Proof Testing of a Shear Deficient Bent Cap

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September 7, 2023

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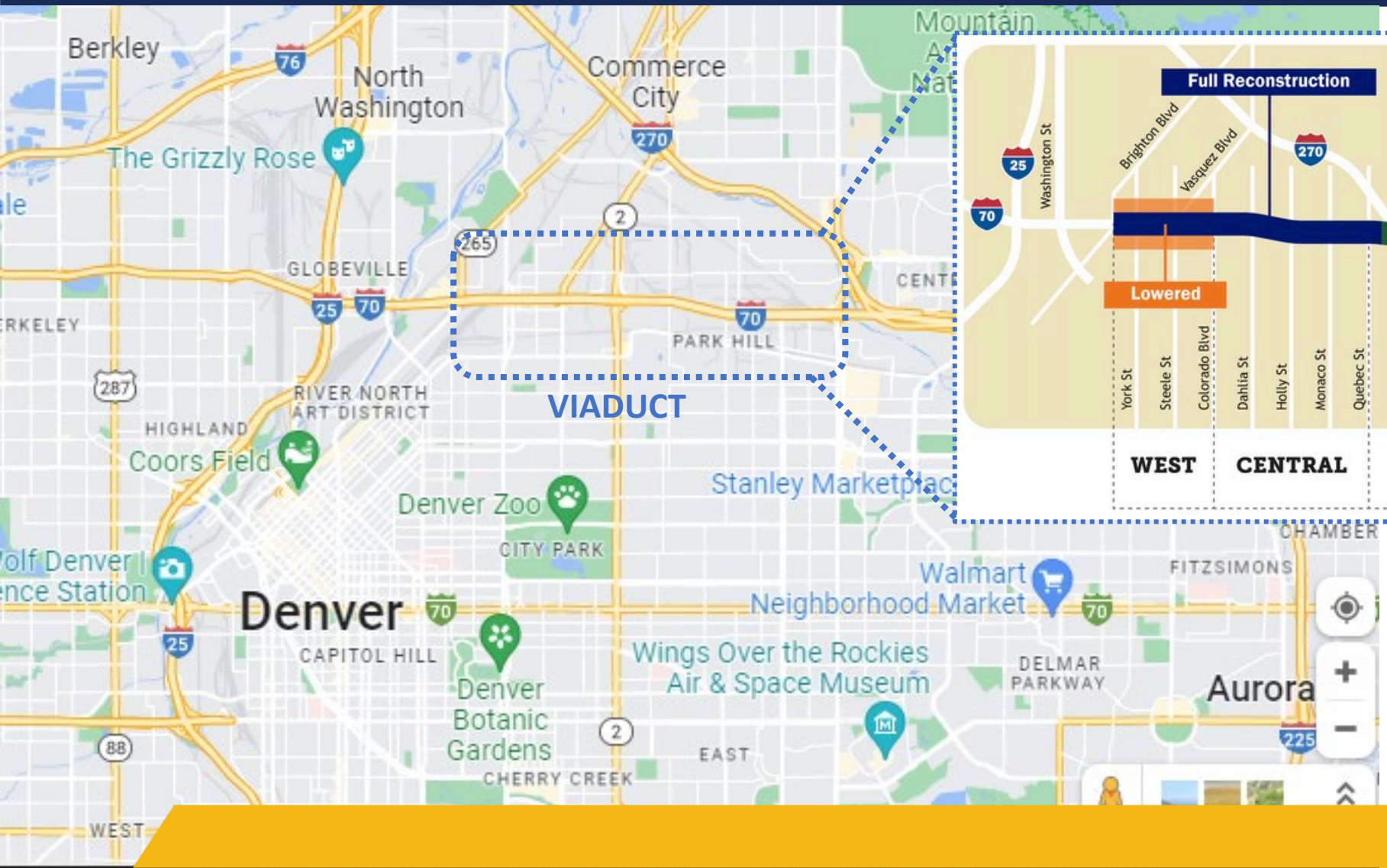
Western Bridge Engineers' Seminar

Outline

- Background
- Methods
- Analysis of Results
- Application of Results
- Summary

Tuchscherer, R., & Eggers, W. K. (2022). “Proof Testing of a Shear Deficient Bent Cap.” *Transportation Research Record*, 2677(5). https://doi.org/10.1177/03611981221130324

