Modeling Post-Tensioned Concrete Haunched Slabs (XCSH) in BrDR

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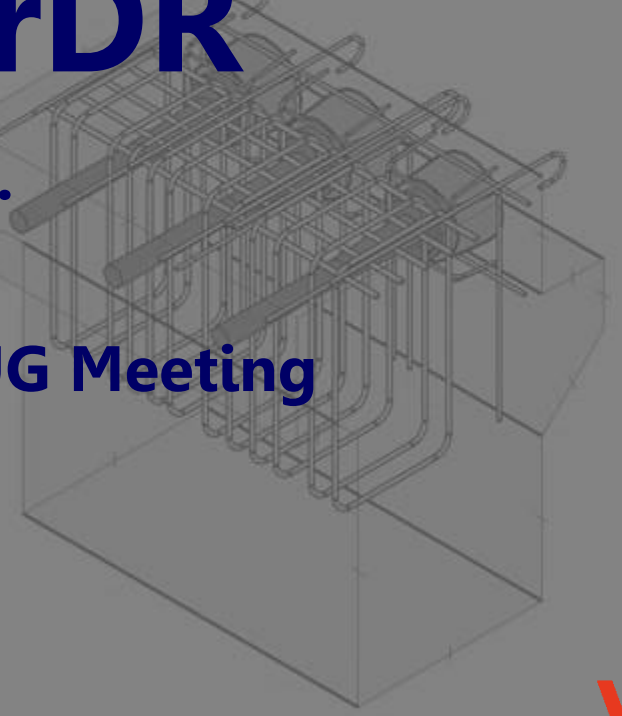
Brad Shores, P.E.

2017 AASHTO Bridge RADBUG Meeting

8/15/2017

Kansas City, KS



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What is a XCSH?

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RCSH Uses Mild Steel + Concrete

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Maximum standard spans: 54’-72’-54’

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Maximum standard spans: 71’-92’-71’

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History of XCSH

- Pre-1989: Need for longer span slab bridges
- 1989: 1st PT, Sedgwick County, 45’-75’-45’
- 1990-2000: 8 more PT’s including 79’-102’-79’
- 2000: Metric PT Standards developed for KDOT
- 2006: Englification of Standards
- 2013: Grout Improvements, Manual Update
- 2017: Standard Update

30+ bridges constructed in 28 years

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2000: 85th St N over WVCFC

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Primary Structure Holding Up?

- 2011 NDT grout investigation two bridges no issues (low profile!)

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Primary Structure Holding Up?

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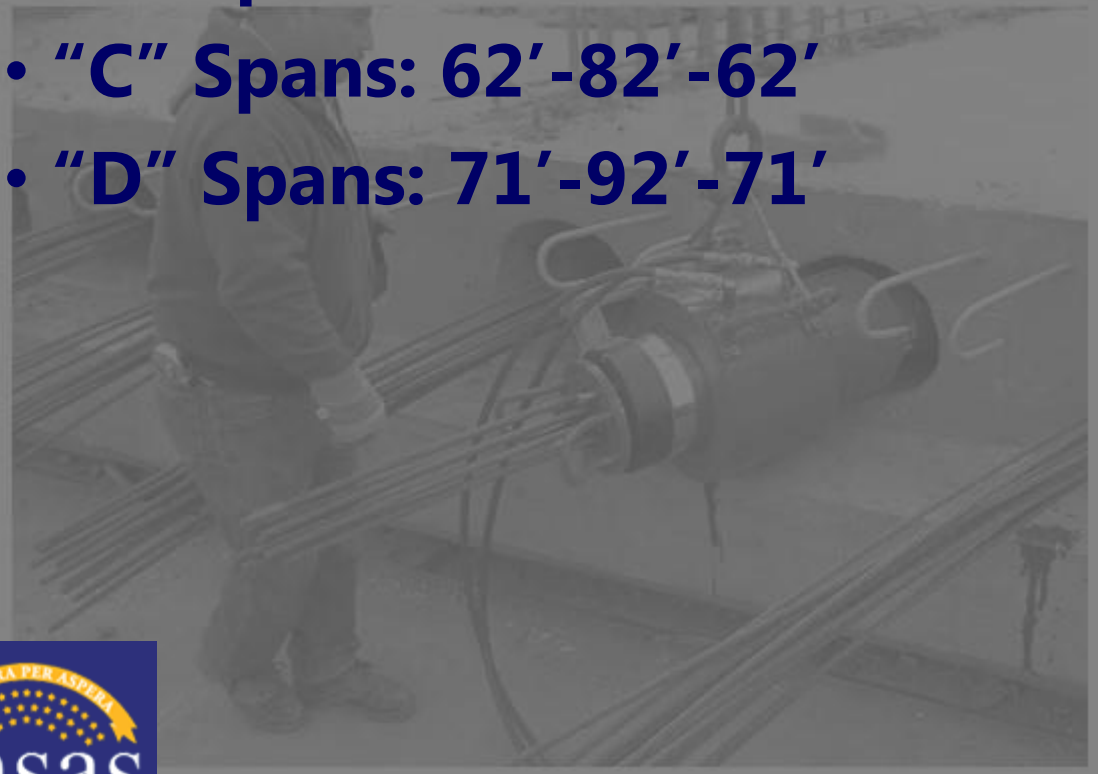
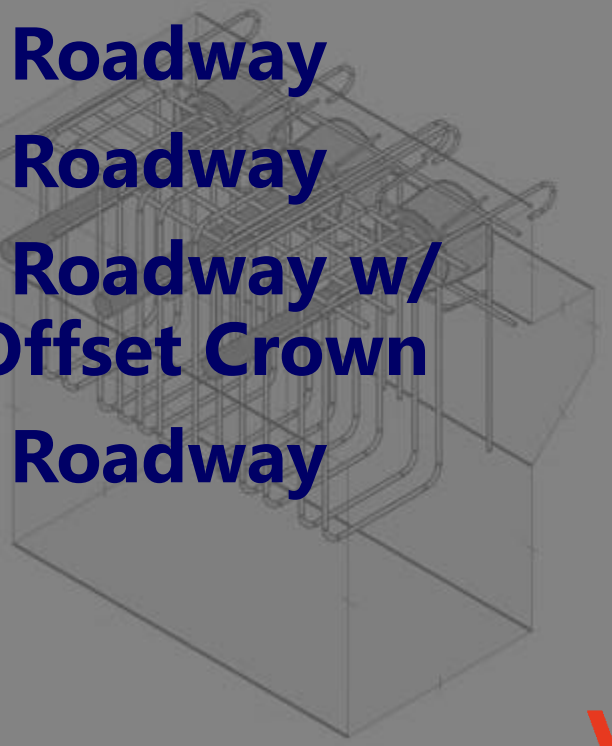
2016-2017 KDOT Standard Update

- "A" Spans: 50'-65'-50'
- "B" Spans: 55'-72'-55'
- "C" Spans: 62'-82'-62'
- "D" Spans: 71'-92'-71'



- 28' Roadway
- 32' Roadway
- 36' Roadway
- 40' Roadway
- 40' Roadway w/ 2' Offset Crown
- 44' Roadway



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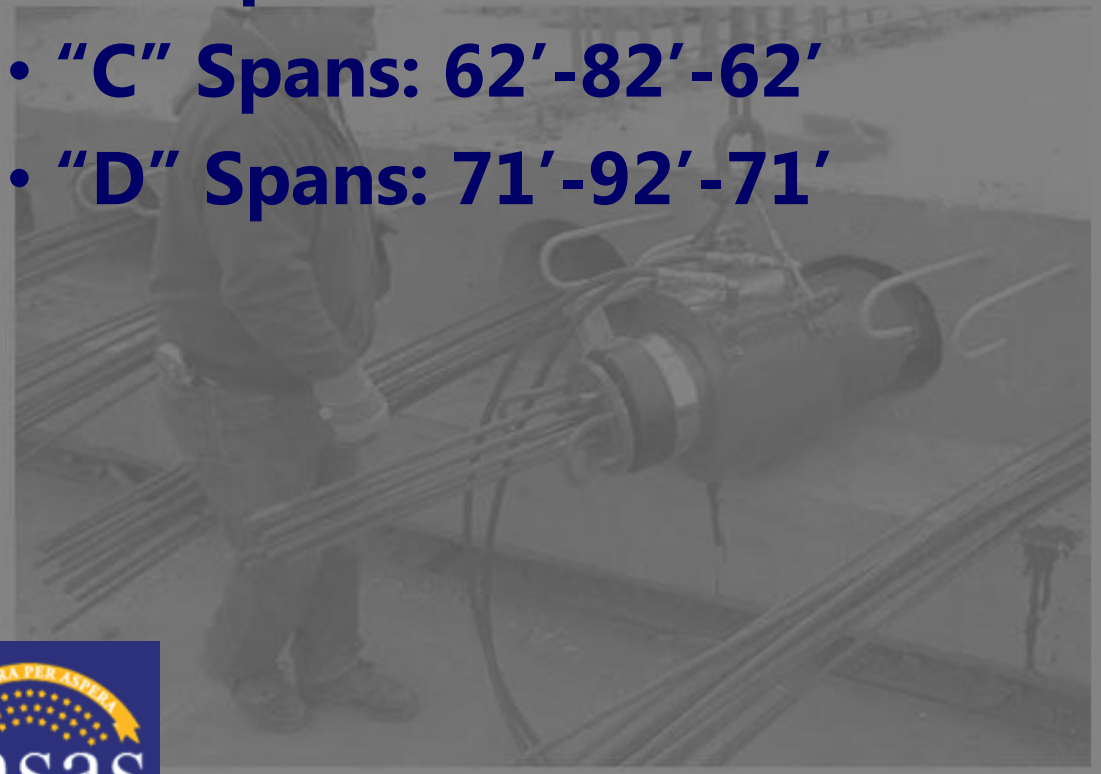

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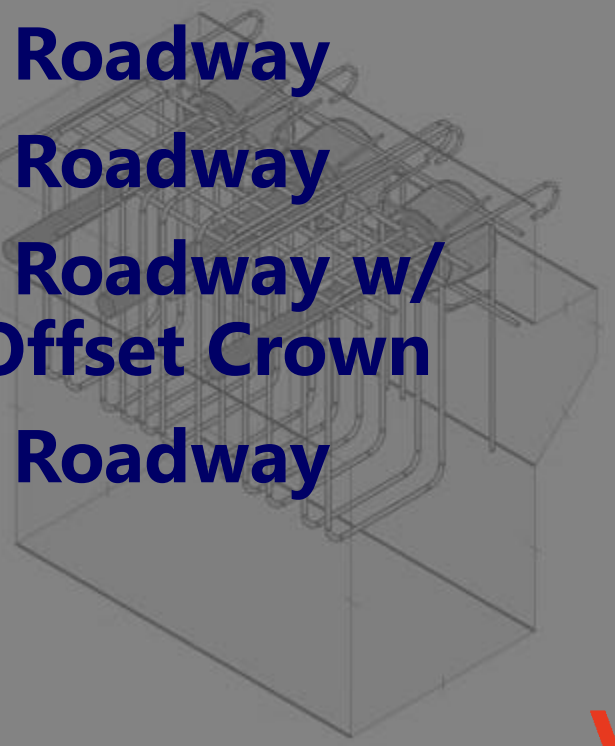

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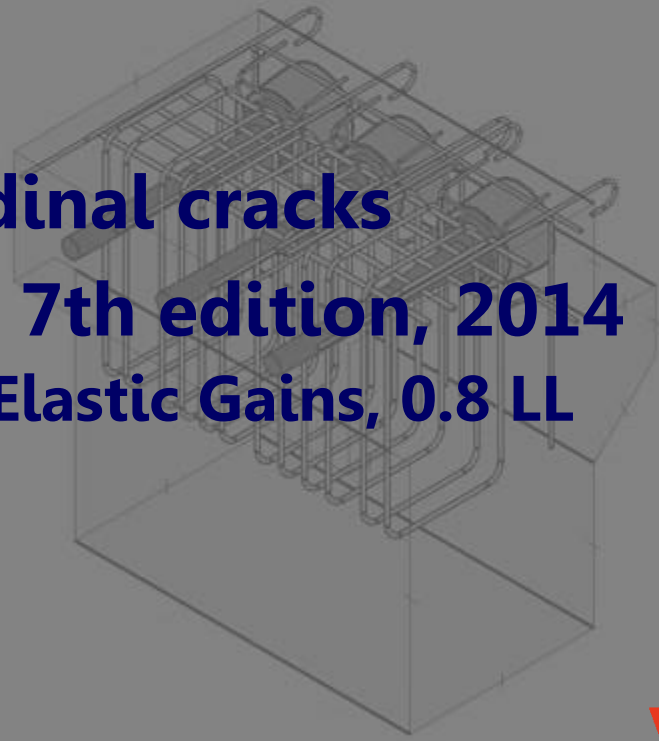
2016-2017 KDOT Standard Update

- Tendon to Protection Level 2 (PL2)
  - PTI/ASBI M50.3-12 Guide Specification for Grouted Post-tensioning
- Review grout specification
- Detailing over the piers for longitudinal cracks
- AASHTO LRFD Bridge Design Specs, 7th edition, 2014
  - With Elastic Gains, 1.00 LL or Without Elastic Gains, 0.8 LL
- Load Rate BrR including SU trucks



