

Conformal frog retrofit to mitigate noise & vibration



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City of Ottawa O-Train System

Confederation Line (Line 1)

- 13 km (8 mi) electrified double tracked
- Alstom Citadis fleet, 100 kph max track speed
- In service since Sept 2019
- 30 to 35 MGTA

Trillium Line (Line 2)

- 8 km (5 mi) non-electrified single tracked
- Alstom Lint fleet, 85 kph max track speed
- In service since 2001
- 7 MGTA



Project Pre Conditions

Trillium Line (Line 2)

- 2001: pilot project with single siding
- 2015: two new sidings added
- 2016: residents issue formal complaints to City on excessive track noise and vibrations from nearby turnout
- 2016: permanent slow order of 55 kph to mitigate against noise / vibration at one siding
- 2017: added pressure for train operations requires increase transit speed to 85 kph



N&V Criteria

Noise Criteria

- City of Ottawa's Environmental Noise Control Guidelines (ENCG)
- Backyard: 55 dBA (daytime), 16-hour average
- Sleeping quarters: 40 dBA (daytime), 16-hour average
- Sleeping quarters: **35 dBA** (nighttime), 8-hour average

Vibration Criteria

- Vibration Criteria (VC) curves
- Root mean square (rms) of each one-third octave band from 1 Hz to 80 Hz
- Residential Day (ISO) limit is **200 $\mu\text{m/s}$**

Vibration Criteria	Max Velocity Amplitude ¹ $\mu\text{m/s}$ ($\mu\text{in/s}$)
Workshop (ISO)	800 (32,000)
Office (ISO)	400 (16,000)
Residential Day (ISO)	200 (8,000)
Residential Night (ISO)	140 (5,600)
Operating Theatre (ISO)	100 (4,000)
VC-A	50 (2,000)
VC-B	25 (1,000)
VC-C	12.5 (500)
VC-D	6.25 (250)
VC-E	3.12 (125)
VC-F	1.56 (62.5)
VC-G	0.78 (31.3)

Noise & Vibration Study

Setup

- Four locations: 2m, 8m, 11m and inside residence
- PCB 393A03 accelerometers (8 units)
- Bruel & Kjaer Analyzer Type 2250 Sound Meter

Noise Results

- Average maximum = 47 dBA \pm 1 dB
- Average equivalent sound (1 hour) = 36 dBA

Vibration Results

- Vertical: 16 $\mu\text{m/s}$ to 37 $\mu\text{m/s}$
- Perpendicular: 10 $\mu\text{m/s}$ to 15 $\mu\text{m/s}$
- Parallel: 13 $\mu\text{m/s}$ to 17 $\mu\text{m/s}$



Possible Mitigations

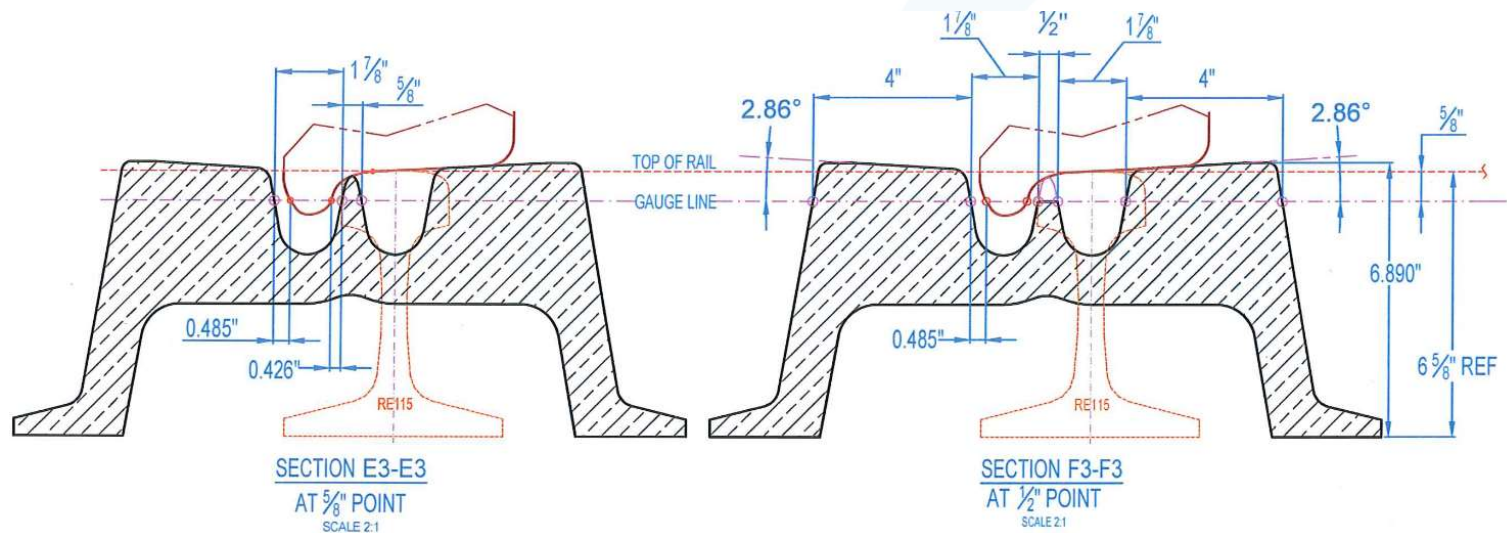
Predicted radiated sound pressure levels:

