Bolted Rail Joint Modeling and Experimentation

FRA and FTA Crosstie and Fastening System Research Program

Industry Partners (IP) Meeting

Bonita Springs, Florida

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WSP | PARSONS BRINCKERHOFF

RAILTEC
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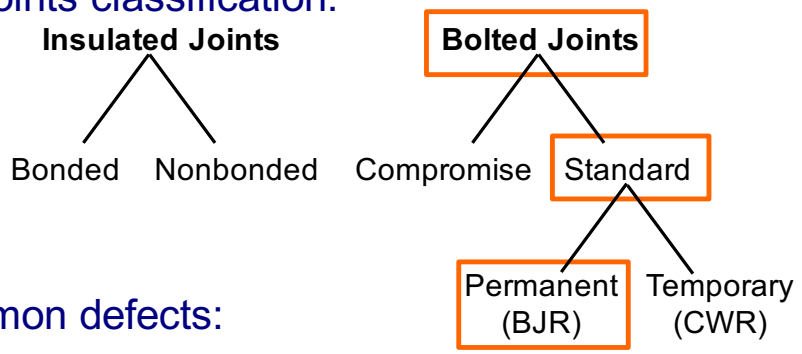
MTA New York City Transit

Presentation Outline

- Problem Statement and Scope of Work
- Finite Element Analysis Results Summary
- Laboratory Experimentation Plan

Background and Problem Statement

- Rail joints classification:



- Common defects:

End Batter

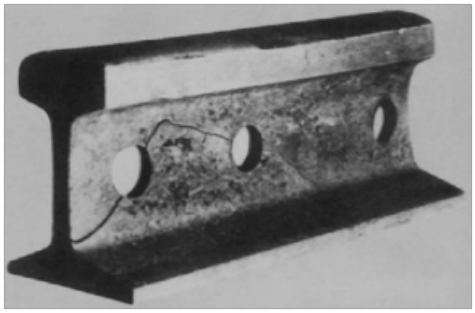
Joint Bar Center Crack

Head-Web Separation

Bolt-Hole Crack

Background and Problem Statement

- Bolt-hole cracks and upper fillet cracks are two of the major hazards, which might cause rail break or even loss of rail running surface.
- Most cracks are found to propagate from the first bolt-hole or upper fillet at the end of the rail.

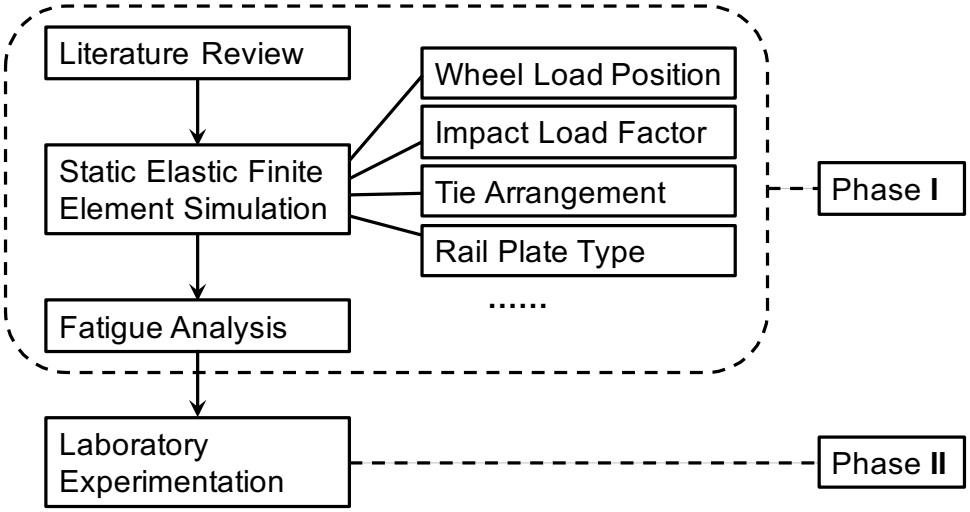


Bolt-Hole Crack

Upper Fillet Crack

Scope of Work

- Scope → Study the feasibility of sponsor-proposed remedial methods to solve or mitigate the rail bolt-hole crack and rail head-web separation problems:



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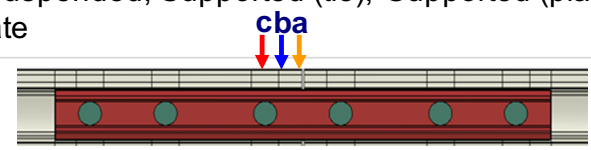
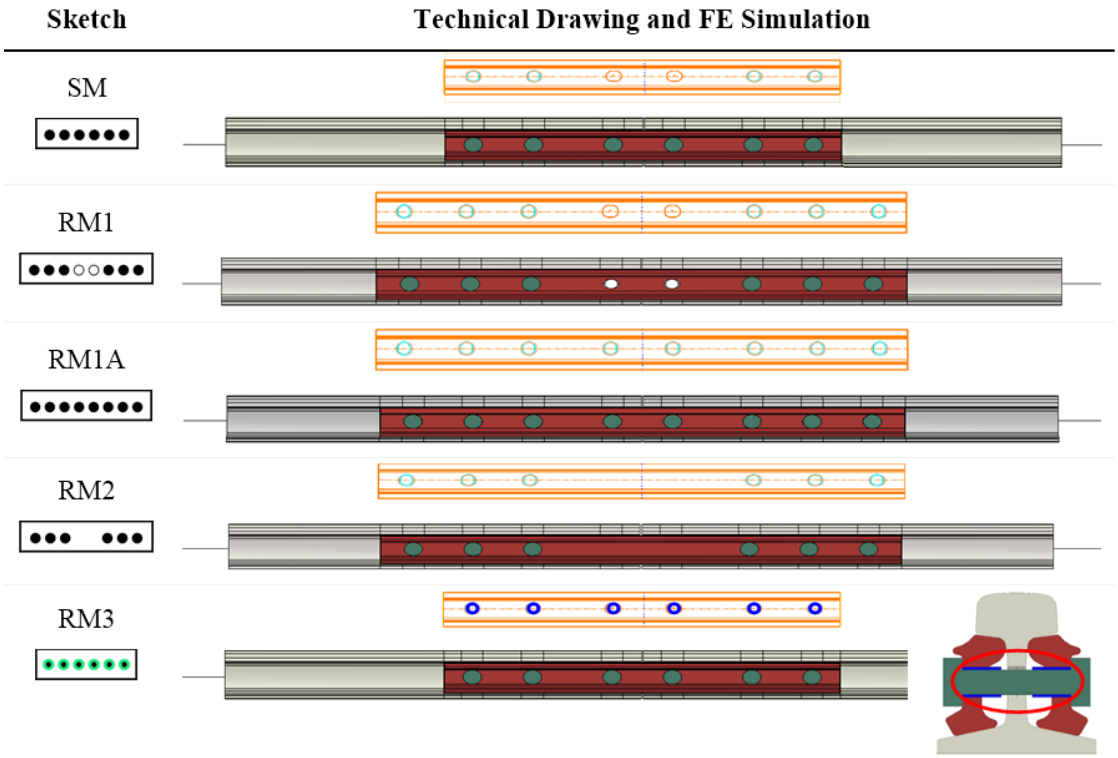
Static FE Parametric Study Matrix

