Characterizing the Effects of Rail Surface Conditions on Noise and Track Components

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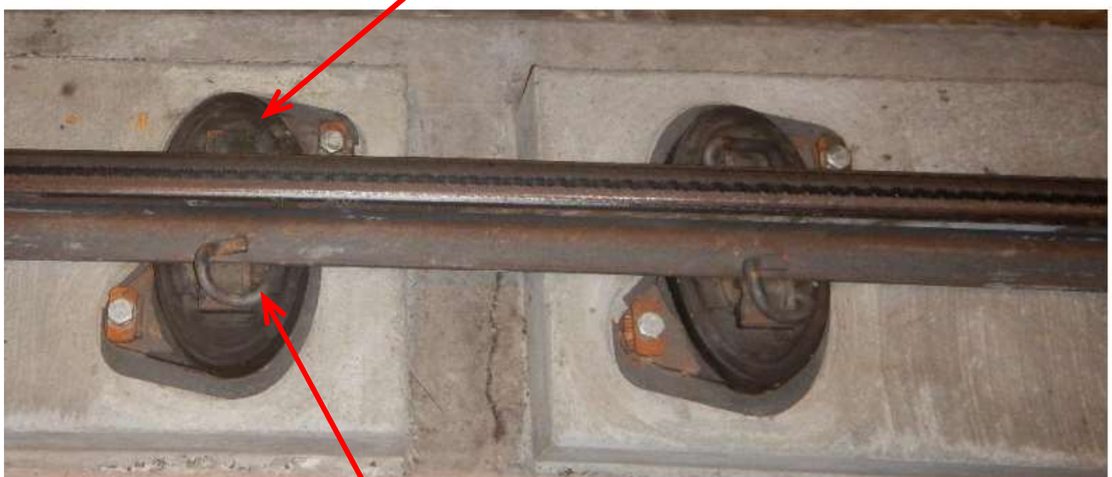
7. ST Design Partner – HNTB

Overview of this Presentation

1. Introduction to Failing Track Component – Rail Clips
2. Root Cause Investigation Strategy
3. Onboard Noise and Track Vibration Results
4. Rail Surface Condition and Corroborative Tests
5. Plausible Root Cause & Remedy Discussion

What are E-Clips?

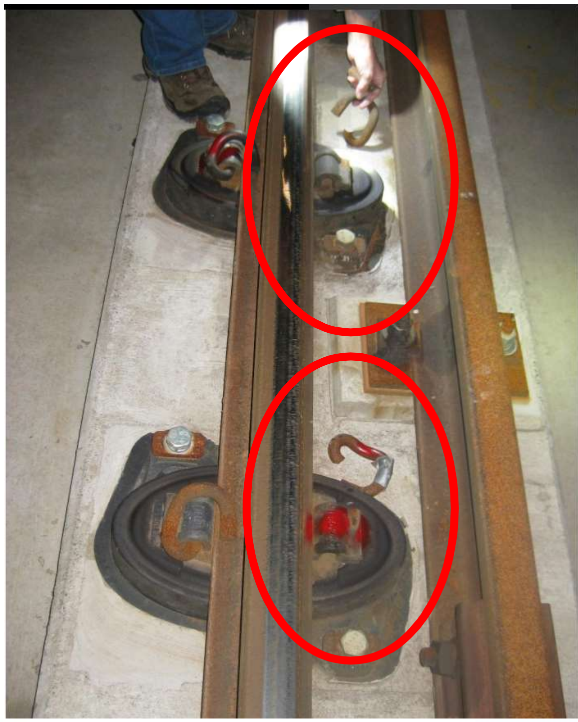
High Resilient DF Fastener

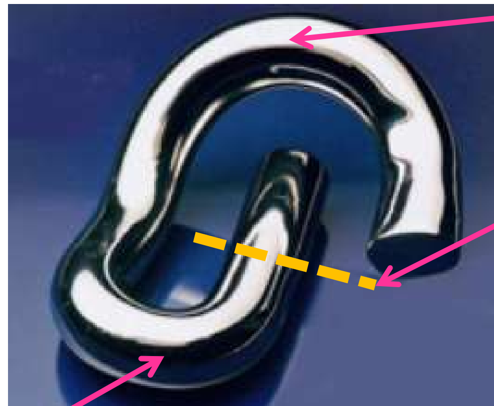


Rail Clip

E-Clip

E-clip Failure Mode

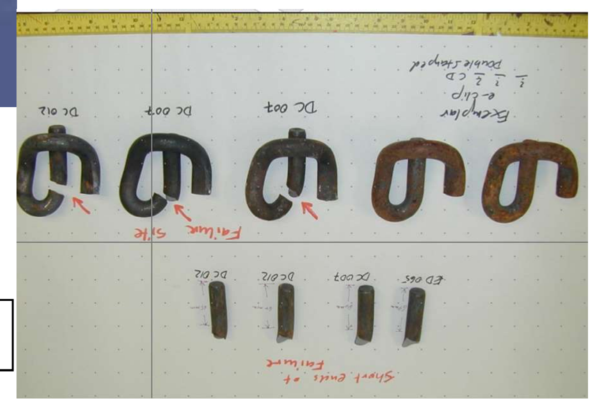




Location 1: Front Arch (lazy bend)

