Comparison of Current Flexural Analysis Methodologies and Sensitivity to Support Conditions

UIUC Industry Partners Meeting

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U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

National University Rail Center - NURail
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Outline

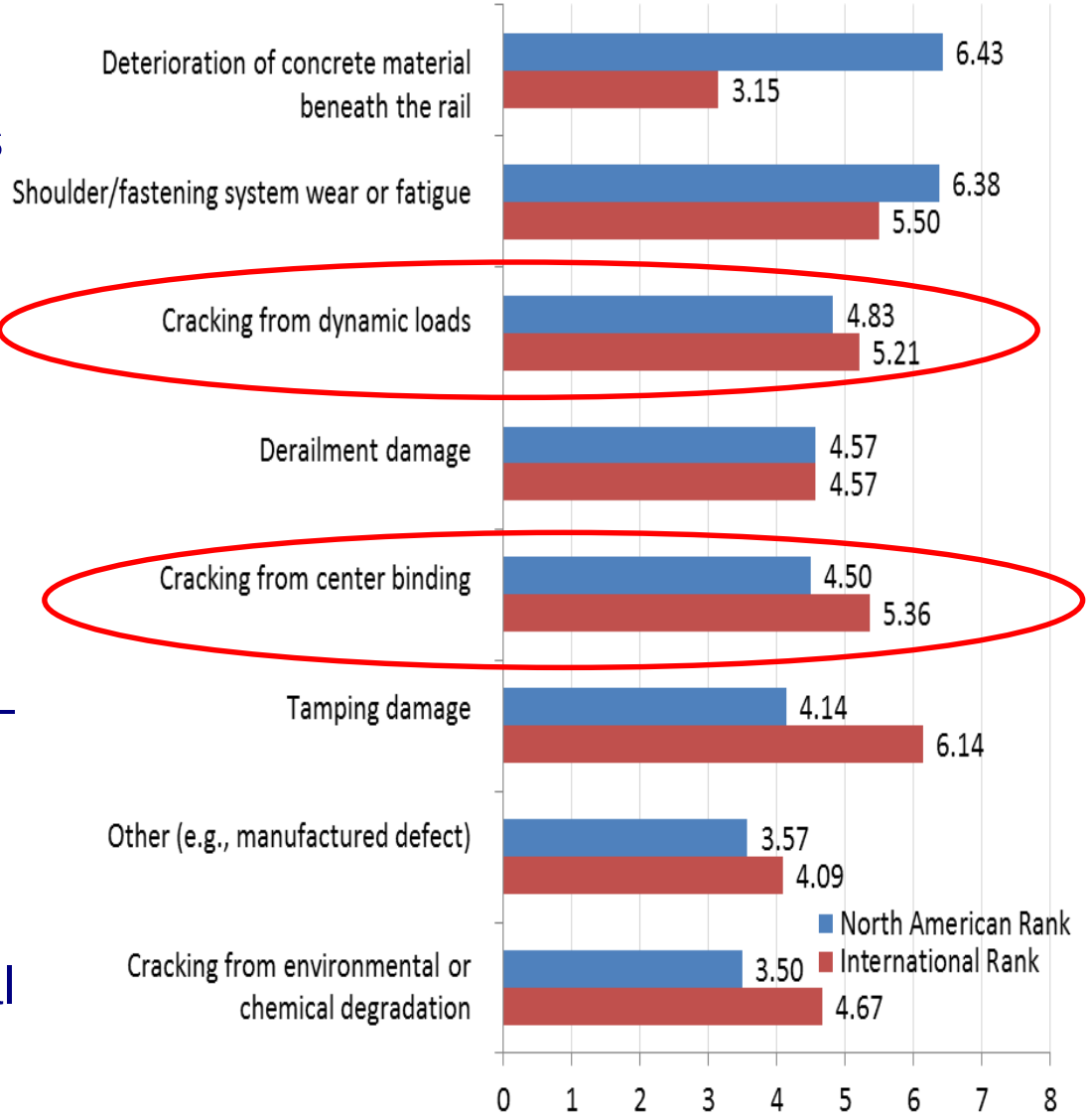
- Introduction to Crossties
- Crosstie Bending
  - Critical Regions
  - Design Standards Comparison
- Sensitivity to Support Conditions
  - Model Development
  - Sensitivity Analysis
  - Field-Measured Support Conditions

Introduction to Crossties

- Ballasted track is the most common track system used in North America
- Ballasted track system typically consists of rail, fastening systems, crossties, ballast, sub-ballast, and subgrade
- Crossties maintain track geometry and transfer applied loads to the track substructure
- Many different material used for ties: timber, concrete, steel, composite
- In North America concrete is used for the most demanding service conditions (high curvature, heavy tonnage, high speed)

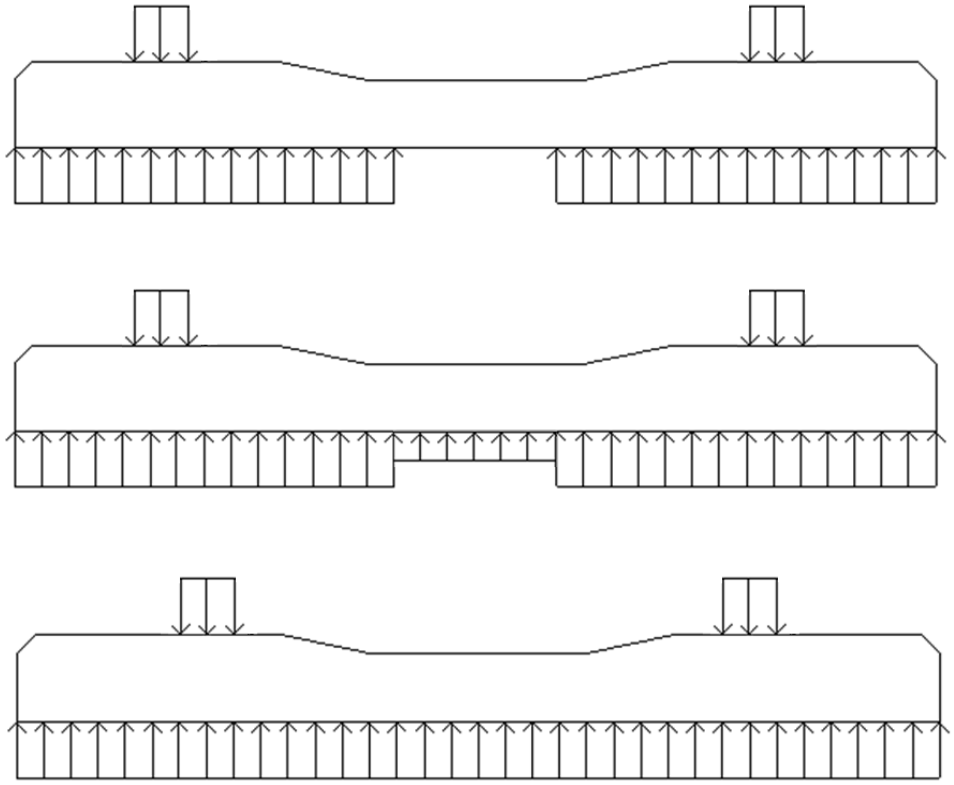
Reason for Study

- In 2013, UIUC conducted international survey to determine most critical issues in concrete crosstie track
- Survey of railroads, concrete crosstie manufacturers, and researchers around the world
- Cracking from center binding (3rd most critical problem – International, 5th most critical – North America)
- Cracking from dynamic loads (3rd most critical problem – North America, 4th most critical – International)

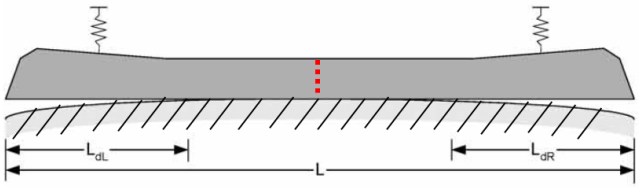


Reason for Study (cont.)

