AASHTOWare™

BRIDGE

DESIGN AND RATING

Columbus, Ohio

Railway Bridge Analysis

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Discussion Points

1. Purpose of the presentation
2. U.S. Railroad Bridge Infrastructure
3. Railway versus Highway Bridge
4. Sample Bridge: Steel Girder Bridge
5. Force effect
6. Capacity
7. Load Rating
8. Conclusion
9. Points for panel discussion

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Purpose of The Presentation

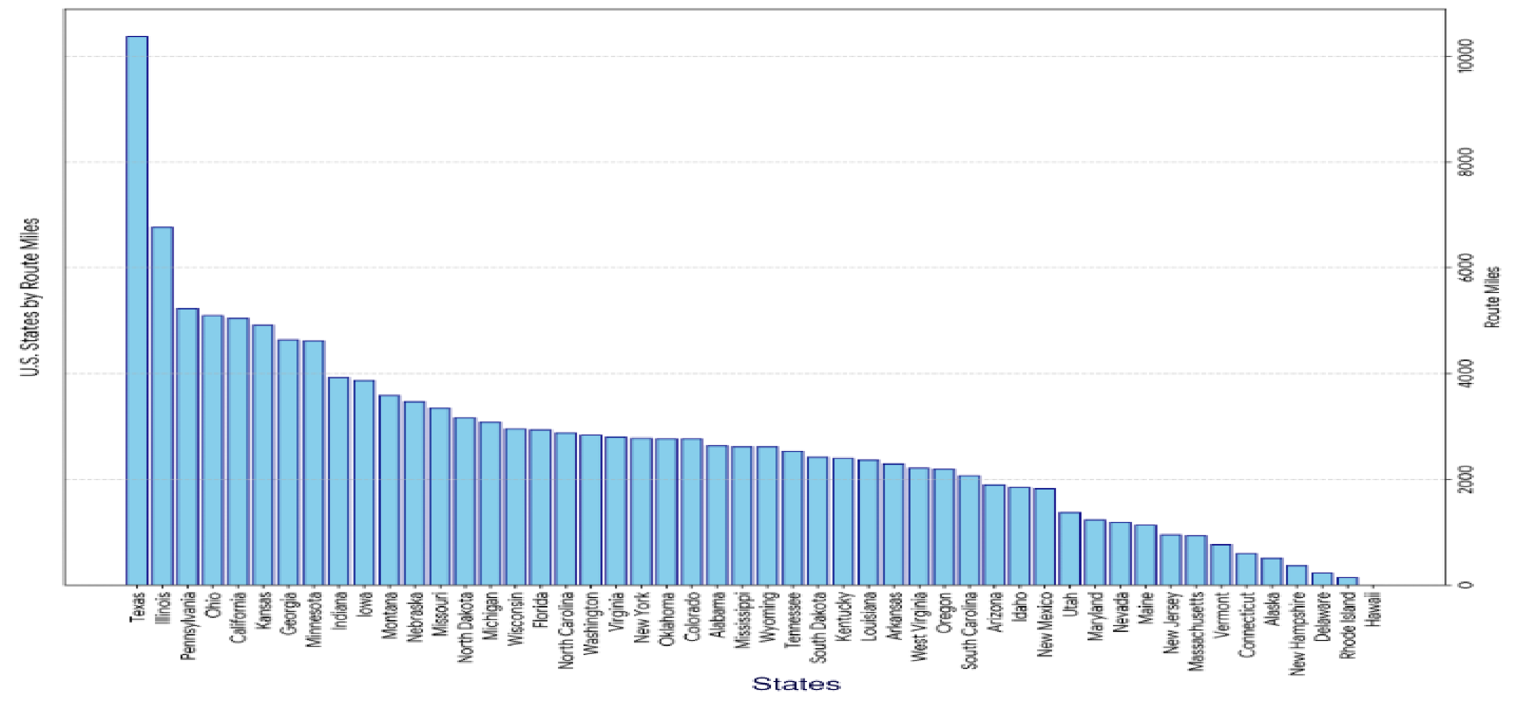
Wishlist:

- Cooperation between AREMA and AASHTO
- Implementation in AASHTOWare (BrR)

U.S Railroad Bridges

Overview:

- Inventory of Railway bridge by state not available
- Railway route milage-Indication of Infrastructure density-Likely number of bridges
- The United States has approximately 140,742 route miles of railroad infrastructure. Texas leading by 10370 route miles.



State Route Mile Bar Chart

State	Route Miles
Texas	10370
Illinois	6768
Pennsylvania	5228
Ohio	5099
California	5050
Kansas	4914
Georgia	4636
Minnesota	4617
Indiana	3925
Iowa	3870
Montana	3588
Nebraska	3466
Missouri	3348
North Dakota	3166
Michigan	3081
Wisconsin	2952
Florida	2935
North Carolina	2876
Washington	2835
Virginia	2802
New York	2777

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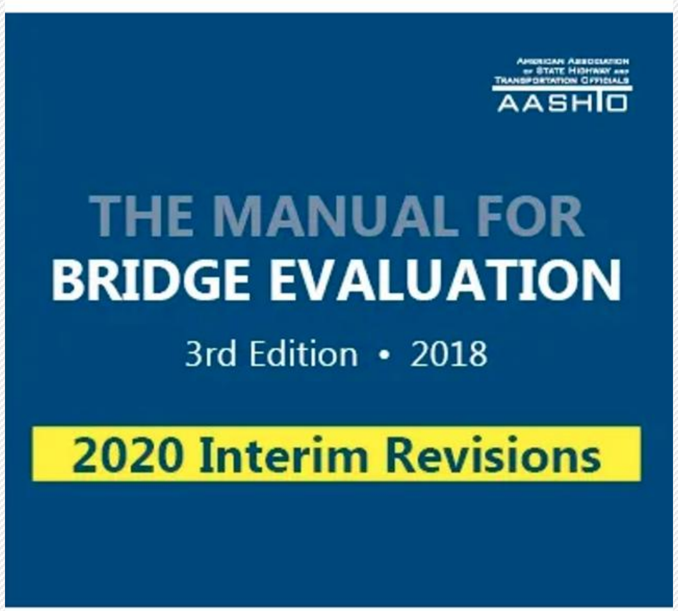
Railway versus Highway Bridge

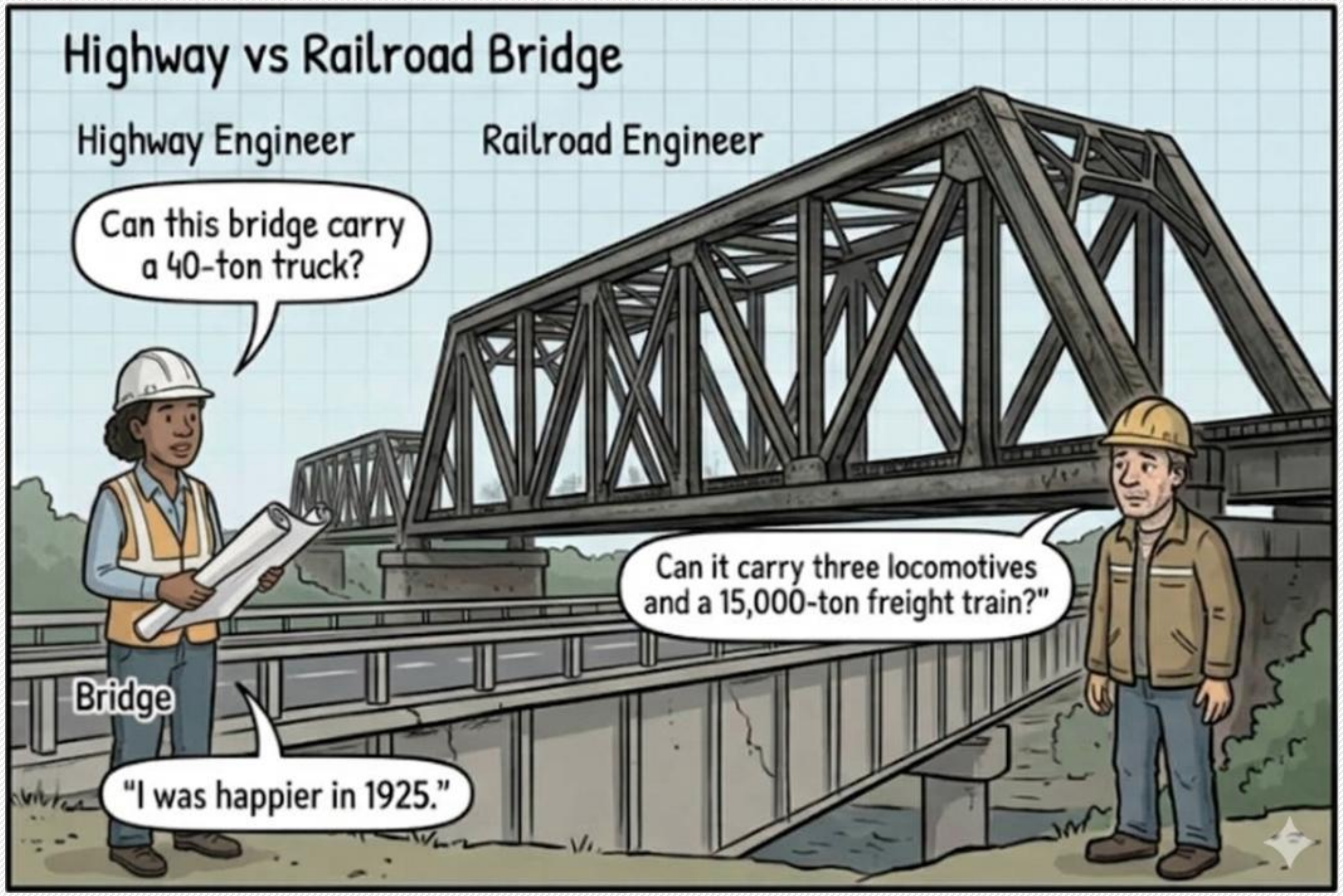
Manual:

