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Evaluating Track Substructure Moduli using Seismic Surface Waves

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2016 International Crosstie and Fastening System Symposium
Track Transitions, Crosstie Support, and Track Substructure
16 June 2016
Urbana, Illinois

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Outline

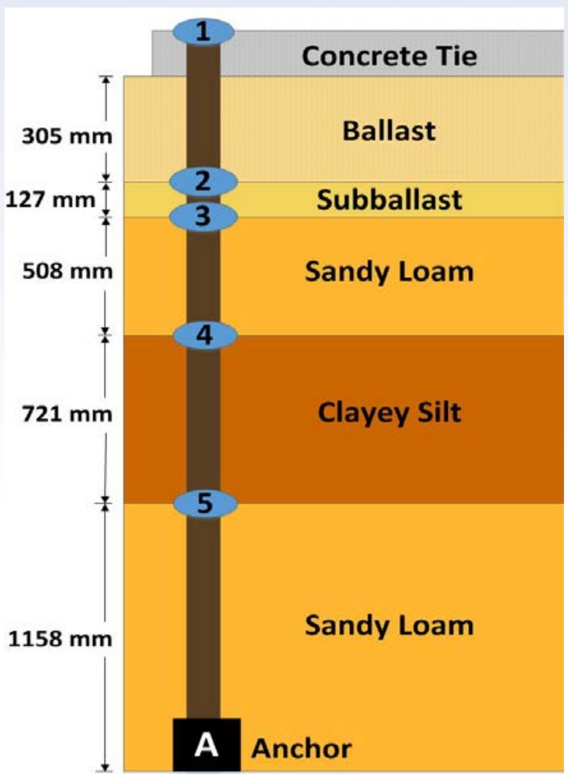
- Track/Ballast Modulus
- Seismic Testing
- BSPA Applications
- Future Work
- Wireless Accelerometers

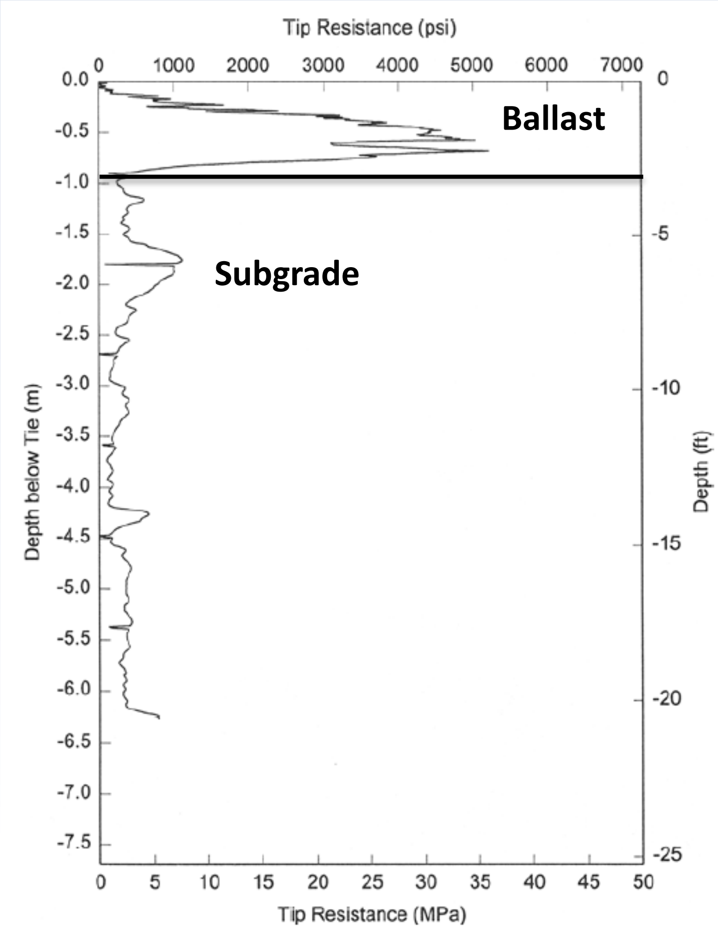
Substructure Properties

- Substructure modulus/stiffness important for track analysis
  - Track designs
  - Ballast conditions
  - Tie support
- Loose ballast/soft substructure
  - Large transient displacements
  - Increased permanent displacements

