AASHTO Design and Material Specification Changes

LRFD BDS Section 6, Various Articles

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NSBA

Bolts

ASTM Specifications High Strength Bolts

- New Specification Combines 4 Specifications into 1 for both buildings and bridges-F3125
  - A325 Standard Hex Bolt
  - F1852 (A325 Tension Control)
  - A490 Standard Hex Bolt
  - F2280 (A490 Tension Control)
  - + Metric
- The old names become Grades

F3125 Significant Changes

- Grade A325- F_u = 120 ksi for all diameters (results in an increase in shear capacity for bolts >= 1 in.)
- Annex A1- Table gives permitted coatings and over tapping required for nuts
  - No hot dip or mechanical galvanizing of Grade A490 bolts
  - F1136 and F2833 Zinc/Aluminum Allowed on **<u>all</u>** Grades A325 and A490
- Rotational Capacity Test in Appendix A2
  - Reduced requirements for A490 bolts
  - *Recommend Specifying Lubricated Nuts for Black A490 Bolts*

AASHTO LRFD Changes

- Bolt Shear Strength
- Slip Critical Categories
- Standard Hole Sizes
- Girder Field Splice Design

Shear Strength
6.13.2.7

- Initial Length Reduction
  - Changed from 0.8 to 0.9
  - Long Joint from 50 to 38 in.
- Bolts with threads in the shear plane: (web bolts)
  - $R_n = \emptyset 0.45\, A_b F_u$ *(old value 0.38)*
- Bolts with threads excluded from the shear plane:
  - $R_n = \emptyset 0.56\, A_b F_u$ *(old value 0.48)*
- The nominal shear resistance of a bolt in <u>lap tension connections</u> greater than 38 in. in length shall be taken as 0.83 times the values above (0.9x0.83=0.75).

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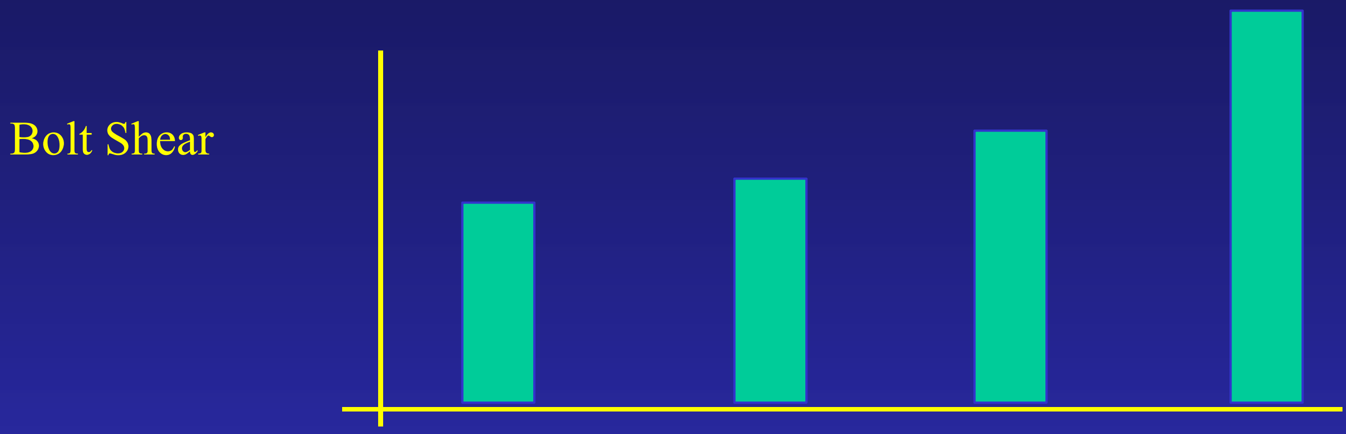
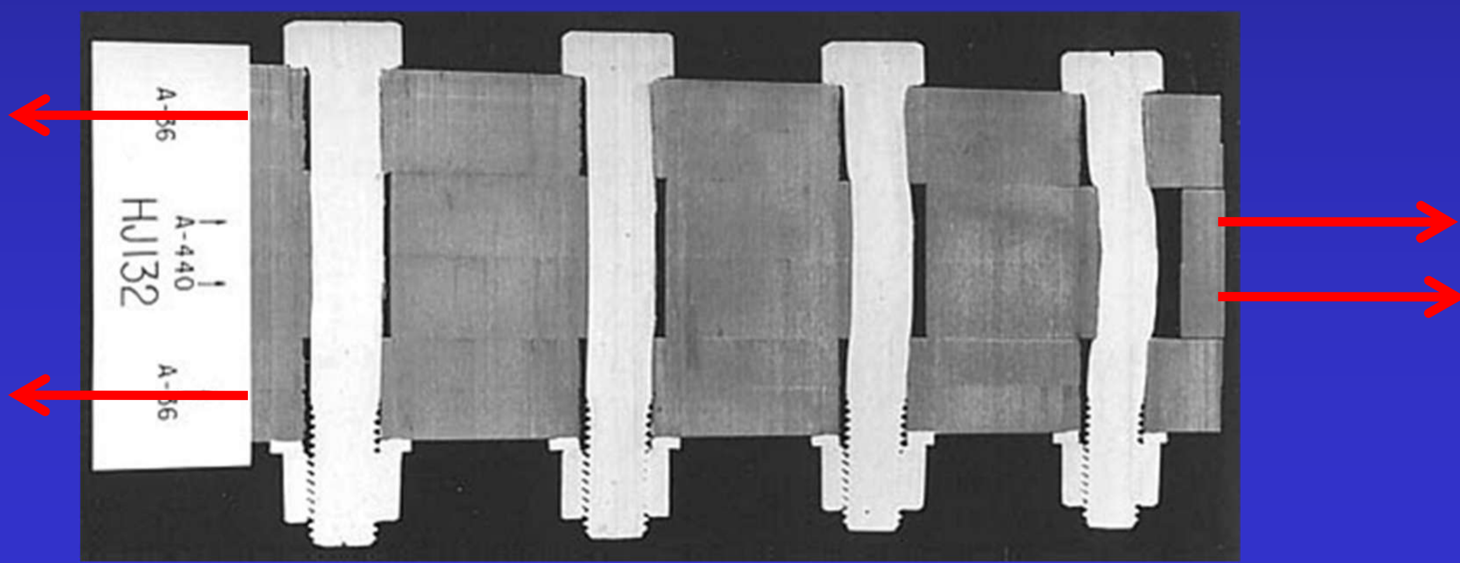
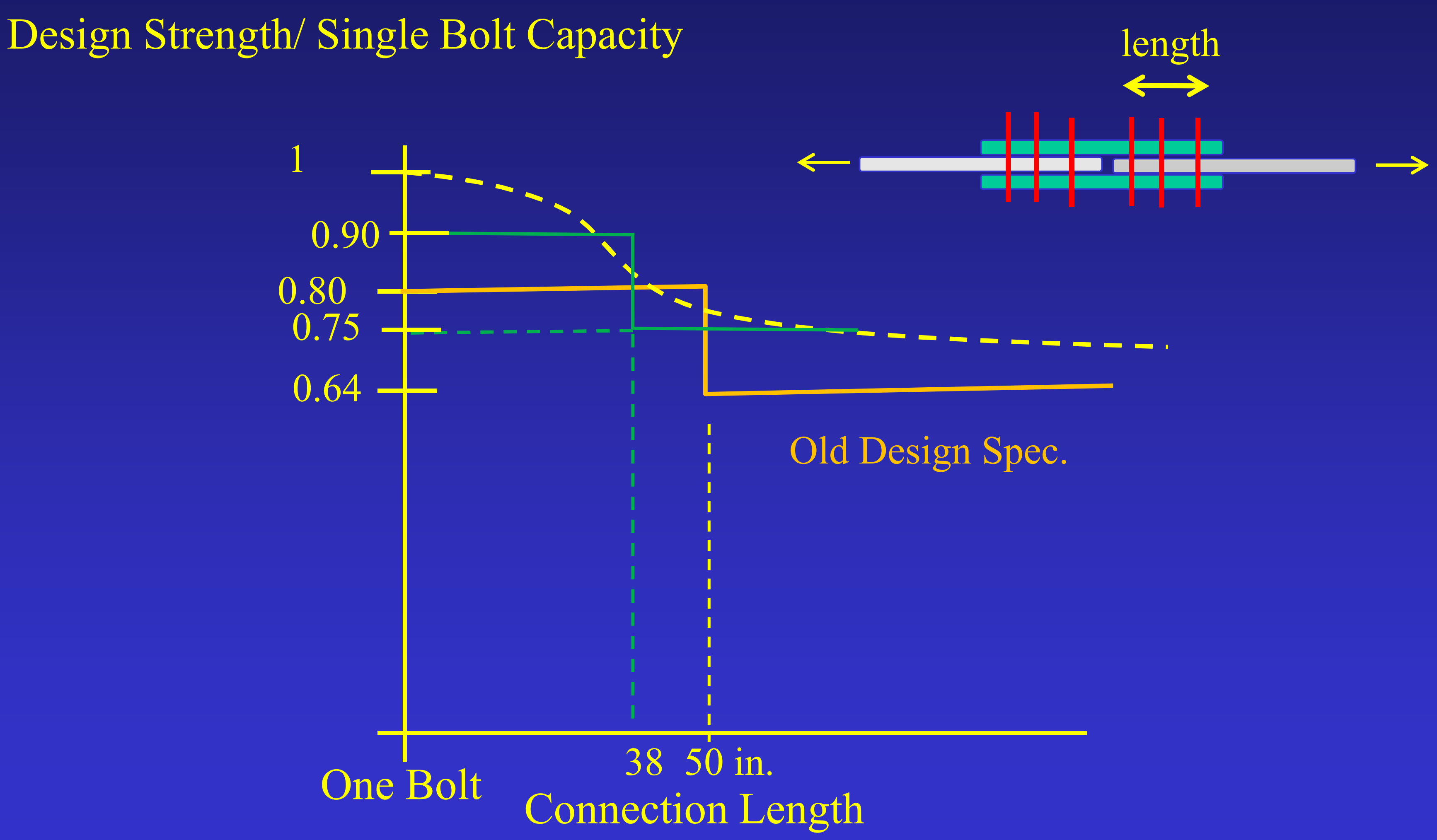
Unequal Bolt Shear In Long Joints