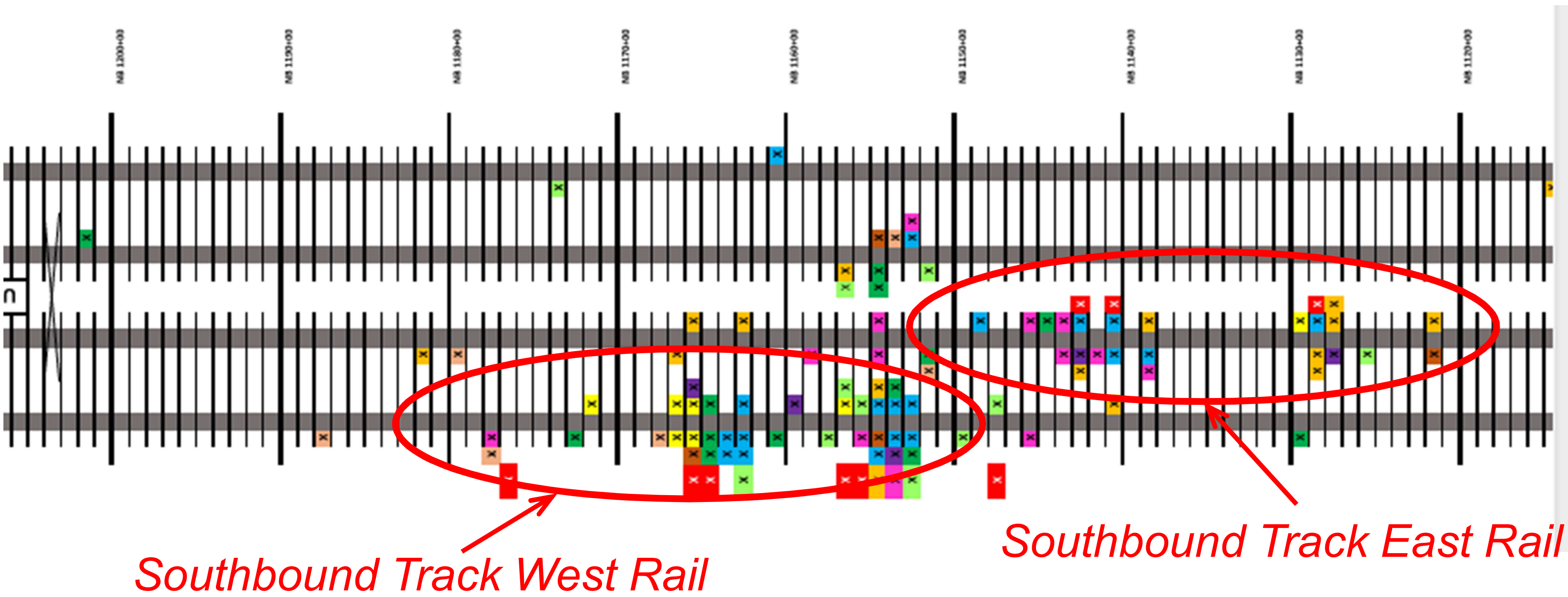
U-Link Clip Failure Location: Center Leg

Location 2: Rear Arch (tight bend)



Fatigue Failure

E-clip Failure Problem



ST Investigation Overview

Design Failure or Manufacturing Defect?

- ***Appropriate Clip Design?***
  Visual Inspection & Lab Tests
- ***Unrefined Fastener Details***
  Planned Fastener Lab Tests
- ***Bad Batch of Fasteners***
  Planned Fastener Lab Tests
- ***Bad Batch of Clips***
  Clip Lab Tests

Dynamic Tests

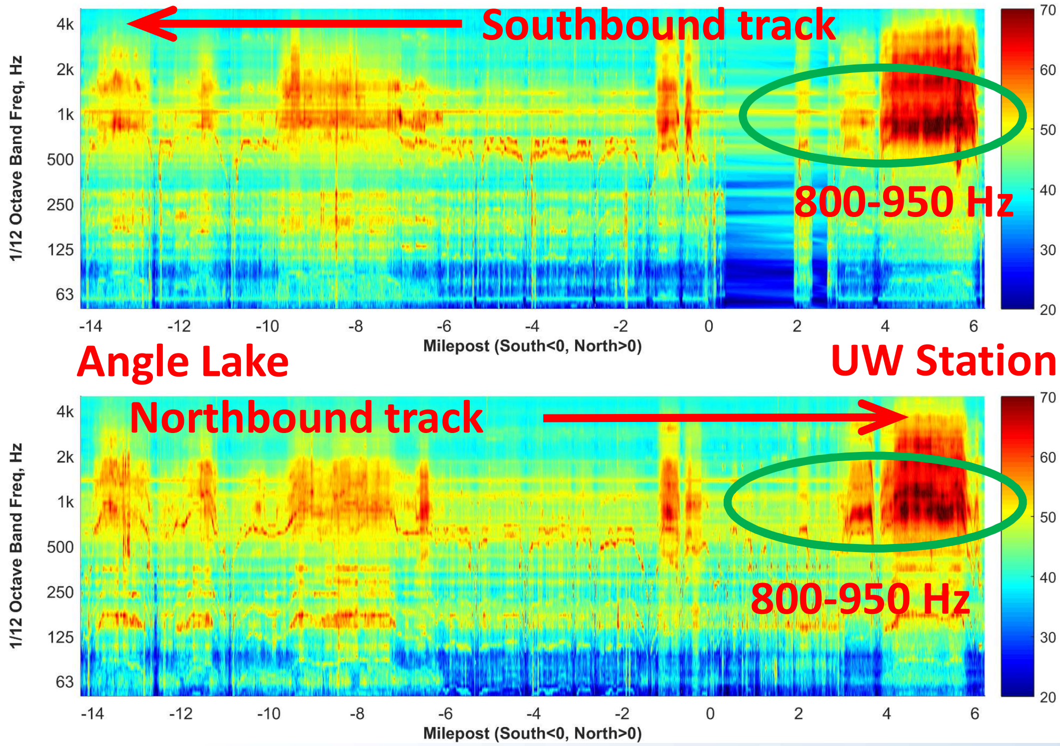
1. *Rail Vibration*
2. *Wayside Vibration*
3. *LVDT & Rail Strain*
4. *Onboard Noise*
5. *Rail Roughness*

Poor Civil Construction?