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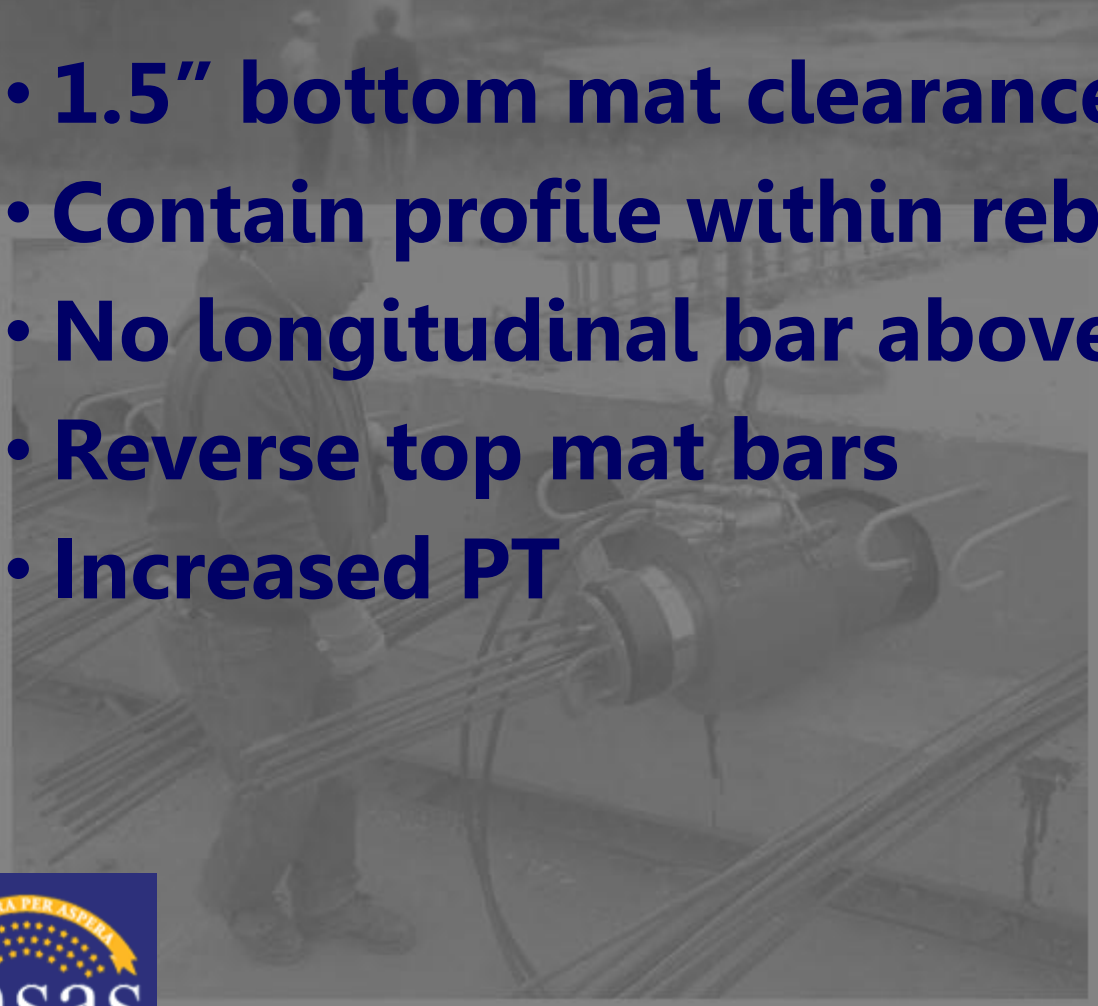
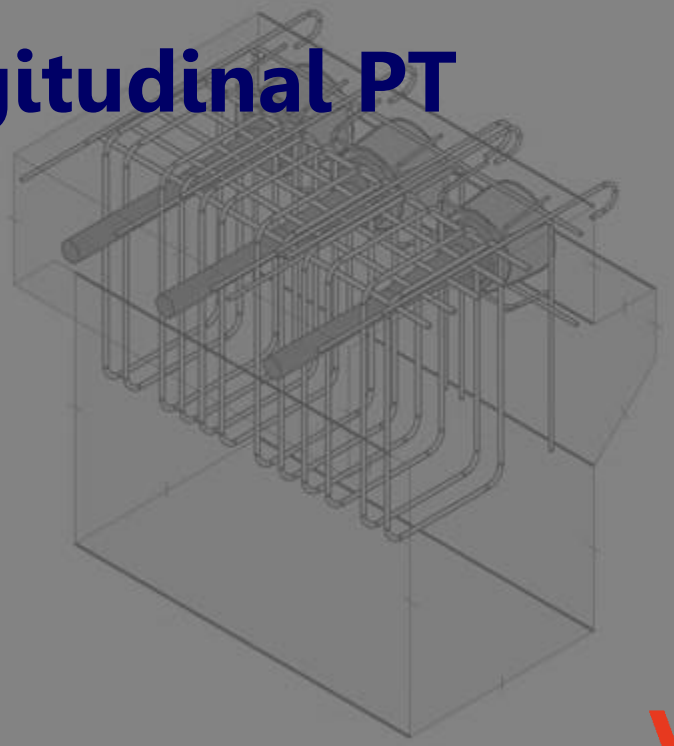
Contain PT in Mild Steel

- 1.5” bottom mat clearance instead of 1.0”
- Contain profile within rebar mats
- No longitudinal bar above longitudinal PT
- Reverse top mat bars
- Increased PT





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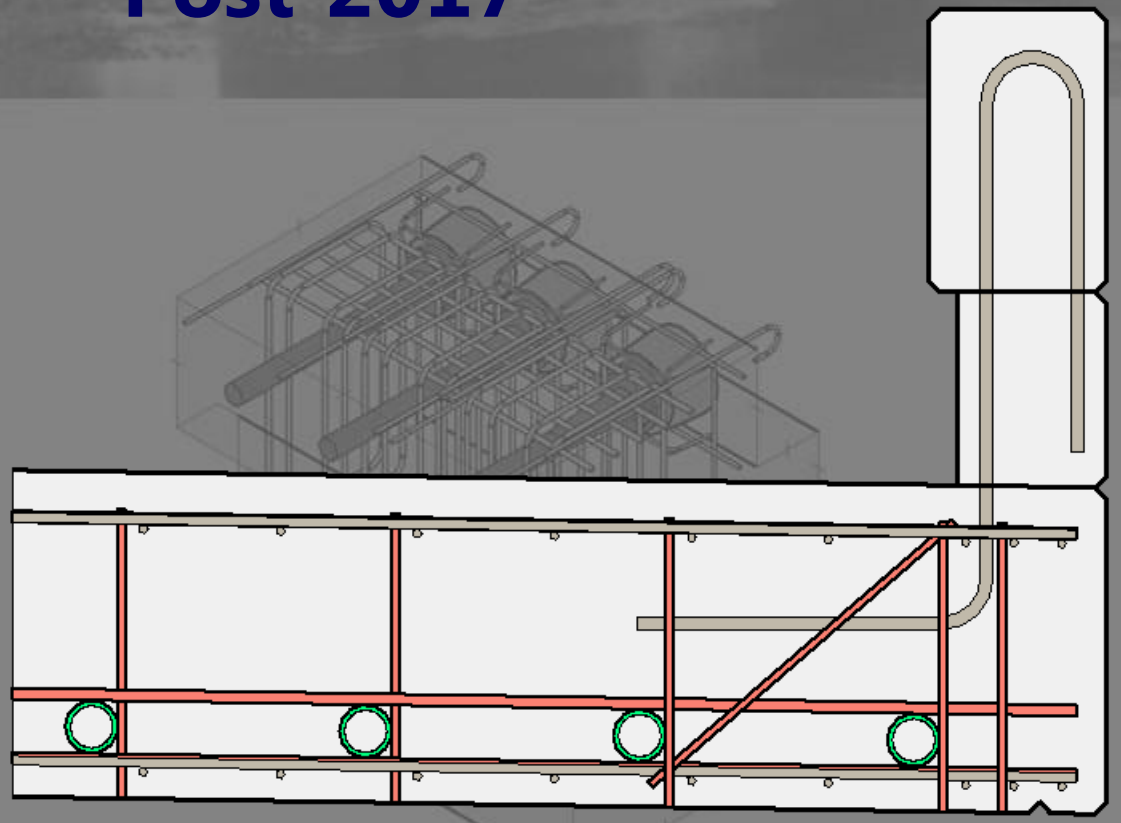
Contain Low PT in Mild Steel

Pre-2017

Post-2017



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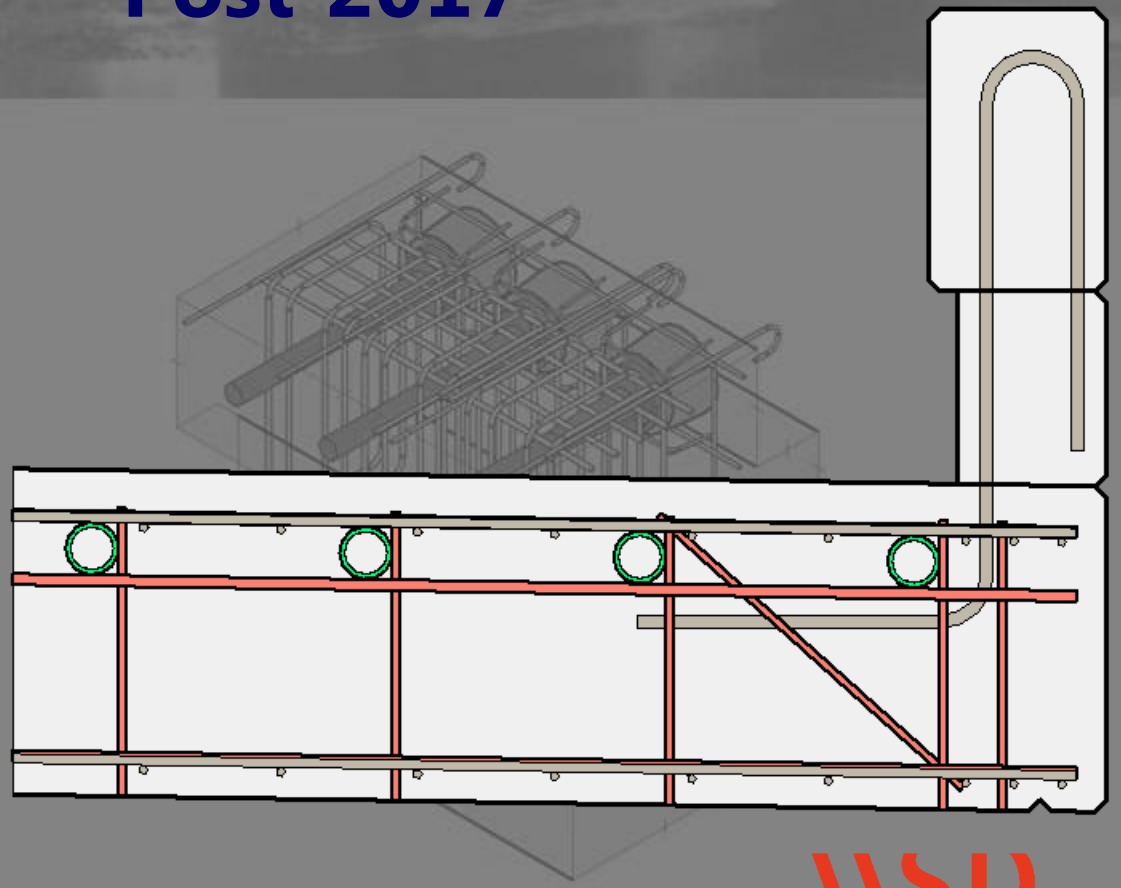
Contain High PT in Mild Steel

Pre-2017

Post-2017



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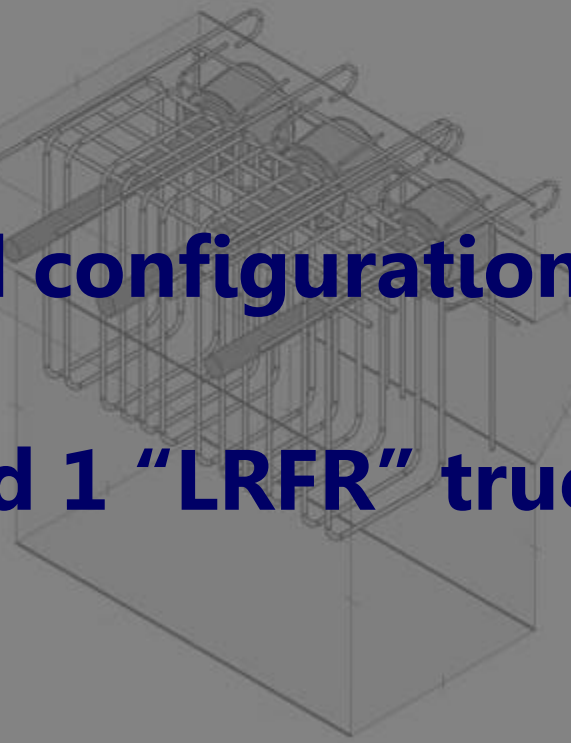
BrR Scope

- Determine best Superstructure Definition for XCSH
- Create BrR files for previous standard configurations
  - 20 Configurations modeled in BrR
- Create BrR files for new standard configurations
  - 15 Configurations modeled in BrR
- Load Rate for 14 “LFR” trucks and 1 “LRFR” truck



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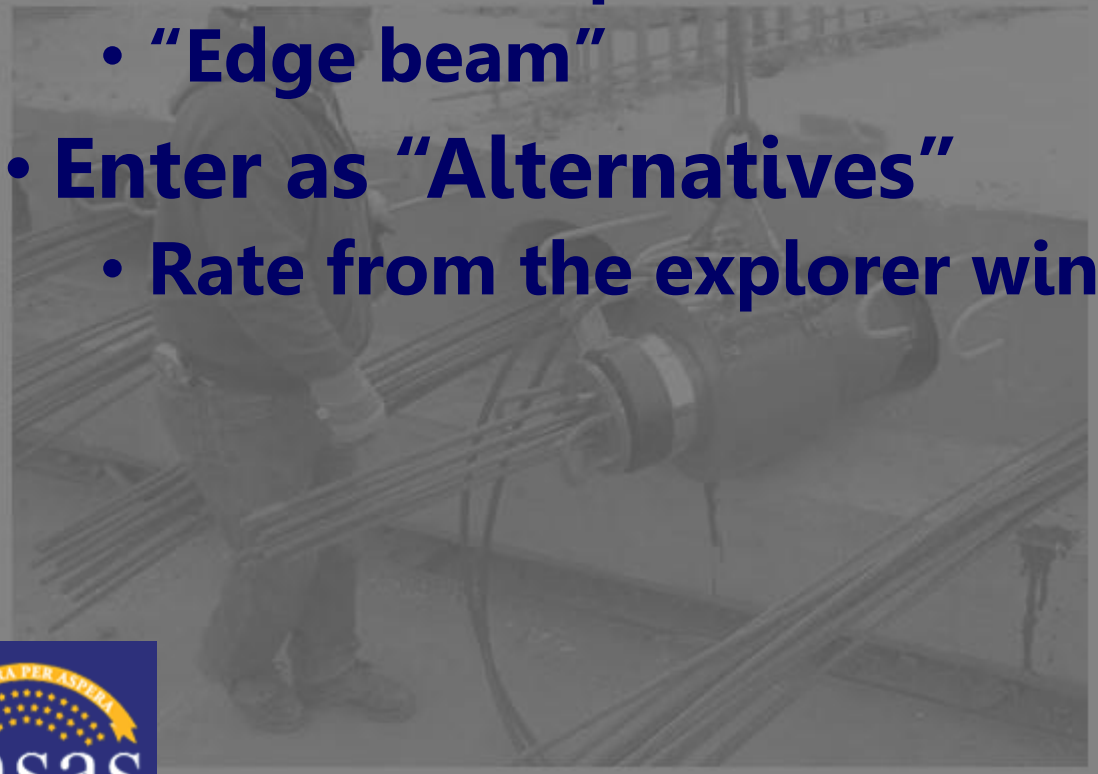
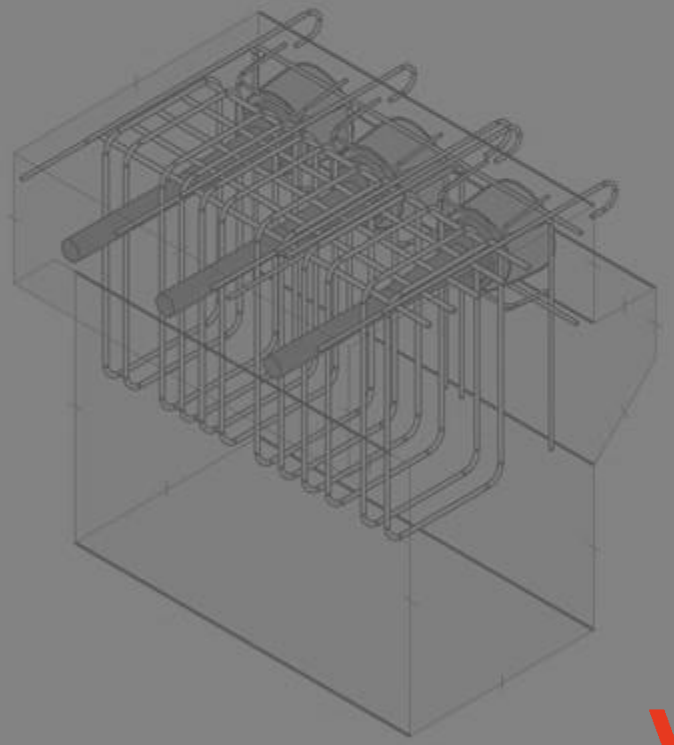
Approach – Our Code Interpretation

- For each configuration, model:
  - "Interior strip"
  - "Edge beam"
- Enter as "Alternatives"
  - Rate from the explorer window





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Strip Widths

- **Interior strip width = Interior Duct Spacing = 1’-9”**
- **Edge beam width per AASHTO LRFD 4.6.2.1.4b**

4.6.2.1.4b—Longitudinal Edges

Edge beams shall be assumed to support one line of wheels and, where appropriate, a tributary portion of the design lane load.