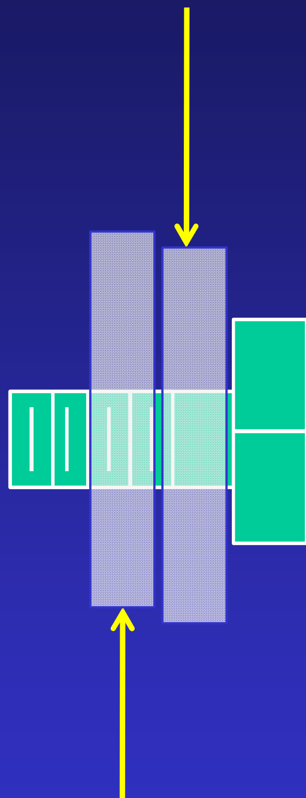
Joint Length Shear Strength Reductions

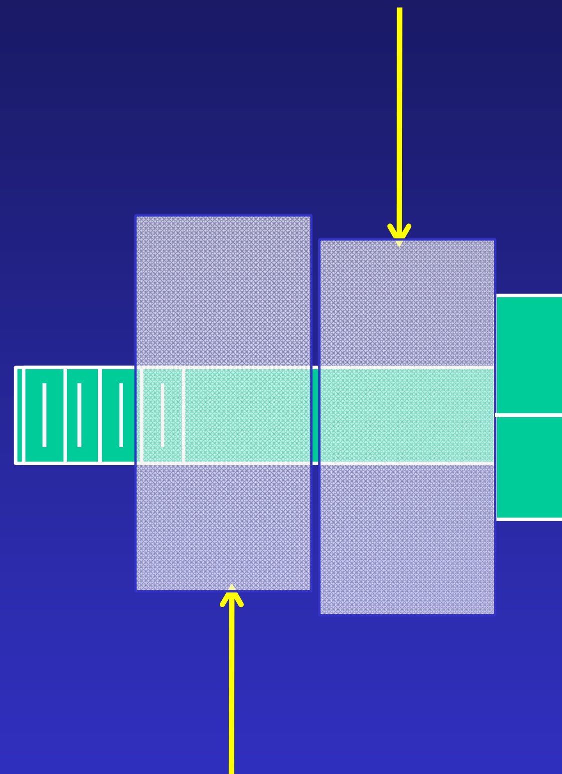


Bolt Shear Strength

Connection Length <= 38 in.

Threads Not
Excluded from
Shear Plane
"N" Bolt





Threads
Excluded from
Shear Plane
"X" Bolt

Shear Strength:
$0.9 \times 0.62 \times F_u \times 0.8\ A_{bolt}$
$0.45 \times F_u \times A_{bolt}$

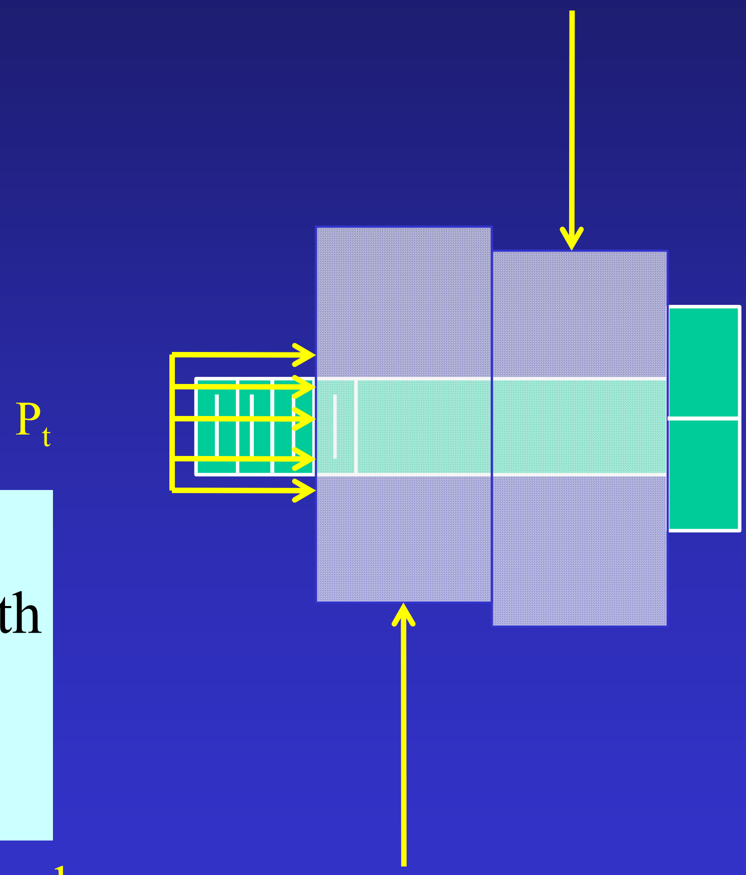
Shear Strength:
$0.9 \times 0.62 \times F_u \times A_{bolt}$
$0.56 \times F_u \times A_{bolt}$

$\Phi_s = 0.80$

Slip Capacity = $R_n = K_h K_s N_s P_t$

Φ_s=1.0 (Art.6.13.2.2)

K_h= Hole Factor
= 1 (normal size holes)
K_s= Surface Condition Slip Coefficient
=0.5(blasted or Zinc Rich)
N_s=Number of Slip Planes per Bolt



Bolt Installed Tension

$P_t = 0.70 \text{ x Tensile Strength}$

$= 0.70 \text{ x } A_{tensile} \text{ x } F_u$

Note Installed Tension Increased for A325 Bolts > 1 in..

AASHTO High Strength Bolt Single Shear Design Capacity

$\phi_{bb}=0.8$ $K_s=0.5$

$\phi_s=0.8$ $K_h=1$

Diameter (in.)	0.625	0.75	0.875	1	1.125	1.25	1.375
A_b (in^2)	0.307	0.442	0.601	0.785	0.994	1.227	1.485
A325 Bolt							
F_{ub} (ksi)	120	120	120	120	120	120	120
F_{ub} A_b (kip)	36.8	53.0	72.2	94.2	119.3	147.3	178.2
P_t (kip)	19	28	39	51	56	71	85
Type	$\phi_s R_n$ (kip)						
A325F	**9.5**	**14.0**	**19.5**	**25.5**	**28.0**	**35.5**	**42.5**
A325N	**13.3**	**19.1**	**26.0**	**33.9**	**42.9**	**53.0**	**64.1**
A325X	**16.5**	**23.8**	**32.3**	**42.2**	**53.4**	**66.0**	**79.8**
A490 Bolt							
F_{ub} (ksi)	150	150	150	150	150	150	150
F_{ub} A_b (kip)	46.0	66.3	90.2	117.8	149.1	184.1	222.7
P_t (kip)	24	35	49	64	80	102	121
Type	$\phi_s R_n$ (kip)						
A490F	**12.0**	**17.5**	**24.5**	**32.0**	**40.0**	**51.0**	**60.5**
A490N	**16.6**	**23.9**	**32.5**	**42.4**	**53.7**	**66.3**	**80.2**
A490X	**20.6**	**29.7**	**40.4**	**52.8**	**66.8**	**82.5**	**99.8**

Slip Critical Connections

Class	Typical Surface	Slip Coefficient	
		Old Specification	New Specification
A	Mill Scale	0.33	0.30
B	Zinc Rich Paint and Blasted	0.50	0.50
C	Galvanized	0.33	0.30*
D	Organic Zinc Rich	-	0.45

*Do not wire brush the surface

Required tension for A325 > 1 in. diameter increased

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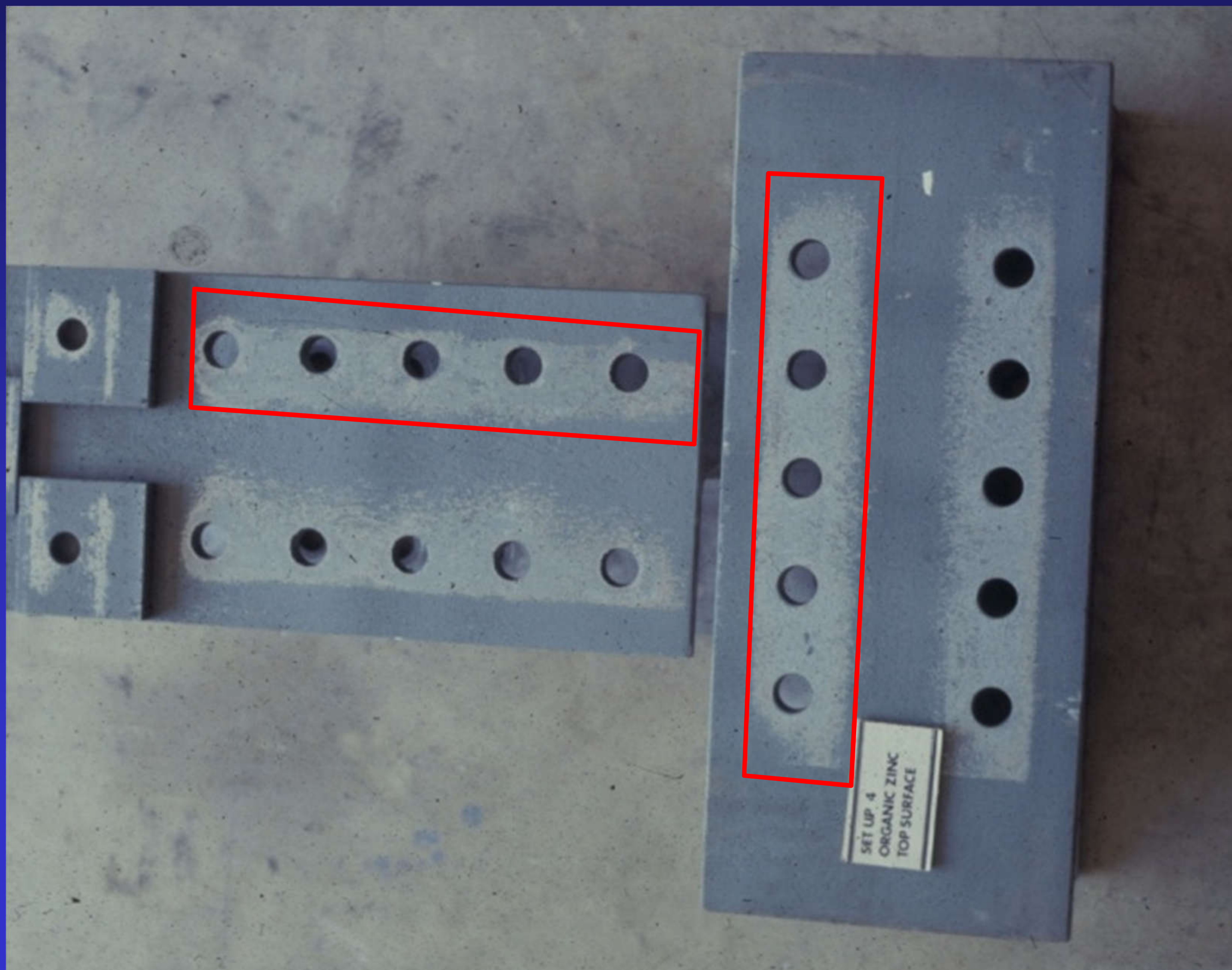
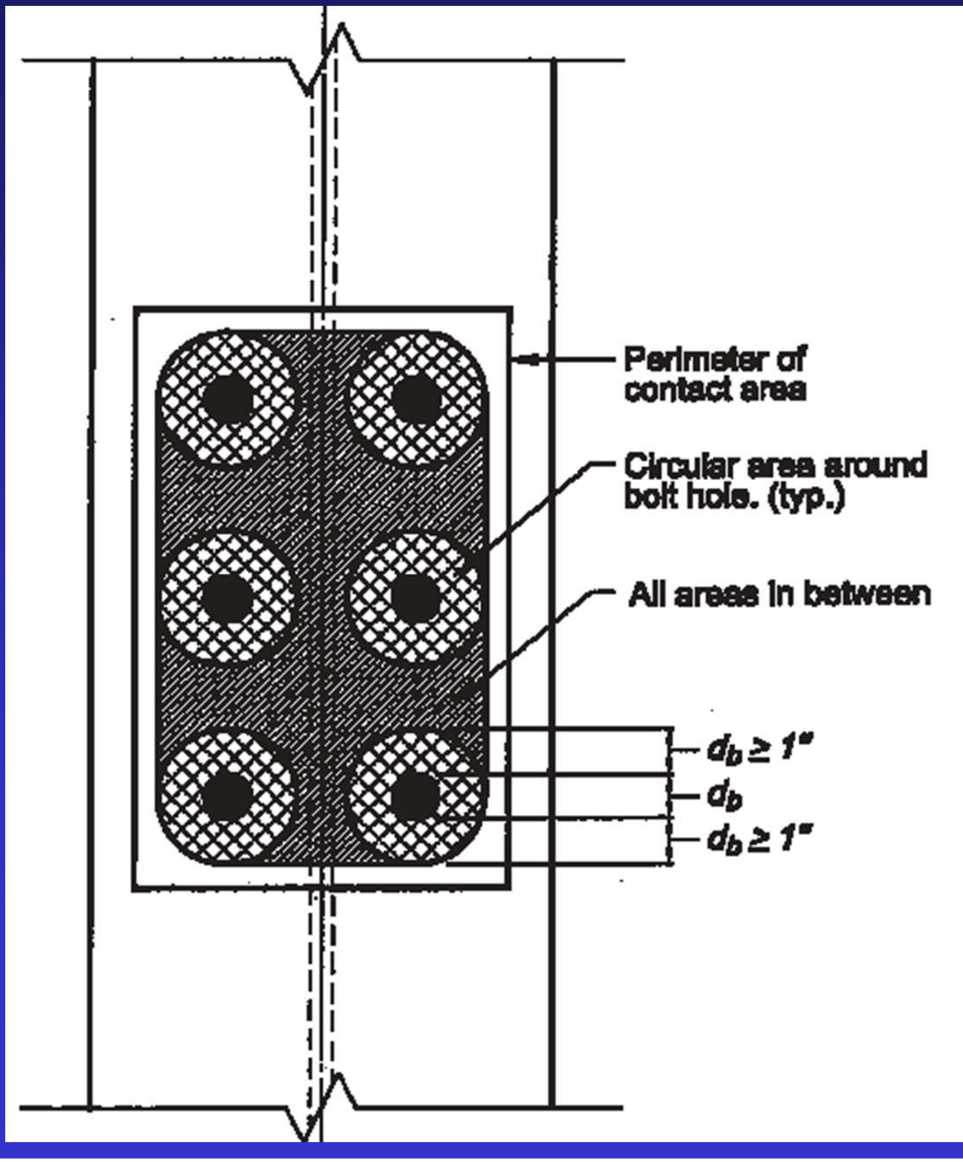
Post Slip Examination of Zinc Rich Paint Specimen