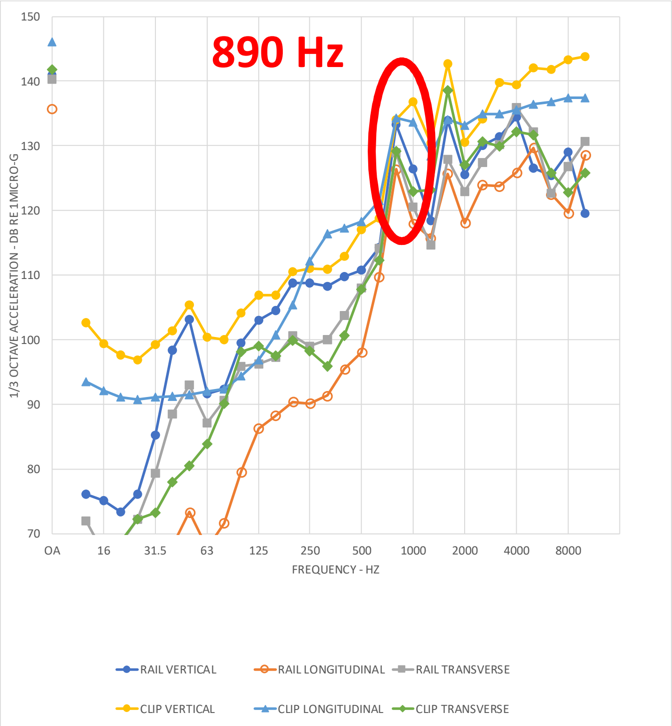
- ***Track Vertical Misalignment***
  Detailed Track Survey
- ***Poor Rail Installation***
  Field Measurements
- ***Return Current Leakage***
  Stray Current Tests
- ***Corrosive Environment***
  Visual & Lab Tests

Unique Phenomenon?

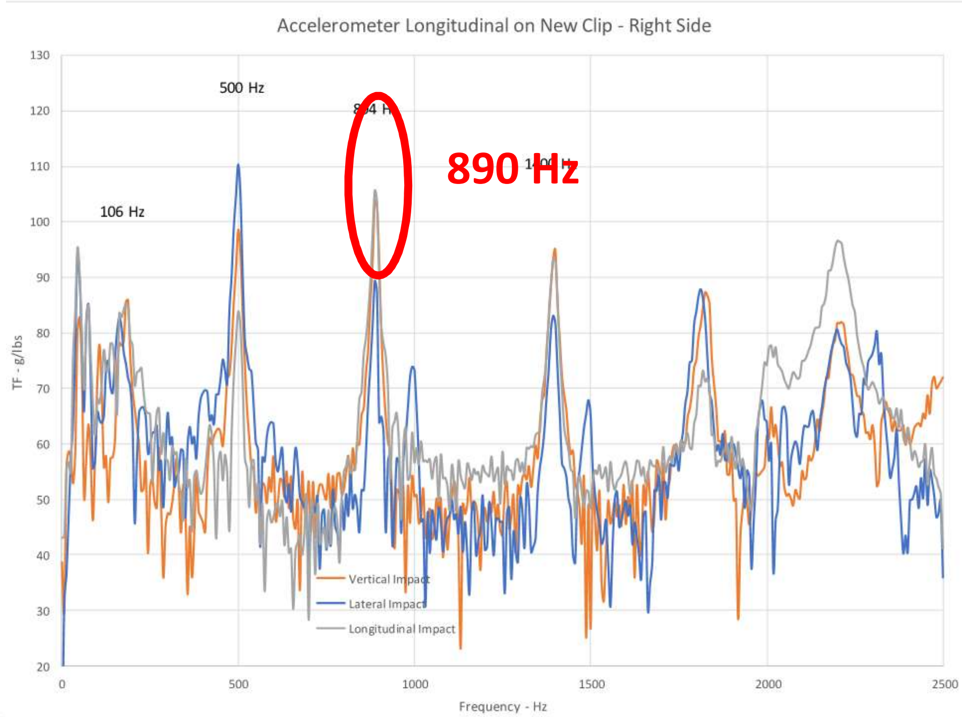
Onboard Noise Data – ATS



Measure e-clip Acceleration on Site (Wilson Ihrig Test)



Measure e-clip Acceleration in Lab (Wilson Ihrig Test)