Background
Location



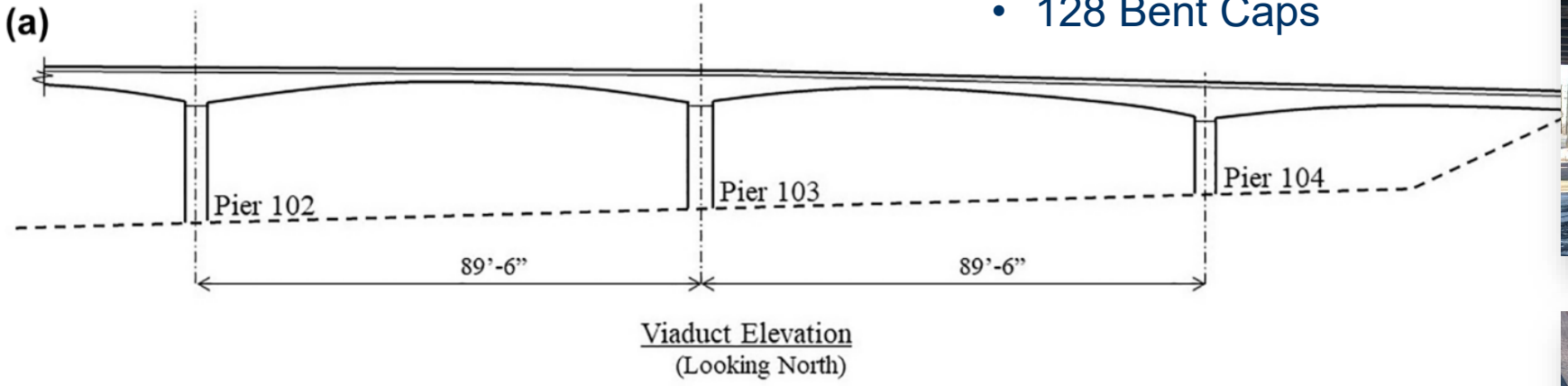
codot.gov/projects/i70east

- 10-mi stretch of I-70
- 1.2-mi-long, built 1963
- $1.2 billion
- 2018-2022

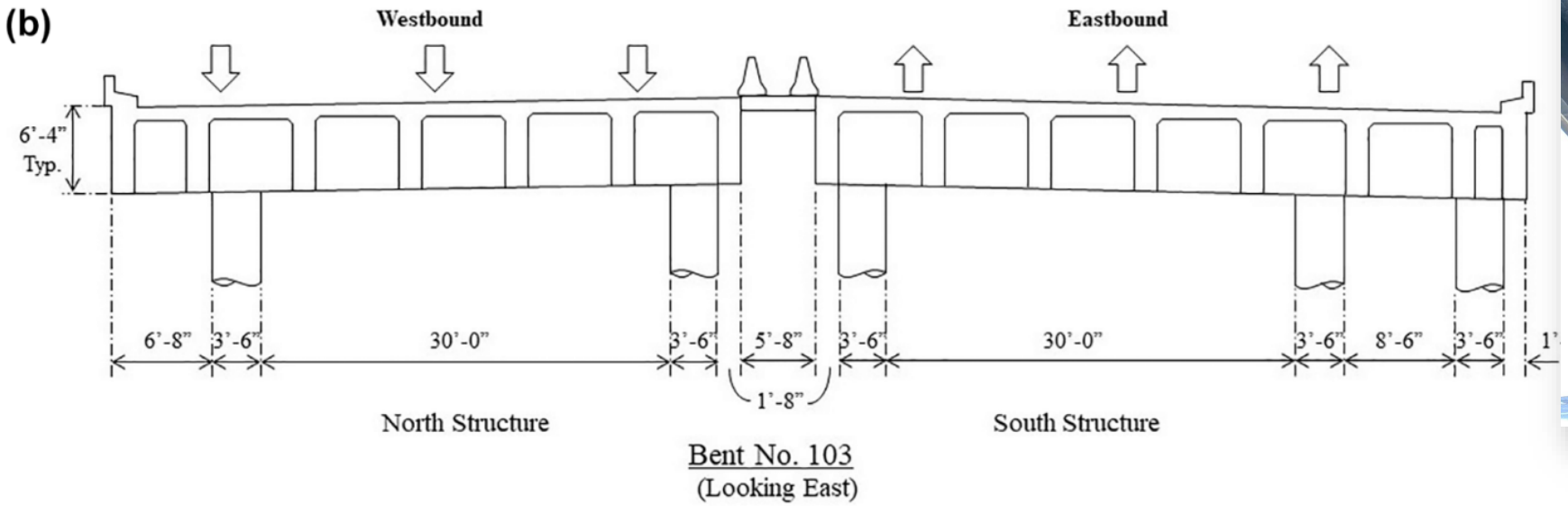
Background

Viaduct

- Built 1963
- CIP Reinforced Concrete
- 71 Spans
- 128 Bent Caps



Viaduct Elevation
(Looking North)



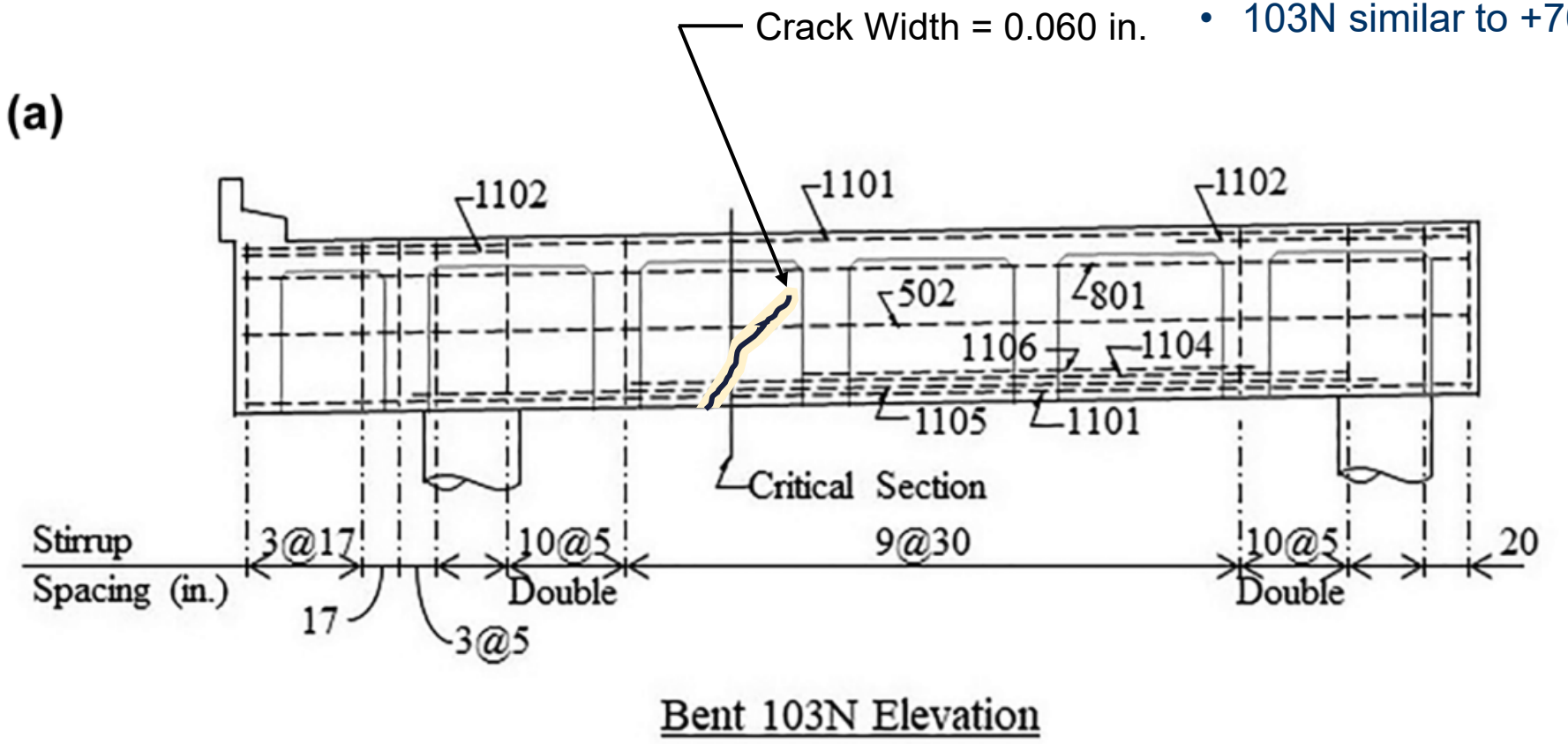
Bent No. 103
(Looking East)