1. Under Sleeper Pads: -1 dBA, insufficient
2. Under Ballast Mats : -7 dBA, would require line shutdown
3. Isolation Trench (geo-foam):, width of 0.25m (10 in) and depth of 4m, -2 dBA above 63 Hz
4. New conformal frog: concern with long lead time to design & supply
5. Movable Point Frog: expensive mitigation and maintenance
6. Field retrofit of existing frog to a conformal design: results would be difficult to predict due to limited published field data, least expensive mitigation

Selected Mitigation

Field retrofit existing frog to a conformal design

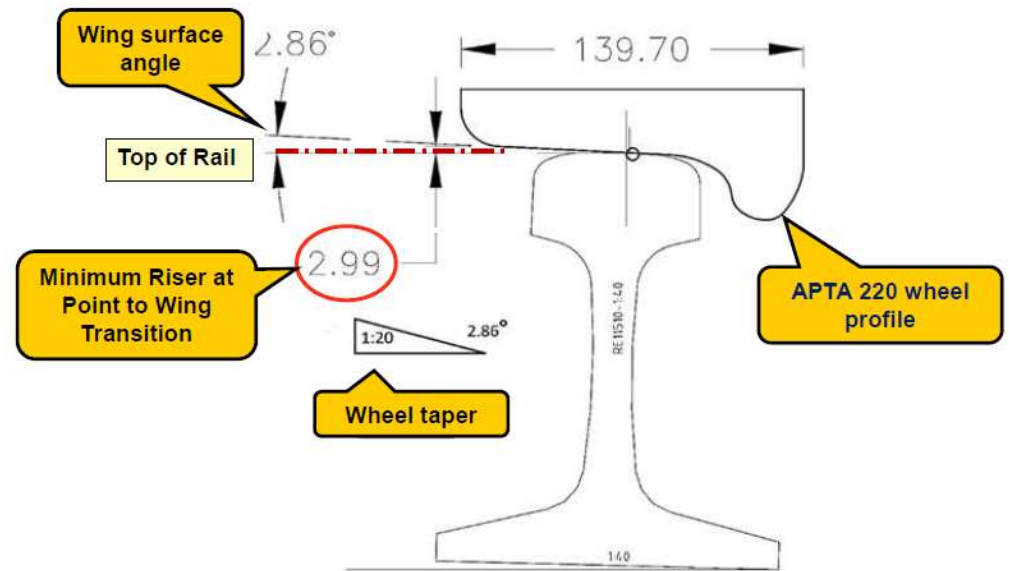
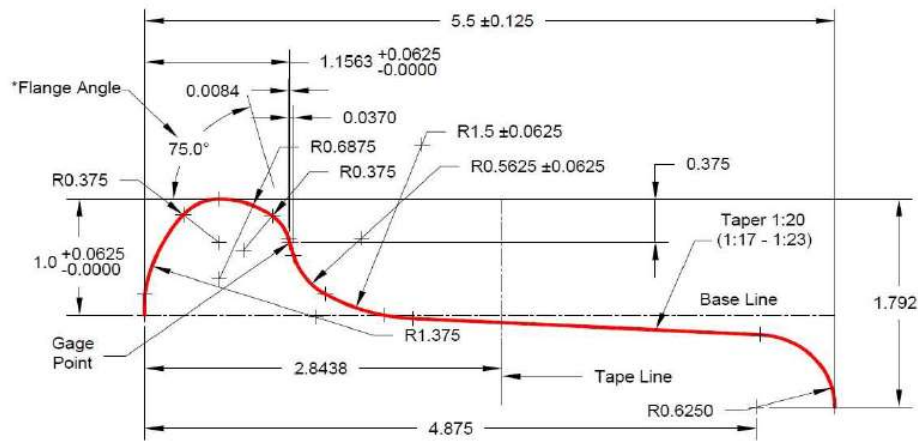
- Previously known as Wheel Matching Technology, currently marketed as Crossflo
- First developed by Bombardier on the JFK AirTrain to improve wheel rail interface
- Most suitable for single wheel profile across fleet
- Objective of maximizing the transition from the wing rail to the point rail



APTA 220 Wheel Profile – Frog Transition Requirement

B.5 APTA 220 Wheel Profile

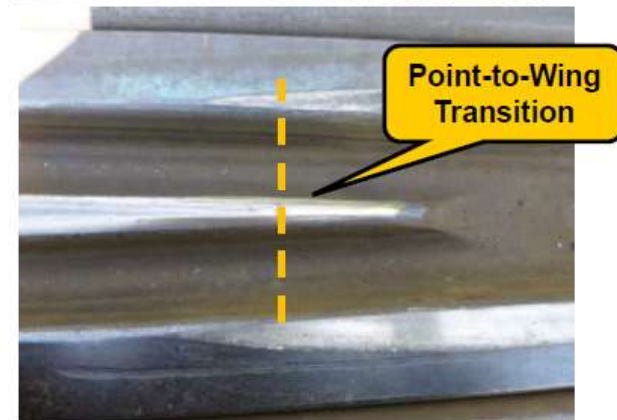
Based on AAR-1B (AAR S-669), 1:20 taper, modified for 5.5 inch wheel width.



