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CONSIDERATION OF GAGE RESTRAINT MEASUREMENTS TO DETECT WEAK CONCRETE TIE TRACK

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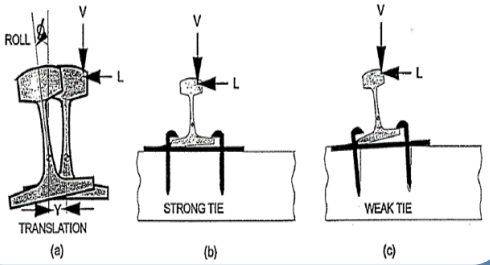
Gage Restraint Measurement System (GRMS)

Split Axle in Raised Position

Gage restraint is the ability of the tie plates, fasteners, and ties to hold the rails at the proper gage under lateral and vertical loads caused by rail traffic.

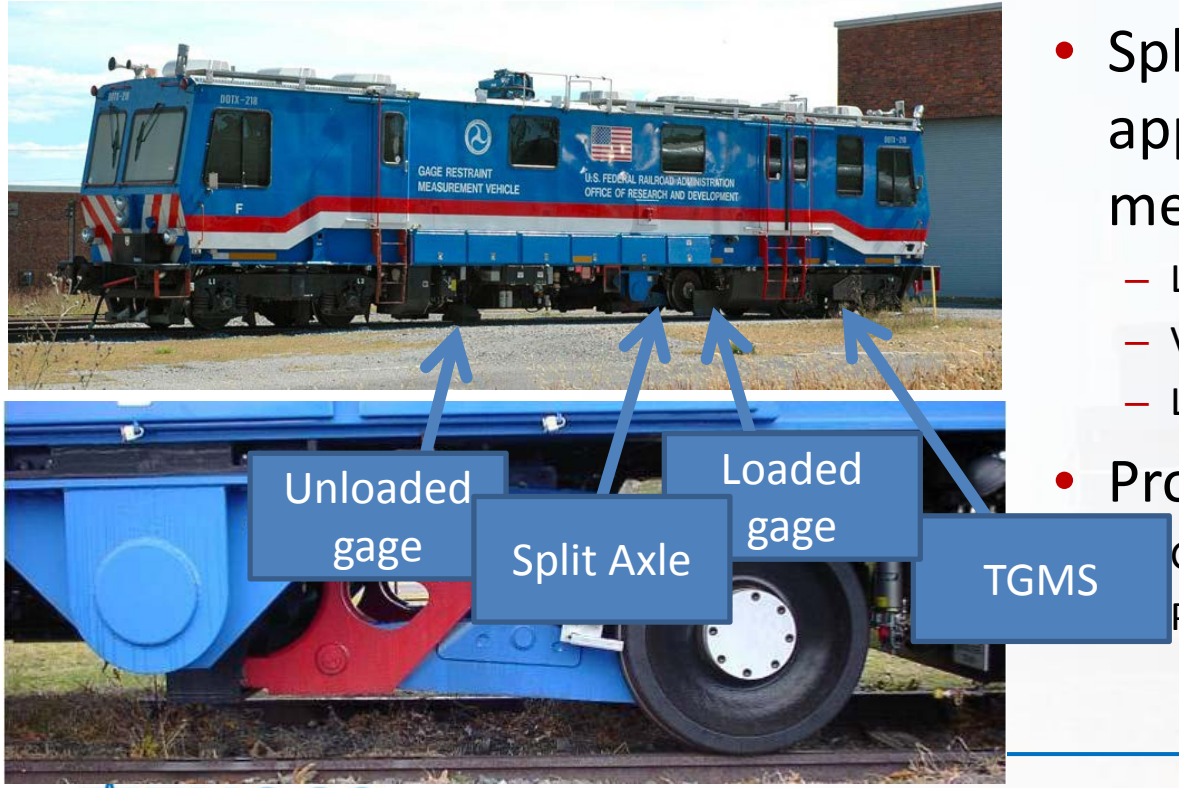


GRMS (or DGRMS) is designed to maintain continuous vertical and lateral loads to the track while measuring the resultant track deformation.

