Controlling Grinding-Induced Corrugation (GIC) to Maintain Lower Wayside Train Noise Levels

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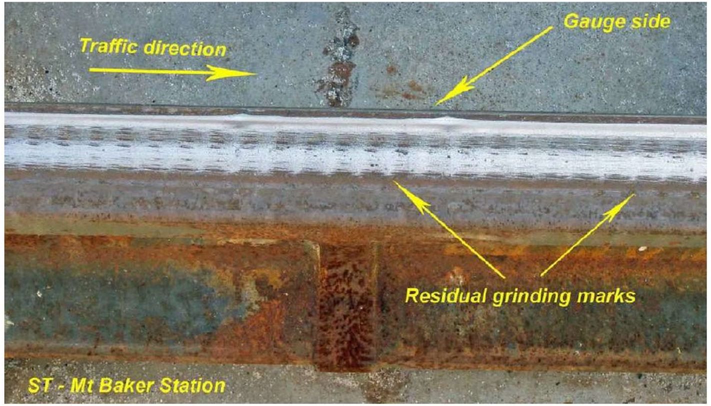
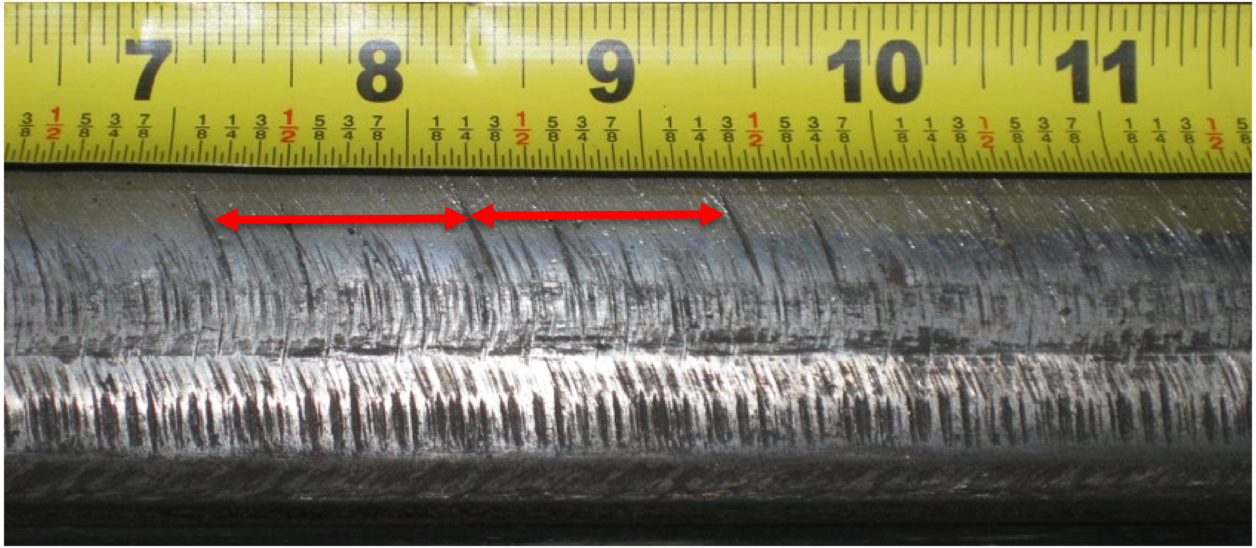
Light Rail Vehicle Noise Source

Key Rail Surface Conditions Affecting Noise



- **Rail Roughness – Non-periodic defect**
- **Rail Corrugation – Periodic defect**
  - Corrugation from wear and tear during service
  - Grinding Induced Corrugation (GIC)

