Characterizing Effect of Rail Hardness on Corrugation Formation, Grinding Cycles, and Noise

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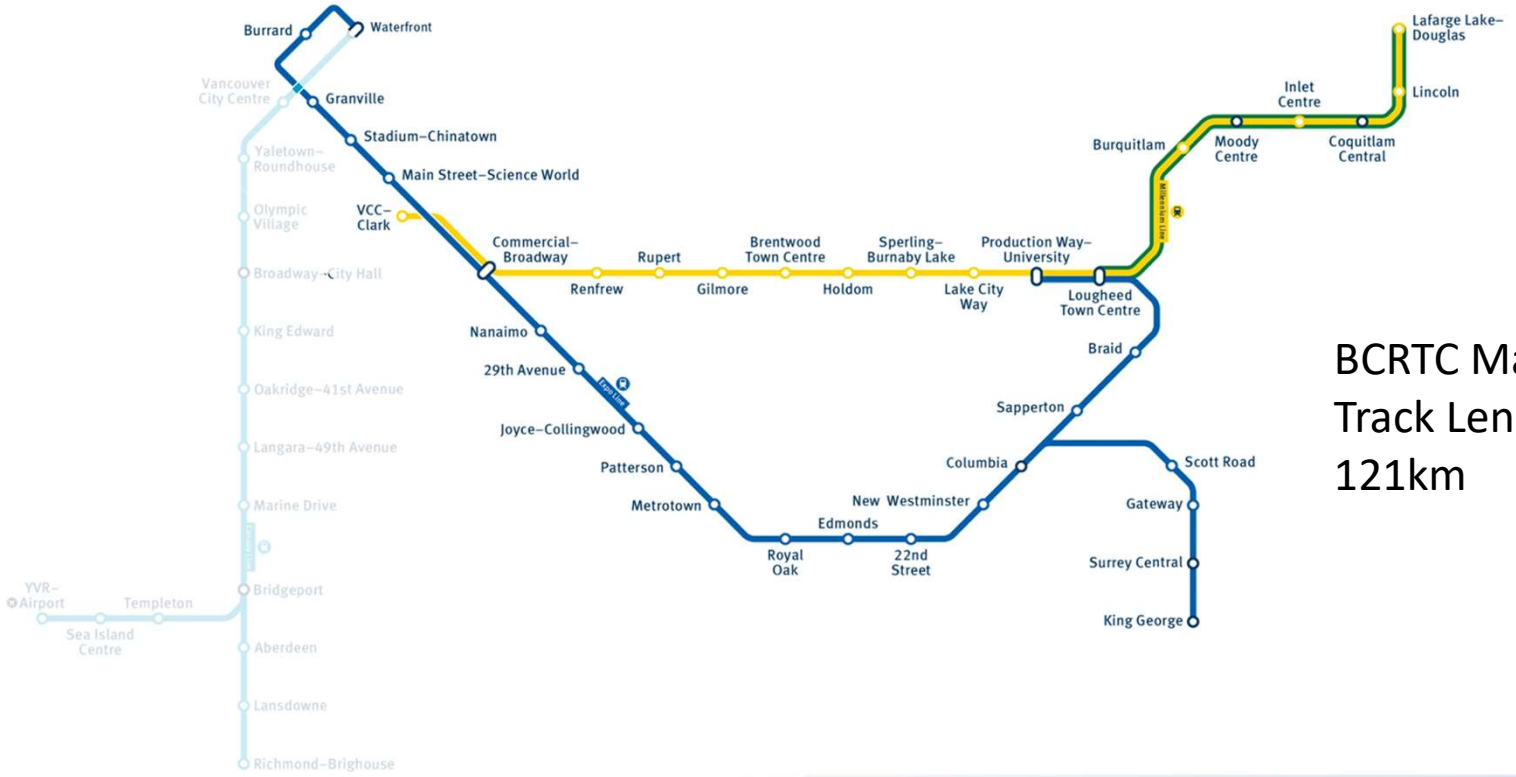
Acknowledgements

TRANS LINK

SLR

ARM ADVANCED RAIL MANAGEMENT CORPORATION 30 SERVING THE INDUSTRY 1990–2020

Vancouver SkyTrain (not incl. Canada Line)