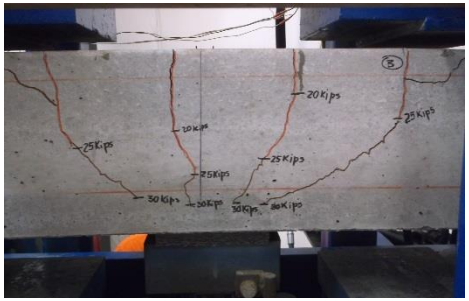
- Improved understanding of support conditions that can cause cracking could help optimize tamping cycles
- Field experimentation could be performed to help measure the degradation of ballast over time

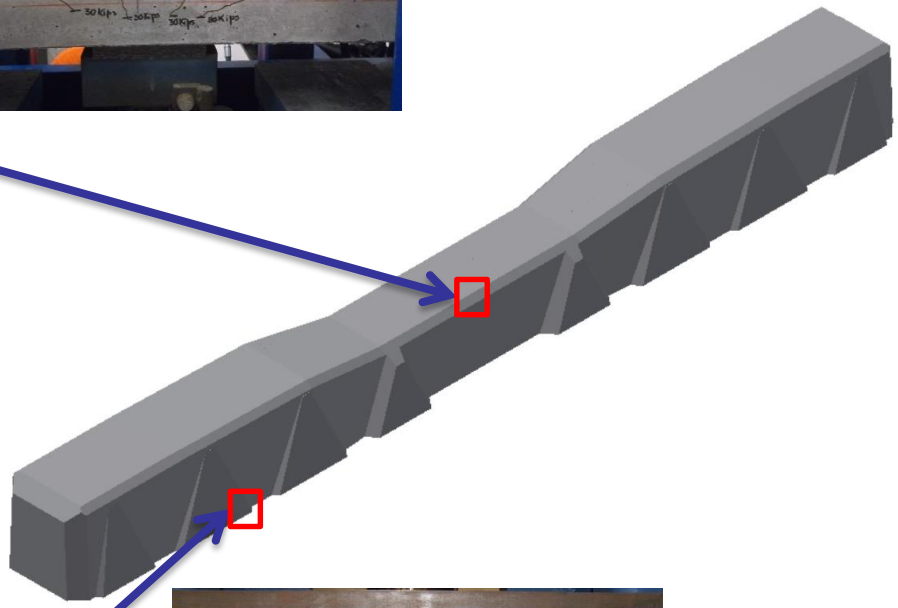


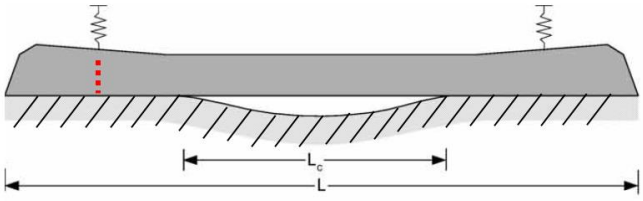
Critical Regions for Flexure



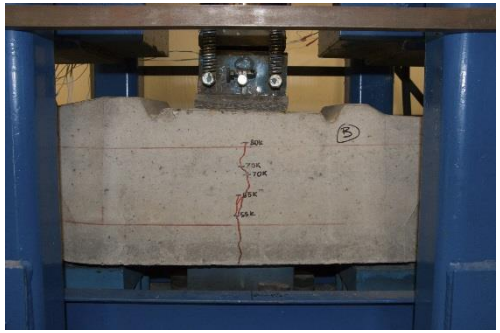
Center Negative







Rail Seat Positive



International Standards to be Compared

- Many codes and recommendations used worldwide
- Each analysis methodology uses different assumptions and equations
- This presentation will focus on comparing the following:
  - AREMA C30.4
  - EN 13230-1/UIC 713R
  - AS 1085.14

AREMA
American Railway Engineering and Maintenance-of-Way Association

cen

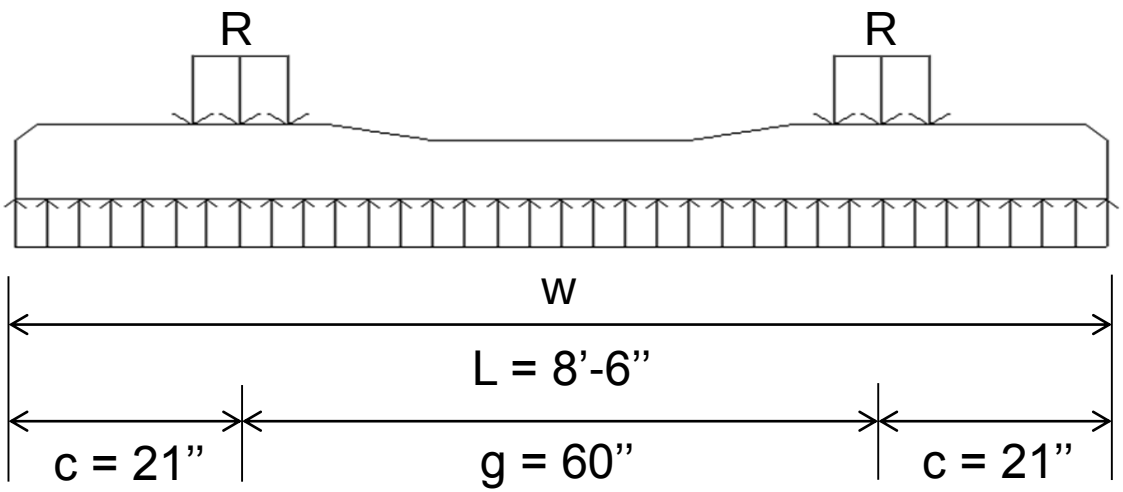
uic
INTERNATIONAL UNION OF RAILWAYS

STANDARDS Australia

Constant Parameters for Analysis

All calculations will use the following parameters:

- 82 kip axle load
- 8’-6” crosstie length
- 60” rail center spacing
- 24” center-to-center crosstie spacing
- 6” rail seat width
- 9” depth



Comparison of International Standards

	AREMA C30.4	UIC 713R	AS 1085.14
Rail Seat Load kips (kN)	62.1 (276.2)	**66.4 (295.4)**	53.3 (237.1)
Rail Seat Positive kip-in (kN-m)	**300 (33.9)**	224 (25.3)	280 (31.6)
Rail Seat Negative kip-in (kN-m)	-159 (-18.0)	-112 (-12.7)	**-187 (-21.1)**
Center Positive kip-in (kN-m)	141 (15.9)	**209 (23.6)**	112 (12.7)
Center Negative kip-in (kN-m)	-201 (-22.7)	**-299 (-33.8)**	-240 (-27.1)

