Current and Proposed Flexural Analysis Methodologies for Concrete Crossties

AREMA C-30 Meeting

Orlando, FL

14 October 2014

Henry Wolf, Steve Mattson

U.S. Department of Transportation
Federal Railroad Administration

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

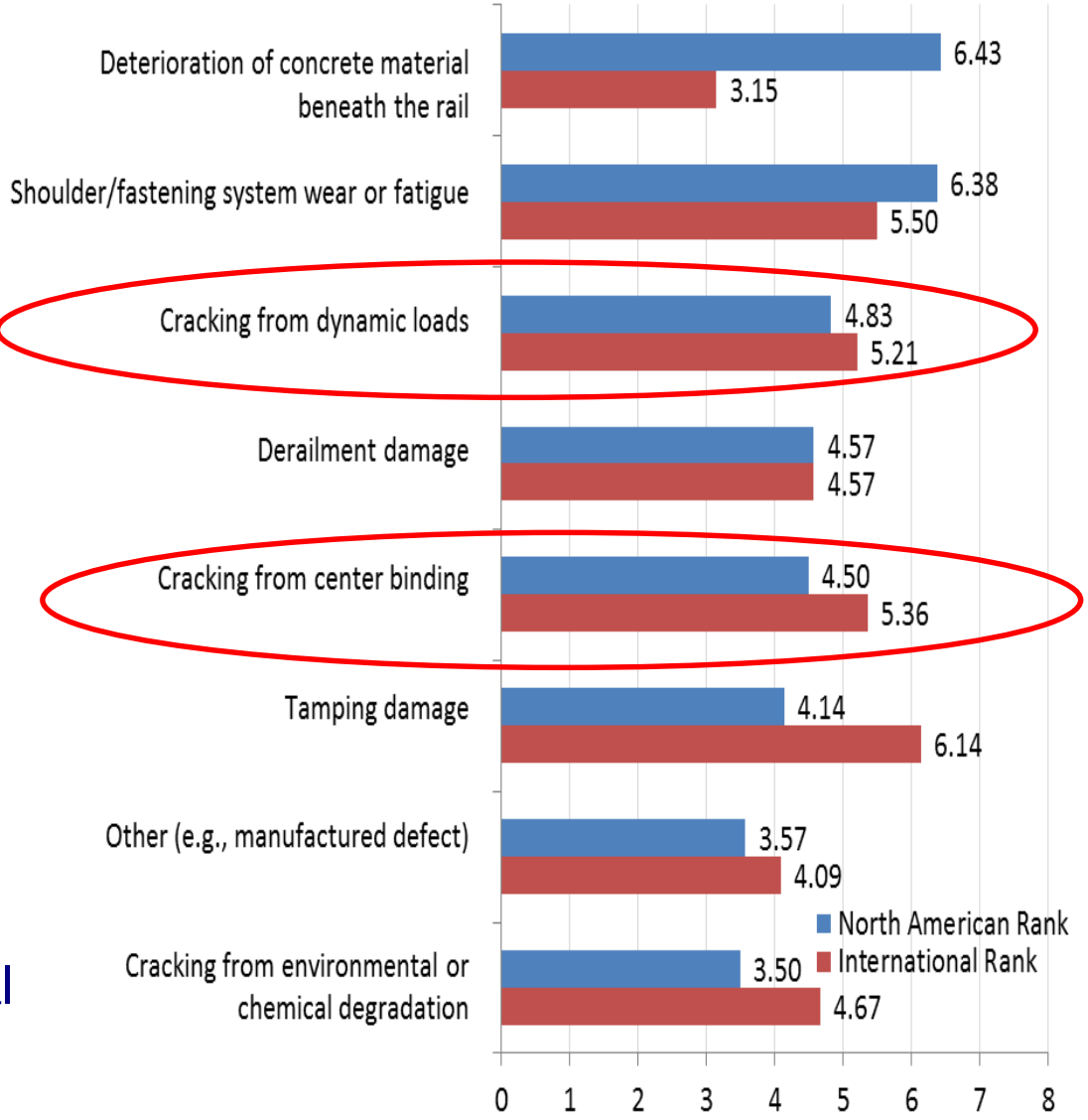
voestalpine
ONE STEP AHEAD.

Outline

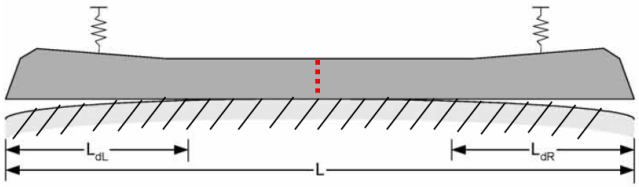
- Introduction/Background
- AREMA C-30.4 Method
- Proposed Method
- AREMA vs. Proposed Comparison
- Advantages to Proposed Method

International Survey Results

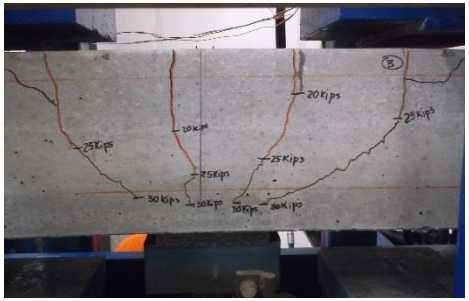
- Survey of railroads, concrete crosstie manufacturers, and researchers around the world
- Conducted by UIUC in 2013
- To determine most critical problems in concrete crosstie track
- Cracking from center binding (5th most critical – North America, 3rd most critical problem – International)
- Cracking from dynamic loads (3rd most critical problem – North America, 4th most critical – International)