RCSC Fig. C-3.1
Areas for Unqualified Paints



1. Area Outside of Shaded Area may have Unqualified Paints.
2. Edges of Plates Not Participating in Developing Slip Resistance.
3. Therefore Do Not Have to Be in Contact.

Footnote on Bolting

- New Hole Size
  - 1 inch and greater: Standard hole = diameter of fastener +1/8 in.
- Miss drilled holes- fill with fully tensioned high strength bolt (Category B fatigue strength)
- New electric wrenches can be programmed for required turn of the nut

New Connection Design Criteria and Methods

- Remove applicability of the 75 percent and average rules in Article 6.13.1 to the design of bolted and welded splices for flexural members.
- 75 percent rules are applicable to connections and splices for primary members subject to axial tension or compression only.
- Clarify application of rules to primary members subjected to force effects acting in multiple directions due to combined loading.

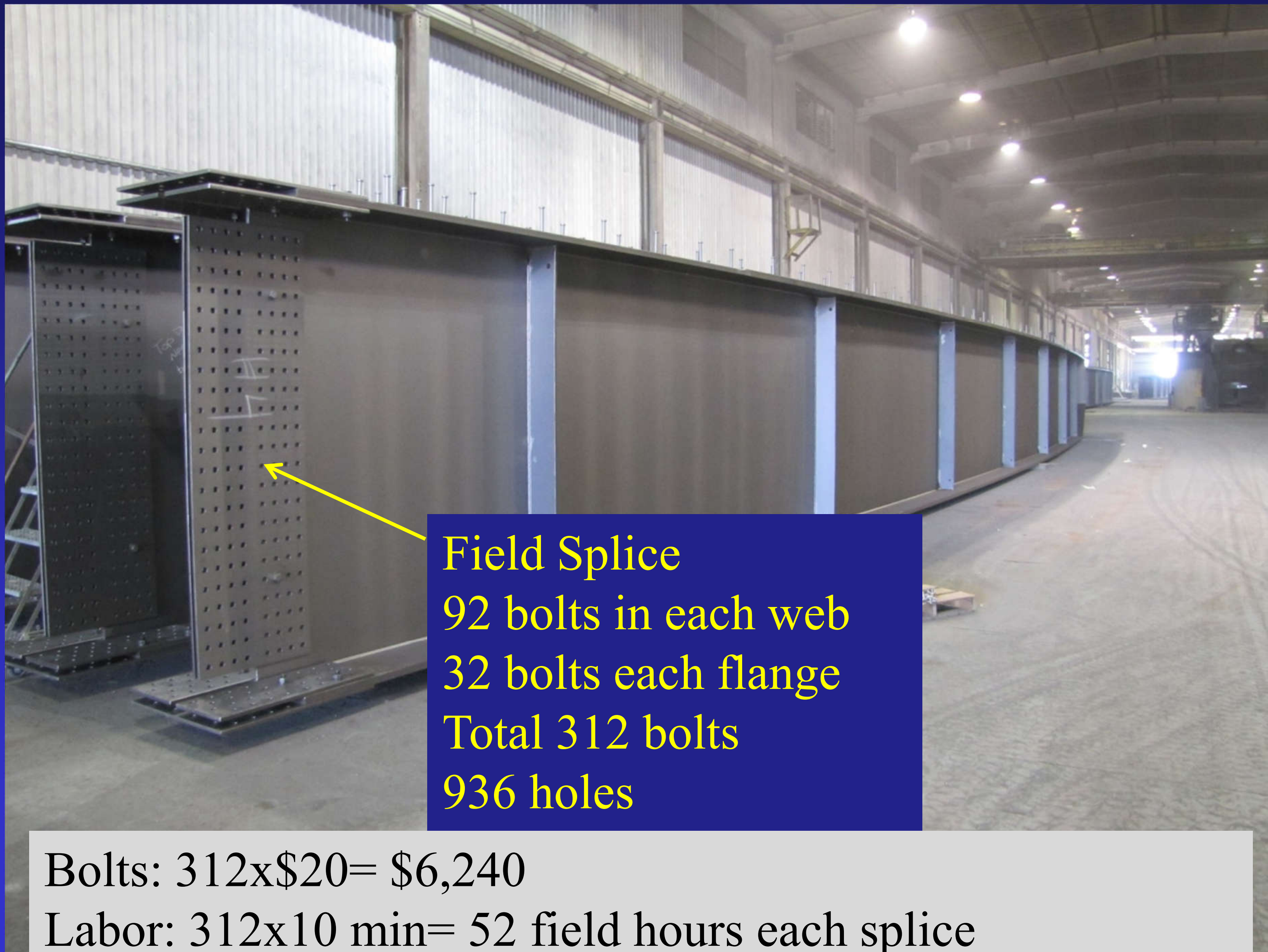
Bolted Field Splices of Flexural Members

- Revised general article on design of bolted splices for flexural members implementing new simplified bolted splice design procedure

- Removal of check for slip of bolts during erection of steel

- **The purpose is implementation of simplified design procedure and more economical field splice designs.**

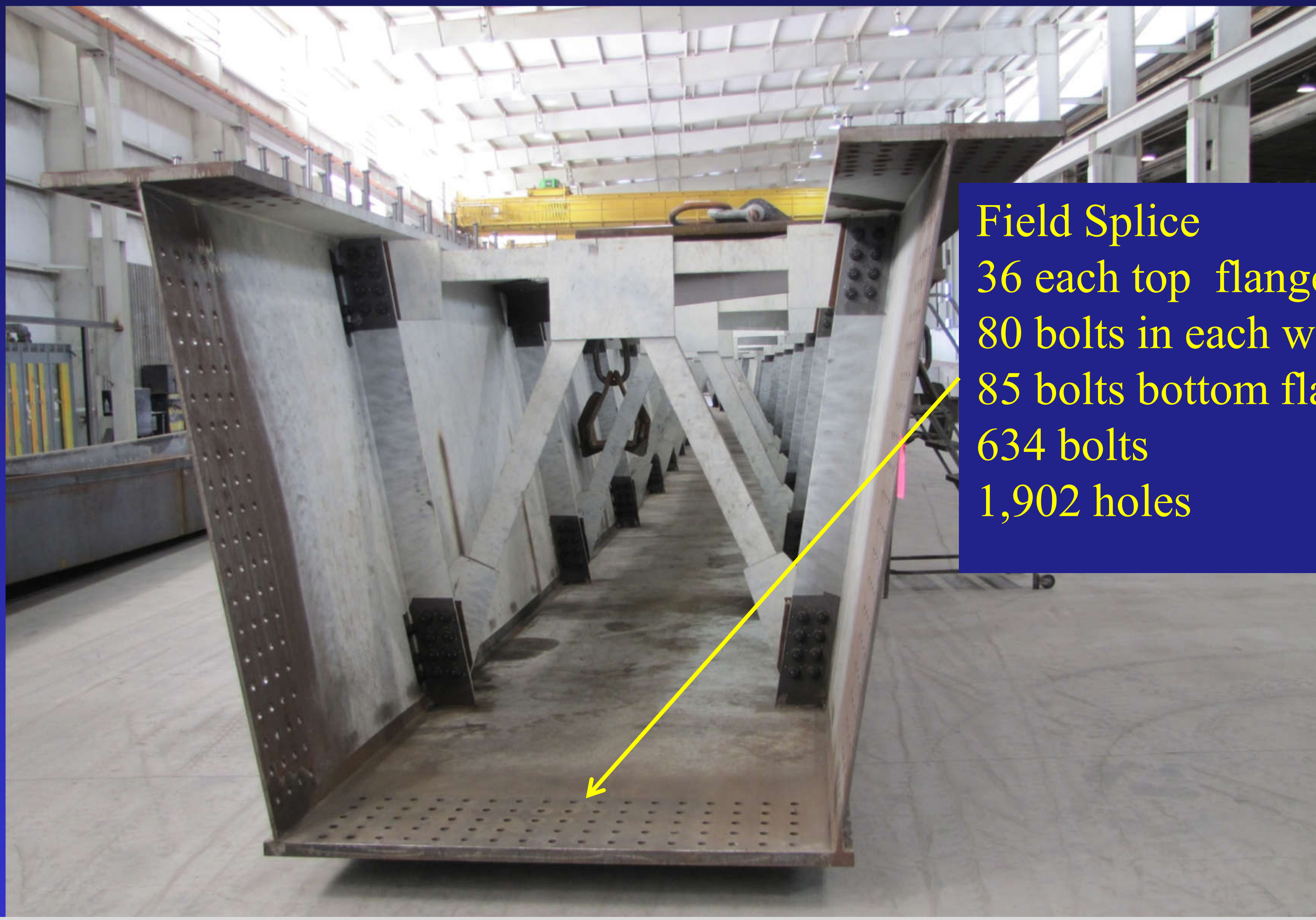
Expensive and Slow to Erect Field Splice