Rail Type	2	100-8 Rail, 115RE Rail
Track Modulus	3	4,000 psi, 11,000 psi, 22,000 psi
Joint Bar Arrangement	8	Standard Method, Remedial Method 1, Remedial Method 1A, Remedial Method 2, Remedial Method 3, Thickened Bar 1 & 1A*
Tie Arrangement	5	Nominal, Suspended, Supported (tie), Supported (plate edge), Broken Plate
Loading Positions	3	a, b, c 
Loading Magnitude	3	1.33, 2.0, 3.0 × 16,500 lb (Static Wheel Load)

Total runs for FE Models = 2 × 3 × 8 × 5 × 3 × 3 = 2,160

* The Thickened Joint Bars was added on later

NYCT-Proposed Remedial Methods



NYCT-Proposed Support Cases

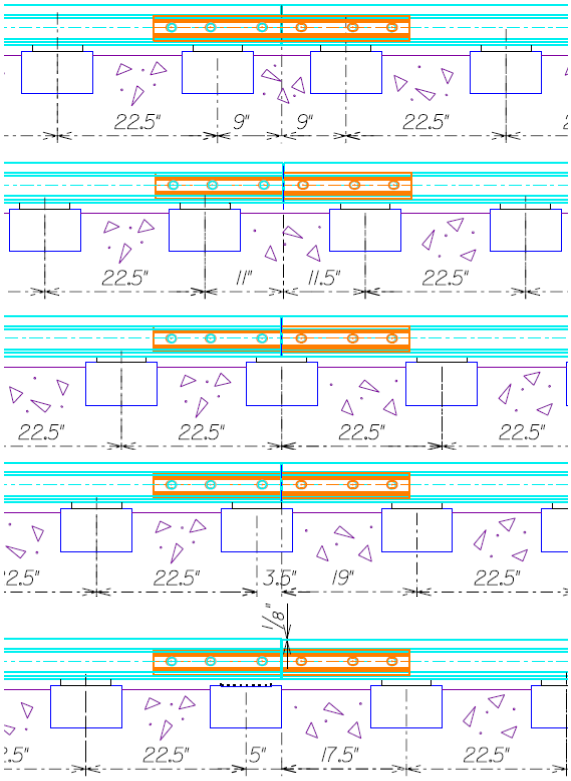
Case A:
Nominal

Case B:
Suspended

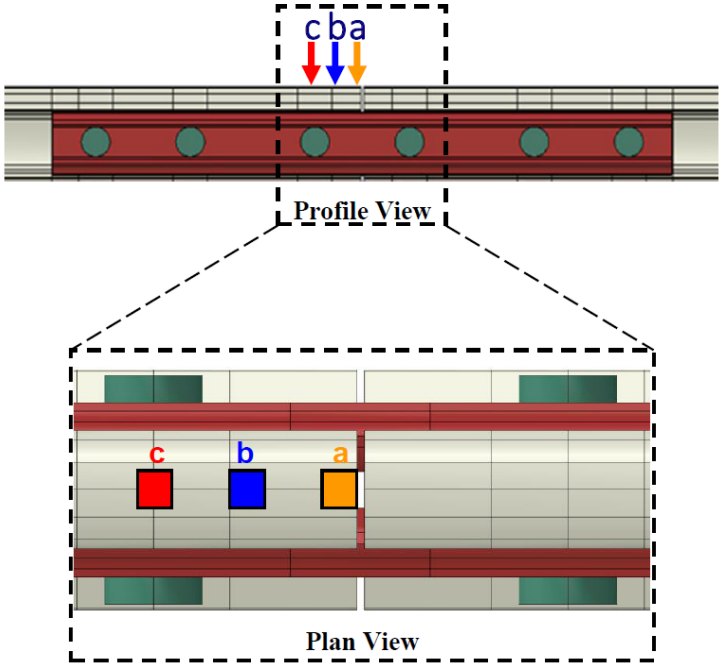
Case C:
Supported (tie)

Case D:
Supported (plate edge)