Background
Viaduct

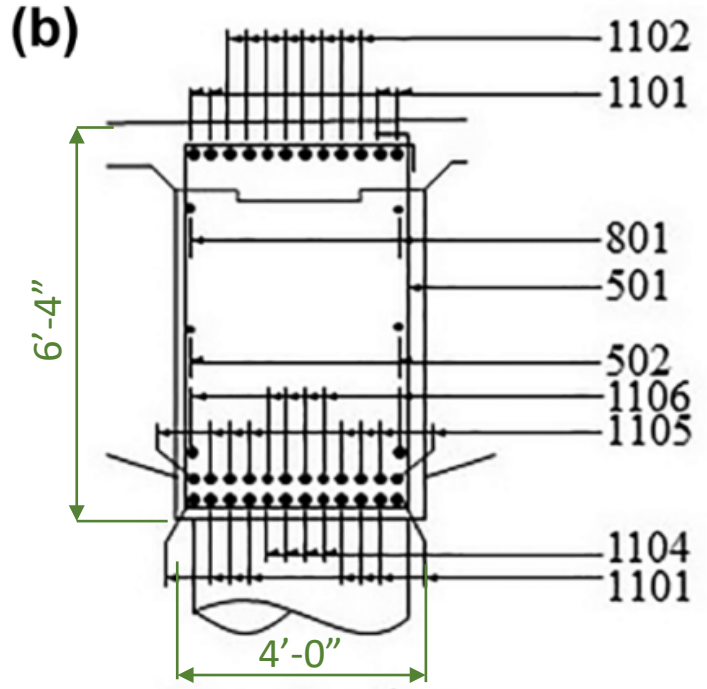
- AASHTO LRFD minimum stirrup = 0.79 in^2/ft
- Provided = 0.25 in^2/ft

- Observed crack widths≈ 0.025- to 0.125-in.
- Acceptable crack width ≈ 0.012- to 0.016-in.

- 103N similar to +70% of all bents



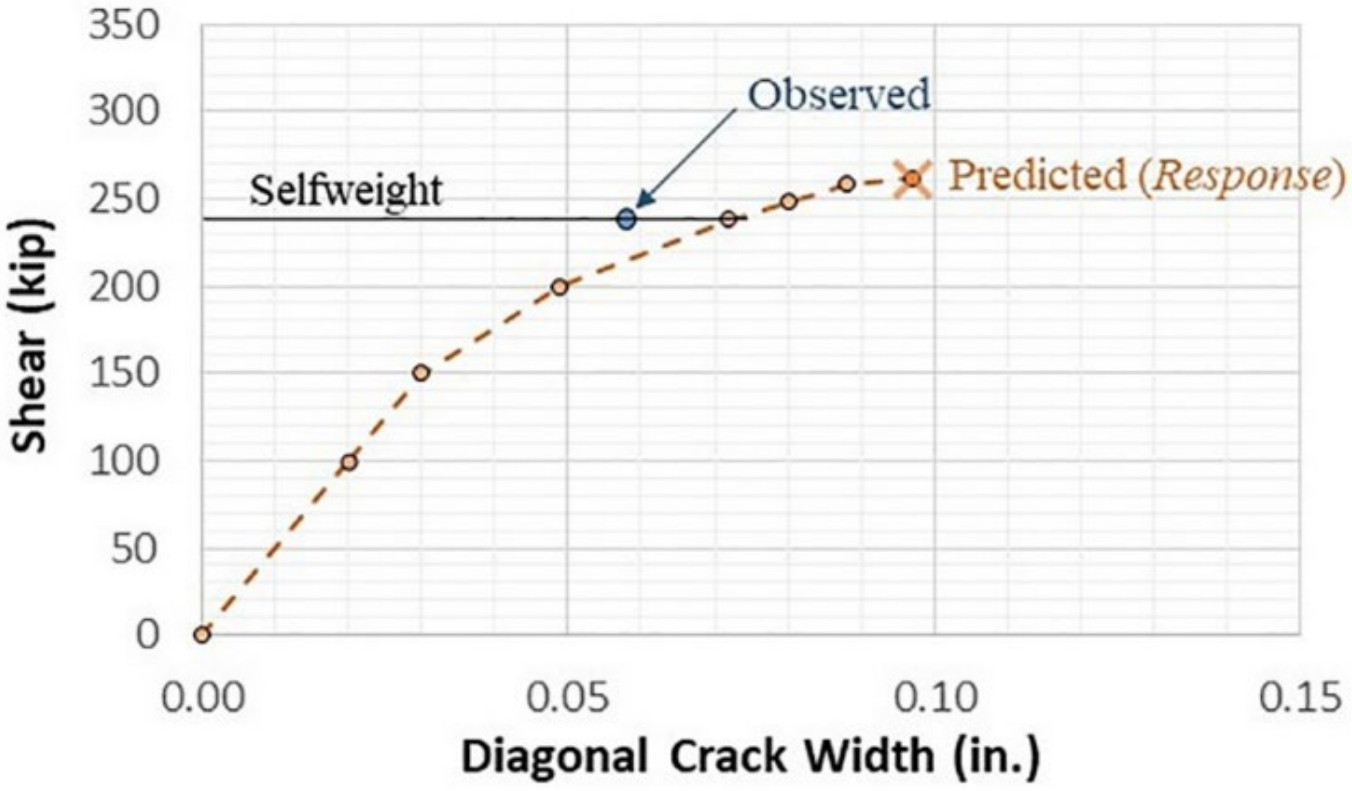
Bent 103N Elevation



Cross Section

Background
Bridge Condition

	Design Load Operating		Type 3-3 Legal Load	
Force	Value	LF	Value	LF
V_{DC}	204 k	1.25	204 k	1.25
M_{DC}	2055 k’		2055 k’	
V_{DW}	34 k	1.5	34 k	1.5
M_{DW}	382 k’		382 k’	
V_{LL+I}	126 k	1.35	78 k	1.45
M_{LL+I}	1402 k’		858 k’	
ϕ_V	0.9		0.9	
ϕV_n	252 k		267 k	
V_u	476 k		419 k	
RF =	**−0.32**		**−0.35**	



Background
Need for Proof Test

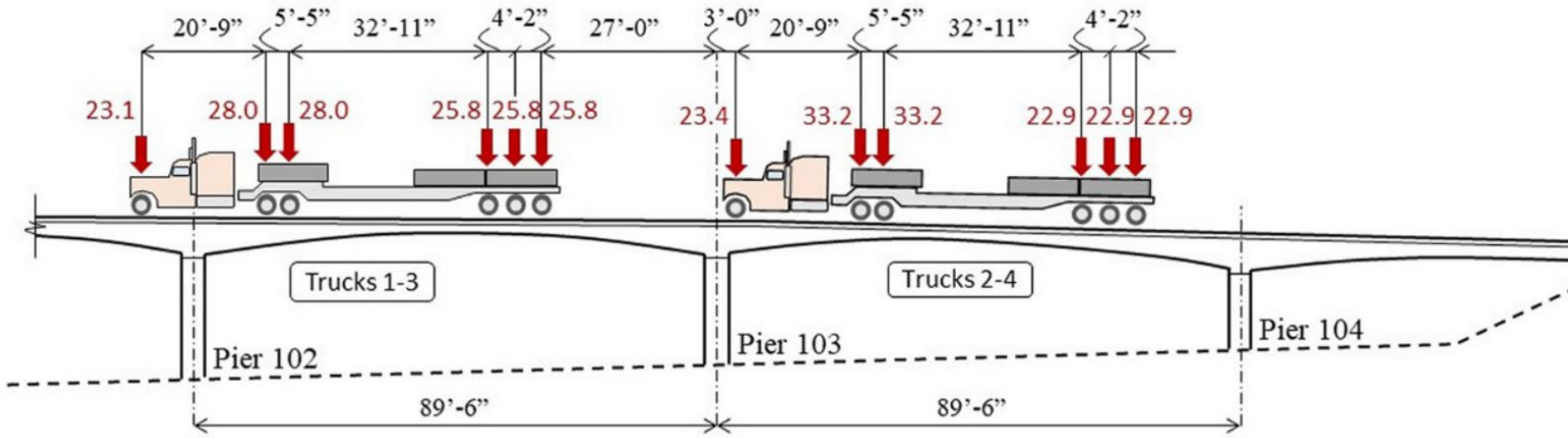
1. Negative Rating Factor (RF)
2. Most Bents exhibited 0.025- to 0.125-in. wide shear cracks
3. Known shear deficiency (i.e. “size effect”) for structures built pre-1970s
4. Unknown variability from construction activities
5. High cost/delays for temp. repair/shoring