BCRTC Mainline Track Length = 121km

Expo/Millennium Line Fleet

Mark I: 2-car units
UTDC
150 cars

Mark II: 2-car units
Bombardier
108 cars

Mark III: 4-car units
Bombardier
84 cars

Standard Features:

- LIM propulsion
- Steerable bogies
- Fully automated train control (driverless)

SkyTrain Noise Study:

- Initial trigger for 2018 study was noise complaints
  - High noise levels are harmful to overall population health in the long term
  - TransLink (Skytrain) wants to be a good neighbor

- Preliminary Assessment demonstrated some locations are quieter than others, proving improvements are feasible

- Noise is radiated by track and wheels, with dominant noise coming from the track due to impacts, rail roughness/corrugation

- Primary objective of study was to assess feasibility and cost-benefit perspective of (6) noise reduction strategies, which would result in actionable implementation plans and recommendations

Noise Mitigations Solutions Studied

★ Rail Roughness/ Corrugation Focused

Switch Maintenance

Guidelines for New Developments

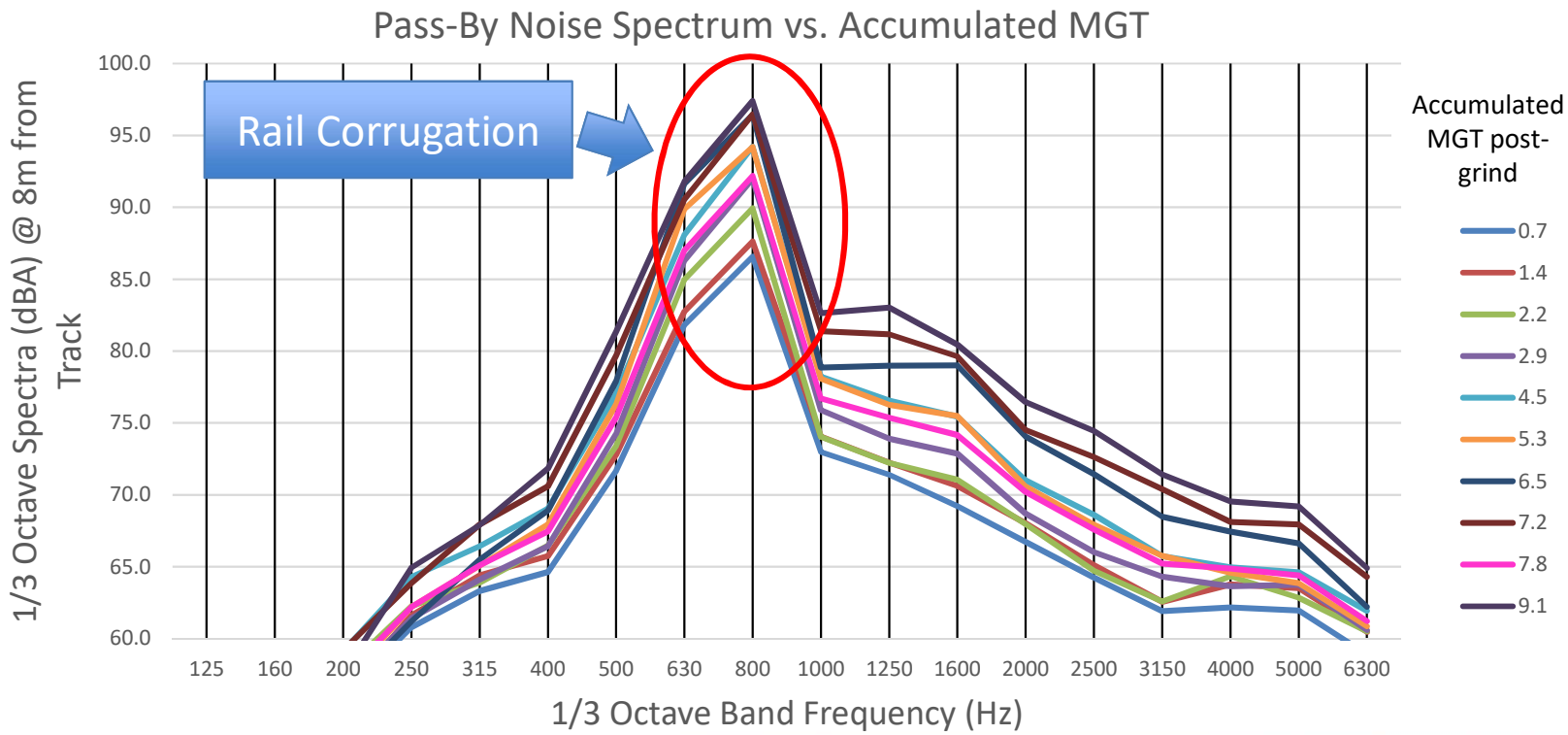
Top of rail friction modifiers ★

Rail Dampers (hotspots) ★

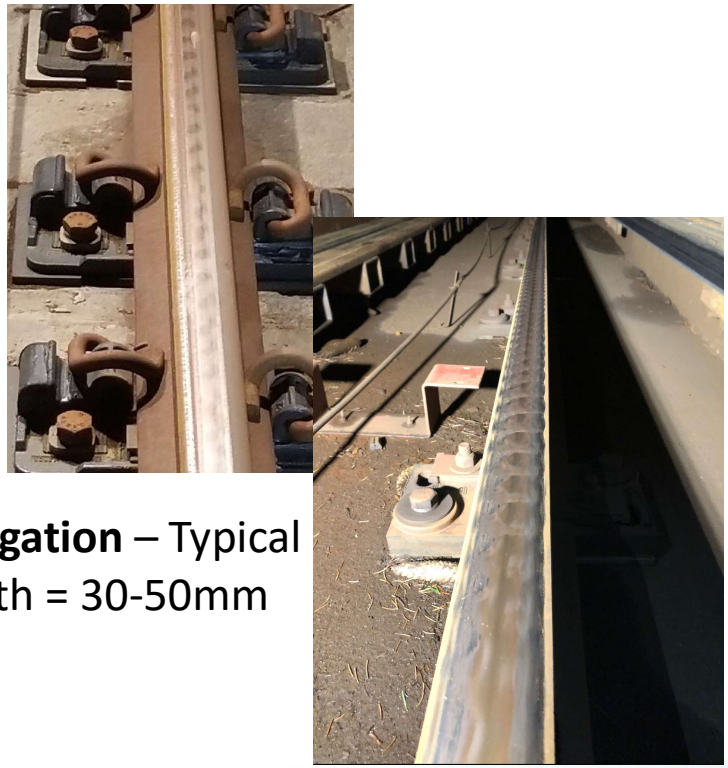
Harder Rail Steel ★

Rail grinding improvements ★

Wayside Pass-By Noise Example

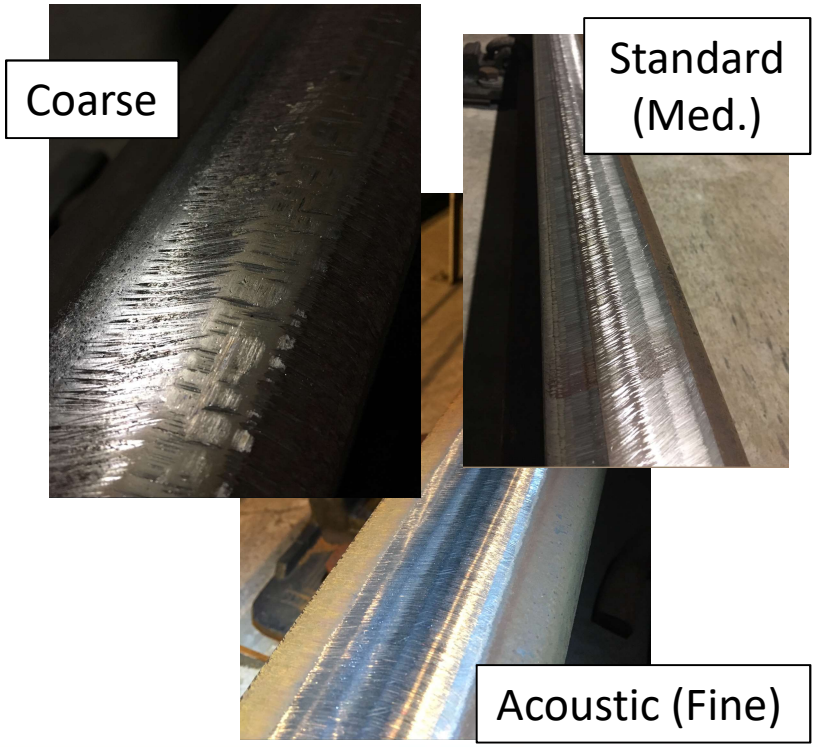


Rail Roughness – Corrugation and Grind Finish



Rail Corrugation – Typical Wavelength = 30-50mm

Grinding Finishes

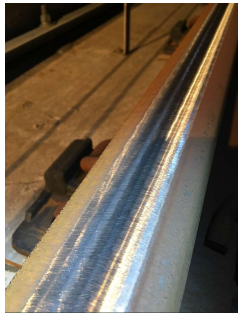


Rail Grinding Strategy

Key focus of Grinding at SkyTrain:

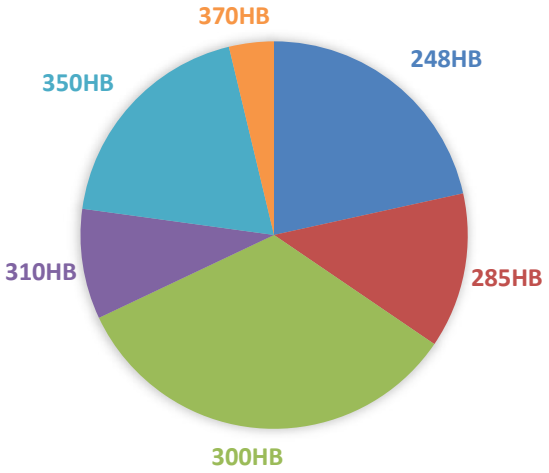
- Transitioning from Corrective to Preventative Grinding
- Focus on minor damage, corrugation, and profile
- Make use of in-house and contract grinding equipment
- Grinding Schedule currently on 2-year cycle
  - Highest Frequency is Quarterly
  - Lowest Frequency is Bi-annual
  - 125km ground per year (Average)

Photo Credit: ARM



Rail Hardness Across the System

Location/ Phase	Approx. In-service Dates	Specified Minimum Hardness (AREMA)	Measured Head Hardness (HB)	Approx. Track Meters
Expo Ph1	1986	248 (SS)	260-280	25,254
Expo Ph2/3	1990-1994	285(SS)	290-300	15,227
Millennium	2002	300 (SS)	290-310	39,253
Capital Re&Re	2015-2019	310 (SS)	335-345	10,795
Evergreen	2016	350 (IH)	345-355	22,379
Capital Re&Re	2020-2021	370 (HH)	365-380	4,389

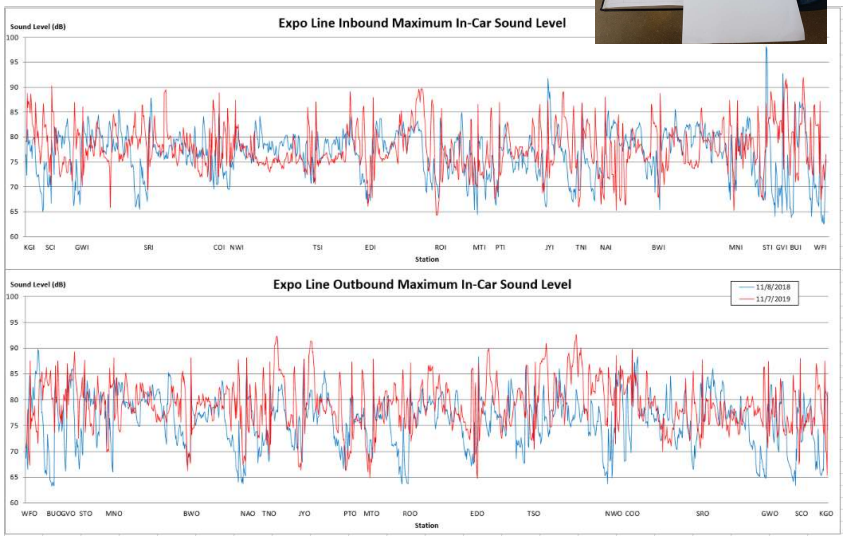


Data Collection Test Train

In-Car Noise

- Dedicated Test train loops system weekly
- Data correlated with train position and records highest dBA value per 25m segment

