DESIGN OF THE ASPHALT LAYER ON HIGH SPEED LINES

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ABSTRACT

The SNCF (French railways operator) and RFF (French railways owner) have launched a research program in order to validate the feasibility and the design of a sub-ballast layer made of a bituminous material for a ballasted track on a high speed line.

The objective of the research was to define the specifications required of the layer of bituminous material to take into account the particularities associated with high speed railways lines, the traffic and the thermal behaviour of this kind of material.

After this research, SNCF and RFF have decided to realise a test zone of 3 Km on the Eastern European High speed Line (LGV Est Européenne).

The test zone has been equipped by mechanical and thermal sensors and the measurements have been made during four years.

The paper will present:

- The asphalt layer design method;
- The test zone;
- The new developments.
INTRODUCTION

The first railway track bed design was developed for the studies of the first French high speed line in the years 1970. The first structural modelling was undertaken starting from road models adapted to railway specificities. These models were based on the experience feedback realised after repairs of the railway platforms were required on the network, due to their being partially destroyed after the Second World War. This dimensioning was thereafter optimised taking into account the improvements made in the quality of granular materials. After 40 years of experience feedback, these structures give satisfaction.

However, the realization of the track bed requires the purchase and transport over long distances of the aggregates and a significant know-how for their placement.

RFF (Réseau Ferré de France, the owner of the network) and the SNCF (Société Nationale des Chemins de Fer Français) thus launched research of alternative solutions.

The initial idea was to borrow from the road companies the techniques used for the complex of layers, integrating an asphalt layer under the ballast. The main objective was to find optimisations for the project: on the one hand, reduction of earthwork volumes and of the granular material supply, thanks to the global reduction in the layers thickness; on the other hand, the ease of placement of the track and of the equipment (catenaries, signalling, etc); lastly, the third optimisation considered, a reduction of the maintenance costs thanks to the flexibility and to the improved stability of the track at high speeds that would be brought using the asphalt layer.

THE DESIGN

The modelling of the asphalt layer put in place in the track bed was made according to the dimensioning method of the roadways.

The justification is based on the behaviour with the fatigue of materials.

The weakest point of the layer is the bottom. So, we will study the horizontal deformation at the bottom of the layer.

The method includes two calculations.

On the one hand, one calculates the horizontal constraints and horizontal deformations which will be exerted on each layer of the structure modelled under the action of a static axle. This calculation is done with computation software to the finite elements usually used in the structural analyses (CESAR, ABAQUS…).

On the second hand, one calculates the permissible deformation during the lifetime of the layer. Each material is characterized by a fatigue curve established with laboratory test.
The fatigue curve represents the permissible deformation $\varepsilon$ versus the number of cycles of solicitation $N$.

Each material is characterized by the fatigue slope $(b)$ and $6$, which represents the deformation leading to the breaking of the sample if it is applied $10^6$ times.

First of all, to get the permissible deformation, we have to calculate $NE$ which represents the number of train axles that we expect during the lifetime of the trackbed.

Two traffics have been taken into account in the model:
- Road traffic related to the construction of the superstructure
- Rail traffic with a design life of 60 years

$$tadm = 6 \times \left( \frac{NE}{10^6} \right)^b \times kc \times kr \times ks$$

With:
- $kc$: adjustment coefficient, linked with the kind of material;
- $ks$: parameter linked with the soil support quality;
kr: it is the most important parameter for the engineer because it is linked with the risk that the owner accepts to take in account. In others words, it allows a balance between the initial investment and the cost of maintenance. Regarding the difficulty for the maintainer to work on a high speed line, the risk coefficient has been chosen very low.

The design is validated if the deformation calculated in the first step under an axle load is less than the permissible deformation tadm.

The calculation made for the Eastwards High Speed lines gave the following design:

**Trackbed geometry:**

- Ballast: 35 cm
- Asphalt layer: 14 cm
- Adjustment layer: 20 cm
- Treated soil: >80 MPa

**Asphalt characteristics:**

- E = 9000 MPa
- E6 = 110 μdef
- Voids index < 4%

**THE TEST ZONE**

The Eastern European High speed Line (LGV Est Européenne) connects Paris to Strasbourg in 1h50.

