Outline

• Method of Quantifying Loads
• Vertical Load Variation
• Lateral Load Variation
• Wheel Load Tables
• Conclusion
Overview of Mechanistic Design

- Design approach utilizing forces measured in track structure and properties of materials that will withstand or transfer them
- Uses responses (e.g. contact pressure, relative displacement) to optimize component geometry and materials requirements
- Based on measured and predicted response to load inputs that can be supplemented with practical experience
- Requires thorough understanding of load path and distribution
- Allows load factors to be used to include variability due to location and traffic composition
- Used in other engineering industries (e.g. pavement design, structural steel design, geotechnical)
Objectives

- Measure magnitude and distribution of wheel loads to be used as an input for mechanistic design
- Quantify variation due to:
  - Car Type and Weight
  - Speed
  - Seasonal Variation
  - Cant Deficiency
- Develop wheel load tables for use in design
Measurement Technologies
Vertical Wheel Load Measurement

Wheel Impact Load Detectors (WILD)

- Sixteen sets of strain gauges to detect full rotation of most wheels
- For each wheel,
  - Labels by vehicle type
  - Measures speed, nominal (static) wheel load, and peak wheel load
Lateral Wheel Load Measurement

Truck Performance Detectors (TPD)

- 6 cribs with strain gauges on the base and web of the rail
- For each wheel,
  - Labels by vehicle type
  - Measures peak vertical and lateral load
Vertical Load Variation
Traffic Distribution – Nominal Wheel Loads

Source: Amtrak – Edgewood, MD (November 2010)
Traffic Distribution – Peak Wheel Loads

- Vertical and Lateral Load Characterization
- Source: Amtrak – Edgewood, MD (November 2010)
Vertical Load Variation - Speed

- Intermodal Freight Cars
- Loaded Freight Cars
- Locomotives
- Unloaded Freight Cars

Peak Load (kips) vs. Speed (mph)
Seasonal Variation of Freight Wheel Loads

Source: Union Pacific – Gothenburg, NE (2010)

10 kips ≈ 45 kN
Seasonal Variation of Highest Freight Wheel Loads

Source: Union Pacific – Gothenburg, NE (2010)

10 kips ≈ 45 kN
Lateral Load Variation
Variation According To Car Type and Weight

- Intermodal Freight Cars
- Freight Locomotives
- Unloaded Freight Cars
- Loaded Freight Cars
- All Car Types

Percent Exceeding

Lateral Load Characterization
Speed– High Rail
Cant Deficiency

- Measure of the difference between equilibrium superelevation and actual superelevation
- Combines the effect of degree of curvature, speed, and superelevation

\[ h_d = \frac{2b_0}{g} \left( \frac{v^2}{1746.40/D} \right) - h_t \]

- \( h_d \) = cant deficiency (mm)
- \( 2b_0 \) = distance between contact patches on a wheel set (assumed 1500 mm)
- \( g \) = acceleration due to gravity (9.81 m/s\(^2\))
- \( v \) = vehicle speed (m/s)
- \( D \) = degree of curvature
- \( h_t \) = actual superelevation of curve (mm)
Cant Deficiency – Low Rail
Cant Deficiency – High Rail

The graph shows the relationship between lateral load (kips) and cant deficiency (inches) for different types of vehicles: Freight Locomotives, Intermodal Freight Cars, Loaded Freight Cars, and Unloaded Freight Cars.
High Rail vs. Low Rail

![Graph showing lateral load characterization for High Rail vs. Low Rail. The graph plots the percentage exceeding on the y-axis against lateral load (in kips) on the x-axis. Three curves are shown: Low Rail below balance speed in blue, High Rail below balance speed in blue dashed, Low Rail above balance speed in red, and High Rail above balance speed in red dashed.]
## Design Vertical Wheel Loads (WILD)

<table>
<thead>
<tr>
<th>Car Type</th>
<th>Nominal Load (kips)</th>
<th>Peak Load (kips)</th>
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<td>Mean</td>
<td>95%</td>
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<tr>
<td>Unloaded Freight Car</td>
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<td>10</td>
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<tr>
<td>Loaded Freight Car</td>
<td>34</td>
<td>40</td>
</tr>
<tr>
<td>Intermodal Freight Car</td>
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<td>36</td>
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<tr>
<td>Passenger Coach</td>
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## Design Vertical Wheel Loads (WILD)

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<th>97.5%</th>
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<td>Passenger Coach</td>
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<table>
<thead>
<tr>
<th>Car Type</th>
<th>Mean</th>
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<th>97.5%</th>
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**Design Lateral Wheel Loads (TPD)**

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<th>Lateral Load (kips)</th>
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<td>97.5%</td>
<td>99.5%</td>
<td>100% (Max)</td>
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<td>6.9</td>
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<td>97.5%</td>
<td>99.5%</td>
<td>100% (Max)</td>
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<tr>
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<td>0.38</td>
<td>0.44</td>
<td>0.56</td>
<td>0.81</td>
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</table>

- Locomotives have higher lateral load than loaded freight cars due to poor curving characteristics
- L/V ratio is most critical for unloaded freight cars
  - Near the danger threshold of 0.68 at 99.5% level
Conclusion

- Most significant predictor of vertical and lateral load is car type and weight
- Speed does not have a significant effect on the magnitude of vertical or lateral load
- Wayside technologies provide an accurate measure of wheel loads that can be used for design
Acknowledgements

Funding for this research has been provided by:
- Federal Railroad Administration (FRA)
- National University Rail Center (NURail)

Industry partnership and support has been provided by:
- Union Pacific Railroad
- BNSF Railway
- National Railway Passenger Corporation (Amtrak)
- Amsted RPS / Amsted Rail, Inc.
- GIC Ingeniería y Construcción
- Hanson Professional Services, Inc.
- CXT Concrete Ties, Inc., LB Foster Company
- TTX Company

For assistance with research, lab work, and previous analysis:
- Zhengboyang Gao, Brandon Van Dyk, Brent Williams
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