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Support Conditions of Standards

M_{RS+} M_{C-}

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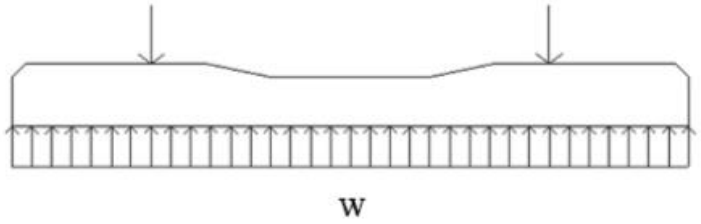

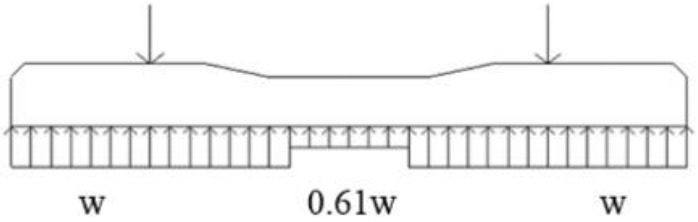

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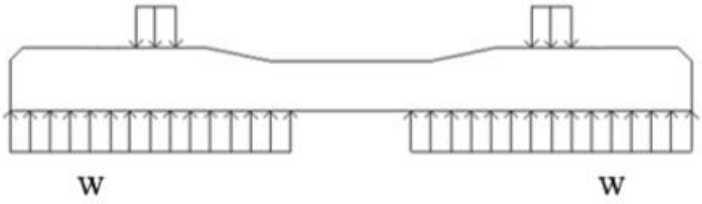
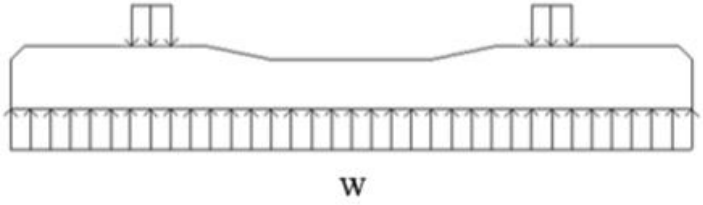
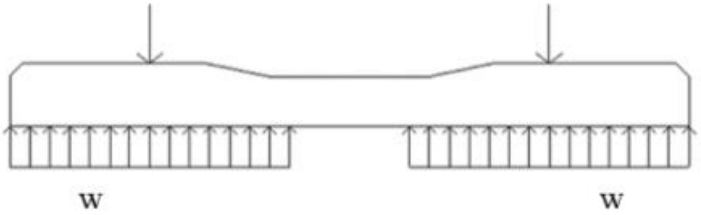
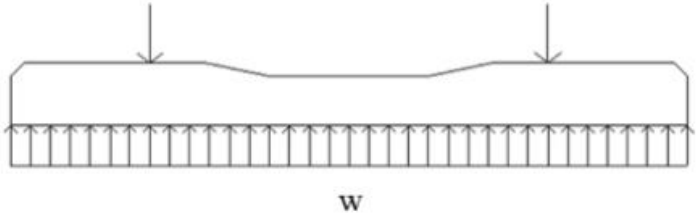