Background

- Geometry standards are intended to limit the loading conditions which could lead to derailment and thus limit the loads that are imparted to the track structure.
- The strength requirements developed for GRMS based on limiting conditions are intended as minimum requirements for all track.
- Another advantage of GRMS testing is the ability to aid in maintenance planning by finding weak sections of track before they pose a derailment risk.
- This presentation highlights the potential to find maintenance opportunities on concrete tie with elastic fastener track with GRMS levels below standard GRMS limits.

GRMS System on DOTX 218



- Split axle nominally applies (actuals are measured):
  - Lateral Force 14 kips
  - Vertical Force 20 kips
  - L/V = 0.7
- Produces:
  - Gage Widening Projection (GWP)
  - Projected Loaded Gage (PLG24)

GRMS Track Strength Indices

Gage Widening Projection (GWP)	Measure of gage widening stiffness. Used to identify locations with deteriorated rail restraint. $$GWP = \Delta Gage \cdot \frac{8.62}{(L - 0.258 \cdot V)}$$
Projected Loaded Gage (PLG24)	Estimate gage under severe loading conditions beyond testing forces. Use to identify locations that could allow wheel drop. $$PLG24 = Gage_{UNLOADED} + \Delta Gage \cdot \frac{13.513}{(L - 0.258 \cdot V) - 0.009 \cdot (L - 0.258 \cdot V)^2}$$

Track Strength Indices

Parameter	Maintenance Limit	Safety Limit
GWP	0.75	1.0
PLG24	58.0	59.0

Types of Concrete Track Degradation

- Missing restraint
  - Missing clips or fasteners
  - Worn or missing insulators
- Damaged ties
  - Cracks
  - Loss of material
- Rail seat deterioration
  - Loss of material directly under the rail seat

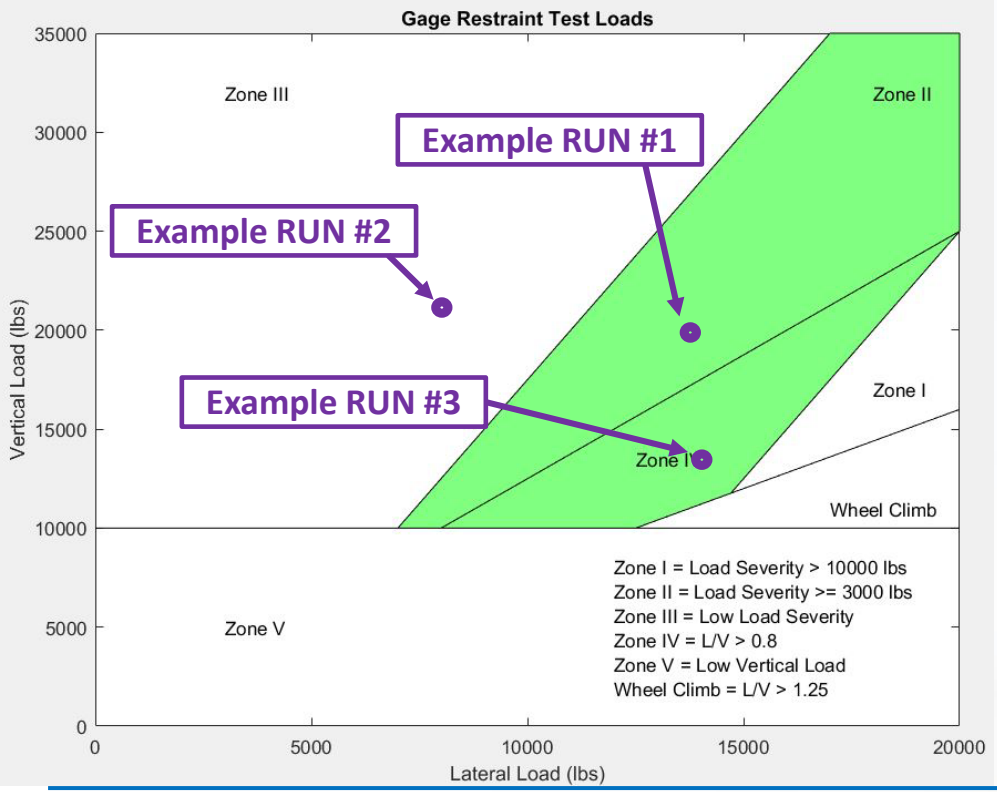
Missing Restraint: Simulated Locations at TTC