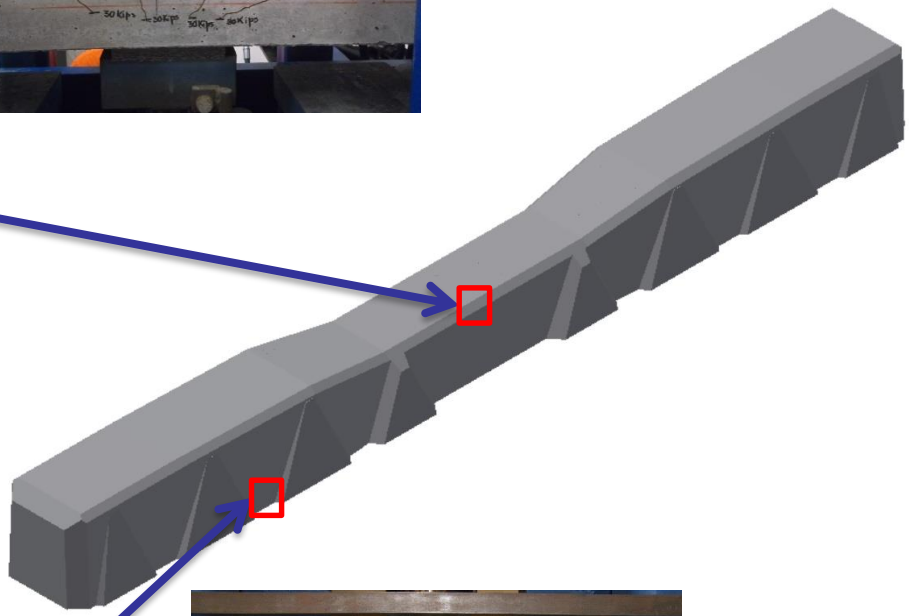


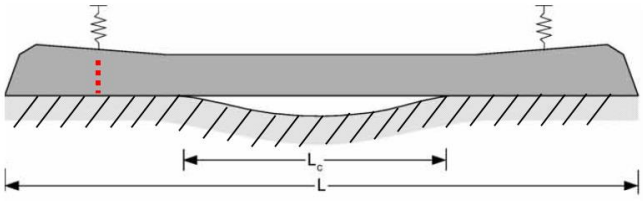
Critical Regions for Flexure



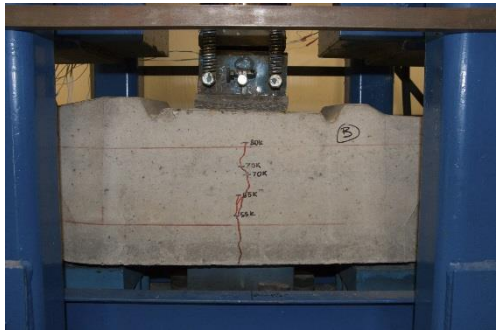
Center Negative







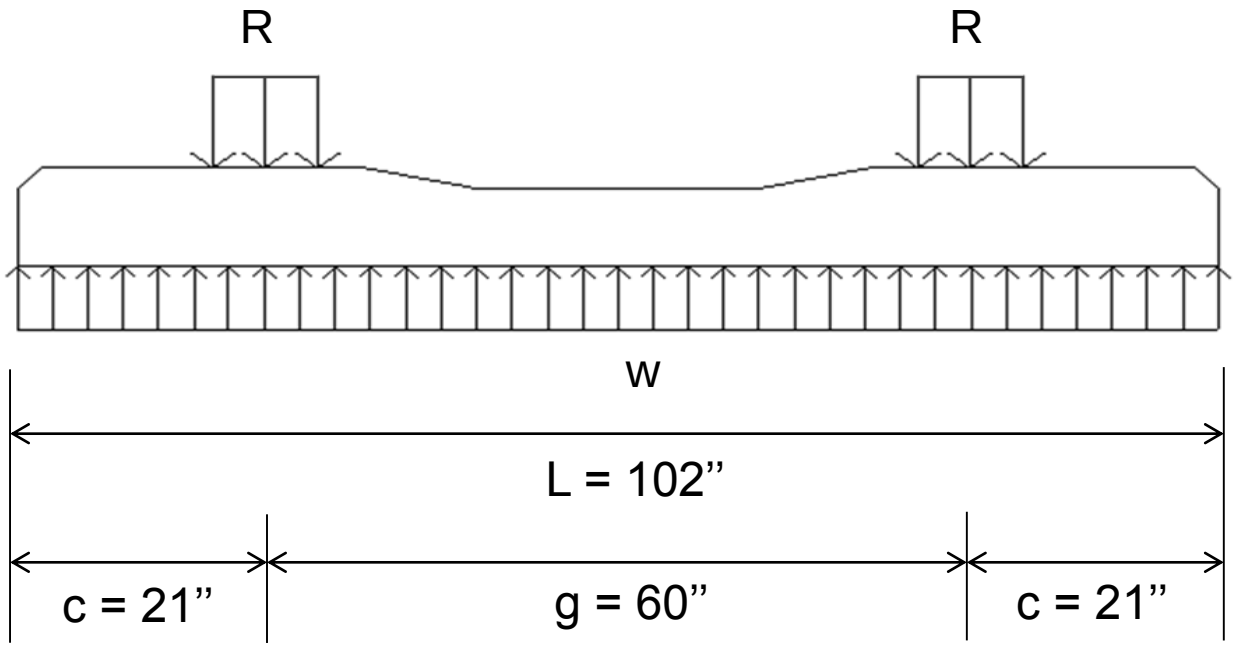
Rail Seat Positive



Constant Properties for Analysis Comparison

All calculations will use the following parameters:

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



Comparison of 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)