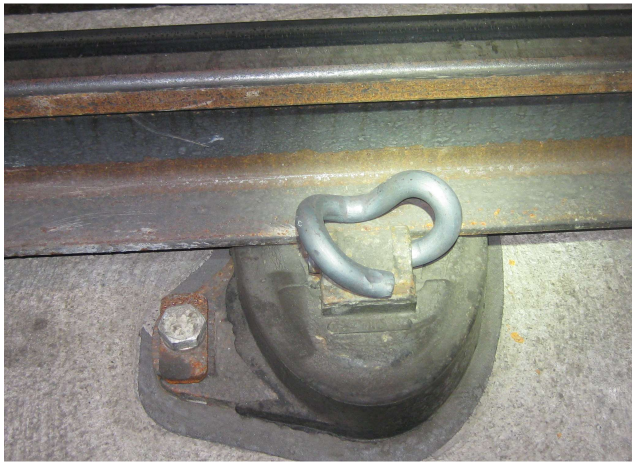
Key Learnings

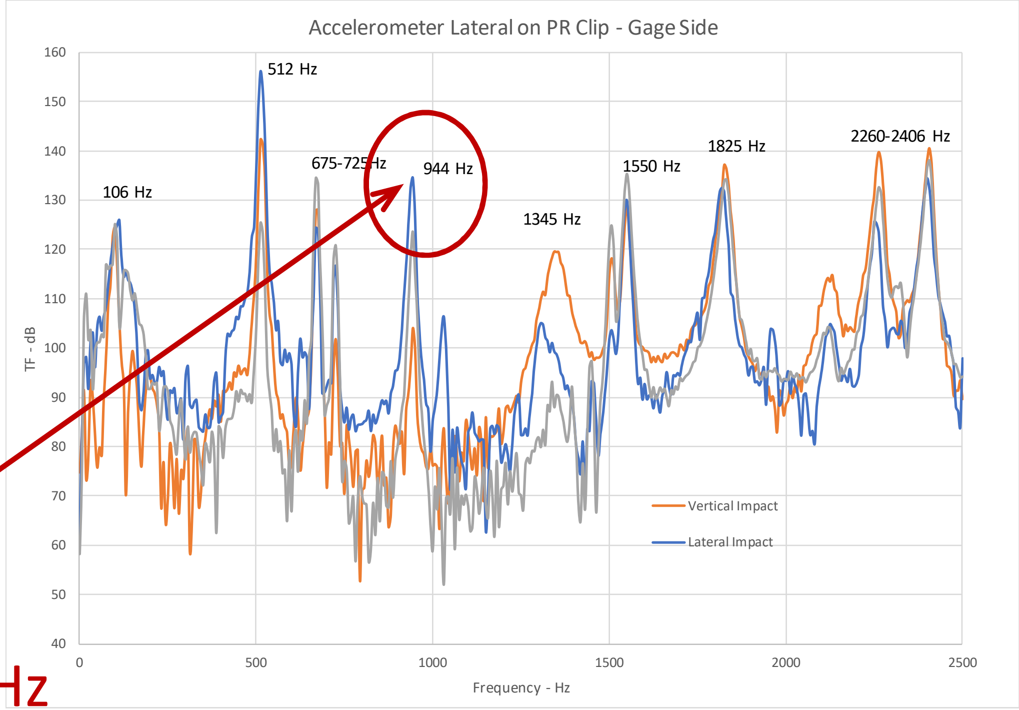
Track System Natural Resonance: ~800-900 Hz

The clips are subject to strains that exceed their design limit

Use of a bigger clip with higher elasticity and strain capacity can potentially arrest the failure rate

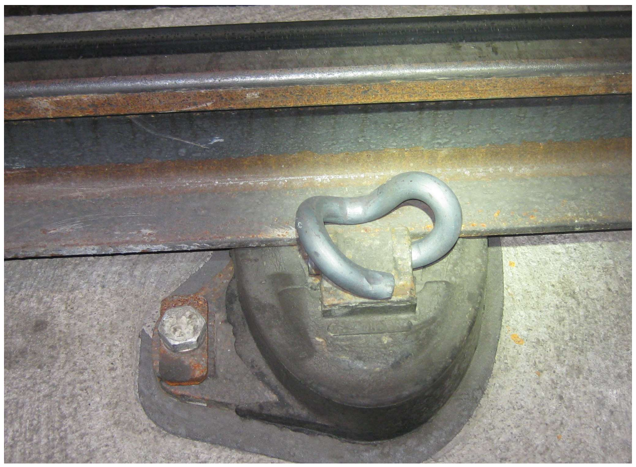
Use of PR Clips to Arrest Failure Rate

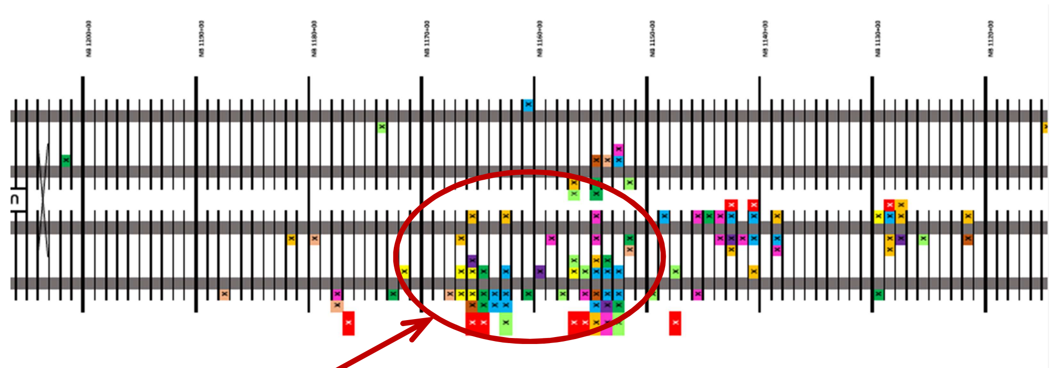




- The PR clip is more robust with higher strain limit
- Clip resonance shifted to ~950 Hz