- Three weak spots manufactured at HTL loop:
  - Clips and insulators removed on 3, 5 and 7 consecutive ties

Missing Restraint: GRMS Testing

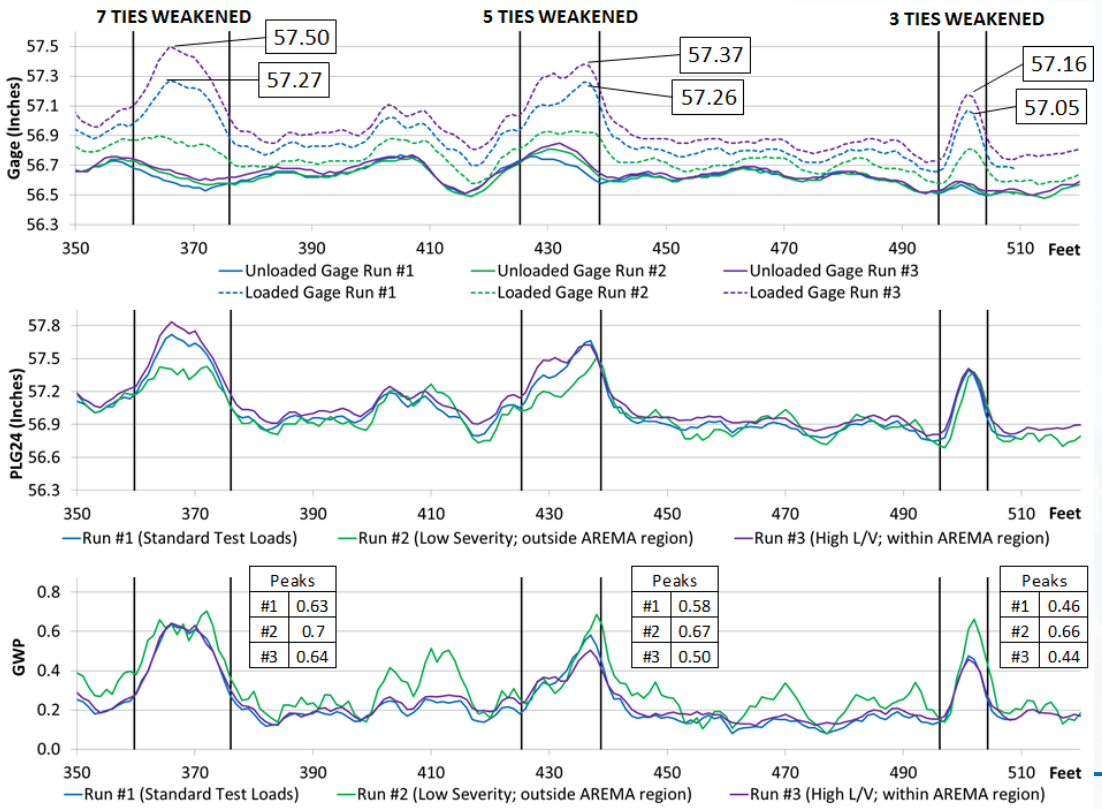
- DOTX 218 traversed the three zones 26 times with L/V ratio varying between 0.36 and 1.00 :
  - Investigate the GRMS response under varying loads on concrete ties
  - Assess normalization/extrapolation used in the GWP and PLG24
  - Identify more effective lateral and vertical forces and GWP thresholds on concrete ties