STANDARDS Australia

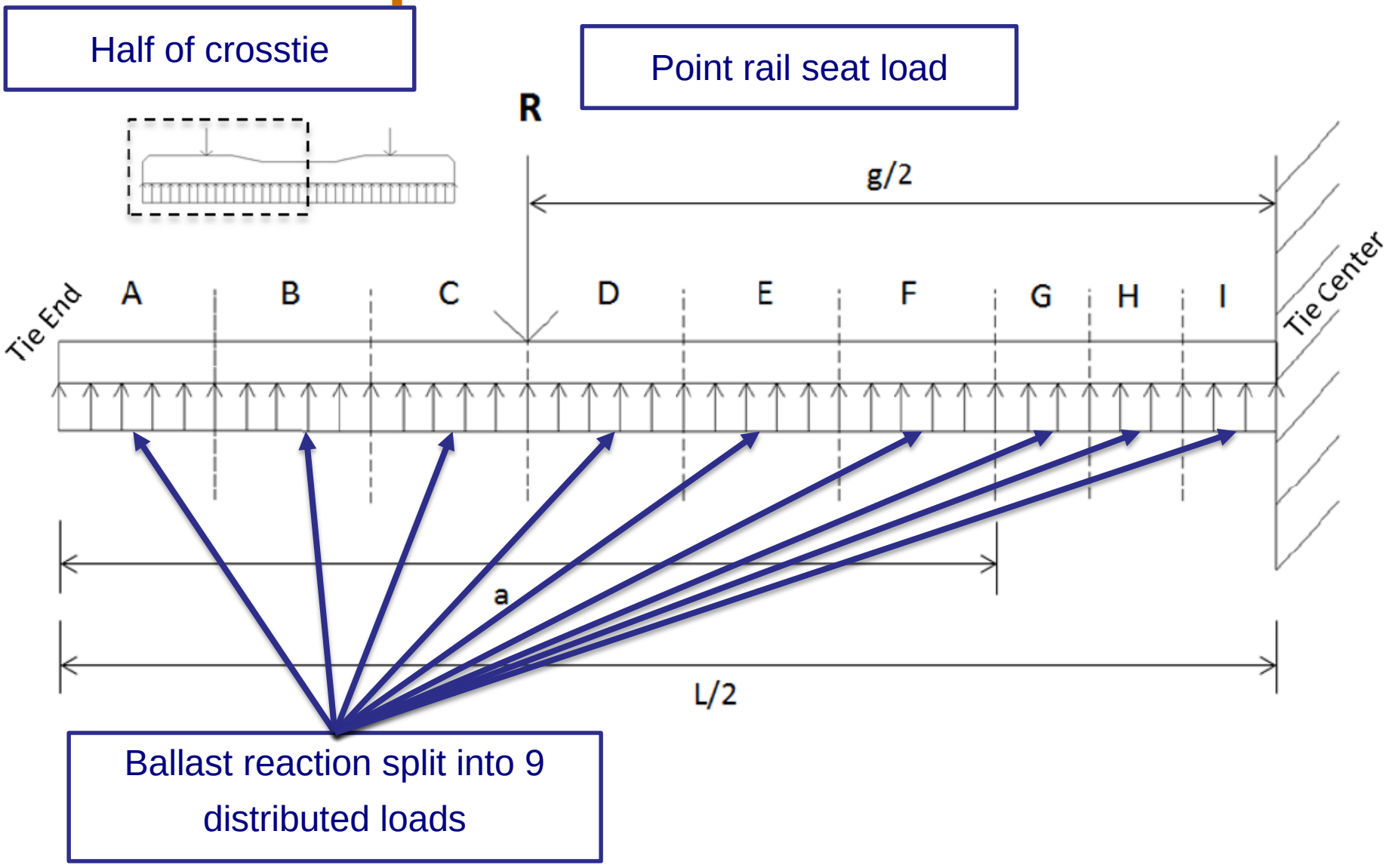




Development of Crosstie Model

Half of crosstie

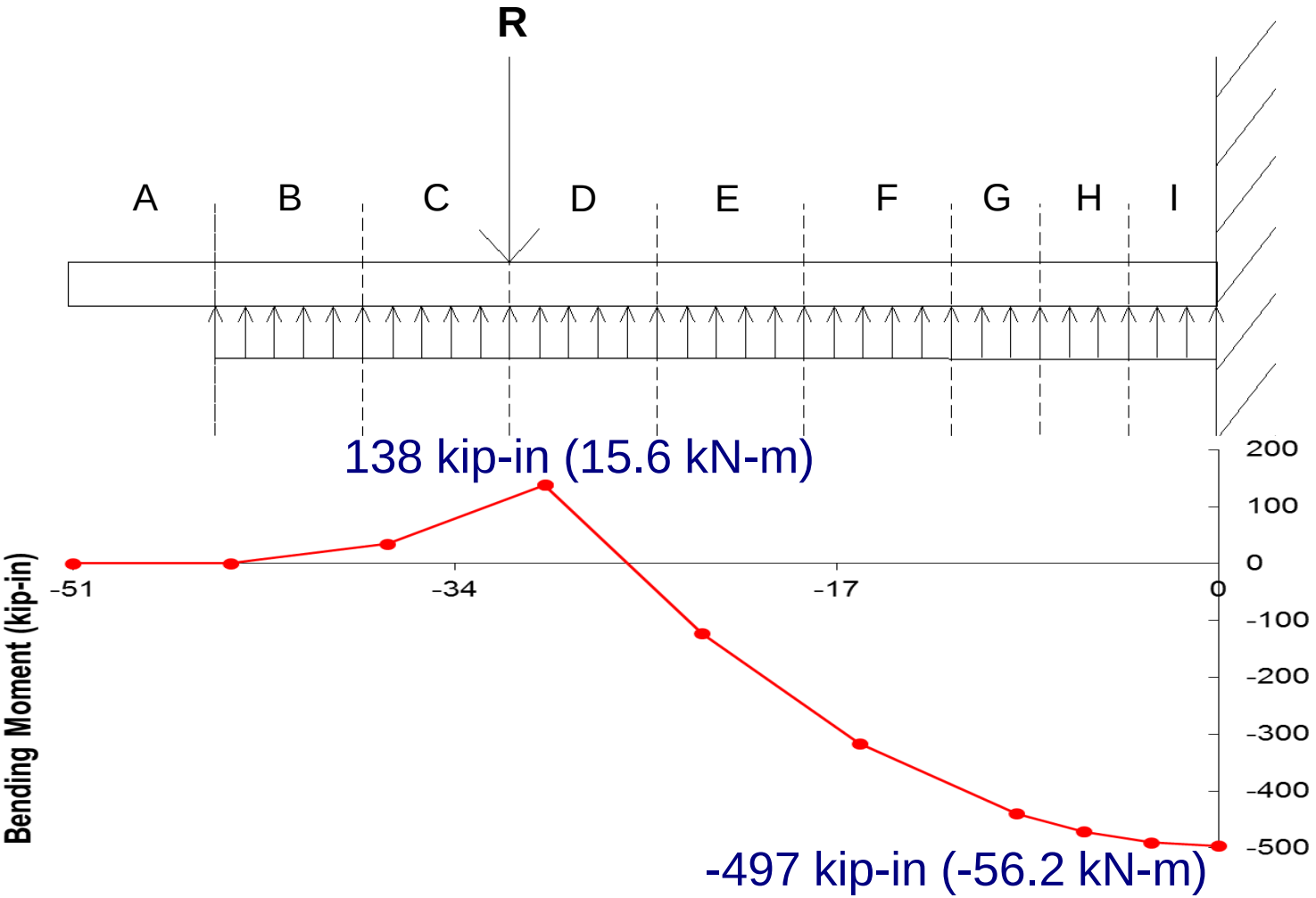
Point rail seat load



Ballast reaction split into 9 distributed loads

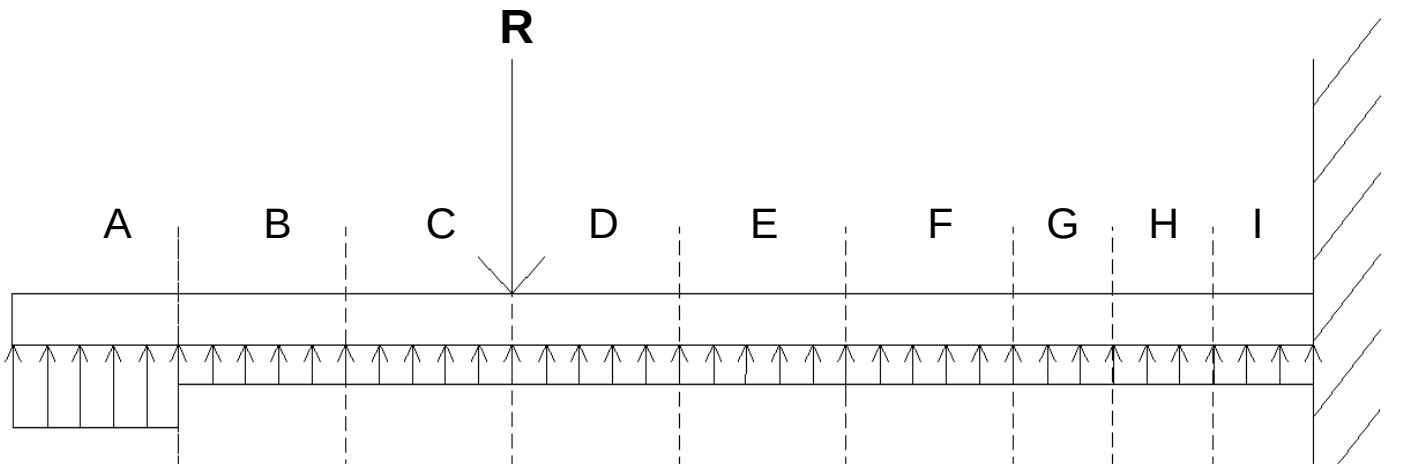
Sensitivity of Crosstie to Support Conditions