**In-car readings are good indicator of track condition week over week, but not directly proportional to exterior noise



Test Train Noise Analysis

Minimum Measured Head Hardness	Grind Freq. - X/year	Average of 10% noise (dB) - "Best Case"		Average of 90% noise (dB) - "Worst Case"		Average of 10%-90% Noise Range (dB)		Total Track Section Length (m)		Tonnage per Grinding Interval (MGT)	
		Tangent	Curve	Tangent	Curve	Tangent	Curve	Tangent	Curve	Tangent	Curve
260HB											
	4	77.05	75.48	86.48	85.07	9.12	9.29	4,800	2,424	3.88	3.88
	2	75.77	76.37	85.96	85.86	8.22	8.58	6,241	635	7.75	7.75
	1	76.97	76.52	87.55	85.38	9.49	8.29	4,931	2,943	15.50	15.50
300HB											
	1	76.49	75.40	84.14	83.21	5.67	6.11	4,696	3,773	8.70	8.70
310HB											
	4	76.06	74.63	81.89	81.47	5.66	6.57	25	227	3.88	3.88
	1	76.66	75.51	84.00	83.38	6.05	6.26	6,595	3,833	6.07	7.13
	0.5	77.02	77.18	84.76	84.33	6.74	6.79	11,491	3,165	9.40	9.40
330HB											
	1	75.99	75.53	83.32	83.94	7.15	8.03	407	884	15.50	15.50
350HB											
	1	77.15	76.87	84.56	84.63	7.32	7.62	203	531	15.50	15.50
	0.5	76.01	77.43	82.16	82.66	6.15	5.23	4,279	519	8.60	8.60
380HB											
	2	75.88	75.24	83.30	82.40	7.20	6.13	201	378	7.75	7.75
	1	76.18	75.61	83.75	82.50	5.11	5.01	273	824	15.50	15.50

Noise Test Train Dataset = 53 Runs over 2.5 years

Track Exclusions from dataset:

- Tunnels
- Switches
- Stations
- Speed < 70km/hr

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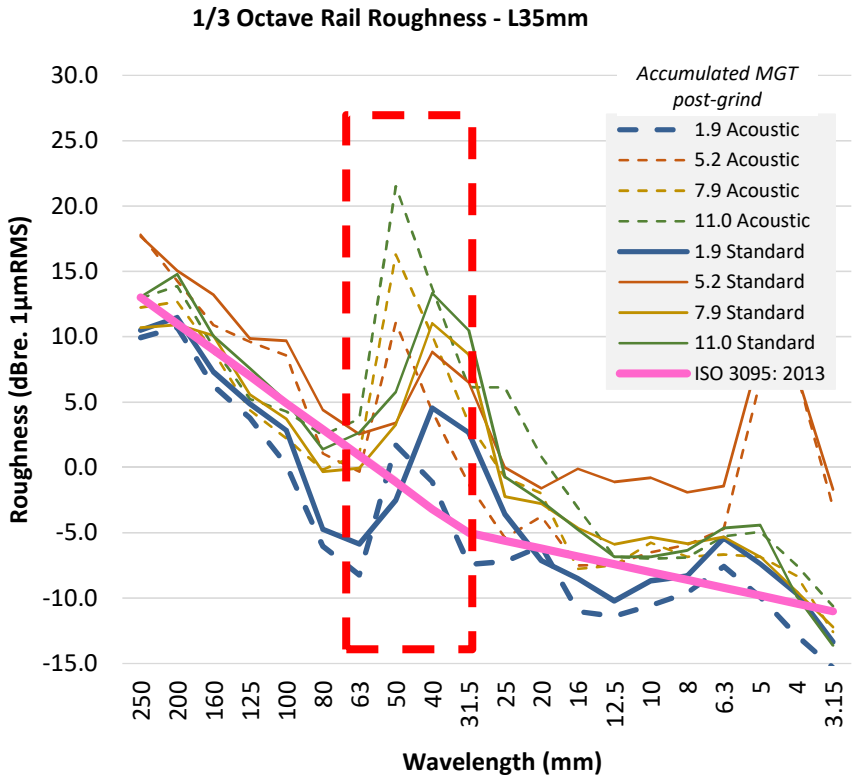
Test Train Noise Analysis Summary