Substructure Properties

- Modulus/stiffness difficult to measure
- Current techniques
  - Invasive techniques (laboratory)
  - Cone-Penetration Tests (CPT)
  - Ground Penetrating Radar (GPR)
  - Inverse Analysis (Numerical Models)
  - Spectral Analysis of Surface Waves (SASW)





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SASW Devices

- SASW devices
  - Impact hammer and accelerometers
  - Rayleigh wave velocity (V_r)
- Accelerometer spacing
  - Deeper depth → large spacing
  - 1 ft. depth requires ~1 ft. spacing
- Focus on ballast directly under tie
  - Small spacing
  - Portable device

BSPA

- **B**allast **S**eismic **P**roperty **A**nalyzer (BSPA)
- Non-invasive, portable
- Multiple applications
- BSPA orientations
  - Across tie (center)
  - Across tie (ends)
  - Parallel to tie

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Applications: Varying Modulus

- Underneath single tie
  - Modulus varies
  - Tie bending / tie failure (how does failure occur?)
  - Load distribution to ballast
- Underneath multiple ties
  - Load distribution
  - Underneath joints or welded rail
  - Rail deviations

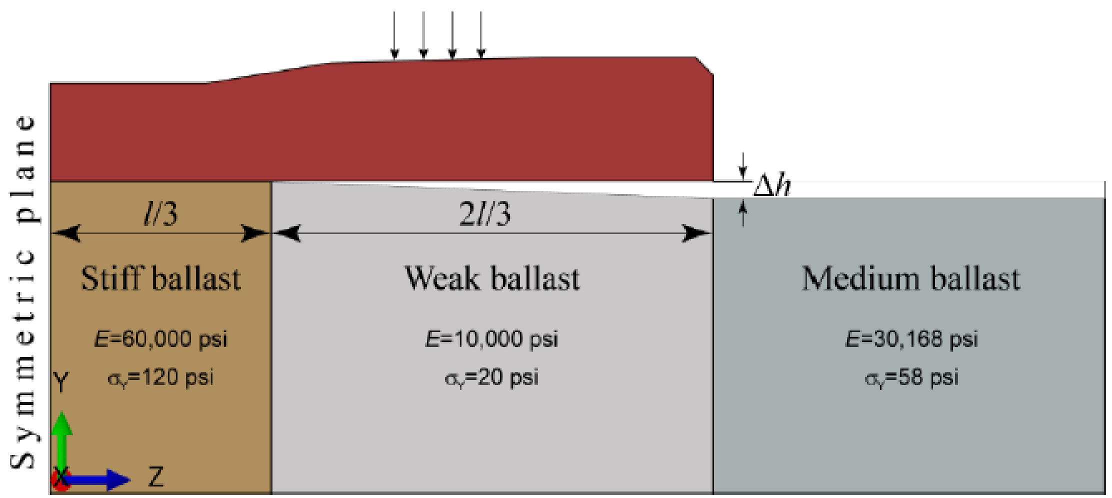

FIGURE 9 A simulated center binding condition with deteriorated ballast support.

Yu et al. (2015)

