

AASHTO Design and Material Specification Changes

LRFD BDS Section 6, Various Articles

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Consultant

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 all 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

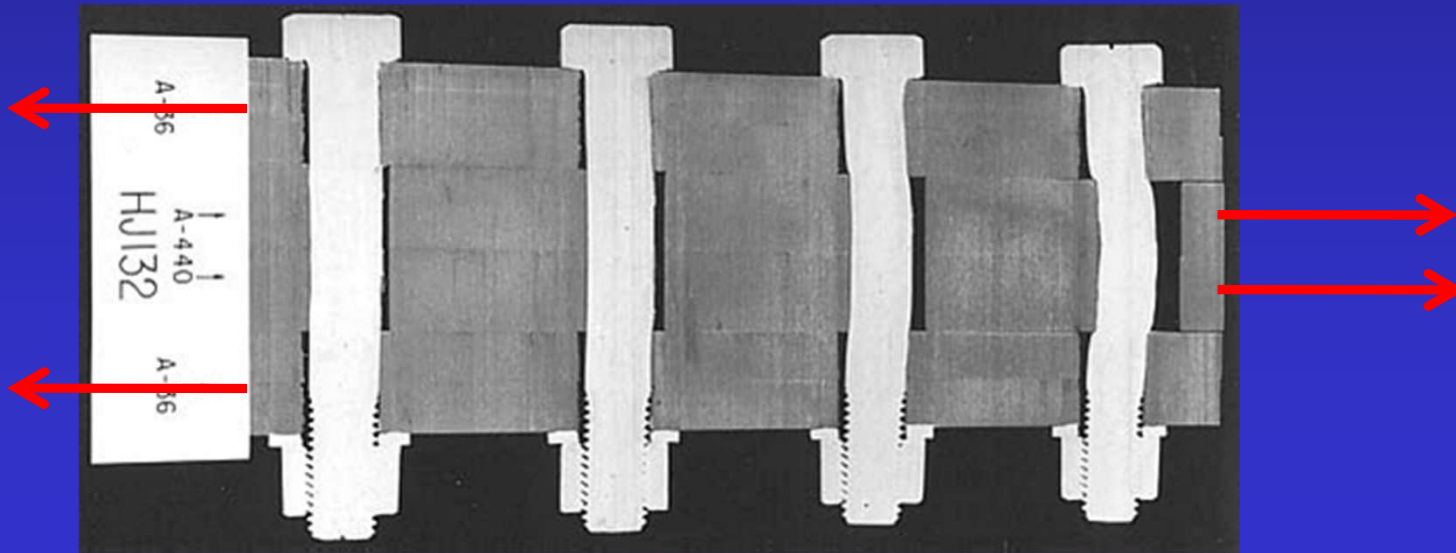
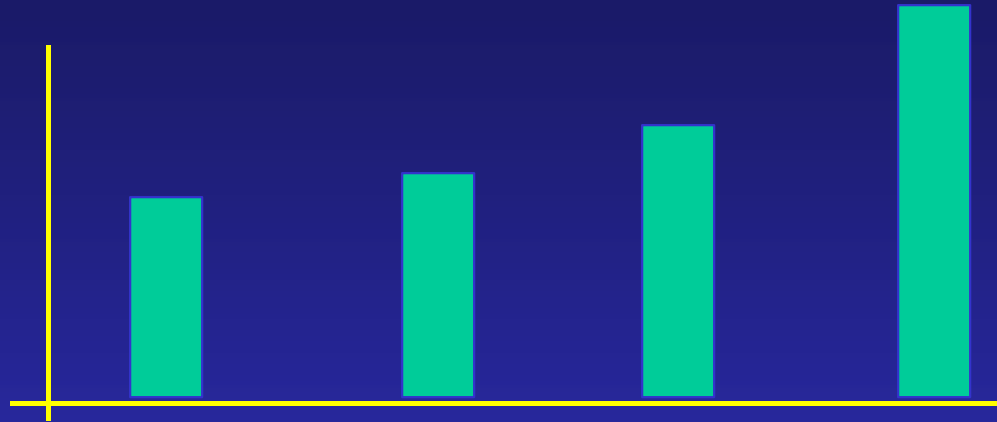
Shear Strength

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)
 - $R_n = \phi 0.45 A_b F_u$ (old value 0.38)
- Bolts with threads excluded from the shear plane:
 - $R_n = \phi 0.56 A_b F_u$ (old value 0.48)
- The nominal shear resistance of a bolt in lap tension connections greater than 38 in. in length shall be taken as 0.83 times the values above ($0.9 \times 0.83 = 0.75$).