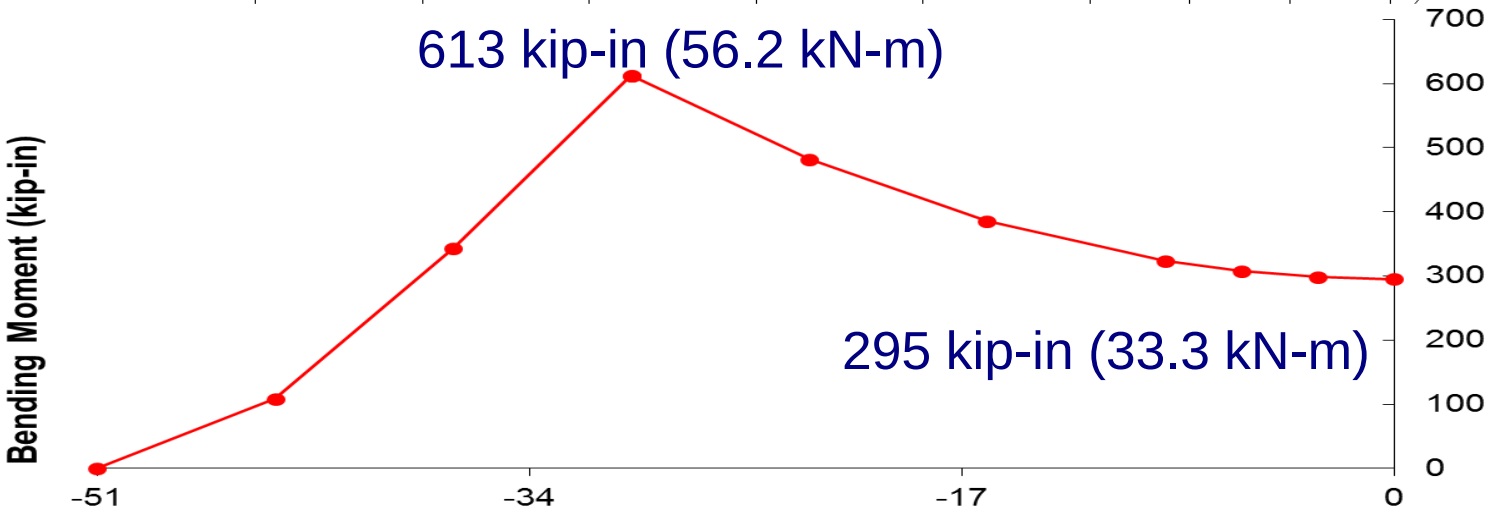
0% of ballast reaction to Bin A



Sensitivity of Crosstie to Support Conditions

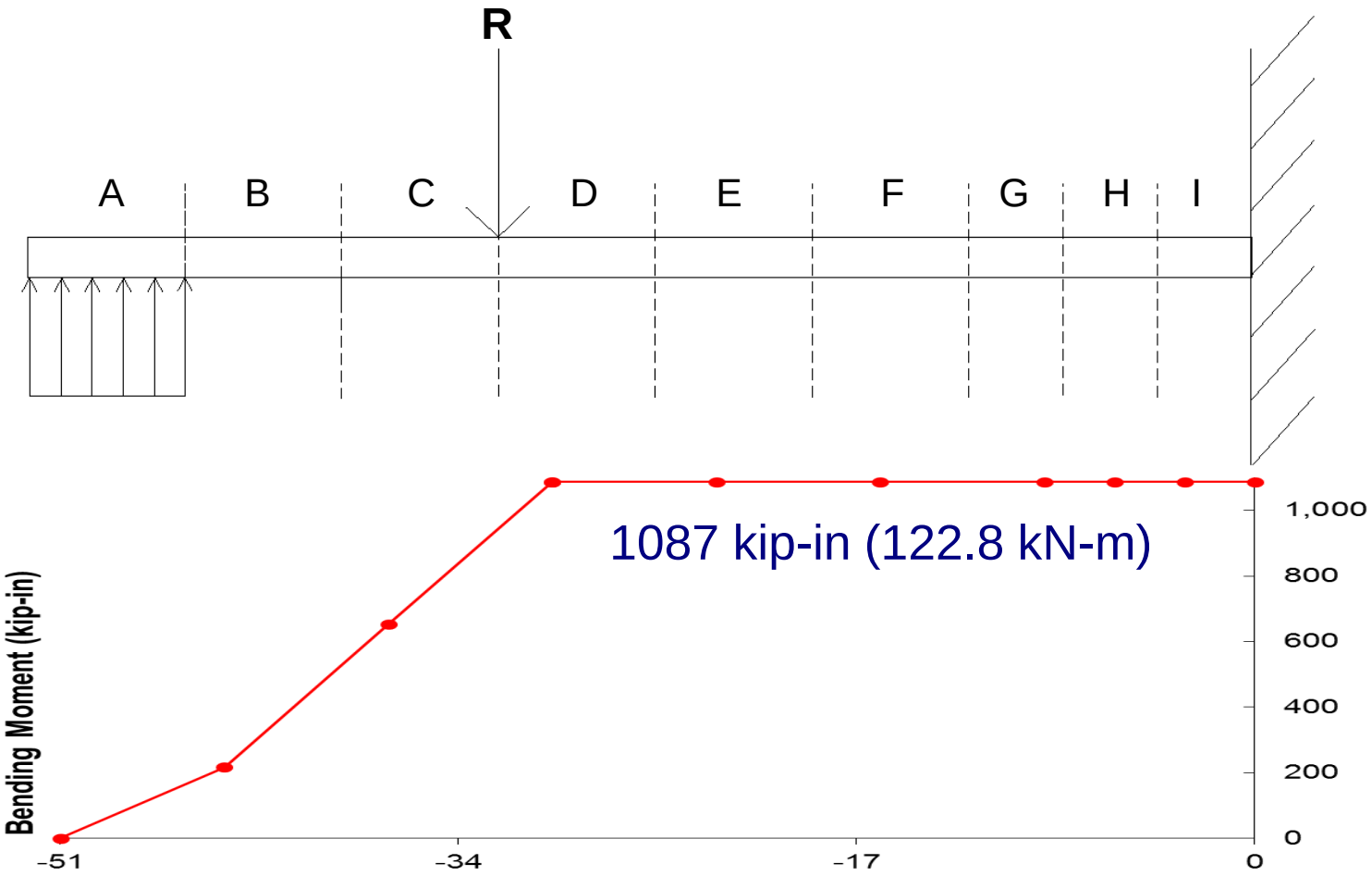