AREMA
American Railway Engineering and Maintenance-of-Way Association

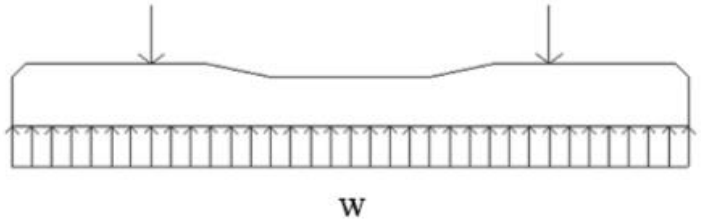
UIC
INTERNATIONAL UNION OF RAILWAYS

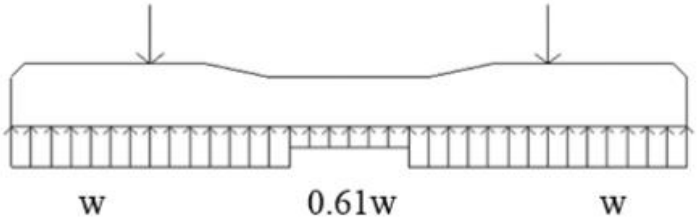
STANDARDS Australia

Support Conditions of Standards

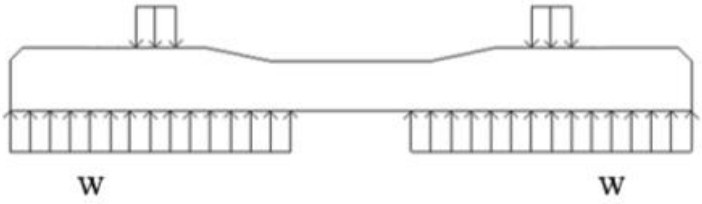
M_{RS+} M_{C-}

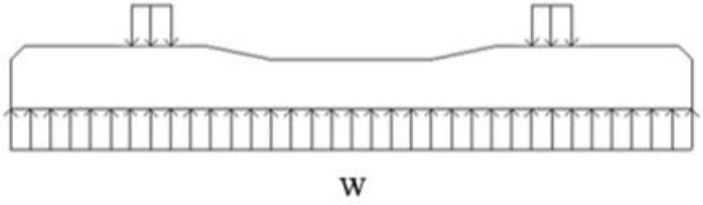
AREMA
American Railway Engineering and Maintenance-of-Way Association