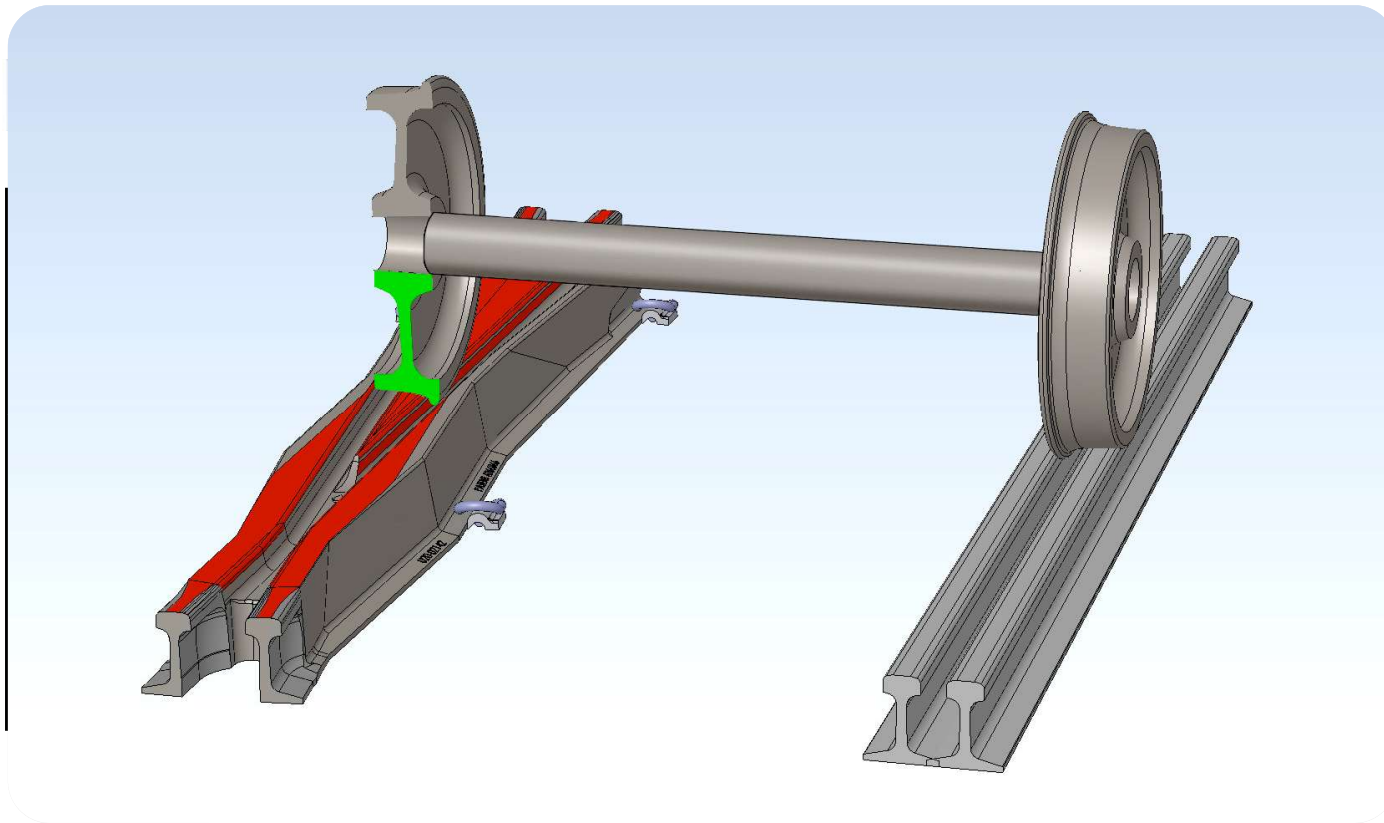
Brookfield - No. 15 Crossover Frog (July 15, 2019)

