Effect of Fixed Structures on Rail Stress Management: Numerical Modeling and a Pilot Field Study

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Introduction

- Improper management of rail neutral temperature (RNT) can raise the risk of pull-aparts or buckles
- Fixed structures (FS) (e.g., turnouts and diamonds) restrict longitudinal rail movement, which can lead to differential displacement and RNT change
- This research aims to improve rail safety by assessing longitudinal rail stress at/near fixed structures to help update RNT adjustment practices
- How might Fixed Structures impact the RNT?
  - Hypothesis 1: Maintenance – after a rail break or cut near a FS, the rail cannot be pulled out. This would lead to non-uniform RNT (i.e., elevated RNT near the cut and reduced away from it) after the new weld
  - Hypothesis 2: Operations – the high longitudinal resistance of the FS restricts normal longitudinal rail creep, causes "bunching", which consequently leads to an RNT drop near the structure

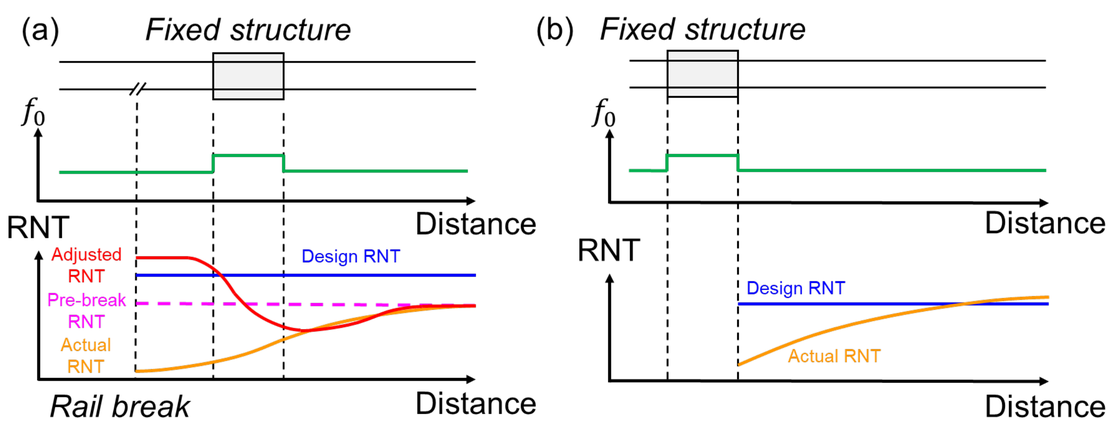

Figure 1. Potential ways that FS impact RNT, (a) RNT improperly set at weld, (b) long-term change over time due to differential rail migration

Methodology

- To test Hypothesis 1, Illi3D, a validated 3D finite element model, simulated single rail breaks (SRB) near FSs
  - It quantified how variables affect rail gap size, a key input into the RNT restoration process (Table 1)
  - Parameters investigated by Illi3D:
    - temperature differential (dt) (i.e., RNT – rail temperature),
    - FS length (FSL),
    - cut distance to FS (D), and
    - anchoring patterns (ETA, and EOTA)
- To test Hypothesis 2, a pilot field study monitored RNT over time near a structure at two locations: one near a FS and one 305 m (1000') away on the same track (i.e., open track (OT)) (Figure 2)
  - Longitudinal rail stress circuits quantified RNT change
  - An unmanned aerial vehicle (UAV) captured images of the track to quantify relative longitudinal rail movement
  - Data comparing longitudinal rail stress and relative rail displacement data are shown in Figure 3

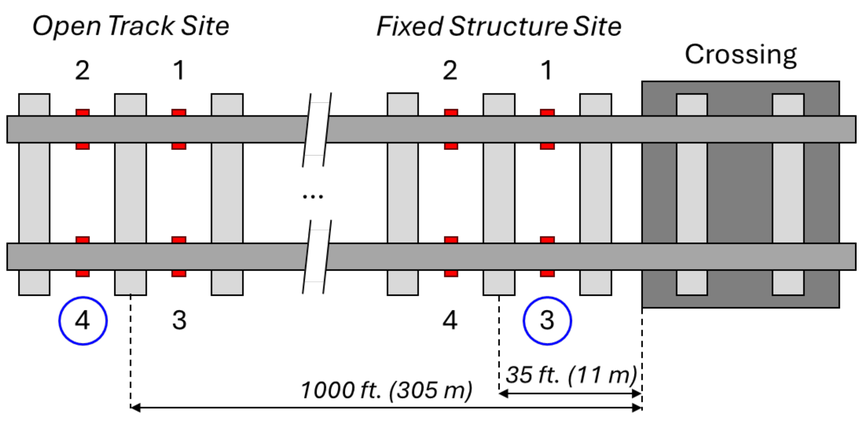

Figure 2. Generic view of the site instrumented with longitudinal track circuits

Results

Table 1. Gap differences (ΔGap) between OT and track with FS.