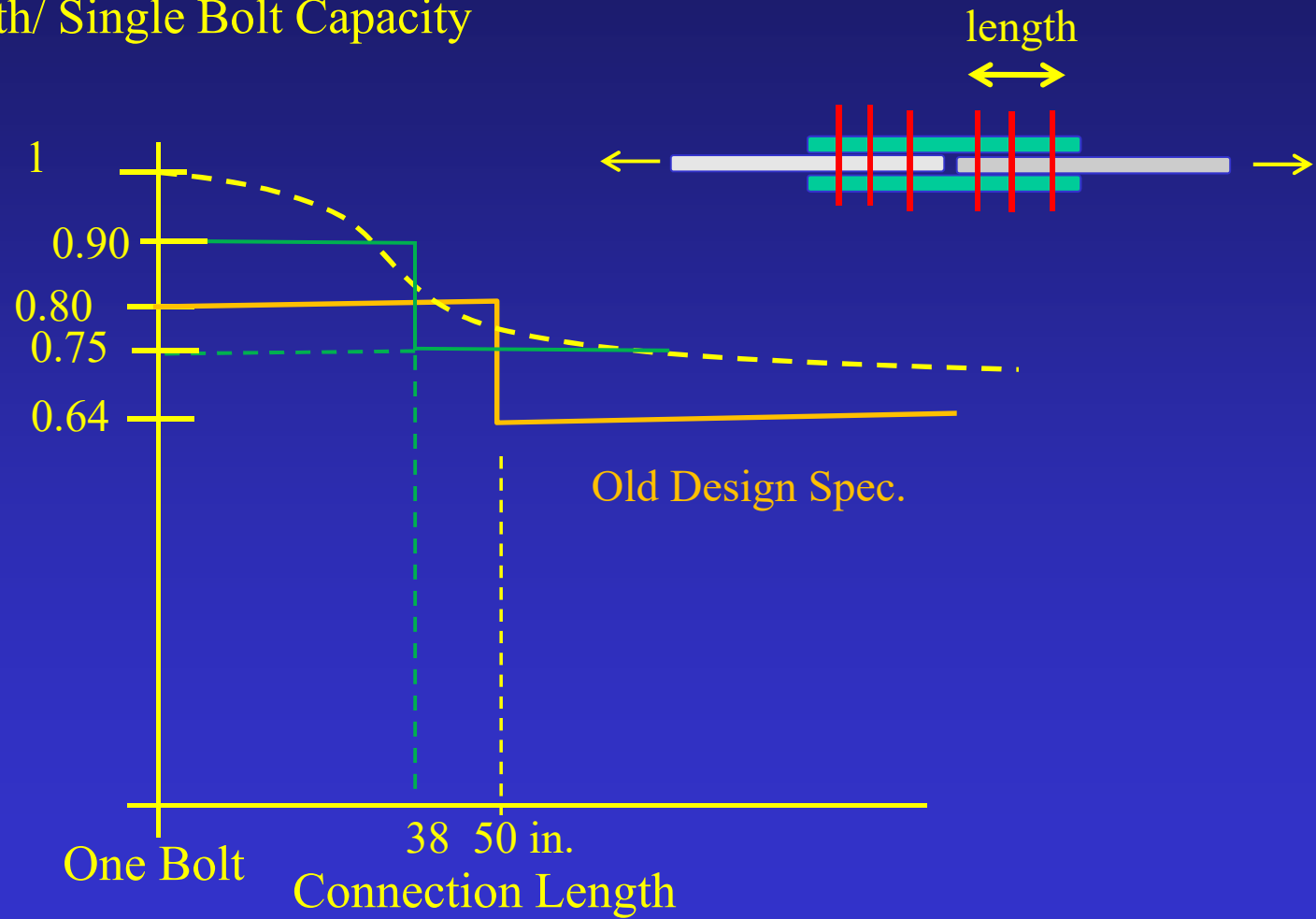
Unequal Bolt Shear In Long Joints

Bolt Shear



Joint Length Shear Strength Reductions

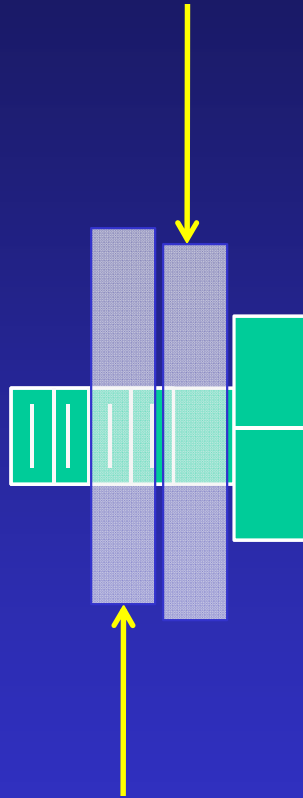
Design Strength/ Single Bolt Capacity



Bolt Shear Strength

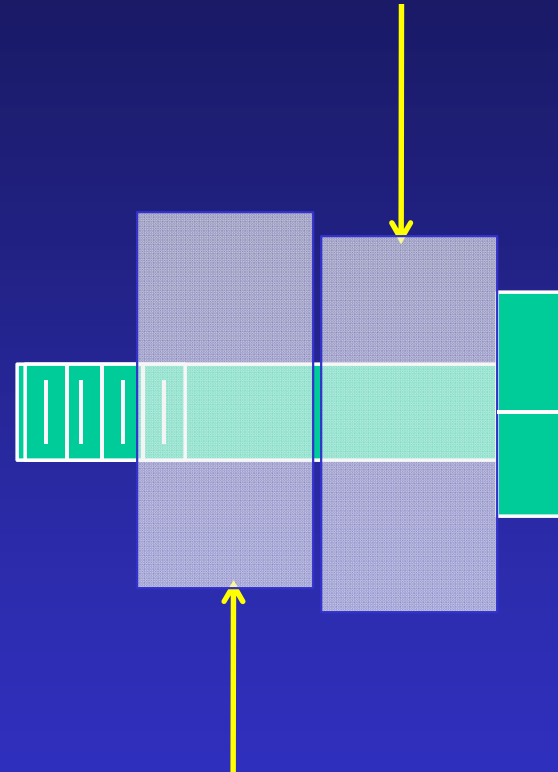
Connection Length ≤ 38 in.

Threads Not
Excluded from
Shear Plane
“N” Bolt



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

Threads
Excluded from
Shear Plane
“X” Bolt



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

$$\Phi_s = 0.80$$

$$\text{Slip Capacity} = R_n = K_h K_s N_s P_t \quad \Phi_s = 1.0 \quad (\text{Art.6.13.2.2})$$