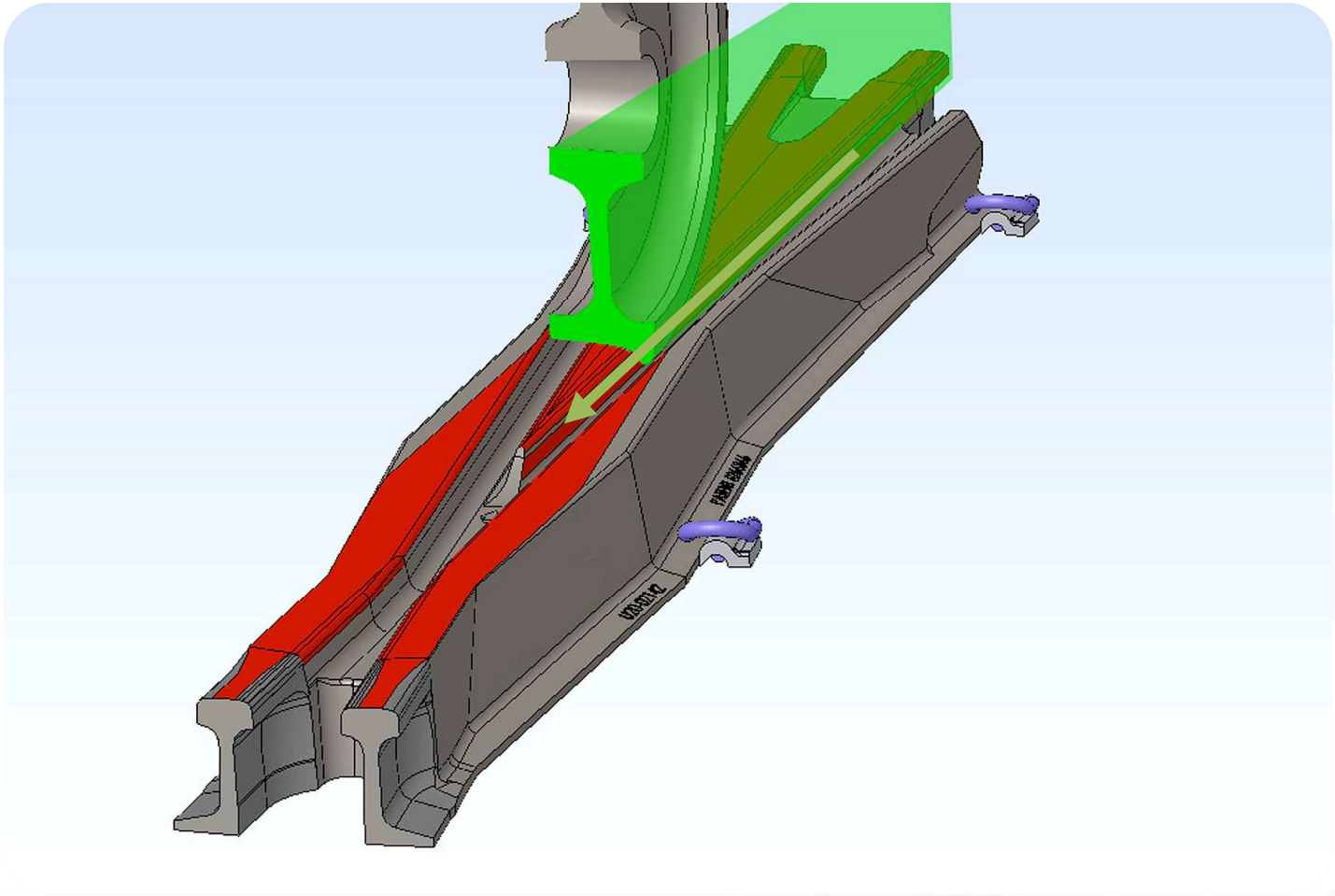


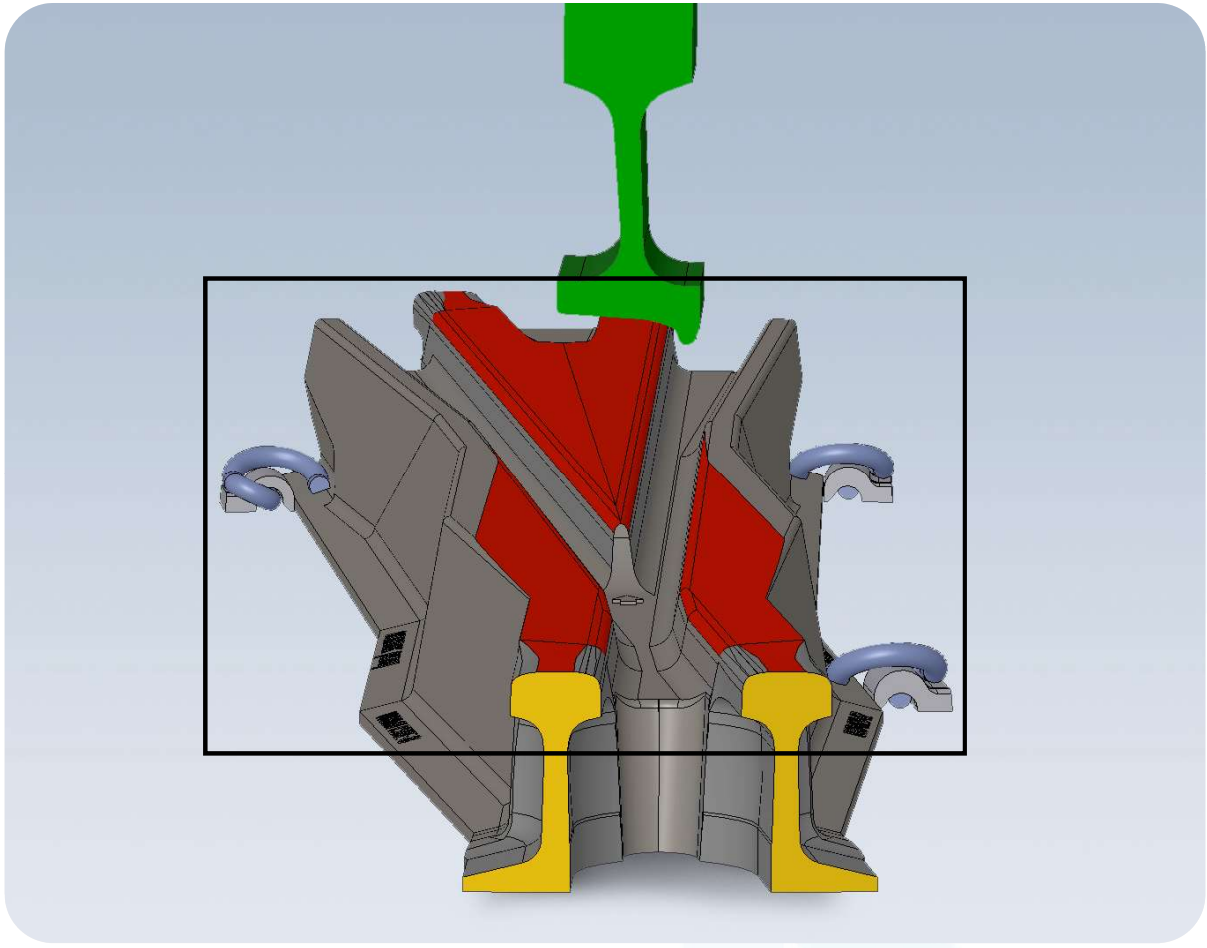
1. For smooth trackwork crossings, contact transitions should be shared and at least 50mm long
2. Sudden transitions and noticeable wear at Point and Throat indicating high wheel/rail impacts