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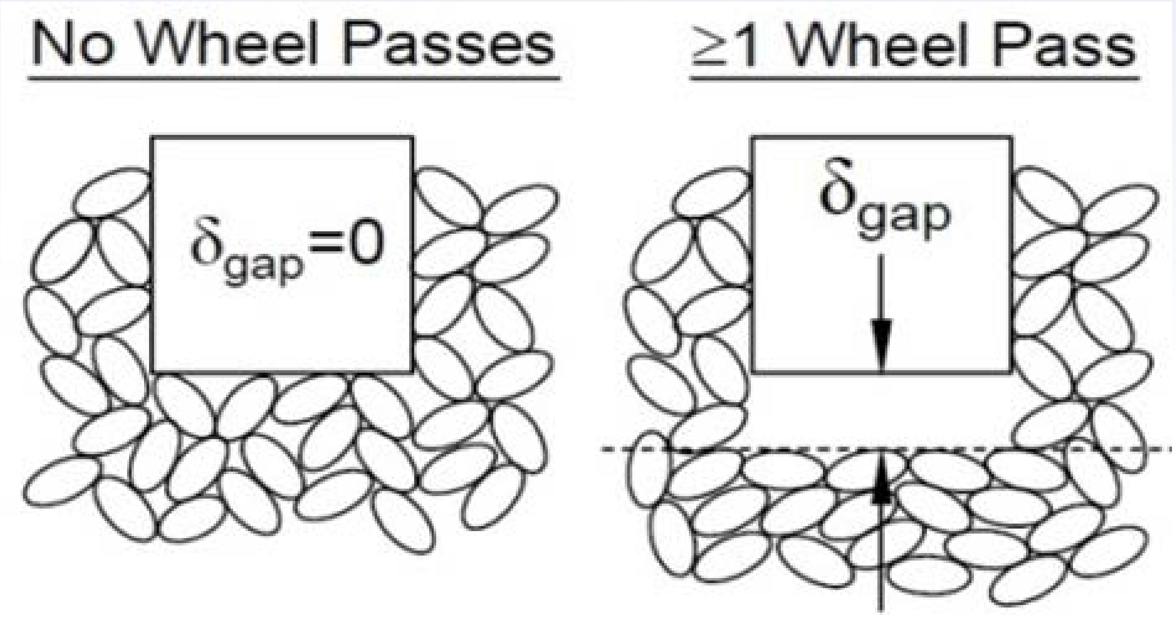
Applications: Ballast Density

- Optimal ballast density
- Loose ballast state after tamping
  - Increased rate of settlement
  - Lower stiffness/modulus
  - Development of tie-ballast gaps
- Tie-ballast gaps can increase dynamic loads and accelerate track degradation leading to increased maintenance
- Use BSPA to determine density that limits ballast settlement



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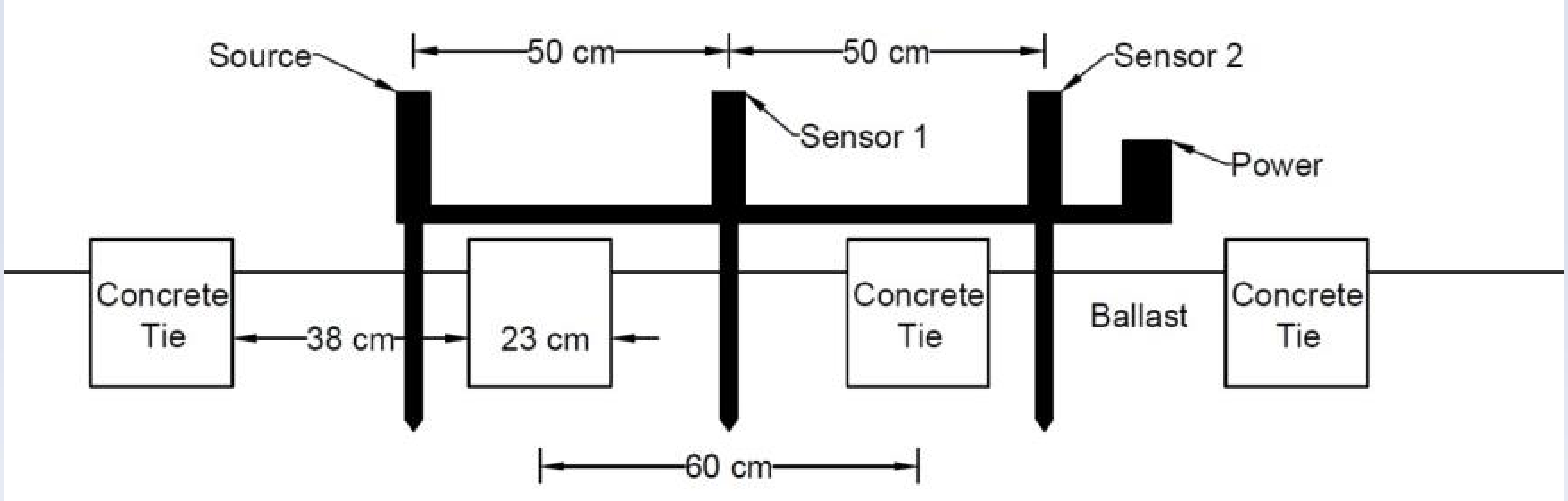
Future Equipment