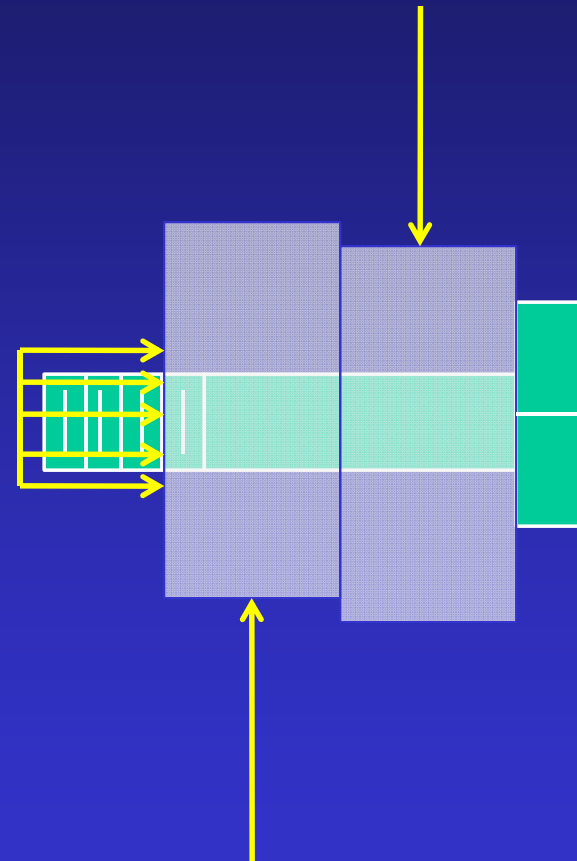
K_h = Hole Factor

= 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

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

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

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

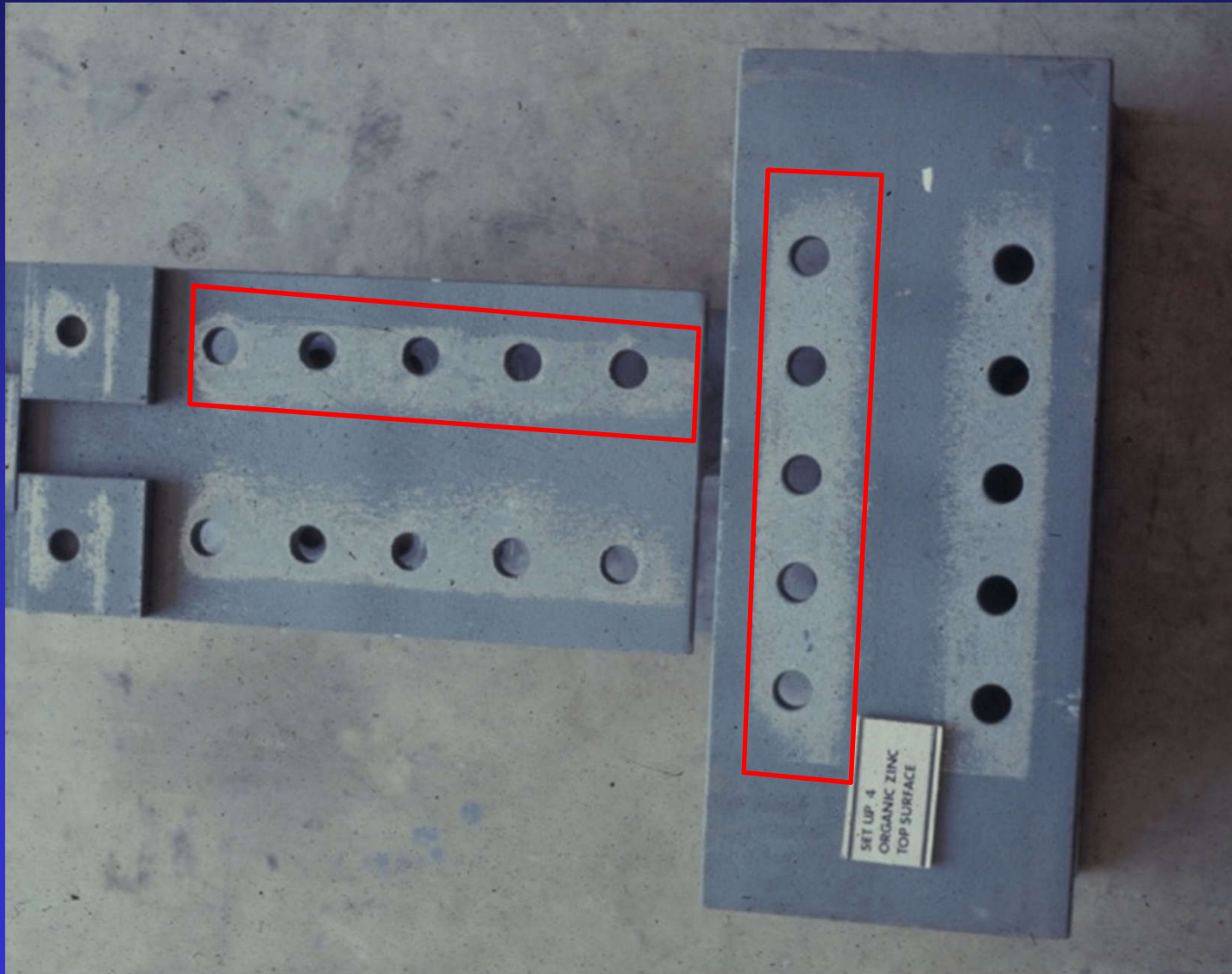
Slip Critical Connections

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

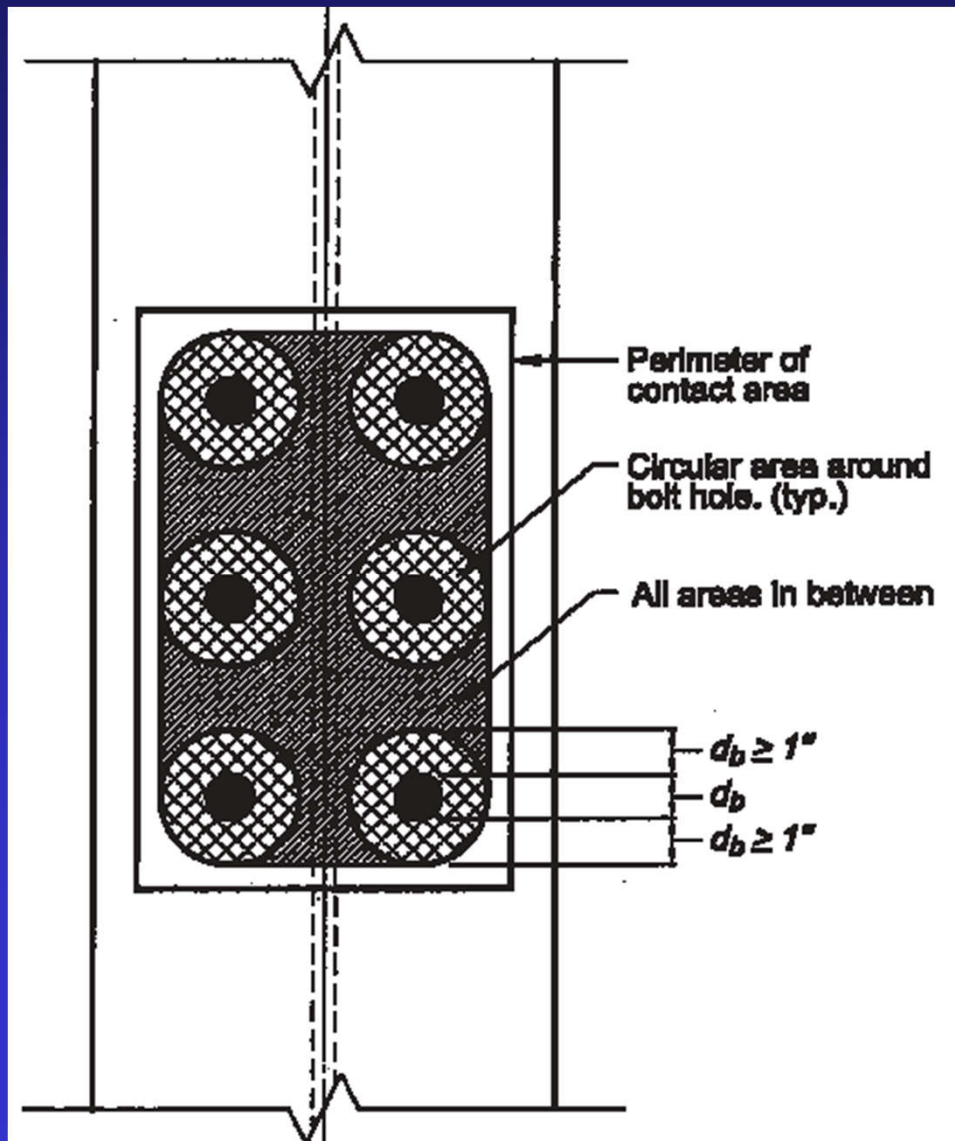
Required tension for A325 > 1 in. diameter increased

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

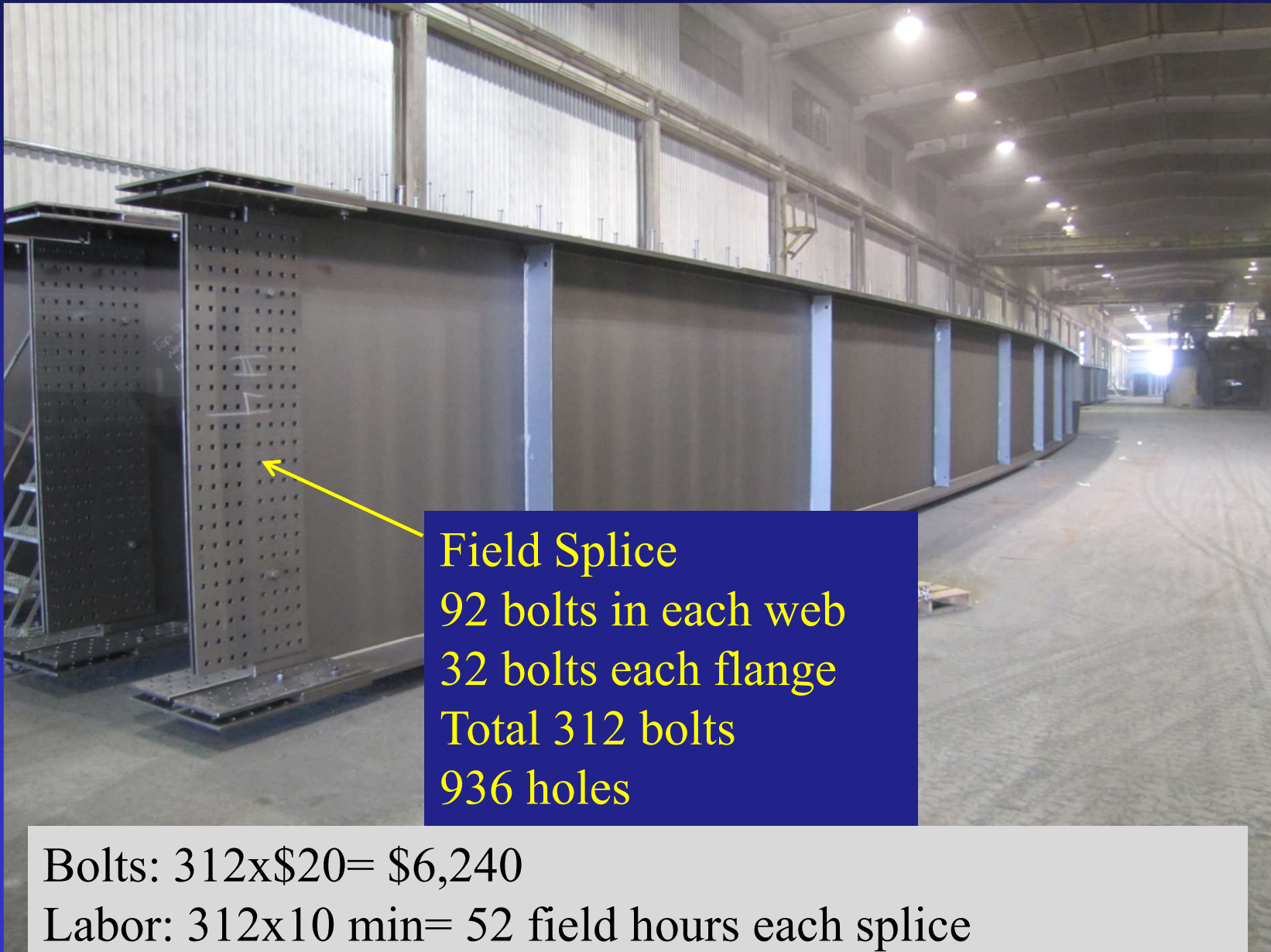
New Connection Design Criteria and Methods

- 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

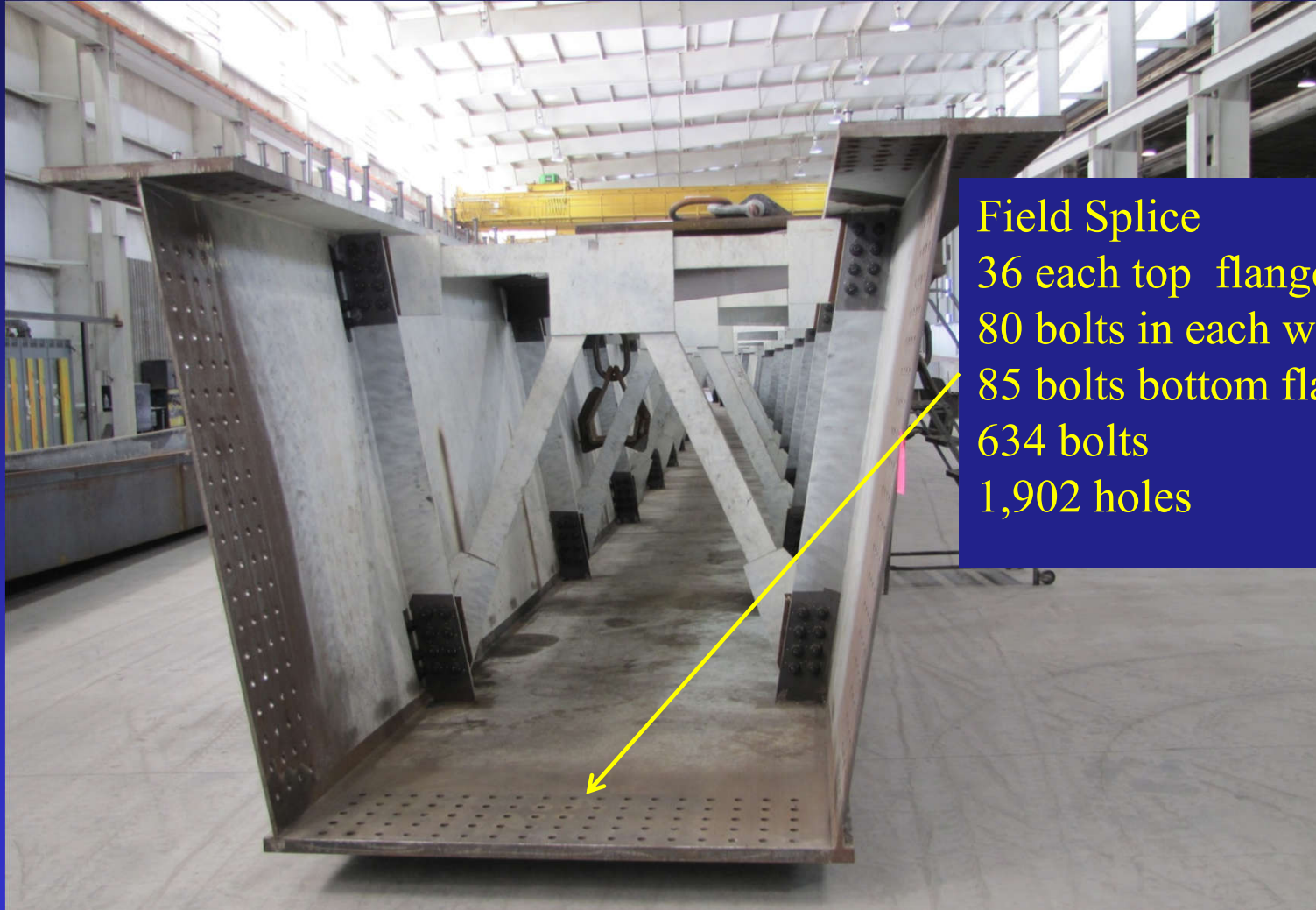


Field Splice
92 bolts in each web
32 bolts each flange
Total 312 bolts
936 holes

Bolts: $312 \times \$20 = \$6,240$

Labor: $312 \times 10 \text{ min} = 52 \text{ field hours each splice}$

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: $634 \times \$20 = \$12,680$

