Domestic and International Design Practices, Applications, and Performances of Asphalt/Bituminous Railway Trackbeds

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Classic All-Granular Trackbed

Typical Thickness (mm)

250-300

100-150
Asphalt Underlayment trackbed without granular subballast layers

Asphalt Combination trackbed containing both asphalt and subballast layers

Ballastless trackbed containing thickened asphalt and subballast layers
United States Applications

Since 1981

- Short Maintenance—Road Crossings, Turnouts, Rail Crossings, Tunnels, Bridge Approaches, WILDS, etc.
- Capacity Improvement—Double Tracking, Line Changes, etc.
Trackbed Measurements & Evaluations

Earth Pressure Cell
Piezoelectric Film Sensor
Track Deflection
Track Stiffness
Long-Term Track Settlement
Pressure Cell

- Geokon Model 3500-2
- 9 in. Diameter
- Strain Gage
- Snap-Master
- Thermistor

Cell Placement on Asphalt
Empty Coal Train at Conway

P-Cell 209 on 5 in. HMA Layer

4 6-Axle Locos

Initial 5 Cars
Reduction of Dynamic Stresses

- 8 in. HMA surface
- Subgrade surface

Stress (psi) vs. Time (s)
View of Tekscan Sensors

Tekscan Measurement Configuration

- Matrix-based array of force sensitive cells
- Silver conductive electrodes
- Pressure sensitive ink – Conductivity varies
- Crossing of ink – strain gauge
This represents a typical pressure distribution between a machined steel tie plate and the rail with an included rubber bladder.
Positioning of Lead Wheel with Respect to Sensor

Snapshot of the Lead Wheel Directly above the Sensor

Lead Wheel Over Sensor

F = 25372 lbf, P = 529 psi
Core Drilling
Subgrade Findings/Discussion

• In-situ Moisture Contents
  – Remain Consistent Over Time
  – Compare Favorably With Optimum
• Assume Unsoaked, Optimum Condition
• Bearing Capacity Remains At or Near Optimum
• Wide Range of Subgrades Evaluated
• Minimum Loading Induced Stress on Subgrade.
Asphalt Findings/Discussions

• Resilient Modulus Values are Intermediate in Magnitude-Typical of Unweathered Asphalt Mixes
• Asphalt Binders do not Exhibit Excessive Hardening (brittleness), Weathering, Deterioration or Cracking
• Asphalt is Insulated from Environmental Extremes
• Asphalt Experiences Minimal Loading Induced Stress
• Conditions Influencing Typical Failure Modes Experienced by Asphalt Highway Pavements don’t Exist in Asphalt Railroads Trackbeds.
International Applications

Italy

France

Germany

Japan

Spain

Austria
Italy

- Debated between cement and asphalt
- Asphalt – designated on all future high-speed passenger lines
• Prevents rainwater from infiltrating the layers below the embankment

• Eliminate high stress loads and failures of the embankment

• Protect the upper part of the embankment from freeze/thaw actions

• Gradually distribute static and dynamic stresses caused by trains

• Eliminate ballast fouling

Buonanno, 2000
Typical Cross Section

- 12 cm of asphalt with 200 MPa modulus
- 30 cm of super compacted subgrade with 80 MPa modulus
- 35 cm of ballast on top
- Increased safety and structural reliability due to increased modulus and uniformity
- Reduced life-cycle cost on the infrastructure from reduced subgrade fatigue
- Increased homogenization of the track bearing capacity on the longitudinal profile and better ballast confinement
- Reduced ballast fouling due to improved drainage
- Reduced vibration levels throughout the track therefore reducing noise
- Reduced thickness compared to a conventional granular design

Policicchio, 2008

Teixeira, 2005
Japan

- Widely Used
- High Speed/Regular
- Firm Support for Ballast
- Reduce Load Level on Subgrade
- Facilitate Drainage

Momoya and Sekine, 2007
New Railway Roadbed Design

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When laying track on earth structures, roadbed performance is extremely important for controlling track settlement and dynamic deflection. In order to meet roadbed performance demands in Japan, concrete roadbed is used for slab track (Fig. 1), and asphalt roadbed is used for ballasted track (Fig. 2); this structure is also standard for the Shinkansen bullet train. The roadbed design methods are described in the “Design Standard for Railway Structures (Earth Structures).” In the January 2007 revision to this design standard, a performance based design method was introduced. As the previous Design Standard for Railway Structures (Earth Structures) was based on specifications, the thickness of each layer of the roadbed design was specifically defined. With the performance based design method, however, it has become possible for the designers to design roadbed thickness to satisfy roadbed performance requirements. Specifically, by considering the fatigue life related to the number of trains, a method of designing thickness according to the importance of a particular section of track is described. Also, while the previous design concept was not consolidated with regard to a concrete roadbed for slab track or an asphalt roadbed for ballasted track, with this revision the roadbed design methods have been grouped together systematically.