50% of ballast reaction to Bin A





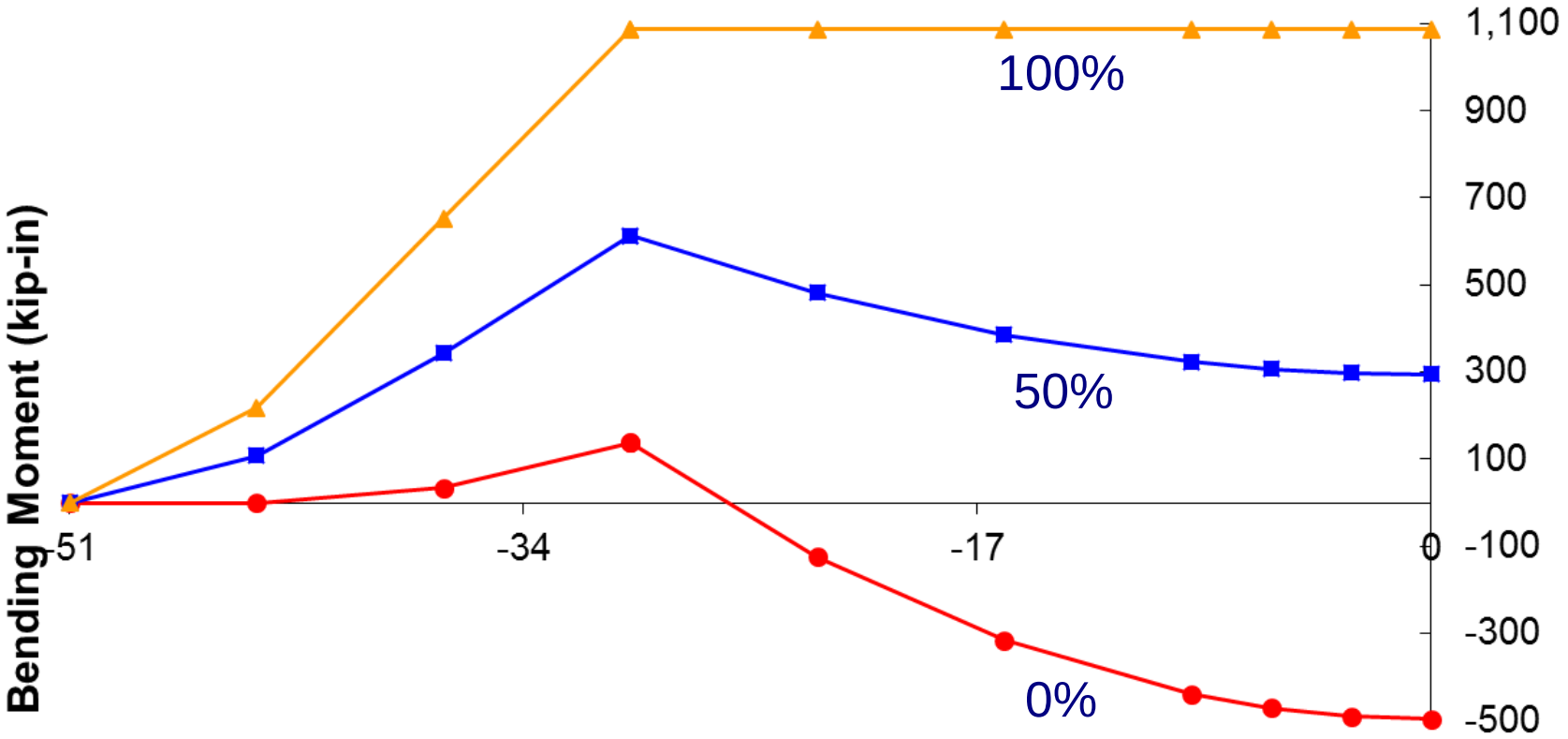
Sensitivity of Crosstie to Support Conditions