Labor: $634 \times 10 \text{ min} = 106 \text{ field hours each splice}$

Splice Design Procedure

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

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

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

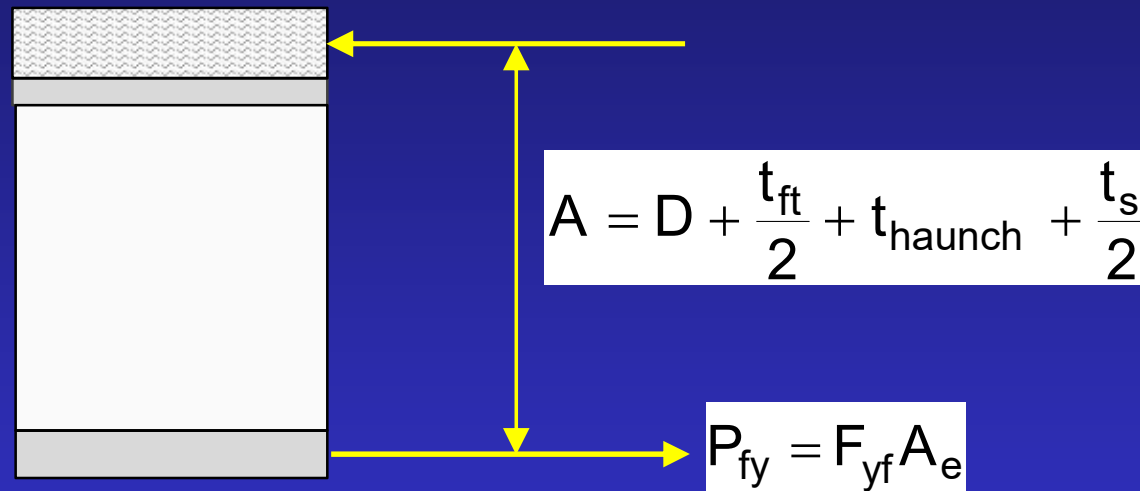
2. Design Web Connection to Develop the Smaller Factored Shear Resistance of the Connected Webs

$$V_r = \phi_v V_n$$

Two Rows of bolts minimum on each side of splice.

Positive Flange Moment Capacity Check

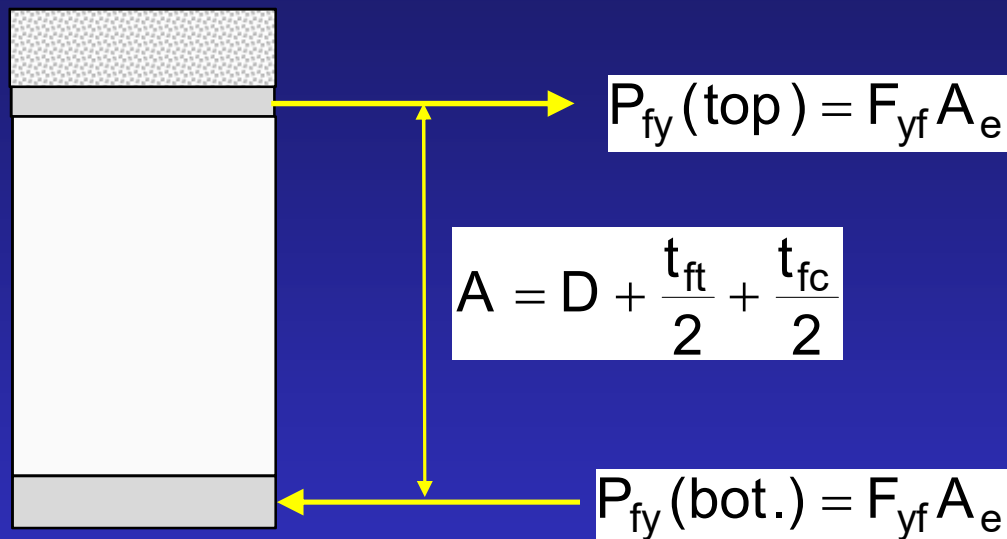
Bottom Flange in Tension



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



Moment Capacity:

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

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

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 - ($P_{fy} \times A$)

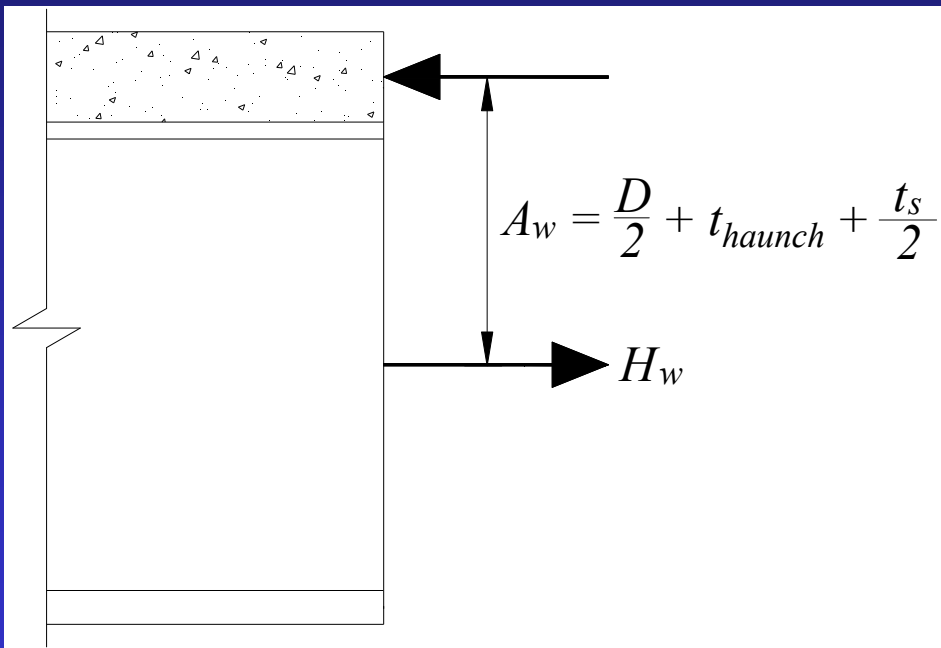
Resisting Web moment = $H_w \times A_w$ = (horizontal web bolt force x moment arm)

Yields Horizontal Web Force H_w :

$$H_w = \frac{\text{Factored Design Moment} - P_{fy} \times A}{A_w} = \frac{\text{Web Moment}}{A_w}$$

Calculation of Horizontal Web Force

Composite Section in Positive Bending

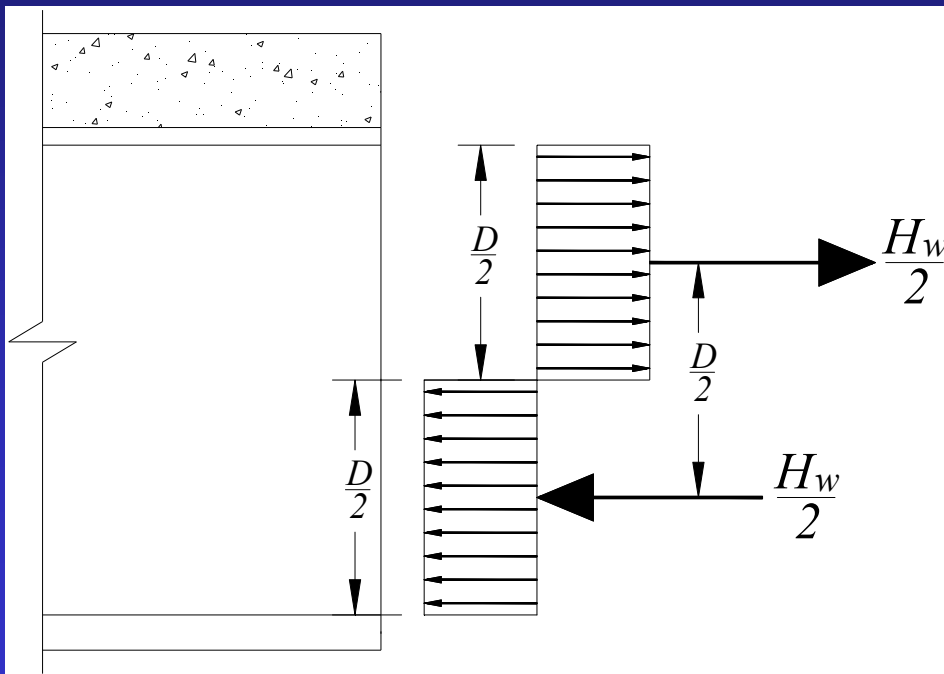


$$\text{Web Moment} = H_w A_w$$

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



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

Resultant Web Horizontal Force:

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

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

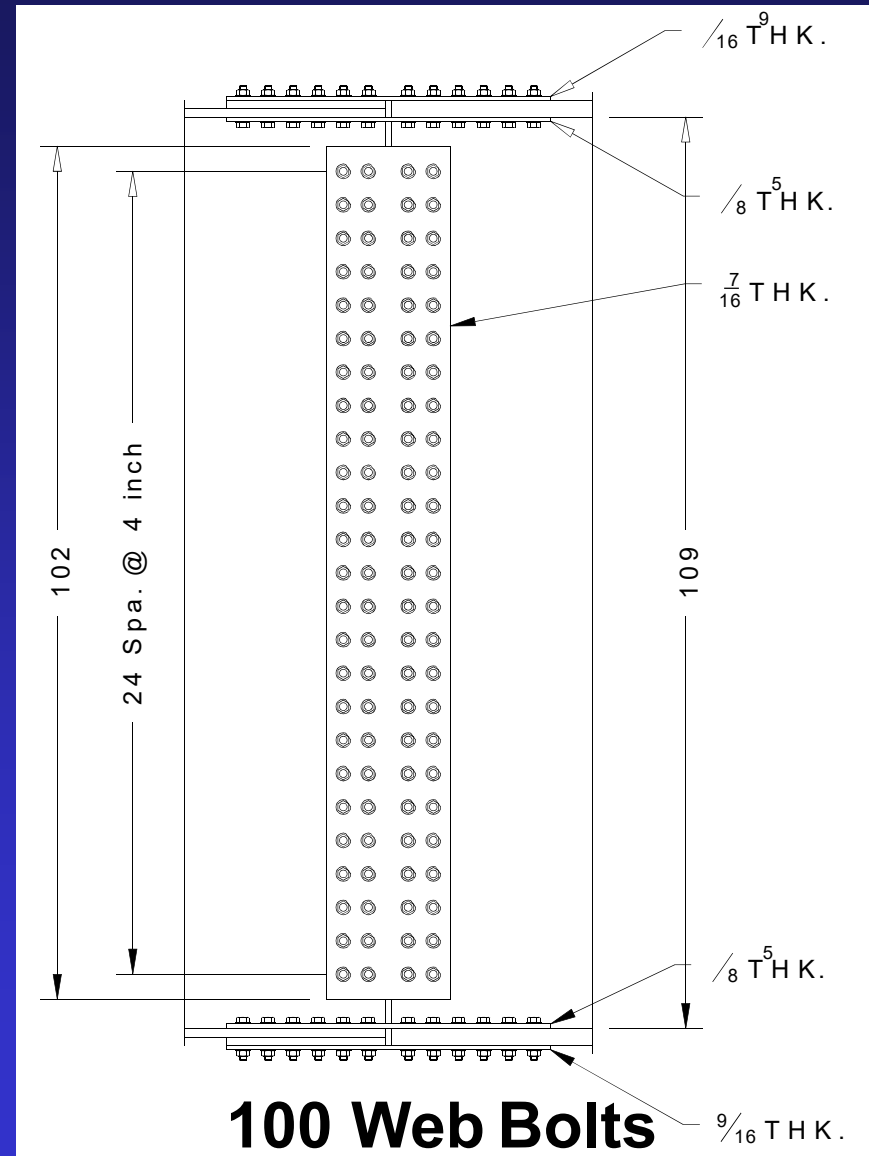
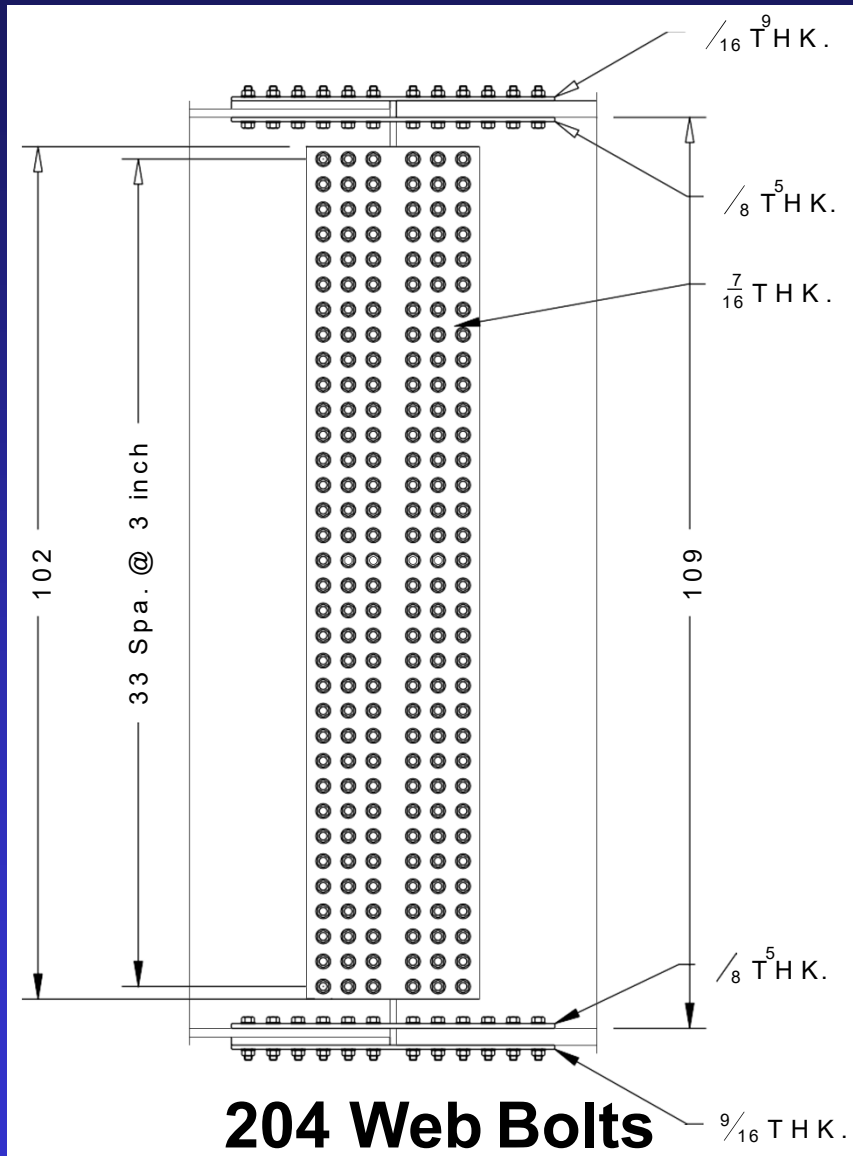
V_r = Vertical Force in Web = Factored Shear Resistance of the Web

