Track Transitions and the Effects of Track Stiffness

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Track Transitions

Problem Description

◆ “Bump at the end of the Bridge”, “Rough Road Crossing”, High Impact Diamond Crossing”
  ● Occurs when track structure changes abruptly
  ● Can generate high dynamic loads
  ● Can result in speed restrictions
  ● May require frequent maintenance

Note: problem is far from universal – many locations perform well
Problem Description

◆ Conventional Wisdom:
  ● Track stiffness change generates dynamic forces that cause rapid degradation of approach track

◆ Project Task:
  ● Determine the effects of track stiffness on approach performance
Track Transition Problems
Reduced Impact Track; Bridge Approach Problems

- Abrupt structure changes
- Different foundation types
### Track Transitions - Tribal Knowledge

<table>
<thead>
<tr>
<th>Commonly Known</th>
<th>How we Know</th>
<th>What we Found</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Stiffness change</td>
<td>Train Observation</td>
<td>Yes, even on ballasted deck concrete</td>
<td>Marysville sub</td>
</tr>
<tr>
<td>Lower Damping</td>
<td>Train Observation</td>
<td>Yes, measured impact tests</td>
<td>FAST, Marysville</td>
</tr>
<tr>
<td>Low spot at end of bridge</td>
<td>Geometry car, Observation</td>
<td>Sometimes, but can be differential</td>
<td>Surveys of approaches</td>
</tr>
<tr>
<td>Stiffness change generates high loads</td>
<td>Observation</td>
<td>Not by itself; ~10% from stiffness alone</td>
<td>Load measuring wheelsets, modeling</td>
</tr>
</tbody>
</table>
FRA Track Transition Study

- Large Stiffness Change
  - Measured using TLV
- Track Modulus:
  - Approach: 3-6,000
  - Bridge: 8 – 12,000

![Graph showing dynamic track modulus vs distance](image)
FRA Track Transition Study

Does Stiffness Change Generate High Loads?

- High loads *always* associated with surface defect
- Surface defect *often* associated with stiffness change
- Also, it is difficult to surface to a fixed elevation (e.g. open deck bridge)
Track Transitions - Theoretical Modeling

Parametric study of:
- Track Stiffness
- Track Damping
- Track Surface

Used Western Coal Route as Base Case
- Recent construction
- Traffic known
- Surfacing records
- Measured track profiles
- Measured track stiffness, damping
NUCARS™ Schematic

Travel

First Rail Element (1380")

Second Rail Element (1380")

239' Total Simulated Track
**NUCARS™ Modeling**

- Track Stiffness change
- No running surface defect
- 60 mph

![Graph showing load (lbs) vs. distance along track (ft)]
**NUCARS™ Modeling**

- No Stiffness Change
- 0.5” vertical perturbations
- 60 mph

![Graph](chart.png)

**Location of 0.5” Perturbation**

**Bridge Abutment**
Effects of stiffness change on smooth track

Axle 1 Vertical Force (pounds)

Axle 2 Vertical Force (pounds)
Effect of Bridge Stiffness on Tie Loads

Maximum Vertical Force beneath each tie (lbs)

Smooth Track Input
All cases @ 50 mph

Vary Track Modulus on Bridge
- 5,000
- 10,000
- 15,000
- 20,000
- Endwall

Tie Number (Spaced @ 20")

Direction of Travel
# Track Transitions Design Factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effect</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stiffness</td>
<td>~ 6%</td>
<td>By itself, a small effect</td>
</tr>
<tr>
<td>Surface Defect</td>
<td>1.5 to 3 x static load</td>
<td>The reason why we have track standards</td>
</tr>
<tr>
<td>Stiffness &amp; Surface Defect</td>
<td>1.5 to 3 x static load</td>
<td>Stiffness effect is negligible</td>
</tr>
</tbody>
</table>
Track Transitions - Theoretical Modeling

Summary:

- Small dynamic load at stiffness change
  - ~10% for freight operations
- Short distance affected
  - ~5 feet
- Unlikely to drive accelerated settlement on approaches
Track Transitions - Measured Forces

Wheel/Rail Forces Measured at Bridge/Approaches:

◆ Facility for Accelerated Service Testing (FAST)
  ● 315K coal hoppers and gons at 40 mph
  ● Measured:
    ▼ Dynamic wheel loads
    ▼ Track surface (loaded)
    ▼ Track stiffness

◆ Amtrak Northeast Corridor
  ● 160K passenger cars at 80 – 125 mph
  ● Measured:
    ▼ Dynamic wheel loads
Minimum and Maximum Vertical Wheel Load and Space Curve Surface
West Approach SOA Bridge, CCW, 40 MPH
**Track Transitions - Measured Forces**

**FAST Track**
- **Track Stiffness**
  - Soft side: 2,500 - 6,000
  - Stiff side: 4,000 - 9,000
- **Track Surface**
  - No class 4 exceptions
- **Dynamic Loads**
  - ~10% > open track

![Vertical Wheel Forces Chart](chart.png)
Track Transitions - Measured Forces

Amtrak Bridges

◆ Conventional track on bridges and approaches
  ● Stiffness not measured

◆ Track Surface
  ● No class 7 exceptions

◆ Train Speeds
  ● 80 – 125 mph

◆ Dynamic Loads
  ● Indistinguishable from open track
Track Transitions - Measured Forces

MP 56.51 AP – Perryville, MD

Left Profile, Space Curve

Vertical Force, Left Front Wheel

Speed = 99 mph
Track Transitions - Measured Forces

MP 40.71 AP – Newark, DE

Left Profile, Space Curve

Vertical Force, Left Front Wheel

Speed = 123 mph
Track Transitions - Measured Forces

MP 13.36 AN – Elizabeth, NJ

Left Profile, Space Curve

Vertical Force, Left Front Wheel

Speed = 83 mph

Distance [feet]

Force [kips]

[inches]

0  80  160  240  320  400

-1.0  0.0  0.5  1.0

-0.5

4  8  12  16  20  24  28

TTCI/AAR, 2006
Track Transitions - Measured Settlement

Revenue Service Measurements of Bridge and Approach Track Surface:

◆ Time series of top of rail surveys conducted on coal line bridges
  ● Before and after maintenance
  ● Differential settlement determined
FRA Track Transition Study

“Low Spot” at end of Bridge

- Case 1 – truly a low spot at approach
- Case 2 – approach no lower than rest of track
Track Transitions - Measured Settlement

Track profiles were measured at Revenue Service bridge approaches:

- Profiles showed “low spot” to be wide and flat
- Track around bridges has settled (i.e. Case 2)
Track Transitions - Measured Settlement

Effect of Increasing Dynamic Load on Approaches:

- Measured dynamic loading not likely to create low spot

![Graph showing change in wheel load vs. change in differential settlement]
Track Settlement Study Conclusions

- Differential track settlement at bridge approaches due to change in track structure
  - Approaches often no worse than track away from bridge
  - Effect of track stiffness change
    - Small dynamic load increase
    - Somewhat higher stresses on tie/ballast interface at abutment only
  - Approaches can be worse than track away from bridge in some cases:
    - Drainage
    - Surfacing to fixed elevation
Track stiffness difference is said to cause dynamic loads by creating a bump in the track at the point where stiffness changes – as the deflection under load will change at this point.

How big a bump is this?
Track Stiffness Difference
2,000 - 10,000

2,000

10,000

0.15 inches
Track Stiffness Difference
2,000 - 10,000

2,000

10,000

0.15 inches

?
Track Stiffness Difference
2,000 - 10,000

2,000

10,000

5 Feet

0.15 inches
A track stiffness difference of 2,000 to 10,000 produces an effect roughly equivalent to a ramp of 1 in 400.

The surface runoff criteria for one large railroad shows a runoff of 1 in 331 as sufficient to create a "smooth ride" at 60 mph.

Design of flange bearing frog ramps:
- 1:240 ramps used for maximum vertical loads of 1.5 x static wheel load at 60 mph
Train Ride Test

- Riding a train soon after the track has been surfaced.
- What vertical effect is felt crossing over bridges?
- You can hear it, but can you feel it?
- Would this suggest that there are dynamic forces large enough to cause accelerated track settlement on bridge approaches?
Conclusions

- Dynamic loads on bridge approaches due to stiffness changes are small
- Stiffness changes do not cause higher settlement on bridge approaches
Acknowledgements

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