Case E:
Broken Plate

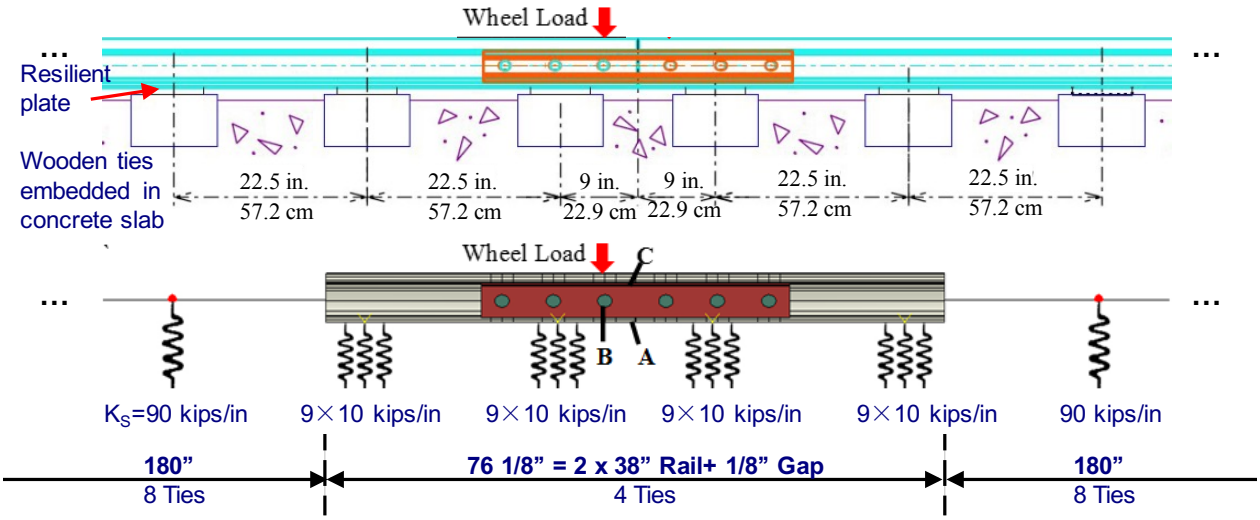


Wheel Loading Cases



The wheel load is assigned as a pressure load over a small area of about 0.5 in^2

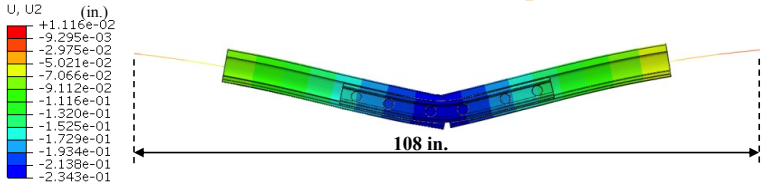
Static FE Model Example



P_w = Wheel Load
= Impact Factor × Static Wheel Load
= 1.33 or 2.0 or 3.0 × 16.5 kips

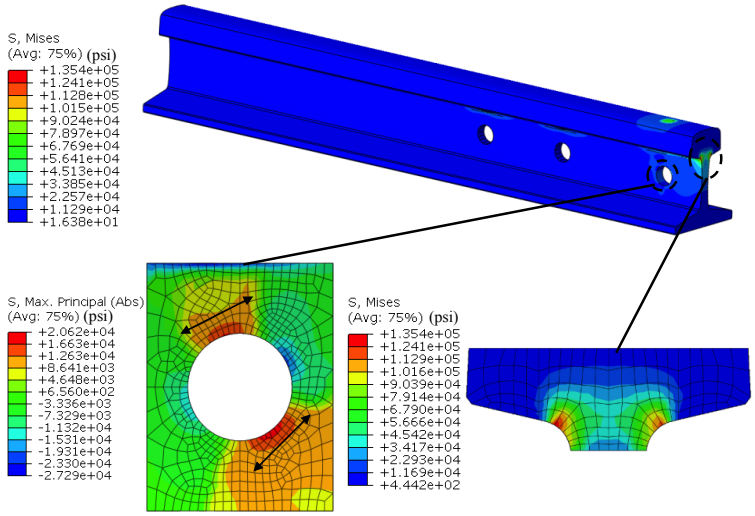
K_S = Spring Stiffness
= Track Modulus × Average Tie Spacing
= 4,000 psi × 22.5 in
= 90,000 lb/in = 90 kips/in

Static FE Model Example Results



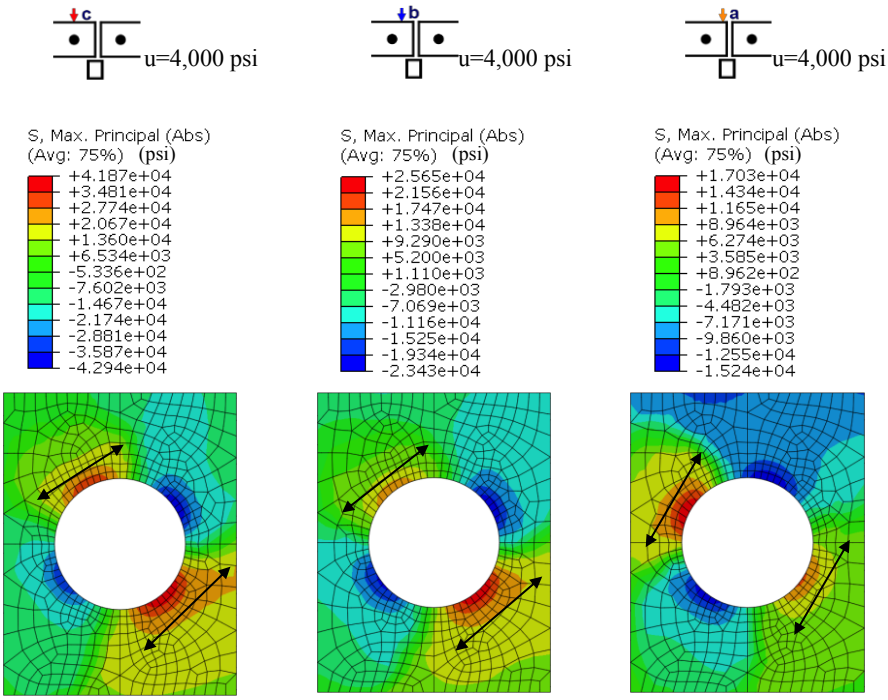
Note: Deformation Scale Factor = 50;
Only portion of the model is ploted, with the length of 108 in.;