Gap Difference (mm (in.))	D (m (ft.))	FSL (m (ft.))	Anchoring	dT (°C (°F)) 5.6 (10)	22.2 (40)	44.4 (80)	66.7 (120)
Hypothesis 1: Maintenance	106.7 (350)	6.1 (20)	ETA	0 (0)	0 (0)	-3 (-0.1)	-14 (-0.5)
			EOTA	0 (0)	0 (0)	-13 (-0.5)	-14 (-0.6)
		18.3 (60)	ETA	0 (0)	0 (0)	-4 (-0.2)	-24 (-0.9)
			EOTA	0 (0)	0 (0)	-16 (-0.6)	-36 (-1.4)
	61 (200)	6.1 (20)	ETA	0 (0)	0 (0)	-11 (-0.4)	-20 (-0.8)
			EOTA	0 (0)	-2 (-0.1)	-21 (-0.8)	-21 (-0.8)
		18.3 (60)	ETA	0 (0)	0 (0)	-14 (-0.5)	-45 (-1.8)
			EOTA	0 (0)	-3 (-0.1)	-30 (-1.2)	-59 (-2.3)
	Edge Cut	6.1 (20)	ETA	0 (0)	-5 (-0.2)	-21 (-0.8)	-28 (-1.1)
			EOTA	0 (0)	-10 (-0.4)	-29 (-1.2)	-29 (-1.2)
		18.3 (60)	ETA	0 (0)	-7 (-0.3)	-36 (-1.4)	-72 (-2.9)
			EOTA	0 (0)	-12 (-0.5)	-56 (-2.2)	-85 (-3.4)

Color shading indicates ΔGap >0.3" (6 mm)

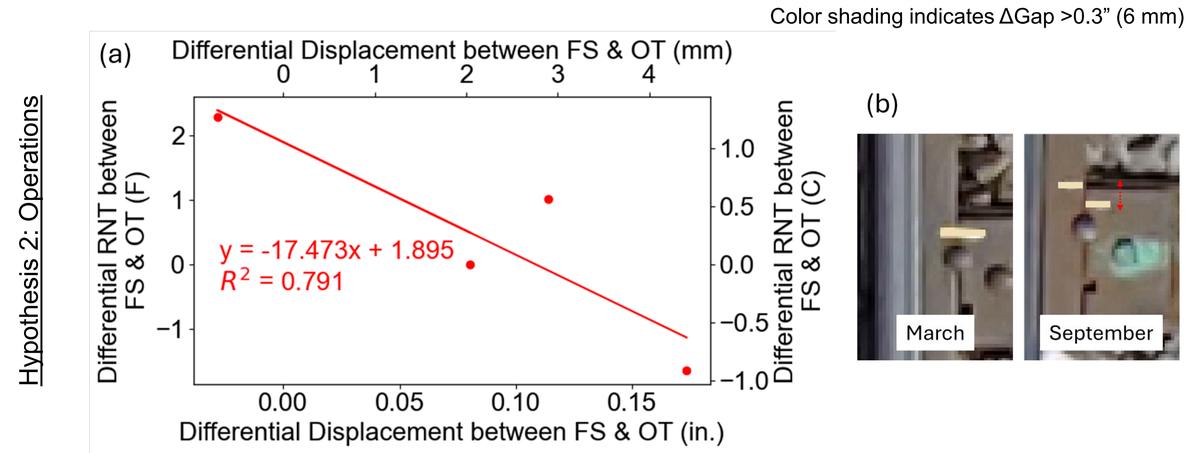

Figure 3. (a) RNT change and rail displacement comparison between FS and OT, and (b) relative displacement of rail to crosstie captured by UAV imaging

Conclusions

- Fixed structures can influence RNT during some maintenance/rail break events
  - Rail gap size is affected when the cut occurs with the right combination of dT, proximity, and FS length.
    - Rail gap is not impacted if dT < 22 °C (40 °F) unless cut/break occurs at the edge
    - Rail gap is impacted if dT > 44 °C (80 °F) when cut/breaks occur up to 107 m (350 ft.)
- Fixed structures can also influence RNT with normal operations
  - There was a relationship between differential rail displacement and differential RNT
- Therefore, railroads should consider:
  - Different CWR management guidelines for open track and track within proximity of a FS
  - More frequent monitoring near FS (compared to open track) to proactively identify and address areas with reduced RNT

Future/on-going Work

- Gather additional data to confirm preliminary conclusions:
  - Differential longitudinal rail displacement is being monitored on 76 rails on 38 tracks near 26 structures to quantify RNT changes during normal operations
  - Additional sites will be monitored with rail stress circuits to develop relationships between differential rail creep and RNT change
  - Quantify impact of de-anchoring length on RNT variation with time
- A dynamic 3D Finite Element Model (FEM) is in development to accurately evaluate the effect of non-uniform longitudinal resistance on rail gap size

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