- AREMA for both Design and evaluation of Railway bridges
- AASHTO for Design and MBE for Evaluation



Railway versus Highway Bridge

Vehicles :



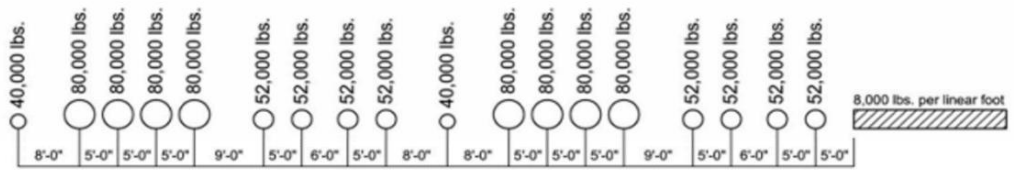
Railway versus Highway Bridge

Vehicles :

- HL-93 is to highway bridges what Cooper E80 is to railroad bridges. Both are baseline conservative vehicles.
- Similar comparison could be made to the rest of the listed of vehicles. Passenger and Fright for trains and Legal and Permit for highway vehicles

VEHICLE TYPE
AREMA Cooper E-80
F40PH (280K) Modified
286K Rail Car
HSP-46 (296K) Locomotive
315K Rail Car
ES44AC

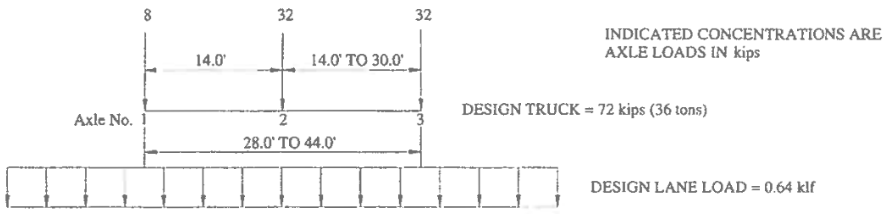
VEHICLE TYPE
HL-93
TYPE 3
TYPE 3S2
SU4



AREMA COOPER E-80 LOADING

LIVE LOAD IN LBS. PER AXLE
RATING IS EXPRESSED IN AXLE LOAD (KIPS)
PROPORTIONAL TO COOPER E-80

APPENDIX C6A—LRFD DESIGN LIVE LOAD (HL-93)
(LRFD DESIGN ARTICLE 3.6.1)



Railway versus Highway Bridge

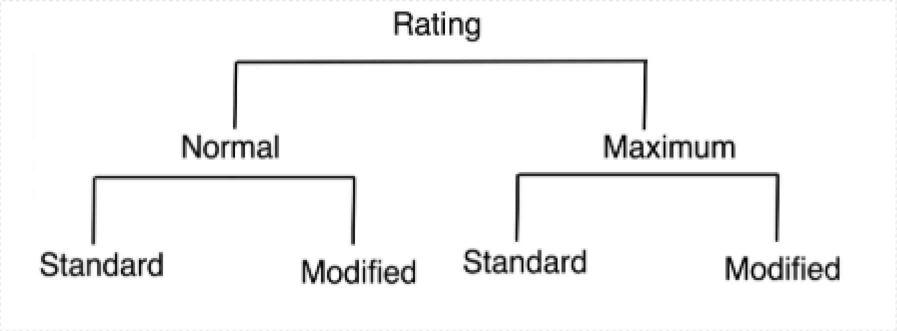
Method of analysis

- Allowable Stress Method (ASR)- RR bridges
- ASR, LFR, and LRFR for Highway bridges
- Flexure & Shear : Applicable for Highway and RR bridges
- Fatigue : Applicable for both but primary consideration for railway bridges due to heavy repetitive loads

Railway versus Highway Bridge

Load Rating Railway bridge:

- Rating analysis is performed under Normal and Maximum loading condition
- Normal and maximum are subdivided into Standard and Modified
- Modified rating includes wind load, longitudinal load and lateral forces in addition to Dead load and live load



Load Ratings:

Normal Rating Equations: (Only including Dead, Live, Impact and Centrifugal Forces)

MOMENT

$$RF = \frac{M_{CAP} - M_{DL}}{M_{LL} + M_{I} + M_{CF}}$$

SHEAR

$$RF = \frac{V_{CAP} - V_{DL}}{V_{LL} + V_{I} + V_{CF}}$$

Per Ch. 15, Sect 7.3.3.8.d,e "The rating stresses shall be checked for longitudinal force combined with wind force, lateral force from equipment and, where appropriate, the provisions related to bracing between compression members."
"When the forces (above) are combined with dead load, live load, impact load, and centrifugal force, the allowable stresses may be taken as 1.25 times those otherwise recommended by the rating."

Modified Rating Equations: (including Wind, Longitudinal, and Lateral forces)

MOMENT

$$RF_{MOD} = \frac{1.25M_{CAP} - M_{DL}}{M_{LL} + M_{I} + M_{CF} + M_{WF} + M_{LNG} + M_{LAT}}$$

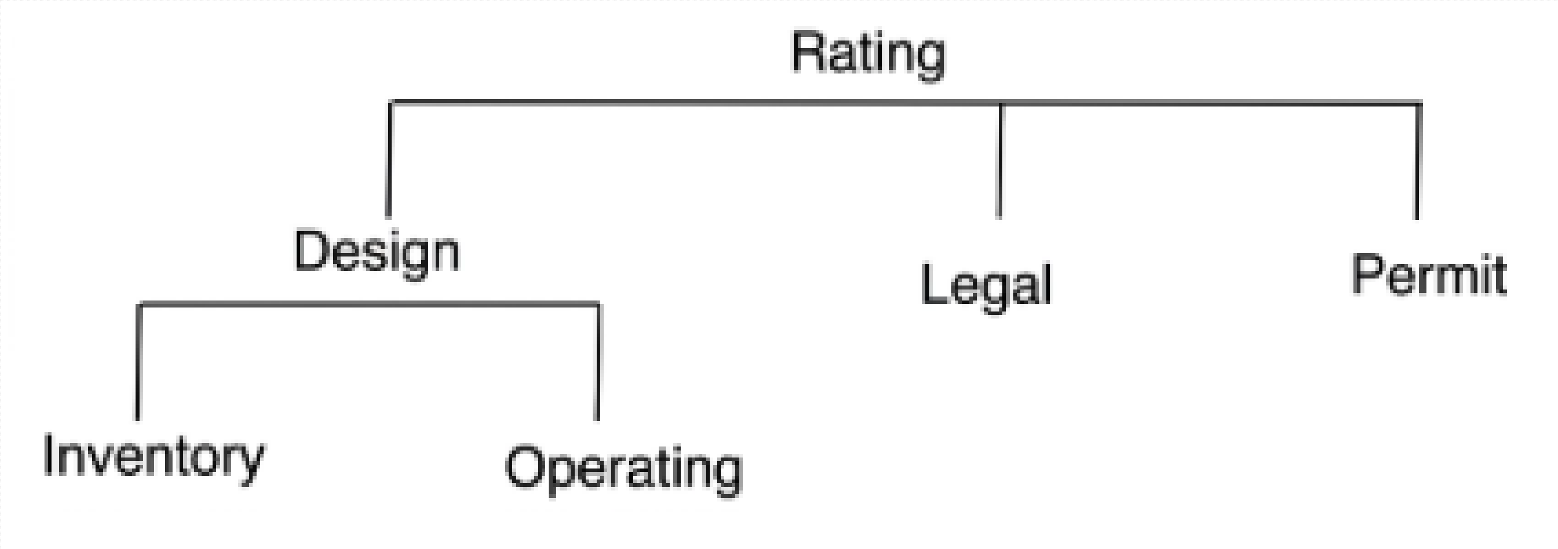
SHEAR

$$RF_{MOD} = \frac{1.25V_{CAP} - V_{DL}}{V_{LL} + V_{I} + V_{CF} + V_{WF} + V_{LNG} + V_{LAT}}$$

Railway versus Highway Bridge

Load Rating Highway bridge:

- Highway bridges mostly uses dead load and live load
- Trucks are categorized into Design, Legal and Permit



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Railway versus Highway Bridge

Posting

- Railroad bridges are usually not posted with signs Instead; restrictions are controlled operationally through communication.