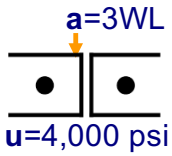
(a)



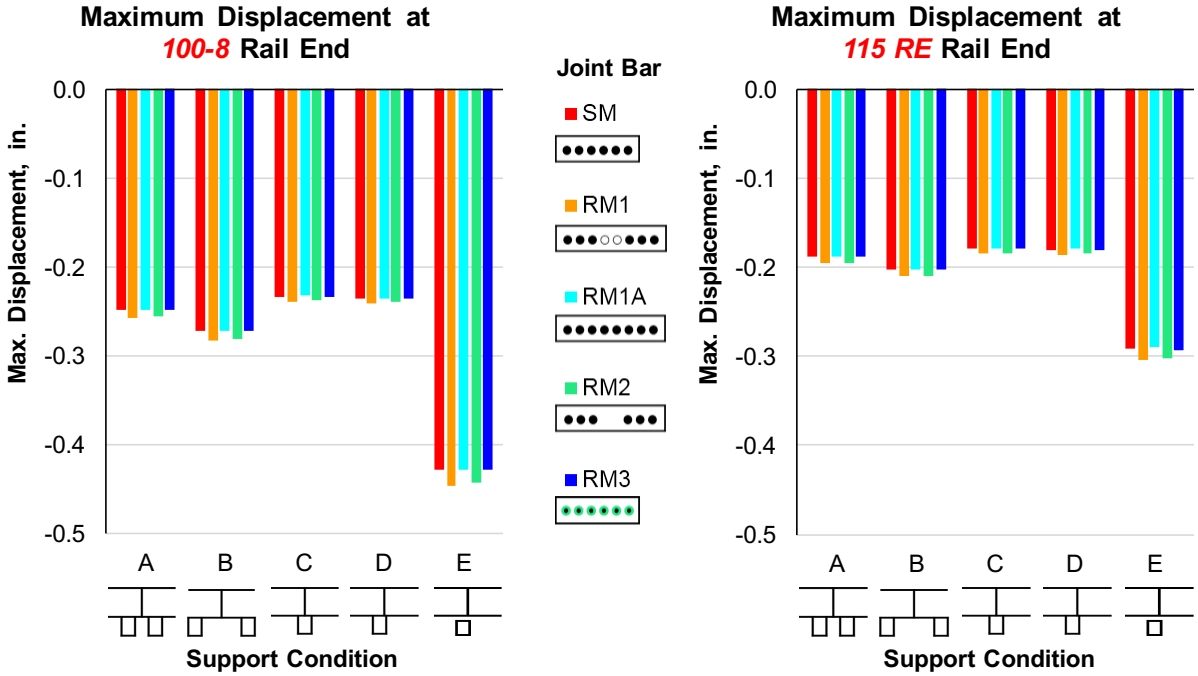
(b) **(c)**

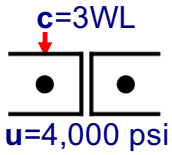
Static FE Models Results — Effect of Wheel Load Position



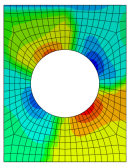


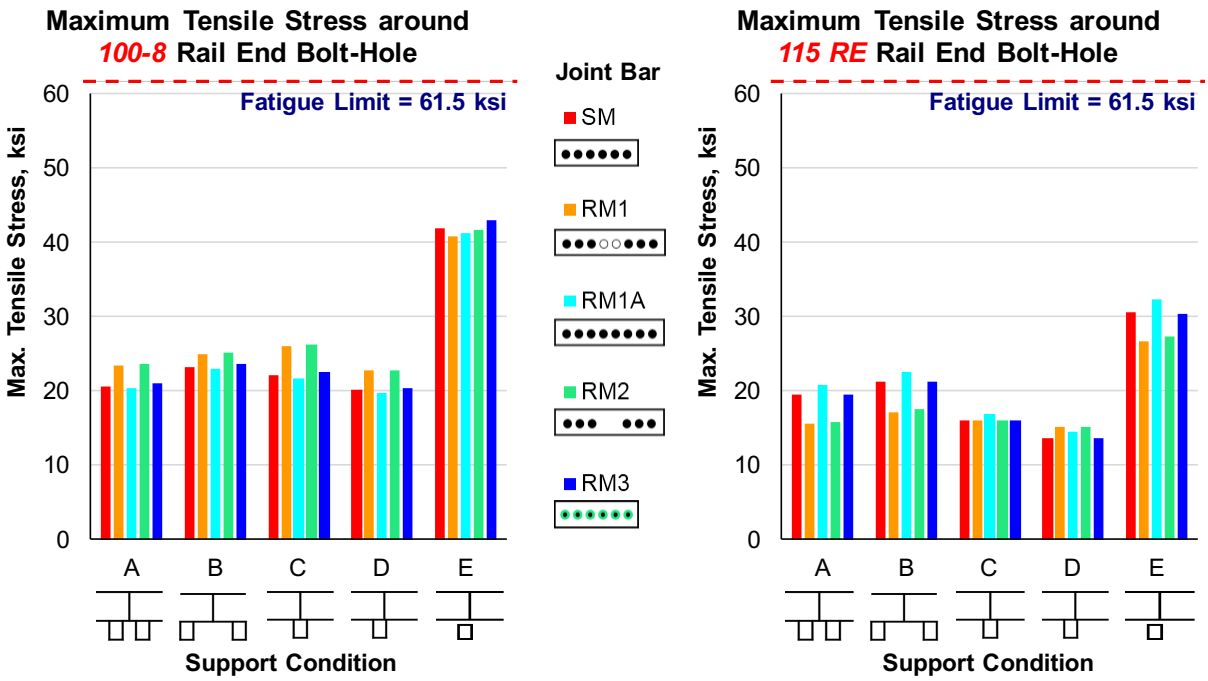
Static FE Models Results — Displacement (in.)