Trial Section with PR Clips





- About 1000 feet replaced with PR Clips
- No PR Clip failure in 9 months

Hypothesis to Identify Root Cause

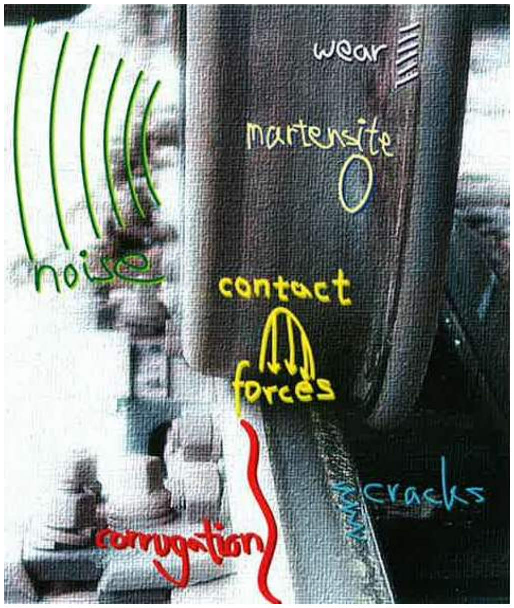
Track System Natural Resonance: ~800-900 Hz

E-Clip Natural Resonances: ~800-900 Hz

What is unique about the e-clip failure areas?

Perhaps external driver at 800 – 900 Hz resulting in Coincidence Phenomenon?

What is the Potential Source Driving the Resonance?

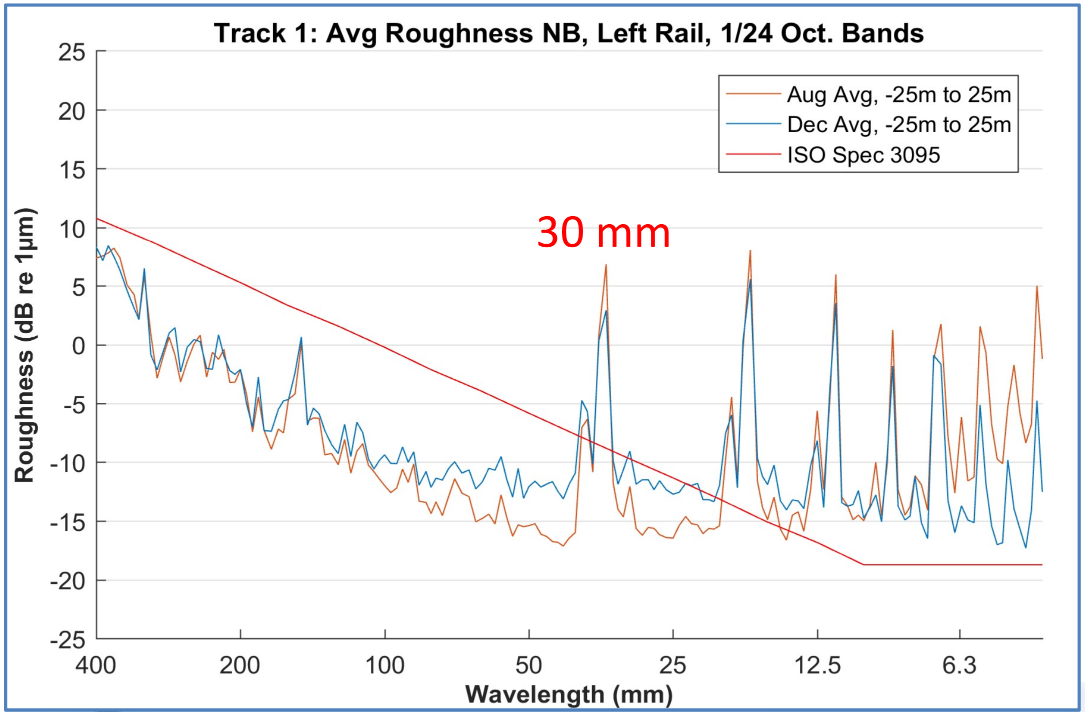


Wheel?

LRV truck?

Rail?

Recent Rail Grinding Signature of Transit Properties in North America

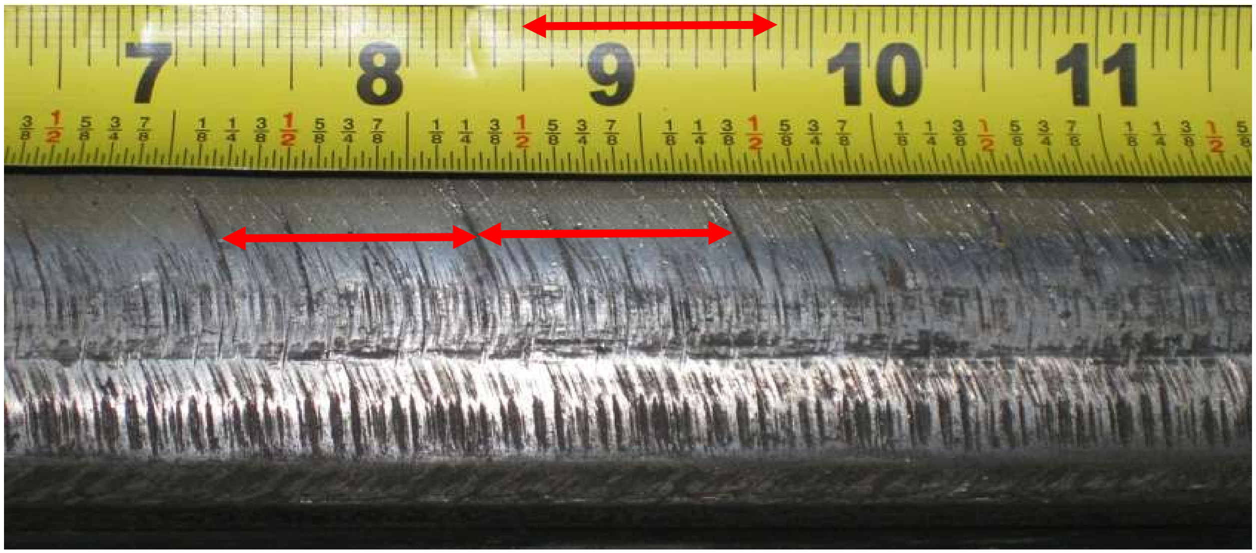


- Rail roughness wavelength peak at 30 mm
- The peaks are caused by:

  Rail grinder speed– 4 mph

  Grinding motor– 3600 rpm

Rail Surface – Visual Inspection



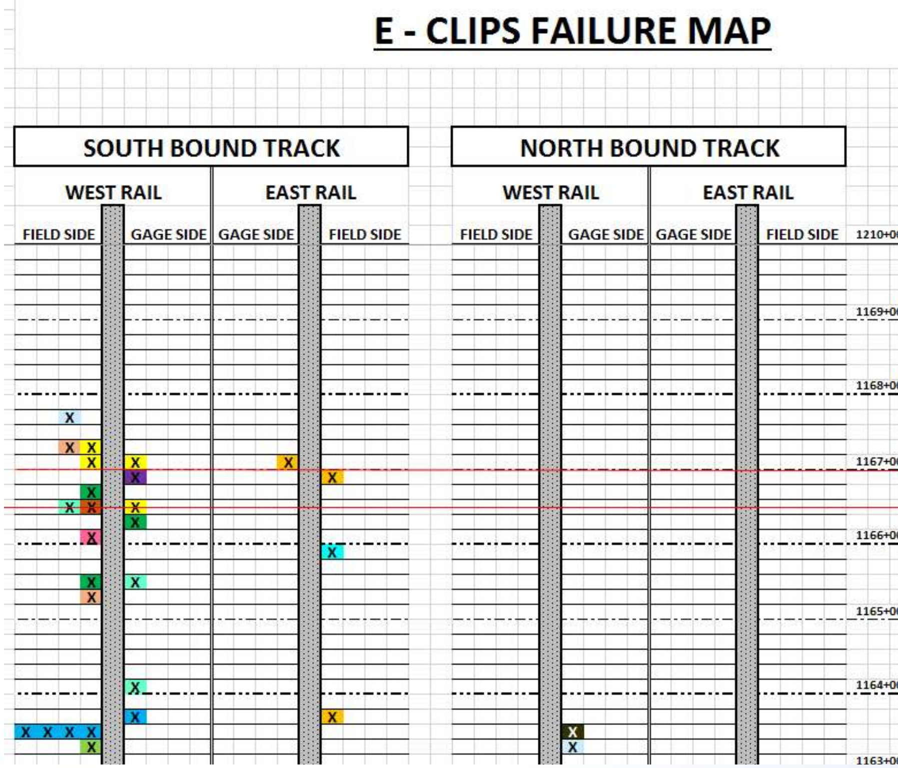
Grinding Marks Pitch

1.2 in

&

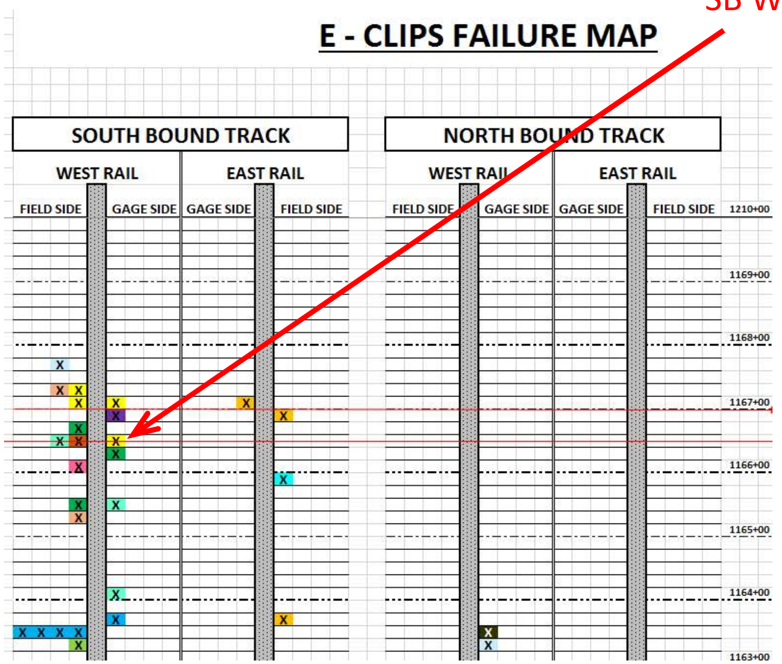
1.1 in

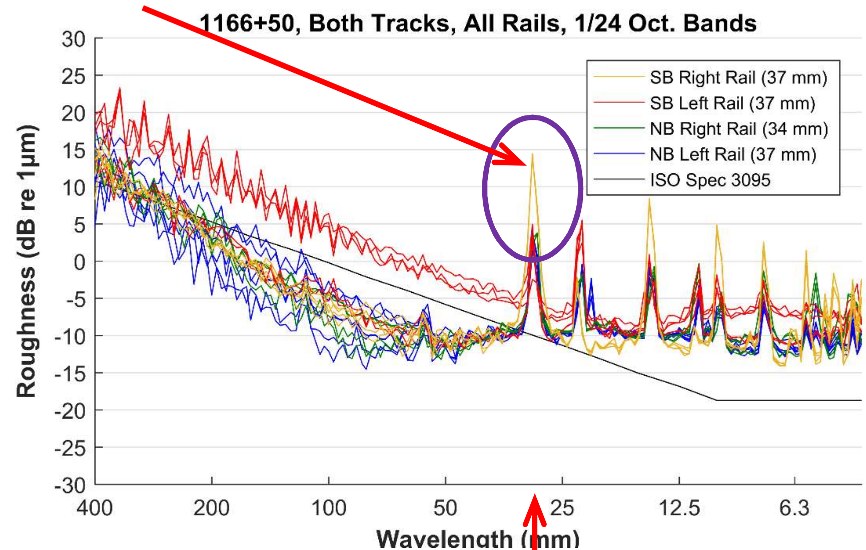