100% of ballast reaction to Bin A

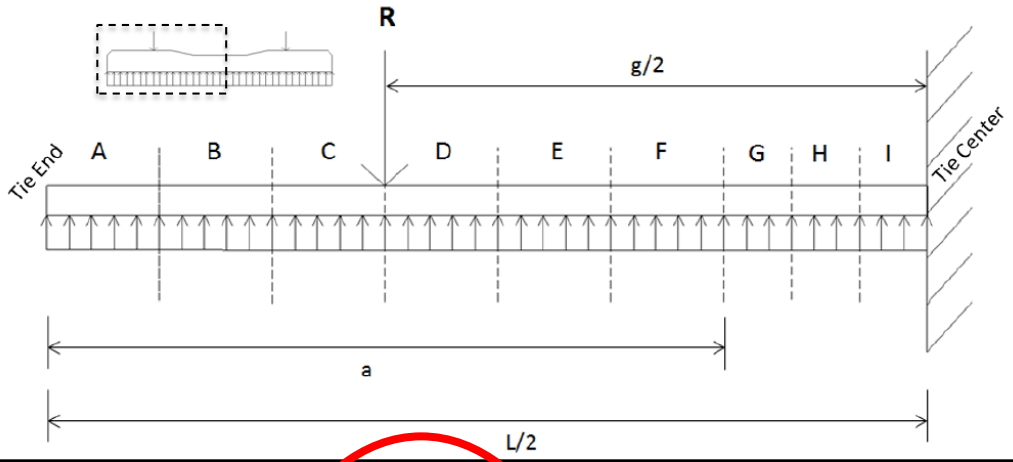


Sensitivity of Crosstie to Support Conditions

0%, 50%,and 100% of ballast reaction to Bin A

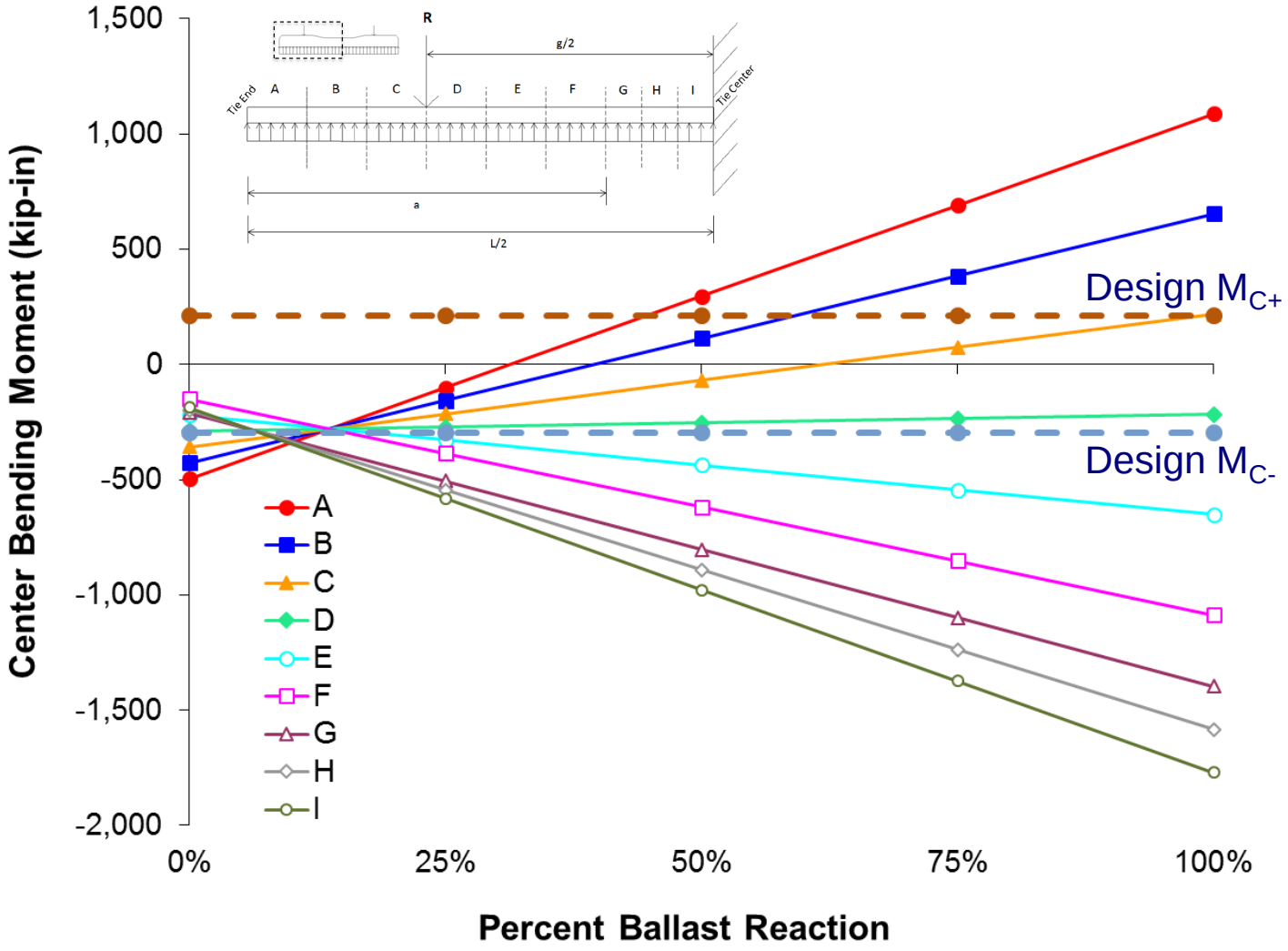


Summary of Sensitivity Study



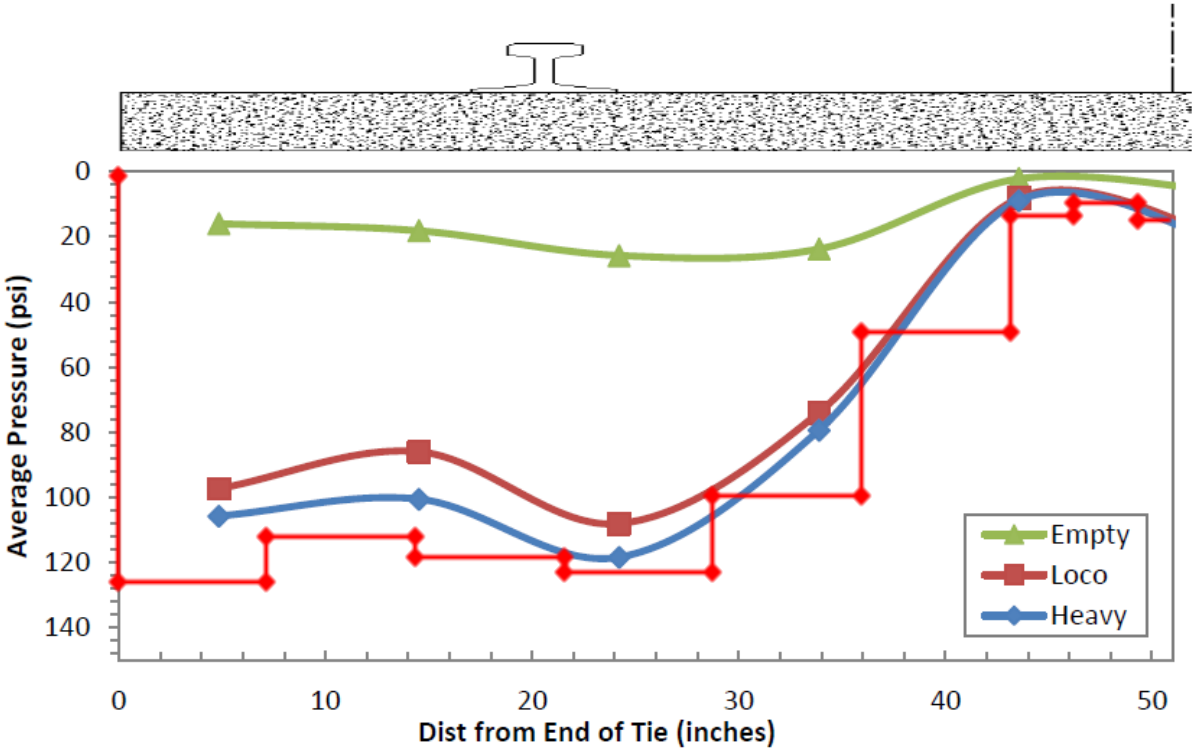
Section		A	B	C	D	E	F	G	H	I
Rail Seat Moment (M_{RS}) (kip-in)	0%	138	207	277	311	311	311	285	285	285
	25%	375	319	262	233	233	233	214	214	214
	50%	613	430	247	156	156	156	143	143	143
	75%	850	541	232	78	78	78	71	71	71
	100%	1087	652	217	0	0	0	0	0	0
Center Moment (M_C) (kip-in)	0%	-497	-428	-358	-289	-220	-151	-210	-198	-187
	25%	-101	-158	-215	-272	-328	-385	-506	-544	-582
	50%	295	113	-70	-253	-436	-618	-804	-891	-978
	75%	691	382	74	-235	-544	-853	-1100	-1237	-1374
	100%	1087	652	217	-217	-652	-1087	-1397	-1584	-1770

