ASPHALT TRACKBEDS
Design, Evaluation and Utilization

"Railroad Track Design Including Asphalt Trackbeds"
Pre-Conference Workshop

by

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University of Kentucky
ASPHALT TRACKBEDS
Design, Evaluation and Utilization

Introduction

Trackbed Measurements & Evaluations

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

Trackbed Materials Classifications

Utilization Applications

KENTRACK Structural Design
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
Composition of Dense-Graded HMA Mix

<table>
<thead>
<tr>
<th>Sieve size</th>
<th>Amount finer, mass %</th>
<th>Recommended</th>
<th>Actual</th>
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<tbody>
<tr>
<td>1.5 inch</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>¾ inch</td>
<td>70 - 98</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>3/8 inch</td>
<td>44 - 76</td>
<td>52</td>
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<tr>
<td>No. 4</td>
<td>30 - 58</td>
<td>41</td>
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<td>No. 8</td>
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<td>No. 16</td>
<td>14 - 35</td>
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<td>11</td>
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<tr>
<td>No. 200</td>
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<td>4.5</td>
<td></td>
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<tr>
<td>Asphalt</td>
<td>3.5 - 6.5</td>
<td>6.4</td>
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Marshall Mix Design Criteria for HMA Underlayment

<table>
<thead>
<tr>
<th>Property</th>
<th>Required Range</th>
<th>Actual Test Results</th>
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<tbody>
<tr>
<td>Compaction</td>
<td>50 blows</td>
<td>50 blows</td>
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<tr>
<td>Stability (lbs)</td>
<td>750 minimum</td>
<td>1730</td>
</tr>
<tr>
<td>Flow (inch)</td>
<td>0.15 – 0.25</td>
<td>0.24</td>
</tr>
<tr>
<td>Percent air voids</td>
<td>1 - 3%</td>
<td>2%</td>
</tr>
<tr>
<td>Voids filled w/asphalt</td>
<td>80 - 90%</td>
<td>86%</td>
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<tr>
<td>In-place density*</td>
<td>92 - 98%</td>
<td>94%**</td>
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</table>

*Maximum density = 151 ptc
** Average nuclear density test results
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
Geokon Hydraulic Earth Pressure Cells

9 in. Diameter
Pressure Cell Measurement Configuration
Empty Coal Train at Conway

P-Cell 206 on 8 in. HMA Layer

4 6-Axle Locos

Initial 5 Cars
Reduction of Dynamic Stresses

- 8 in. HMA surface
- Subgrade surface

The graph shows the comparison of dynamic stresses over time between an 8 in. HMA surface and a subgrade surface. The stresses are measured in psi, and the time is in seconds.
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

-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Time (s)
Deflection (in.)

2 6-Axle Locos
Initial 7 Cars

Loaded Coal Train at Conway

5 in. HMA Layer on Wood Tie Track

-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Time (s)
Deflection (in.)

2 6-Axle Locos
Initial 7 Cars
Loaded Coal Train at Conway

8 in. HMA Layer on Wood Tie Track

Time (s)
Deflection (in.)

2 6-Axle Locos
Initial 7 Cars
Loaded Coal Train at Brush Creek

HMA Layer on Concrete Tie Track

Deflection (in)

Time (s)

2 6-Axle Locos
Initial 6 Cars
HMA Temperature vs. Air Temperature

[Graph showing temperature fluctuations over time, with two lines representing air and HMA average temperatures.]
Typical Cross-section
Pressure Cell

- Geokon Model 3500-2
- 9 in. Diameter
- Strain Gage
- Snap-Master
- Thermistor
Cell Placement on Asphalt
Cell Location at Richmond
Loaded Coal Train at Richmond

P-Cell 819 Beneath Rail in Crib

P-Cell 820 Beneath Rail and Tie

P-Cell 821 C/L Track in Crib

P-Cell 822 C/L Track and Tie

2 6-Axle Locomotives
Initial 2 Cars

Time (s)
Pressure (psi)
Loaded Auto Train at Richmond

P-Cell 819 Beneath Rail in Crib

P-Cell 820 Beneath Rail and Tie

P-Cell 821 C/L Track in Crib

P-Cell 822 C/L Track and Tie

<table>
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<th>Time (s)</th>
<th>Pressure (psi)</th>
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<tr>
<td>2</td>
<td>5</td>
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<td>3</td>
<td>10</td>
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<td>6</td>
<td>25</td>
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<td>7</td>
<td>30</td>
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</tbody>
</table>
Loaded Concrete Truck at Richmond
Cell Location at Lackey
Loaded Coal Train at Lackey