Missing Restraint: Sample Test Runs



- Run #1; L/V=0.68
  L=13.8 kips, V=20.2 kips
- Run #2; L/V=0.36
  L=8.0 kips, V=22.0 kips
- Run #3; L/V=1.00
  L=14.0 kips, V=14.0 kips

Missing Restraint: TTC Testing



- Lateral deflection grows with increasing load severity
- Max GWP observed was 0.7
- GWP and PLG24 match for runs with loads within AREMA recommended loadings

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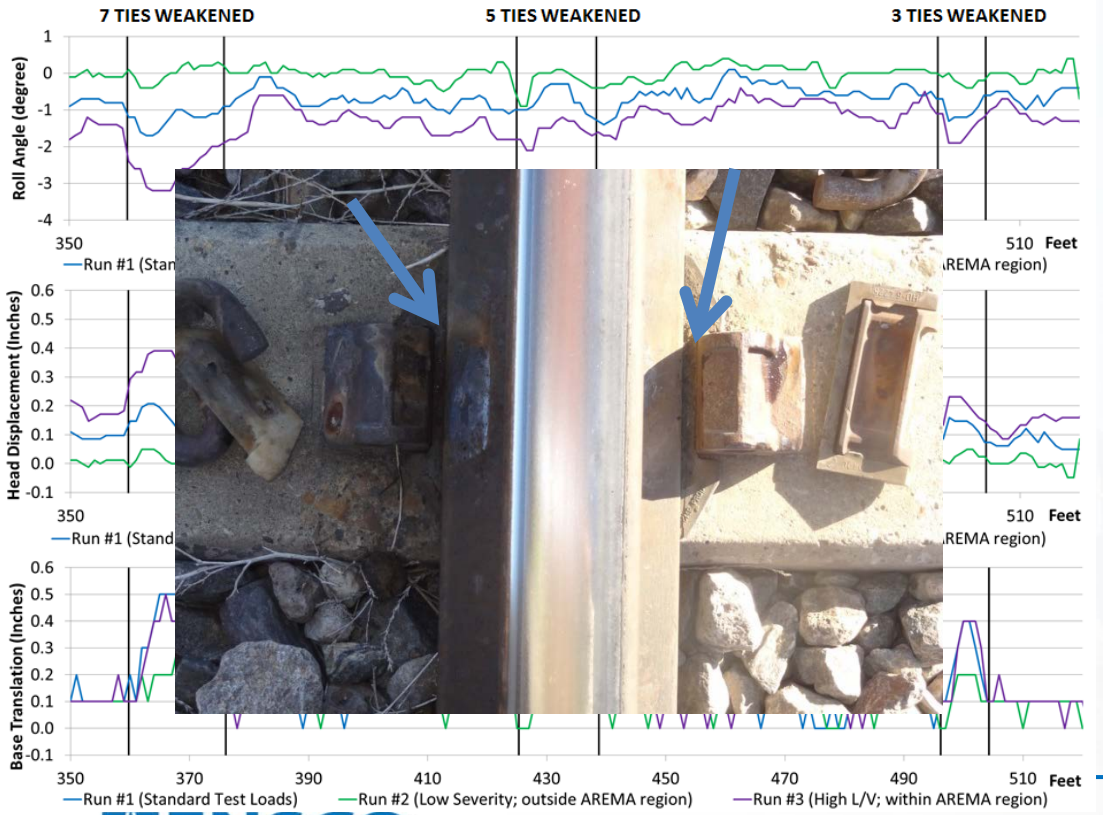
Missing Restraint: Explaining GRMS Response



- A large portion of gage widening originates from base translations
- 0.5 inch lateral gaps present when insulators are removed