Grinding Induced Corrugation with High Roughness



Grinding Marks Pitch: 30 mm

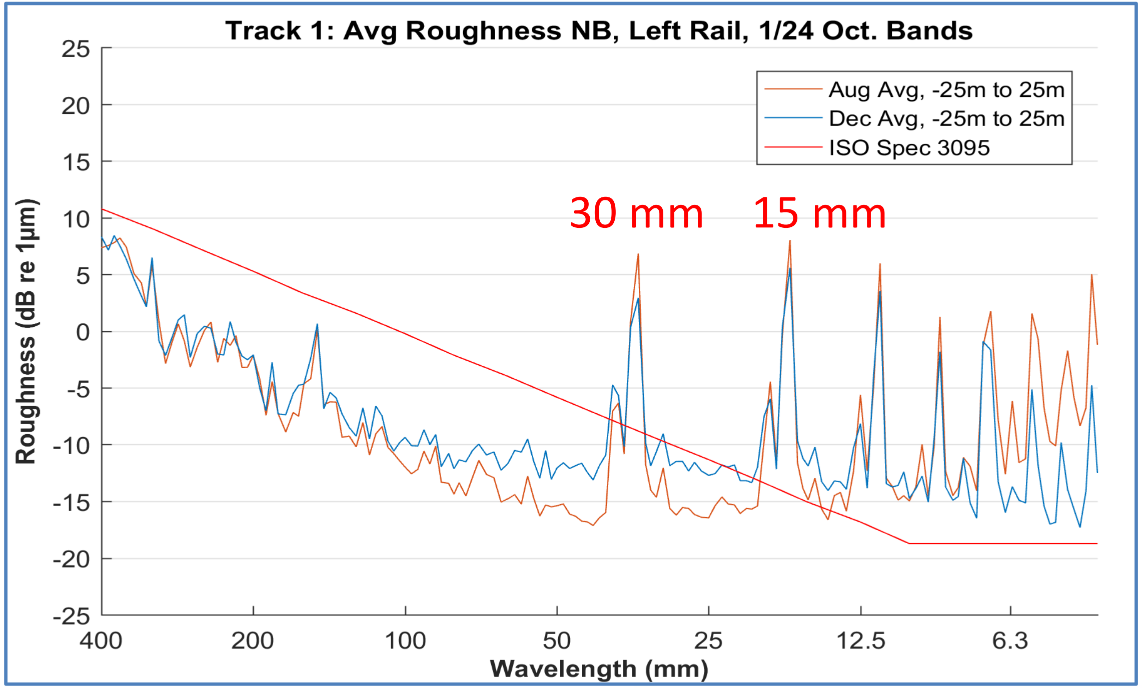
Rail Roughness Measurements

A Corrugation Analysis Trolley (CAT) measures roughness of one rail at a time

(or)

a Bi-CAT that measures roughness of both rails simultaneously

Typical Rail Grinding Signature



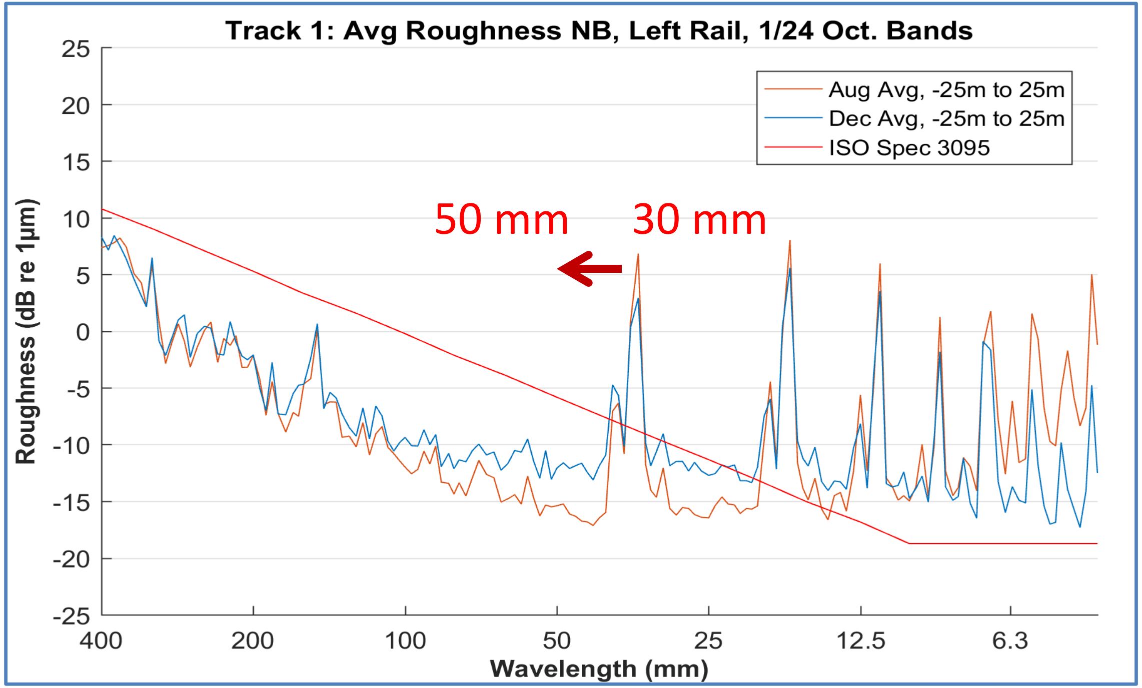
- Primary rail roughness peak at 30 mm due to GIC. 30 mm @ 55 mph = 825 Hz noise
- Secondary peak 15 mm @ 55 mph = 1650 Hz

Sound Transit's Grinding Strategy

GIC Wavelength / Train Speed	25 mm	32 mm	40 mm	50 mm	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
50 mph	894 Hz	698 Hz	559 Hz	*447 Hz*	355 Hz	492 Hz
55 mph	983 Hz	780 Hz	615 Hz	*492 Hz*	390 Hz	307 Hz

The GIC primary peaks were targeted to range between 250 Hz and 500 Hz for all train speeds

Shifting the Rail Grinding Signature



- 30 mm @ 55 mph = 825 Hz noise
- 50 mm @ 55mph = 492 Hz

Rail Grinding Steps and Grinder Speeds

For a 3600 RPM grinder on DF tracks or Ballast & Tie Tracks, 2 steps used:

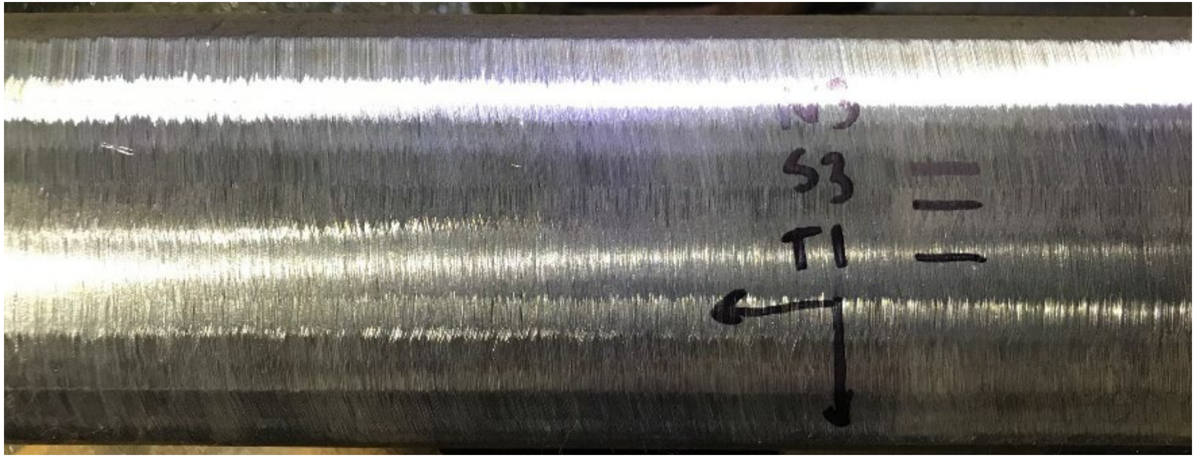
- **Grinding step** – use coarse stone and slow speed (**4 mph**)

  Shapes the rail profile.

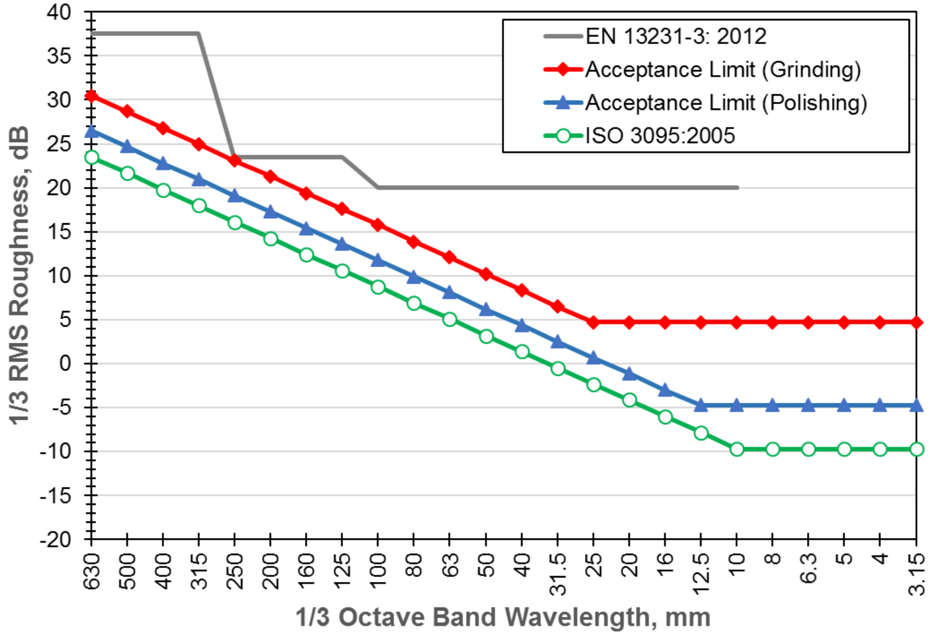
- **Polishing step** – use softer stone and faster speed (**6mph**)

  Finishes the surface.

