KENTRACK
Version 2.0.1

Railway Trackbed Structural Design Software
Background

• KENTRACK
  – Developed specifically to analyze HMA trackbeds
  – Has the versatility to analyze all-granular trackbeds
  – Initially a DOS based program
  – Upgraded to a windows based platform with a Graphic User Interface
Theory behind KENTRACK

• Superposition of Loads

\[ S'_1 = S_2 \frac{P_1}{P} + S_4 \frac{P_2}{P} \]
Theory behind KENTRACK

- Finite Element Method

- To calculate stresses and strains in rail and tie
Theory behind KENTRACK

- Multilayered System

- To calculate stresses and strains in the layers
Theory behind KENTRACK

- Material Properties
  - HMA trackbed is comprised of ballast, HMA and subgrade
  - All-granular trackbed is comprised of ballast, subballast and subgrade
  - Different equations are used to describe the material properties
Theory behind KENTRACK

- **Ballast**
  - In a new trackbed it behaves non-linearly
  - In an aged trackbed it behaves linearly

\[ E = K_1 \theta^{K_2} \]
\[ \theta = \sigma_1 + \sigma_2 + \sigma_3 + \gamma(1 + 2K_0) \]

- **Subgrade**
  - Linearly elastic material
Theory behind KENTRACK

• Hot Mix Asphalt (HMA)
  Visco-elastic material
The dynamic modulus of HMA depends on
  - Temperature
  - Aggregate passing No. 200 sieve in %
  - Volume of bitumen %
  - Volume of air voids %
  - Asphalt viscosity
  - Load frequency
Theory behind KENTRACK

- **Damage Analysis**
  - Based on minor linear damage analysis criteria
  - Performed by periods (seasons, months)

\[
L = \frac{1}{\sum_{i=1}^{n} \frac{N_p}{N_a \text{ or } N_d}}
\]
**Theory behind KENTRACK**

- **Predicted number of repetitions**

 Wheel Load = 36000 lb/wheel

For one car the total weight = 36000 lb/wheel x 8
= 286,000 lb/rep / 2000
= 143 ton/rep

The number of repetitions assumed per year = 200,000 rep/yr

The traffic per year = 200,000 rep/yr x 143 ton/rep
= 28,600,000 GT/yr / 1 x 10^6
= 28.6 MGT/yr
Theory behind KENTRACK

- HMA Damage Analysis
  - Fatigue cracking controls failure
  - Fatigue cracking is governed by the tensile strain at the bottom of HMA
  - Based on highway experience
  - Number of allowable repetitions \((N_a)\) before failure

\[
N_a = 0.0795 \epsilon_t^{-3.291} E_a^{-0.853}
\]
Theory behind KENTRACK

• Subgrade Damage Analysis
  - Excessive permanent deformation controls failure
  - Deformation is governed by the vertical compressive stresses on top of subgrade
  - Based on highway experience
  - Number of allowable repetitions \((N_d)\) before failure

\[
N_d = 4.837 \times 10^{-5} \sigma_c^{-3.734} E_s^{+3.583}
\]
Theory behind KENTRACK

Stresses and Strains

Asphalt Trackbed

All-Granular Trackbed
## Methodology

- Critical outputs for the two sections

<table>
<thead>
<tr>
<th>Variable</th>
<th>Standard HMA trackbed</th>
<th>Standard Ballast Trackbed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subgrade Vertical Compressive Stress (psi)</td>
<td>11.9</td>
<td>13.8</td>
</tr>
<tr>
<td>HMA Tensile Strain (in/in)</td>
<td>0.000183</td>
<td>N/A</td>
</tr>
<tr>
<td>Service life of Subgrade (yrs)</td>
<td>15.2</td>
<td>5.6</td>
</tr>
<tr>
<td>Service life of HMA (yrs)</td>
<td>19.8</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Effect of Subgrade Modulus on $\sigma_c$

Axle Load – 36 tons

![Graph showing the effect of subgrade modulus on vertical compressive stress. The x-axis represents subgrade modulus in psi, ranging from 3000 to 21000. The y-axis represents vertical compressive stress in psi, ranging from 0 to 18. The graph compares HMA Trackbed and Ballast Trackbed.](image)
Effect of Subgrade Modulus on L

Axle load - 36 tons

![Graph showing predicted service life vs. subgrade modulus for different trackbed types.](chart.png)

- **Subgrade Life in Ballast Trackbed**
- **Subgrade Life in HMA Trackbed**
- **HMA Life in HMA Trackbed**
Effect of Subgrade Modulus on $\varepsilon_t$

Axle load – 36 tons
### Predictive Values Versus In-track Data

#### 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/TTD psi</th>
<th>Vertical Compressive Stress on <strong>HMA</strong> KPV/TTD psi</th>
<th>Vertical Compressive Stress on <strong>Subgrade</strong> KPV/TTD psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 / 5</td>
<td>47.9 / -</td>
<td>21.0 / 16.0</td>
<td>13.6 / -</td>
</tr>
<tr>
<td>10 / 8</td>
<td>48.7 / -</td>
<td>22.0 / 15.0</td>
<td>11.7 / -</td>
</tr>
</tbody>
</table>

#### Comparison of the KENTRACK Predictive values (KPV) Versus In-Track Data (ITD) at TTCI in Pueblo, Colorado

<table>
<thead>
<tr>
<th>Thickness Ballast-HMA inches</th>
<th>Vertical Compressive Stress on <strong>Ballast</strong> KPV/TTD psi</th>
<th>Vertical Compressive Stress on <strong>HMA</strong> KPV/TTD psi</th>
<th>Vertical Compressive Stress on <strong>Subgrade</strong> KPV/TTD psi</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>47.0 / -</td>
<td>21.9 / 114.9</td>
<td>8.2 / 7.7</td>
</tr>
</tbody>
</table>
Summary

• KENTRACK is a versatile program that can be used to analyze HMA and all-granular trackbeds
• HMA trackbeds improve the service life and perform better than all-granular trackbeds
• Damage analysis values are conservative
• Subgrade modulus is a very important factor in trackbed design