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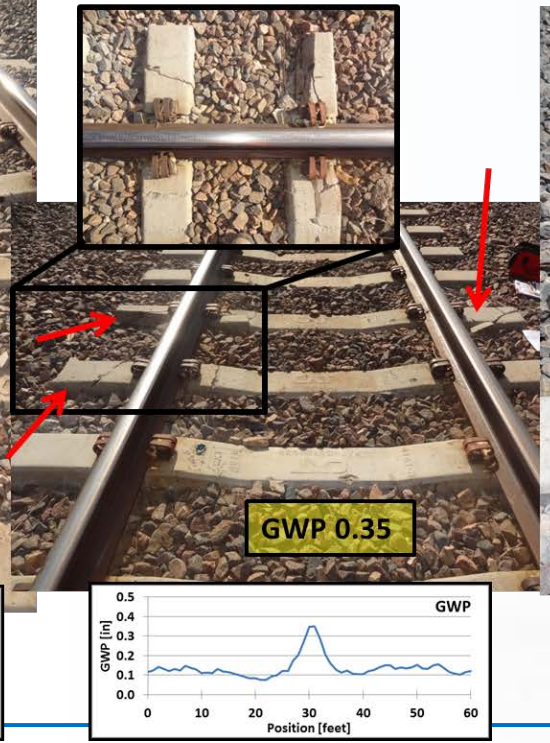
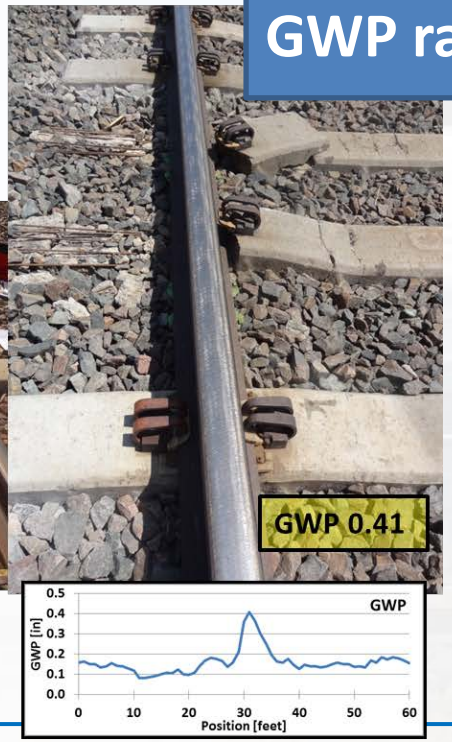
Missing Restraint Observations

- Missing Restraint: TTC
  - Standard GRMS test loads are suitable for testing on concrete ties for detecting missing fasteners.
  - Normalization/extrapolation used in the GWP and PLG24 parameters worked correctly for runs within AREMA guidelines for recommended loads.
  - Track structural problems including 7 consecutive ties with missing clips and insulators on both rails resulted in max GWP of 0.7 inches, which is below the current GWP maintenance level of 0.75.

Damaged Ties: Revenue Service Test

- DOTX 218 traversed 130 miles on a heavy haul (200MGT/year), Class 4 track, various concrete ties, SAFELOK I clips
  - GRMS thresholds lowered to identify locations with peak values below the current safety and maintenance thresholds
  - Field investigation followed to document tie conditions at selected locations