Where decks span primarily in the direction of traffic, the effective width of a strip, with or without an edge beam, may be taken as the sum of the distance between the edge of the deck and the inside face of the barrier, plus 12.0 in., plus one-quarter of the strip width, specified in either Article 4.6.2.1.3, Article 4.6.2.3, or Article 4.6.2.10, as appropriate, but not exceeding either one-half the full strip width or 72.0 in.

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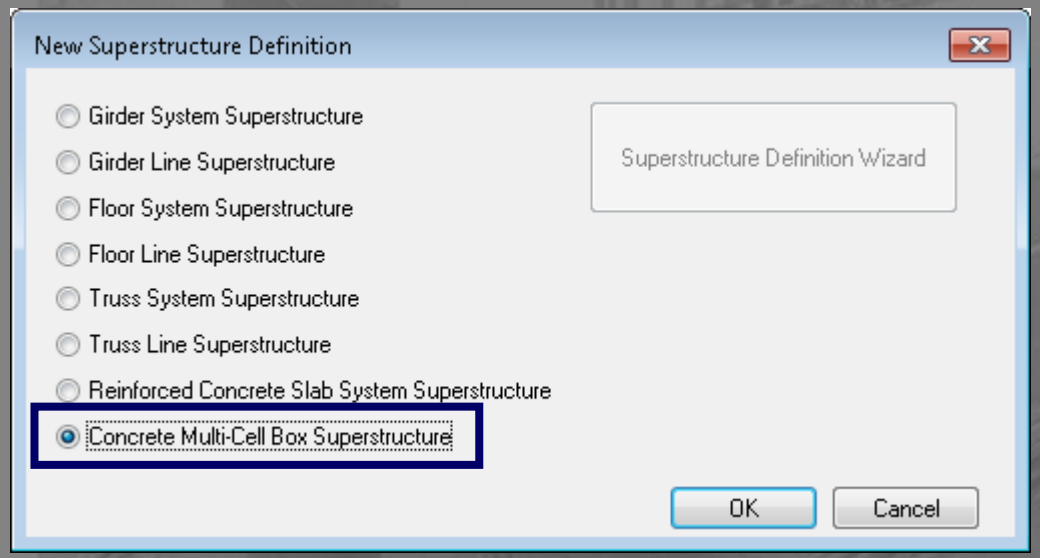
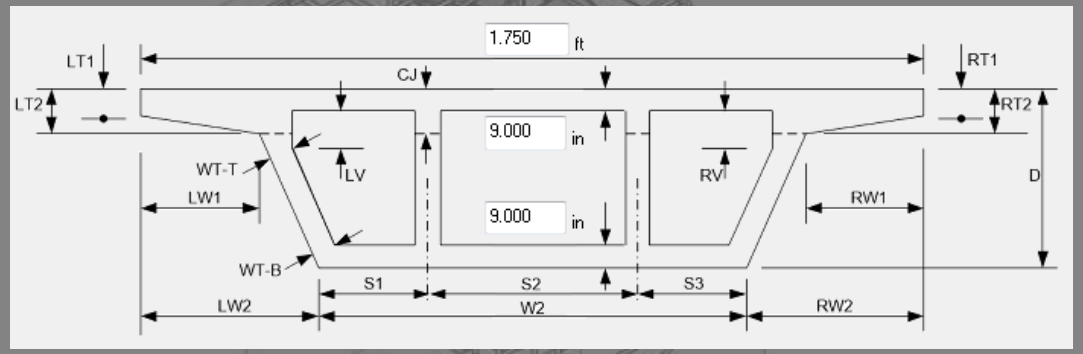
Superstructure Definition

- **Superstructure Definition:**
  - **Concrete Multi-Cell Box Superstructure**





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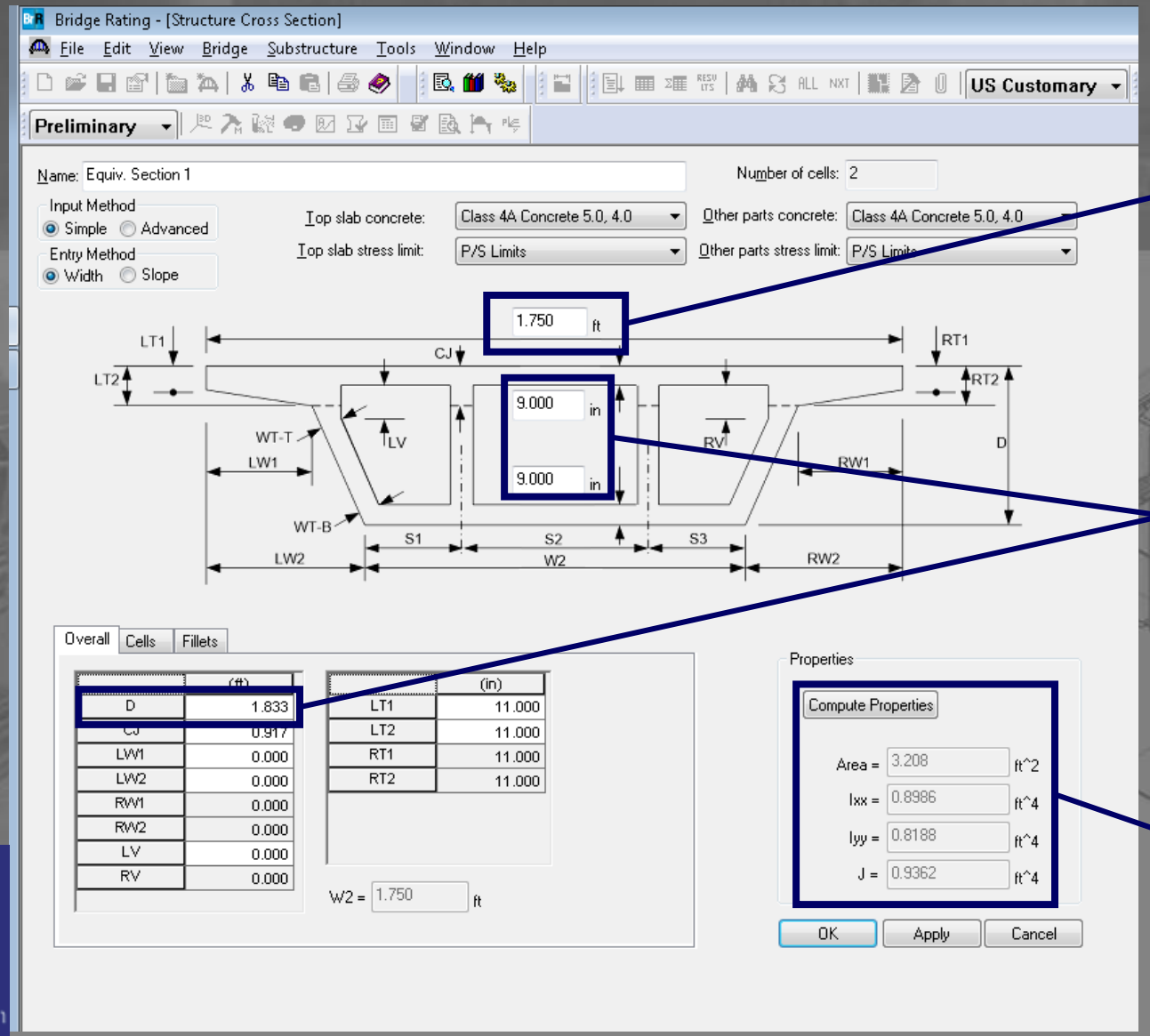
Structure Cross Sections: Define Two



Strip Width = Duct Spacing

Not equal; Arbitrary 4”x0” void required

Check section properties

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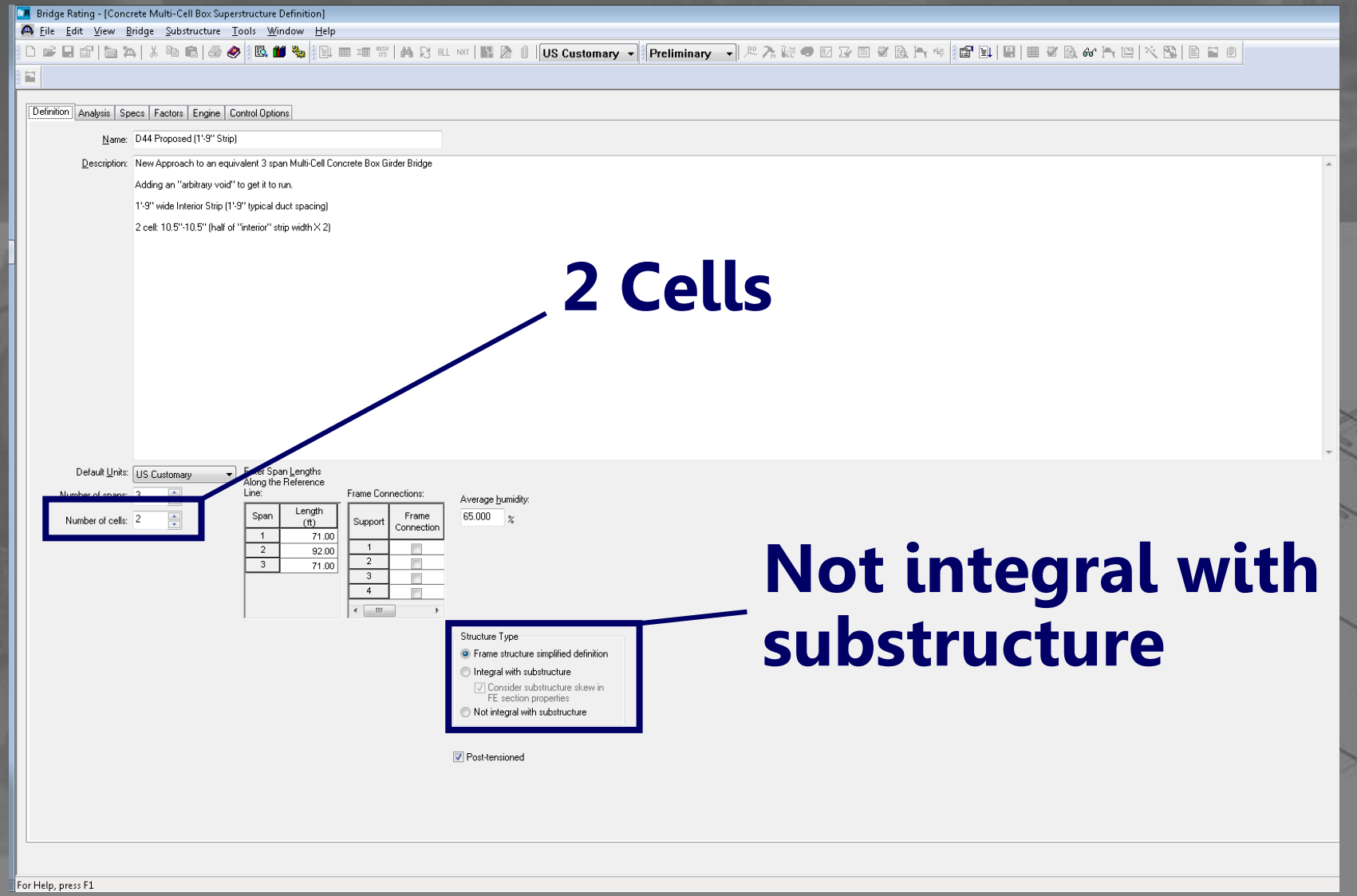
Superstructure Definition



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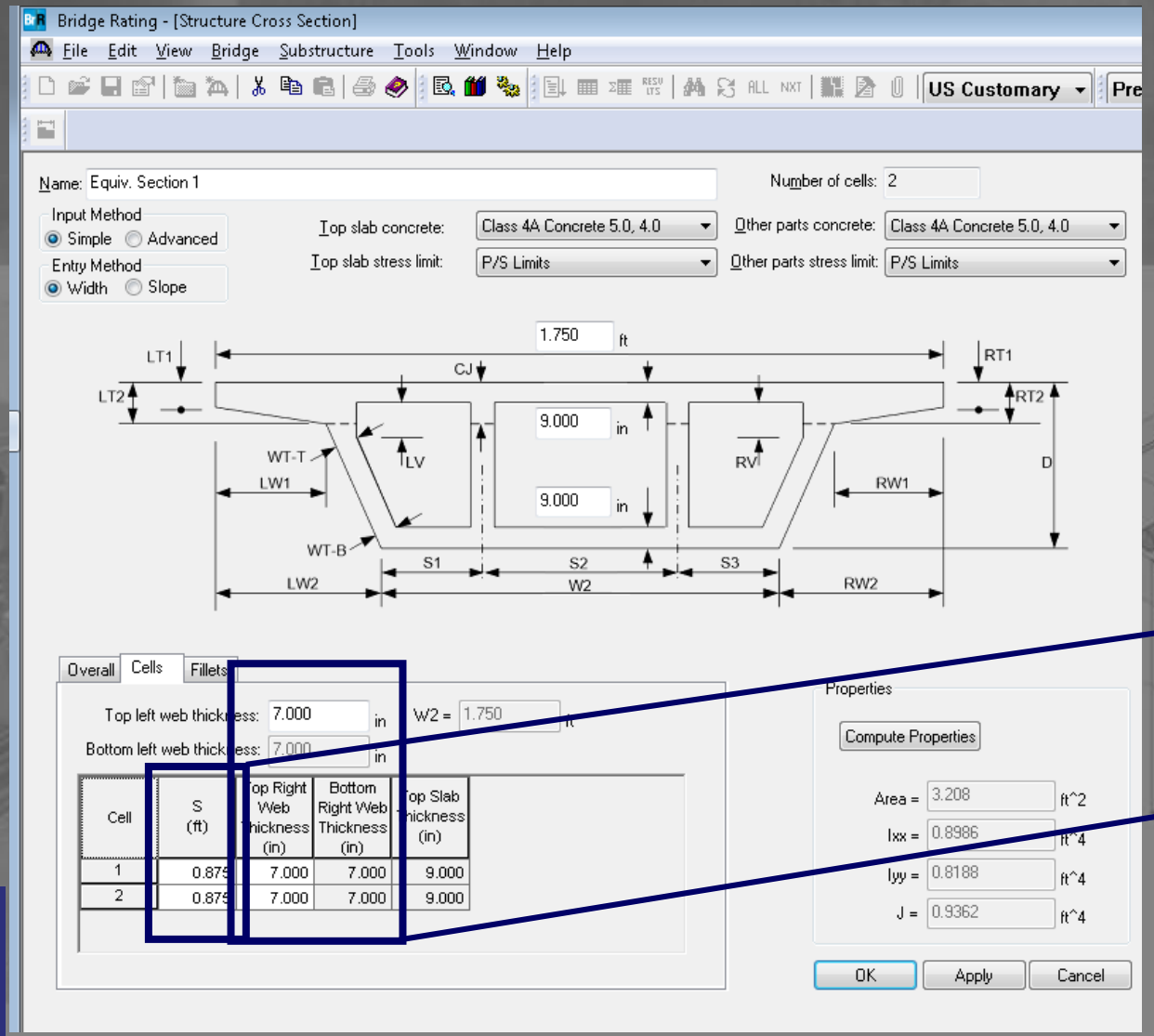
Structure Cross Sections: Key Dim's