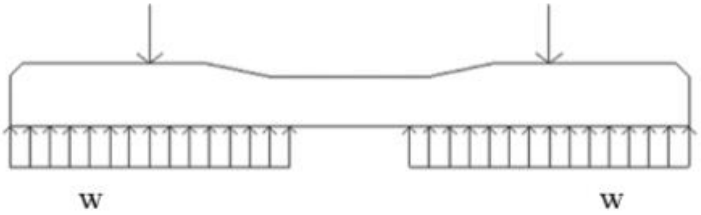


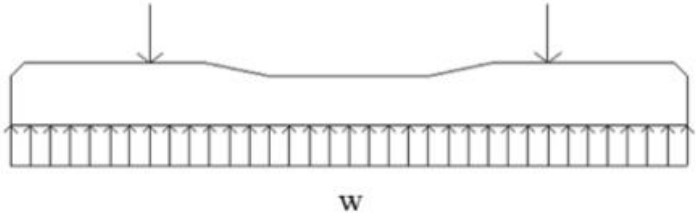
UIC
INTERNATIONAL UNION OF RAILWAYS





STANDARDS Australia





AREMA C30.4 Analysis

- Based on: crosstie length, spacing, annual tonnage, and train speed

$$M = B * V * T$$

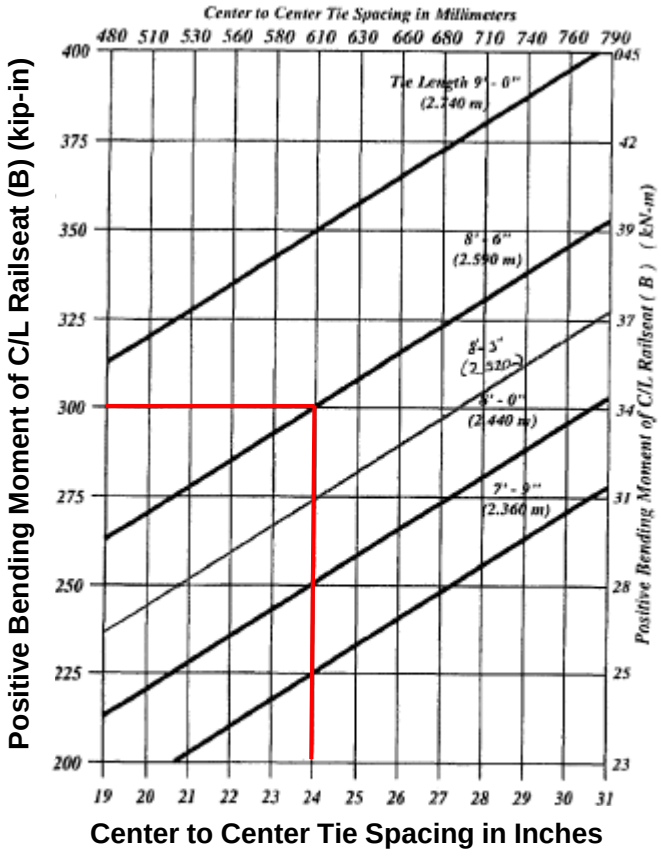


Figure 30-4-3. Unfactored Bending Moment at Centerline of Rail Seat

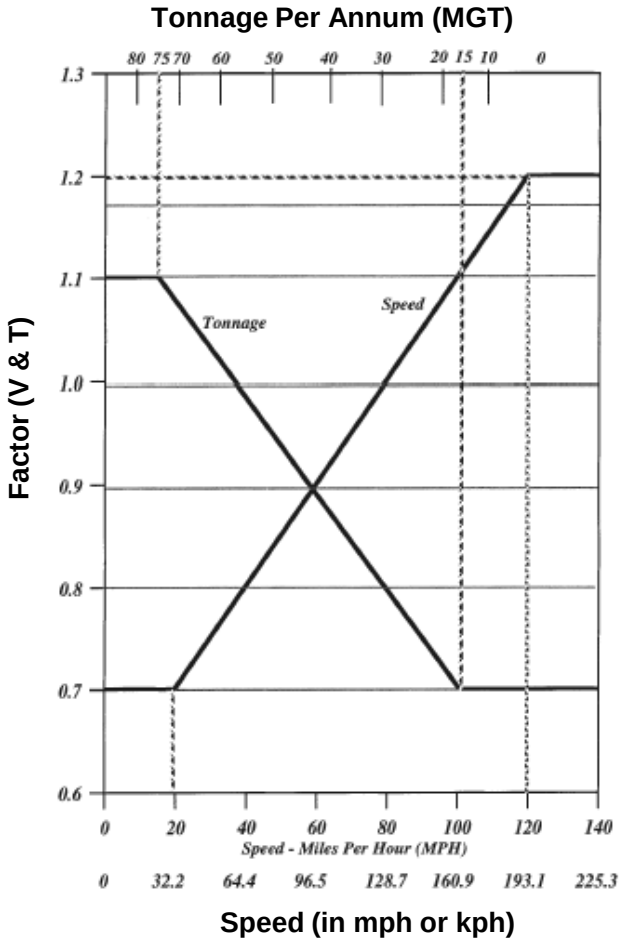
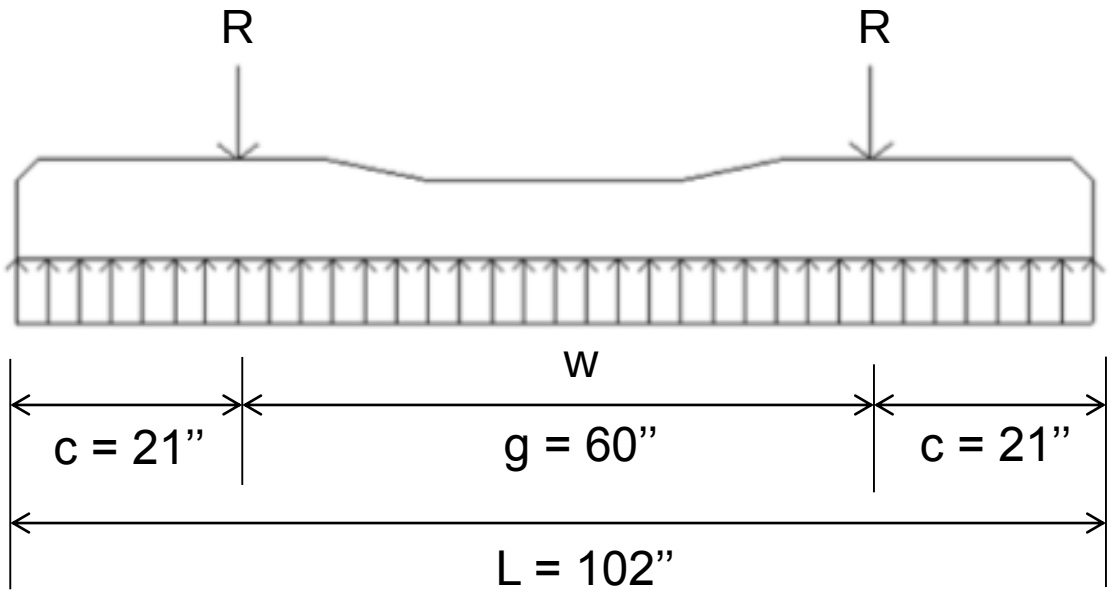


Figure 30-4-4. Tonnage and Speed Factors

M= design railseat positive bending moment (kip-in)
B = unfactored rail seat positive bending moment (kip-in)
V = speed factor
T = tonnage factor

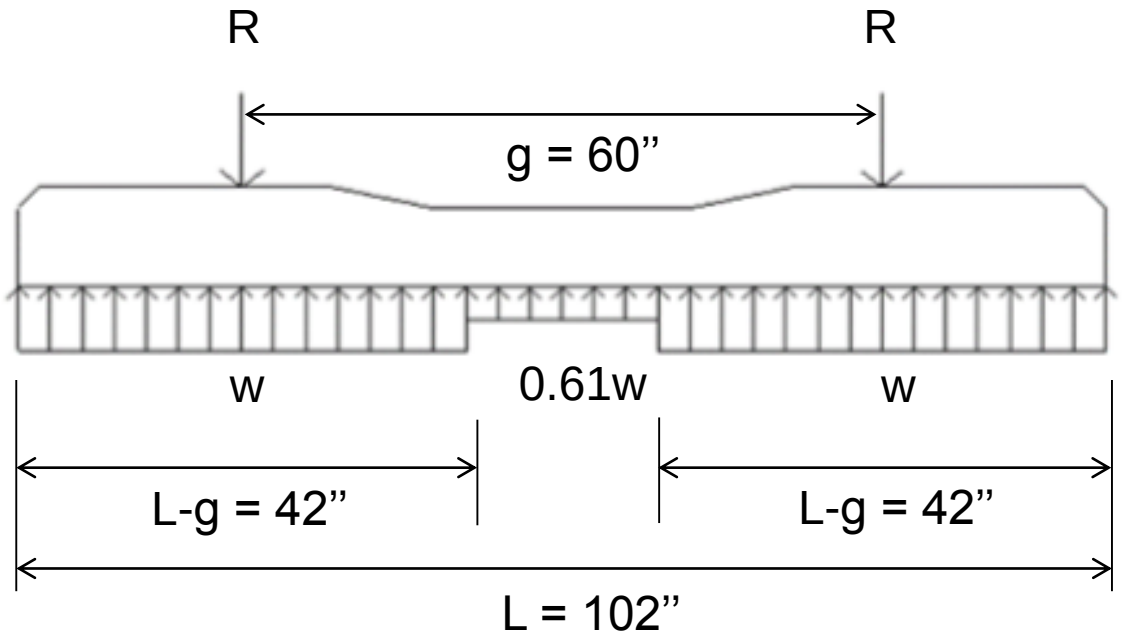
Tie Length	Center Negative
7'-9"	1.13M
8'-0"	0.92M
8'-3"	0.77M
8'-6"	0.67M
9'-0"	0.57M

Theoretical Basis of AREMA C30.4 Analysis (M_{RS+})