- Expand BSPA
- Measure modulus across two ties

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Additional Applications

- Tie integrity
  - Both concrete and timber ties

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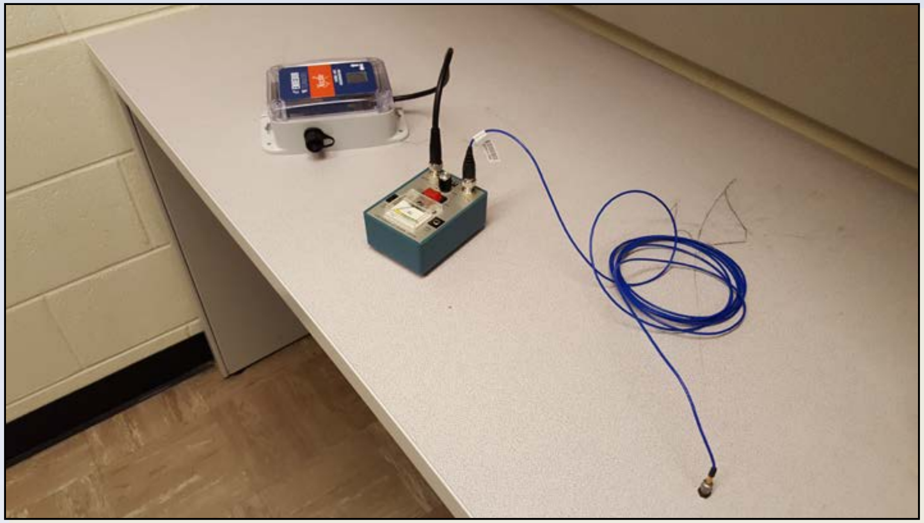
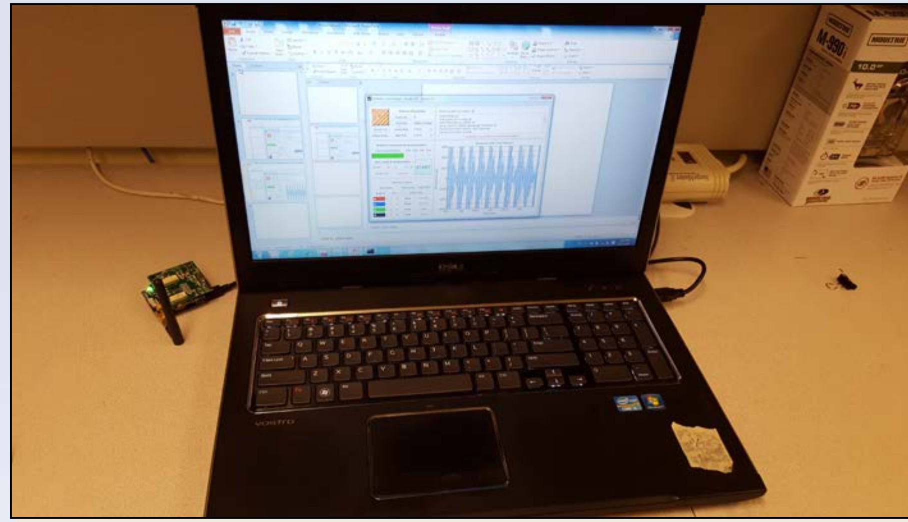
Railroad Ballast