Rail Roughness Measurements – ATS



Rail Roughness Results

SB West Rail =15 dB



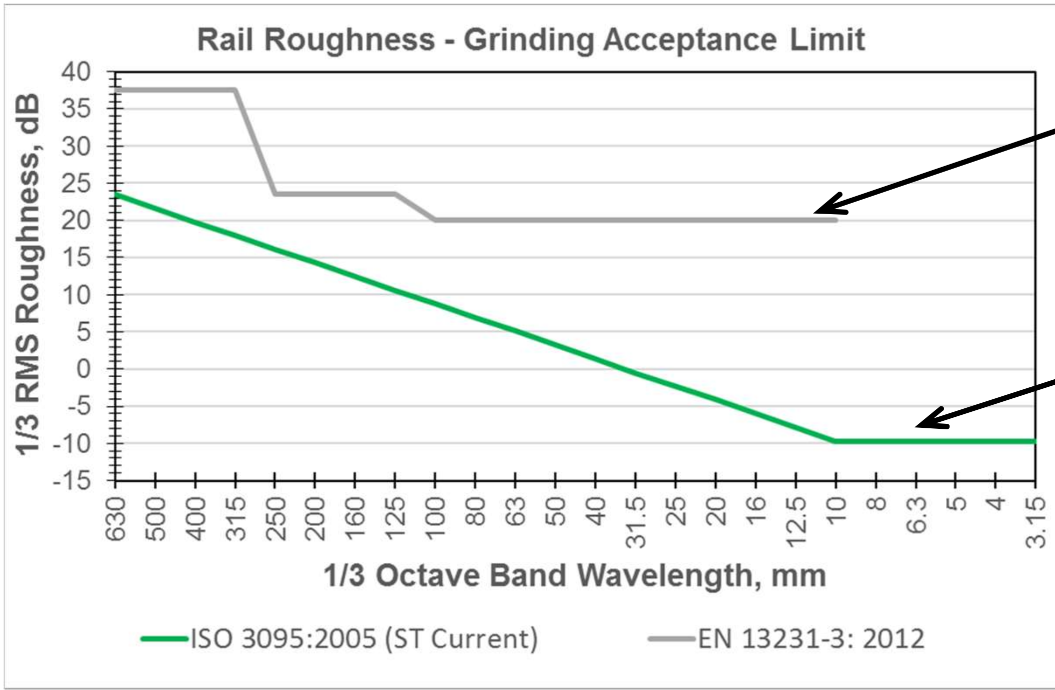


29.8 mm = 890 Hz
(at 55 mph train speed)

What is the Potential Root Cause Fix?

FOCUS ON THE RAIL GRINDING FINISH !