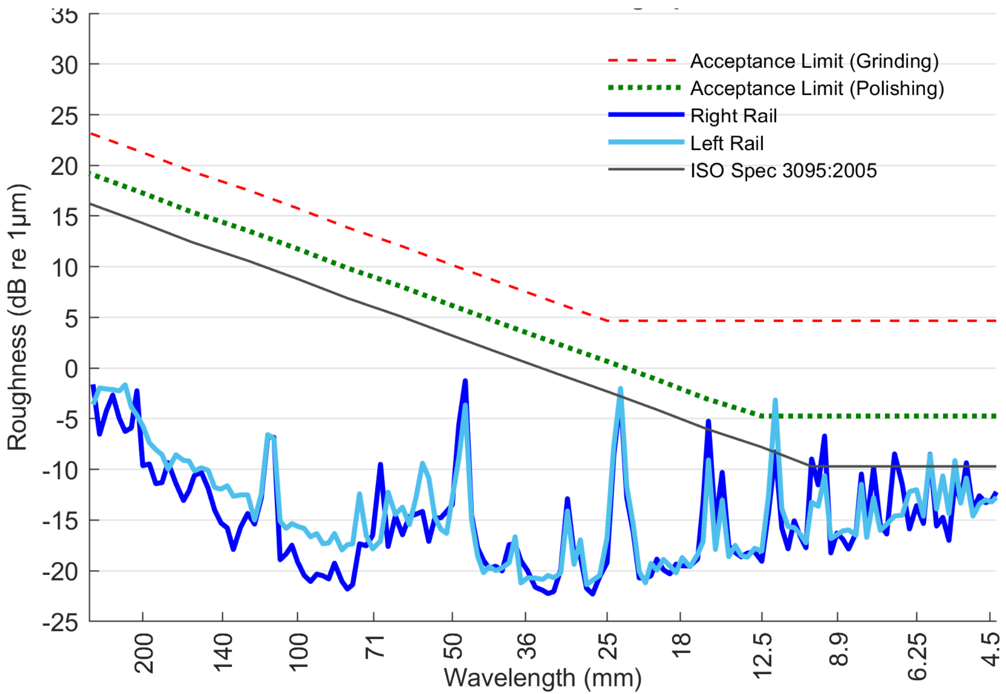
Sound Transit's Rail Grinding Finish



Rail Grinding – Sound Transit's Roughness Criteria



Measured Post-Grinding Roughness



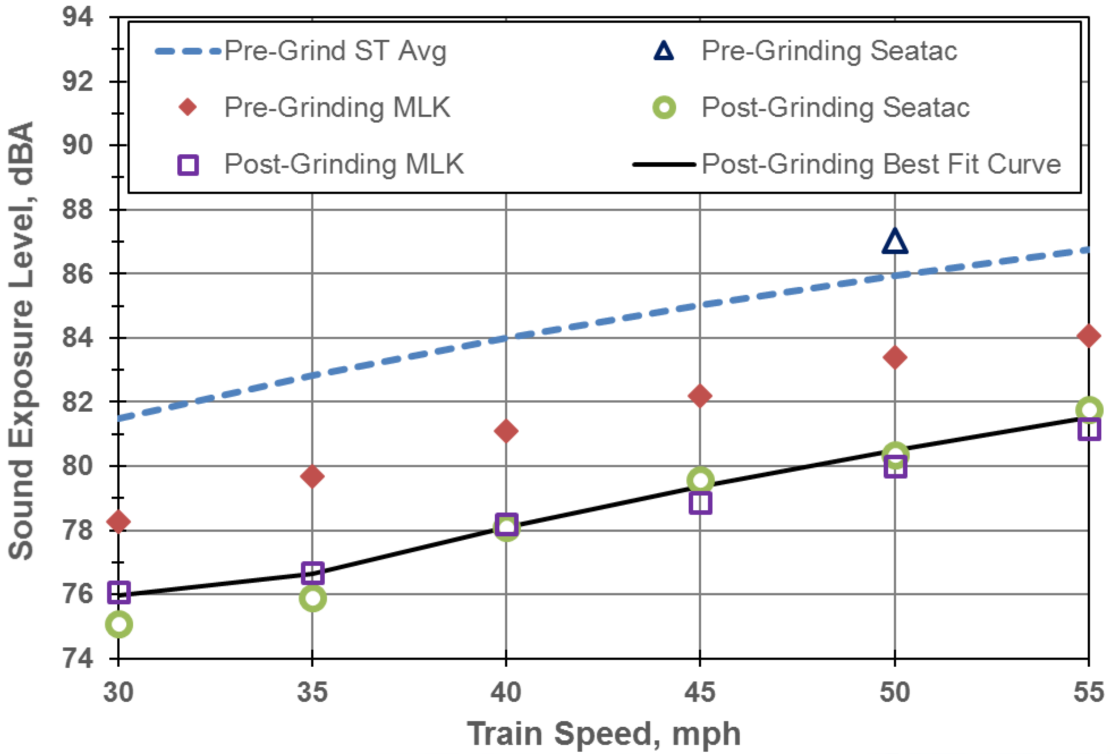
Measured Rail Roughness Peaks

Test Site	Rail Roughness Peak 1		Rail Roughness Peak 2	
	Wavelength	Roughness Level	Wavelength	Roughness Level
Pre-Grinding				
Tukwila 2013	40 mm	6 dB[1]	20 mm	3 dB[1]
MLK 2017	47.1 mm	7 dB[1]	23.5 mm	2 dB[1]
Seatac 2017	34 mm	7 dB[1]	17.2 mm	4 dB[1]
Post-Grinding				
MLK 2019	50 mm	0 dB[1]	25 mm	0 dB[1]
Seatac 2019	50 mm	3 dB[1]	25 mm	-3 dB[1]

[1] This rail roughness decibel uses 1 micron as the reference level.