codot.gov/projects/i70east

Methods
Loading

Type 3-3 Minimum

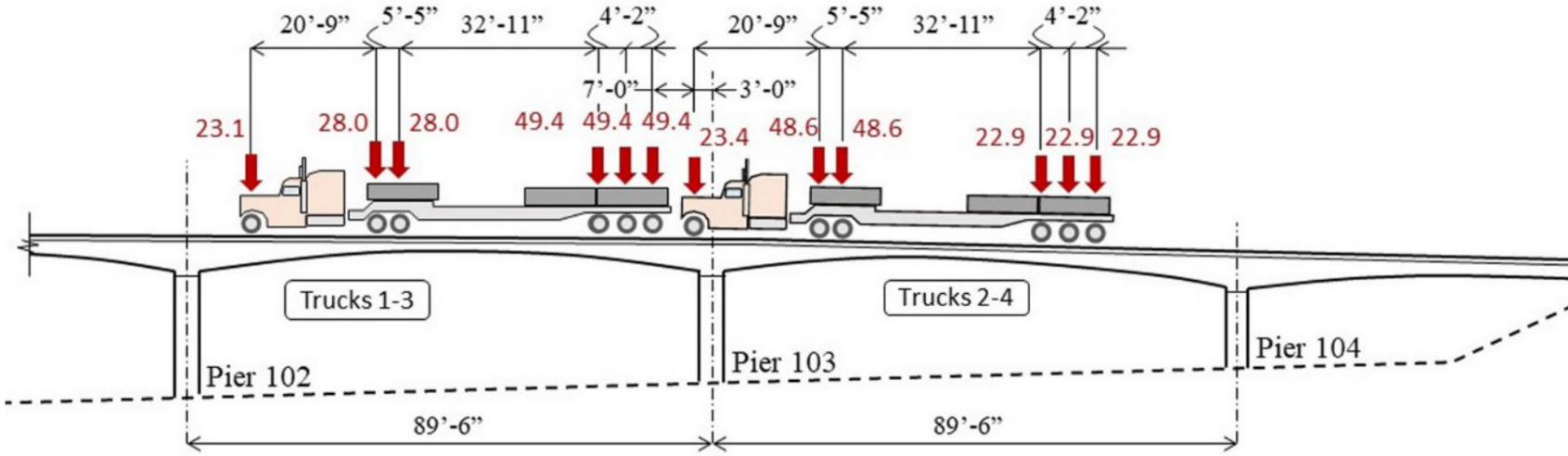
- Effect of four Type 3-3 trucks
- No reduction for multiple trucks



Type 3-3 Minimum Load (kip)
(Looking North)

Type 3-3 Legal Load

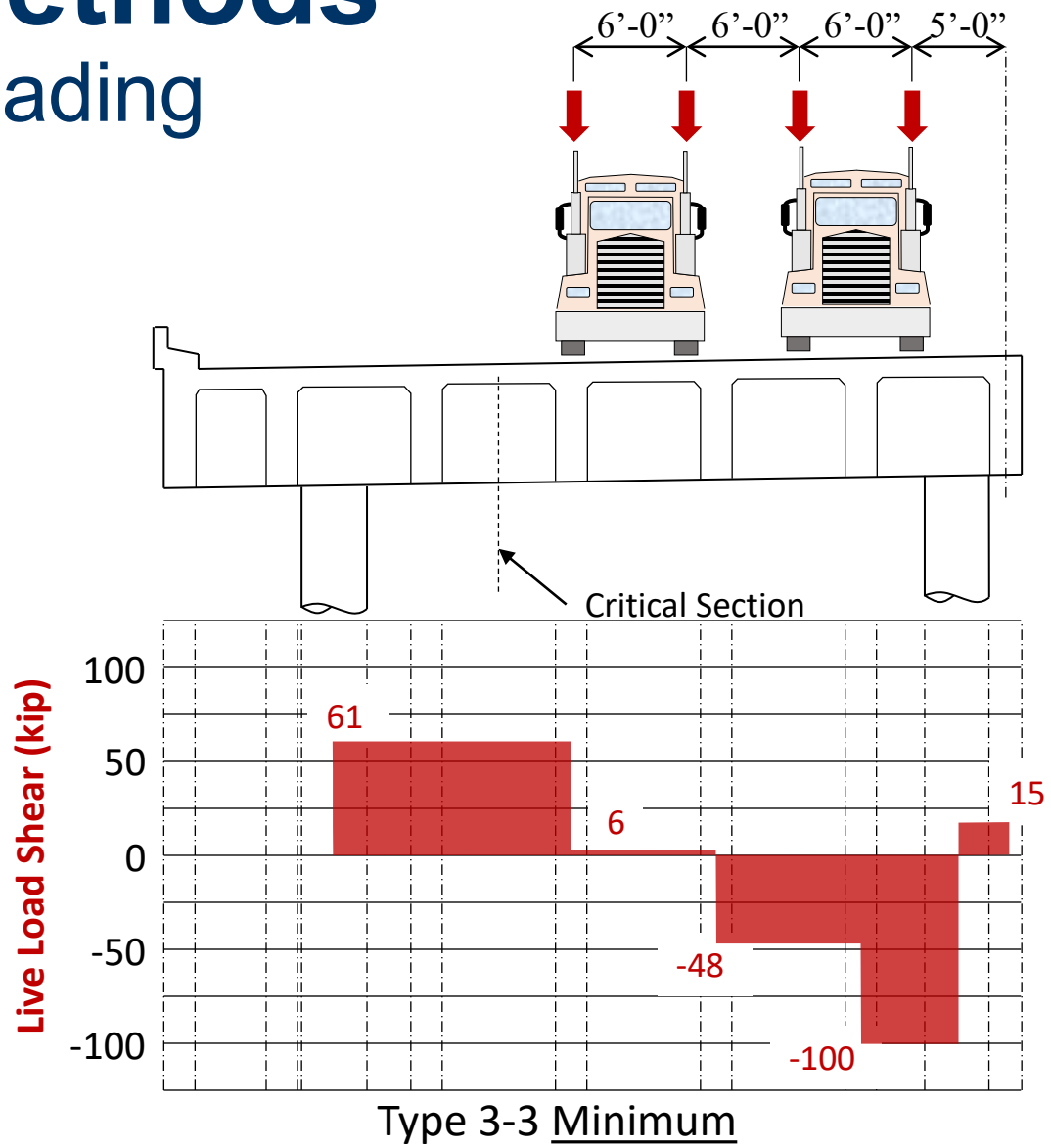
- Effect of four Type 3-3 trucks
- and 0.20 k/ft lane load
- 20% impact
- 25% reduction for multiple trucks