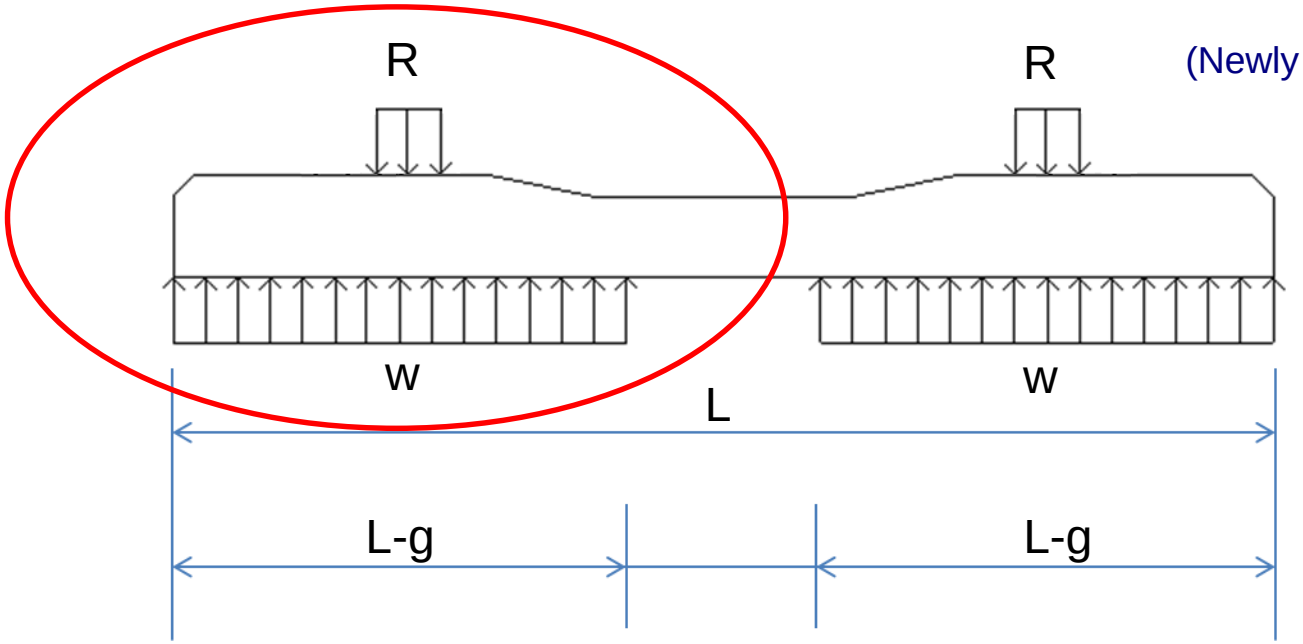
- Based on calculations in 1983 paper by P.J. McQueen
- Assumes uniform ballast reaction, 82 kip axle load, 60 inch gauge and 24 inch tie spacing
- Also includes 10% increase and 5 kip-in rounding

Theoretical Basis of AREMA C30.4 Analysis (M_{C-})

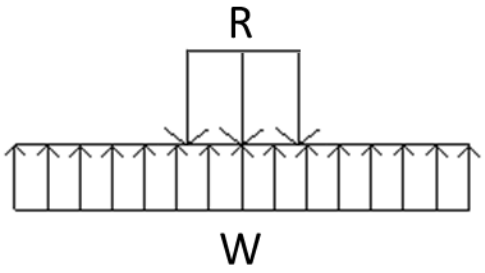


- Following McQueen methodology, support conditions for current M_{C-} recommendations were found, showing a reduction of center reaction of 39%

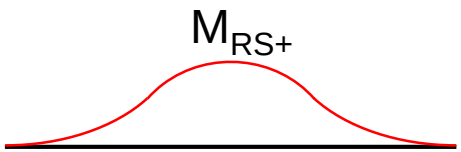
Proposed Analysis Method (M_{RS+})



(Newly tamped assumption)



Free-Body Diagram

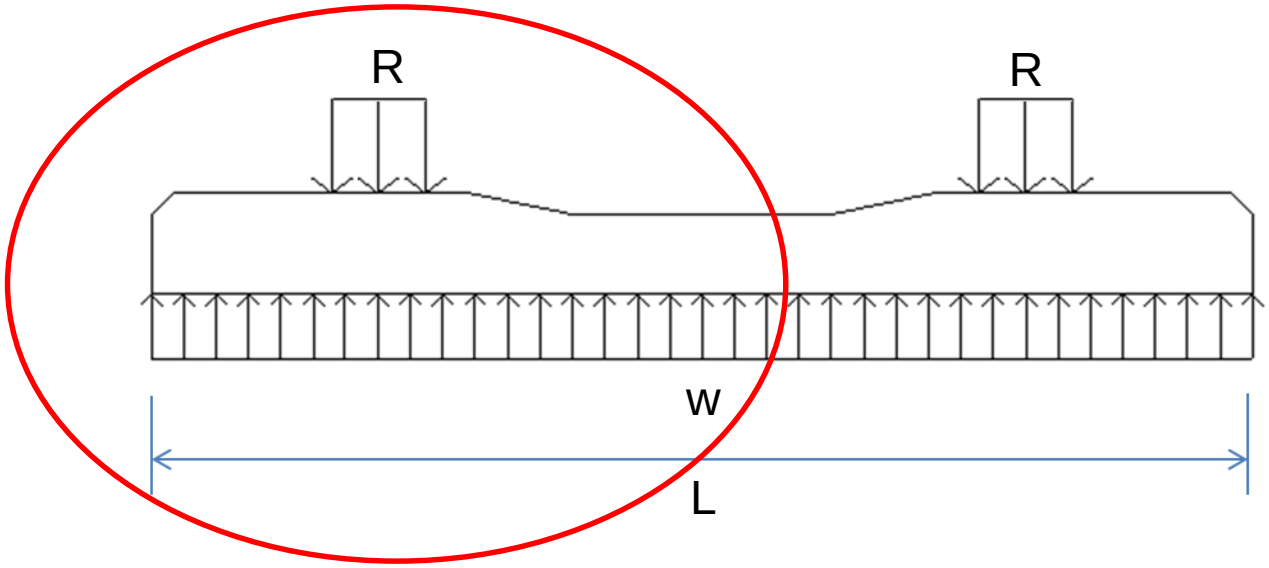


Bending Moment Diagram

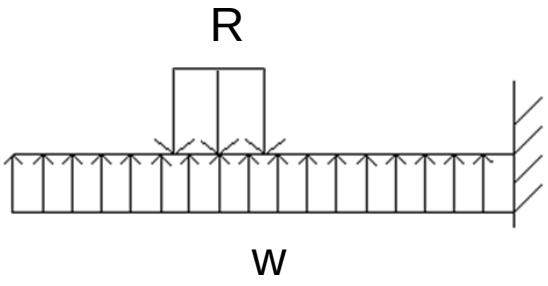
$$M_{RS+} = \frac{R(L-g-s)}{8}$$

Maximum Bending Moment

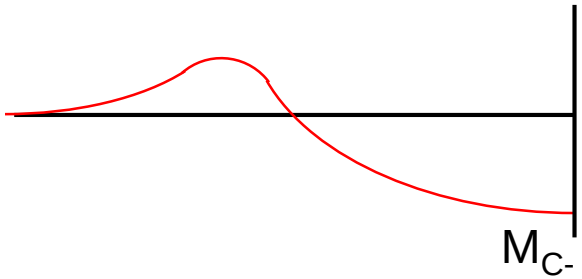
Proposed Analysis Method (M_{C-})



(Uniformly supported)