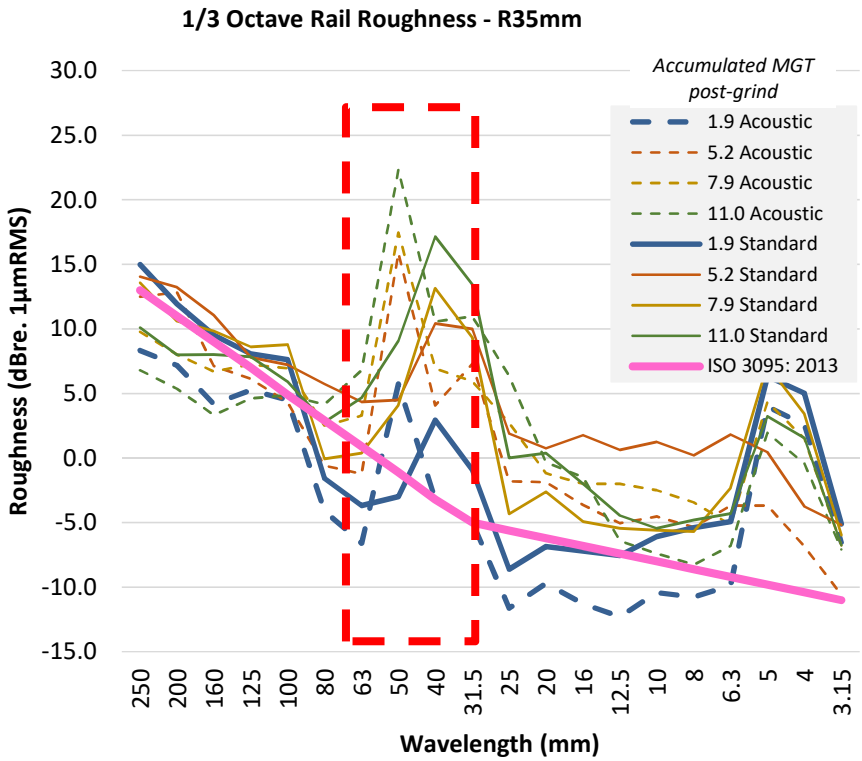
- 10th Percentile “Best Case” is same for all rail types, approx. 75-77dBA
- Difference Between 10th and 90th Percentile or “Range” represents grinding cycle
- When ranges compared against Accumulated MGT during grinding cycle, harder rail demonstrates noticeably less range in in-car noise increase with comparable MGT
- Summary of In-car Noise Range by rail Hardness:
  - Softer: 260HB Rail = 8-10dB
  - Mid-range: ~310HB Rail = 6-8dB
  - Hard :350+HB Rail = 5-6dB

Roughness Growth Analysis – CAT

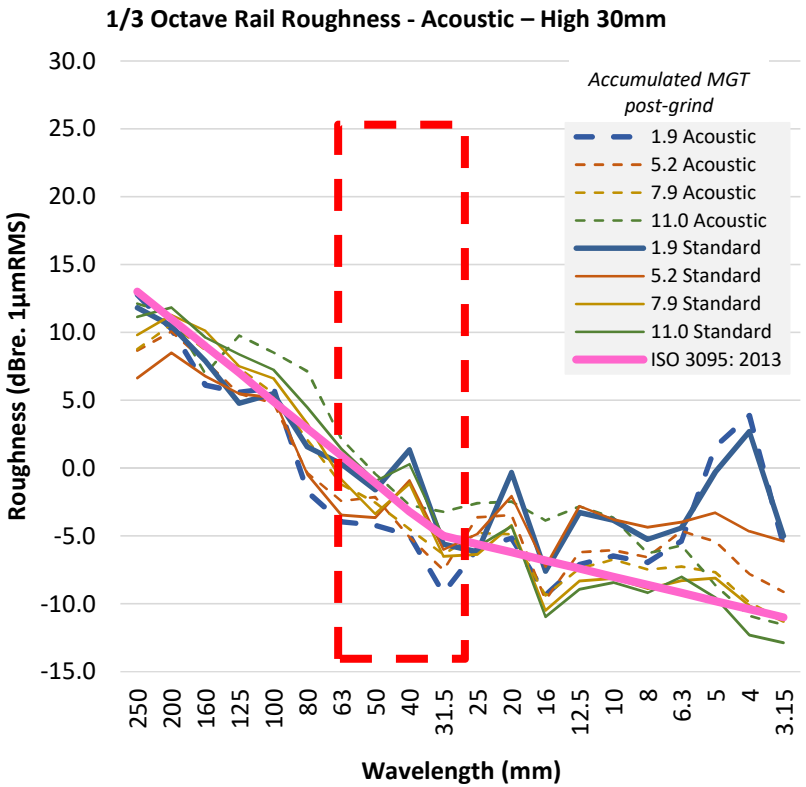
- 8 Sites Chosen based on varying rail hardness (Test Site = ~300m length)
- Test sites were split into halves and baseline ground “Standard” and “Acoustically”
- Each test site had monthly CAT measurements for approx. 10 months or approx. 10-11 MGT

