Comparisons of Railroad Track and Substructure Computer Model Predictive Stress Values and In-Situ Stress Measurements

By: Dr. Jerry G. Rose, Ph.D., PE
Bei Su, MSCE and
Frank Twehues, EIT
Earth Pressure Cell

Predicts

Measures

Computer

Tekscan Sensor
Tekscan Sensor

Geokon Pressure Cell

Wooden Tie
Ballast
Subballast/HMA
Subgrade

Geokon Pressure Cell

Tekscan Sensor

Geokon Pressure Cell
Pressure Cell

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

Cell Placement on Asphalt
Pressure Cell Measurement Configuration
• 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
Traditional Track Structure

Track Structure With Asphalt Underlayment

- 5-10 feet beyond crossing
- Typical highway dense-graded base mix
- 0.5% higher asphalt content
Installation of HMA Underlayment Using Paver

Installation of HMA Underlayment by Back-Dumping
Pueblo, Colorado Longitudinal Section

Existing Conditions at Transportation Technology Center, Pueblo, Colorado
Conway, Kentucky Longitudinal View

Existing Conditions at Conway, Kentucky

- Clay subgrade: 9 in., 8 in., 9 in., 5 in.
- HMA
- Ballast: 1000 ft, 1000 ft
Representative Dynamic Compressive Stress on HMA Layer Measured for Empty Coal Train on CSX Transportation Mainline at Conway, KY
Dynamic Compressive Pressures Measured on TTCI Test Track
<table>
<thead>
<tr>
<th>Thickness Ballast/HMA inches</th>
<th>Vertical Compressive Stress on <strong>Ballast</strong> KPV/ITD, psi</th>
<th>Vertical Compressive Stress on <strong>HMA</strong> KPV/ITD, psi</th>
<th>Vertical Compressive Stress on <strong>Subgrade</strong> KPV/ITD, psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 / 5</td>
<td>47.9 / -</td>
<td>21 / 16</td>
<td>13.6 / -</td>
</tr>
<tr>
<td>10 / 8</td>
<td>48.7 / -</td>
<td>22 / 15</td>
<td>11.7 / -</td>
</tr>
</tbody>
</table>

Comparison of the KENTRACK Predictive Values (KPV) Versus In-Track Data (ITD) for the CSX Mainline at Conway, Kentucky

<table>
<thead>
<tr>
<th>Thickness Ballast/HMA inches</th>
<th>Vertical Compressive Stress on <strong>Ballast</strong> KPV/ITD, psi</th>
<th>Vertical Compressive Stress on <strong>HMA</strong> KPV/ITD, psi</th>
<th>Vertical Compressive Stress on <strong>Subgrade</strong> KPV/ITD, kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 / 4</td>
<td>43.5 / -</td>
<td>11.7 / 14.9</td>
<td>8.3 / 8.0</td>
</tr>
<tr>
<td>8 / 8</td>
<td>47 / -</td>
<td>21.9 / 14.9</td>
<td>8.2 / 7.7</td>
</tr>
</tbody>
</table>

Comparison of the KENTRACK Predictive Values (KPV) Versus In-Track Data (ITD) at TTCI in Pueblo, Colorado
Vertical Pressure on Asphalt Surfaces for Various Loadings

- 286,000 lb, 13 - 17 psi
- 62,000 lb, 2 - 4 psi
- 180 lb, 6 psi
- 100 - 200+ psi
In Track Placement During First Test

Typical Pressure Distribution Plot from Tekscan System
This represents a typical pressure distribution between a steel tie plate and the rail.
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

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

Lead Wheel Position

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

Average Pressure (psi)

Lead Wheel Position

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

Snapshot of the Lead Wheel Directly above the Sensor

Lead Wheel Over 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$^2$

<table>
<thead>
<tr>
<th>Force vs. Frames</th>
</tr>
</thead>
<tbody>
<tr>
<td>10000</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pressure vs. Frames</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>
Front Tire of a CSXT Suburban on Asphalt Parking Lot in Ashland Oil Company. May 25, 2004

1652 lb

75 PSI

22.15 in^2

Force vs. Frames

Pressure vs. 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
FINDINGS

• **KENTRACK** -- utilized to predict stresses in the track structure and foundation

• Earth Pressure Cells -- provide direct measurement of pressures (stresses) in the track structure and foundation

• Computer Predictions -- compare favorably with Pressure Cell Measurements at the ballast/subballast and subballast/subgrade interfaces

• Pressure Cells -- technique presently being developed for tie/ballast interface pressure measurements
FINDINGS

• KENTRACK -- utilized to predict stresses in the track structure and foundation

• Earth Pressure Cells -- provide direct measurement of pressures (stresses) in the track structure and foundation

• Computer Predictions -- compare favorably with Pressure Cell Measurements at the ballast/subballast and subballast/subgrade interfaces

• Pressure Cells -- technique presently being developed for tie/ballast interface pressure measurements
FINDINGS

• KENTRACK -- utilized to predict stresses in the track structure and foundation

• Earth Pressure Cells -- provide direct measurement of pressures (stresses) in the track structure and foundation

• Computer Predictions -- compare favorably with Pressure Cell Measurements at the ballast/subballast and subballast/subgrade interfaces

• Pressure Cells -- technique presently being developed for tie/ballast interface pressure measurements
FINDINGS

• KENTRACK -- utilized to predict stresses in the track structure and foundation

• Earth Pressure Cells -- provide direct measurement of pressures (stresses) in the track structure and foundation

• Computer Predictions -- compare favorably with Pressure Cell Measurements at the ballast/subballast and subballast/subgrade interfaces

• Pressure Cells -- technique presently being developed for tie/ballast interface pressure measurements
Findings (conti.)

- Tekscan Sensors -- technology developed for using them for track pressure measurements at the rail/plate and plate/tie interfaces
  - Sensors are thin and non-intrusive
  - Repeatability is very good - consider loads applied, loading rate, and surrounding material
  - Calibration is very important consideration
  - Thin rubber bladder must be used on steel tie plates
  - Shim stock is necessary
  - Wide range of track related applications
Findings (conti.)

- **Tekscan Sensors** -- technology developed for using them for track pressure measurements at the rail/plate and plate/tie interfaces
  - Sensors are thin and non-intrusive
  - Repeatability is very good - consider loads applied, loading rate, and surrounding material
  - Calibration is very important consideration
  - Thin rubber bladder must be used on steel tie plates
  - Shim stock is necessary
  - Wide range of track related applications
Potential Tekscan Applications

• Superelevation – Curve design

• Impact pressures – diamonds
   -- bridge approaches

• Plates, Pads, Fastenings & Ties

• ?? ?? ?? ??
Acknowledgements