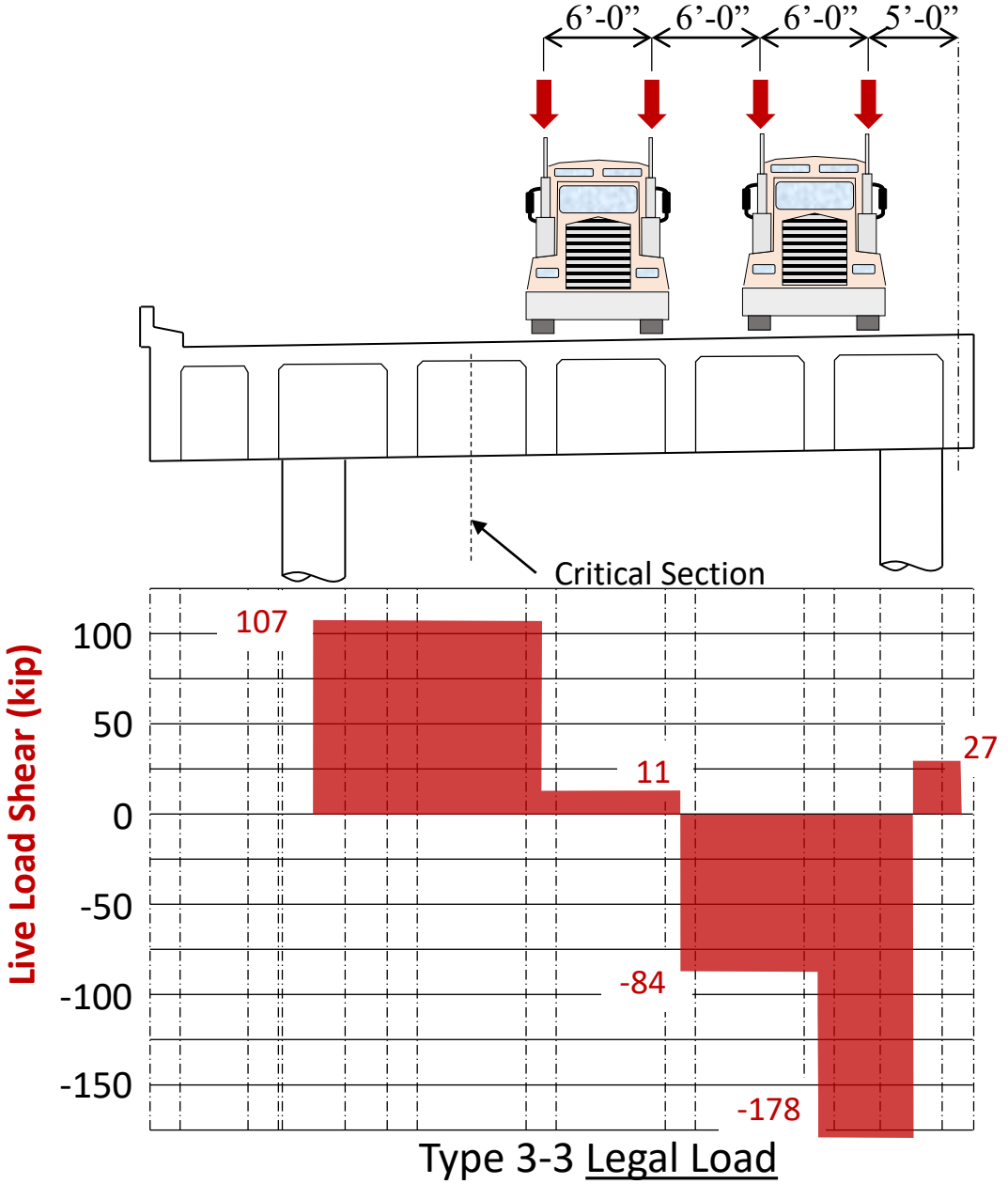
Type 3-3 Legal Load (kip)
(Looking North)