- When a highway bridge has insufficient capacity, sign will be posted

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Sample Bridge:

Client and Bridge Location

- Needham MA
- Massachusetts Bay Transportation Authority MBTA (MBTA)

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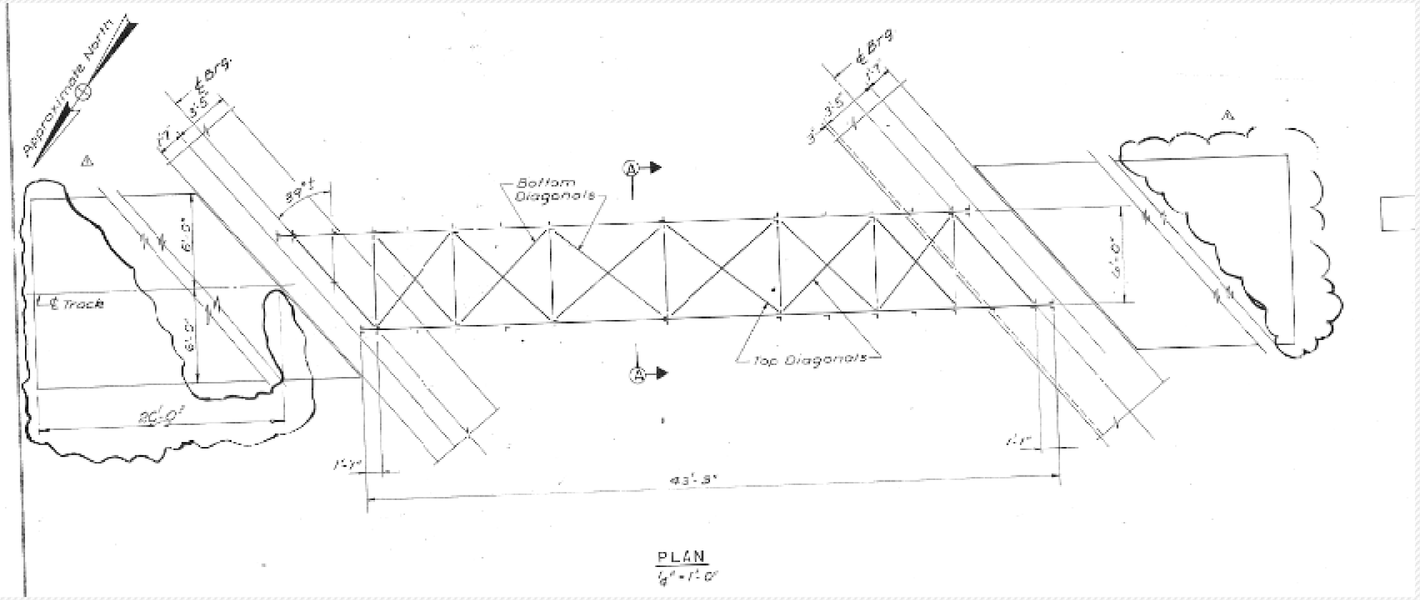
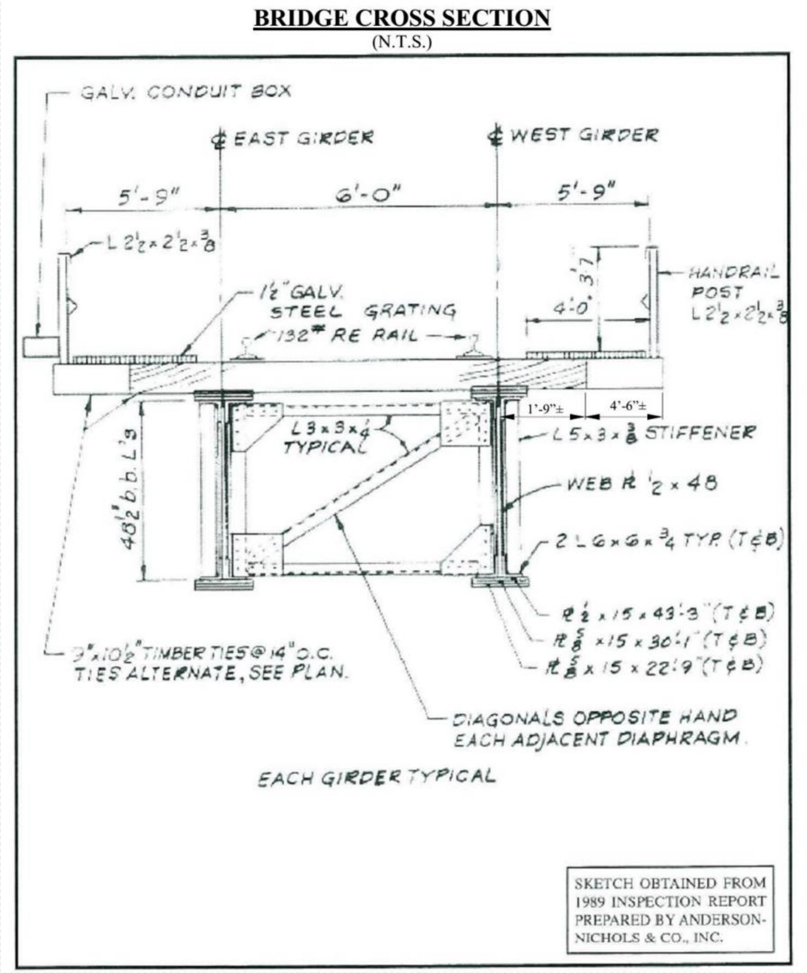
Sample Bridge

Bridge Type and Geometry

- Two Girder system
- Simple span
- Span length 41′-2″
- Bridge width: 17′-5″





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Force Effect

Dead load

- Self-weight and Superimposed dead loads
- BrR Input

Dead Load Summary

Applied Load Summary

Load Type	Section[1] 1 ω (lb/ft)	2 ω (lb/ft)	3 ω (lb/ft)
Track	100.00	-	-
Ties (Long)	107.13	-	-
Ties (Short)	76.52	-	-
Spacer	6.22	-	-
Stiffeners	12.12	-	-
Cross and Lateral Bracing	29.94	-	-
Walkway	29.40	-	-
Railing	20.00	-	-
Electrical Conduit	15.00	-	-
Total (North Girder)	381.32	0.00	0.00
Total (South Girder)	396.32	0.00	0.00

Girder Dead Load (Self Weight)

γ_{steel} = 490.00 lb/ft³ Steel unit weight

Section	A_g (in2)	ω (lb/ft)	ω[1] (lb/ft)	Δω[2] (lb/ft)	Start (ft)	end (ft)	Length (ft)
1	71.97	244.89	257.13	257.13	0.00	41.17	11.09
2	90.72	308.69	324.12	66.99	5.54	35.63	7.33
3	109.47	372.49	391.12	66.99	9.21	31.96	22.75

Average SW= 343.13 lb/ft

Page 1

Pedestrian load: lb/ft

Uniform Distributed Concentrated Settlement

Load case name	Span	Uniform load (kip/ft)	WS field measured*	Description
DL	All Spans	0.396		Dead Load
WL	All Spans	0.338		Wind Load
SW	All Spans	0.343		Self Weight

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Force Effect

Wind load:

- Wind load on Train : Applied 8 ft over the rail
- Wind load on Girder

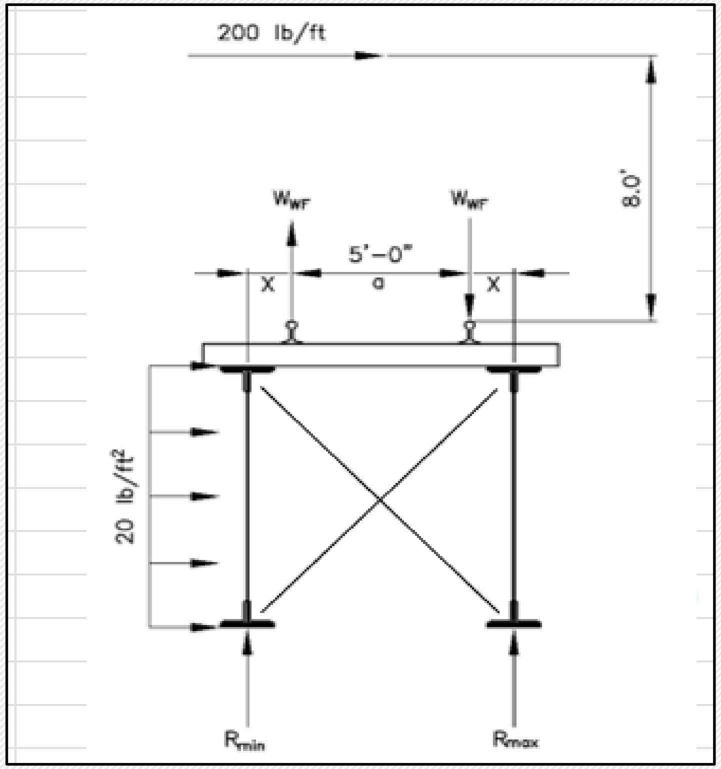
7.3.2.5 Wind Force

a. The wind force shall be considered as a moving load in any horizontal direction. Wind force on the train shall be taken as 200 lb per linear foot on one track applied 8 feet above the top of rail. Wind force on the bridge shall be taken as 20 lb per square foot of the following surfaces:

(1) For girder spans, 1.5 times the vertical projection of the span.

(2) For truss spans, the vertical projection of the span plus any portion of the leeward trusses not shielded by the floor system.

(3) For viaduct towers and bents, the vertical projections of all columns and tower bracing.