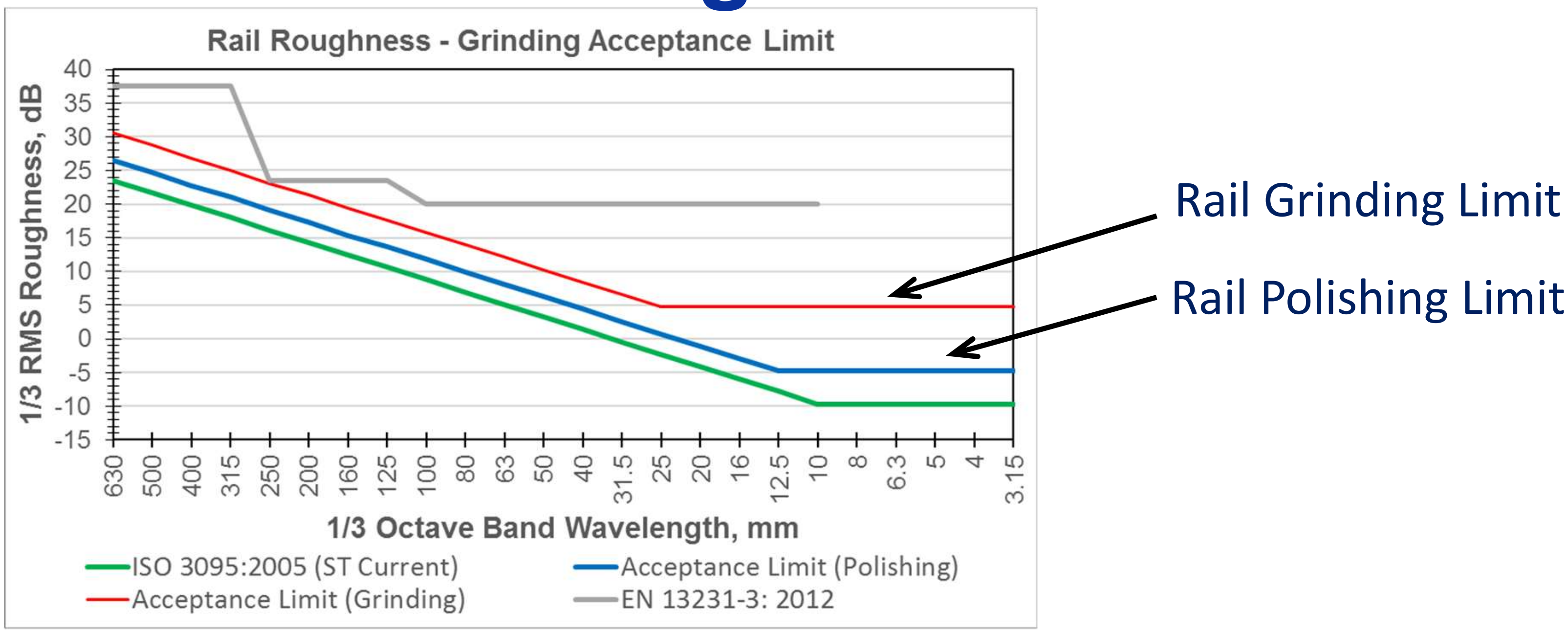
Transit Rail Grinding – Status Quo



EN 13231-3:2012
Limit Proposed by Rail Grinding Companies

ISO 2095: 2005
ST's Current Rail Grinding Limit

Sound Transit's Revised Rail Roughness Limits

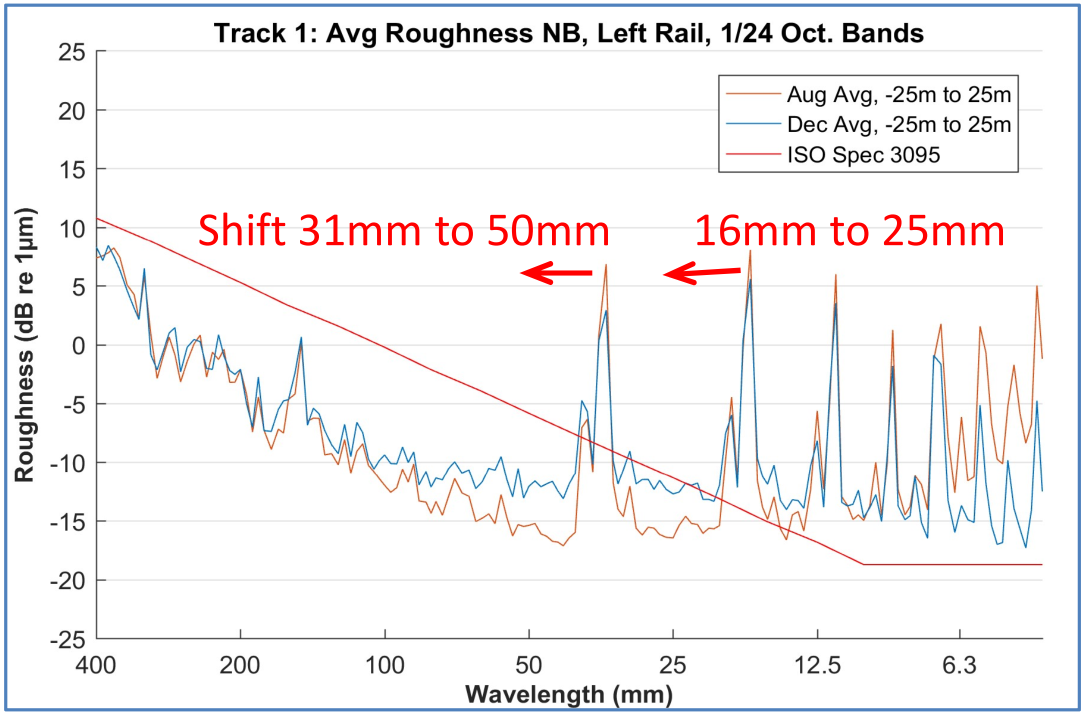


Revised Rail Grinding Strategy

1. Separate metal removal step (rail grinding) from rail polishing step

2. Use different roughness limit for the two steps and monitor during intermediate rail grinding stages

How to Meet New Grinding Spec?



- Employ different grinding speeds and grit sizes for the two steps
- Factor the track time and budget needed to grind the rails

Why 50mm Roughness Wavelength?

Rail Roughness Wavelength / Train Speed	25 mm	32 mm	40 mm	50 mm (Safe for N&V)	63 mm	80 mm
30 mph	536 Hz	426 Hz	335 Hz	**268 Hz**	213 Hz	168 Hz
35 mph	626 Hz	497 Hz	391 Hz	**313 Hz**	248 Hz	196 Hz
40 mph	715 Hz	568 Hz	447 Hz	**358 Hz**	284 Hz	224 Hz
45 mph	805 Hz	639 Hz	503 Hz	**402 Hz**	319 Hz	251 Hz
55 mph	983 Hz	780 Hz	615 Hz	**492 Hz**	390 Hz	307 Hz

Revised ST Rail Grinding Requirements

Step 1 – Grinding

Step 1a – Check rail roughness to verify compliance

Step 2 – Polishing (higher grinding speed and finer grit stones)

Step 2a – Check rail roughness to verify compliance to polishing limit

Step 3 – Confirm conformance to rail roughness limit before leaving

Summary

- E-clip failure investigation unexpectedly showed rail surface condition as the plausible compounding root cause.
- Bigger rail clips are currently tried as a mitigation option to reduce the propensity for failures at extreme conditions.
- Grinding the rails to tighter tolerances would lead to smoother finish and can potentially eliminate the root cause for failure.
- Sound Transit has revised the rail grinding specification.