Methods

Loading



Type 3-3 Minimum

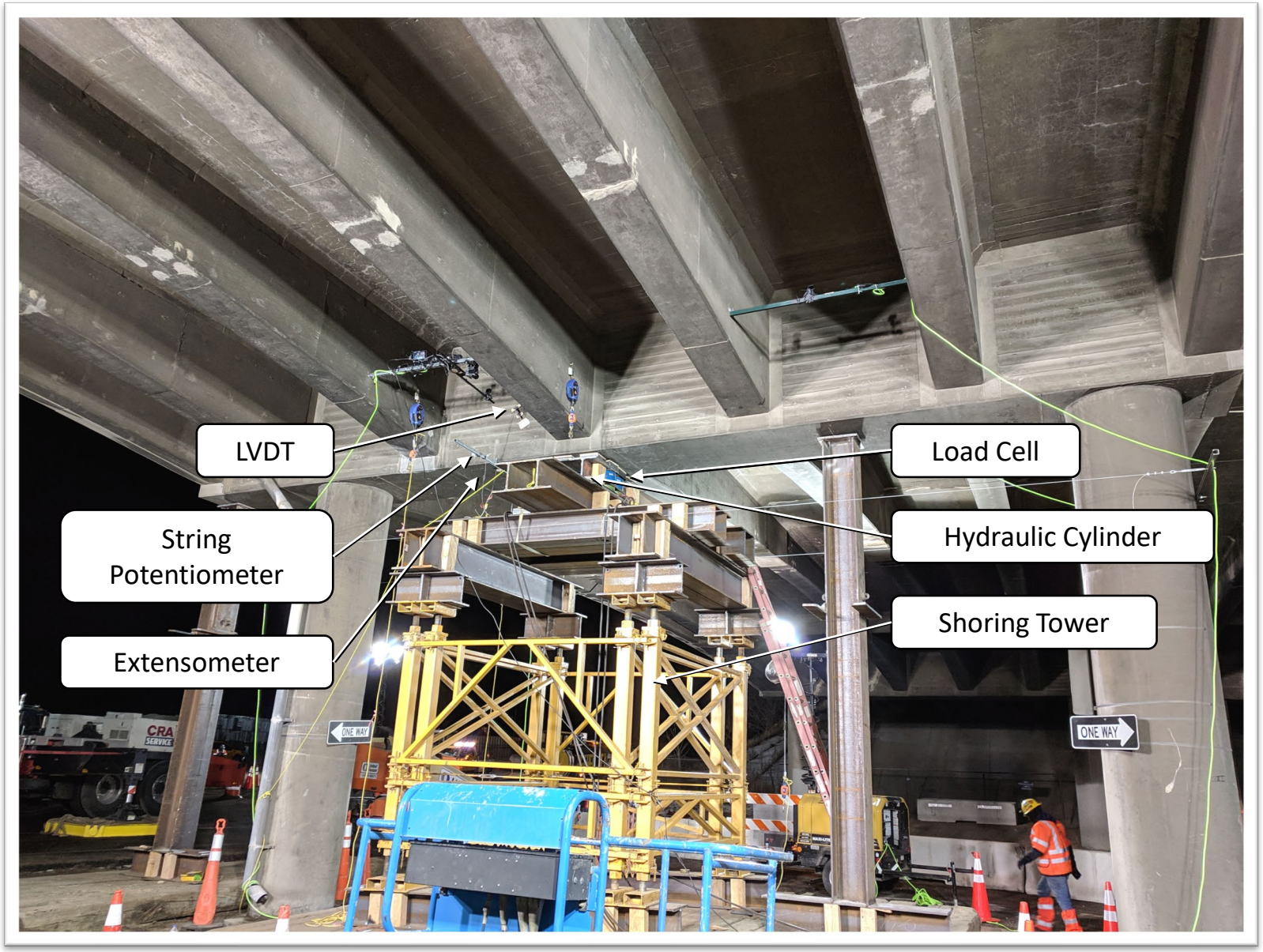


Type 3-3 Legal Load

Methods

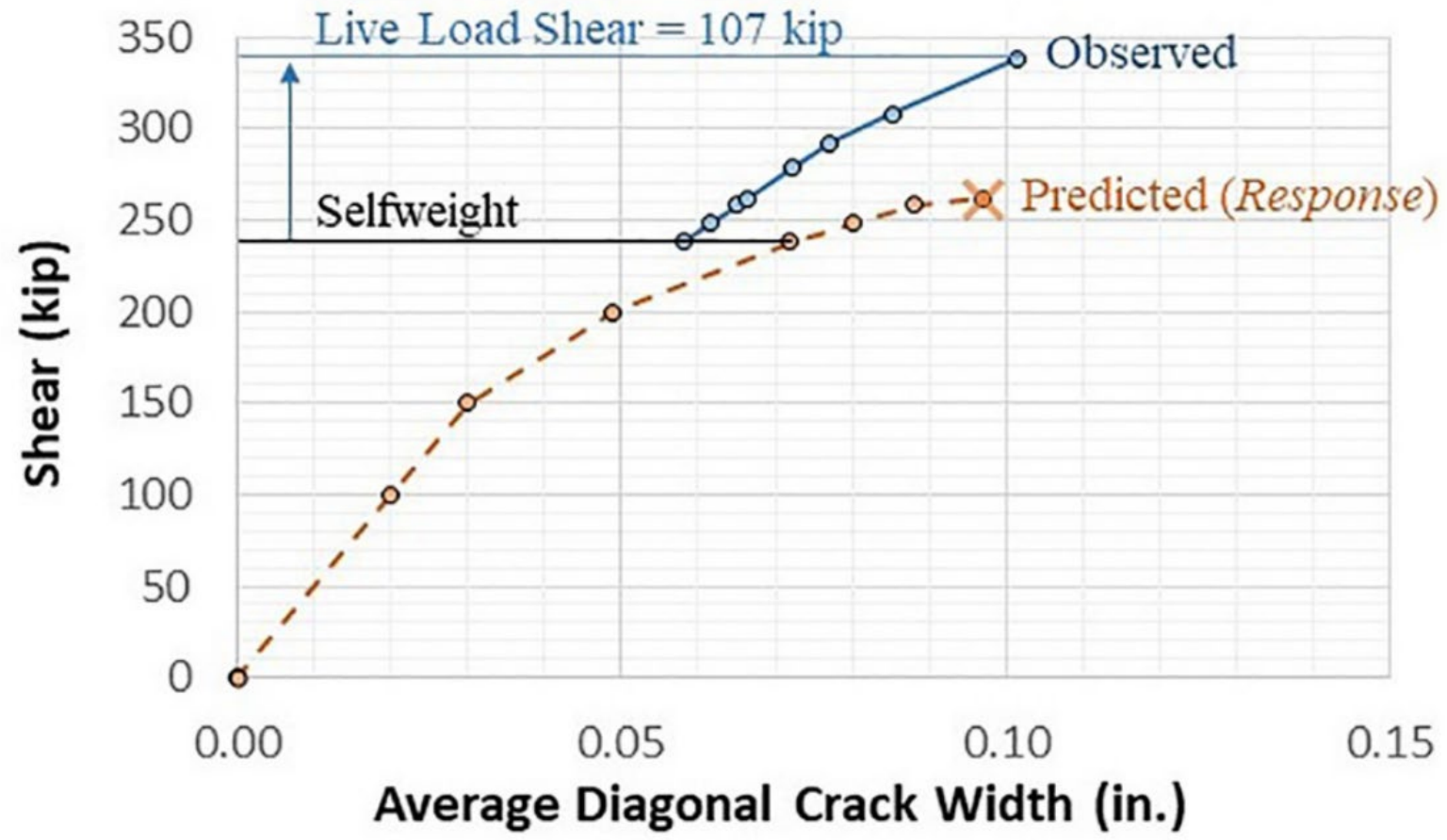
Test Setup

- January 5, 2019. 12:00am–2:30am
- Hydraulic rams counter truck loading
- Instruments confirmed with visual checks