- **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	

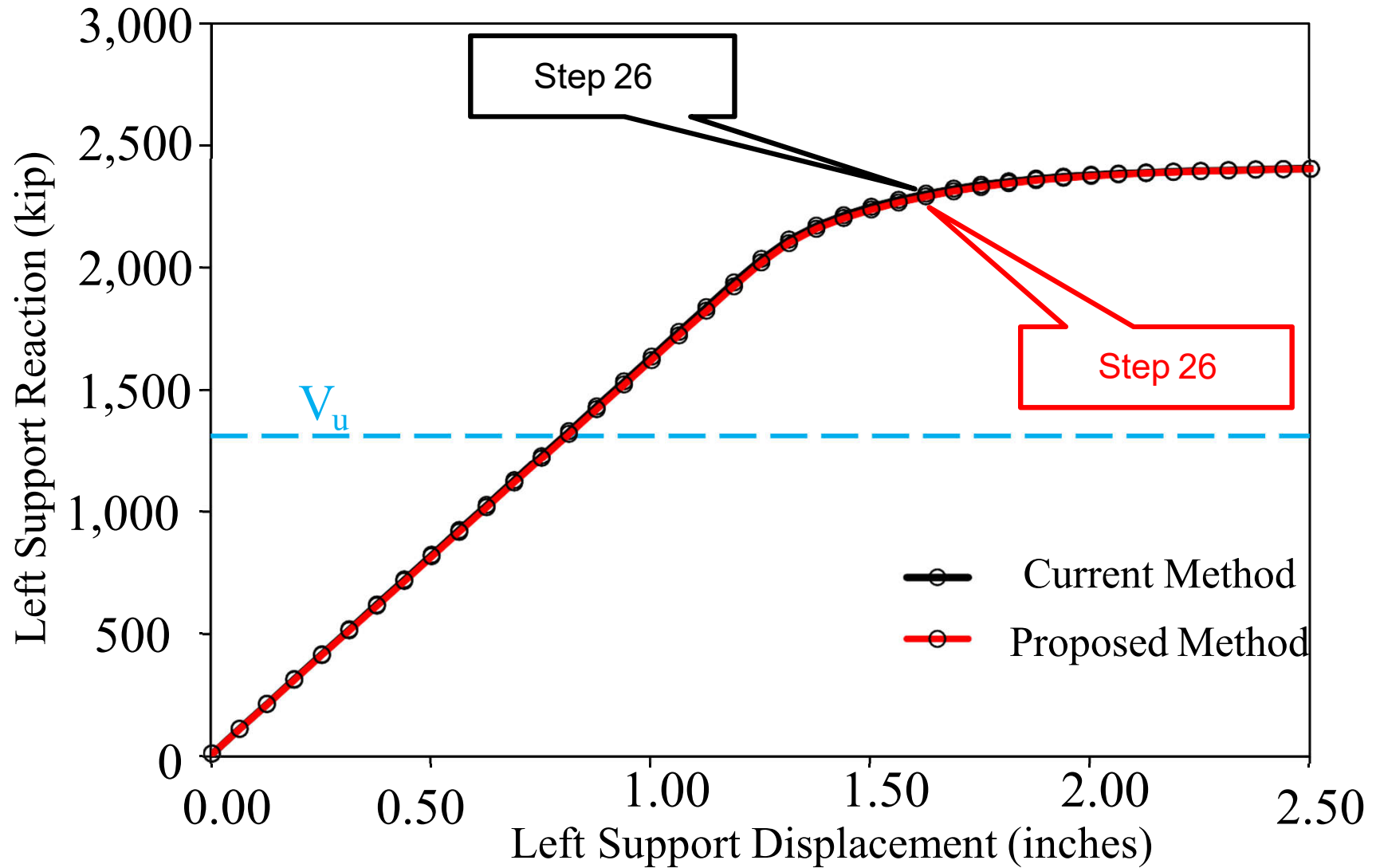
Validation Finite Element Analysis



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



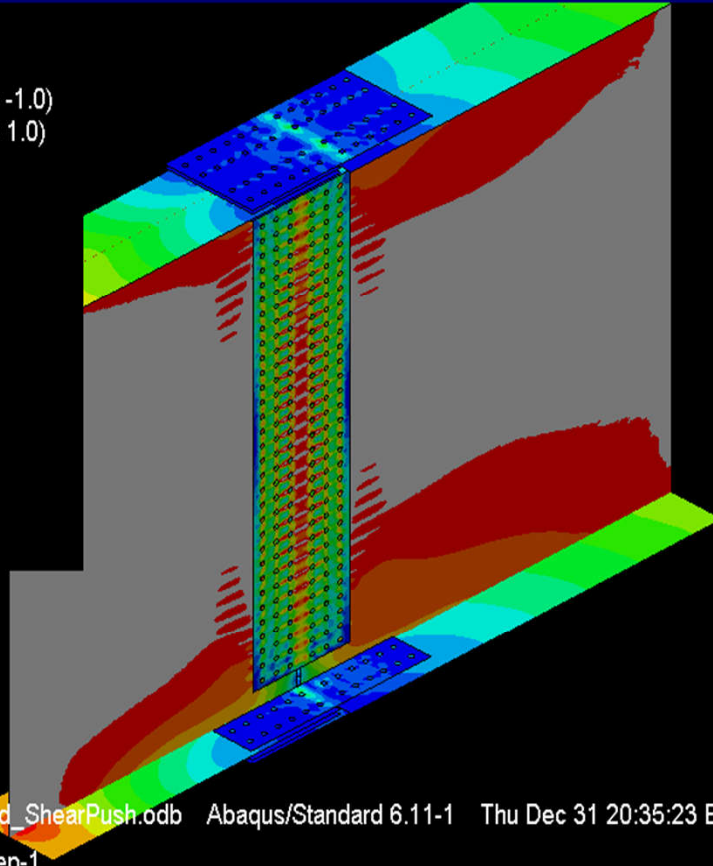
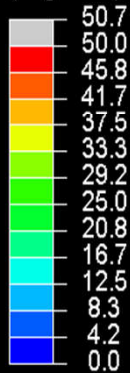
Results – High Shear

Von Mises Stresses @ Step 26

Viewport: 1 ODB: C:/Temp/Old_ShearPush.odb

Viewport: 2 ODB: C:/Temp/new_ShearPush.odb

S, Mises
SNEG, (fraction = -1.0)
SPOS, (fraction = 1.0)
(Avg: 75%)

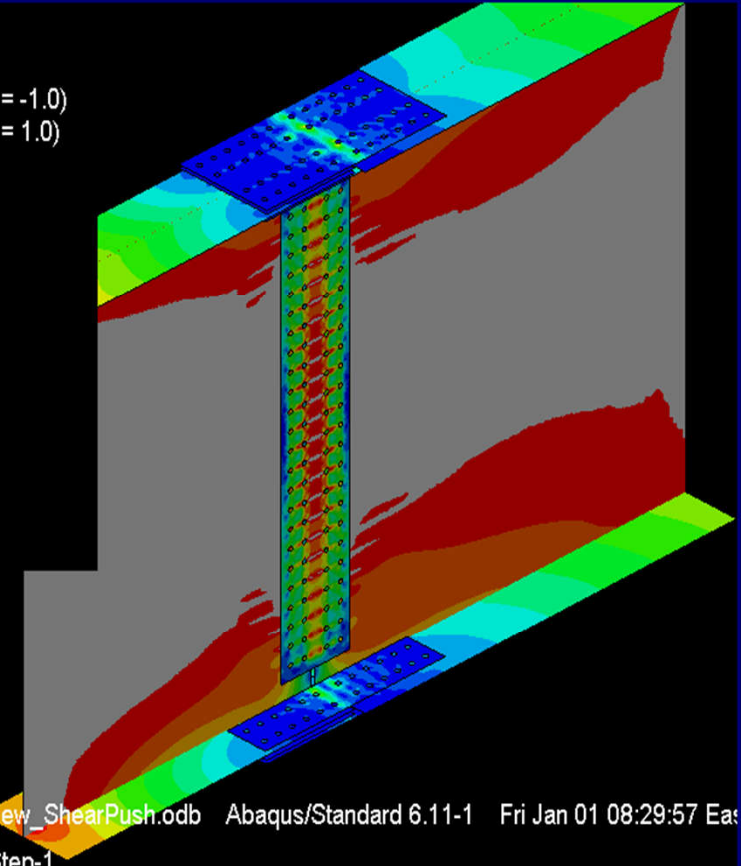


ODB: Old_ShearPush.odb Abaqus/Standard 6.11-1 Thu Dec 31 20:35:23 E

Step: Step-1
Increment 26: Step Time = 0.6500
Primary Var: S, Mises

CURRENT

S, Mises
SNEG, (fraction = -1.0)
SPOS, (fraction = 1.0)
(Avg: 75%)



ODB: new_ShearPush.odb Abaqus/Standard 6.11-1 Fri Jan 01 08:29:57 E

Step: Step-1
Increment 26: Step Time = 0.6500
Primary Var: S, Mises

PROPOSED

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

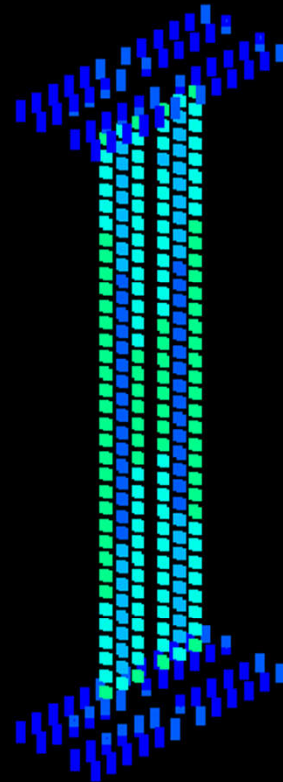
Results – High Shear

Bolt Shear Forces @ Step 26

Viewport: 1 ODB: C:/Temp/Old_ShearPush.odb

Viewport: 2 ODB: C:/Temp/new_ShearPush.odb

CTF_SRSS_Step26
(Avg: 75%)