Test Train Wayside Noise Measurement

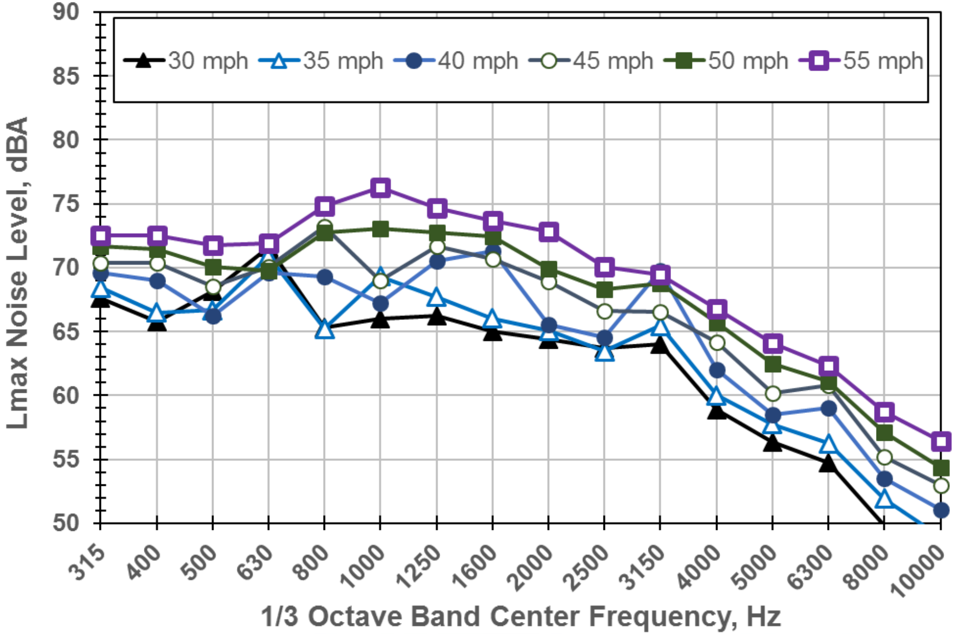
Normalized 1-car LRV Noise at 50 ft



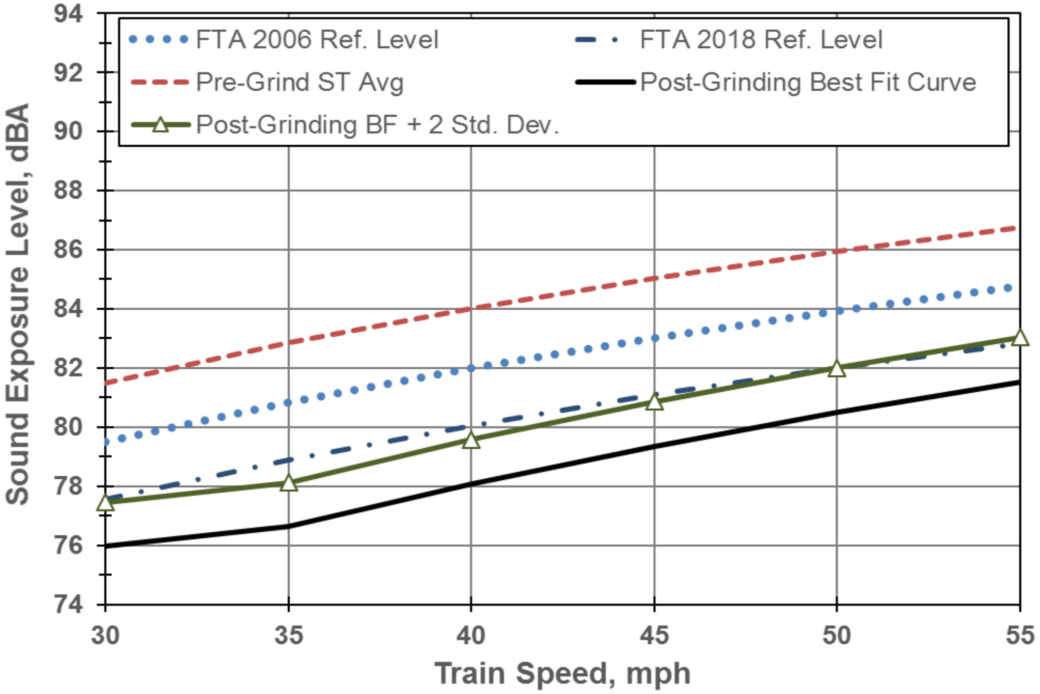
Noise Peak Frequencies: Modeled versus Measured

Train Speed	Estimated Train Noise Frequency Based on Rail Roughness Peaks		Wayside Train Noise 1/3 Octave Band Center Frequency	
	1st Peak at 50 mm	**2nd Peak at 25 mm**	**Modeled**	**Measured**
30 mph	268 Hz	536 Hz	**500 Hz**	**500 Hz/ 630 Hz**
35 mph	313 Hz	626 Hz	**630 Hz**	**630 Hz**
40 mph	358 Hz	715 Hz	**800 Hz**	**800 Hz**
45 mph	402 Hz	805 Hz	**800 Hz**	**800 Hz**
50 mph	447 Hz	894 Hz	**1000 Hz**	**1000 Hz**
55 mph	492 Hz	983 Hz	**1000 Hz**	**1000 Hz**

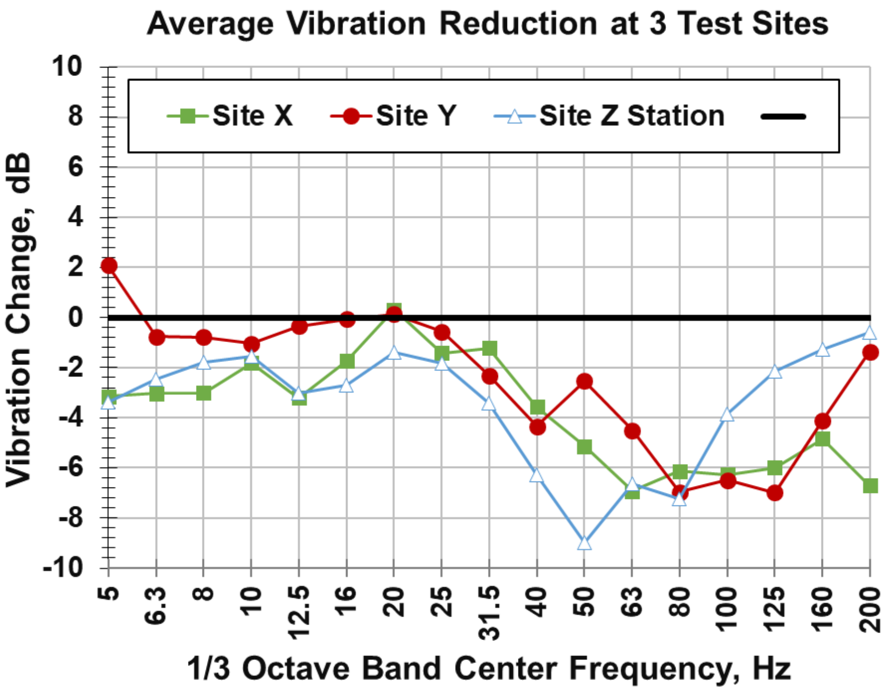
Measured 4-car LRV Noise Level at 50 ft from Seatac Test Site



