Case Study of Concrete Tie Base Wear with Implications for Tie Performance

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Outline

- History and Background
- Site Information
- Observed Behavior
- Track Characteristics
- Tie Performance Observations
- Summary
History and Background

- Site Location
  - Edgewood, MD
  - MP 74.7, Track 3

- Investigation: 1996-1999
  - Track Investigation
    - Track geometry degradation: trends and maintenance intervention
    - Track structural characteristics: track stiffness, modulus
    - Substructure: ballast fouling, drainage
    - Structural capacity (life) vs. ballast layer properties and thickness
  - Multi Depth Deflectometer Installation
    - Wheel load and Layer deformation
    - Settlement trends
    - Track Performance Modeling

- 8 Miles from the Concrete Tie Correlation Study Site - MP 68.7
  - Battelle Columbus Labs study (1979-1982)
  - Data on tie loads, traffic, track conditions

- Traffic = 40 MGT, 2/3 Freight, 1/3 Passenger
Site Location
Site Information (Circa 1997)

- Double mainline tangent track
- 30-40 MGT with high-speed passenger traffic
- 136 RE Rail
- Concrete ties: San Vel
- Pandrol E clip
- Low fill – good external drainage
- Basalt ballast
  - Varying from recently undercut to fouled through the zone of abrasion
- Thick Roadbed – 36 – 48 in.
- Stable subgrade
  - Stiff to firm silty clay and clay
Site View
San Vel Tie
<table>
<thead>
<tr>
<th>Tie design</th>
<th>Reinforcement</th>
<th>Strand preload (kips) / Strands</th>
<th>Total prestress load (kips)</th>
<th>Cross sectional dimensions at rail seat (inches)</th>
<th>Minimum concrete cover to tie side (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>Single wire; 0.2 in. diameter</td>
<td>6.55 / 24</td>
<td>157.2</td>
<td>10.375 x 9.625</td>
<td>1.39</td>
</tr>
<tr>
<td>San-Vel</td>
<td>7 wire; 0.375 in. diameter</td>
<td>16.68 / 8</td>
<td>133.4</td>
<td>11 x 9.5</td>
<td>1.61</td>
</tr>
</tbody>
</table>
Observed Behavior

Right Profile Roughness (mm²)

[Graph showing a line plot with data points from January 1994 to May 1998]
Track Geometry (Track 3)

Crosslevel (in.)

62 ft MCO Profile (in.)

Field Side, West Rail

Distance (ft)
Settlement

Site 12 Track 2

Site 12 Track 3

Elevation (ft)

Time (mos.)

Trk 2 East
Trk 2 West
Trk 3 East
Trk 3 West
Top of Rail Profile Track 3

Elevation (ft)

Tie Number

10/16/97
10/22/97
Track Characteristics

Graphs showing load in kN versus deflection in mm for different locations labeled A12DS1, A12DS26, A12DS48, and A12DS56. The graphs compare West Rail and East Rail for each location.
## Track Stiffness

**West Rail Track Modulus = 8100-9800 psi**

<table>
<thead>
<tr>
<th>Location</th>
<th>Deflection</th>
<th>Load</th>
<th>Track Stiffness</th>
<th>Track Modulus</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mm</td>
<td>in.</td>
<td>kN</td>
<td>kip/mm</td>
</tr>
<tr>
<td>A12DS1E</td>
<td>3</td>
<td>0.12</td>
<td>133.4</td>
<td>44.47</td>
</tr>
<tr>
<td>A23DW56</td>
<td>1.2</td>
<td>0.05</td>
<td>133.4</td>
<td>111.2</td>
</tr>
</tbody>
</table>

*Static Load = 2 U28B Locomotives*

Intermediate-Sized Rails Fall Within Shaded Band

Hay, 1984
**Track Deflection Thresholds Hay (1984)**

![Diagram showing track deflection ranges](image)

<table>
<thead>
<tr>
<th>Range</th>
<th>Track Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Deflection range for track that will last indefinitely</td>
</tr>
<tr>
<td>B</td>
<td>Normal maximum desirable deflection for heavy track to give requisite combination of flexibility and stiffness</td>
</tr>
<tr>
<td>C</td>
<td>Limit of desirable deflection for track of light construction ($\leq 100$ lb)</td>
</tr>
<tr>
<td>D</td>
<td>Weak or poorly maintained track that will deteriorate quickly</td>
</tr>
</tbody>
</table>

Values of deflection are exclusive of any looseness or play between rail and plate or plate and tie and represent deflections under load.
Deflection Variation

Load 1 = 10 kips
Load 2 = 15 kips
Load 3 = 30 kips
Load Distribution Along Track

Percentage of Load on Each Tie

<table>
<thead>
<tr>
<th>Deflection Max. (in.)</th>
<th>10%</th>
<th>22%</th>
<th>33%</th>
<th>22%</th>
<th>10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.07</td>
<td>4%</td>
<td>24%</td>
<td>44%</td>
<td>24%</td>
<td>4%</td>
</tr>
<tr>
<td>0.05</td>
<td>1%</td>
<td>23%</td>
<td>51%</td>
<td>23%</td>
<td>1%</td>
</tr>
</tbody>
</table>
Track Analysis

- Ensure the stress applied to the substructure does not exceed allowable limits

\[ P_S = 36 \text{ k}, \ P_D = 54 \text{ k} \] (1.5 x)
Allowable stress

ballast = 85 psi (AREMA)
avg. subgrade = 20 psi (AREMA)

Applied stress

1/3 of Length Under Rail Seat for a 8 ft long, 10 in. wide conc. tie, 24 in. Spacing
Ballast = 68 psi (76%) for 40% on center tie
Ballast = 84 psi (100%) for 50% on center tie
Ballast = 101 psi (119%) for 60% on center tie
Ballast = 113 psi for 100%

Subgrade stress: requires analytical model
Based on Approach by Hay (1984)
Subgrade = 31 psi for 40% on center tie
Subgrade = 51 psi for 100% on center tie
Observations

- Ballast fouled in rough track geometry zone
  - Gray fouling indicative of tie abrasion
- Clean ballast in smooth track geometry zone
  - Undercut within the previous year
- Strong stiff roadbed
  - Underlain by hand placed brick (historic use – water trough?)
- Tie Condition
  - Rough zone: abraded $\frac{1}{2}$ in.
  - Smooth zone: abraded 1 $\frac{1}{2}$ in.
    - Track must have deteriorated faster: undercut earlier
Slurry Abraded Concrete Ties
Track Deflection

Too soft:
- Ballast instability
- Subgrade failure
- Joint bar overload

Too stiff:
- Rail corrugation
- Tie abrasion
- Ballast crushing
- Crushed railhead

Large void:
- Track shift/buckling
- Track geometry
- Tie failure
- Fouled ballast
How does this site compare?
If Not Identified and Corrected, Poor Track Support May Cause…