S = Overall width / 2

Web thickness = Overall width / 3

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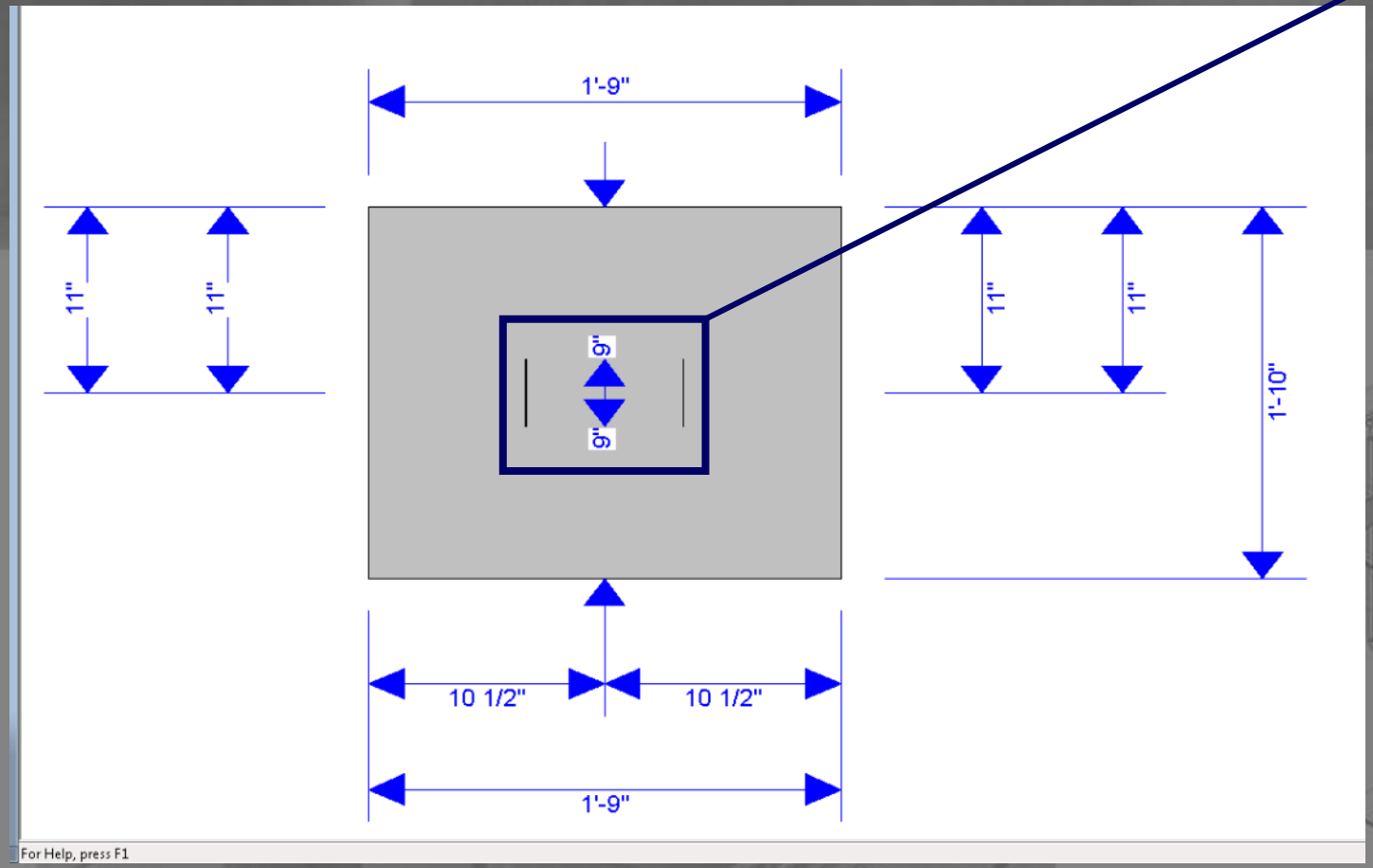
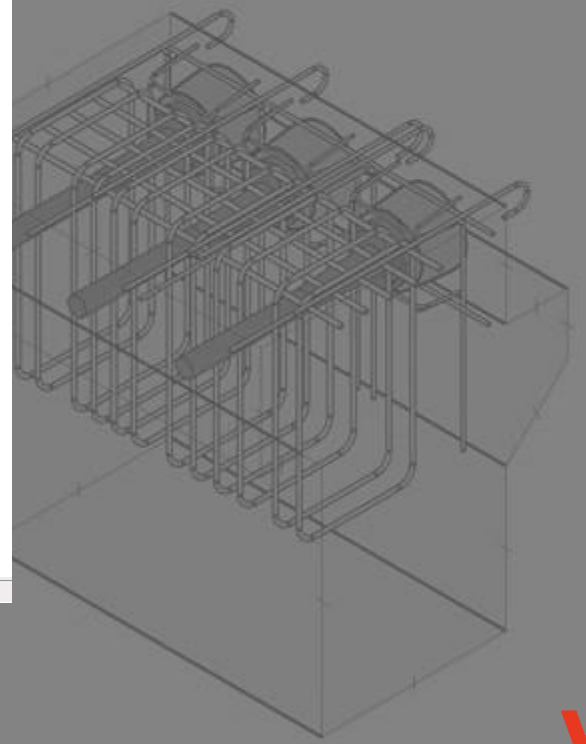
Section View

Arbitrary voids





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Cross Section Range Properties

Bridge Rating - [Cross Section Ranges]

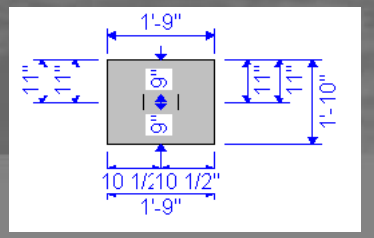
File Edit View Bridge Substructure Tools Window Help

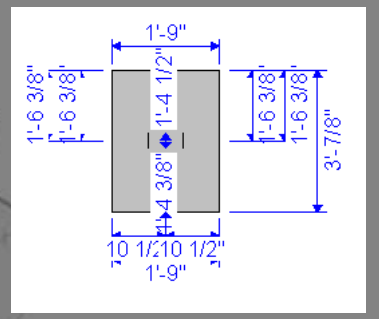
Preliminary

Cross Sections | Post Tensioning | Effective Supports

Left end projection: 18.000 in Right end projection: 18.000 in

Start Section	End Section	Depth Vary	Solid Section	Support Number	Start Distance (ft)	Length (ft)	End Distance (ft)
Equiv. Section 1	Equiv. Section 1	None		1	0.000	25.000	25.000
Equiv. Section 1	Equiv. Section 2	Parabolic Concave		1	25.000	44.333	69.333
Equiv. Section 2	Equiv. Section 2	None		1	69.333	3.333	72.667
Equiv. Section 2	Equiv. Section 1	Parabolic Concave		2	1.667	44.333	46.000
Equiv. Section 1	Equiv. Section 2	Parabolic Concave		2	46.000	44.333	90.333
Equiv. Section 2	Equiv. Section 2	None		2	90.333	3.333	93.667
Equiv. Section 2	Equiv. Section 1	Parabolic Concave		3	1.667	44.333	46.000
Equiv. Section 1	Equiv. Section 1	None		3	46.000	25.000	71.000





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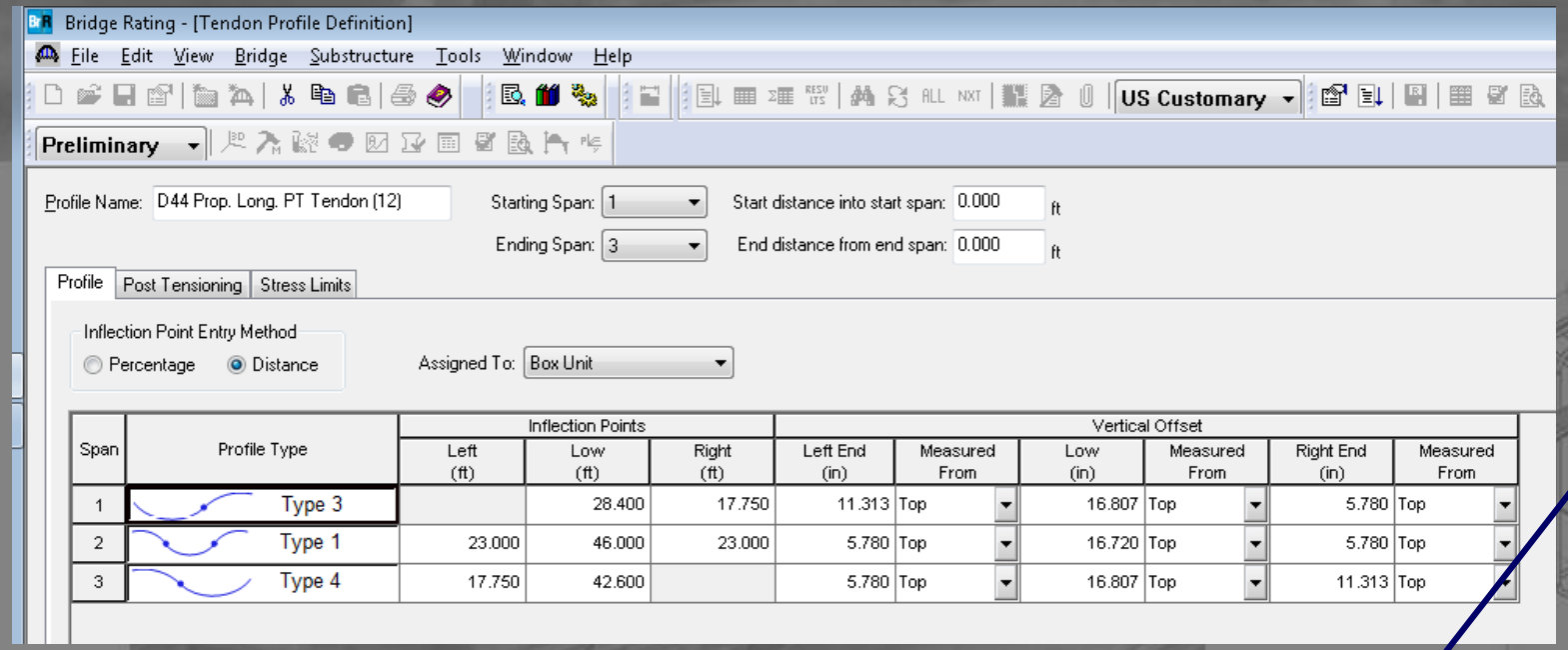
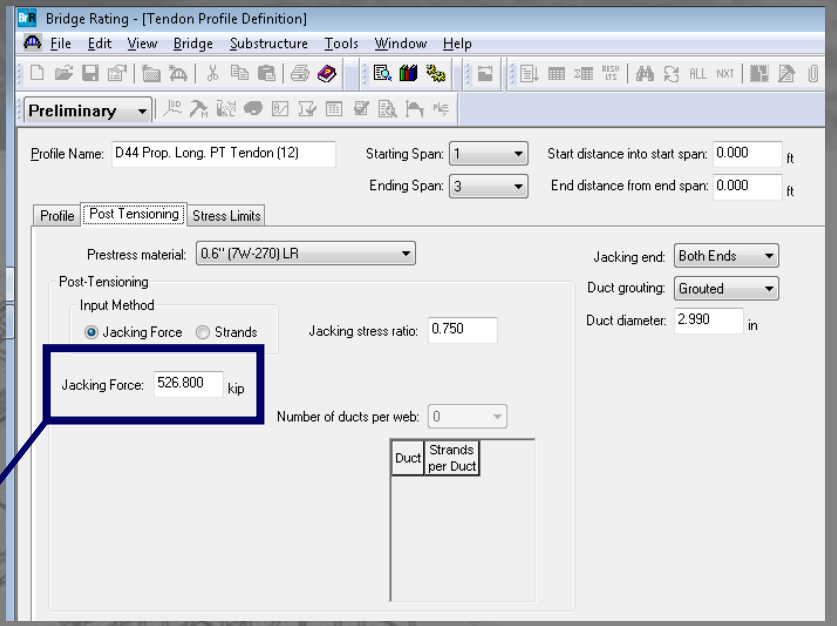
Tendon Profile Definitions





Specify jacking force rather than # of strands, especially for edge beam

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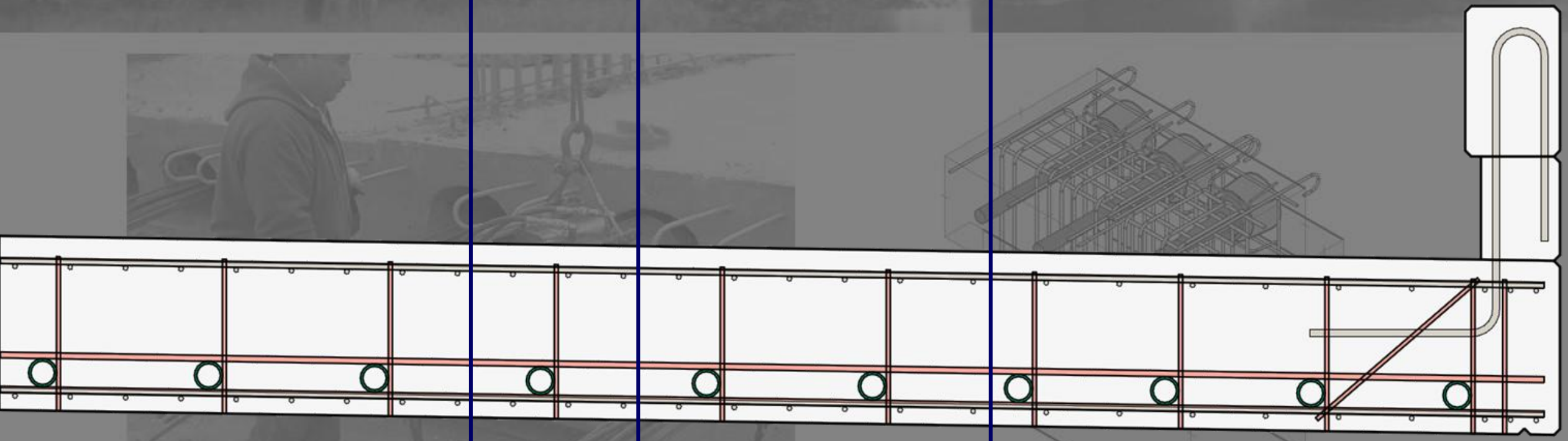
Tendon Profile Definitions



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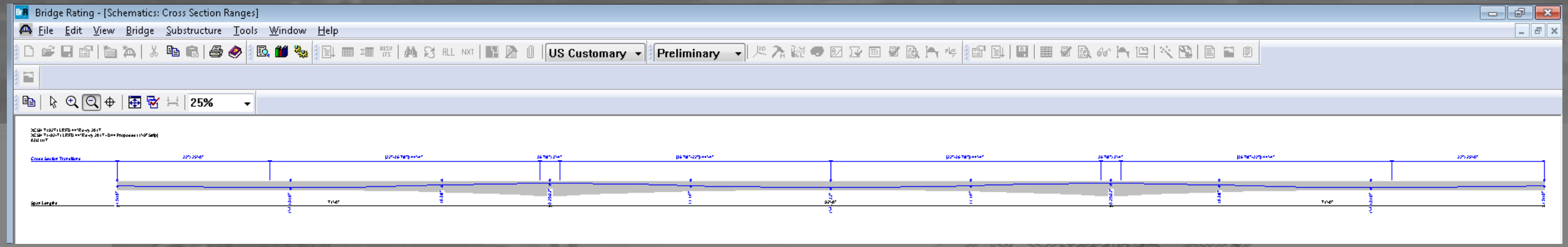
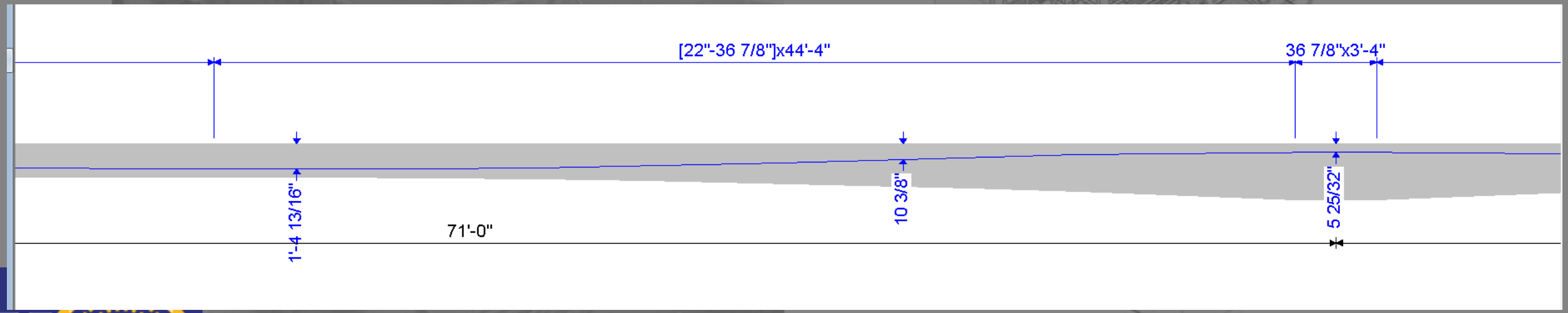
Cross Section Range Properties: Schematic