With the new design standard, the earth structure performance rank for the relevant track is determined by the relative importance of the section of track and the track type. When designing the roadbed, a type of roadbed is selected to suit each of the various performance ranks. For performance rank I, concrete roadbed or asphalt roadbed for ballastless track is selected; for performance rank II, asphalt roadbed for ballasted track is used; and for performance rank III, crushed stone roadbed for ballasted track is selected.

After the type of roadbed has been selected in this way, the roadbed structure design is carried out. In the case of a concrete roadbed (Fig. 3), the following effects of train loads are checked for: displacement of the roadbed, breakage of the reinforced concrete base, fatigue damage, cracking, contraction, and thermal stresses. For asphalt roadbeds, the following effects of train loading are checked: displacement of the roadbed and fatigue damage of the asphalt mixture layer. In particular, in the case of an asphalt roadbed for ballasted track (Fig. 4), fatigue failure had not been considered in the previous design; however, this time a design method based on fatigue life has been introduced.

In this way, by systemizing roadbed design thinking to suit the design standard revision, and with the introduction of the performance-based design method, flexible design to suit the importance of the track section has now been made possible.
• **Performance Rank I**: Concrete roadbed or asphalt roadbed for ballastless track
  – Concrete base thickness = 190 mm
  – Asphalt base thickness = 150 mm
  – Stone base thickness = 150 mm

• **Performance Rank II**: Asphalt roadbed for ballasted track
  – Ballast thickness = 250-300 mm
  – Asphalt base thickness = 50 mm
  – Stone base thickness = 150-600 mm

• **Performance Rank III**: Crushed stone roadbed for ballasted track
Ballastless Cross Section

- Mainly used for viaducts and tunnels
- Proposed a low noise solid bed track on asphalt pavement
Ballasted Cross Section

- Asphalt Thickness: 5 cm
- Well-Graded Crushed Stone Thickness: 15-60 cm

Figure 12: Performance Rank II Cross-Sectional Profile (Momoya and Sekine, 2007)
France

- Paris to Strasbourg high-speed line
- 3 km asphalt subballast
- 574 km/hr (357mph) (test)
Comparative Cross-Sectional Profiles

Figure 13. Traditional and Asphalt Cross Sections (Bitume Info, 2005)
Figure 14. Asphalt Placement and Compaction (Faure, 2005)
• Reduces overall cross-sectional thickness by 36 cm

• Reduces quantity of fill material by 5,000 cubic meters/kilometer

Bitume Info, 2005
Testing

- Conduct tests for 4 years (2007-2011)
- Temperature sensors continuously recording air temperature
- Pressure Sensors and Strain Gages checked twice a year
- Accelerometers
Spain

- Madrid – Valladolid
- Barcelona – French Border
Figure 15. Bituminous subballast sections built on the high-speed line Madrid-Valladolid, section between Segovia and Valdestillas (left) and on the high-speed line Barcelona-French Border, section Sils-Riudellots (right). Source: Teixeira (2009).
Figure 16. Track design with bituminous sub-ballast for Spanish high-speed lines standards. Source: Teixeira et al. (2009)
Germany

- Utilize several alternatives to conventional ballast design
- German Getrac A1/A3 – ballastless slab consisting of asphalt
- Concrete ties are anchored to the asphalt
Figure 18. German Getrac A1 Cross Sectional Profile
Figure 19. Getrac A1 Cross Sectional Profile with Hydraulically Bound Layer
Figure 23. Finished Getrac A3 Track at Brandleite Tunnel
Reasons for Implementing Asphalt Layers

How to install an Asphalt Layer?

Targets of an Asphalt Layer

– to allow road vehicles running on the sub-layer during construction phase independently from weather and sub-soil situation
– clear separation of sub- and superstructure during the whole service life

Advantages

– drainage effect for raining water hindering it penetrating the substructure
– avoiding the pumping up of fines into the ballast
– delivering a certain amount of elasticity
– homogenising the stresses affecting the substructure
Long Term Experiences
Jauntal, Carinthia
Conclusions

Asphalt layers improve the quality of track in defining a clear and long lasting separation between superstructure and substructure. This separation results in less maintenance demands of track and (thus) longer service lives.

These benefits must be paid by an additional investment of 10€/m² within the initial construction.

*Life cycle cost analyses show that it is worth to implement asphalt layers on heavy loaded lines (> 15,000 gt per day and track), as then the annual average track cost can be reduced by 3% to 5%.*

However, implementation of asphalt layers cannot be proposed for branch lines carrying small transport volumes.

Asphalt Layers must be understood as an additional investment in quality, then it pays back its costs. It must not be implemented in order to reduce quality in sub-layers, by for example reducing the thickness of the frost-layers.
Implementation

Consequently asphalt layers of 8 cm to 12 cm form a standard element for new high capacity and high speed lines in Austria.

Due to the long interruption of operation installing of asphalt layers are not proposed within track re-investment and maintenance operations.

picture a to c: new Koralm link, picture d: Schoberpass-line, built in 1991
Closure

• Current Practices

• Not All-Encompassing

• Typical Activities