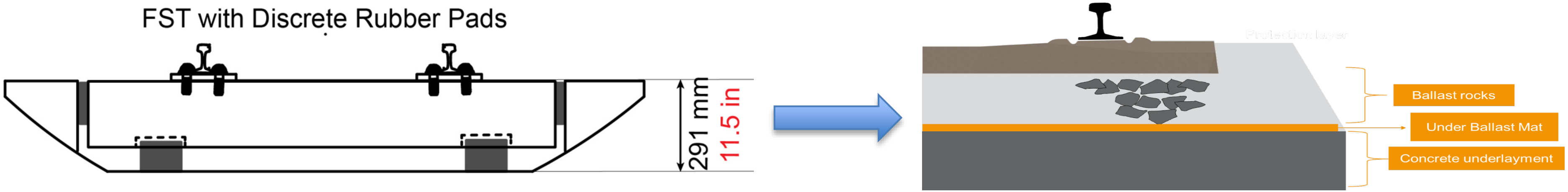
Reference 1-car LRV Noise Level at 50 ft



Vibration Reduction from Rail Grinding



Benefits of Good Rail Grinding Program



- Lowering train vibration signature through good rail grinding reduces vibration mitigation costs.
- In this example, a floating slab track recommendation was replaced with a ballast mats because of a good rail grinding specification

Embedded Track Rail Grinding Speeds

- It may not be practical to grind the embedded rails at speeds greater than 5 mph.

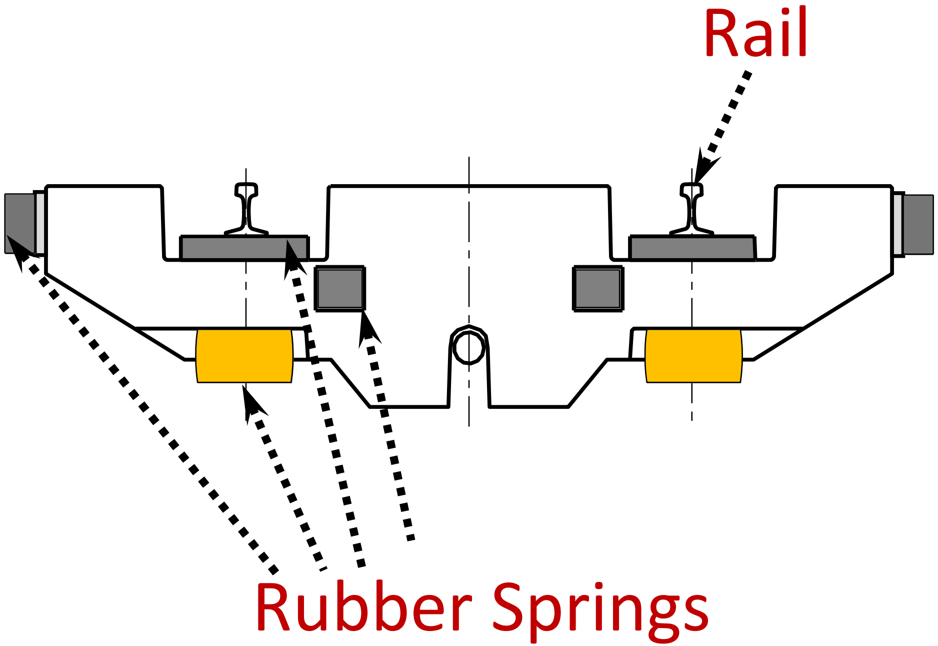
An approach used for a 3600 RPM grinder:

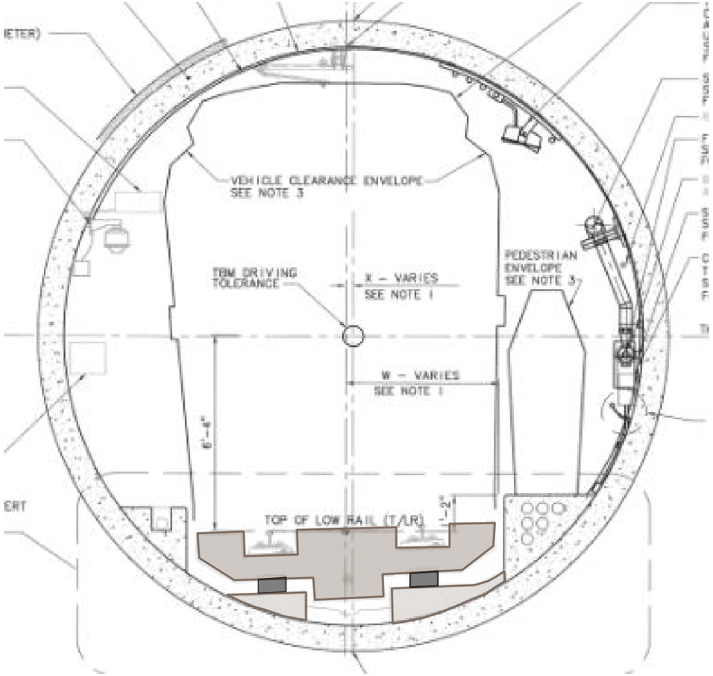
- **Grinding step** – use coarse stone and slower speed (**3 mph**)
- **Polishing step** – use softer stone and faster speed (**4.5 mph**)