P-Cell 510 Beneath High Rail and Tie

2 6-Axle Locomotives  Initial 2 Cars

Pressure (psi)

Time (s)

P-Cell 806 C/L Track and Tie

2 6-Axle Locomotives  Initial 2 Cars

Pressure (psi)

Time (s)

P-Cell 511 Beneath High Rail and Tie

2 6-Axle Locomotives  Initial 2 Cars

Pressure (psi)

Time (s)

P-Cell 207 Beneath Low Rail and Tie

2 6-Axle Locomotives  Initial 2 Cars

Pressure (psi)

Time (s)
Flat Wheel on an Empty Coal Train at Lackey

P-Cell 511 Beneath Rail and Tie

Time (s)
Pressure (psi)

2 6-Axle Locomotives
95 Empty Cars
Loaded Coal Truck at Lackey

P-Cell 510 Beneath High Rail and Tie

Time (s)
Pressure (psi)
• Matrix-based array of force sensitive cells
• Silver conductive electrodes
• Pressure sensitive ink – Conductivity varies
• Crossing of ink – strain gauge

View of Tekscan Sensors

Tekscan Measurement Configuration

Diagram showing the Tekscan Measurement Configuration with connections to a computer, magma, power supply, and tekscan sensor.
In Track Placement During First Test

Typical Pressure Distribution Plot from Tekscan System

Scale in PSI
This represents a typical pressure distribution between a machined steel tie plate and the rail with an included rubber bladder.
This represents a typical pressure distribution between a polyurethane plastic tie plate and the rail.
Positioning of Lead Wheel with Respect to Sensor

Lead Wheel Position

Average Pressure (psi)

5 Ties Before Sensor
4 Ties Before Sensor
3 Ties Before Sensor
2 Ties Before Sensor
1 Tie Before Sensor
Directly Above Sensor
1 Ties Past Sensor
2 Ties Past Sensor
3 Ties Past Sensor
4 Ties Past Sensor
5 Ties Past Sensor

Snapshot of the Lead Wheel Directly above the Sensor

Lead Wheel Over Sensor
F = 20985 lbf, P = 437 psi
Positioning of Lead Wheel with Respect to Sensor

Lead Wheel Position

Average Pressure (psi)

10 Ties Before Sensor
8 Ties Before Sensor
6 Ties Before Sensor
4 Ties Before Sensor
2 Ties Before Sensor
Directly Above Sensor
2 Ties Past Sensor
4 Ties Past Sensor
6 Ties Past Sensor
8 Ties Past Sensor
10 Ties Past Sensor

F = 25372 lbf, P = 529 psi
Rear Tires of Tractor of a 151,000 lb Loaded Coal Truck on Concrete Crossing of
Kentucky Coal Terminal, Mile Post 6.6. May 25, 2004

9842 lb

135 psi

72.93 in^2

Force vs. Frames

Pressure vs. Frames
Front Tire of a CSXT Suburban on Asphalt Parking Lot in Ashland Oil Company. May 25, 2004

- Force: 1652 lb
- Pressure: 75 PSI
- Contact Area: 22.15 in^2

Graphs showing force and pressure over frames.
Rear Tire of a CSXT Suburban on Asphalt Parking Lot in Ashland Oil Company. May 25, 2004

2197 lb

81 PSI

27.15 in^2

Force vs. Frames

Pressure vs. Frames
Summary

Asphalt Trackbeds – 286,000 lb (130 metric ton) Loading

Dynamic Pressure @ Rail Base/ Tie Plate
400 – 600 psi (2800 – 4200 kPa)

Dynamic Pressure @ Top of Asphalt Mat
13 – 17 psi (90 – 120 kPa)

Dynamic Pressure @ Asphalt/ Subgrade Interface
7 – 8 psi (50 – 55 kPa)

Dynamic Track Deflection
0.25 in. (6.4 mm) – Wood, 0.05 in. (1.3 mm) - Concrete

Dynamic Track Modulus
2900 lb/in/in (20 MPa) – Wood, 7200 lb/in/in (50 MPa) - Concrete
Tire- Pavement Contact Pressure

- Similar to Tire Inflation Pressure
Long-Term Track Settlements

(Top-of-Rail Elevations)
Longitudinal view of highway/rail crossing containing asphalt underlayment