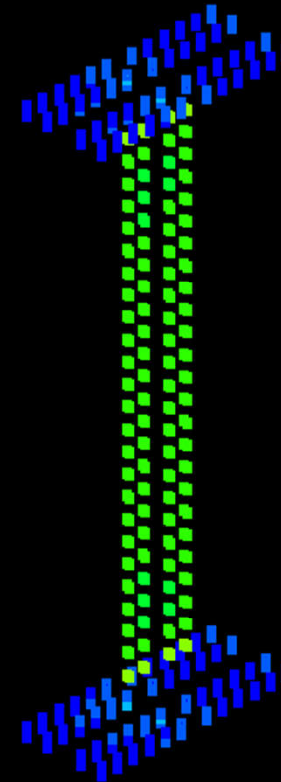
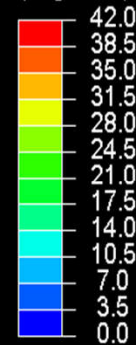


ODB: Old_ShearPush.odb Abaqus/Standard 6.11-1 Thu Dec 31 20:35:23 E

Step: Session Step, Step for Viewer non-persistent fields
Session Frame
Primary Var: CTF_SRSS_Step26

CURRENT

CTF_SRSS_Step26
(Avg: 75%)



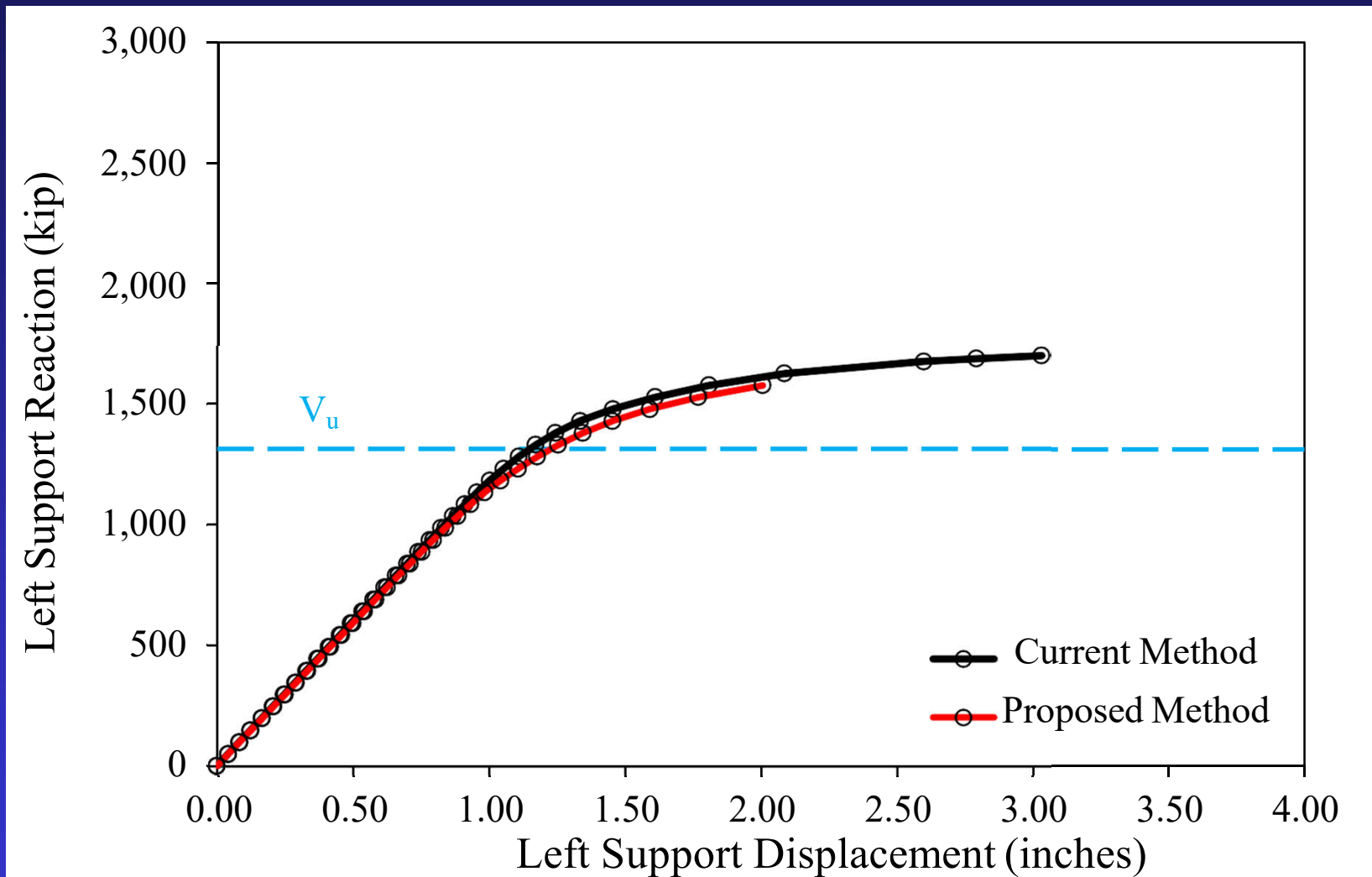
ODB: new_ShearPush.odb Abaqus/Standard 6.11-1 Fri Jan 01 08:29:57 Eas

Step: Session Step, Step for Viewer non-persistent fields
Session Frame
Primary Var: CTF_SRSS_Step26

PROPOSED

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

Results – Prop Neg Mom & Shear

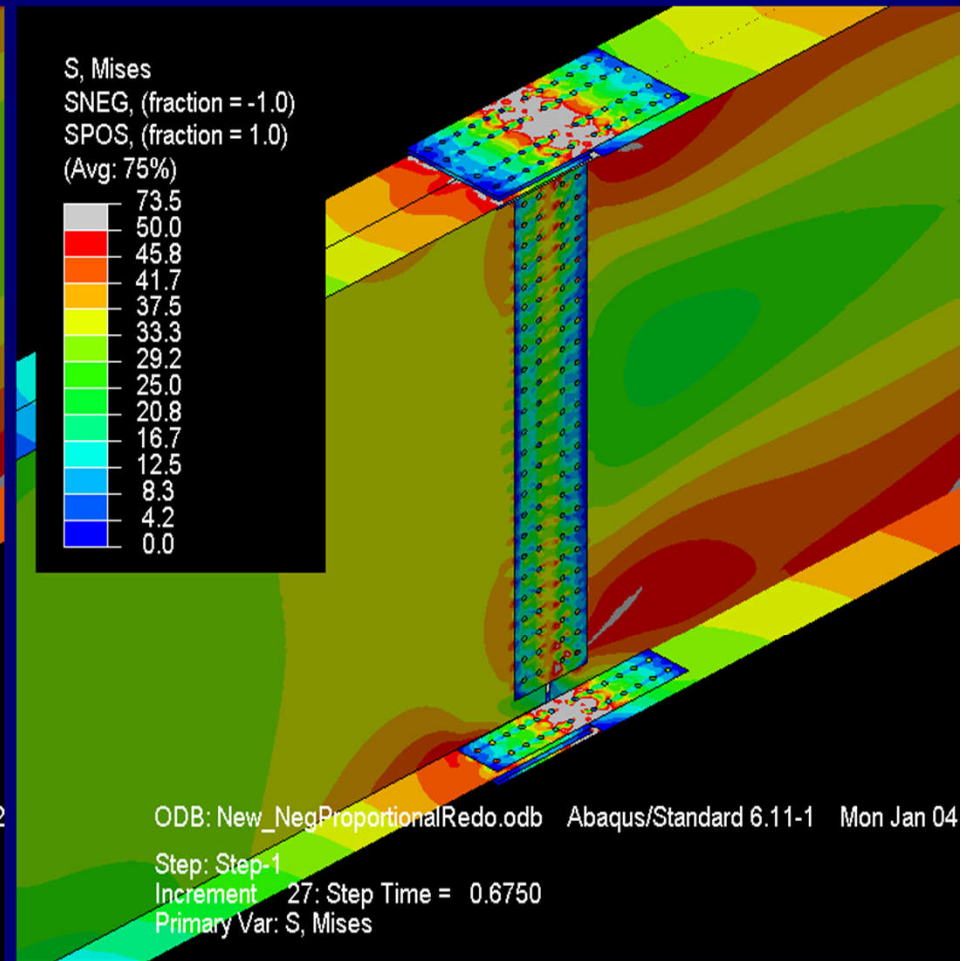
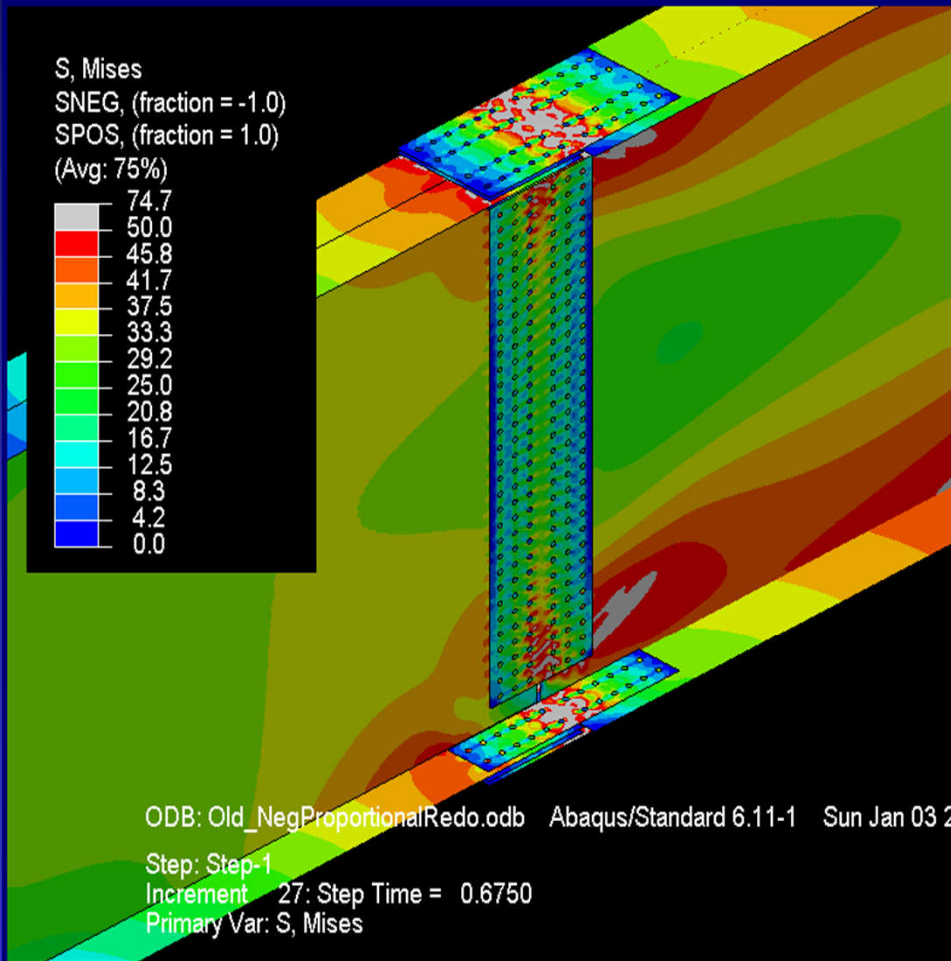