Sound Transit's Grinding Strategy for Embedded Rail

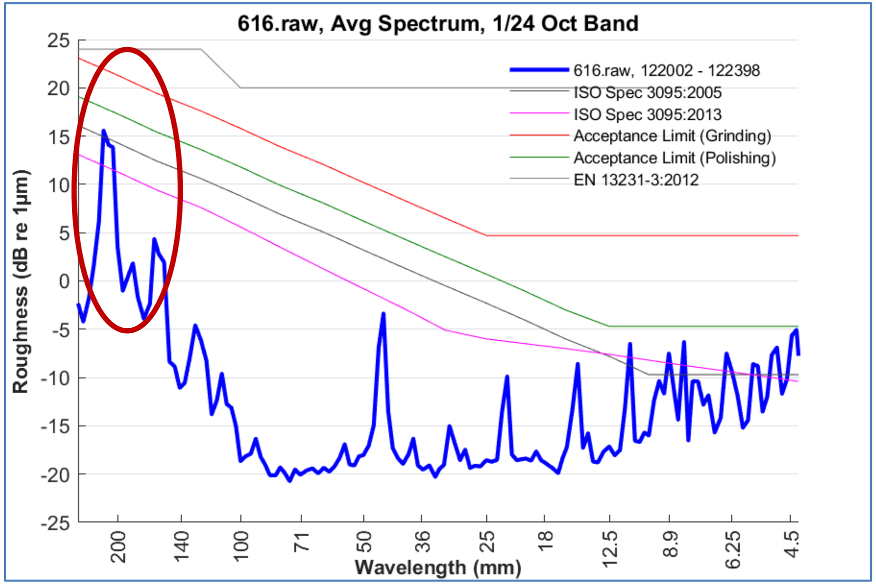
GIC Wavelength / Train Speed	24 mm	36 mm	40 mm	50 mm
30 mph	559 Hz	373 Hz	335 Hz	268 Hz
35 mph	652 Hz	435 Hz	391 Hz	313 Hz
40 mph	745 Hz	497 Hz	447 Hz	358 Hz