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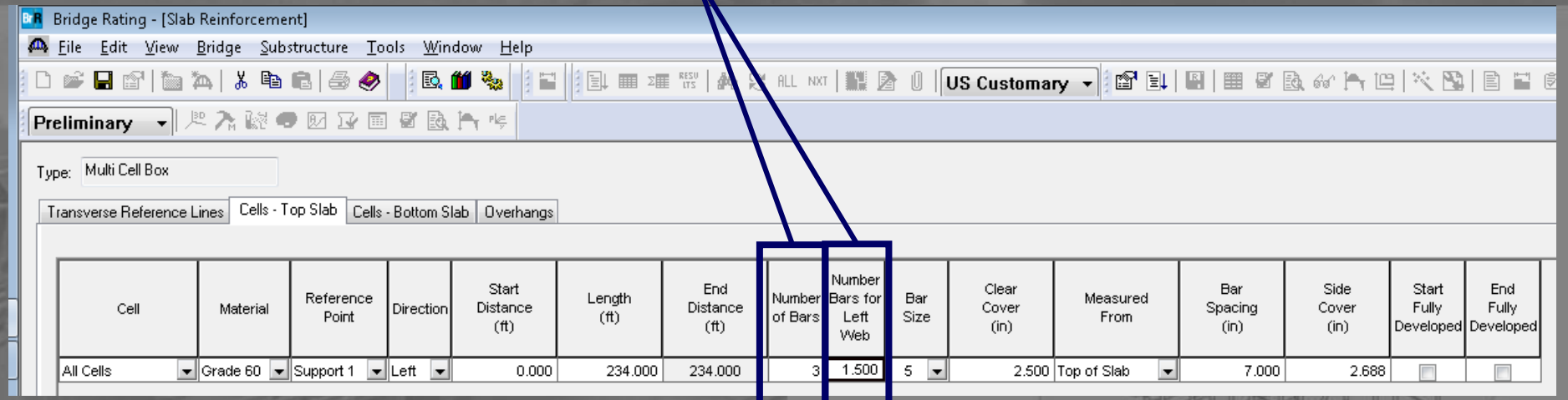
Slab Reinforcement

Enter total # of bars as decimal

Bars Left Web = half total



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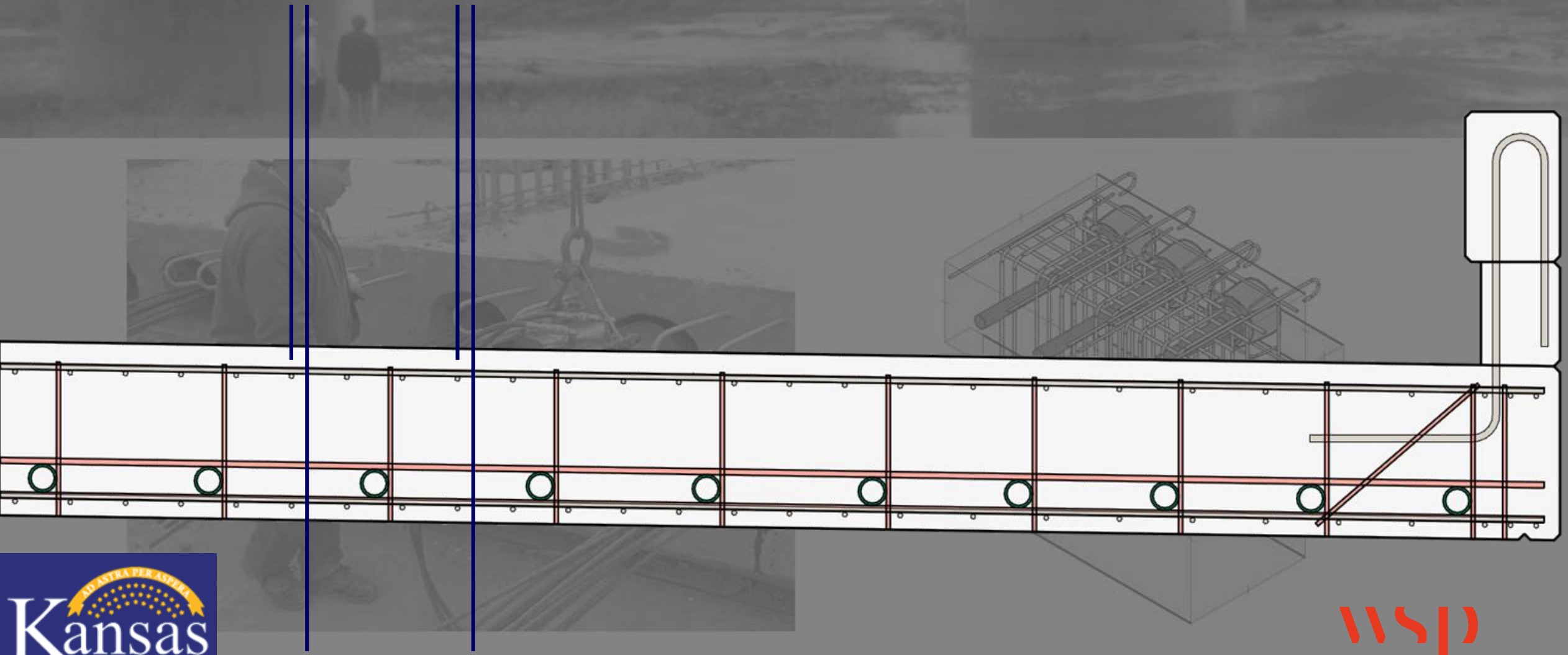
Slab Reinforcement



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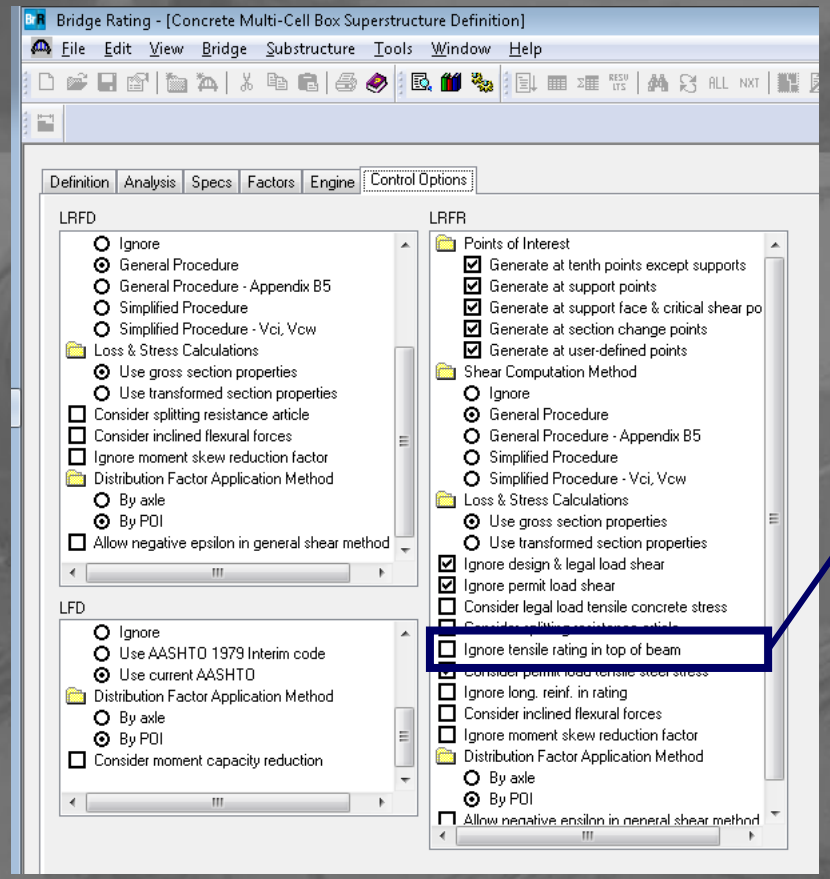
Superstructure Definition



KDOT ignores tensile rating in top of beam for P/S

Different for XCSH

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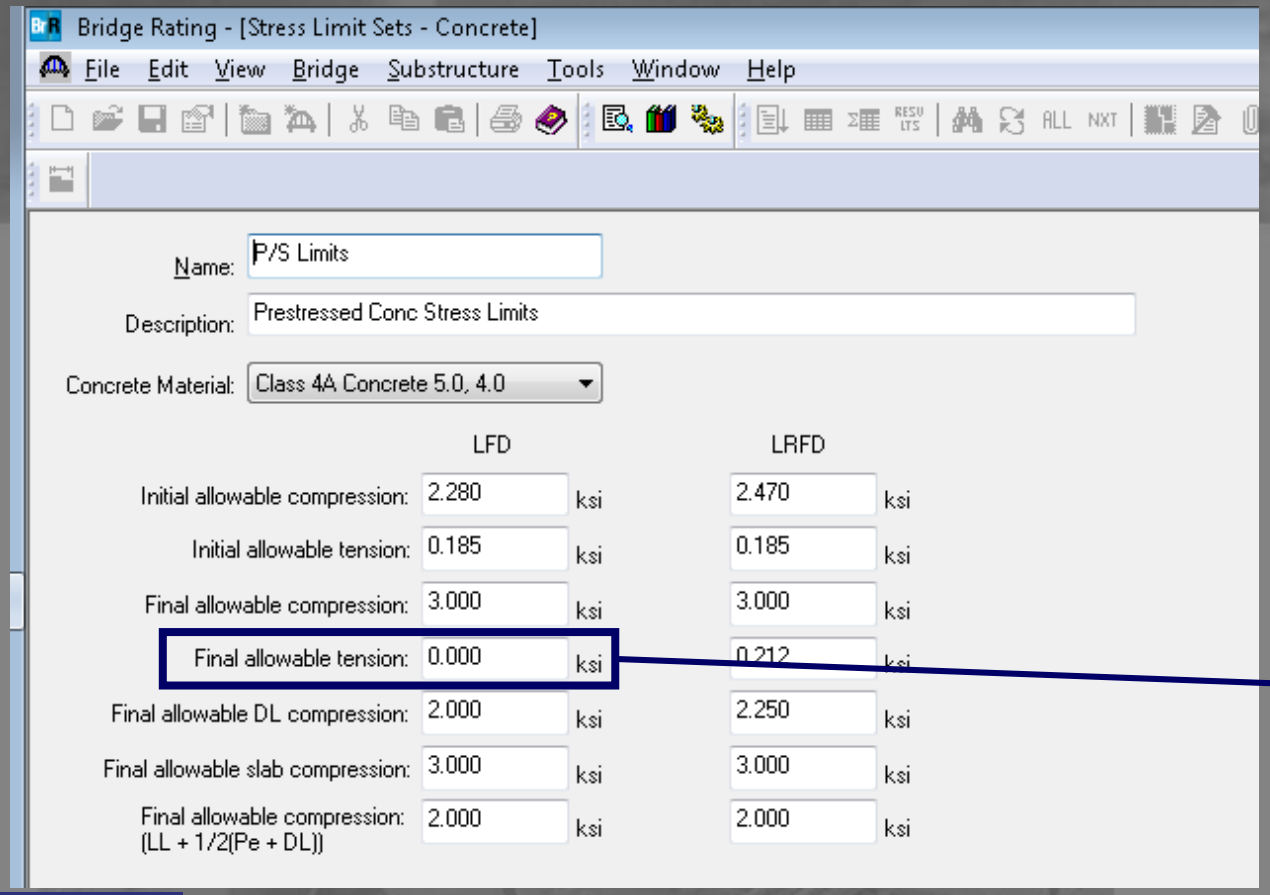
P/S Limits



Can't enter one value for INV and one for OPER; conservatively used 0 for both

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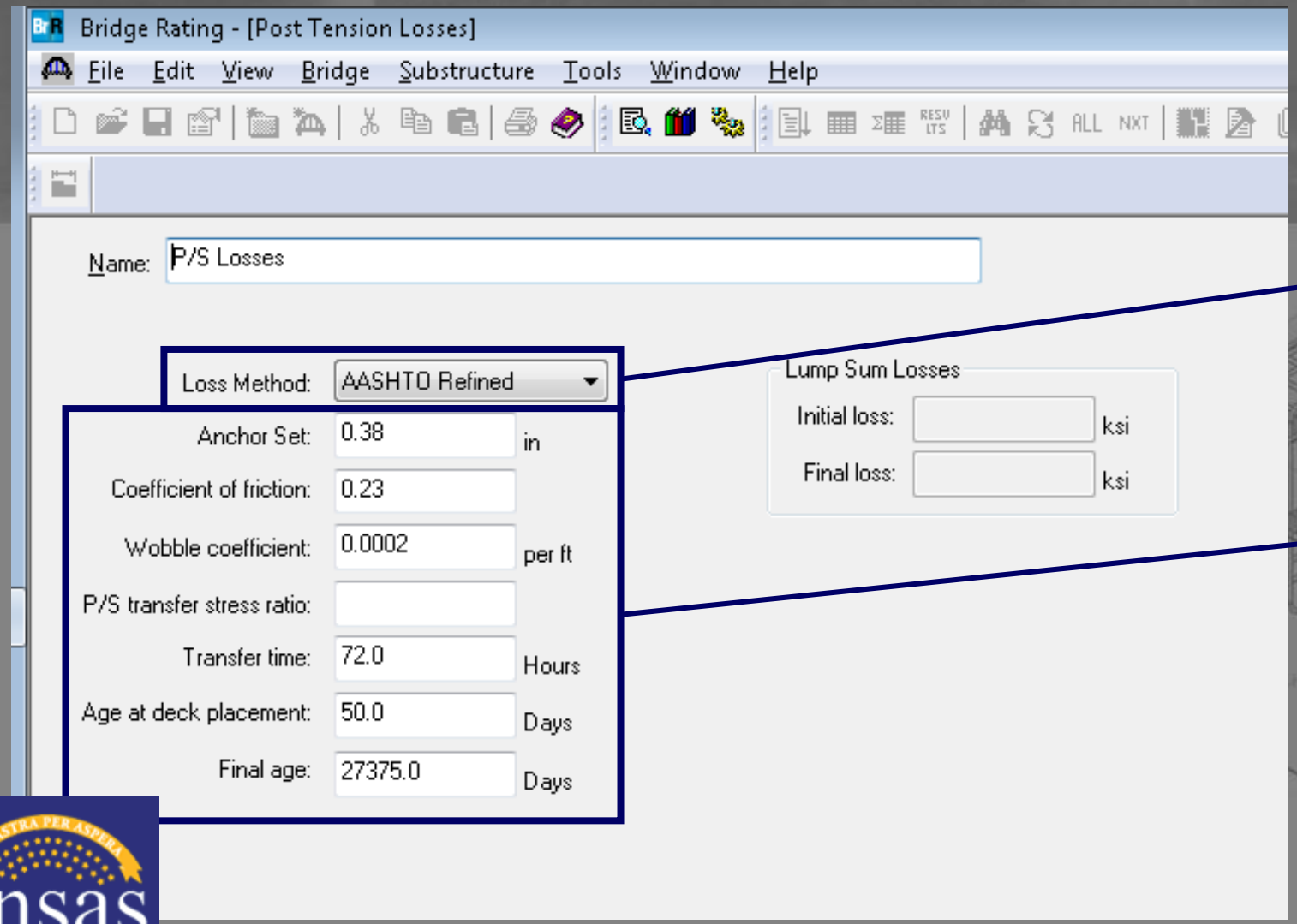
P/S Losses