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Force Effect

Wind load: On Train

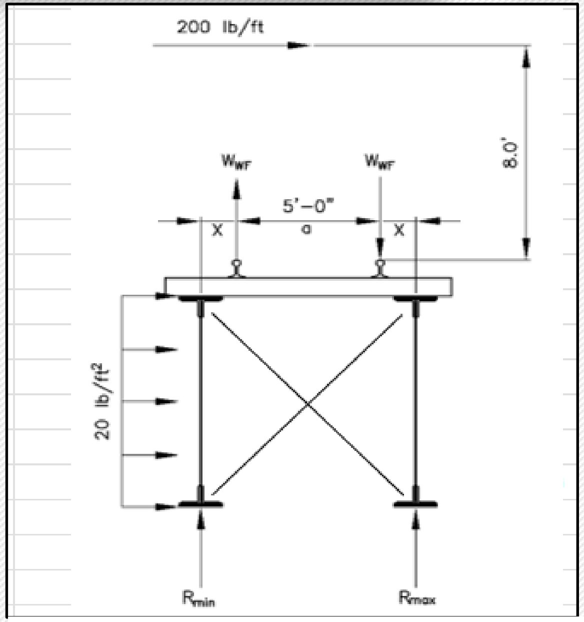
$X =$	0.50	ft	CL Left Girder to CL Left Exterior Track	
$a =$	5.00	ft	Track gauge	
$d =$	6.00	ft	CL Girder to CL Girder Spacing	
$h_a =$	8.00	ft	Height of lateral wind force above the top rail	(AREMA 15-7.3.2.5.a)
$h_{rail} =$	7.125	in	Height of Rail type 132 RE	(Arema Standard Rail)
$h_{ties} =$	10.50	in	Height of timber ties	(2025 Inspection Report)
$H =$	9.47	ft	Height of lateral wind force above top of girders	
$\omega_{wind,\ train} =$	200.00	lb/ft	Lateral wind force acting on the train	(AREMA 15-7.3.2.5.a)

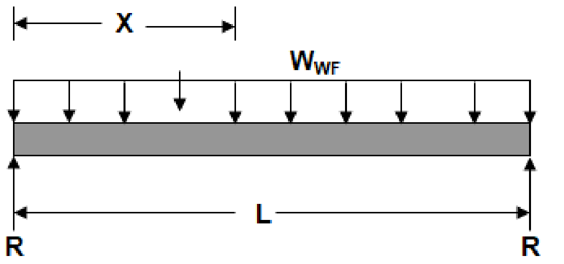
$$\omega_{WF} = \omega_{wind,train} * H \,/\, a$$

$\omega_{WF} =$	378.75	lb/ft	Equivalent wind force acting on bridge from lateral train wind load

$$R_{max} = (\omega_{WF} * \left(d - x + \frac{a}{2}\right) - \omega_{WF} * (d - x - \frac{a}{2}))\,/\,d$$

$R_{max} =$	315.63	lb/ft	Wind force acting along the full length of the girder
$\omega_{lat,\ train} =$	315.63	lb/ft	Equivalent vertical line load acting on one girder from the lateral train wind load





Longitudinal Girders

Force Effect

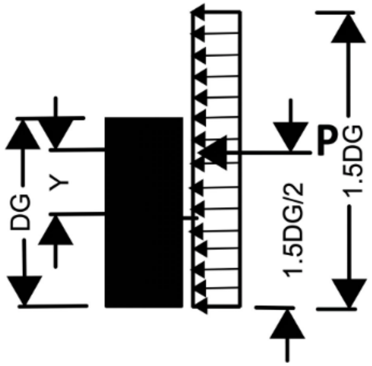
Wind load: On Girder

Lateral Wind Force (Cont.)

Lateral Wind Force on the Bridge

Cover Plate	Depth (D) (in)	Length[1] (L) (ft)	D*L (ft^2)
1	49.50	11.08	45.7
1,2	50.75	7.33	31.0
1,2,3	52.00	22.75	98.6

(1) Lengths are calculated from the physical cut-off points, not the calculated theoretical cut-off points.



$D_G = \dfrac{\sum D * L}{\sum L}$ = 4.26 ft Weighted girder depth

S_G = 6.00 ft Girder spacing

$\omega_{wind,\ bridge}$ = 20.00 lb/ft^2 Lateral wind force acting on the bridge (AREMA 15-1.3.6.a)

$\omega_{lat,\ bridge} = \omega_{wind,\ bridge} * (1.5 * D_G/2 - D_G/2) * 1.5*D_G / S_G$

$\omega_{lat,\ bridge}$ = 22.67 lb/ft Equivalent vertical line load acting on one girder from the lateral bridge wind load

Total Lateral Wind Force

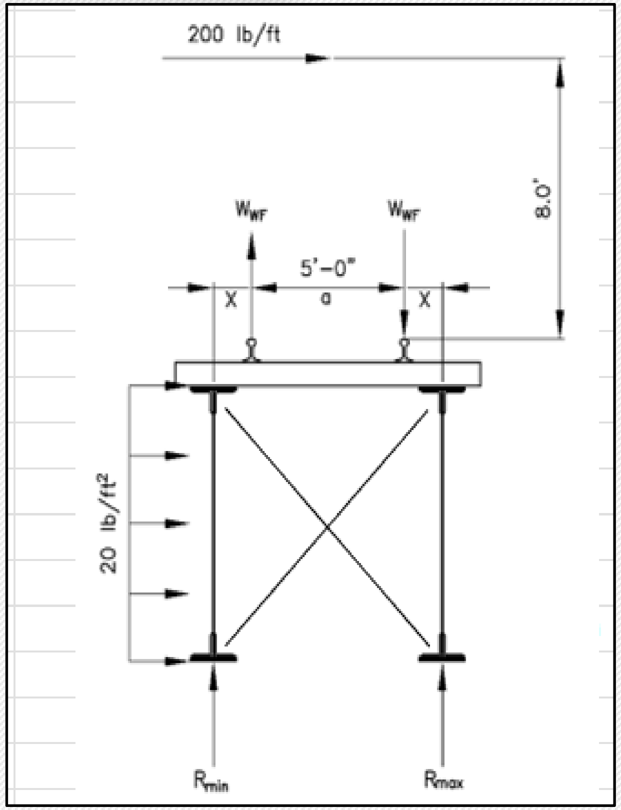
$\omega_{lat} = \omega_{lat,train} + \omega_{lat,bridge}$

ω_{lat} = 0.338 k/ft Total equivalent vertical load acting on one girder from lateral wind loads

Pedestrian load: lb/ft

Uniform | Distributed | Concentrated | Settlement

Load case name	Span	Uniform load (kip/ft)
DL	All Spans	0.396
WL	All Spans	0.338
SW	All Spans	0.343



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Force Effect

Impact

- Vertical Effect: Percentage increase to the live load
- Rocking Effect: Vertical force couple 20% of the wheel load downward on one rail and upward on the other.

Impact: (For Open Deck Bridges)

Per AREMA Ch. 15, Sect. 1.3.5.a: "Impact load… shall be determined by taking a percentage of the live load specified in Article 1.3.3 and shall be applied vertically at top of each rail."

Impact Load due to Rocking Effects:

Per AREMA Ch. 15, Sect. 1.3.5.d: "… RE shall be calculated from loads applied as a vertical force couple, each being 20 percent of the wheel load without impact, acting downward on one rail and upward on the other."

Force Effect

Impact: Vertical

Impact Load

Base Impact Load

L_G = 41.17 ft — Girder span length (CL Bearing to CL Bearing)

$$I = \begin{cases} 40 - \dfrac{3L^2}{1600}, & L < 80\ ft \\ 16 + \dfrac{600}{L-30}, & L \geq 80\ ft \end{cases}$$

= 36.82%

Impact Load Reduction Factor

S_{60} =	60.00	mi/hr	Train speed
S_{50} =	50.00	mi/hr	Train speed reduced to 50 mph due to low rating
S_{40} =	40.00	mi/hr	Train speed reduced to 40 mph due to low rating
S_{30} =	30.00	mi/hr	Train speed reduced to 30 mph due to low rating
S_{20} =	20.00	mi/hr	Train speed reduced to 20 mph due to low rating
S_{10} =	10.00	mi/hr	Train speed reduced to 10 mph due to low rating

$$I_{reduction} = max\left\{1 - \frac{0.8}{2500}(60 - S)^2, \quad IF\ (S < 60\ mph)\right.$$

$I_{reduction,\ 60}$ =	1.000
$I_{reduction,\ 50}$ =	0.968
$I_{reduction,\ 40}$ =	0.872
$I_{reduction,\ 30}$ =	0.712
$I_{reduction,\ 20}$ =	0.488
$I_{reduction,\ 10}$ =	0.200

$$I = I * I_{reduction}$$

I_{60} =	36.82%
I_{50} =	35.64%
I_{40} =	32.11%
I_{30} =	26.22%
I_{20} =	17.97%
I_{10} =	7.36%

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Force Effect

Impact:

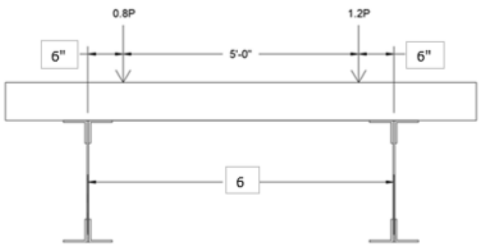
- Due to Rocking Effect
- Total Impact

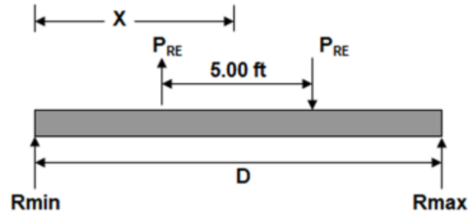
X =	0.50	ft	CL Left Girder to CL Left Exterior Track
a =	5.00	ft	Track gauge
d =	6.00	ft	CL Girder to CL Girder Spacing