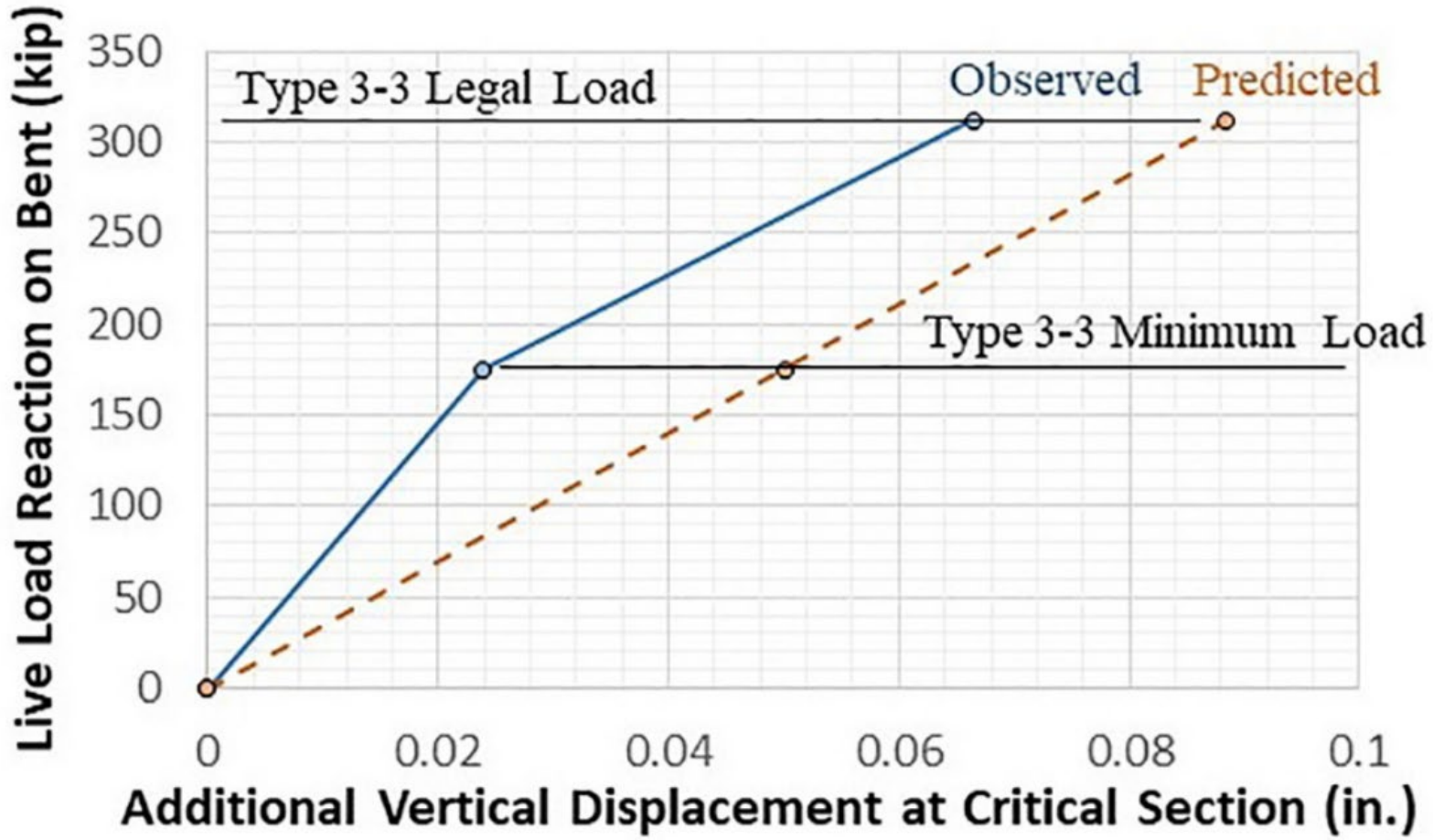
Analysis of Results

Shear Force vs. Diagonal Crack Width



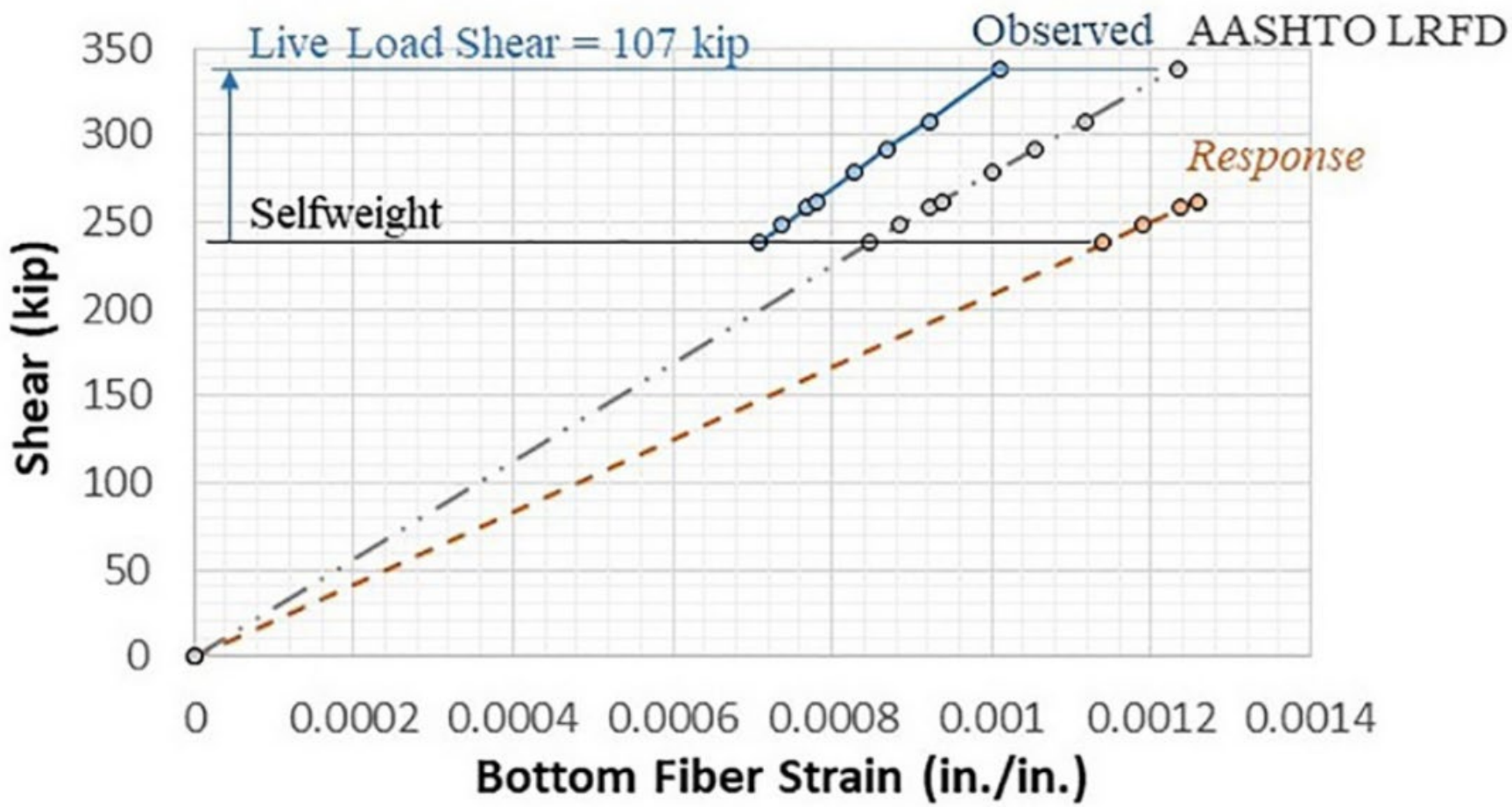
Analysis of Results

Total Live Load Reaction vs. Vertical Displacement



Analysis of Results

Shear Force vs. Bottom Fiber Strain



Application of Results
Legal Load Rating

	Type 3-3 Legal Load BEFORE Proof Test		Type 3-3 Legal Load AFTER Proof Test	
Force	Value	LF	Value	LF
V_{DC}	204 k	1.25	204 k	1.25
M_{DC}	2055 k’		2055 k’	
V_{DW}	34 k	1.5	34 k	1.5
M_{DW}	382 k’		382 k’	
V_{LL+I}	78 k	1.45	78 k	1.45
M_{LL+I}	858 k’		858 k’	
ϕ_V	0.9		0.9	
ϕV_n	267 k		**1.57** × 267 k = 419 k	
V_u	419 k		419 k	
RF =	**−0.35**		**1.0**	