Approximate is not an option; use "AASHTO Refined"

Values from plans

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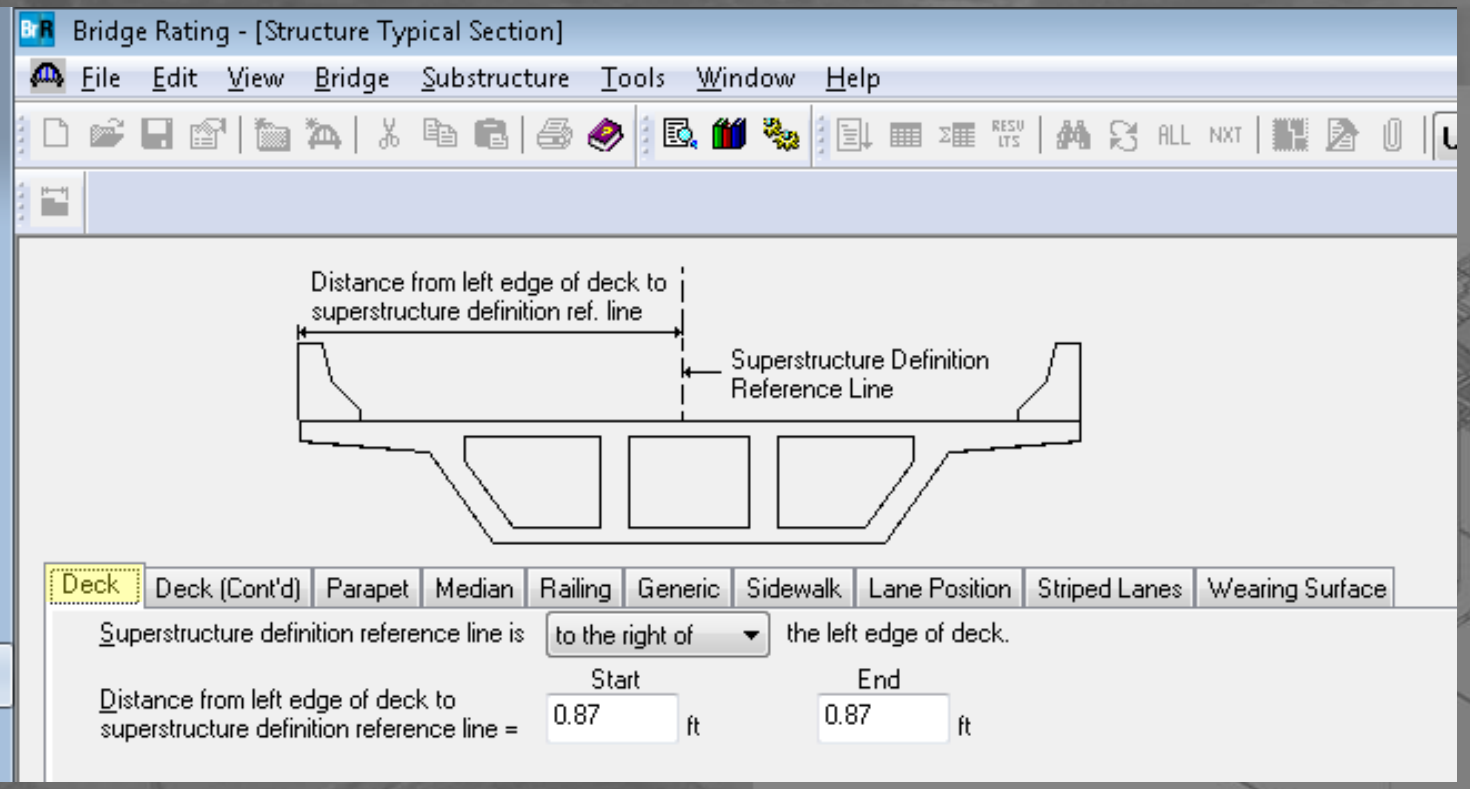
Structure Typical Section

- Deck



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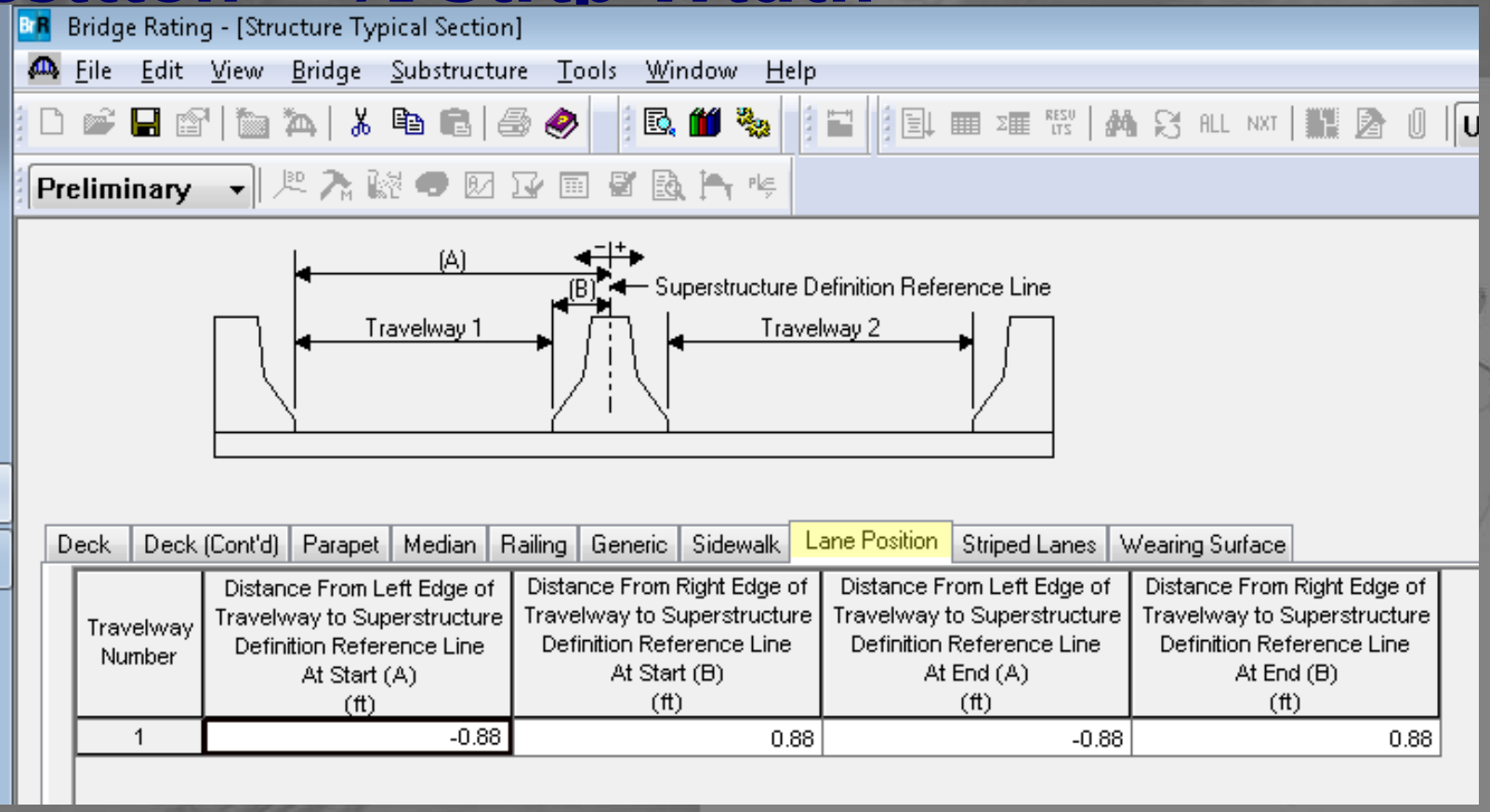
Structure Typical Section

- Lane Position = ½ Strip Width



Travelway Number	Distance From Left Edge of Travelway to Superstructure Definition Reference Line At Start (A) (ft)	Distance From Right Edge of Travelway to Superstructure Definition Reference Line At Start (B) (ft)	Distance From Left Edge of Travelway to Superstructure Definition Reference Line At End (A) (ft)	Distance From Right Edge of Travelway to Superstructure Definition Reference Line At End (B) (ft)
1	-0.88	0.88	-0.88	0.88

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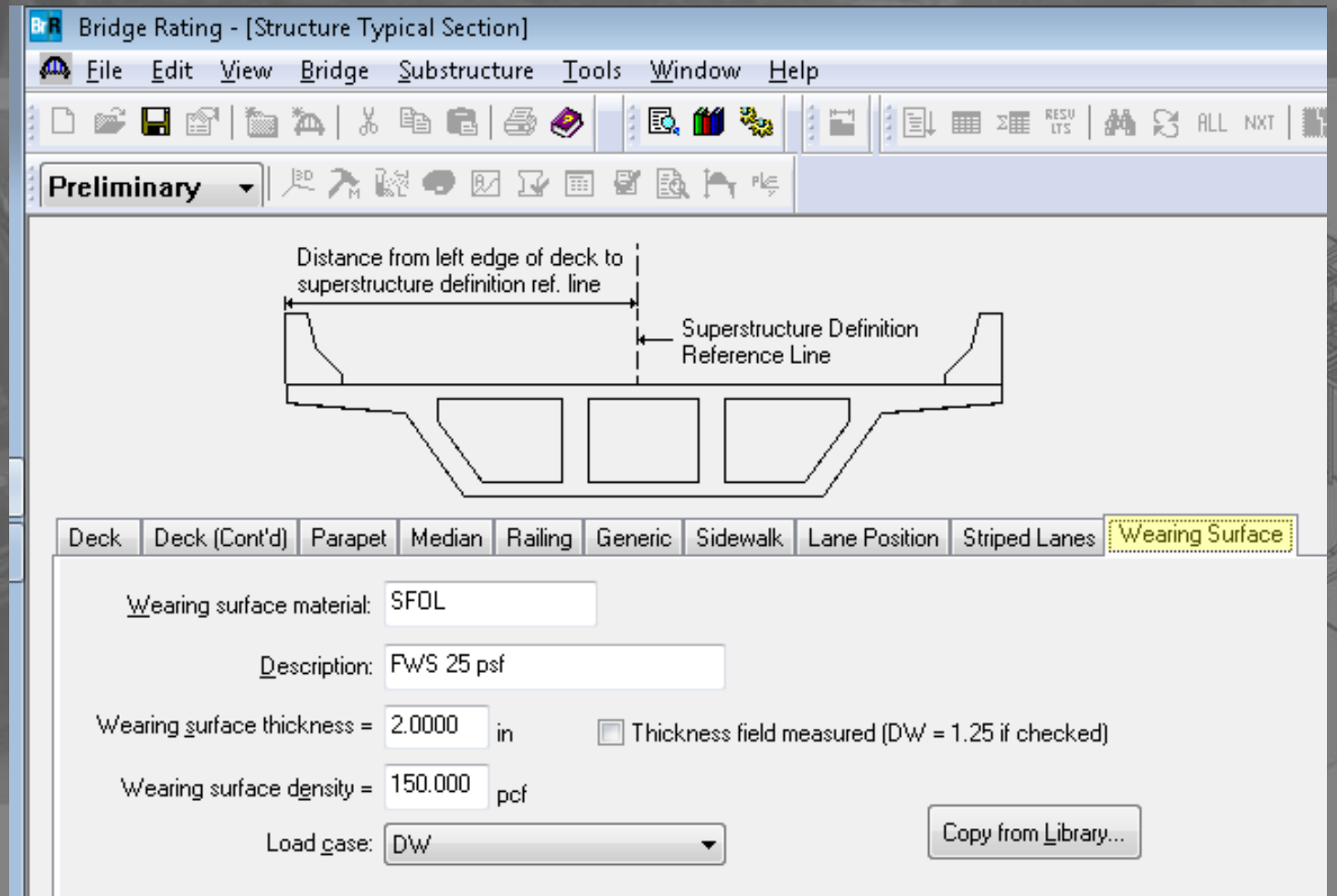
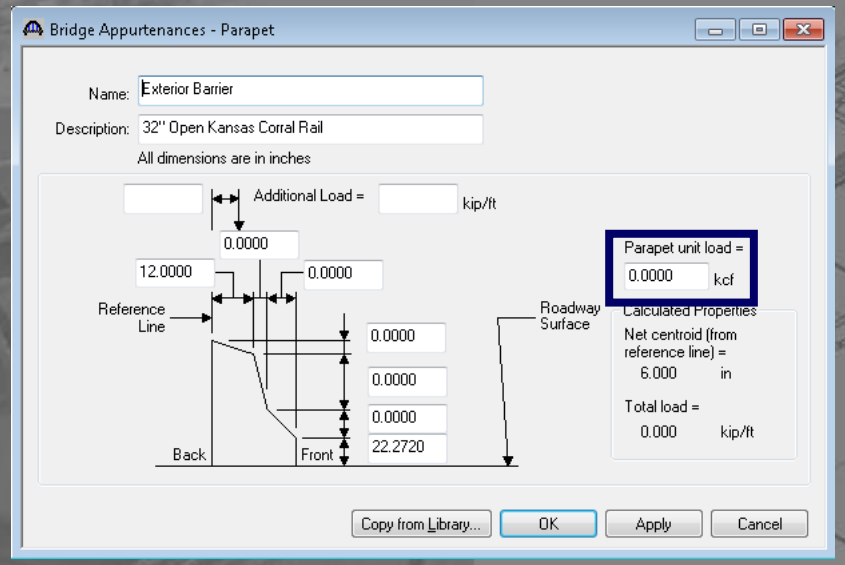
Structure Typical Section