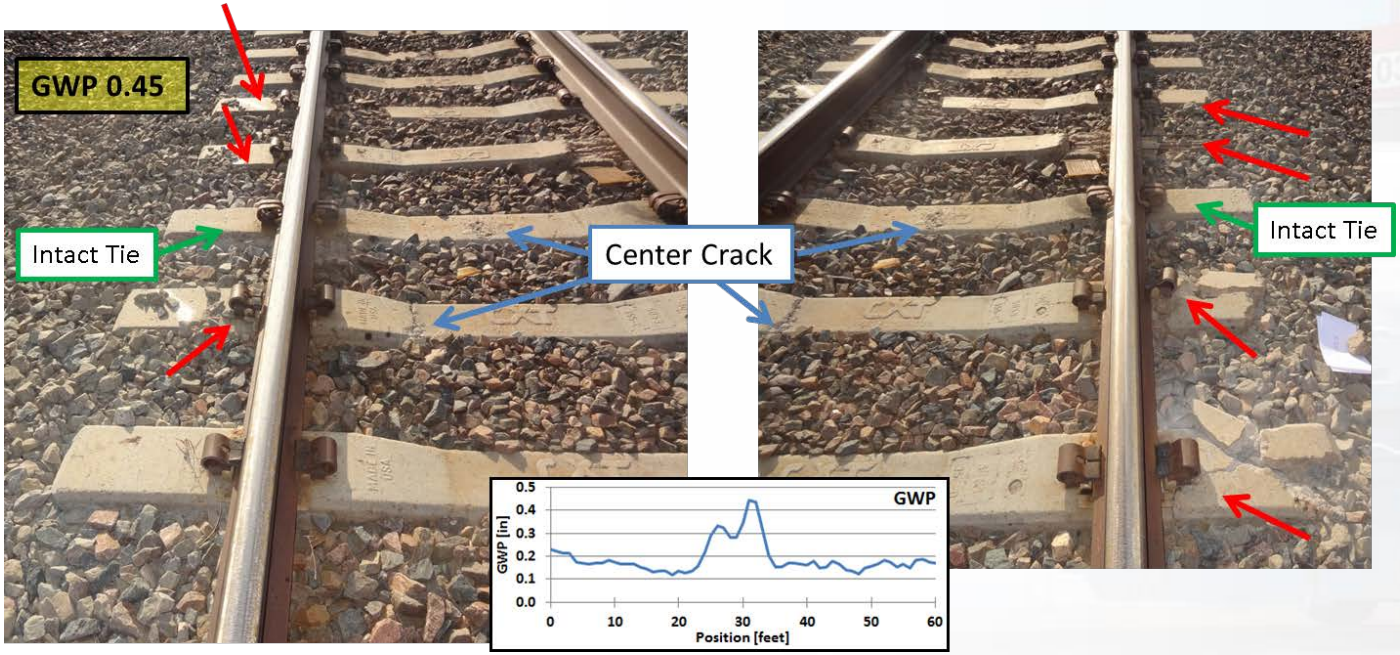


Damaged Ties: 1-2 Broken

GWP range: 0.34 - 0.41

- 1-2 consecutive broken ties
- Adjacent ties exhibited worn insulators

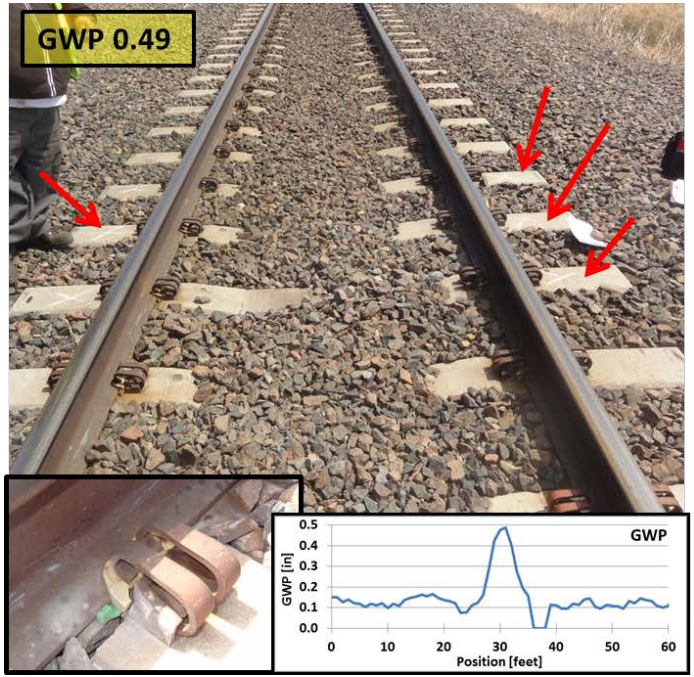
Damaged Ties: 2 Broken Ties + 2 Broken Ties