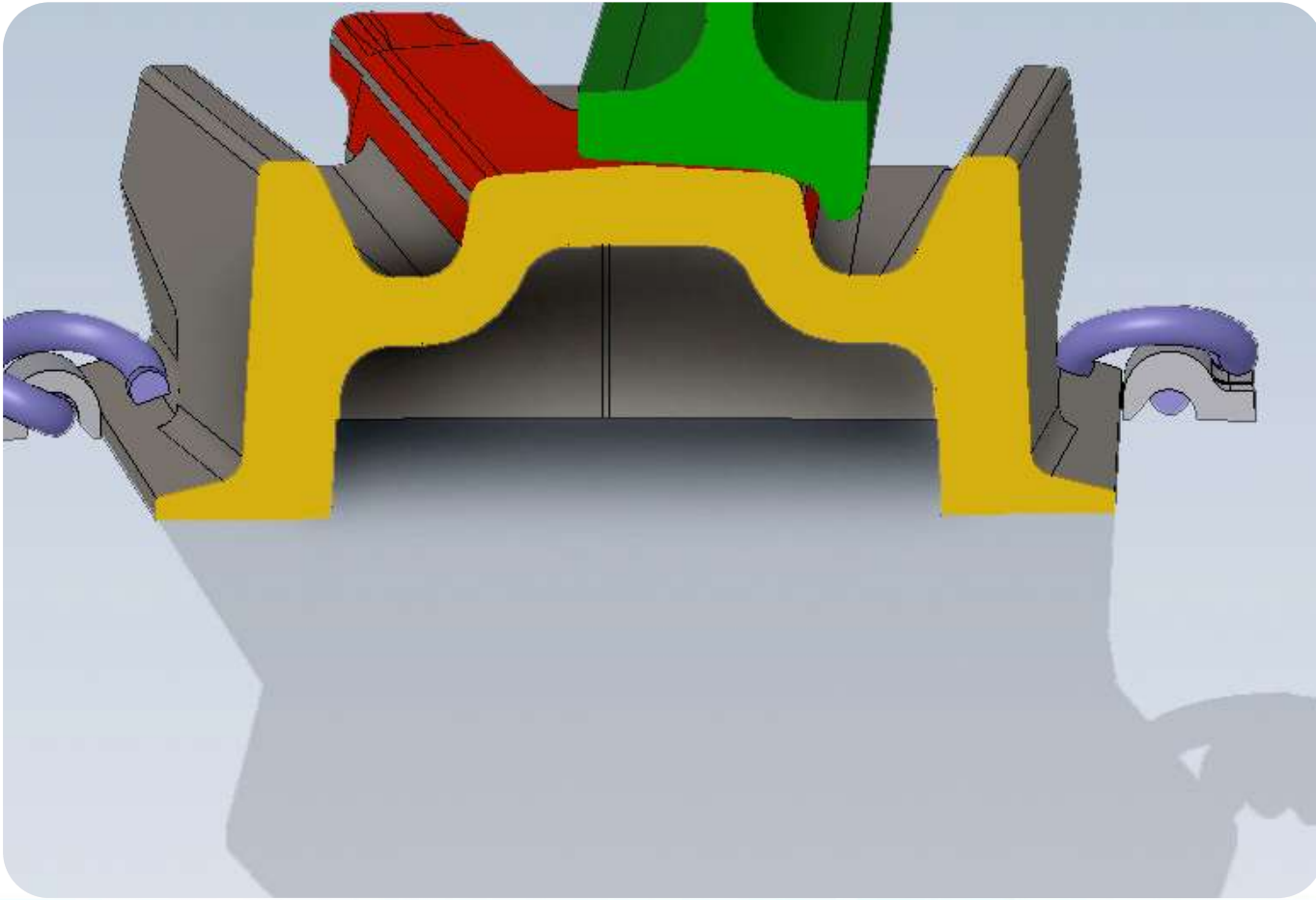


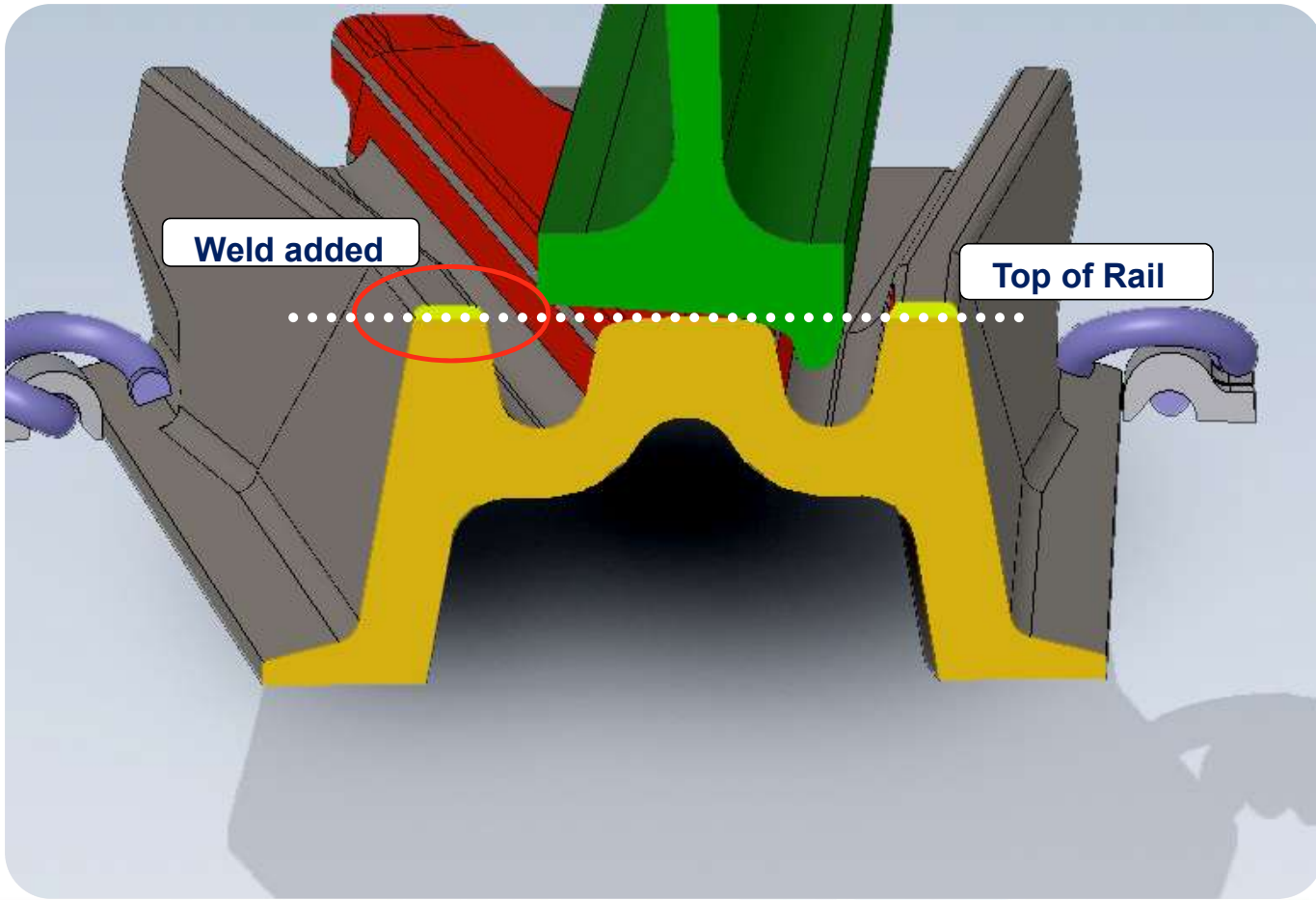
What is a Conformal Frog ?