- FWS



Rail Definition

- Define weightless barrier



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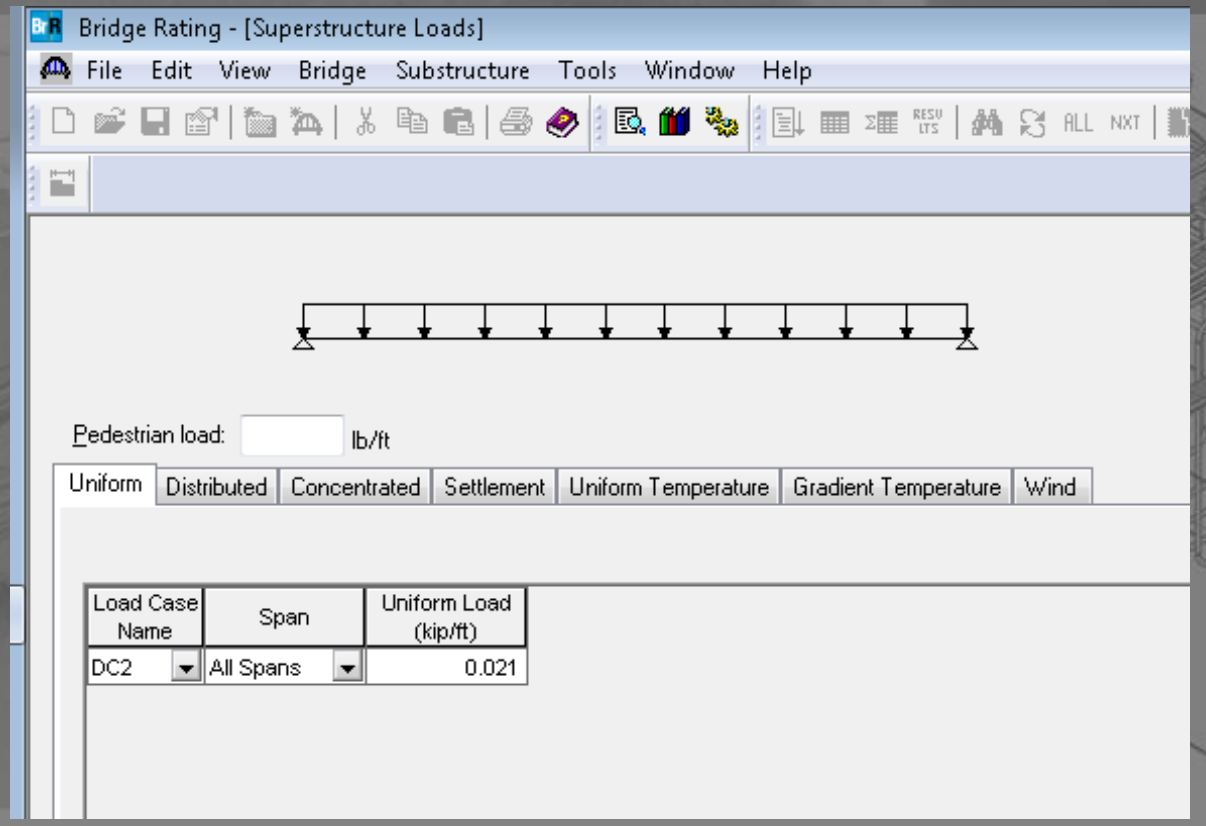
Superstructure Loads

- Barrier, proportioned to strip width



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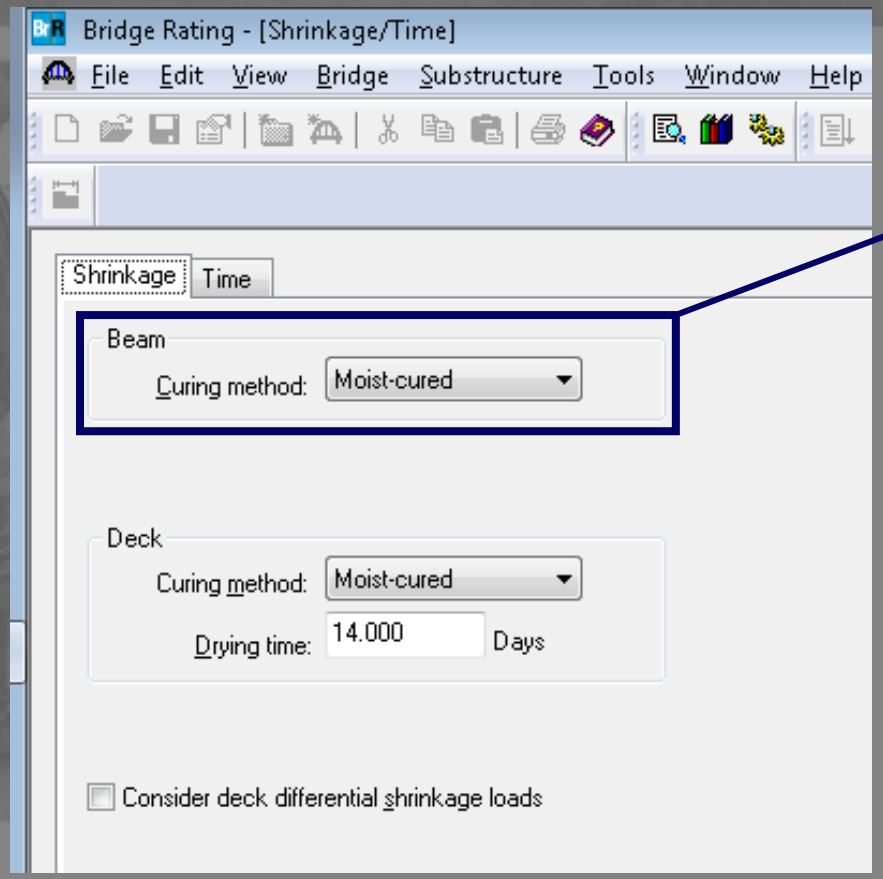
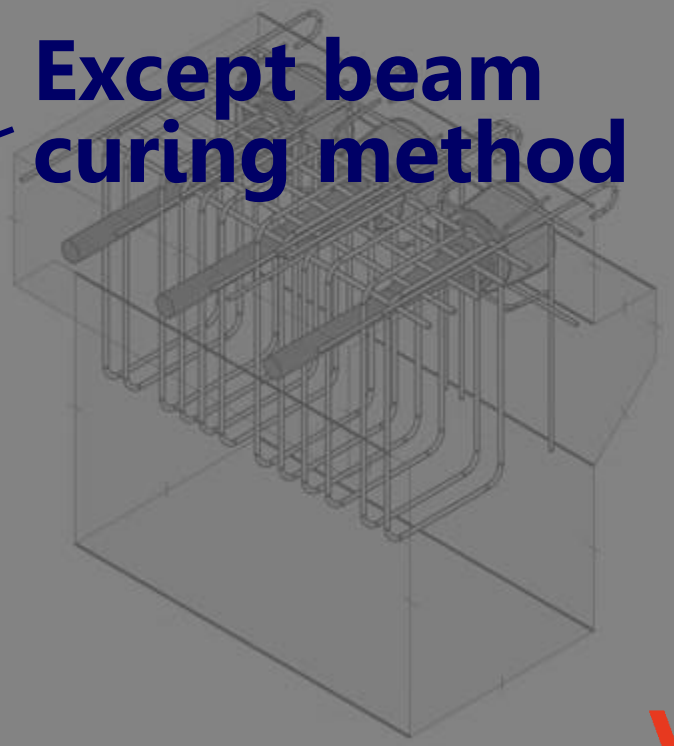
Shrinkage/Time

- Values as per KDOT



Except beam curing method



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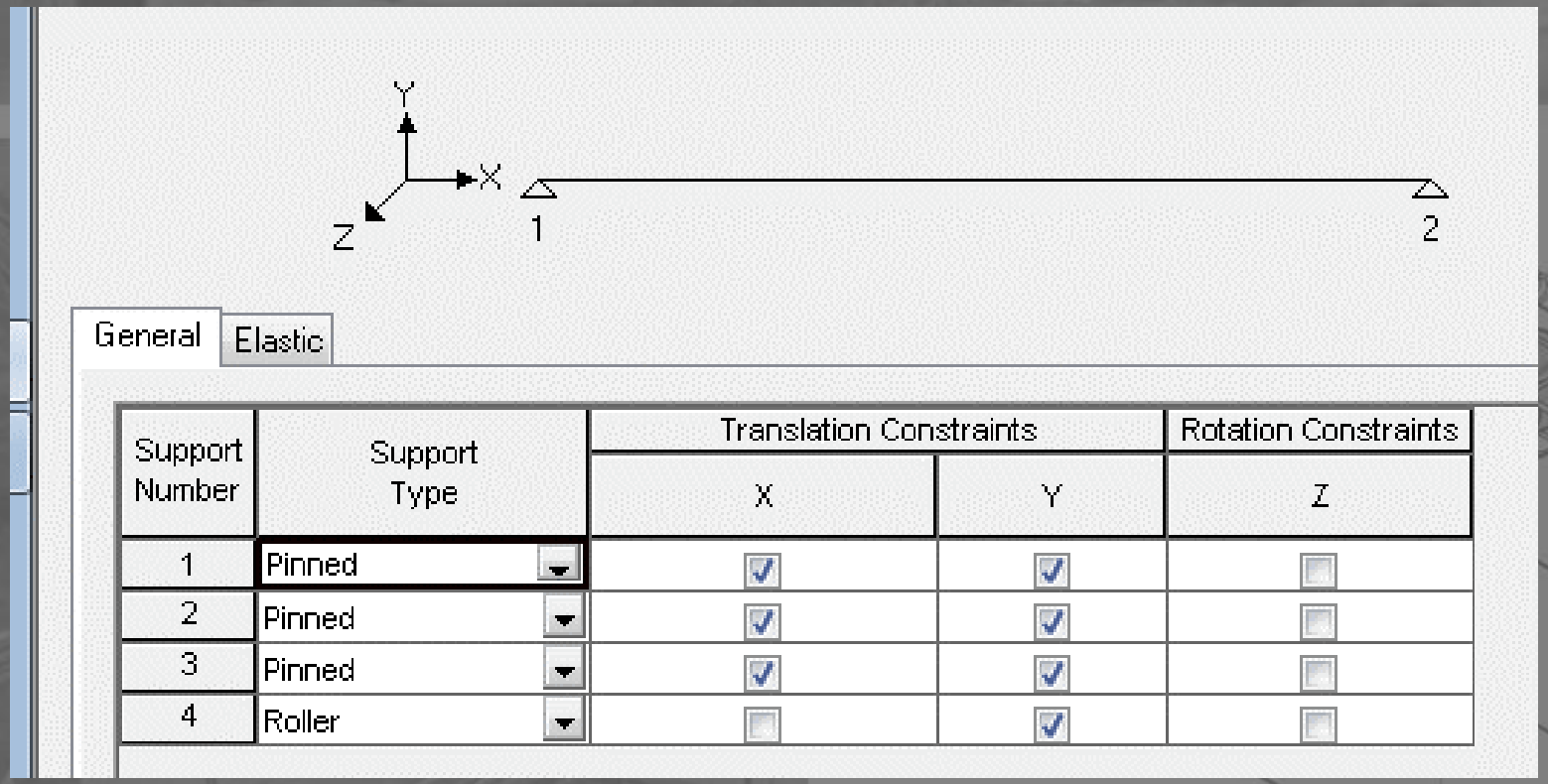
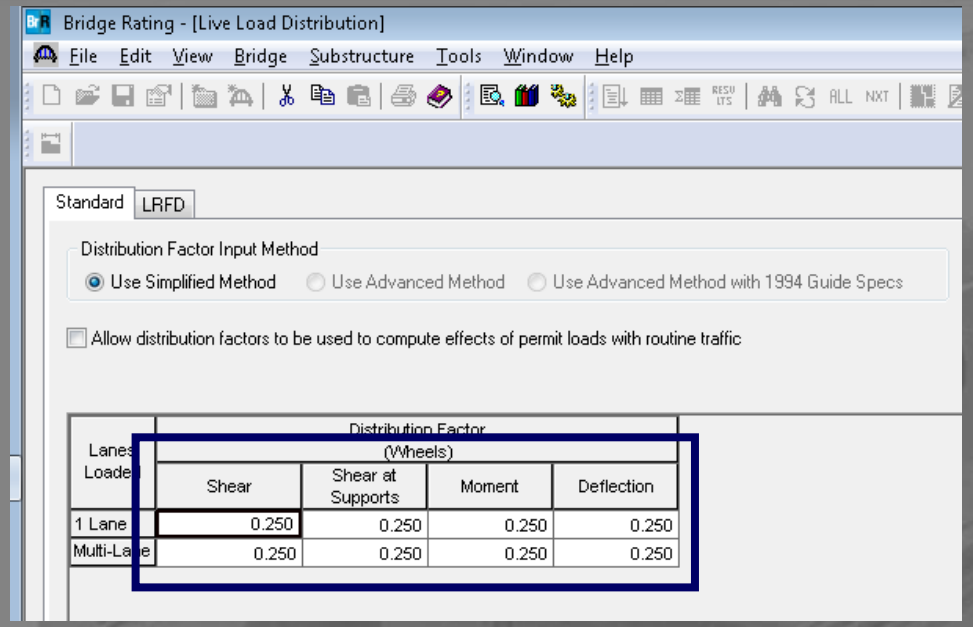
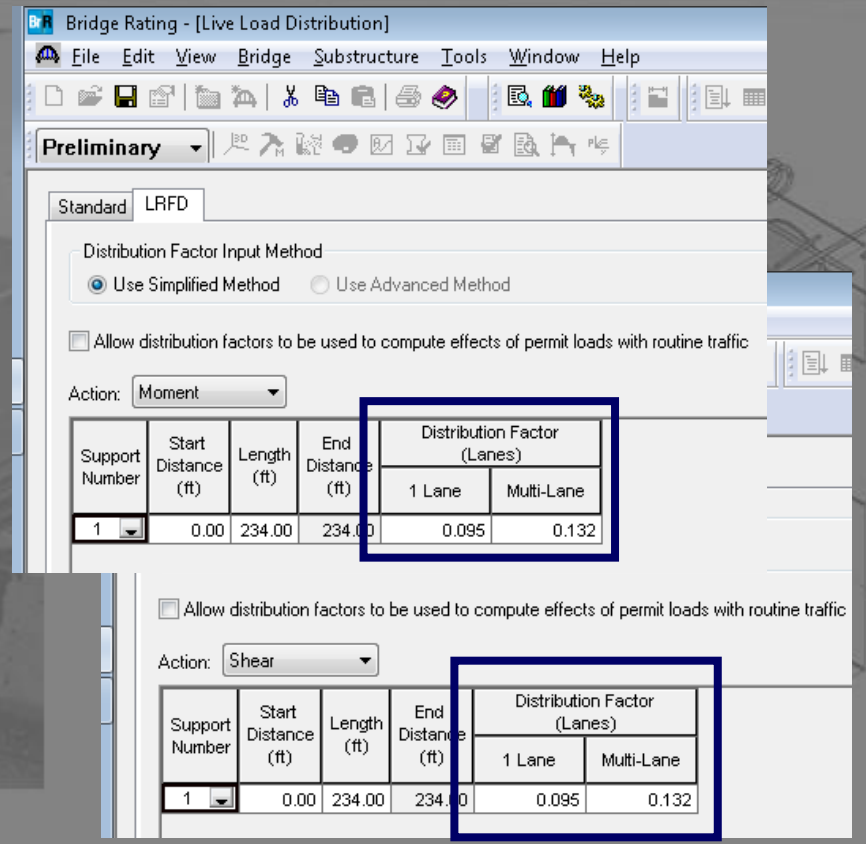
Supports


Y
X
Z
1
2
General
Elastic
Support Number
Support Type
Translation Constraints
X
Y
Rotation Constraints
Z
1
Pinned
2
Pinned
3
Pinned
4
Roller

Live Load Distribution

- Hand calculate LLDF based on modeled width





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Load Rating Results

RATING SUMMARY - LFR						
	INVENTORY RATING FACTOR			OPERATING RATING FACTOR		
TRUCK	D Spans	C Spans	B Spans	D Spans	C Spans	B Spans
H-20	1.84	1.68	1.81	2.89	3.04	3.295
Type 3	1.68	1.77	1.76	2.80	3.00	2.944
HS-20	1.32	1.44	1.43	1.98	2.13	2.103
Type 3S2	1.38	1.47	1.55	2.23	2.45	2.507
Type 3-3	1.36	1.46	1.83	2.21	2.43	2.542
Type T130	1.56	1.75	1.63	2.14	2.34	2.654
Type T170	1.73	1.68	1.66	2.32	2.65	3.116
HET				1.17	1.28	1.27
SU4	1.53	1.50	1.61	2.56	2.74	2.684
SU5	1.39	1.42	1.52	2.27	2.43	2.387
SU6	1.36	1.30	1.38	2.07	2.24	2.207
SU7	1.30	1.25	1.29	1.91	2.07	2.06
Type EV2				2.40	2.57	2.517
Type EV3				1.62	1.73	1.696

RATING SUMMARY - LRFR						
	INVENTORY RATING FACTOR			OPERATING RATING FACTOR		
TRUCK	D Spans	C Spans	B Spans	D Spans	C Spans	B Spans
AASHTO HL-93	1.31	1.56	1.65	3.48	3.63	3.274