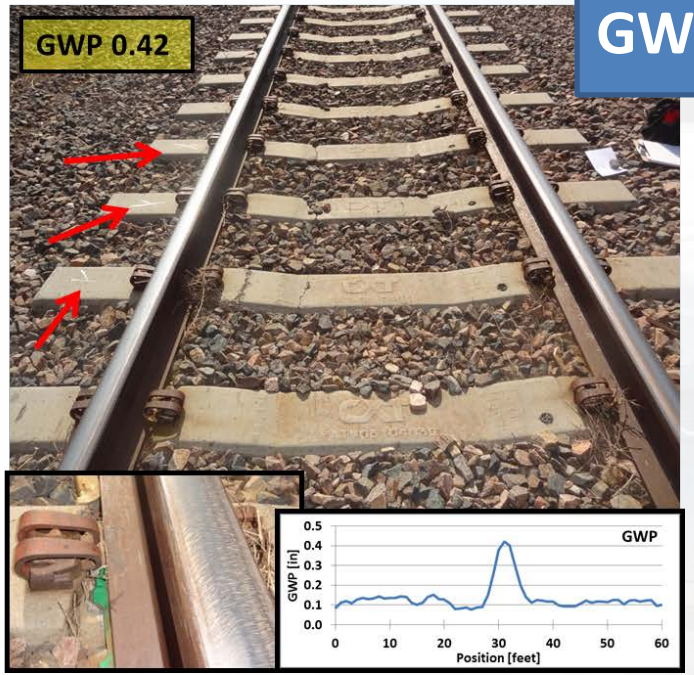


GWP: 0.45

- Two sets of two broken ties in row
- Intact tie in the middle severely worn insulators

Damaged Ties: 3 Broken Ties





GWP: 0.49 and 0.42

- Three consecutive broken ties
- Break at the rail seat is hard to spot from hi-rail inspection

Damaged Tie Observations

- Damaged Ties: Revenue Service Track
  - Tie conditions at GWP levels between 0.34-0.49 affected by broken tie failure mode on up to 3 consecutive ties with insulator wear on adjacent ties.
  - Weak track conditions of maintenance interest in concrete track produce GWP values significantly below current thresholds.
  - GRMS can detect types of weak track conditions difficult to identify from a hi-rail inspection.

Conclusions

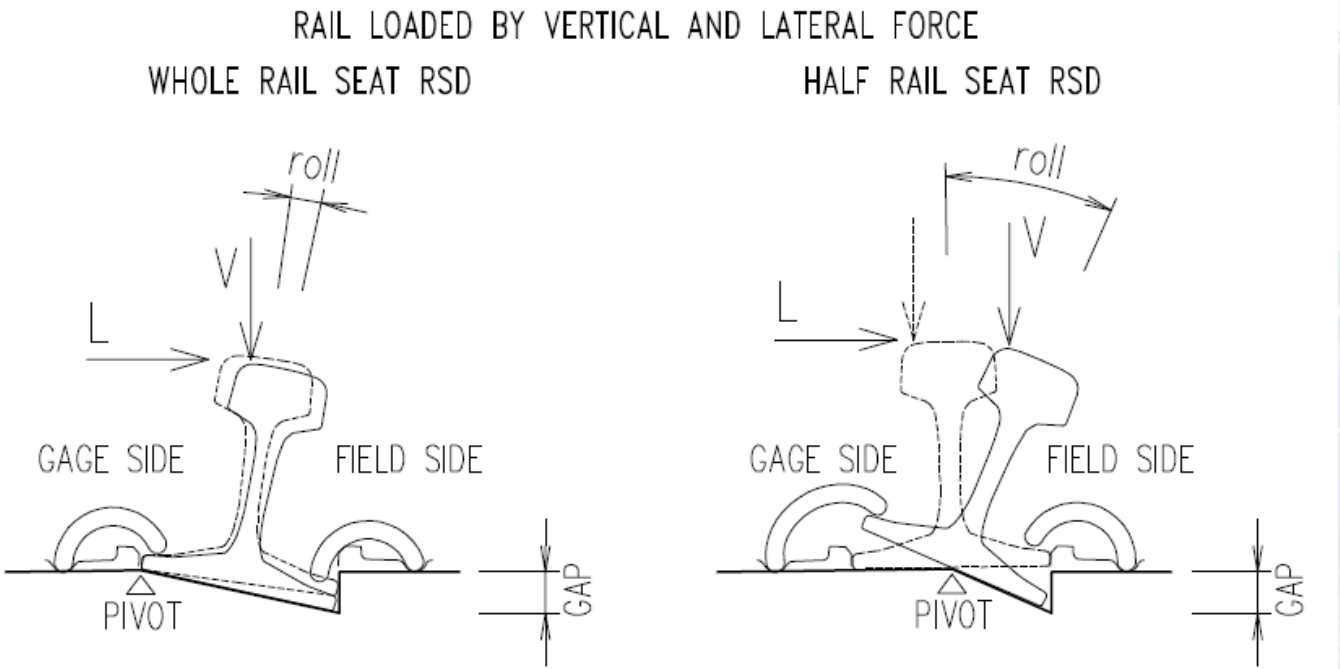
- These tests show that GRMS measurements significantly above mean values can be correlated to specific failures in track structure.
- Some of these failures in track structure may be difficult to detect by traditional means.
- Furthermore, the data has shown a positive correlation between GRMS measurement and severity of the failure.