Reaction Without Rocking:

$R = (1.0\,P_{LL} * (x) + 1.0\,P_{LL} * (x + a))$ / d

R = 1.00 P_{LL}





Reaction With Rocking: 20% of wheel load without impact, acting downward on one rail and upward on the other. The additional 20% is positioned on the right side of each rail to maximize the reaction load. (AREMA 15-1.3.5.d)

$R_{max} = (0.8\,P_{LL} * (x) + 1.2\,P_{LL} * (x + a))$ / d

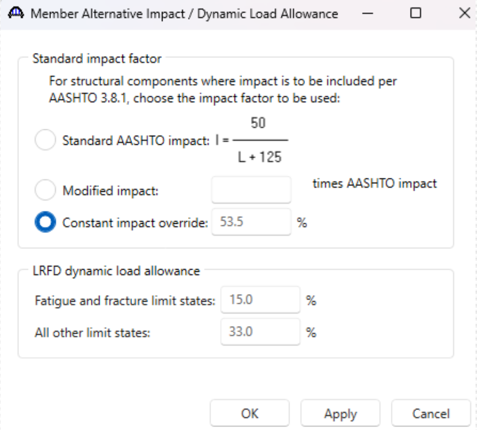
R_{max} = 1.17 P_{LL}

Percent increase due to Rocking Effect

= 16.67%

Combined Impact Load

I_{LL_60} =	53.49%	Impact load increase for open deck structures
I_{LL_50} =	52.31%	Reduced Speed (50 mph) Impact load increase for open deck structures
I_{LL_40} =	48.78%	Reduced Speed (40 mph) Impact load increase for open deck structures
I_{LL_30} =	42.88%	Reduced Speed (30 mph) Impact load increase for open deck structures
I_{LL_20} =	34.64%	Reduced Speed (20 mph) Impact load increase for open deck structures
I_{LL_10} =	24.03%	Reduced Speed (10 mph) Impact load increase for open deck structures



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Force Effect

Longitudinal Load

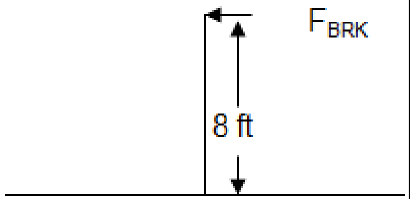
- Braking
- Traction

Longitudinal Loads:

Per AREMA Ch. 15, sect. 1.3.12:	The longitudinal force for E-80 loading shall be taken as the larger of the force due to braking or the force due to traction.
	"For loads other than E-80, these forces shall be scaled proportionally. The points of force application shall not be changed."

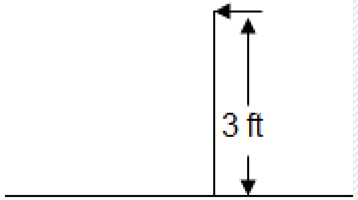
Force Due to braking:

$$F_{BRK} = 45 + 1.2L$$



Force Due to traction:

$$F_{TRC} = 25(L)^{1/2}$$



Force Effect

Longitudinal Load

- Force due to braking controls

Longitudinal Force

The longitudinal force due to braking only applies to engine cars. As a result, this force is not considered for the 286K and 315K Rail Cars.

L_G =	41.17	ft	Girder span length (CL Bearing to CL Bearing)	

$$M_{braking,\,E-80} = max\begin{cases} 8\ ft * (45 + 1.2L) \\ 3\ ft\ * 25\sqrt{L} \end{cases}$$

Moment due to braking (AREMA 15-1.3.12.a)
Moment due to traction

$$M_{braking,\,scaled} = M_{braking,\,E-80} * \frac{(\sum P_{axle})_{Vehicle}}{(\sum P_{axle})_{Cooper\ E-80}}$$

(AREMA 15-1.3.12.a)

Braking Force

$F_{braking}$ =	94.40	kips	(AREMA 15-1.3.12.a)
$M_{braking}$ =	755.2	k-ft	(AREMA 15-1.3.12.a)

Traction Force

$F_{traction}$ =	160.40	kips	(AREMA 15-1.3.12.a)
$M_{traction}$ =	481.21	k-ft	(AREMA 15-1.3.12.a)

Braking Moment

$M_{braking}$ =	755.20	k-ft/train	Maximum longitudinal braking moment
$M_{braking}$ =	377.60	k-ft/engine	Divide by 2 for 2 engines per train

Equivalent Axle Force Equations

$$\bar{x} = \frac{\sum(P_{axle} * x)}{\sum P_{axle}}$$

Engine load centroid

$$d_1 = \bar{x} - x$$

Distance from axle to engine load centroid

$$I = \sum {d_1}^2$$

$$S = \frac{I}{d_1}$$

Equivalent braking moment factor

$$P_{braking,\,equiv.} = \frac{P_{axle}}{S}$$

Equivalent braking moment as vertical axle load

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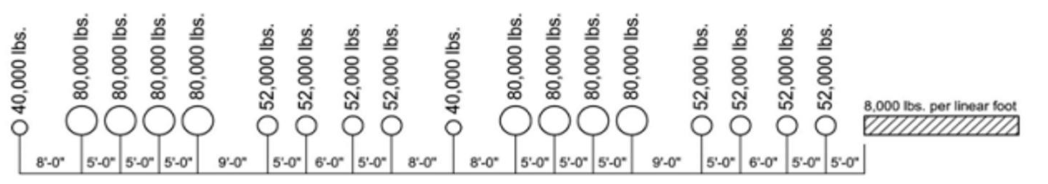
Force Effect

Longitudinal Load

- Equivalent axle load



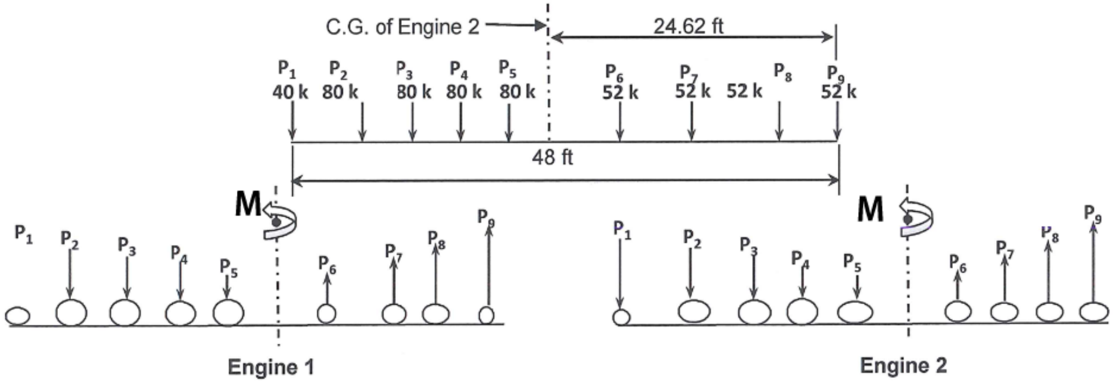
AREMA COOPER E-80 LOADING

LIVE LOAD IN LBS. PER AXLE
RATING IS EXPRESSED IN AXLE LOAD (KIPS)
PROPORTIONAL TO COOPER E-80

$M_{braking}$ = 377.60 k-ft/engine   Cooper E-80 engine braking moment

Axle	Load (k)	x (ft)	Load * x (k-ft)	d_1 (ft)	d_1^2 (ft^2)	S (ft)	$P_{braking, equiv.}$ (k)
1	40.00	0.00	0.00	23.38	546.64	92.85	4.07
2	80.00	8.00	640.00	15.38	236.55	141.15	2.68
3	80.00	13.00	1040.00	10.38	107.75	209.14	1.81
4	80.00	18.00	1440.00	5.38	28.95	403.49	0.94
5	80.00	23.00	1840.00	0.38	0.14	5708.64	0.07
6	52.00	32.00	1664.00	-8.62	74.30	-251.85	-1.50
7	52.00	37.00	1924.00	-13.62	185.50	-159.39	-2.37
8	52.00	43.00	2236.00	-19.62	384.93	-110.65	-3.41
9	52.00	48.00	2496.00	-24.62	606.13	-88.18	-4.28