Application of Results
Reliability Index for All Other Bents

Strength based on Proof Test (β=2.5)
$R_n = 1.4(L+I) + D$
Strength based on Calculations (β=2.5)
$R_n = 1.45(L+I) + 1.25DC + 1.5DW$

Statistical Parameters (β=2.5 for 103N):

	Bias ($^{Mean}/_{Nominal}$)	COV ($^{Std\ Dev}/_{Mean}$)	Source
Dead Loads	1.0[a]	0.0[a]	[1]
Live Loads	1.2	0.135	[2]
Impact	0.10	0.80	[2]
Resistance	1.2	0.10[b]	[2,3]

[a]Dead load of all bents known with as much certainty as 103N
[b]Within range of sources and calibrated so β = 2.5 for 103N

$$\beta = \frac{R_n \cdot \lambda_R \cdot (1 - 2 \cdot V_R) \cdot (1 - \ln(1 - 2 \cdot V_R)) - m_Q}{\sqrt{(R_n \cdot V_R \cdot \lambda_R \cdot (1 - 2 \cdot V_R))^2 + (\sigma_Q)^2}}$$

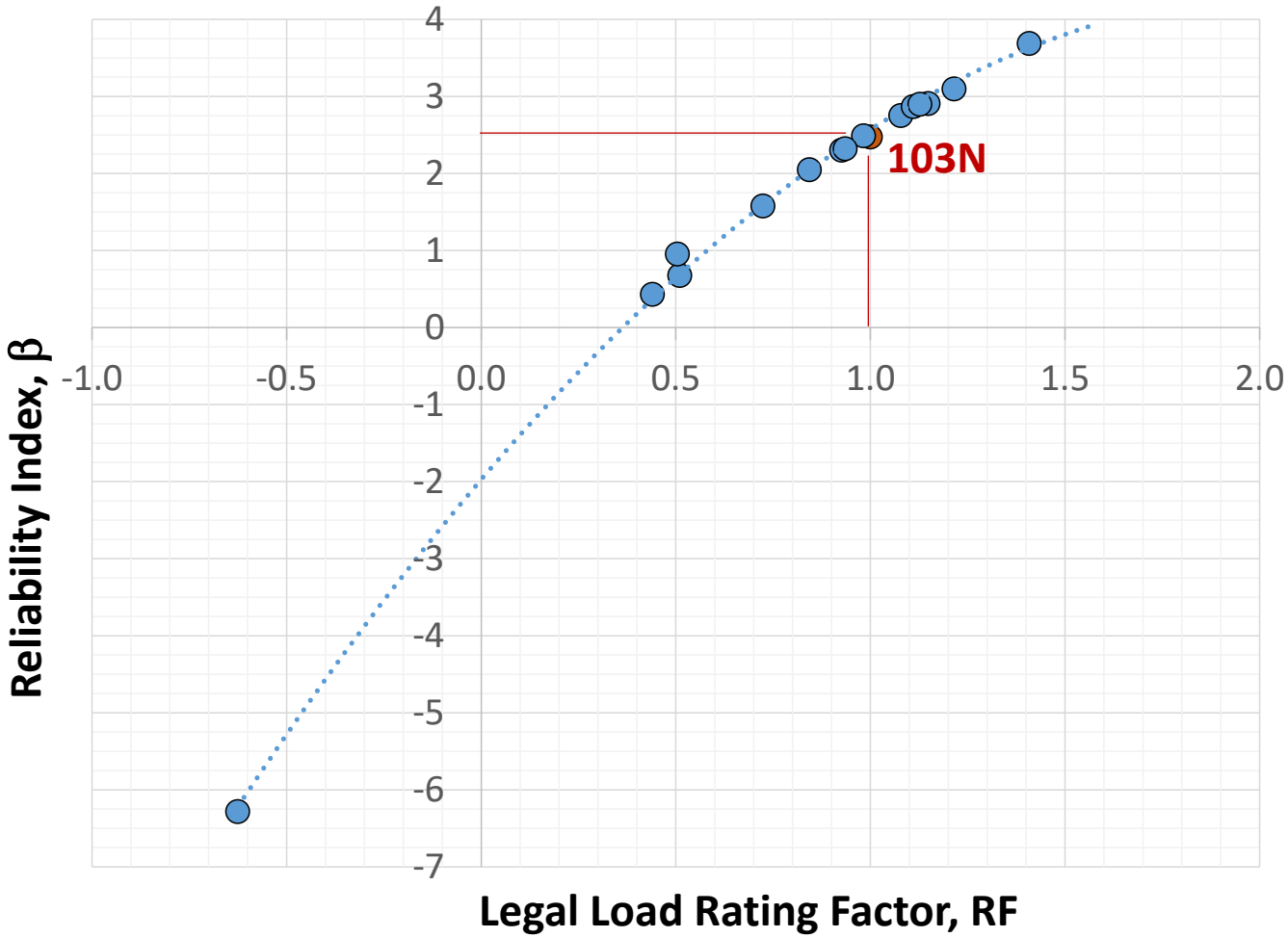
[1] Lichtenstein, A.G. 1993. *Bridge Rating through Nondestructive Load Testing.* NCHRP 12-28(13)A.

[2] Nowak, A.S. 1999. *Calibration of LRFD Bridge Design Code*. NCHRP 368.

[3] Bentz, E.C.; Vecchio, F.J.; and Collins, M.P. 2006. "Simplified Modified Compression Field Theory for Calculating Shear Strength of Reinforced Concrete Elements." *ACI Str. J.* 103(4).

Application of Results

Reliability Index vs. Rating Factor



Summary

- The resistance of Bent 103N is at least 1.57 times higher than demand.
- Predictive models are reasonably accurate.
- Rating Factor (RF) of Bent 103N was at least 1.0. Thus, Reliability Index based on calculations was at least $\beta = 2.5$. These results were extrapolated to other untested Bents because they were similar construction/condition.
- There is a need to better quantify the shear capacity of large-sized beams that contain minimum reinforcement but an amount less than the code limit.

Questions?

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