Results – Prop Neg Mom & Shear

Von Mises Stresses @ V_u

Viewport: 1 ODB: C:/Temp/Old_NegProportionalRedo.odb

Viewport: 2 ODB: C:/Temp/New_NegProportionalRedo.odb



CURRENT

PROPOSED

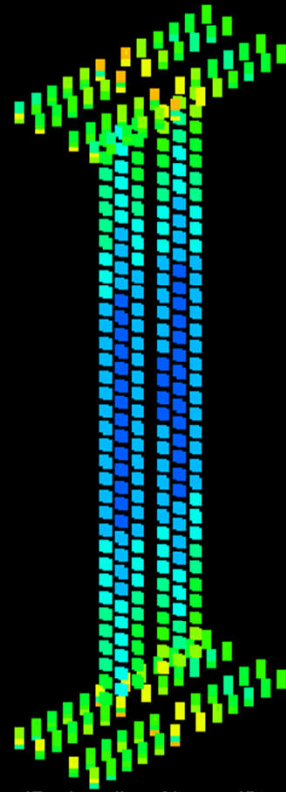
Results – Prop Neg Mom & Shear

Bolt Shear Forces @ V_u

Viewport: 1 ODB: C:/Temp/Old_NegProportionalRedo.odb

Viewport: 2 ODB: C:/Temp/New_NegProportionalRedo.odb

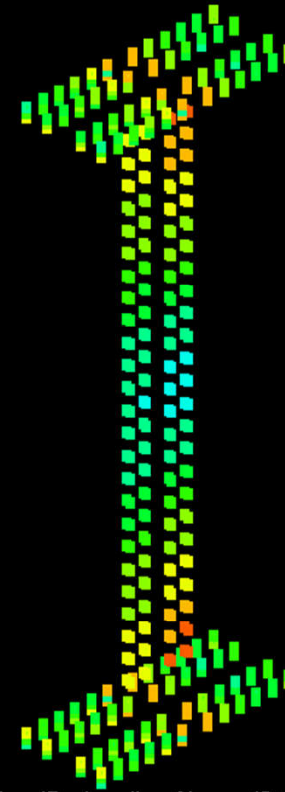
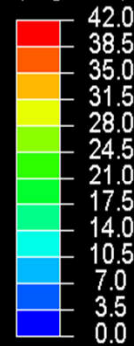
CTF_SRSS_Step27
(Avg: 75%)



ODB: Old_NegProportionalRedo.odb Abaqus/Standard 6.11-1 Sun Jan 03 2

Step: Session Step, Step for Viewer non-persistent fields
Session Frame
Primary Var: CTF_SRSS_Step27

CTF_SRSS_Step27
(Avg: 75%)



ODB: New_NegProportionalRedo.odb Abaqus/Standard 6.11-1 Mon Jan 04

Step: Session Step, Step for Viewer non-persistent fields
Session Frame
Primary Var: CTF_SRSS_Step27

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)						Factored 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	
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)
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	

Navigation: **FILE** | **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

The image shows a screenshot of the National Steel Bridge Alliance (NSBA) website. The top navigation bar includes links for AISC, CERTIFICATION, MEMBERSHIP, MODERN STEEL, BRIDGES (highlighted in blue), WHY STEEL, and CONFERENCE. A search bar and shopping cart icon are also present. Below the navigation bar is the NSBA logo (founded 1995) and a secondary menu with links for PRIZE BRIDGE AWARDS, PUBLICATIONS, DESIGN RESOURCES, WHY STEEL BRIDGES?, ABOUT, and EVENTS. The main content area features a large background image of a steel truss bridge over a snowy landscape. Overlaid on this image is the text 'NATIONAL STEEL BRIDGE ALLIANCE' and a vertical list of menu items: STEEL BRIDGE FORUMS, PRIZE BRIDGE AWARDS, DESIGN RESOURCES (highlighted with a red box), and AASHTO/NSBA COLLABORATION. At the bottom of the page, there is a section for 'Your NSBA Contact' and an 'EVENTS' button with a right-pointing arrow.

NSBA Splice Spreadsheet - Download



LRFD SIMON

Simon is a line-girder analysis software that can be used to analyze straight and low skew plate girder and tub girder bridges. Simon is perfect for those bridge projects that don't require a 3D finite model and where hand calculations would be too involved.

CONTINUE



NSBA SPLICE

NSBA Splice takes the time consuming task of designing and checking a bolted splice connection and rewrites the process as a simple input and output form. NSBA Splice allows the designer to quickly analyze various bolted splice connections to determine the most efficient bolt quantity and configuration.

CONTINUE



IRM EVALUATOR

The IRM Evaluator automates much of the process for evaluation of built-up members for internal redundancy. The IRM Evaluator follows provisions of the new *AASHTO Guide Specifications for Internal Redundancy of Mechanically-Fastened Built-up Steel Members* evaluating internal redundancy and establishing a special inspection interval.

CONTINUE

For questions regarding Design Resources, please send an email to nsbasimon@steelbridges.org.

NSBA Splice Spreadsheet - Download

IN THIS SECTION

- Steel Span to Weight Curves
- Continuous Span Standards
- LRFD Simon
- NSBA Splice**
- IRM Evaluator

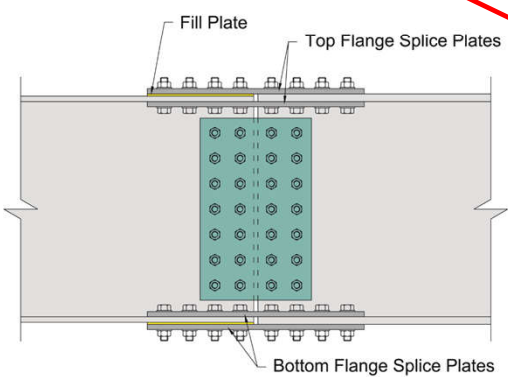
UPDATED: NSBA Splice

Sp NSBA Splice takes the time consuming task of designing and checking a bolted splice connection and rewrites the process with a simple input page and output form. NSBA Splice can be incorporated as a design tool on plate bridges allowing the designer to quickly analyze various bolted splice connections to determine the most efficient quantity and configuration. Based upon the updated AASHTO LRFD 8th Edition, Splice allows the user to explore effects of bolt spacing, bolt size, strength and connection dimensions on the overall splice design.

Splice is presented in an easy to understand Microsoft Excel spreadsheet format allowing users with Microsoft Excel 2010 or later to access and utilize. Included in the download is the design spreadsheet as well as two completed examples. The examples are the inputs and solutions for Examples 1 and 2 presented in [Bolted Field Splices for Steel Bridge Flexural Members](#).

The current version of NSBA Splice (v3.05) was released on August 2, 2019 ([Release Notes](#)).

[DOWNLOAD NSBA SPLICE](#)



Fill Plate
Top Flange Splice Plates
Bottom Flange Splice Plates

Design Guide

Spreadsheet Download

Result of Changes to Field Splice Design

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

A New Day- Another Bridge

