Utilization of Asphalt/Bituminous Layers and Coatings in Railway Trackbeds – A Compendium of International Applications

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• Introductory Remarks
• United States Applications
  – Typical Design
  – Installation Procedures
  – Descriptions of Projects
  – Tests and Evaluations
• International Applications
  – Italian
  – Japanese
  – French
  – Spanish
  – German
Early Track

Present Day Track
Figure 1. Classic All-Granular trackbed without asphalt layer
Figure 2a. Asphalt Underlayment trackbed without granular subballast layer

Figure 2b. Asphalt Combination trackbed containing both asphalt and subballast layers

Figure 2c. Ballastless trackbed containing thickened asphalt and subballast layers
United States Applications

• 1980 Deregulation

• Capacity Improvement – Freight

• Commuter/Short-Medium – Passenger

• Combination
Strengthens Trackbed Support

Waterproofs Underlying Roadbed

Confines Ballast and Track

Dense-Graded Highway Base Mix
1 – 1 ½ in. Maximum Size Aggregate
Asphalt Binder +0.5% above Optimum
Low to Medium Modulus Mix, 1 - 3% Air Voids
Cleveland, OH (1968)

Experimental track section Cleveland Transit System

Standard Tie
Ballast
Subgrade
10'
Asphalt Concrete Base, 4" to 5" thick
A conventional paving machine was used to place the Santa Fe 2100-foot test section of asphalt concrete base built in three 700-foot sections 2 1/2, 5, and 7 1/2 inches thick and about sixteen feet wide.
Conway, KY (1983)
Figure 5. Typical Asphalt Underlayment track section on BNSF ‘transcon’ line
Relationships for Roadbed/Subgrade In-Situ and Optimum Moisture Contents

![Graph showing relationships between in-situ moisture contents and optimum moisture contents for 1998, 2007, and current years.](image)

- In-situ Moisture Contents, % vs. Optimum Moisture Contents, %
  - Linear (1998)
  - Linear (2007)
  - Linear (In-Situ = Optimum)
Subgrade Findings/Discussions

• 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 Tests
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 Railroad Trackbeds
Pressure Cell

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

Cell Placement on Asphalt
Pressure Cell Measurement Configuration
Empty Coal Train at Conway

P-Cell 209 on 5 in. HMA Layer

Initial 5 Cars

4 6-Axle Locos
Loaded Coal Train at Richmond

- **P-Cell 819 Beneath Rail in Crib**
  - 2 6-Axle Locomotives
  - Initial 2 Cars

- **P-Cell 820 Beneath Rail and Tie**
  - 2 6-Axle Locomotives
  - Initial 2 Cars

- **P-Cell 821 C/L Track in Crib**
  - 2 6-Axle Locomotives
  - Initial 2 Cars

- **P-Cell 822 C/L Track and Tie**
  - 2 6-Axle Locomotives
  - Initial 2 Cars

Time (s) vs. Pressure (psi) graphs for each of the above locations.
Reduction of Dynamic Stresses
Test Results in Track Modulus and Subgrade Stress

![Graph showing test results in track modulus and subgrade stress.]

- **Track Modulus (lb/in./in.):**
  - 18 in. granular tracks
  - 4 in. HMA
  - 8 in. HMA

- **Subgrade Stress (psi):**
  - 18 in. granular tracks
  - 4 in. HMA
  - 8 in. HMA
Loaded Coal Train at Conway

5 in. HMA Layer on Wood Tie Track

Deflection (in.)

Time (s)
Loaded Coal Train at Brush Creek

HMA Layer on Concrete Tie Track

Time (s)
Deflection (in)

2 6-Axle Locos
Initial 6 Cars

Loaded Coal Train at Brush Creek
HMA Temperature vs. Air Temperature

![Graph showing temperature variation over dates. The graph compares air temperature with HMA temperature. The x-axis represents dates from September 1 to June 28. The y-axis represents temperature in Fahrenheit.]
International Applications

Italy

France

Spain

Japan

Germany
• Rome-Florence: 252 km (1977-1986)
• 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
“Supercompattato”  Bituminous sub-ballast
- 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
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
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 21. Paving with Asphalt

Figure 22. Installation of Concrete Ties
Figure 23. Finished Getrac A3 Track at Brandleite Tunnel
Closure

• Current Practices

• Not All-Encompassing

• Typical Activities