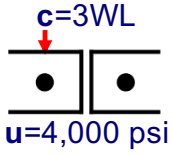




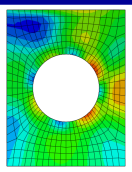
Static FE Models Results — Bolt-Hole Tensile Stress (ksi)

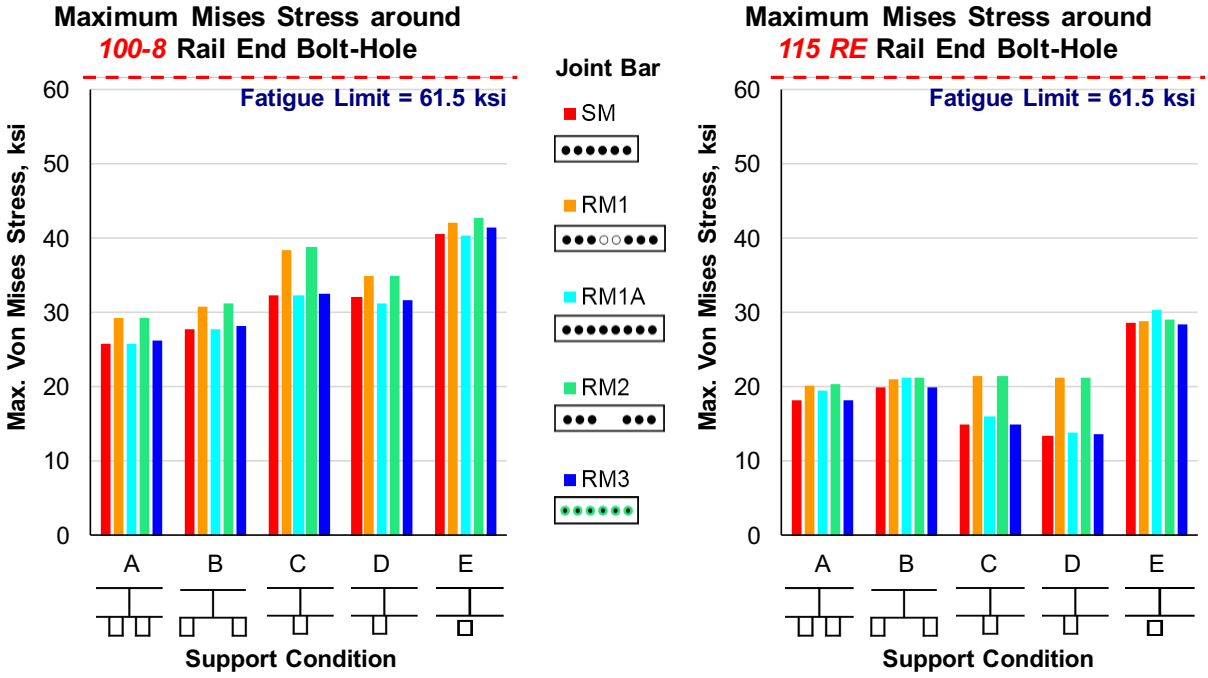


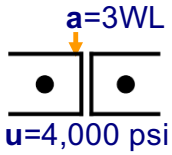




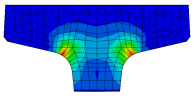
Static FE Models Results — Bolt-Hole Mises Stress (ksi)