$\bar{x}$ = 23.38 ft   I = 2170.89 ft^2



Determining Engine Axle Loads Due to Longitudinal Force

Axle Load P_n = (Moment M * d) / $I_{\text{of System (Whole Engine Wheel)}}$

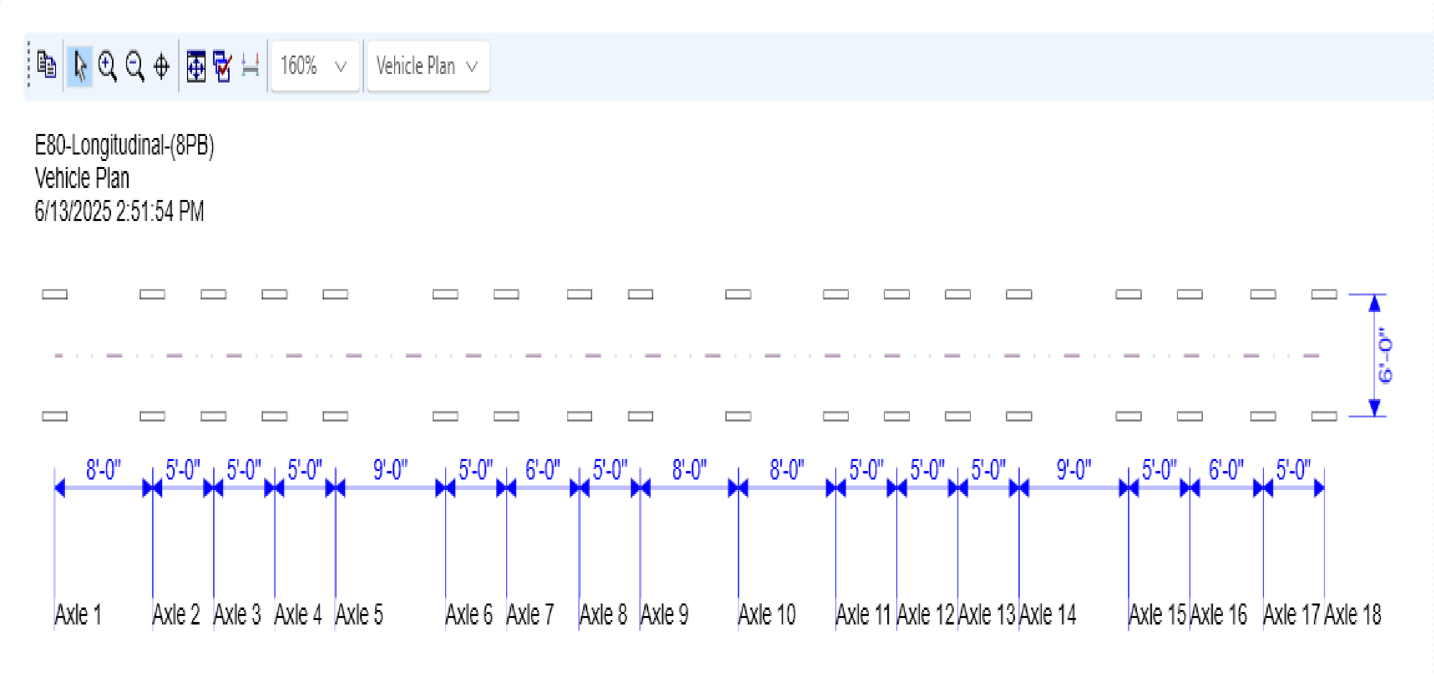
$I_{\text{of Whole wheels}} = I_{\text{of Wheels}} + A*d^2$

$I_{\text{of Whole wheels}} = \sum d^2$ (Ignoring Area A and I)

Force Effect

Longitudinal Load

- BrR Vehicle definition



Name: E80-Longitudinal-(8PB)

Description: E80-Longitudinal-(8PB)

Truck | Tandem | Lane

Axle no.	Axle load (kip)	Gage dist. (ft)	Wheel contact width (in)	Axle spacing (ft)	
				Minimum	Maximum
1	4.07	6.00	5.0000		
2	2.68	6.00	5.0000	8.00	8.00
3	1.81	6.00	5.0000	5.00	5.00
4	0.94	6.00	5.0000	5.00	5.00
5	0.07	6.00	5.0000	5.00	5.00
6	-1.50	6.00	5.0000	9.00	9.00
7	-2.37	6.00	5.0000	5.00	5.00
8	-3.41	6.00	5.0000	6.00	6.00
9	-4.28	6.00	5.0000	5.00	5.00
10	4.07	6.00	5.0000	8.00	8.00
11	2.68	6.00	5.0000	8.00	8.00
12	1.81	6.00	5.0000	5.00	5.00
13	0.94	6.00	5.0000	5.00	5.00
14	0.07	6.00	5.0000	5.00	5.00
15	-1.50	6.00	5.0000	9.00	9.00
16	-2.37	6.00	5.0000	5.00	5.00
17	-3.41	6.00	5.0000	6.00	6.00
18	-4.28	6.00	5.0000	5.00	5.00
Totals:	-4.0 kip			104.00	104.00

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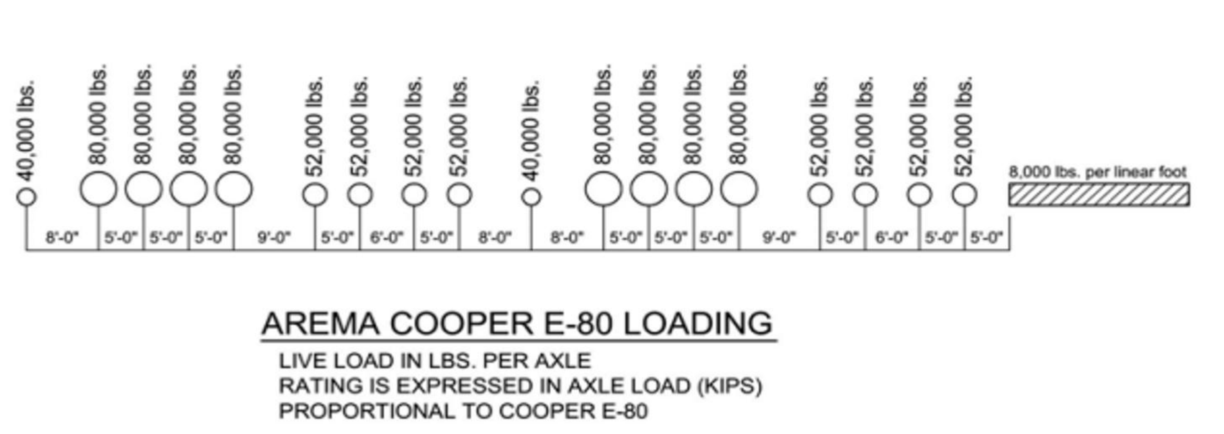
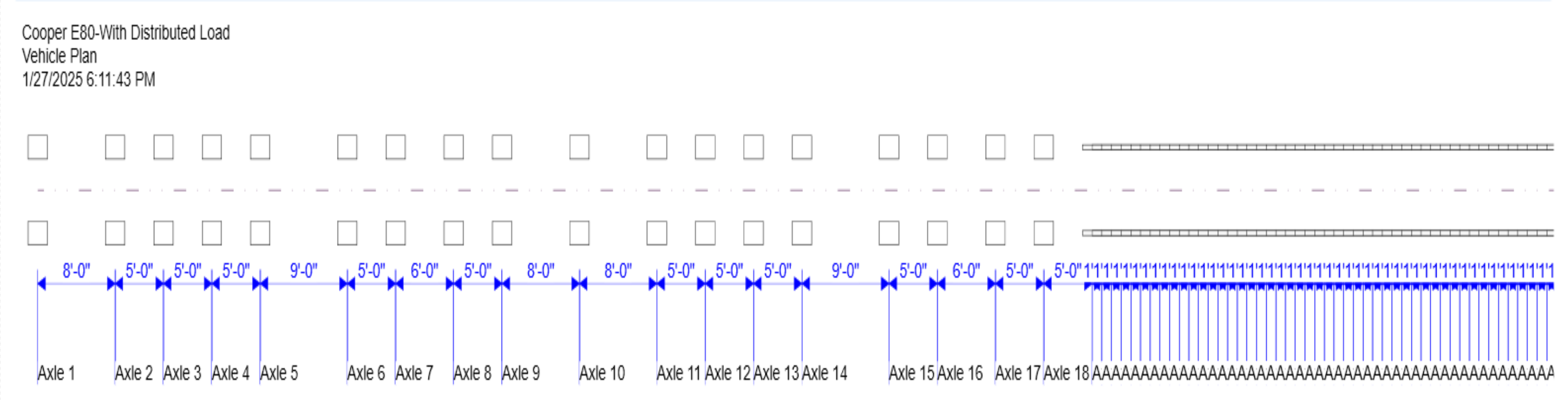
Force Effect

Live Load

- Cooper E80
- BrR Vehicle definition





Truck | Tandem | Lane

Axle no.	Axle load (kip)	Gage dist. (ft)	Wheel contact width (in)	Axle spacing (ft)	
				Minimum	Maximum
1	40.00	6.00	20.0000		
2	80.00	6.00	20.0000	8.00	8.00
3	80.00	6.00	20.0000	5.00	5.00
4	80.00	6.00	20.0000	5.00	5.00
5	80.00	6.00	20.0000	5.00	5.00
6	52.00	6.00	20.0000	9.00	9.00
7	52.00	6.00	20.0000	5.00	5.00
8	52.00	6.00	20.0000	6.00	6.00
9	52.00	6.00	20.0000	5.00	5.00
10	40.00	6.00	20.0000	8.00	8.00
11	80.00	6.00	20.0000	8.00	8.00
12	80.00	6.00	20.0000	5.00	5.00
13	80.00	6.00	20.0000	5.00	5.00
14	80.00	6.00	20.0000	5.00	5.00
15	52.00	6.00	20.0000	9.00	9.00
16	52.00	6.00	20.0000	5.00	5.00
17	52.00	6.00	20.0000	6.00	6.00
18	52.00	6.00	20.0000	5.00	5.00
19	8.00	6.00	4.0000	5.00	5.00
20	8.00	6.00	4.0000	1.00	1.00
21	8.00	6.00	4.0000	1.00	1.00
22	8.00	6.00	4.0000	1.00	1.00