Free-Body Diagram

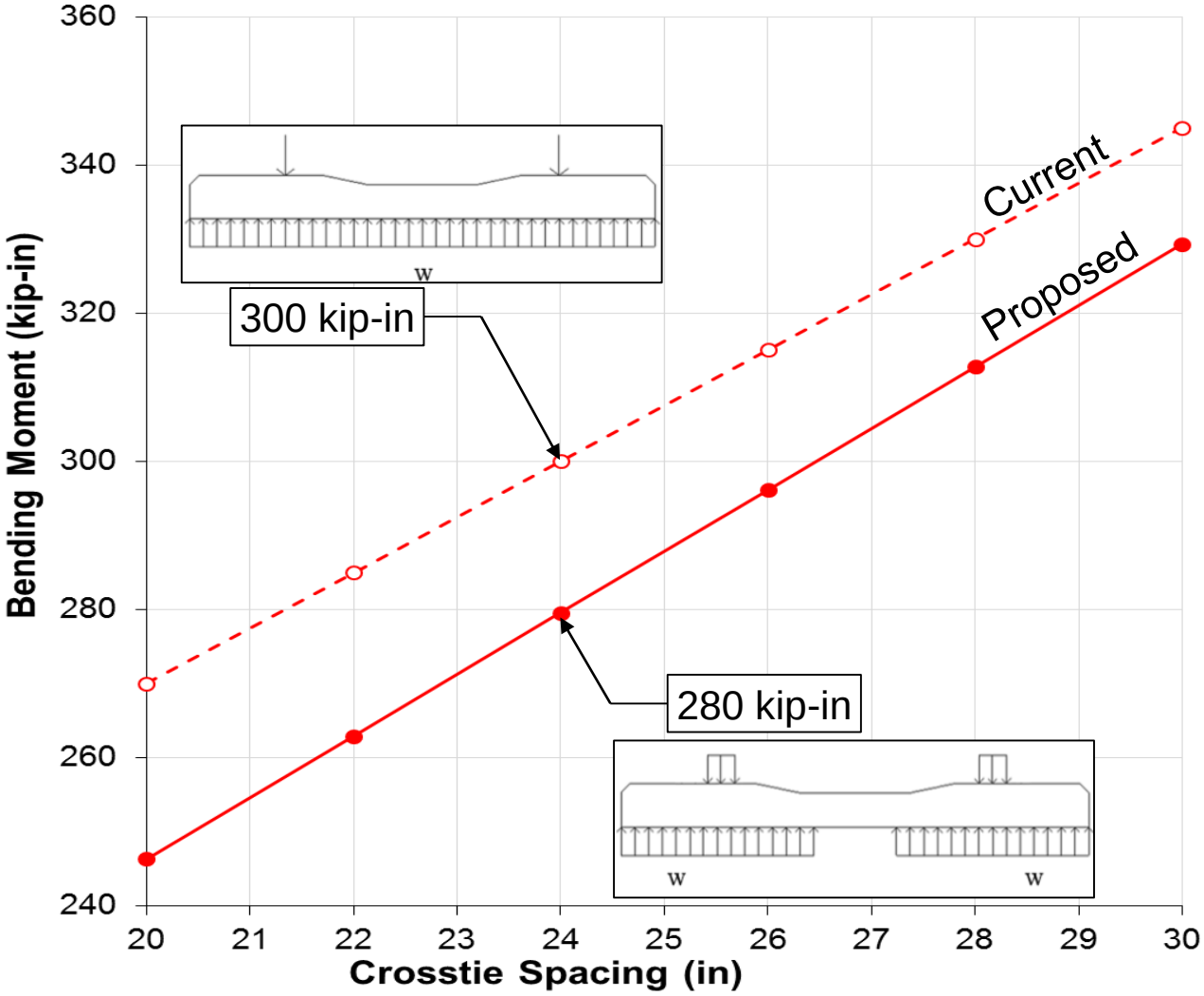


Bending Moment Diagram

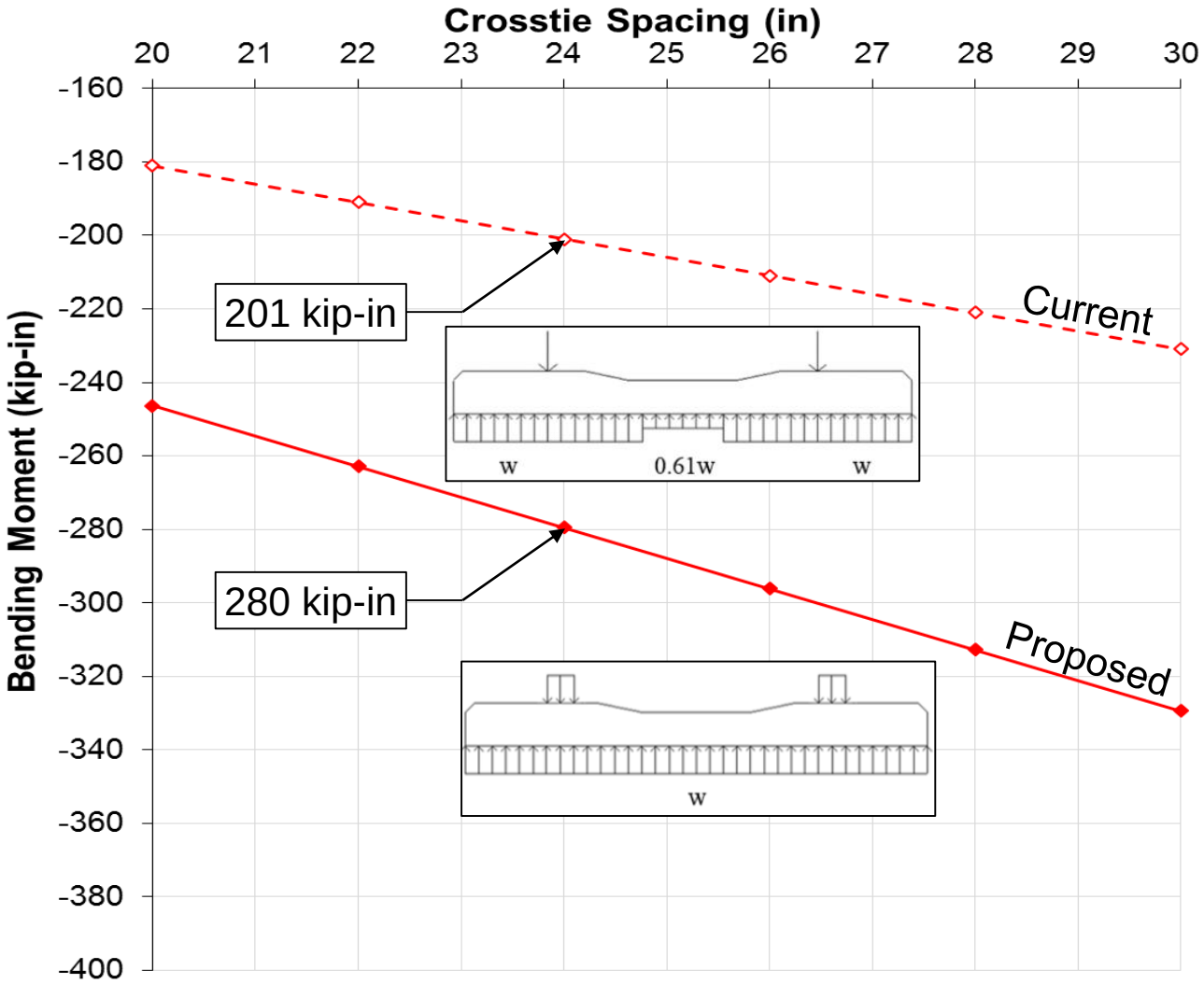