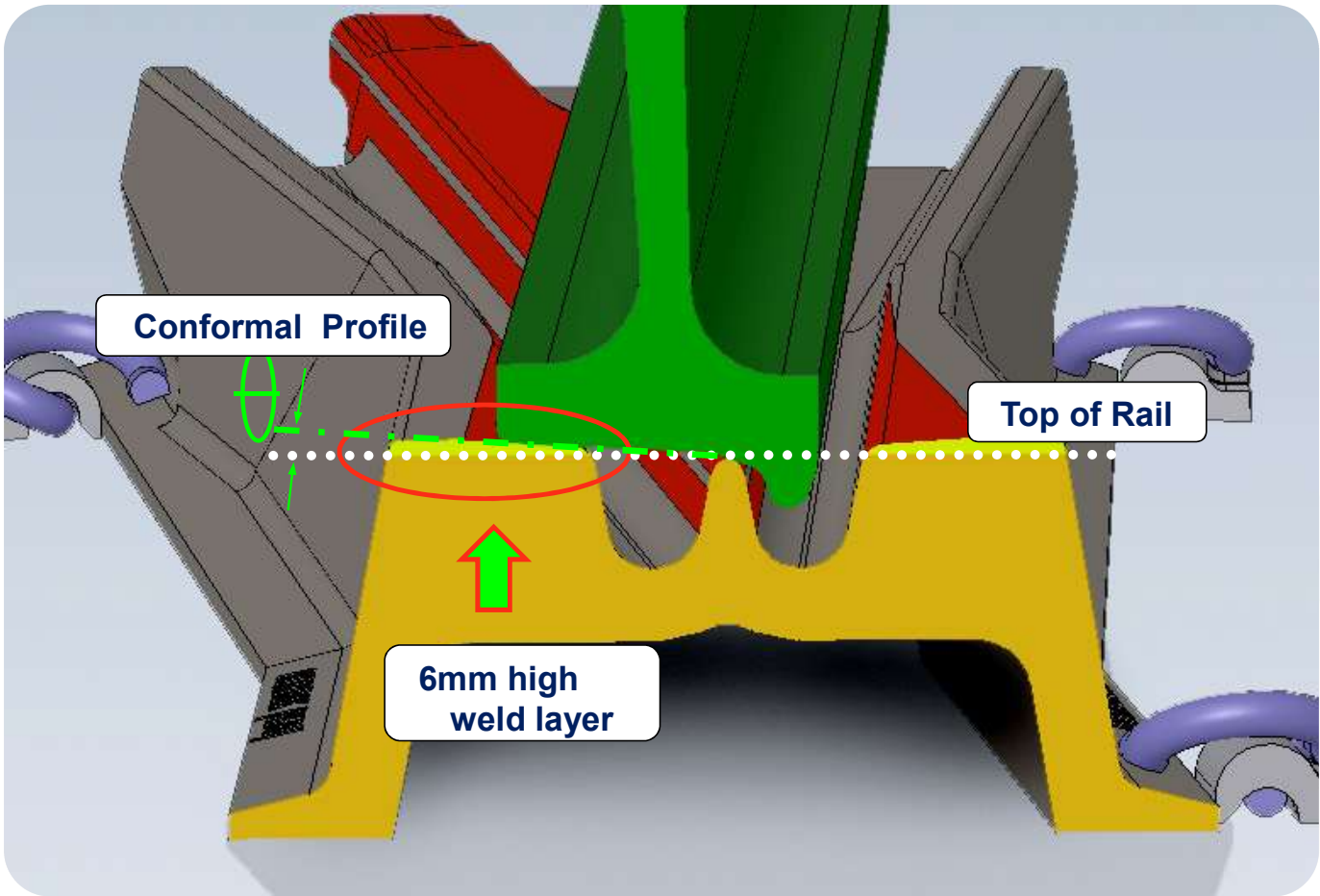


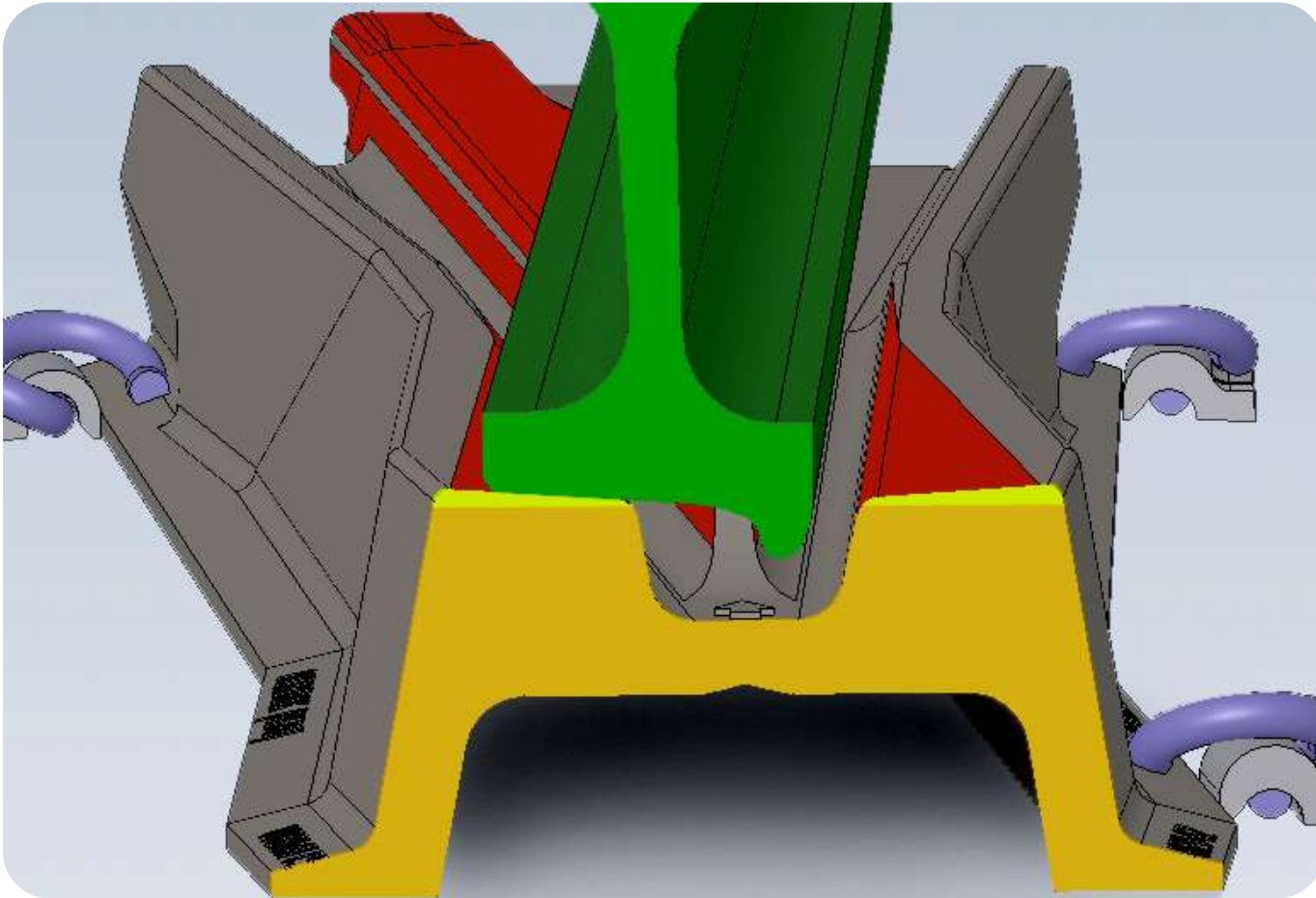
















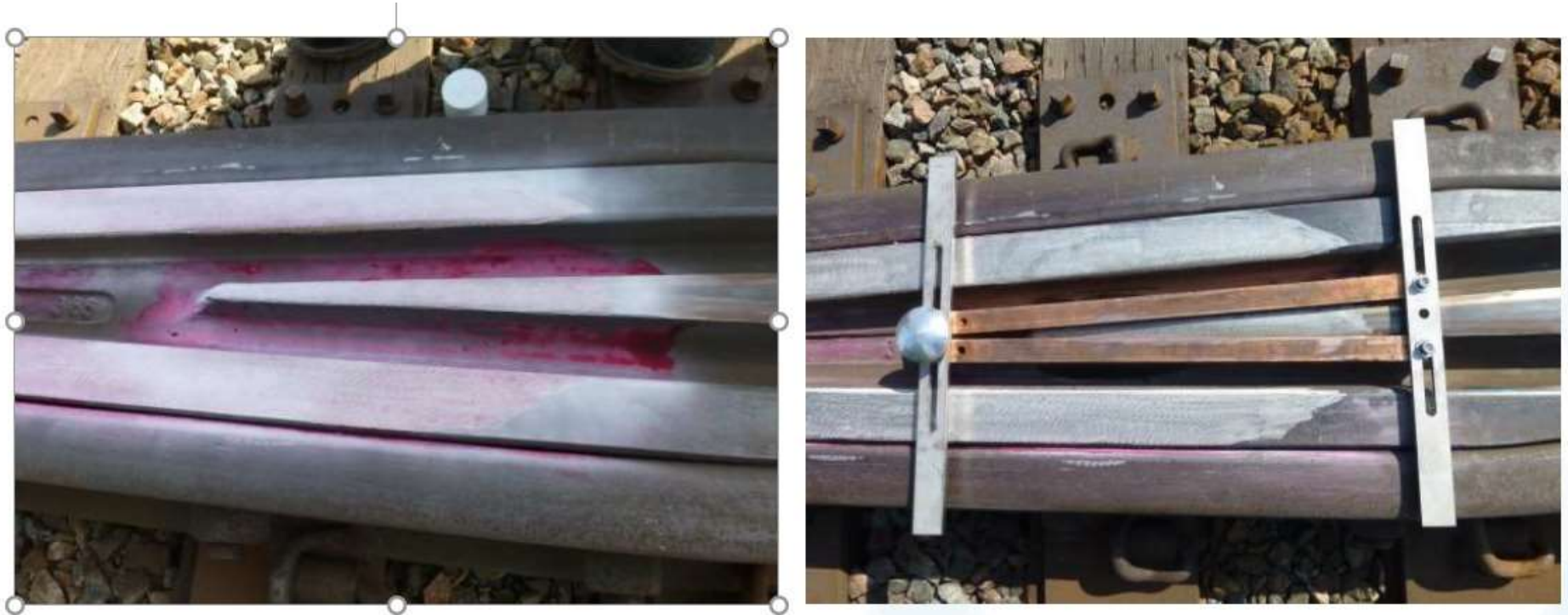
Repair Process- pre-grinding



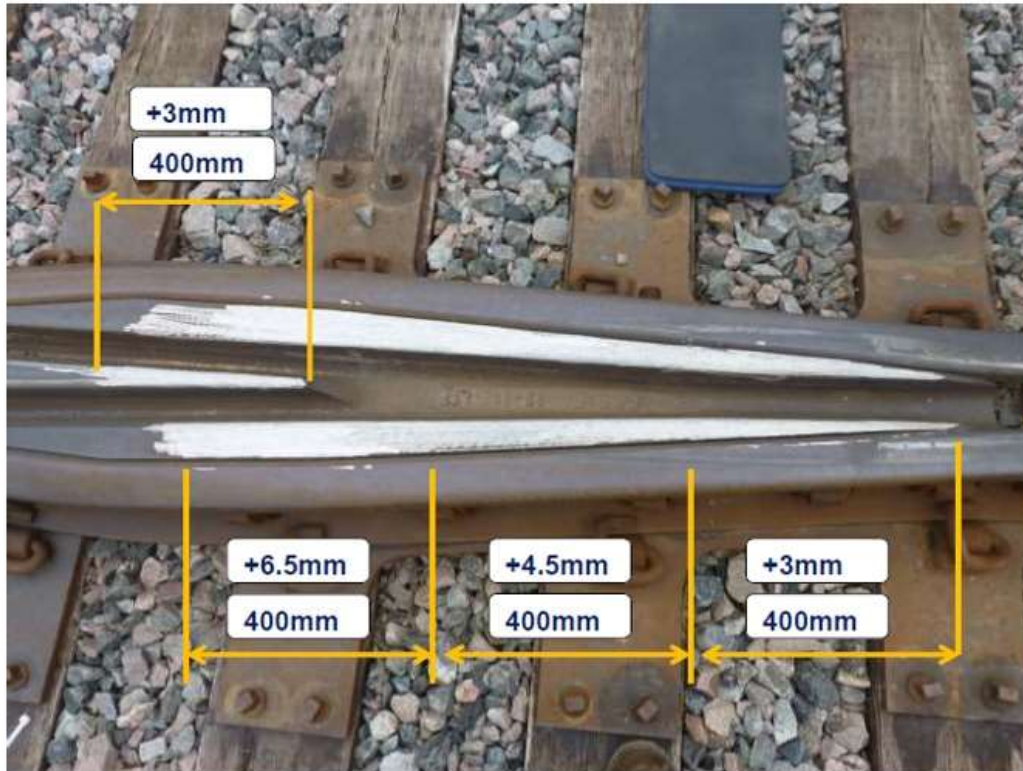
Apply straight hand grinder to remove surface hardness and defects including minor cracks – target measured hardness 300HB (+/- 30).



Repair Process- NDT Inspection and Point Welding Jig



Frog Repair Process- welding layering



Repair Process- WMT Frog Profiling Platform (1.6m linear slide)



Repair Process- finished Conformal Frog



Post Mitigation Results

Operational Changes:

- Speed restriction removed
- Speeds increased from 55 kph to 85 kph

Noise Improvement

- Pre maximum sound pressure level: 47 dBA @ 55kph
- Post maximum sound pressure level: 43 dBA @ 85 kph

Vibration Improvement:

- Average reduction of 40% in vibrations

Sensor Location	Direction	Average Maximum Measured 1/3 Octave Velocity Level		Δ (%)
		Pre	Post	
2m	Vertical	919	603	-52%
	Perpendicular	1237	1707	28%
	Parellel	1924	1789	-8%
8m	Vertical	282	156	-81%
	Perpendicular	193	129	-50%
	Parellel	329	210	-57%
11m	Vertical	72	73	1%
	Perpendicular	193	167	-16%
	Parellel	333	146	-128%