Force Effect

BrR Output

- Dead Load
- Wind load
- Live load and Longitudinal load

Dead Load

Location	Self Weight		Dead Load (North)		Dead Load (South)		Total (North)		Total (South)	
	Moment (k-ft)	Shear (k)	Moment (k-ft)	Shear (k)	Moment (k-ft)	Shear (k)	Moment (k-ft)	Shear (k)	Moment (k-ft)	Shear (k)
0	0	6.78	0	7.85	0	8.16	0	14.63	0	14.94
2.17	14.13	6.24	16.14	7.02	16.77	7.3	30.27	13.26	30.9	13.54
4.12	25.82	5.76	29.08	6.28	30.23	6.53	54.9	12.04	56.05	12.29
4.75	29.44	5.61	37.63	5.74	34.3	6.27	67.07	11.35	63.74	11.88
5.54	33.77	5.41	50.79	4.78	39.11	5.96	84.56	10.19	72.88	11.37
8.04	46.33	4.63	51.71	4.71	52.78	4.97	98.04	9.34	99.11	9.6
8.23	47.22	4.57	56.12	4.34	53.74	4.89	103.34	8.91	100.96	9.46
9.21	51.53	4.27	65.77	3.38	58.33	4.51	117.3	7.65	109.86	8.78
10.67	57.36	3.72	66.74	3.27	64.49	3.93	124.1	6.99	121.85	7.65
11.71	61.03	3.33	67.86	3.14	68.36	3.52	128.89	6.47	129.39	6.85
12	61.98	3.22	73.73	2.32	69.36	3.4	135.71	5.54	131.34	6.62
12.35	63.09	3.09	77.56	1.57	70.53	3.26	140.65	4.66	133.62	6.35
14.5	68.86	2.28	80.79	0	76.63	2.41	149.65	2.28	145.49	4.69
16.47	72.63	1.54	77.56	1.57	80.61	1.63	150.19	3.11	153.24	3.17
18	74.55	0.97	71.88	2.61	82.64	1.02	146.43	3.58	157.19	1.99
20.58	75.81	0	67.86	3.14	83.97	0	143.67	3.14	159.78	0

Wind Load

Location	Wind Load	
	Moment (k-ft)	Shear (k)
0	0	6.96
2.17	14.3	6.22
4.12	25.78	5.57
5.54	33.36	5.09
8.04	45.02	4.24
8.23	45.83	4.17
9.21	49.75	3.84
11.71	58.3	3.00
12	59.16	2.90
12.35	60.15	2.78
14.5	65.35	2.06
16.47	68.75	1.39
20.58	71.61	0.00

Cooper E-80

Location	Live Load		Long. Load	
	Moment (k-ft)	Shear (k)	Moment (k-ft)	Shear (k)
0	0	236.4	0	3.73
2.17	468.75	216.01	7.76	4.40
4.12	818.2	198.74	14.17	4.20
5.54	1031.05	186.11	18.30	4.05
8.04	1367.69	165.71	24.59	3.76
8.23	1393.92	164.03	25.03	3.74
9.21	1515.78	155.59	27.11	3.66
11.71	1756.92	133.97	31.06	3.45
12	1780.53	131.46	31.43	3.43
12.35	1807.33	128.6	31.85	3.39
14.5	1958.75	112.09	33.76	3.21
16.47	2040.11	96.98	34.92	3.06
20.58	2116.41	68.67	36.24	2.82
24.7	2040.11	96.98	34.92	3.06

Impact	53.5%

Note: Longitudinal Loads are divided by 1.535 to remove impact.

AI Engineers

Force Effect

AREMA

LL without impact for comparison

SECTION 1.15 LIVE LOAD MOMENTS, SHEARS AND REACTIONS

1.15.1 TABULATED VALUES FOR SIMPLE SPANS (2003) R(2022)

For the maximum moments, shears and pier (or floorbeam) reactions for Cooper E 80 live load (Figure 15-1-2) or alternate live load (Figure 15-1-3) refer to Table 15-1-15.

Table 15-1-15. Maximum Moments, Shears and Pier (or Floorbeam) Reactions for Cooper E 80 Live Load or Alternate Live Load (Rounded to 3 Significant Figures)

All Values are for one rail (one-half track load)

Span Length Ft	Maximum Moment Ft–Kips		Maximum Moment Quarter Point Ft–Kips		Maximum Shears Kips At End		Maximum Shears Kips At Quarter Point		Maximum Shears Kips At Center		Maximum Pier Reaction Kips (2)	
	E-80	Alt.	E-80	Alt.	E-80	Alt.	E-80	Alt.	E-80	Alt.	E-80	Alt.
5	50.0	62.5	37.5	46.9	40.0	50.0			20.0	25.0	40.0	50.0
6	60.0	75.0	45.0	56.3	46.7	58.3	30.0	37.5	20.0	25.0	53.3	58.3
7	70.0	87.5	55.0	68.8	51.4	64.3	31.4	39.3	20.0	25.0	62.9	71.4
8	80.0	100	70.0	87.5	55.0	68.8	35.0	43.8	20.0	25.0	70.0	81.3
9	93.9	117	85.0	106	57.6	72.2	37.8	47.2	20.0	25.0	75.8	88.9
10	113	141	100	125	60.0	75.0	40.0	50.0	20.0	25.0	80.0	95.0
11	131	164	115	144	65.5	77.3	41.8	52.3	21.8	27.3	87.3	100
12	160	188	130	163	70.0	83.3	43.3	54.2	23.3	29.2	93.3	108
13	190	213	145	181	73.8	88.5	44.6	55.8	24.6	30.8	98.5	115
14	220	250	165	200	77.1	92.9	47.1	57.1	25.7	32.1	104	121
16	280	325	210	250	85.0	100	52.5	62.5	27.5	34.4	114	131
18	340	400	255	319	93.3	111	56.7	68.1	28.9	36.1	121	139
20	413	475	300	363	100	120	60.0	72.5	28.7	37.5	131	145
24	570	669	420	500	111	133	70.0	83.3	31.8	41.7	148	154
28	731	866	555	650	121	143	77.1	92.9	34.3	46.4	165	
32	911	1060	693	800	131	150	83.1	100	37.5	50.0	182	
36	1100	1260	852	950	141	156	88.9	107	41.1	55.6	199	
40	1310	1460	1010	1100	151	160	93.6	110	44.0	60.0	216	
45	1600	1710	1230	1290	163	164	100	114	45.9	64.5	237	
50	1900	1960	1470	1480	174		106	118	49.7	68.0	258	

Capacity

Allowable Stress Capacity

AREMA

Capacity Equations

Force	Normal (AREMA T15-1-11, AREMA A1.1.4.1)	Maximum (AREMA T15-7-2)
Flexural Compression	$F_c = 0.55F_y - \frac{0.55F_y^{\,2}}{6.3\pi^2 E} * \left(\frac{l}{r_y}\right)^2$	$F_c = K - \frac{K * F_y}{1.8x10^9} * \left(\frac{l}{r_y}\right)^2$
Flexural Tension	$F_t = 0.55F_y$	$F_t = K$
Shear	$F_v = 0.35F_y$	$F_v = 0.75F_y$

AASHTO (Section 10 article 10.32 & 10.48)

```
COMPRESSION FLANGE ALLOWABLE

   IF full lateral support THEN
      Fb = B1*Fy*R
   ELSE
      IF unbraced cantilever THEN
         Cb = 1.0
      ELSE
         Cb = 1.75 - 1.05*(M1/M2) + .3*(M1/M2)^2 <= 2.3
            (note: a positive M1/M2 => single curvature)
                                     _                  _
           91,000,000*Cb*Iyc        |        J        ( d)^2|
      Fb = ----------------- SQRT|0.772 --- + 9.87(--)   |*R <= B1*Fy
             FS * Sxc * Lb          |_      Iyc       (Lb) _|

      where FS = 1.82 (inventory)
               = 1.34 (operating)

   where, R = hybrid reduction factor (10.40)

TENSION FLANGE ALLOWABLE

   IF there are holes in the flange THEN:
      Fb = min(B1*Fy*((Ag*)/Ag)*R, B2*Fu*An/Ag)
   ELSE
      Fb = B1*Fy*R

B1, inv = 0.550
B2, inv = 0.500
B1, op  = 0.750
B2, op  = 0.670
```

```
Web allowable, Fv = .33*Fyw
```

Capacity

- AREMA

AASHTO

South Girder @ Midspan (20.58')

r_y = 3.30 in — Radius of gyration about the y axis

Force	Normal psi	Maximum psi
F_c	16305.28	23716.27
F_t	16500.00	24000.00
F_v	10500.00	18000.00

COMPRESSION FLANGE ALLOWABLE

Load Group	Load Comb	Flexure Type	Component	B1	B2	R	M1 (kip-ft)	Mmid (kip-ft)	M2 (kip-ft)	Cb	Fb (ksi)
Inventory	1, INV, MAX	Pos	Top Flange	0.55	0.50	1.000	2370.9	2397.3	2309.2	1.000	16.50
Inventory	1, INV, MIN	Pos	Top Flange	0.55	0.50	1.000	299.2	300.9	287.7	1.000	16.50
Operating	1, OPG, MAX	Pos	Top Flange	0.75	0.67	1.000	2370.9	2397.3	2309.2	1.000	22.50
Operating	1, OPG, MIN	Pos	Top Flange	0.75	0.67	1.000	299.2	300.9	287.7	1.000	22.50