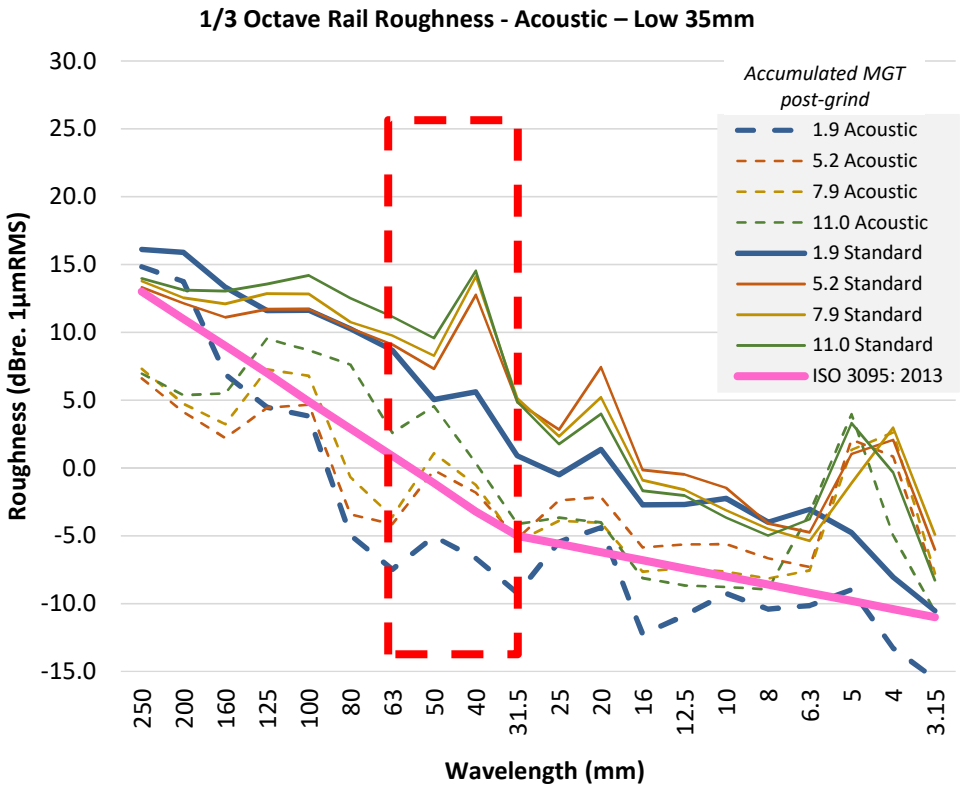
1/3 Octave Analysis of Roughness vs. Grinding Finish: **260HB**