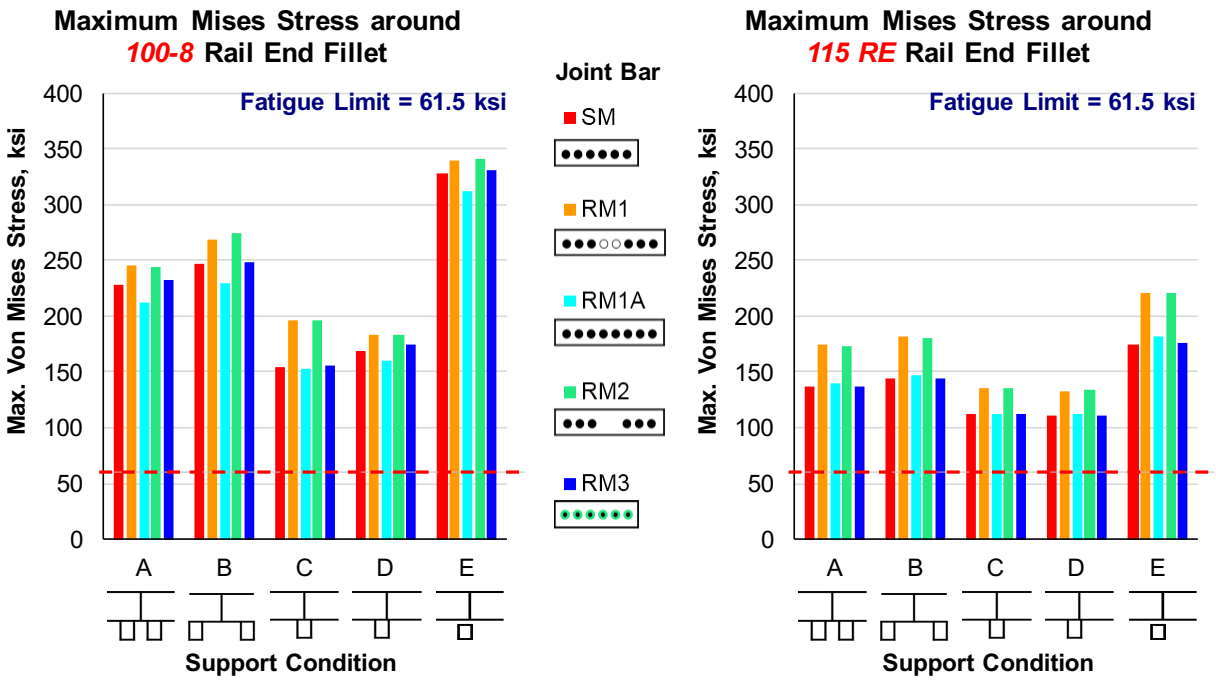






Static FE Models Results — Fillet Mises Stress (ksi)





Fatigue Analysis – Procedure

Stress calculated from elastostatic FE simulations by **Abaqus**

Fatigue analysis performed by **fe-safe**

Predicted fatigue life

Loading history

Material properties:
Ultimate tensile strength (UTS);
Surface finish factor (K_t) …

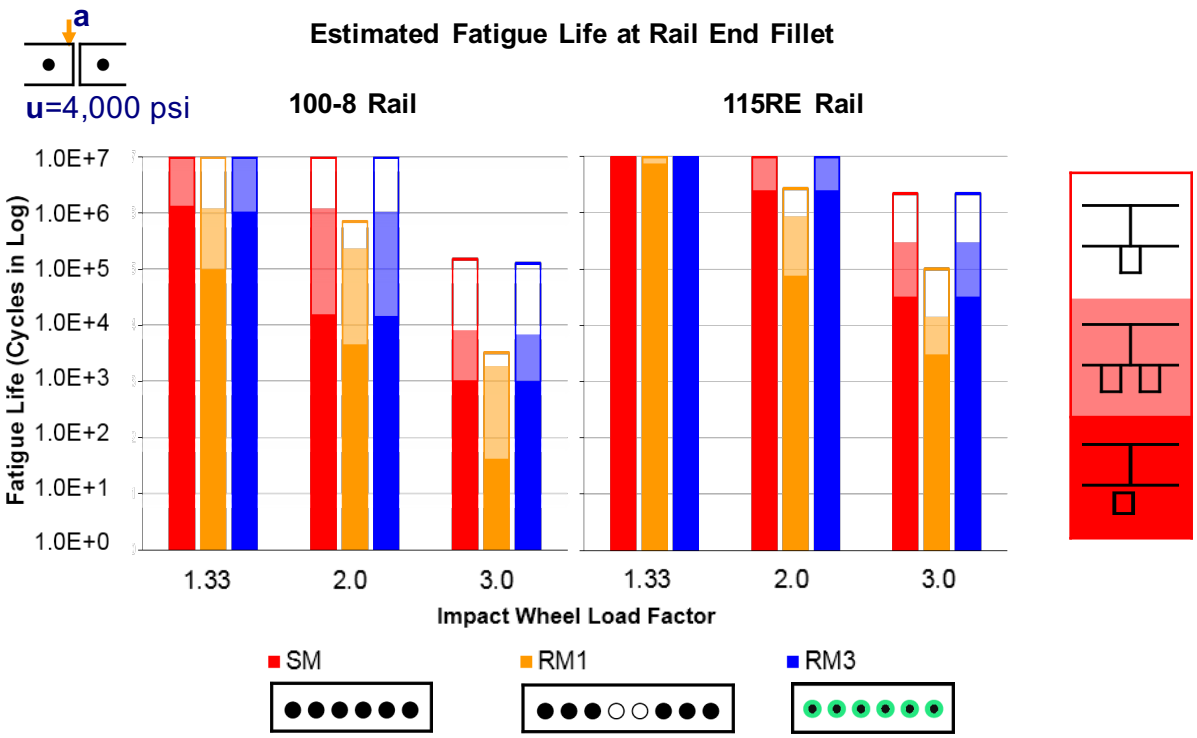
Fatigue algorithms:
Brown-Miller;
Principal stress;
Von Mises stress …

Mean stress corrections:
Morrow;
Goodman;
Gerber …

Fatigue Analysis – Material Properties

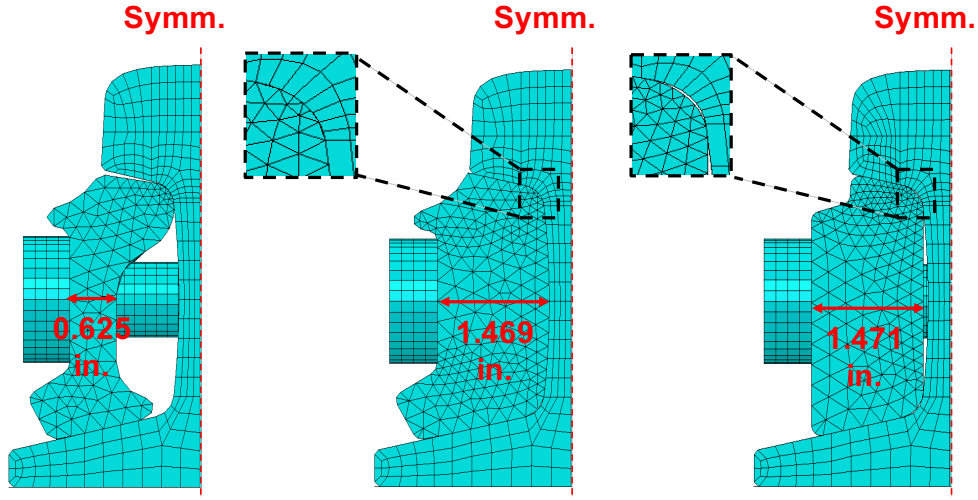
Parameters	Symbols	Values
Ultimate Tensile Strength	UTS	177.0 ksi
Strength at 10^5 cycles	-	112.2 ksi
Strength at 10^7 cycles (Fatigue Limit)	-	61.5 ksi
Young's Modulus	E	29,000 ksi
Poisson's Ratio	v	0.33
Strain Hardening Coefficient	K'	292.0 ksi
Strain Hardening Exponent	n'	0.15
Fatigue Strength Coefficient	σ_f'	265.5 ksi
Fatigue Strength Exponent	b	-0.087
Fatigue Ductility Coefficient	ε_f'	0.361
Fatigue Ductility Exponent	c	-0.58
Surface Finish Factor	K_t	1.38