Field Splice
92 bolts in each web
32 bolts each flange
Total 312 bolts
936 holes

Bolts: 312x$20= $6,240
Labor: 312x10 min= 52 field hours each splice

The Problem: Tub Girder Splice



Field Splice
36 each top flange
80 bolts in each web
85 bolts bottom flange
634 bolts
1,902 holes

Bolts: 634x$20= $12,680
Labor: 634x10 min= 106 field hours each splice

Splice Design Procedure

1. Design Flange Connection to Develop the Smaller Design Yield Resistance of the Connected Flanges

Design Yield Resistance: $P_{fy} = F_{yf} A_e$

$$A_e = \left(\frac{\phi_u F_u}{\phi_y F_{yf}} \right) A_n \leq A_g$$

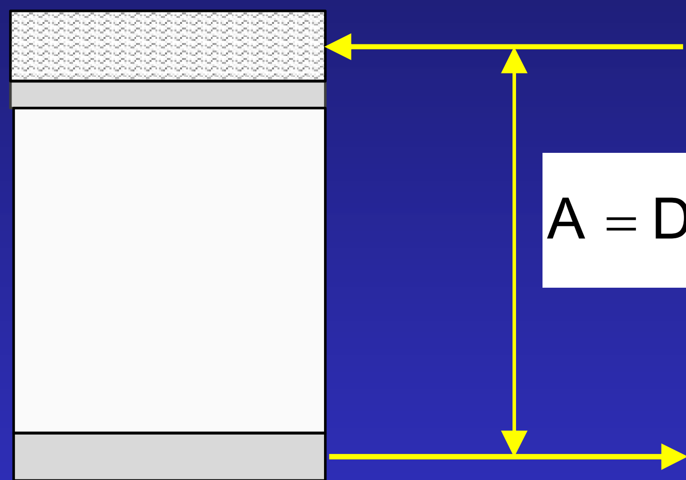
2. Design Web Connection to Develop the Smaller Factored Shear Resistance of the Connected Webs

$$V_r = \phi_v V_n$$

Two Rows of bolts minimum on each side of splice.

Positive Flange Moment Capacity Check

Bottom Flange in Tension



$$A = D + \frac{t_{ft}}{2} + t_{haunch} + \frac{t_s}{2}$$

$$P_{fy} = F_{yf} A_e$$

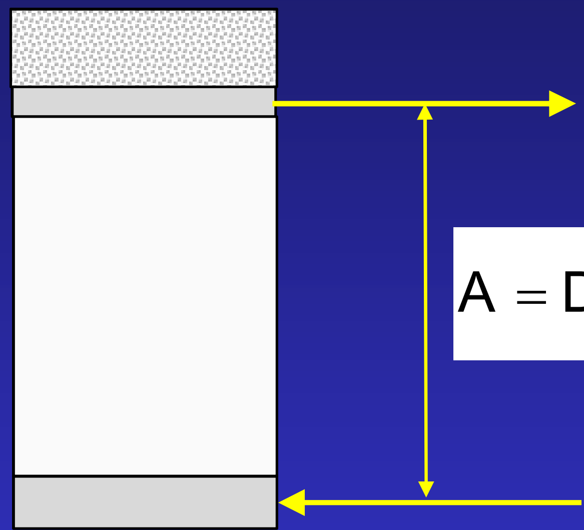
Moment Capacity:

P_{fy} for the Bottom Flange x Moment Arm to Mid- Depth of Deck

$= (F_{yf} \times A_e) \times A$

Negative Flange Moment and Non Composite Capacity Check

Ignore Tensile Contribution of Deck Reinforcement



$$P_{fy}(top) = F_{yf} A_e$$

$$A = D + \frac{t_{ft}}{2} + \frac{t_{fc}}{2}$$

$$P_{fy}(bot.) = F_{yf} A_e$$

Moment Capacity:

Smallest Value of P_{fy} x Distance Between Flange Centroids

= (F_{yf} x A_e) x A

If Moment From Flanges is Not Sufficient to Resist Factored Design Moment

Calculate Additional Resisting Moment to be Provided by the Web

Applied Web Moment= Factored Moment –Moment Resistance of the Flange

= Factored Design Moment- (P_{fy} x A)

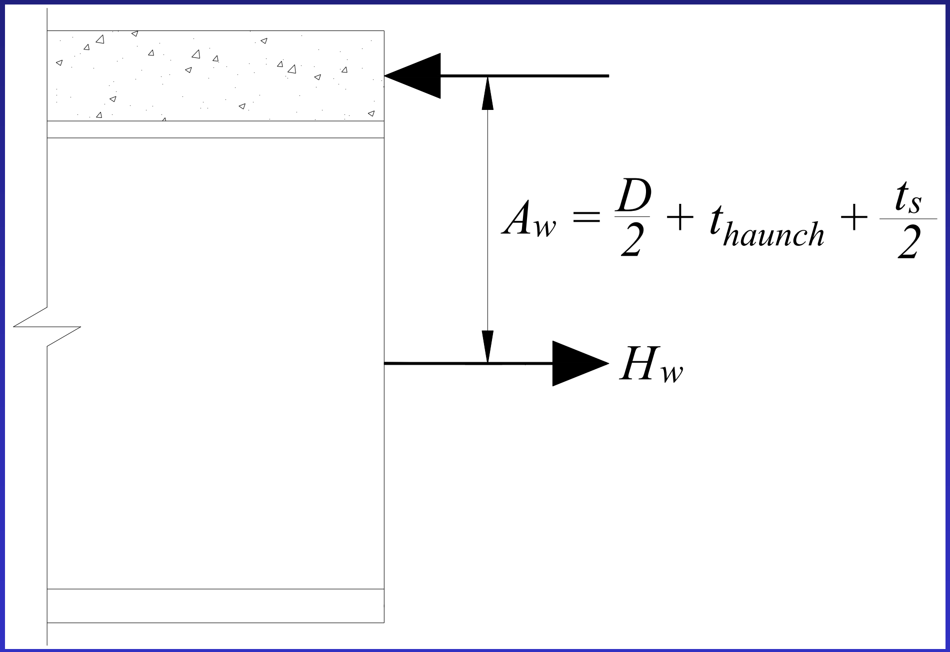
Resisting Web moment= H_w x A_w = (horizontal web bolt force x moment arm)

Yields Horizontal Web Force H_w :

$$H_W = \frac{\text{Factored Design Moment} - P_{fy} \text{ x } A}{A_W} = \frac{\text{Web Moment}}{A_W}$$

Calculation of Horizontal Web Force

Composite Section in Positive Bending



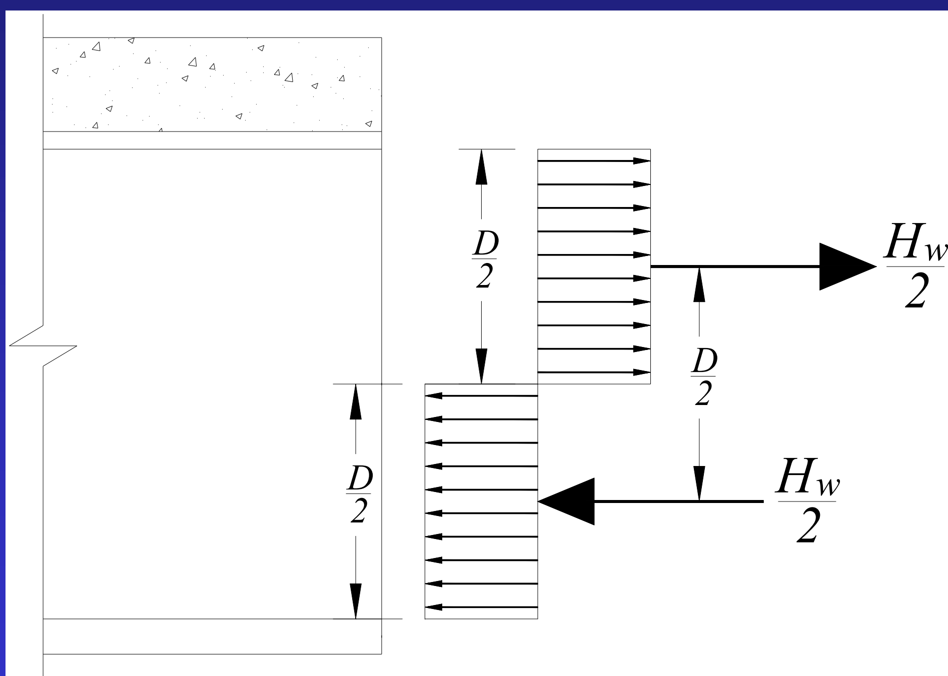
$$\text{Web Moment} = H_w A_w$$

Resultant Web Horizontal Force:

$$H_w = \frac{\text{Web Moment}}{A_w}$$

Calculation of Horizontal Web Force

Composite Section in Negative Bending or Non-Composite Section



$$Web\ Moment = \frac{H_w}{2}\left(\frac{D}{2}\right)$$

Resultant Web Horizontal Force:

$$H_w = \frac{Web\ Moment}{D/4}$$

Web Splice Force=Vector Resultant from Moment and Shear

$$R = \sqrt{(V_r)^2 + (H_w)^2} = \sqrt{(\phi_v V_n)^2 + (H_w)^2}$$

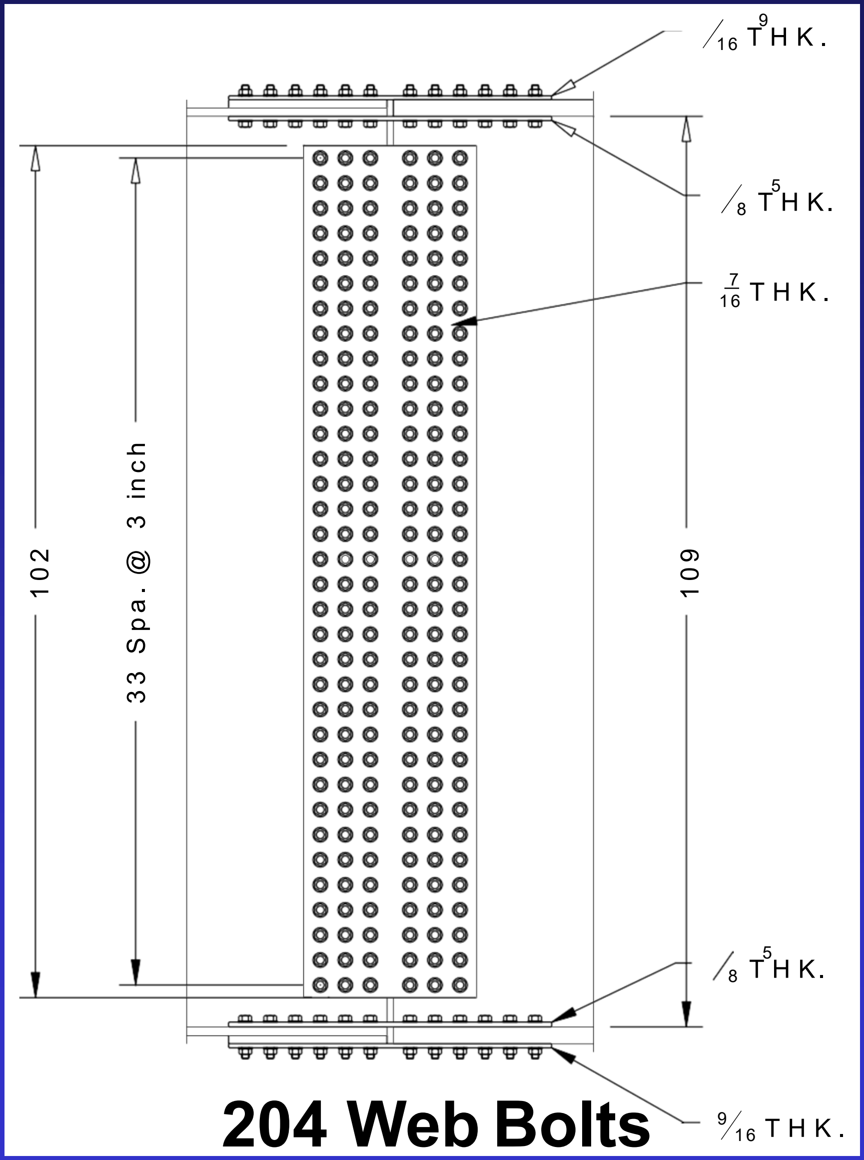
H_w = Horizontal Force in Web To Resist Design Moment
V_r= Vertical Force in Web = Factored Shear Resistance of the Web

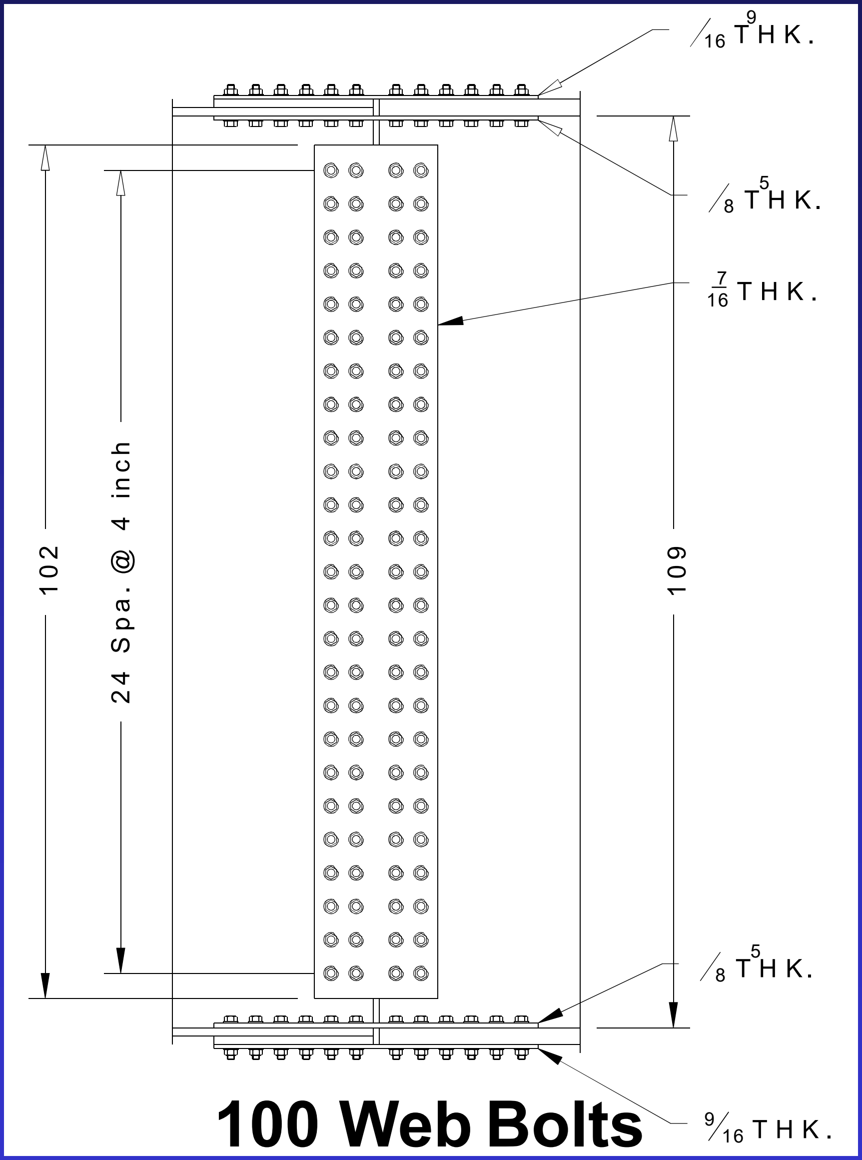
- **Number Bolts Required = R / Bolt Shear Capacity**
- **Minimum of Two Rows each side of splice**
- **Normally Maximum Spacing and 2 Row Requirement Controls Web Bolts**
- **Assume Threads in the Shear Plane!**

Design Comparison

Girder Depth in.	Number of Bolts Required				
	Design Method	Top Flange	Web	Bottom Flange	Difference Old-New
72	Old	12	36	24	6
	New	16	22	28	
111	Old	16	84	28	6
	New	24	70	28	
80 Tub Girder	Old	16	34	54	-3
	New	20	28	59	

Validation Finite Element Analysis





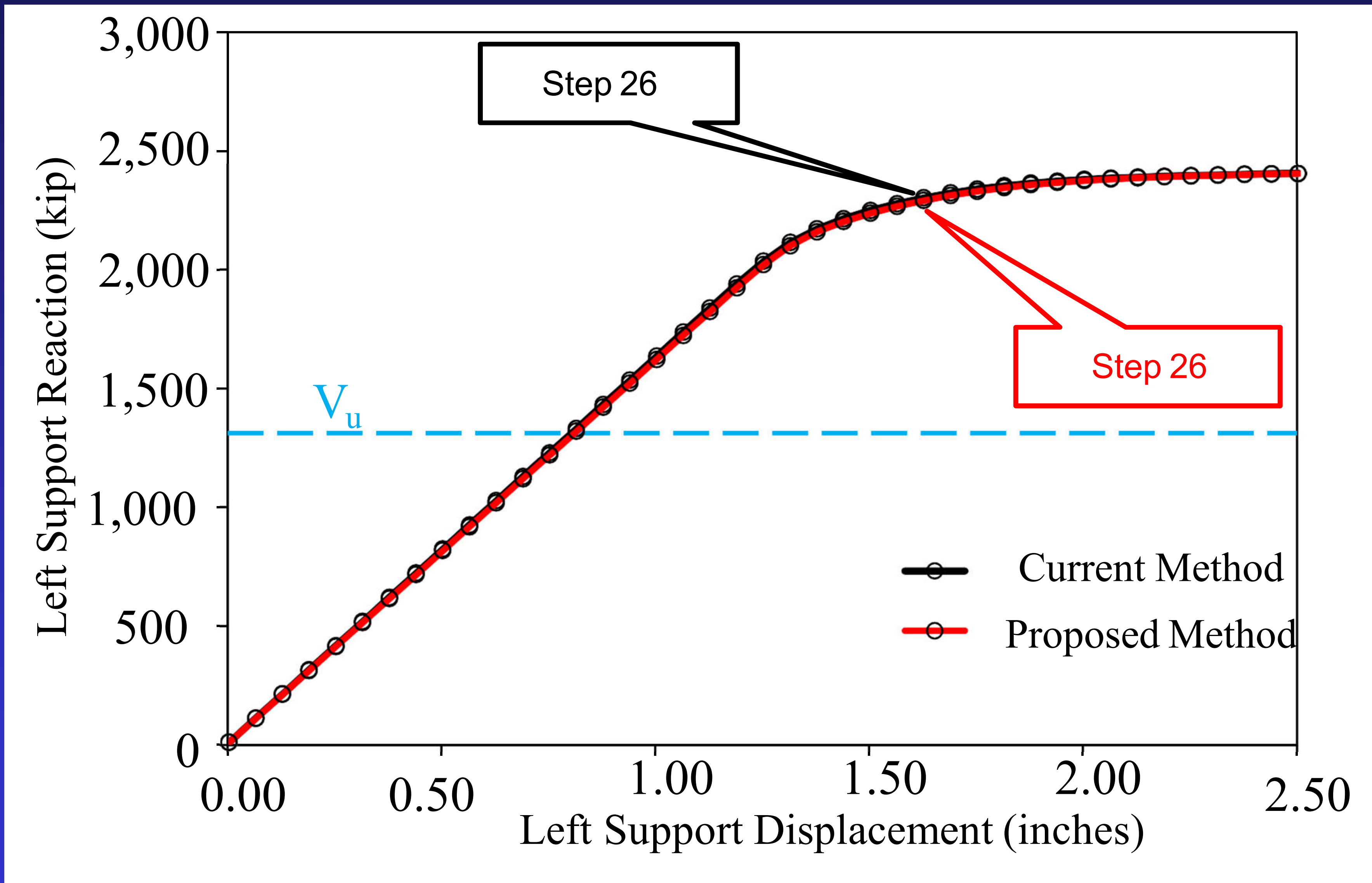
"Simplified Design of Bolted Splice Connections for Steel Girders" – Frank, Ocel, and Grubb