<table>
<thead>
<tr>
<th>Station 1</th>
<th>Station 9</th>
<th>Station 12</th>
<th>Station 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing Surface</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphalt Underlayment</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Station 8</td>
<td>RoadBed</td>
<td>Station 13</td>
<td></td>
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</table>
Top of Rail Elevations for Flagspring NO ASPHALT

99.5
99.75
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Station
Elevation (ft)
5/13/02
7/25/02
6/09/03
2/10/04
2/2/2005
3/14/2006

WB
EB
Installed 5/13/2002
Average Asphalt/Approach Settlement for Flag Spring (no underlayment)

Installed 5/13/2002
Top of Rail Elevations for South Portsmouth

- Station
- Elevation (ft)

- 6/11/02
- 7/25/02
- 6/09/03
- 2/10/04
- 2/2/2005
- 12/20/2005

- WB
- EB

Installed 6/11/2002

Graph showing elevation changes over time for different stations.
Average Asphalt/Approach Settlement for South Portsmouth

Installed 6/11/2002
1.0 in. = 25.4 mm
KY Coal Term
Top of Rail Elevations for KY Coal Terminal # 2 Track

Installed 11/14/02

EB

WB

11/14/02
11/21/02
1/13/04
5/25/2004
4/13/2005
12/20/2005
Average Asphalt/Approach Settlement for KY Coal Terminal #2

- Approaches
- Crossing

Installed 11/14/2002

Settlement (in.)

Time (Months)

0.00 - 2
0.22

0.24 - 16
0.40

0.98 - 18
0.55

1.00 - 24
0.90

1.10 - 30
1.42

1.71 - 38

- Chart shows the settlement over time for Approaches and Crossing approaches.
- The chart indicates that settlement occurs over the months following installation.
- The settlement values are given in inches.
Average top of Rail Elevations for KY 7 - No Name

Note:
- Installed 10/14/2005
- South Approach
Surfaced 10/18/2005
- New Rail West side
Stations 1-6, 21-26, 5/7/07

Asphalt Underlayment stations 8-21 (Bold Lines)
Average Asphalt/Approach Settlement for No Name

<table>
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<th>Time (months)</th>
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<tr>
<td>1</td>
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<td>0.21</td>
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<td>0.51</td>
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<td>0.37</td>
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<tr>
<td>20</td>
<td>0.37</td>
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Installed 10/14/2005
Stanley
## Average Top of Rail Elevations for US 60 Stanley

<table>
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<tr>
<th>Date</th>
<th>Elevation (ft.)</th>
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<tbody>
<tr>
<td>5/16/2002</td>
<td>99.95</td>
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<tr>
<td>6/13/2002</td>
<td>100</td>
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<tr>
<td>8/28/2003</td>
<td>100.05</td>
</tr>
<tr>
<td>1/20/2004</td>
<td>100.1</td>
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<td>7/12/2004</td>
<td>100.15</td>
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<td>6/10/2005</td>
<td>100.2</td>
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<tr>
<td>2/13/2006</td>
<td>100.25</td>
</tr>
<tr>
<td>11/16/2006</td>
<td>100.3</td>
</tr>
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</table>

The graph shows the average top of rail elevations over time for US 60 Stanley. The elevation data was installed on 5/16/2002.
Average Asphalt/Approach Settlement for US 60 Stanley

- Approaches
- Crossing

Installed 5/16/2002
Advantages of Enhanced Support

• Clearly Demonstrated
• Minimize Long-Term Settlement
• Settlement Asphalt Crossings was 41% of non-Asphalt Crossings
• Settlement Asphalt Crossings was 44% of Abutting Approaches
• Settlement of Non-Asphalt Crossings & Approaches – Similar
• Fast-Track is Feasible
• Cooperative Approach is Desirable
Trackbed Materials Classifications
Tests and Evaluations

Trackbed Materials

• Ballast

• Subgrade
  Moisture Content
  Proctor Moisture-Density Classification
  CBR

• Asphalt
  Core Tests
  Recovered Binder Tests

1998 - 2007
Trackbed Test Sites
Core Drilling
Core Drilling
Core Drilling
Soil Tests
Relationships for Roadbed/Subgrade In-Situ and Optimum Moisture Contents
## Unified Soil Classification

