into the first phase of the EE HSL near the city of Reims. The chosen line section is 3 km long and comprises straight and curve alignments in cutting and embankment configurations. The two segments of the test zone addressed in this paper are in straight alignment and level ground. One segment has a conventional track structure with only unbound granular materials (UGM), which will hereafter be called conventional track. It serves as reference zone. The other segment has a bituminous sub-ballast layer and henceforth will be called bituminous track. Both segments are equipped with accelerometers on the sleepers, stress gauges on the rails and pressure gauges at the top of the soil. The track also has strain gauges and temperature probes at the base of the bituminous layer. Fig. 1 illustrates the instrumentation and structure configuration for both studied segments of the EE HSL test zone.

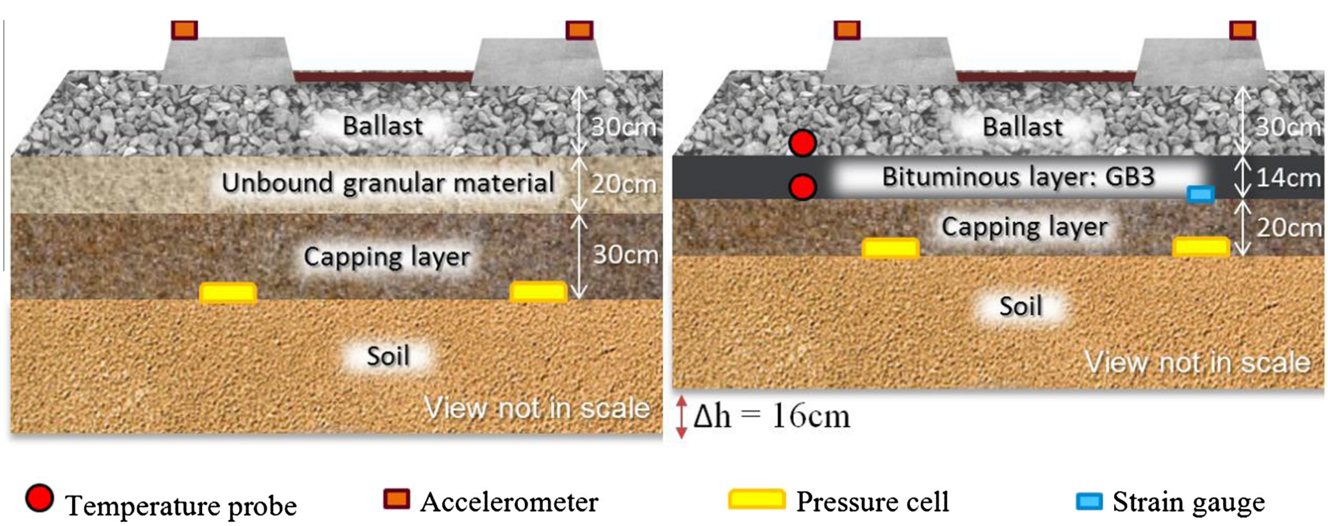

Fig. 1. Instrumentation and structure configuration of the conventional track (left) and of the bituminous track (right) of the EE HSL test zone.