TENSION FLANGE ALLOWABLE

Load Group	Load Comb	Flexure Type	Component	B1	B2	R	An (in^2)	Ag (in^2)	Ag* (in^2)	Fu (ksi)	Fb (ksi)
Inventory	1, INV, MAX	Pos	Bot Flange	0.55	0.50	1.000					16.50
Inventory	1, INV, MIN	Pos	Bot Flange	0.55	0.50	1.000					16.50
Operating	1, OPG, MAX	Pos	Bot Flange	0.75	0.67	1.000					22.50
Operating	1, OPG, MIN	Pos	Bot Flange	0.75	0.67	1.000					22.50

Web allowable, Fv = .33*Fyw = 9.90 (ksi)

AI Engineers

Rating

- AREMA

Rating Equations

$$RF = \frac{f_{capacity} - f_{DL}}{f_{LL} + f_I + f_{CF}}$$

$$RF_{Modified} = \frac{1.25 f_{capacity} - f_{DL}}{f_{LL} + f_I + f_{CF} + f_{LF} + f_{WF}}$$

(AREMA 15.7.3.2.8.e)

South Girder, Point 5 @ 20'-7" **Midspan**

$S_{x, bottom, net}$ =	2112.35	in^3	$S_{x, top, gross}$ =	2112.35	in^3	$A_{web, gross}$ =	23.88	in^2
$f_{cap, moment, bottom, normal}$ =	16305	lb/in^2	$f_{cap, moment, top, normal}$ =	16500	lb/in^2	$f_{cap, shear, normal}$ =	10500	lb/in^2
$f_{cap, moment, bottom, max}$ =	23716	lb/in^2	$f_{cap, moment, top, max}$ =	24000	lb/in^2	$f_{cap, shear, max}$ =	18000	lb/in^2

Stress Summary: Moment

Vehicle	M_{DL} (k-ft)	$f_{DL,n}$ psi	$f_{DL,g}$ psi	$M_{LL+I+CF}$ (k-ft)	$f_{LL+I+CF,n}$ psi	$f_{LL+I+CF,g}$ psi	M_{LF} (k-ft)	$f_{LF,n}$ psi	$f_{LF,g}$ psi	M_{WF} (k-ft)	$f_{WF,n}$ psi	$f_{WF,g}$ psi
E-80	159.80	907.80	907.80	2116.41	12023.06	12023.06	36.24	205.86	205.86	71.61	406.81	406.81
F40PH	139.39	791.86	791.86	1036.50	5888.23	5888.23	22.72	129.06	129.06	71.61	406.81	406.81
286K	139.39	791.86	791.86	1582.31	8988.91	8988.91	0.00	0.00	0.00	71.61	406.81	406.81
HSP-46	139.39	791.86	791.86	1058.83	6015.08	6015.08	17.69	100.49	100.49	71.61	406.81	406.81
315K	139.39	791.86	791.86	1672.28	9500.02	9500.02	0.00	0.00	0.00	71.61	406.81	406.81
ES44AC	139.39	791.86	791.86	1624.93	9231.03	9231.03	23.81	135.24	135.24	71.61	406.81	406.81

Rating: Moment

Vehicle	Normal		Maximum		Rating	
	RF	$RF_{Modified}$	RF	$RF_{Modified}$	Normal	Maximum
E-80	1.28	1.54	1.90	2.27	E-102	E-151
F40PH	2.62	3.03	3.88	4.48	732	1085
286K	1.71	2.07	2.54	3.06	490	593
HSP-46	2.56	2.99	3.79	4.41	758	1123
315K	1.62	1.97	2.40	2.90	511	756
ES44AC	1.67	1.99	2.47	2.94	721	1068

AI Engineers

Rating

- AASHTO

INPUT:

Stage 1 DC Moment = 159.8 (kip-ft)
Stage 2 DW Moment = 0.0 (kip-ft)
Note: If the capacity has been overridden, the Resistance is computed as override phi*override capacity.
Otherwise the Resistance is computed as per the Specification.

All Stages:

Component	C (in)	S (in^3)	Fy (ksi)
Top CP 3	26.000	-2112.35	30.00
Bot CP 3	-26.000	2112.35	30.00

Section Type: Noncomposite
Top Flange Continuously Laterally Supported: No

Allowable Stress Flexure Rating Calculations

$$RF = \frac{C - A1*(fDC + fDW)}{A2*fLL} \qquad (6B.4.1\text{-}1)$$

A1	A2
1.00	1.00

where,

C = Capacity flange stress
fDC = Stage 1 dead load flange stress
fDW = Stage 2 dead load flange stress
fLL = Stage 3 live load flange stress (including impact)

Component: Top CP 3

Load	Vehicle	Type	LL (kip-ft)	Adj. LL (kip-ft)	A1	A2	fDL1 (ksi)	fDL2 (ksi)	fLL (ksi)	Adj. fLL (ksi)	fR (ksi)	fR (Override) (ksi)	RF	Capacity (Ton)
Inventory	1	Pos	2116.4	---	1.00	1.00	-0.91	-0.00	-12.02	---	-16.50	---	1.297	1011.56
Inventory	1	Pos	0.0	---	1.00	1.00	-0.91	-0.00	-0.00	---	-16.50	---	99.000	77220.00
Operating	1	Pos	2116.4	---	1.00	1.00	-0.91	-0.00	-12.02	---	-22.50	---	1.796	1400.81
Operating	1	Pos	0.0	---	1.00	1.00	-0.91	-0.00	-0.00	---	-22.50	---	99.000	77220.00

Component: Bot CP 3

Load	Vehicle	Type	LL (kip-ft)	Adj. LL (kip-ft)	A1	A2	fDL1 (ksi)	fDL2 (ksi)	fLL (ksi)	Adj. fLL (ksi)	fR (ksi)	fR (Override) (ksi)	RF	Capacity (Ton)
Inventory	1	Pos	2116.4	---	1.00	1.00	0.91	0.00	12.02	---	16.50	---	1.297	1011.56
Inventory	1	Pos	0.0	---	1.00	1.00	0.91	0.00	0.00	---	16.50	---	99.000	77220.00
Operating	1	Pos	2116.4	---	1.00	1.00	0.91	0.00	12.02	---	22.50	---	1.796	1400.81
Operating	1	Pos	0.0	---	1.00	1.00	0.91	0.00	0.00	---	22.50	---	99.000	77220.00

Rating: Comparision

- AREMA

AASHTO

South Girder, Point 5 @ 20'-7"	Midspan				
$S_{x,\ bottom,\ net}$ =	2112.35	in^3	$S_{x,\ top,\ gross}$ =	2112.35	in^3
$f_{cap,\ moment,\ comp,\ normal}$ =	16305	lb/in^2	$f_{cap,\ moment,\ ten,\ normal}$ =	16500	lb/in^2
$f_{cap,\ moment,\ comp,\ max}$ =	23716	lb/in^2	$f_{cap,\ moment,\ ten,\ max}$ =	24000	lb/in^2

Rating: Moment

Vehicle	Normal		Maximum		Rating	
	RF	$RF_{Modified}$	RF	$RF_{Modified}$	Normal	Maximum
E-80	1.28	1.54	1.90	2.27	E-102	E-151
F40PH	2.63	3.05	3.89	4.49	737	1090
286K	1.73	2.08	2.55	3.07	493	596
HSP-46	2.58	3.00	3.81	4.42	763	1128
315K	1.63	1.98	2.41	2.91	514	760
ES44AC	1.68	2.00	2.48	2.95	726	1072

```
Component: Bot CP 3
-------------------

Load                 Vehicle      fR      fR (Override)       RF
                                 (ksi)        (ksi)
-------------------- -----------------------------------------------
Inventory            1          16.50         ---            1.297
Inventory            1          16.50         ---           99.000
Operating            1          22.50         ---            1.796
Operating            1          22.50         ---           99.000
```

```
Component: Top CP 3
-------------------

Load                 Vehicle      fR      fR (Override)       RF
                                 (ksi)        (ksi)
-------------------- -----------------------------------------------
Inventory            1         -16.50         ---            1.297
Inventory            1         -16.50         ---           99.000
Operating            1         -22.50         ---            1.796
Operating            1         -22.50         ---           99.000
```

AI Engineers

Conclusion

- AASHTOWare BrR can be used for railroad bridge ratings using practical workarounds.
- AREMA Normal Ratings produced results comparable to AASHTO Inventory Ratings.
- BrR currently has limitations for AREMA Modified Ratings because it does not support the application of longitudinal and wind loads.
- The gap appears manageable and could be addressed with modest enhancements and collaboration.

Points for Panel Discussion

- What level of interest exists within the AASHTOWare user community for railroad bridge load rating capabilities?
- Are there opportunities for greater collaboration between AASHTO and AREMA in bridge evaluation and load rating methodologies?
- What challenges currently limit the use of AASHTOWare for railroad bridge applications?
- Is there an opportunity to bridge the gap between highway and railroad bridge rating practices through future software enhancements?

AI Engineers

QUESTIONS?