Track Performance and Degradation Monitoring Technologies

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Inspection

- Visual
- Geometry
- Gage Restraint Measurement
- Ground Penetrating Radar
- Track Deflection
Visual Inspection

- Hy-rail / Walk
- Observe:
  - ROW
    - fences, drainage...
  - track structure condition
    - rails, ties, fasteners, joints
  - geometry
Track Geometry Measurement

• Rail Position
  – Profile, Alignment
  – Gage, Crosslevel
• Autonomous
Gage Restraint Measurement System (GRMS)

• Split axle nominally applies:
  – Lateral Force 14kips
  – Vertical Force 21kips
  – L/V = ~0.7
  – Actual Forces Measured

• Produces:
  – Gage Widening Projection (GWP)
  – Projected Loaded Gage (PLG24)
Ground Penetrating Radar (GPR)

- **GPR Parameters**
  - Ballast Fouling Index (BFI)
    - 2 GHz Antenna
  - Ballast Thickness Index (BTI)
    - 400 MHz and 2 GHz
  - Layer Roughness Index (LRI)
  - Free Draining Layer (FDL) Depth Index

- **Moisture Detection**
  - (400 MHz and 2 GHz)

- **Free Draining Layer Depth (FDL)**
  - Thickness of clean ballast to assess:
    - Drainage
    - Moisture damage to wood ties
    - Subgrade deformation potential
  - Based on BFI using threshold of 20

- **Supplied by Balfour Beatty Rail / Zetica produces several metrics that characterize track**

- **Upcoming: Real-time FDL**
Vertical Track Deflection Measurement System (VTDMS)

- Developed by the University of Nebraska-Lincoln under grant from FRA; commercialized by MRail and available through Harsco Rail.
- System measures a component of the total vertical deflection of a rail.
• Goal: quantify basic engineering parameters
• Provide means to assess track substructure properties during inspection and investigations
• Data can be used to understand track behavior → improved safety
  • Information that can determine root cause of track conditions and inform remedial actions
  • Data that can be used to develop objective rules

Comprehensive Inspection

Kashani and Hyslip, 2018
Goal: Single Pass Track Structural Inspection
Informing Predictive Analytics (4.0)

Digital Twin + Analytics = Forecast

Li et al., 2015
Monitor track for changes during waiver period

Solar panels and wind generators

Sites monitor:
- Daily train loading
- Support conditions
- Transient deflections
- Soil moisture changes
- Weather patterns

Insight into mechanisms underlying track geometry changes.

Instrumentation Locations – Monitored by UIUC: Tim Stark
Concrete sites have 10 tie strain gauges
Installed Accelerometers & Targets

Triaxial Accelerometer & Western Targets

Uniaxial Accelerometer

Eastern Targets
Installing Rail Strain Gages
Calibrating Rail Strain Gages
Installing Soil Moisture Probes
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Effort of Tie Support on Track Geometry

- SE drops from 29% to 9% at Track Profile change
- Difference in tie-ballast gap larger during low SE
- Peak SE @ freezing temp.
Summary of Long-Term Monitoring To Date

- Fouling condition and weather significantly impact track geometry
- Track support changes rapidly and affects track geometry deterioration rates well after change occurred
- Rapid changes in track support highlight the potential for rapid changes in track geometry that have not been observed
- Track load redistribution occurs routinely with fouling and is a focus of future measurements
Problem Detection for Ballast

**Track Support Problems**
- Track Load Redistribution
- Ballast Rearrangement
- Track Geometry

**Tie Bearing Capacity Problems**
- Tie and Rail Loads
- Cross Level and Geometry
- Track Position Movement

**Inspection: GPR** (Ground Penetrating Radar)
- Clean Ballast Depth, Moisture
- Longitudinal Variations

**Inspection: Seismic (SASW)**
- Resilient Modulus
- Density

Figure courtesy Mario Ruel, CN
Figure courtesy FRA
Problem Detection for Subgrade

Squeeze/Heave

Ballast Pockets

Photo: T. R. Sussmann

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Li et al., Railway Geotechnics, 2017

Inspection/Quality Control: Strength from Modulus Correlation
- Settlement: 30 cm over 8 years
- Failure due to sudden and significant settlement
- Spurred Canadian research into VTD

Figures: Canadian Transportation Safety Board Railway Investigation Report: R04Q0040, 2004
The Future: RR 4.0

- Inspection and monitoring technology
  - Detect and quantify safety critical track structure parameters
  - Predict future condition and safe inspection interval
- Analytical solutions from smart sensors
  - Track load redistribution
  - Ballast properties for tie support, settlement rate, and lateral resistance
  - Track load redistribution analysis
- Condition forecasting will require site specific properties