- GRMS data can be used to identify safety risks with current limits and to prioritize maintenance efforts with modified thresholds for structural health monitoring.

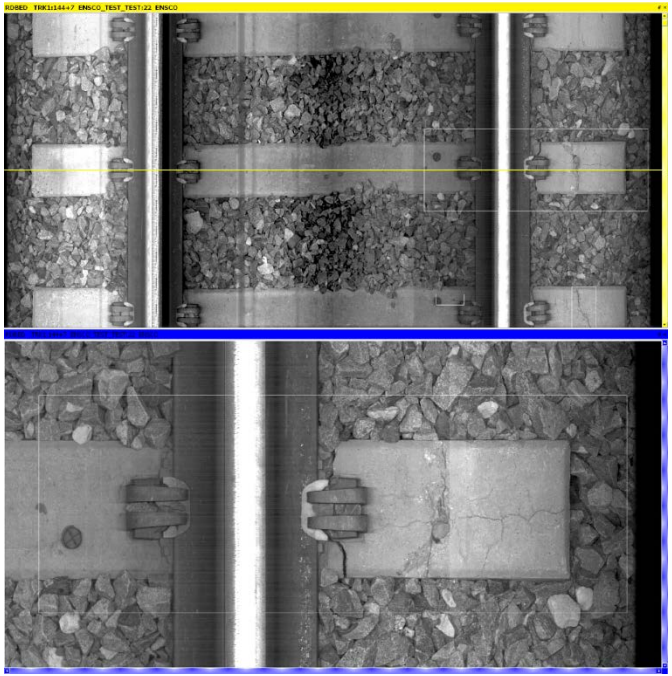
Questions for Future Work

- How can the results of these studies be validated and better understood through additional GRMS testing?
- What different data interpretation methods for GRMS can detect deteriorating tie conditions on track with concrete ties and elastic fasteners?
- How can GRMS detect other types of track deterioration and the combinations thereof (i.e. RSD, tie conditions, rail and support conditions, etc)?
- How rapidly do different types of track conditions deteriorate?
- Would different strength criteria for higher classes of track be useful?
- How can other technologies be combined to allow for a better measurement of track condition?

RSD Detection Aided by GRMS



Machine Vision as a Complimentary Technology for use with GRMS



- Today, machine vision is being used to support collecting, processing, and reviewing continuous, hi-resolution track bed images
- Visible track conditions that are potentially relevant to GRMS exceptions include:
  - Ineffective concrete ties
  - Missing fasteners
  - Severe rail base corrosion
  - Fouled ballast.

Synchronizing machine-based image processing with GRMS data may ultimately provide useful, real-time insight into the underlying cause of each GRMS exception.

Acknowledgments

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