Rail Grinding for 5 Hz Floating Slab

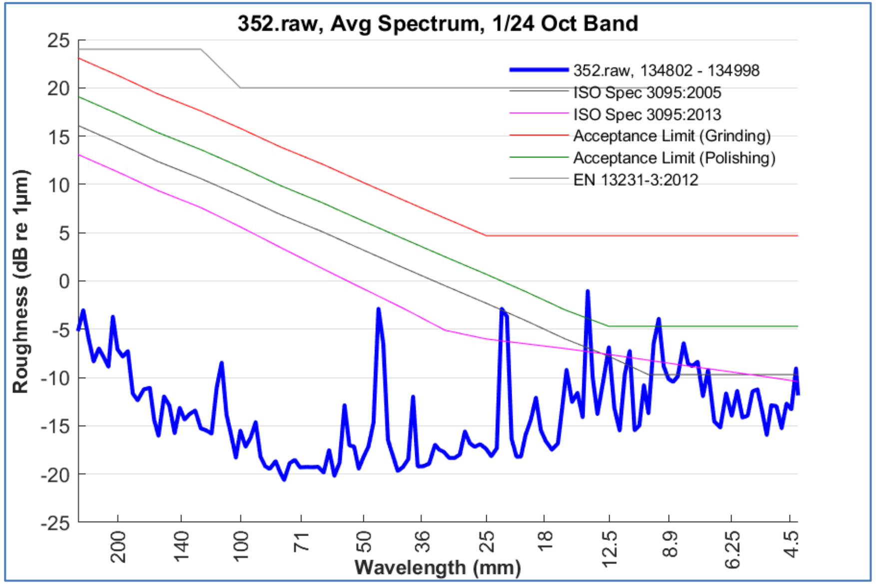




Rail Roughness on a 5 Hz floating Slab Track System

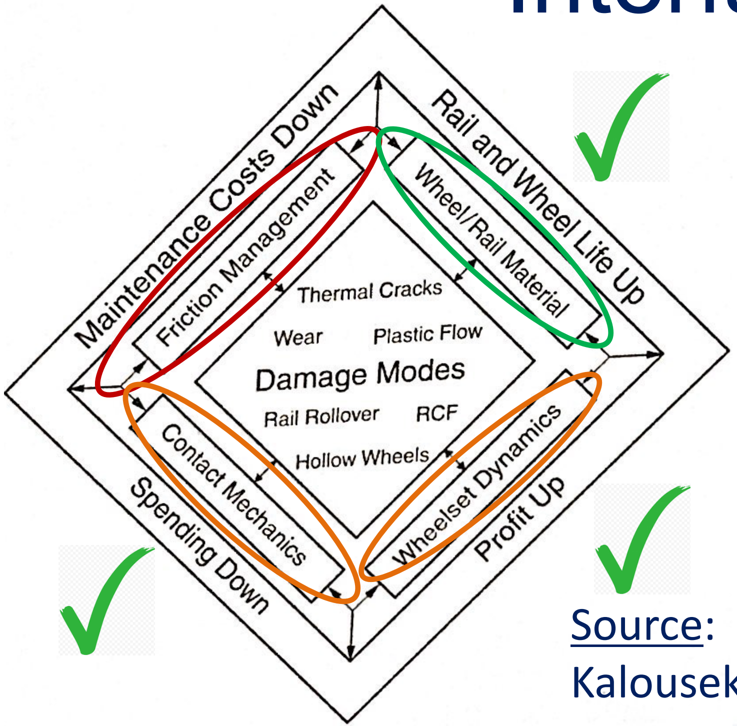


Floating Slab Track



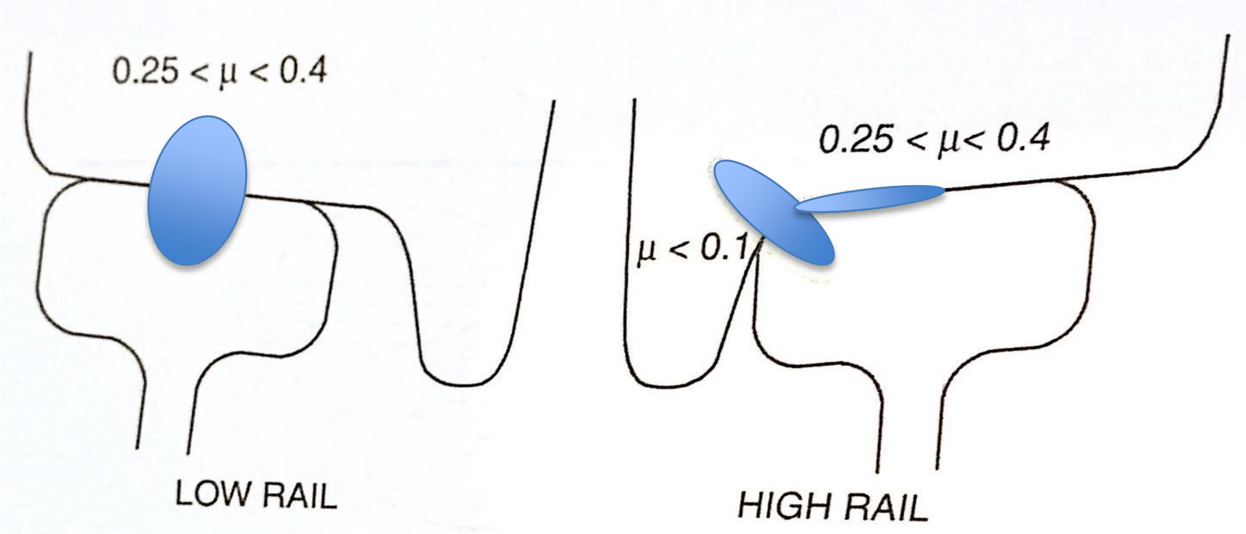
Standard Direct Fixation Track

Systems Approach to Wheel/Rail Interface R&D



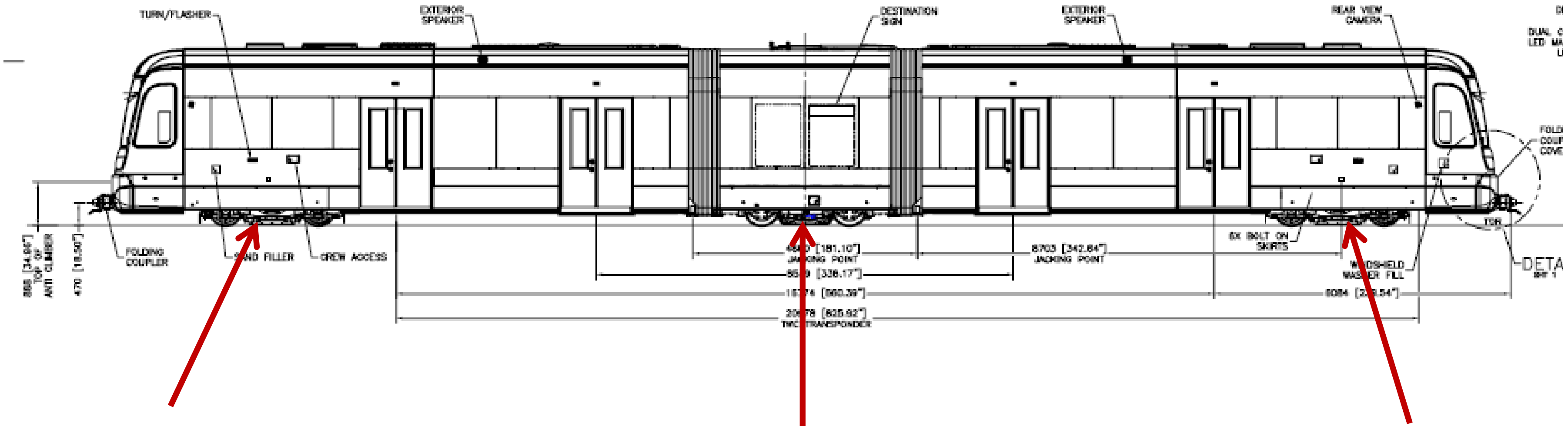
Source:
Kalousek, J., and Magel, E., Railway Track Struc., 93,..1997

Ideal Friction Coefficient in the Wheel-Rail Contact



Source: Iwnicki, S. (Ed.), Handbook of Railway Vehicle Dynamics. 2006

70% Low Floor Vehicle - Seattle



Power Truck (A-car)

Trailer Truck (C-car with Independent Rotating Wheels)

Power Truck (B-car)

Conclusion

- The advanced rail grinding program at Sound Transit showed 2 dB to 6 dB reduction in wayside noise.
- Direct correlation between grinding-induced corrugation and wayside noise was seen.
- The optimal grinder speeds for grinding and polishing steps depend on the grinder rpm and train speeds.

Conclusion

- A good rail grinding strategy to minimize the effect of Grinding Induced Corrugation on noise and vibration can result in significant savings in mitigation costs.
- A long-term wheel/rail strategy is critical for successful maintenance of the lower wayside noise and vibration levels.

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