$$M_{C-} = \frac{R(2g - L)}{4}$$

Maximum Bending Moment

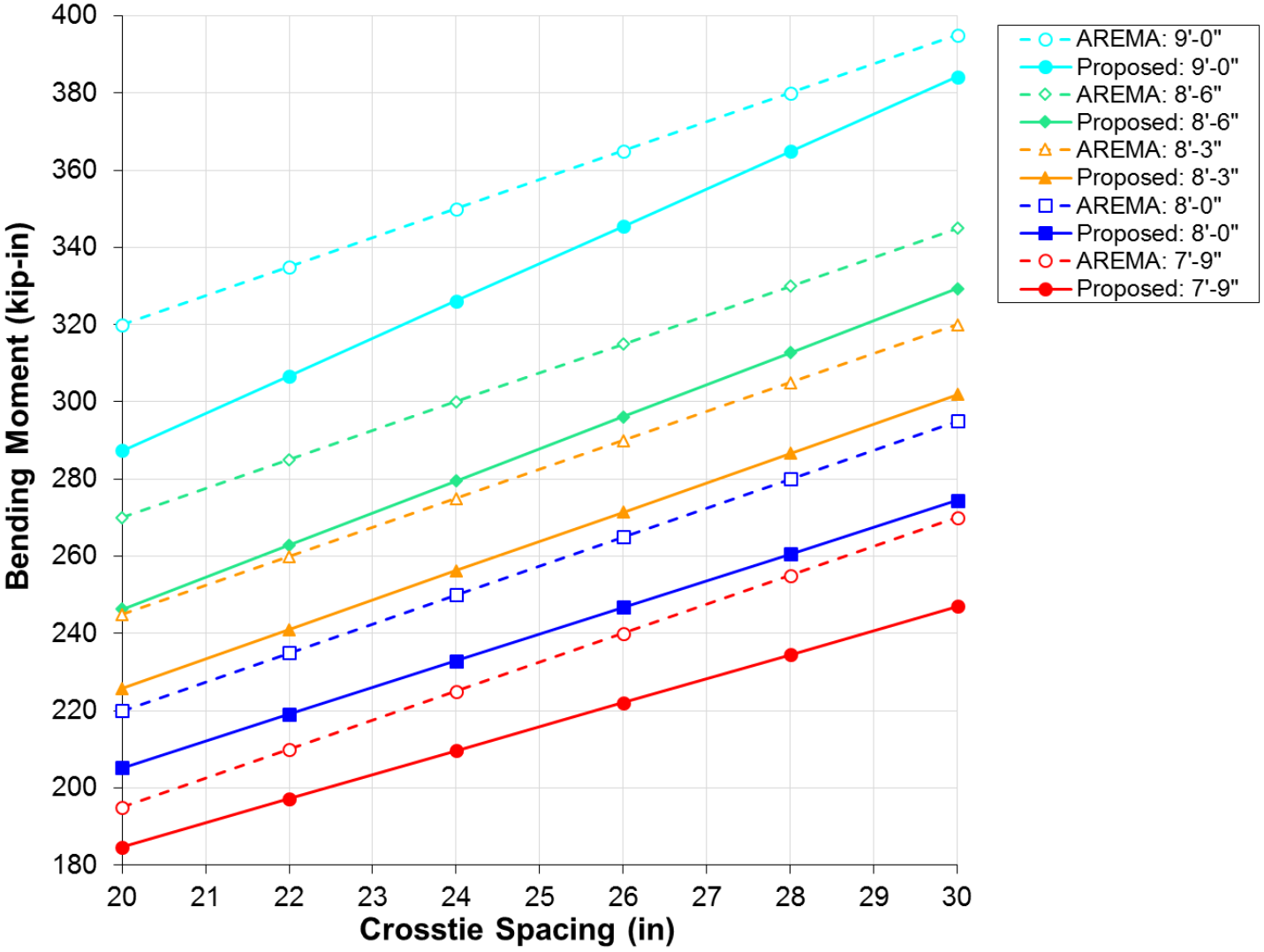
Comparison Between Current and Proposed (M_{RS+})