The 3 km long test area starts at kilometer 109 of the line, near the station “Champagne Ardenne”.

The selected test zone presents a very heterogeneous character since there are embankments, cuttings, curves, alignments, together with structures and switches equipments.

The placement of the bitumen gravel was undertaken using typical road methods.
In consideration of financial implications, and in order to allow a simplified placement for the signal and telecommunication cables, the installation of the sand-gravel mix bitumen was limited laterally to the ballast sides.

With an aim of checking the dimensioning assumptions and of ensuring a proper experience feedback on the innovative structure, a significant amount of instrumentation was installed on the test area.
Four zones of monitoring have been installed on the test zone.

The reference zone is out of the test zone. This zone is equipped with a standard granular track bed.

The purpose of the pressure sensors is to determine the pressure on the ground under the track bed.

The sensor placed on the reference zone allows a comparison between classical and bituminous track beds.

The strain gauges are placed under the bituminous layer. They allow the measurement of the tensile strength at the basis of the layer.

This point is very important for the fatigue modeling of the loss of strength with time in the layer.

The thermometers allow a permanent survey of the temperature in the bituminous layer.

Finally, some accelerometers have been placed on sleepers on the four zones: they allow a comparison to be made of the track behaviour between the classical granular zone and the bituminous zone.
THE MAIN RESULTS

The track behaviour

The Figure 4 is an example of the graphic tool (TIMON) used by SNCF to assess the behaviour of the track. The line is divided in 1 km sections, each one being represented by a graph. The upper part of the graph shows the maintenance effort undertaken for each section. The lower part shows the evolution of the track quality from the beginning of its exploitation up to the current days. The analysis of the graphs shows a relatively low track maintenance effort on the test zone for a good track quality.

Pressure

The comparison between the pressure on the ground between the classical and the bituminous track bed shows a strong reduction of the pressure due to the bitumen gravel. This result corresponds with the model.

Strain gauge

The tensile strength at the base of the bituminous layer is a very important characteristic of the model. It is the most delicate point of the design. The results of the measurement are in conformity with the model.
Temperature

The curve of figure x shows the repartition of temperature in the bitumen gravel layer (in dark) and the ambient temperature (in blue), as measured between 2006 and 2009.

We can observe a Gaussian repartition of the ambient temperature between -14°C and 42°C.

The repartition of the temperature in the bitumen gravel layer is more concentrated between 2°C and 25°C with a maximum of occurrences at 6°C and 15°C.

THE DEVELOPMENT

New high speed lines

Three new high speed lines are under construction in France:

- SEA : « Sud Europe Atlantique » 340 km
- BPL : « Bretagne Pays de Loire » 182 km
- CNM : « contournement Nîmes Montpellier » 80 km.

The three projects include partially or totally asphalt layers.

The third line, CNM, will be submitted to a mix traffic, passengers during the day and some freight train during the night.
It means that the time available for the maintenance will be very short during the lifetime of the line. So, the owner decided to install asphalt layers on the 100% of the line to allow maintenance compatible with the available time.

Research projects

SNCF have launched two research projects in the field of asphalt for railways.

High speed lines

A research has been launched in order to characterize the linear thermo-viscoelastic behaviour of asphalt mixes used in railway infrastructures. We need to have a better knowledge on the characterization of the bituminous materials working under high speed traffic conditions given the fact that they present a viscoelastic behaviour. The existing linear viscoelastic (LVE) models for bituminous mixtures are mostly conceived for the road industry and need to be validated to railway applications. Identifying the LVE behaviour of bituminous mixtures submitted to typical railway conditions (loading, frequency and environmental exposure) is therefore necessary to create a rational track structure design methodology, so as to optimize the use of asphalt concrete in railway sub-ballast layers. This can be achieved by modelling the LVE behaviour of bituminous mixtures in order to define their constitutive equations and integrate them to complex sub-ballast layer design methods.

Classical lines

SNCF has launched with others companies a new research dedicated to the classical lines; the goal is to design a new ballastless track, put on an asphalt slab in order to get a thin track, especially available in tunnels where we have some gauge problems.

An experimentation of asphalted ballastless track has already been done near Strasbourg. We will work to optimize the design.

Figure 8 : Strasbourg ballastless asphalted track