FEA Model Description

- Shell element models in Abaqus
- Adapted fastener models from NCHRP 12-84
- Five loading scenarios
  - Pure positive moment
  - Pure negative moment *
  - High shear (as little moment as possible) *
  - Proportion design positive moment/shear
  - Proportional design negative moment/shear *

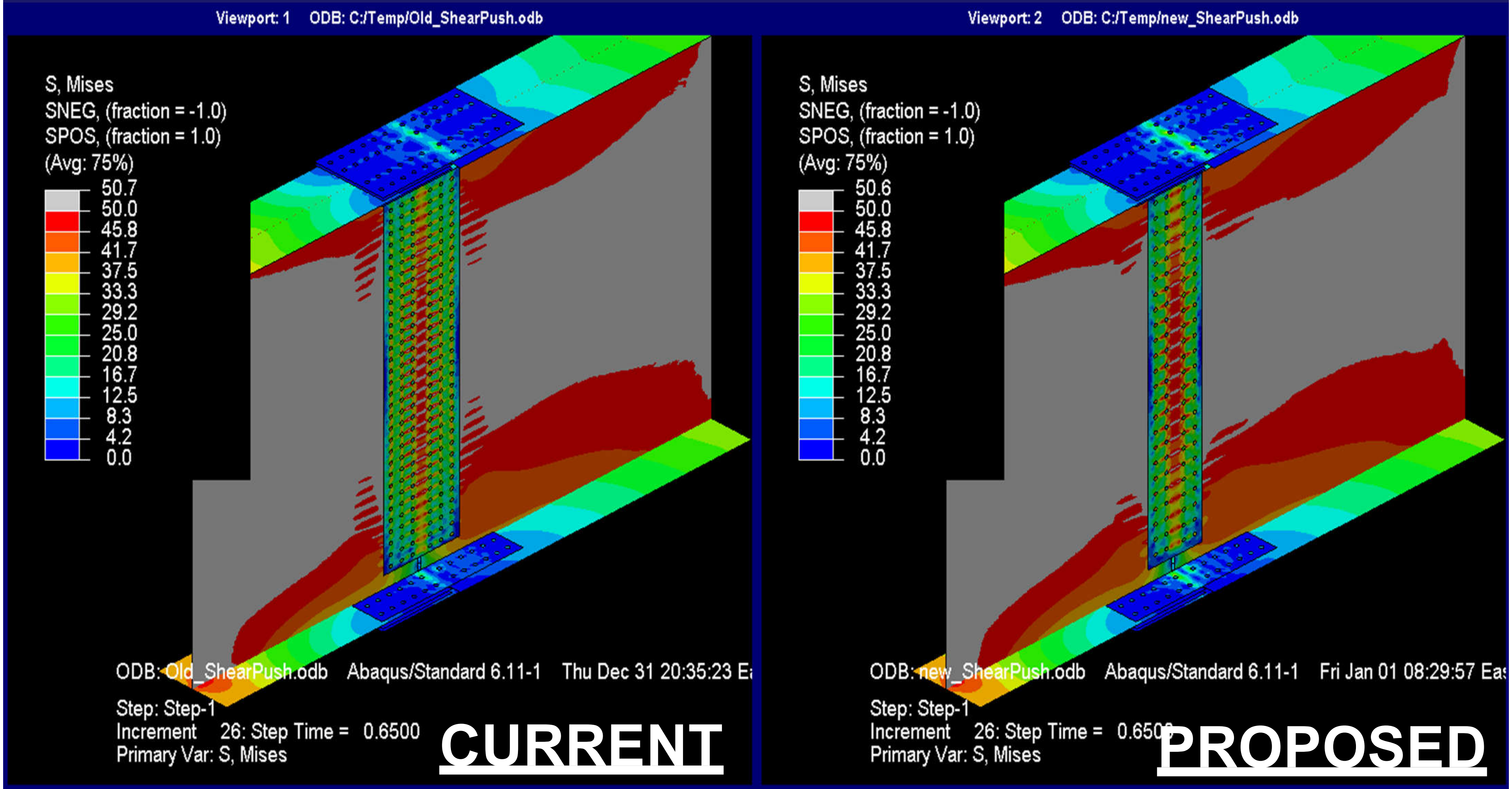
*= deck not present

Results – High Shear



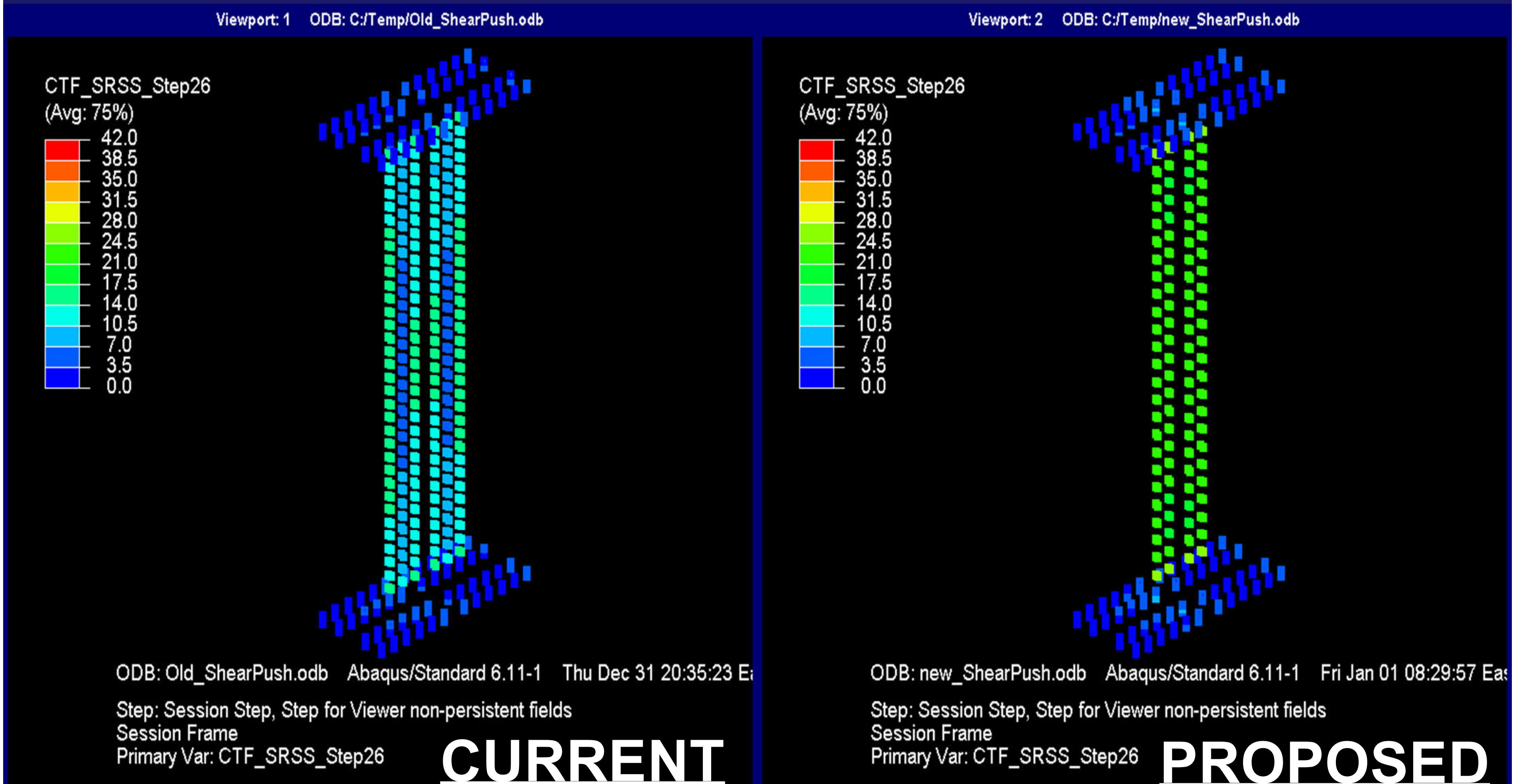
Results – High Shear

Von Mises Stresses @ Step 26

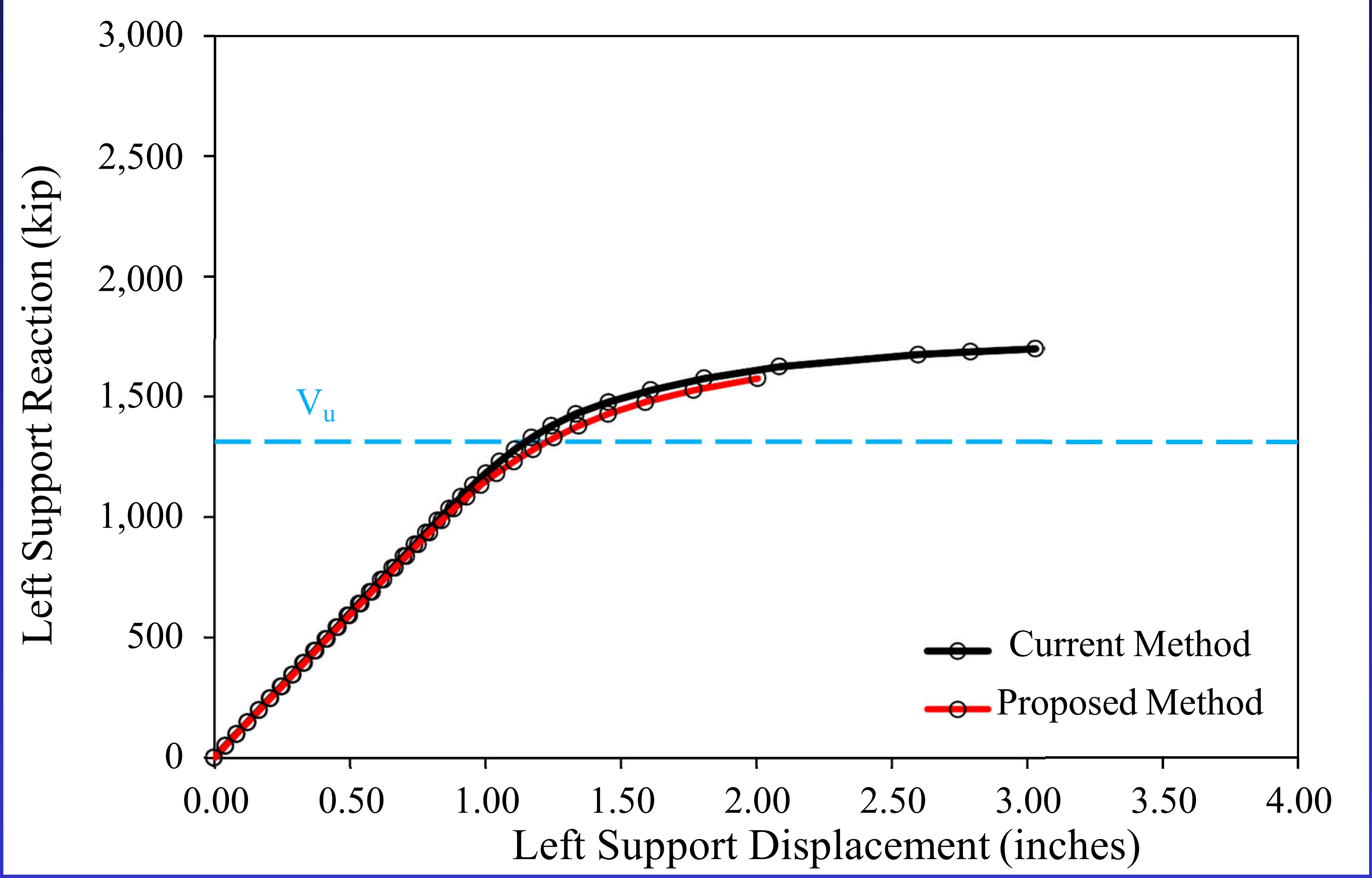


Results – High Shear

Bolt Shear Forces @ Step 26

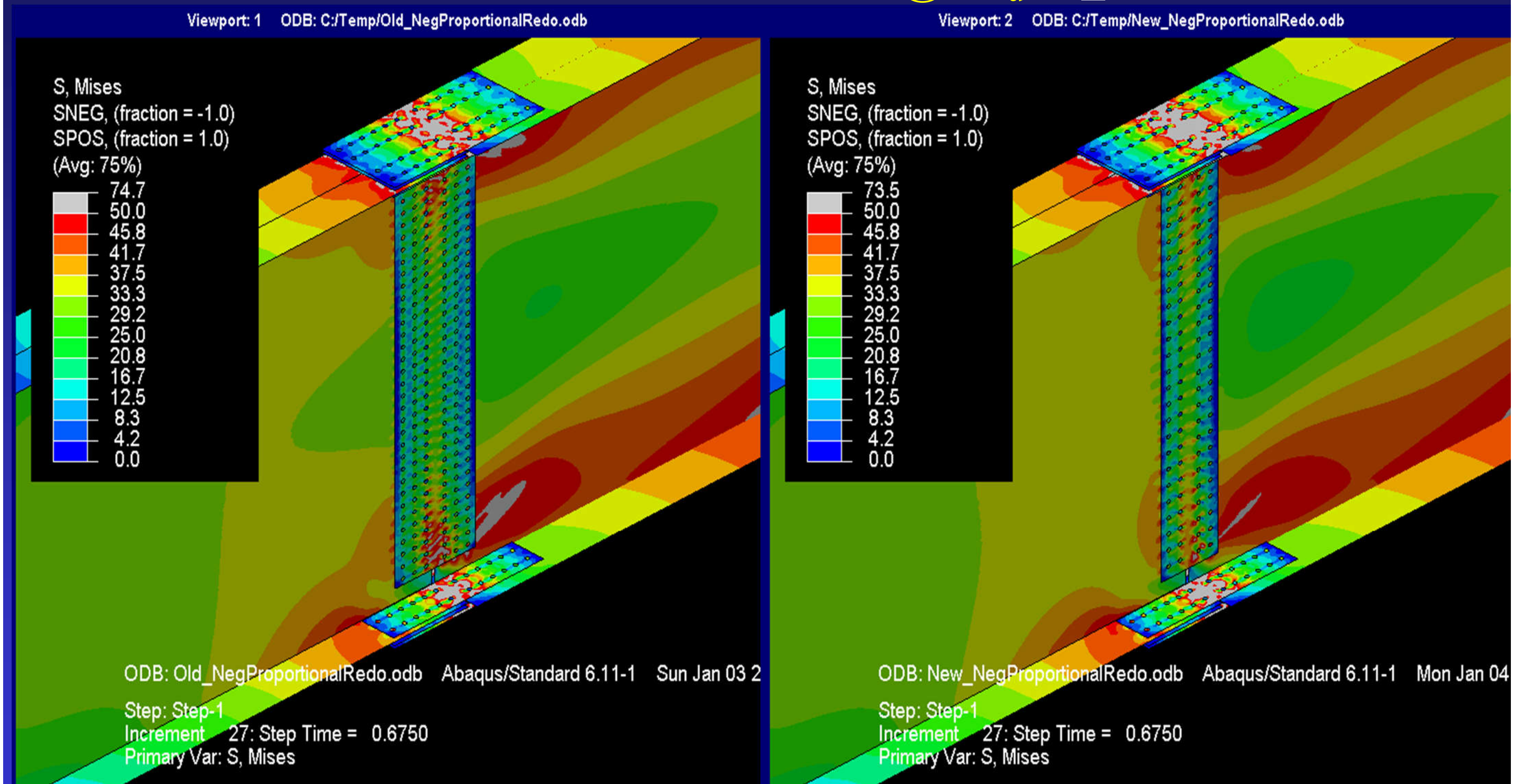


Results – Prop Neg Mom & Shear



Results – Prop Neg Mom & Shear

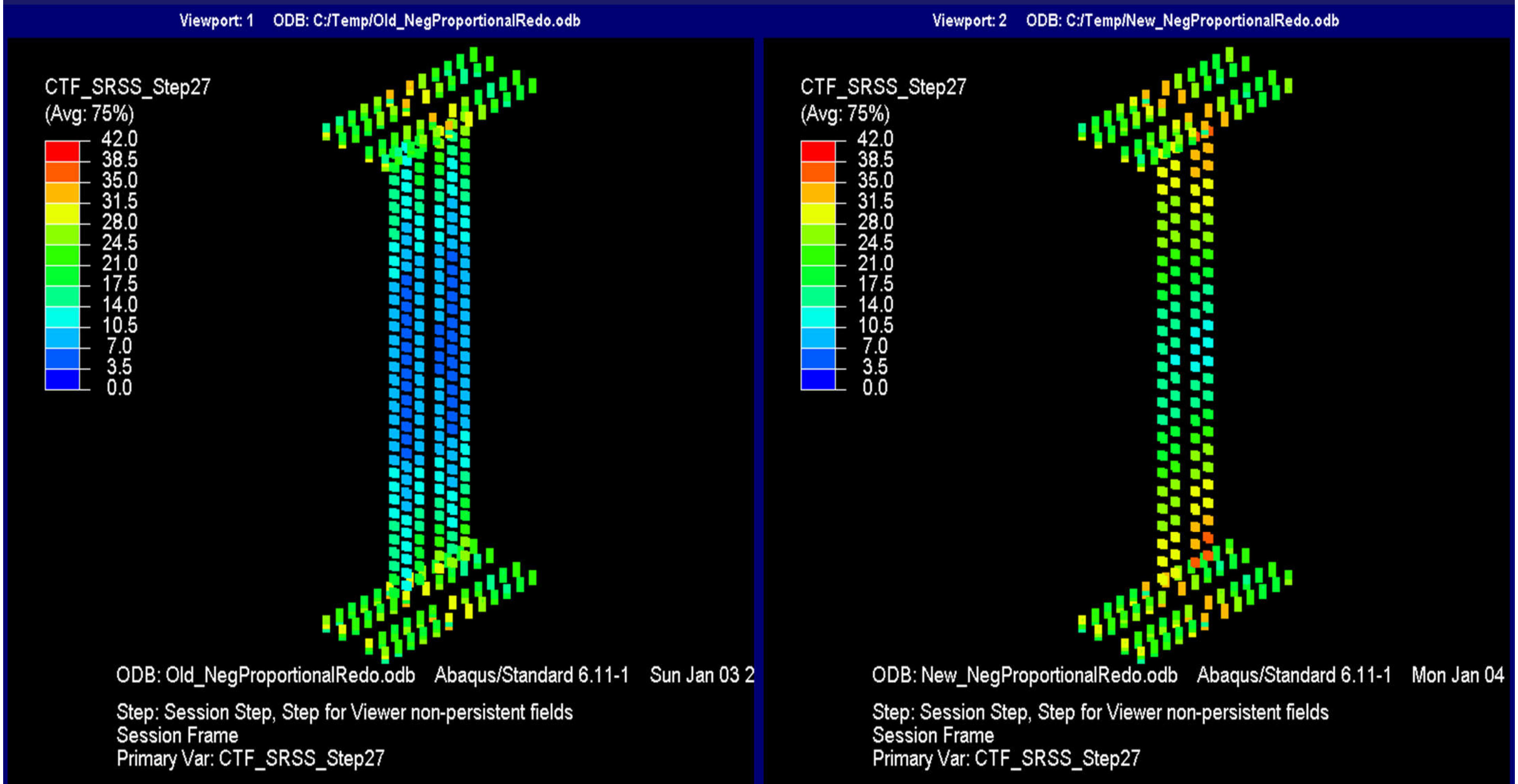
Von Mises Stresses @ V_u



CURRENT **PROPOSED**

Results – Prop Neg Mom & Shear

Bolt Shear Forces @ V_u



CURRENT **PROPOSED**

Anticipated Effect on Bridges:

- Application of the new proposed design provisions for bolted field splices will typically result in a few more bolts in the flange splices and significantly fewer bolts in the web splices than under the current design provisions.
- The overall simplification in the design procedure should result in easier interpretation of the provisions, faster and more efficient design of field splices, and more consistent and cost-effective designs.
- Clarifications to the application of the 75 percent and average rules to the design of connections and splices in primary members at the strength limit state subject to combined force effects should also be beneficial to designers.