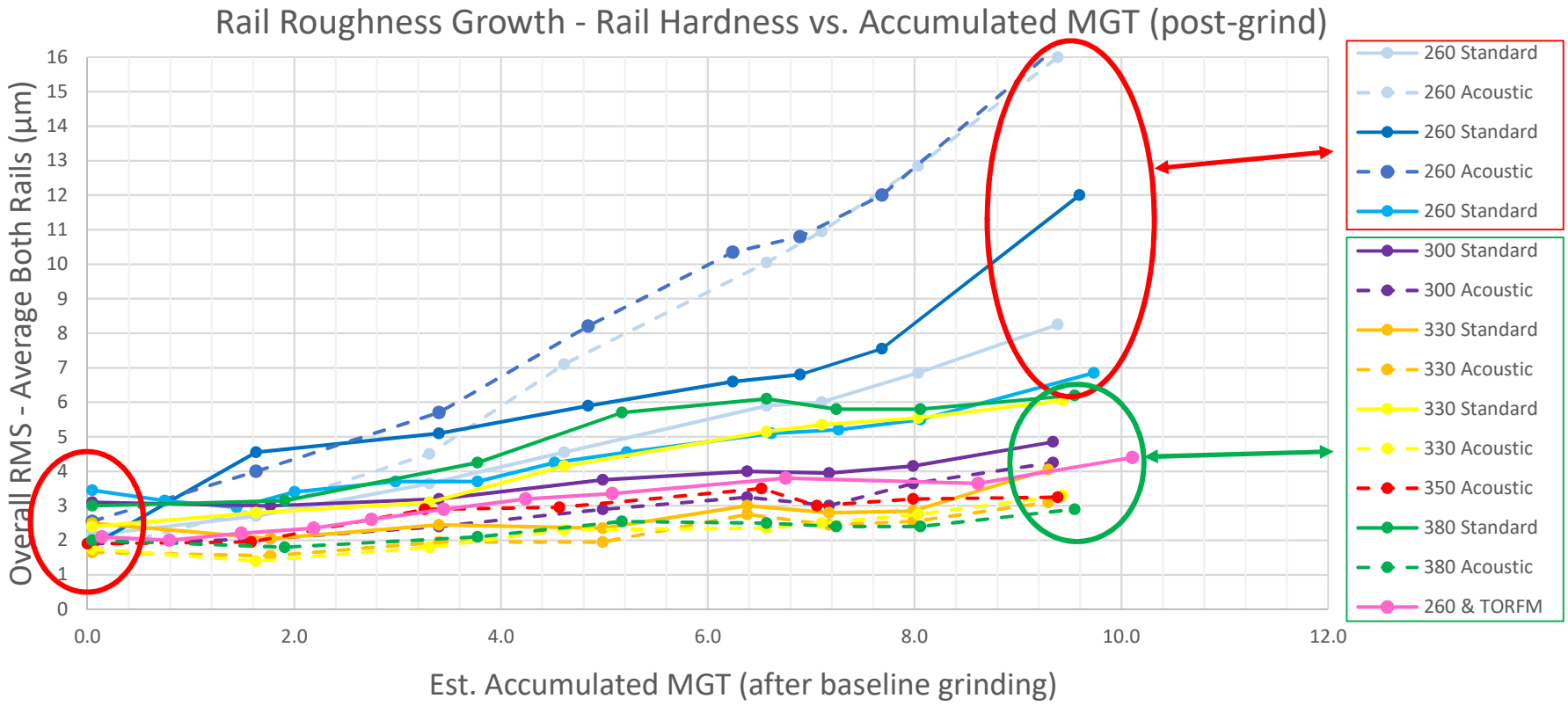


1/3 Octave Analysis of Roughness vs. Grinding Finish : **370HB**





Roughness Growth Analysis – 8 Test Sites



Corrugation and Roughness Analysis Summary

- Softer Rails Steels show rapid increase in overall RMS roughness over a short duration, specifically in known corrugation wavelengths of 30-50mm
  - Type of grinding finish does not show any benefit to reducing corrugation growth

- Harder Rail Steels demonstrate resistance to corrugation growth, and also generally maintain their “as-ground” finish

- Manipulating the dominant wavelength of grind signature (eg. 31.5mm vs. 50mm), results in dominant roughness forming at that wavelength

Benefits and Opportunities

- Review Spec of ongoing Running Rail replacement project
  - 3km rail/yr
  - Ongoing and budgeted

- Map Grinding program/schedule and apply acoustic grinding on existing harder rail where benefits are demonstrated

- Ability to review reduction of grinding in high frequency areas to remove corrugation
  - Maintenance Capacity and Asset Life

- Continue progress towards preventative grinding strategy, focus on MWR
  - Remove right amount of material at the right time

Risks and Concerns

Concern	Mitigation
Increasing Rail hardness may increase wheel wear	- Much of system already near 1:1 ratio of wheel-rail hardness - Gradual implementation (3km/yr or 2%) - Ability to move maintenance into car shop, rather than guideway
Concerns that Rolling Contact Fatigue (RCF) may not Naturally Wear Away with Harder Rail	- No significant RCF concerns on our system - Can't eliminate grinding, but work on achieving MWR, continue inspections, etc.
Concerns that an "acoustically rough" grinding finish may not seat in (smooth out) easily, or even at all	- Perform preventative grinding with acoustic parameters in areas where harder rail is installed

THANK YOU!