Fatigue Analysis Results

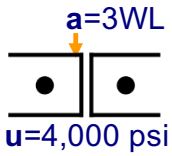


Note: For steel, reaching the loading cycles of 10^7 indicates that no damage will occur under same condition.

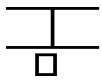
New Thickened Joint Bar Designs

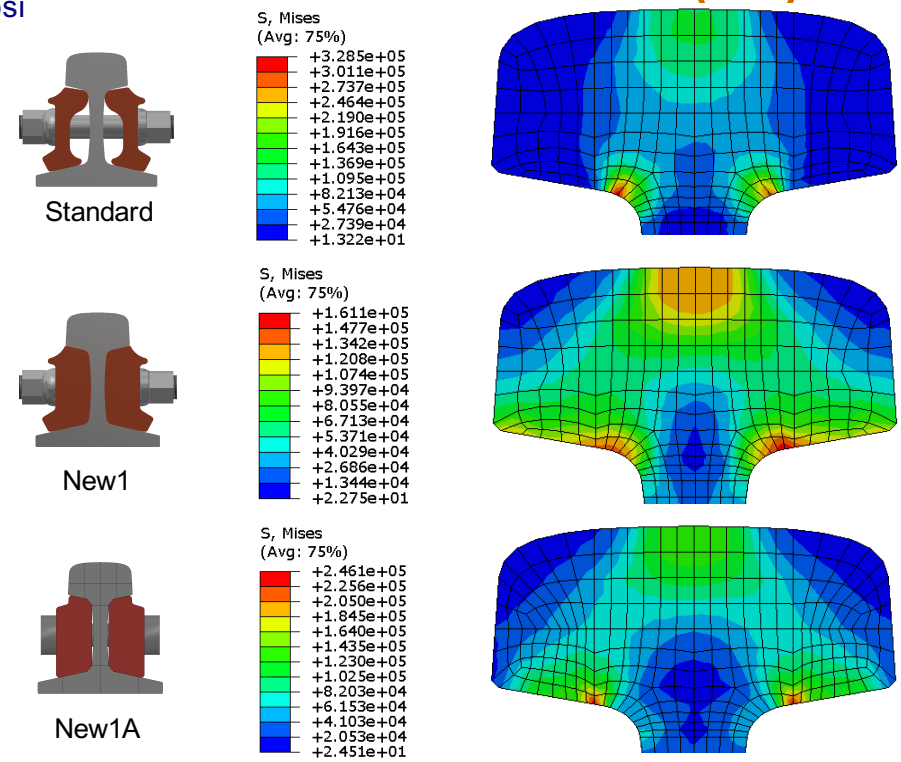


	Standard	New 1	New 1A
Two Joint Bars Area	6.80 in^2	10.16 in^2	9.25 in^2
Moment of Inertia	8.10 in^4	9.75 in^4	7.90 in^4

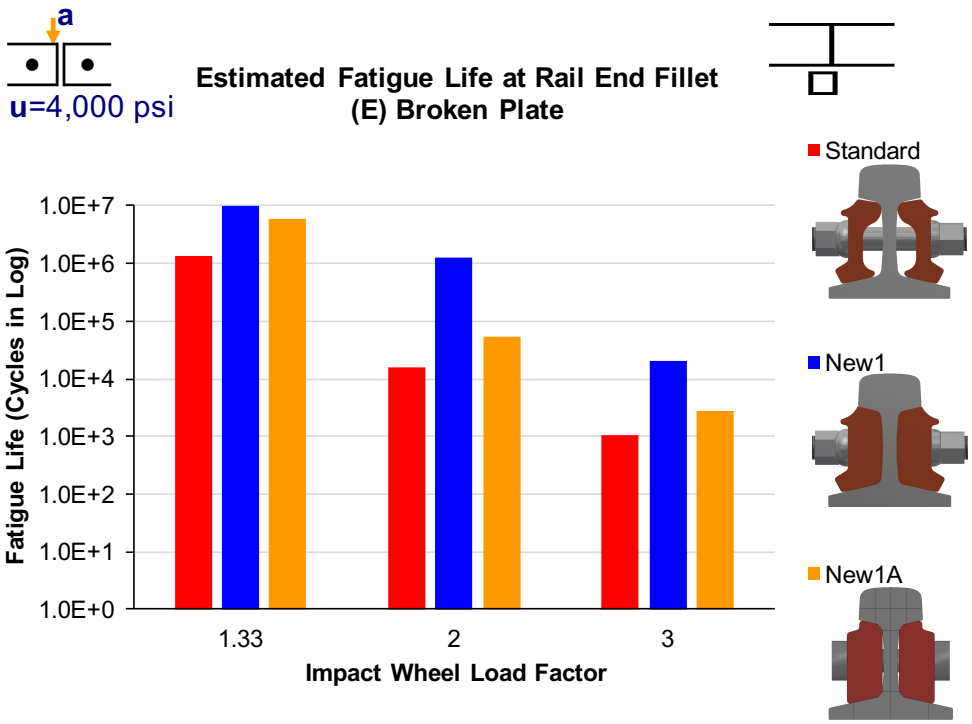


Finite Element Models Results — Fillet Mises Stress (ksi)





Fatigue Analysis – Upper Fillet



Note: For steel, reaching the loading cycles of 10^7 indicates that no damage will occur under same condition.