<table>
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<tr>
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<th>CBR</th>
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<tbody>
<tr>
<td>Guthrie</td>
<td>1989</td>
<td>Silty sand</td>
<td>12%</td>
<td>14/5</td>
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<td>OK City</td>
<td>1992</td>
<td>Lean clay</td>
<td>18%</td>
<td>8/3</td>
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<td>Quinlan</td>
<td>1995</td>
<td>Lean clay</td>
<td>17%</td>
<td>9/4</td>
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<tr>
<td>Quinlan</td>
<td>1995</td>
<td>Sandy silt</td>
<td>13%</td>
<td>3 3/26</td>
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<td>Hoover</td>
<td>1994</td>
<td>Subballast</td>
<td>9%</td>
<td>56/46</td>
</tr>
<tr>
<td>Hoover</td>
<td>1994</td>
<td>Clayey sand</td>
<td>11%</td>
<td>7/4</td>
</tr>
</tbody>
</table>
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
Resilient Modulus
25°C (77°F)
1Hz
Dynamic Shear Rheometer
25°C (77°F)
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
UTILIZATION APPLICATIONS FOR ASPHALT TRACKBEDS

Domestic and International

Typically as an Underlayment Layer Topped with Ballast Layer but can have Ties or Slab Positioned Directly on Asphalt without Ballast Layer

NEW TRACKBEDS – PAVER LAID WITH HIGHWAY PAVING EQUIPMENT

Long Distances – New Alignments and Double-Tracking

Re-Alignments of Existing Tracks – Approaches to New Bridges, etc.
REHABILITATION (RENEWAL) OF EXISTING TRACKBEDS – BACK DUMPED

Short Distances – Quick Fixes under Traffic

Typically Special Trackworks

- Turnouts, Crossovers, Railroad Crossing Diamonds
- Highway At-Grade Crossings
- Bridge Approaches
- Tunnel Floors and Approaches
- Various Types of Detectors
- Short Sections of Unstable Trackbeds
Excavating trackbed and checking grade

Removing old crossing 08:30

Began excavating

KY 3 Condition prior to rebuild
Dumping and spreading ballast

Spreading asphalt

Compacting asphalt and dumping ballast

Dumping and spreading ballast
Tamping ballast

Positioning new panel

Spreading cribbing rock 11:30

Tamping ballast
3 weeks later

Compacting hand-spread approaches

Regulating ballast 12:40

Finished compacting asphalt approaches 16:50

3 weeks later
Removing track and location 2 (1/30/97)

Hauling fouled ballast from tunnel

Loading steel ties and roadbed at north end

Excavating trackbed material
Unloading hot mix asphalt for transloading to hi-rail dump

Unloading hot mix asphalt at north end to be distributed by loader

Unloading hot mix asphalt inside tunnel

Spreading cold mix on floor
Looking north at south portal to tunnel #3 at PN 2.5. Pumping station at left. All 4 tunnels have sump pump systems. All 4 have asphalt.

South portal to tunnel #1 from 22nd Street station, PN 1.9. Asphalt placed in tunnels and approaches during 1999. No surfacing required. Wood ties used in tunnels.
Italian High-Speed Passenger Lines

- Debated between cement and asphalt
- Asphalt performed better – opted for use on all high-speed passenger lines
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
High Speed Rail Construction
Asphalt Over Super Compacted Layer
Spreading Ballast
Compacting Ballast
Finished Product
Turin - Salerno - 2009

- Turin - Milan
- Milan - Bologna
- Bologna - Florence
- Florence - Rome
- Rome - Naples
- Naples - Salerno
Germany

- German Getrac ballastless track
- Track Panels are directly supported by asphalt
- Two Types: Getrac A1 and Getrac A3
Dimensions

- Getrac A1:
  - 300 cm of asphalt
  - 600 cm of subgrade
  - Concrete Ties
  - Used for open track

- Getrac A3:
  - 260 cm of asphalt
  - 600 cm of subgrade
  - Concrete Ties
  - Used for restricted spaces: tunnels
Asphalt Layer

• Paved in 3 different layers:
  1. 0/22 mm aggregate – initial base layer
  2. 0/16 mm aggregate – medium layer
  3. 0/8 mm aggregate – covering layer
Getrac A1 Cross-Section
Japan

- Shinkansen Lines “Bullet Train”
- 1964 – Tokyo to Osaka
- Other lines branched off
- Estimated 396 billion people*km using trains
Ballasted Cross Section

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

Figure 1: Typical cross-section of railway asphalt roadbed.
Ballastless Cross Section

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