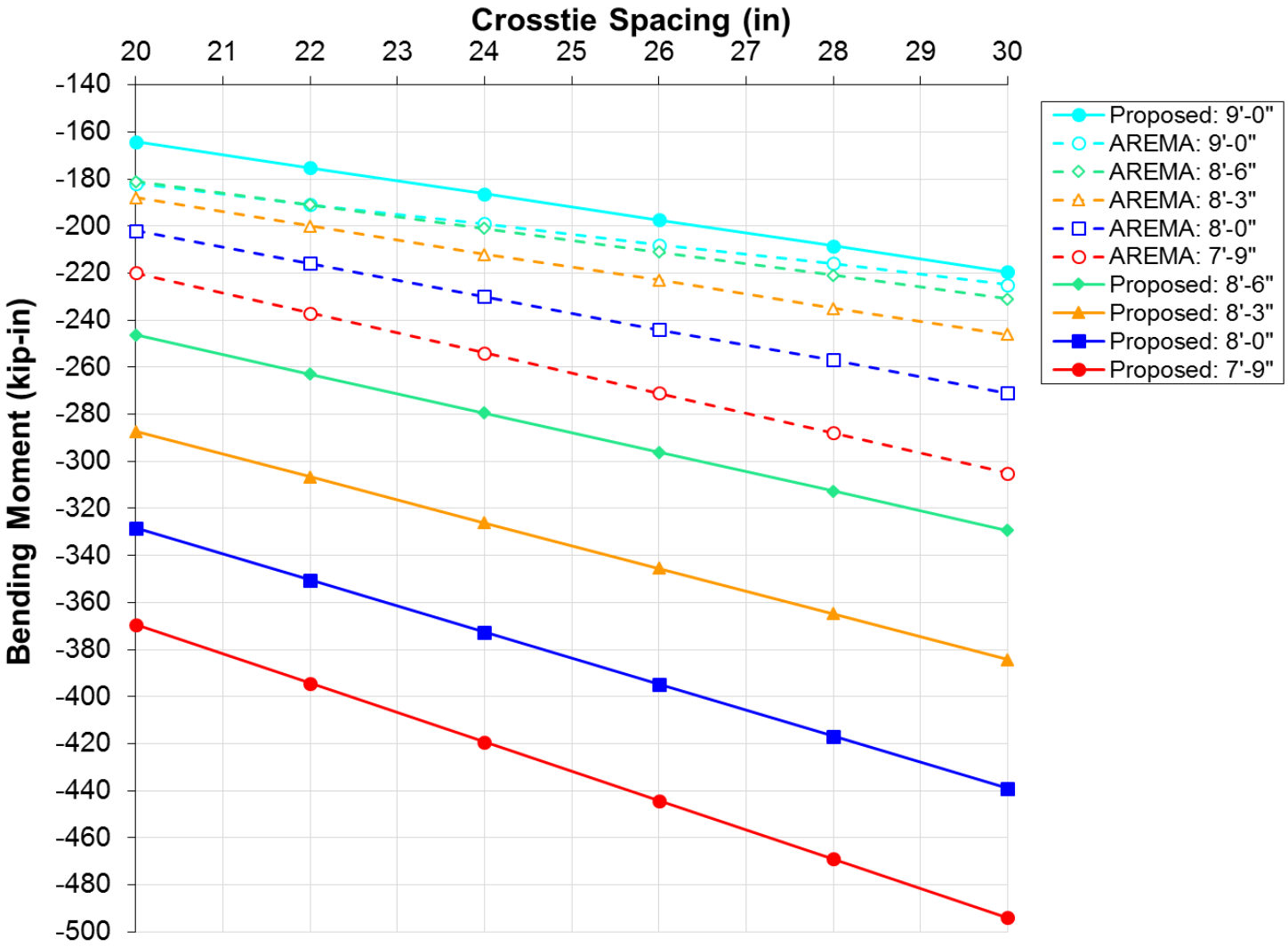
Comparison Between Current and Proposed (M_{C-})



Comparison Between Current and Proposed (M_{RS+})



Comparison Between Current and Proposed (M_{C-})



Comparison Between Current and Proposed (M_{RS+} and M_{C-})

		8'-6" Ties - Freight						8'-3" Ties - Transit					
Tie Spacing (in)		24	24	24	24	24	24	30	30	30	30	30	30
Tie Length (in)		102	102	102	102	102	102	99	99	99	99	99	99
Axle Load (kips)		82.0	71.5	65.8	59.0	51.0	35.5	48.0	40.0	35.0	30.0	27.5	25.0
Rail C-C Spacing (in)		60	60	60	60	60	60	60	60	60	60	60	60
Railseat Width (in)		6	6	6	6	6	6	6	6	6	6	6	6
Current	M_{RS+} (kip-in)	300	300	300	300	300	300	275	275	275	275	275	275
	M_{RS-} (kip-in)	159	159	159	159	159	159	160	160	160	160	160	160
	M_{C+} (kip-in)	141	141	141	141	141	141	140	140	140	140	140	140
	M_{C-} (kip-in)	201	201	201	201	201	201	212	212	212	212	212	212
Proposed	M_{RS+} (kip-in)	269	234	215	193	167	116	165	137	120	103	94	86
	M_{RS-} (kip-in)	142	124	114	102	89	62	95	80	70	60	55	50
	M_{C+} (kip-in)	196	171	157	141	122	85	149	124	109	93	85	78
	M_{C-} (kip-in)	280	244	224	201	174	121	225	187	164	141	129	117

Advantages of Proposed Method

- All assumptions (support conditions, rail seat load area, etc.) are clearly stated
- Dependent on axle load, can lead to more efficient design and better performance
- Increased design recommendations for center negative flexure should reduce center cracking

Acknowledgements

U.S. Department of Transportation
Federal Railroad Administration

National University Rail Center - NURail
USDOT-RITA Tier I University Transportation Center

- **Funding for this research has been provided by:**
  - **Federal Railroad Administration (FRA)**
  - **National University Rail Center (NURail)**
- Industry Partnership and support has been provided by
  - Union Pacific Railroad
  - BNSF Railway
  - National Railway Passenger Corporation (Amtrak)
  - Amsted RPS / Amsted Rail, Inc.
  - GIC Ingeniería y Construcción
  - Hanson Professional Services, Inc.
  - CXT Concrete Ties, Inc., LB Foster Company
  - TTX Company
- For assistance with research and lab work
  - Zhengboyang Gao

FRA Tie and Fastener BAA Industry Partners:

UNION PACIFIC
BUILDING AMERICA®
BNSF RAILWAY
AMTRAK®
Amsted RPS
An Amsted Rail Company
GIC
HANSON
LBFoster
CXT Concrete Ties
TTX

Thank You

RAILTEC
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Henry Wolf
Graduate Research Assistant
email: wolf24@illinois.edu

Riley Edwards
Senior Lecturer and Research Scientist
email: jedward2@illinois.edu

Marcus Dersch
Senior Research Engineer
email: mdersch2@illinois.edu

voestalpine
ONE STEP AHEAD.

Steve Mattson
Technical Manager – Concrete Ties
email: steve.mattson@voestalpine.com