Parametric Study of Support Conditions

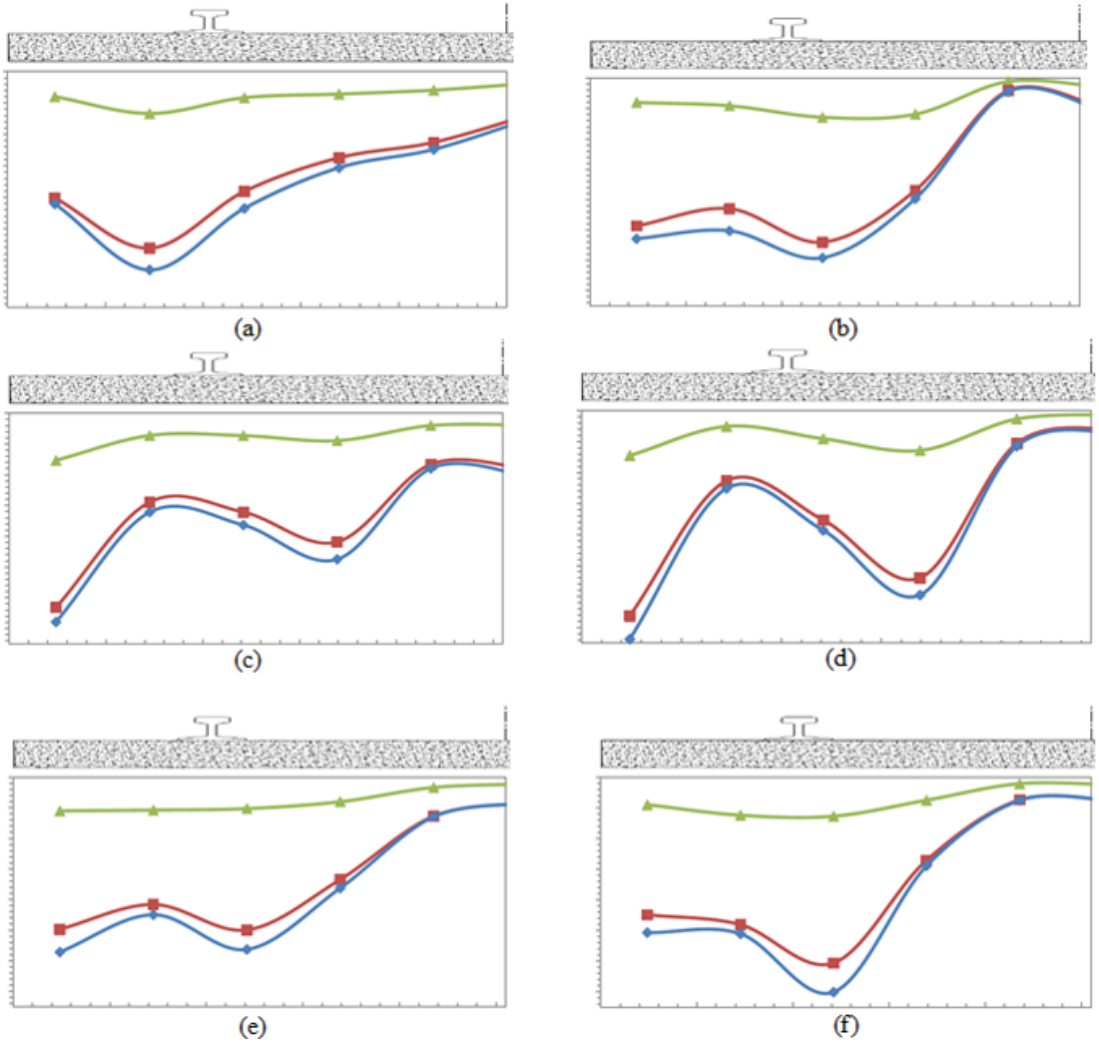


Field-Measured Support Conditions

- Ballast reaction measured at Transportation Technology Center, Inc. (TTCI) using Matrix-Based Tactile Surface Sensors (MBTSS)
- Measured ballast reaction from “heavy” car was used in Crosstie Model to calculate theoretical bending moment under ballast reaction



Theoretical Bending Moments Under 62.1 kip (14.0 kN) Rail Seat Load



Tie	M_{RS} kip-in (kN-m)	M_C kip-in (kN-m)
(a)	364 (41.1)	105 (11.9)
(b)	308 (34.8)	-76 (-8.6)
(c)	395 (44.1)	21 (2.4)
(d)	403 (45.5)	59 (6.7)
(e)	363 (41.0)	61 (6.9)
(f)	346 (39.1)	98 (11.1)

Conclusions

- Crosstie flexure is highly dependent on support conditions
- Center bending moment is highly sensitive to ballast reaction between the rail seat center spacing
- Rail seat positive bending may be experiencing deep beam behavior
  - To be investigated further
- New design recommendation based on clear support condition assumptions is needed
  - Will be proposed in C30 Meeting

Acknowledgements

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TTX

Thank You

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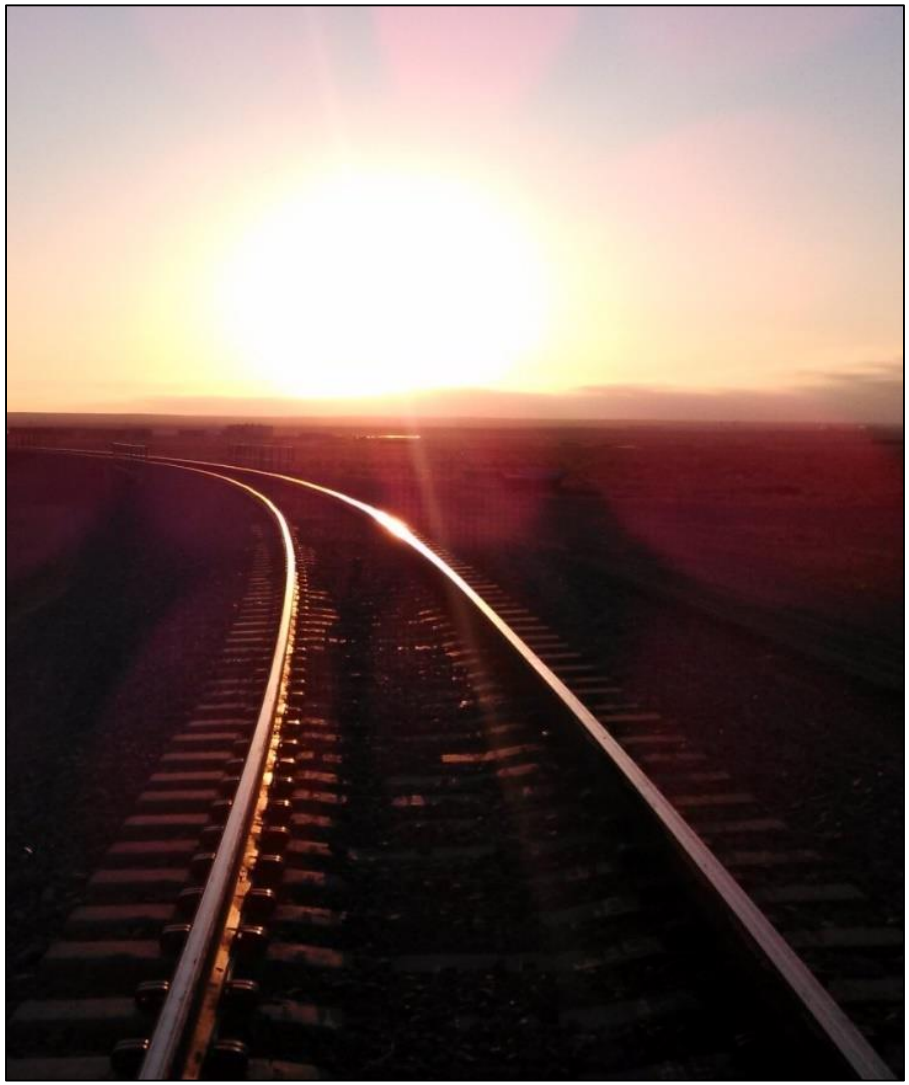
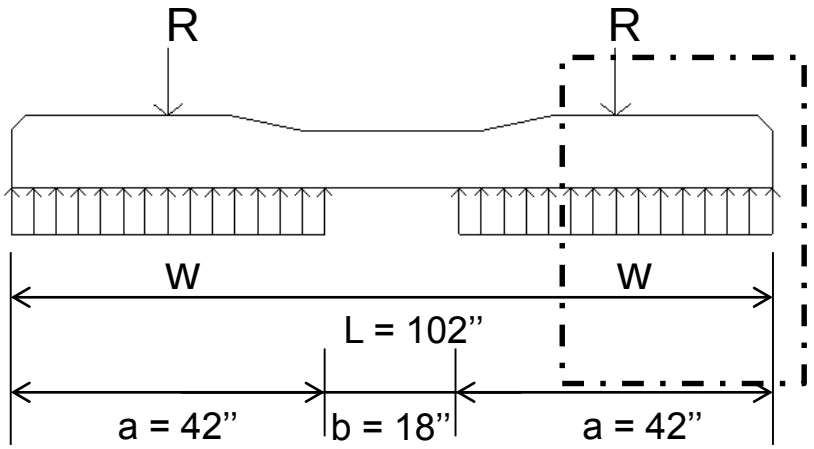


UIC 713R Analysis (M_{RS+})



Assumes end to compressive strut to be cantilever, rail seat load to be distributed, and compressive strut to neutral axis

$$M_{RS+} = \frac{R}{4}\left(L_p - \frac{f}{2} - \frac{h}{2}\right)$$

$$= \frac{66.4}{4}\left(21" - \frac{6"}{2} - \frac{9"}{2}\right)$$

$$= \mathbf{224\ kip\text{-}in}$$