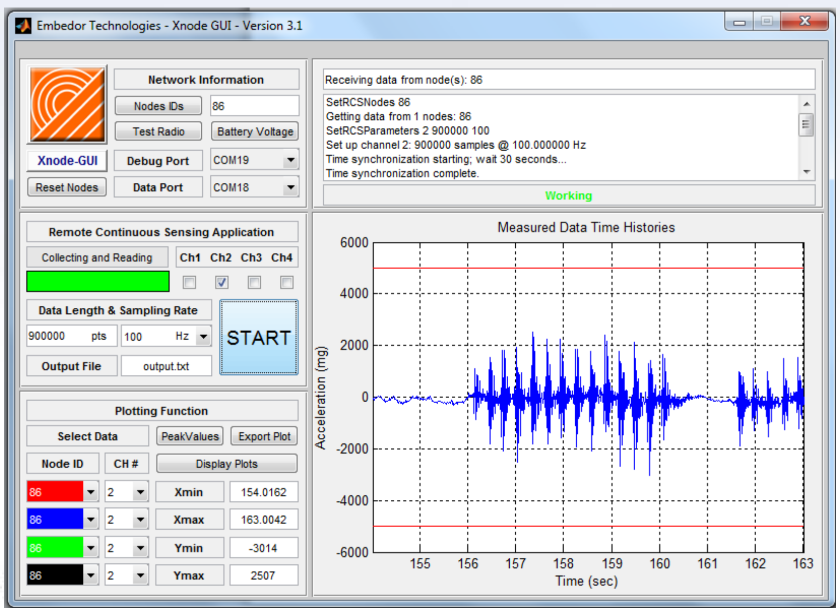
- Federal Track Safety Standards (FTSS) for Ballast (§213.103)
  - Transmit and distribute load to the subgrade;
  - Restrain track laterally, longitudinally, and vertically;
  - Provide adequate drainage; and
  - Maintain proper track crosslevel, surface, and alinement.

Wireless Accelerometers

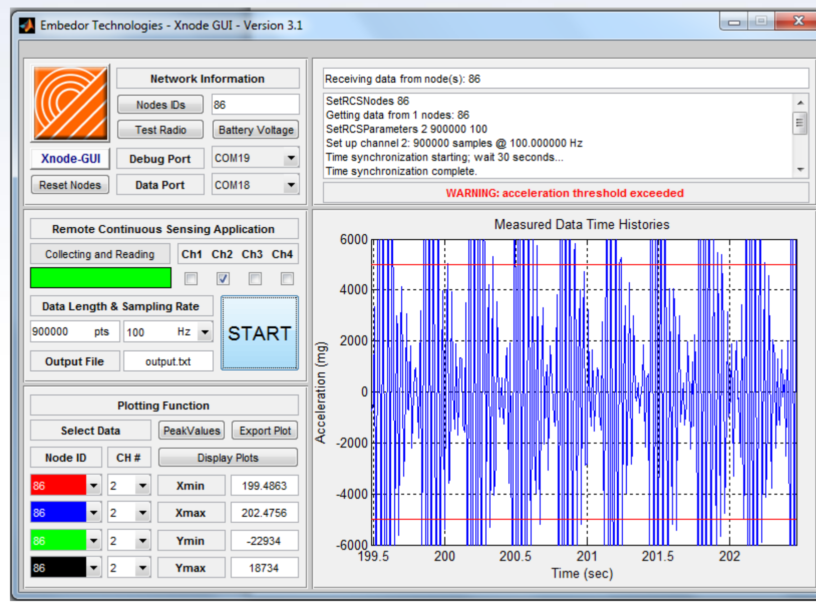




Good Support



Poor Support



Wireless Accelerometers

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Applications: Ballast Fouling

- Increased settlement
- Changes modulus/stiffness
- Decreased permeability

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- Increased maintenance
- Potential shear failures

Need better assessment of how fouling relates to track behavior

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Ballast Modulus – Fouling

Material Type	Seismic Testing Young's Modulus (MPa)
Dry & Wet Clean Ballast	200 – 275
Dry Fouled Ballast	340 – 380
Wet Fouled Ballast	135 - 170

- Testing at TTCI
  - Multiple test sites (clean & fouled)
- Results:
  - Dry fouled ballast increases in modulus
  - Wet fouled ballast decreases in modulus
  - 50% reduction from dry to wet fouled ballast
  - Little change from dry to wet clean ballast