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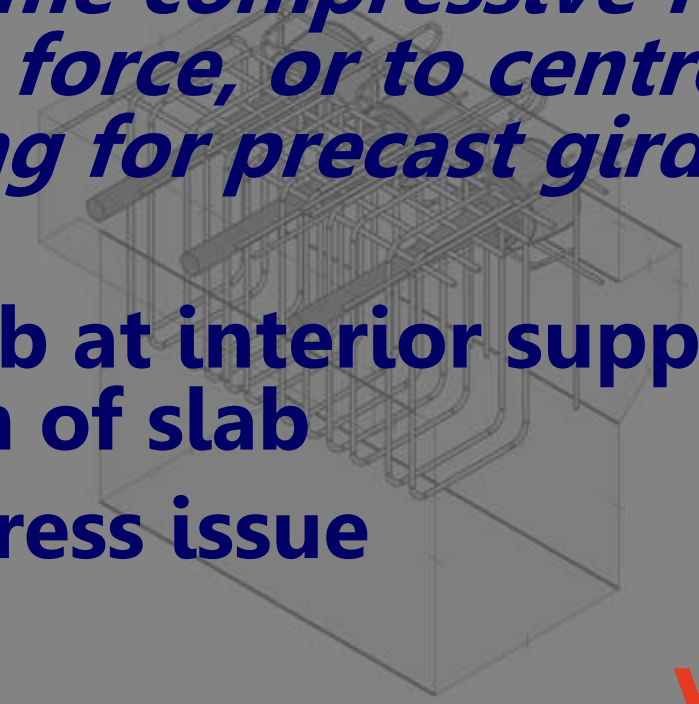
Future Software Update

- Shear controls some of the LR's, unexpected for a slab bridge
- "d" is the "*distance from extreme compressive fiber to centroid of the prestressing force, or to centroid of negative moment reinforcing for precast girder bridges made continuous.*"
- V_{ci} calculated *d* from top of slab at interior support; should have been from bottom of slab
- BRDRSUP-1248 created to address issue



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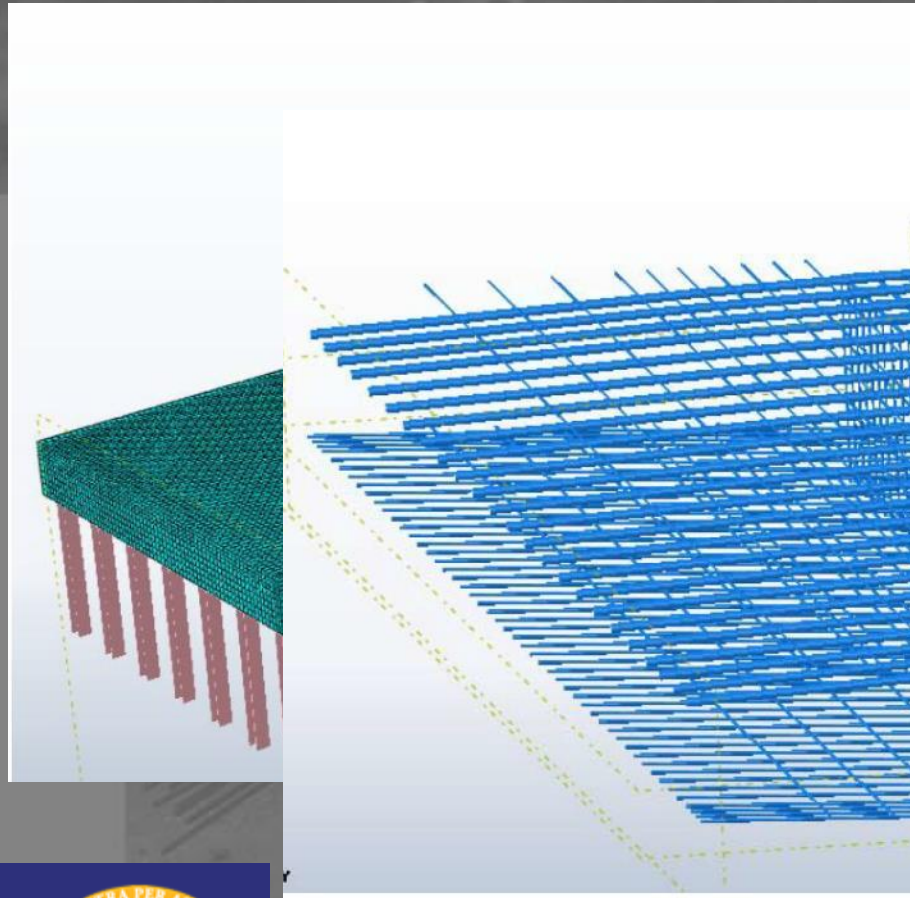
Verification of Results



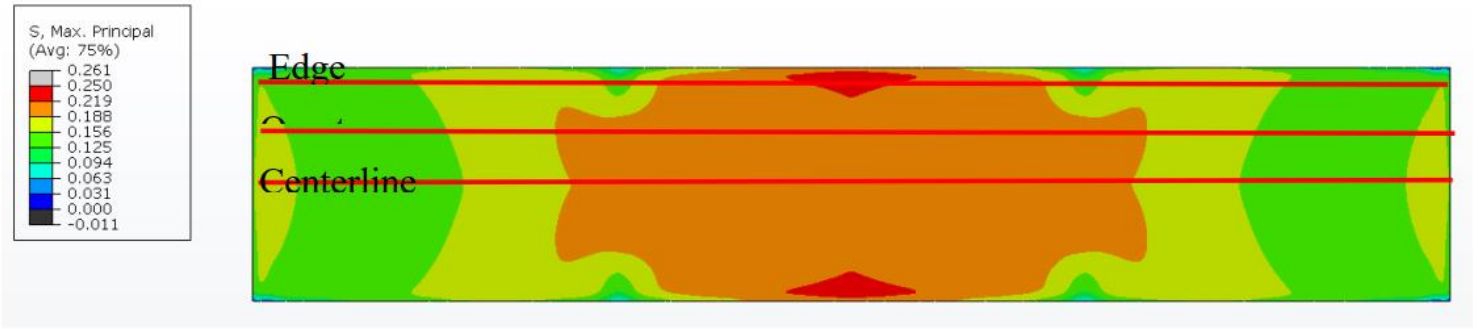


Figure 22: Maps of Principal Tension at the Top of the Deck due to Negative Temperature Gradient

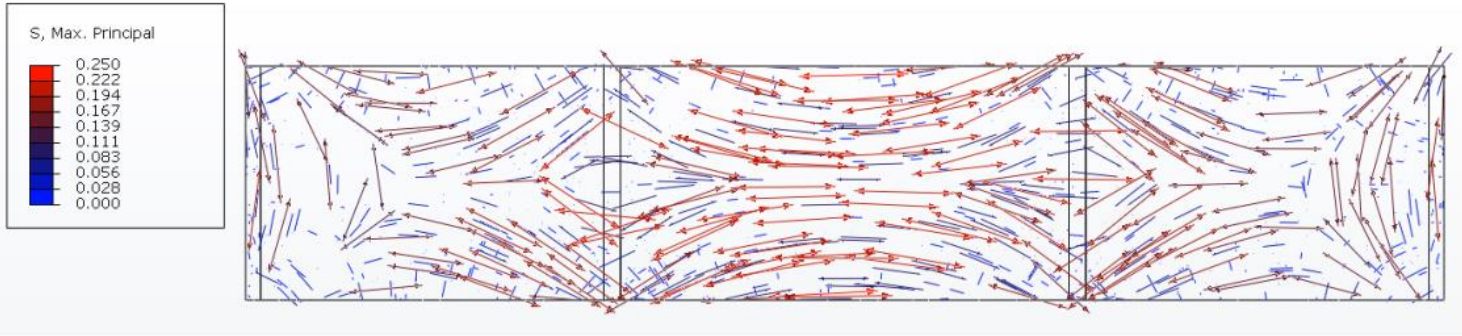


Figure 23: Directions of Principal Tension due to Negative Temperature Gradient

Figure 16: Rendering of the Reinforcement at the Pier Location

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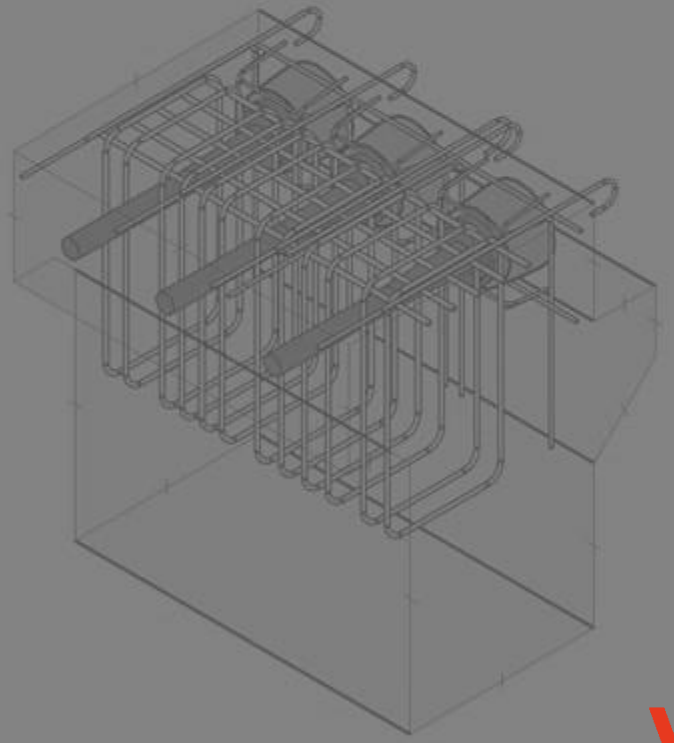
Why XCSH?

- Shallow superstructure, longer spans
- Cost Effective
- Durability

Challenges

- Side Pockets



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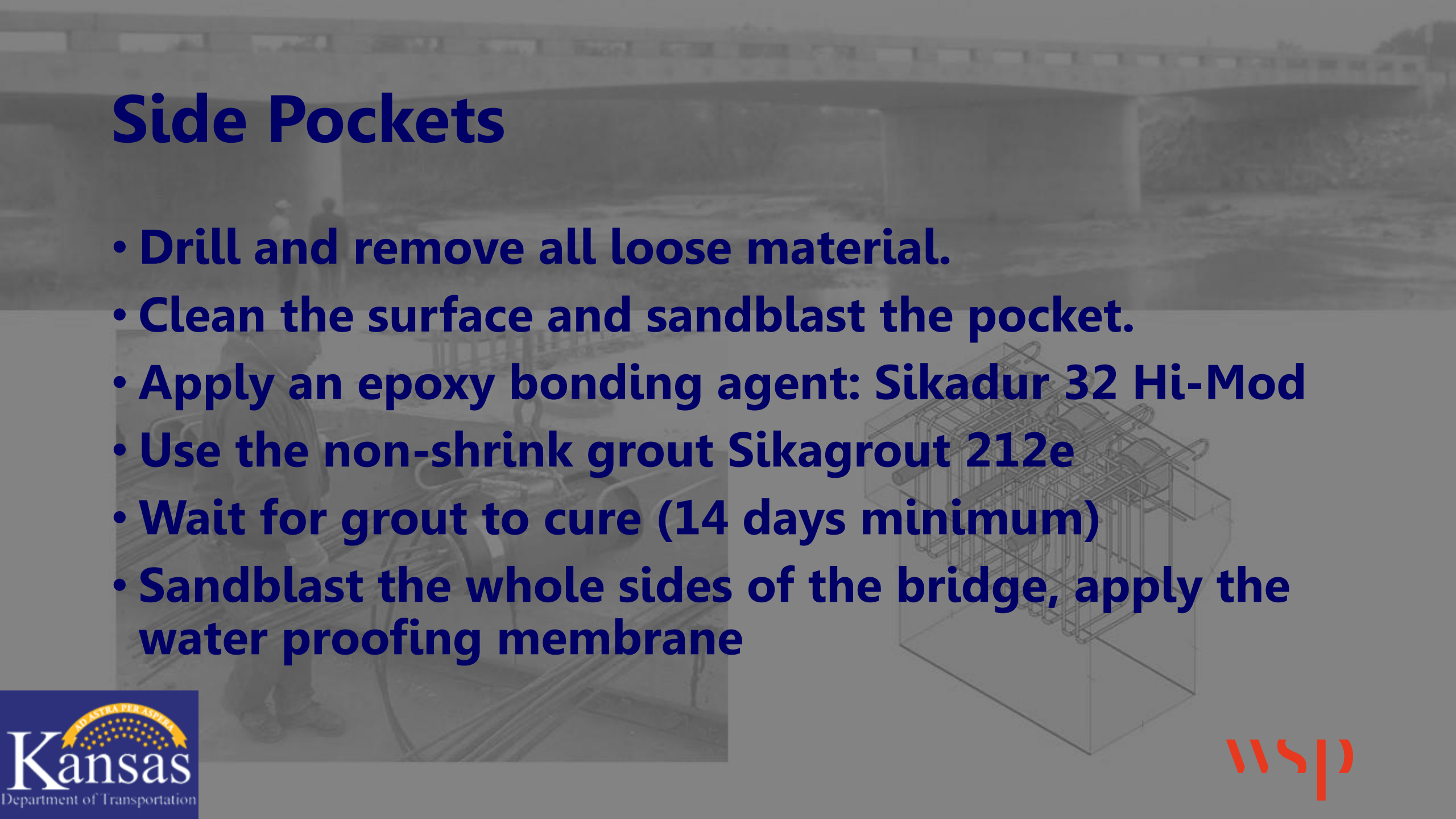
Side Pockets

- Drill and remove all loose material.
- Clean the surface and sandblast the pocket.
- Apply an epoxy bonding agent: Sikadur 32 Hi-Mod
- Use the non-shrink grout Sikagrout 212e
- Wait for grout to cure (14 days minimum)
- Sandblast the whole sides of the bridge, apply the water proofing membrane



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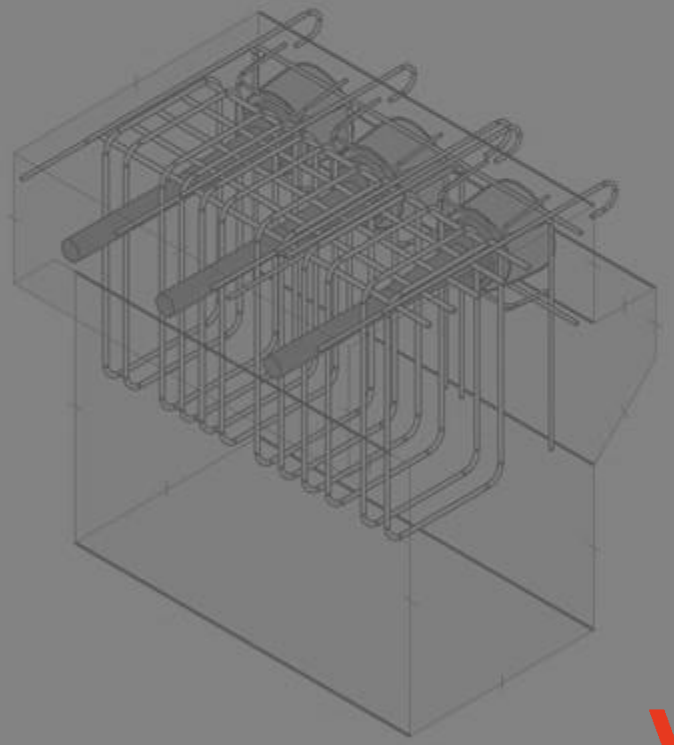
Special Thanks

- Mark Hoppe, P.E., KDOT
- John Jones, P.E., KDOT
- Dean Teal, P.E., KDOT



Questions?