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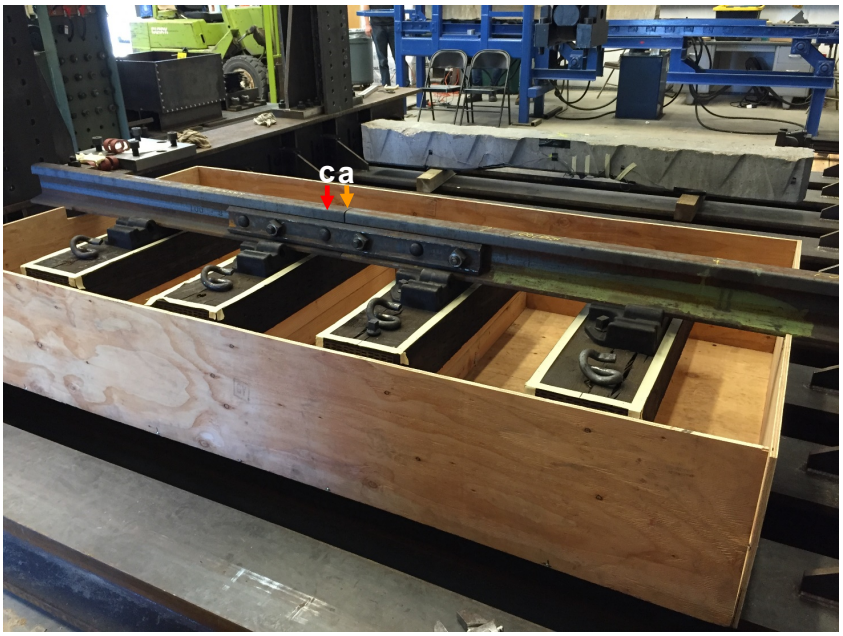
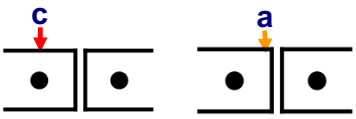
Laboratory Experimentation Setup (under Construction)





Full Scale Test

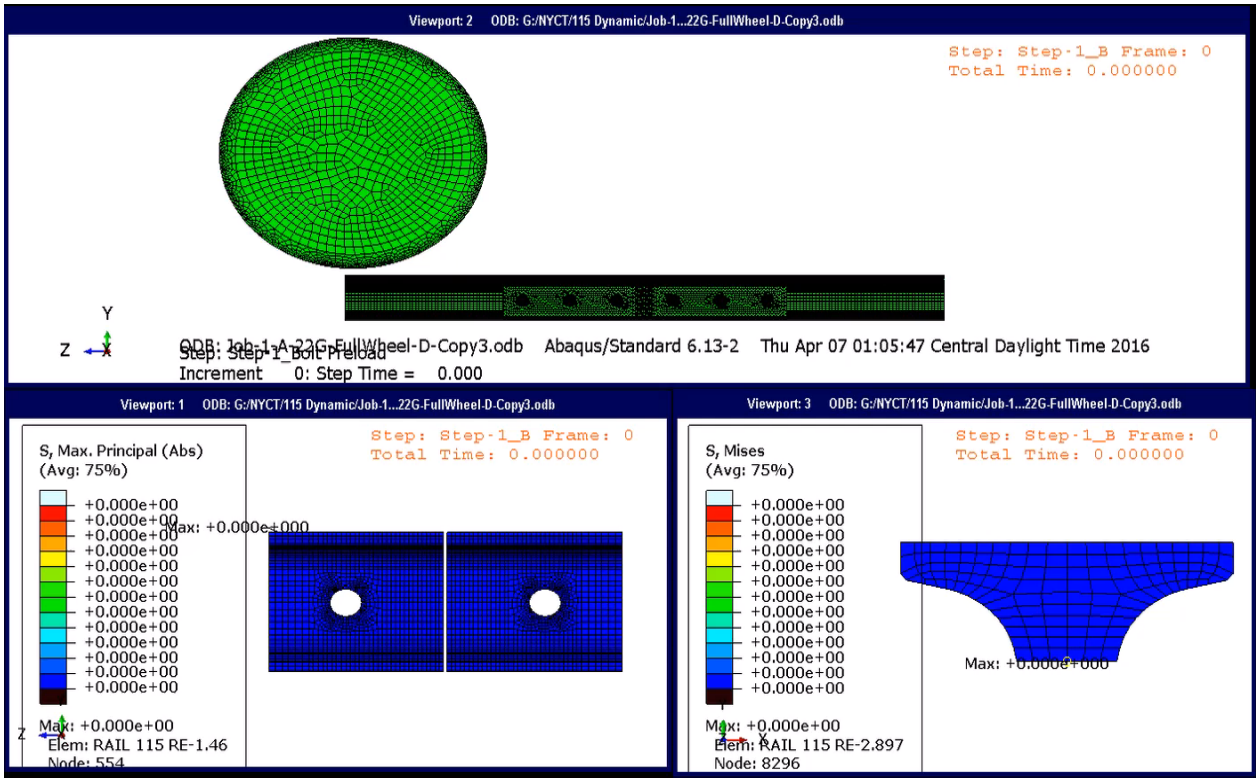
Customized Loading

Standard & Thickened Joint Bars

Different Pads

Note: block will be embedded in concrete

Dynamic Model Simulation



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