Bolted Field Splices Document

www.steelbridges.org/nsbasplice

Design Tools – Splice Spreadsheet

NSBA Bolted Splice Designer - Plate Girder

NOTICE: DO NOT MODIFY THIS SHEET

Web Calculations

Load Combinations - Factored Shear

	Shear (kip)						
	Noncomposite Dead Load (DC1)	Superimposed Composite Dead Load (DC2)	Future Wearing Surface (DW)	Positive Live Load plus Impact (LL+ + I)	Negative Live Load plus Impact (LL- + I)	Deck Casting	
Load Combination	-82.00	-12.00	-11.00	19.00	-112.00	-82.00	Factored Shear (kip)
Deck Casting	0.00	0.00	0.00	0.00	0.00	1.40	-114.80
Service II - Positive	1.00	1.00	1.00	1.30	0.00	0.00	-80.30
Service II - Negative	1.00	1.00	1.00	0.00	1.30	0.00	-250.60

Bolt Factored Shear Resistance

Location	Bolt Type	Bolt Area (sq-in)	K_h	ϕ_s	F_u (ksi)	P_t (kip)	R_r - Single Shear (kip)	R
Web	A325 - Included	0.6013	Standard	0.80	120	39.00	25.98	

Bolt Nominal Slip Resistance

Faying Surface Class (K_s)	Hole Size Factor (K_h)	P_t (kip)	Slip Capacity - Double (kip)
0.50	1.00	39.00	39.00

Flange Design Results

Flange Moment Resistance Check Results

	H_w (kip)	Controlling
Positive	DNA	
Negative	DNA	

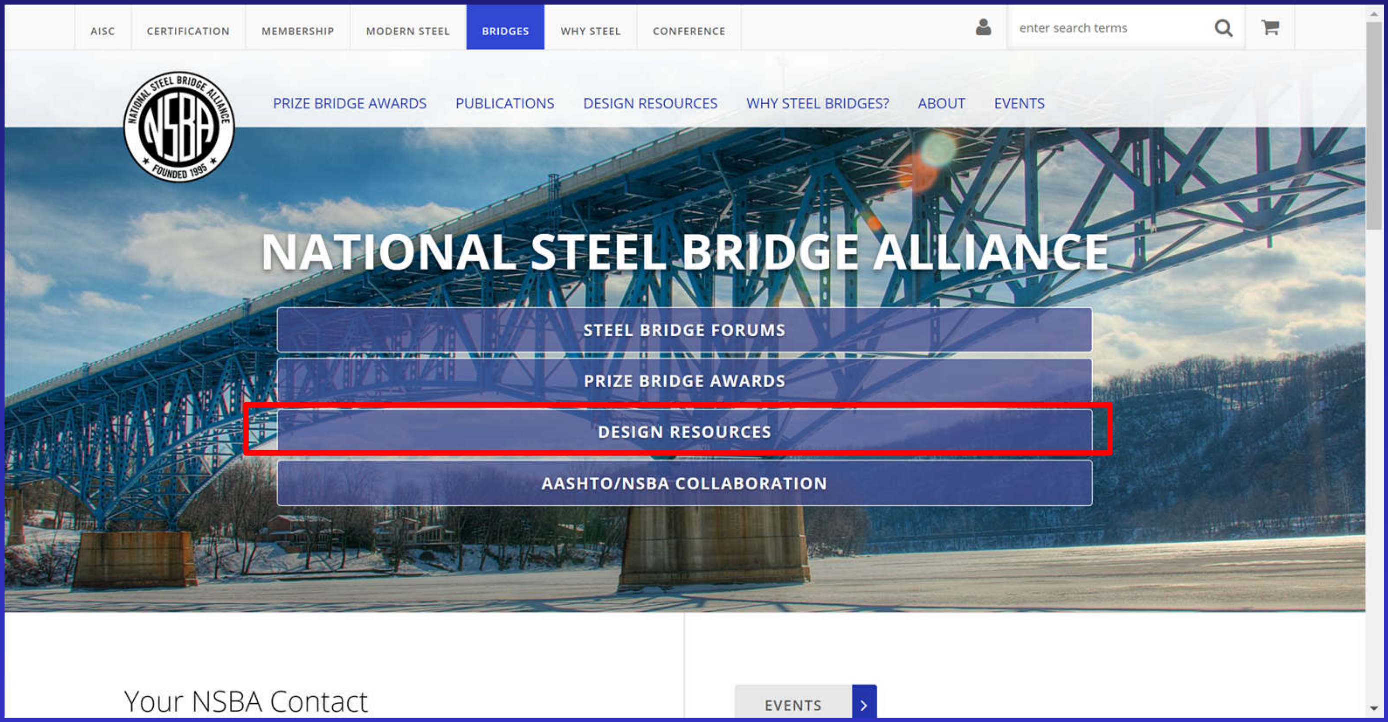
EULA | Input | Figures | Design Result Summary | Design Check Summary | Flange Splice Design | **Web Splice Design**

NSBA Splice Spreadsheet

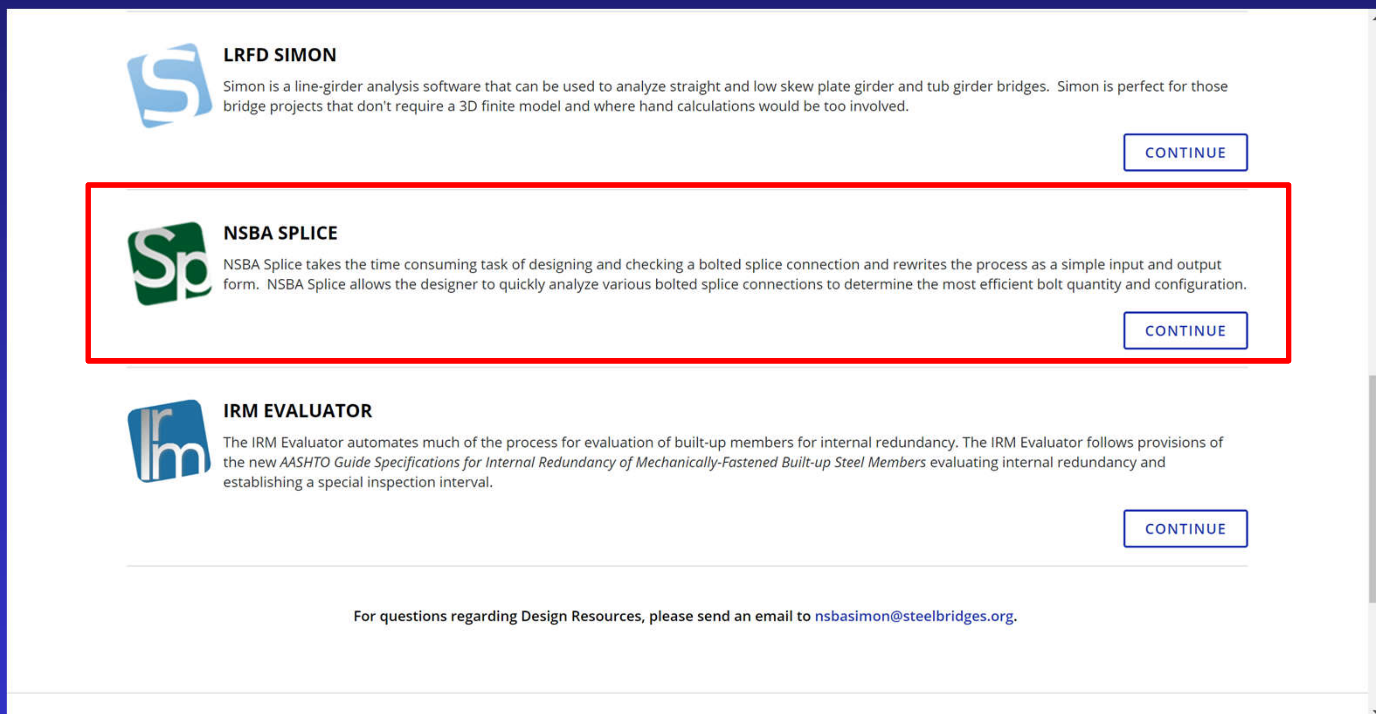
- NSBA Splice Spreadsheet
  - Plate Girder Bolted Splice Design Tool.
  - 8th Edition AASHTO Design Specification Compliant.
  - Updated May 2019.
  - Subscribe to NSBA Newsletter for up-to-date information.

www.steelbridges.org/nsbasplice

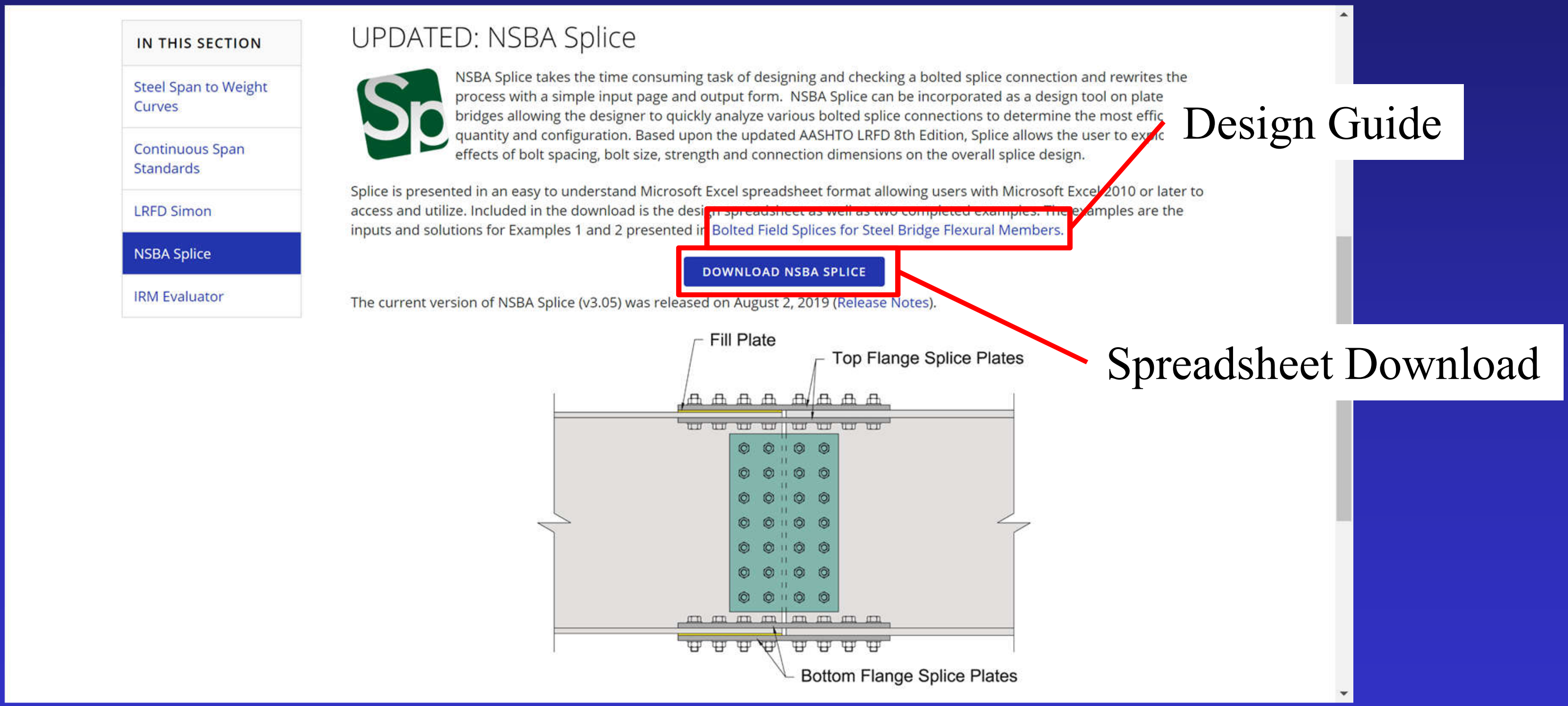
NSBA Splice Spreadsheet - Download



NSBA Splice Spreadsheet - Download



NSBA Splice Spreadsheet - Download



Result of Changes to Field Splice Design

- ***Reduced Design Effort and Cost, Lower Connection Costs, & Faster Erection***

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A New Day- Another Bridge