Basics of Bolted Field Splice Design

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National Steel Bridge Alliance

Importance of Good Design

Field Splice
600 Bolts in Web
42 Bolts each Flange
Total 684 bolts

Fabrication: 684 x $20 = $13,680
Erection: 684 x 10 min = 114 field hours each splice

Corman, Roger. (Director). (1957). Not of This Earth [Motion Picture]. United States: Allied Artists.
Shear Resistance – AASHTO 6.13.2.7

- Initial Length Reduction
  - Changed from 0.8 to 0.9.
  - Long Joint from 50 to 38 in.
- Bolts with threads excluded from the shear plane:
  - \( R_n = 0.56 \, A_b \, F_{ub} \, N_s \) (old value 0.48).
- Bolts with threads in the shear plane: (web bolts)
  - \( R_n = 0.45 \, A_b \, F_{ub} \, N_s \) (old value 0.38).
- Nominal shear resistance in lap tension connections longer than 38 in. taken as 0.83 times the values above.
LRFD Specification - Comparison

Slip Resistance – AASHTO 6.13.2.8

<table>
<thead>
<tr>
<th>Class</th>
<th>Typical Surface</th>
<th>7th Edition</th>
<th>8th Edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Mill Scale</td>
<td>0.33</td>
<td>0.30</td>
</tr>
<tr>
<td>B</td>
<td>Zinc Rich Paint, Metalized* and Blasted</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>C</td>
<td>Galvanized**</td>
<td>0.33</td>
<td>0.30</td>
</tr>
<tr>
<td>D</td>
<td>Organic Zinc Rich</td>
<td>-</td>
<td>0.45</td>
</tr>
</tbody>
</table>

* Unsealed metalized zinc or 85/15 zinc aluminum (t\textsubscript{coating} ≤ 16 mils). Sealed metalized coatings are not included – must be qualified by test.

** Do not wire brush the surface.

LRFD Specification - Comparison

Hole Size – AASHTO 6.13.2.4.2

- Maximum hole size in Table 6.13.2.4.2-1 for bolts greater than or equal to 1” in diameter is increased to the nominal diameter of the bolt plus 1/8”.
- Eliminates need to field ream holes to fit large-diameter hot forged bolts.
LRFD Specification - Comparison

Removed 75 percent and average rules in AASHTO LRFD Article 6.13.1.
Develop the full flange capacity.
  • Is it enough to carry factored moment?
  • If so... you are done.
Develop the full shear capacity of the web.
  • Assign the balance of the moment to the web force.
Design Procedure - Overview

Flange Splice Plate Sizing - Width

Outer Width: \( b_{outer} = \min(b_{f1}, b_{f2}) \)

Clearance: \( clearance \geq \max(t_{w1}, t_{w2}) + 2\left[\text{weld size} + \frac{1}{8}\right] \)

Inner Width: \( b_{inner} = \frac{b_f - clearance}{2} \)

Design Procedure - Overview

Flange Splice Plate Sizing - Thickness

Thickness: \( t_{splice} \geq \left(\frac{t_f}{2}\right) + \frac{1}{16} \)

10% Rule: \( 0.90b_{outer}t_{outer} \leq 2b_{inner}t_{inner} \leq 1.1b_{outer}t_{outer} \)

\( b_{inner} = \frac{b_f - clearance}{2} \)

\[ 0.90t_{outer} \leq \left[1 - \frac{\text{clearance}}{b_f}\right]t_{inner} \leq 1.1t_{outer} \]

\( \therefore \text{Solve for } t_{inner} \)
Design Procedure - Overview

Flange Splice Plate Sizing – Filler

• Typical where adjoining plates at the point of splice are different.
• Thickness is difference in thickness of adjoining flange or web plates.
• Reduction factor is applied to bolt shear resistance if filler is ¼" or greater.

Design Procedure - Overview

Web Splice Plate Sizing

• Symmetrically with plates on each side of web
• Splice plates must extend nearly the full web depth
• No filler plates needed if difference in web thickness is less than 1/16 inch.
• See AASHTO 6.13.6.1.3c
Design Procedure - Overview

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

Design Yield Resistance: \[ P_{fy} = F_{yf} A_e \] 6.13.6.1.3b-1

Effective Flange Area: \[ A_e = \left( \frac{\phi_u F_u}{\phi_y F_{yf}} \right) A_n \leq A_g \] 6.13.6.1.3b-2

Where:
- \( \phi_u = 0.80 \) resistance factor for fracture of tension members.
- \( \phi_y = 0.95 \) resistance factor for yielding of tension members.
- \( A_n \) = net area of the flange.
- \( A_g \) = gross area of the flange.
- \( F_{yf} \) = yield strength of the flange (Table 6.4.1-1).
- \( F_u \) = tensile strength of the flange (Table 6.4.1-1).

Positive Flange Moment Capacity Check

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

Moment Resistance:
- \( P_{fy} \) for the Bottom Flange x Moment Arm to Mid - Depth of Deck
  \[ = (F_{yf} \times A_e) \times A \]
**Design Procedure - Overview**

**Negative Flange Moment Capacity Check**

\[ P_{fy}(\text{top}) = F_{yf}A_e \]

\[ A = D + \frac{t_{ft}}{2} + \frac{t_{fe}}{2} \]

\[ P_{fy}(\text{bottom}) = F_{yf}A_e \]

Moment Resistance:
Smallest Value of \( P_{fy} \times \) Distance Between Flange Centroids
\( = (F_{yf} \times A_e) \times A \)

---

**Design Procedure - Overview**

**Flange Splice Bolts**

Minimum Number of Bolts:
\[ N_{min} = \frac{P_{fy}}{R_r R} \]

Where:
- \( P_{fy} \) = Design yield resistance of the flange.
- \( R_r \) = Factored shear resistance of the bolts.
- \( R \) = Reduction factor due to the presence of any filler plates.

Nominal Shear Resistance (Excluded):
\[ R_n = 0.56A_b F_{ub} N_S \quad 6.13.2.7-1 \]

Factored Shear Resistance:
\[ R_r = \phi_s R_n \]

Where:
- \( A_b \) = Area of the bolt corresponding to the nominal diameter.
- \( F_{ub} \) = Minimum tensile strength of the bolt specified (6.4.3.1.1).
- \( N_S \) = Number of shear planes per bolt (\( N_S = 2 \)).
- \( \phi_s \) = Resistance factor for shear of bolt (0.80).
Design Procedure - Overview

Design Web Connection to Develop the Smallest Factored Shear Resistance of the Connected Web.

Factored Shear Resistance of Web: \( V_r = \phi_v V_n \)

Where: \( \phi_v = \) Resistance factor for shear (1.0). 
\( V_n = \) Nominal shear resistance of the web (6.10.9 or 6.11.9).

---

If Moment From Flanges is Not Sufficient to Resist Factored Design Moment, Calculate Additional Moment to be Provided by the Web.

Web Design Force = Vector sum of smallest factored shear and horizontal force.

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

Where: \( V_r = \) Smaller factored shear resistance. 
\( H_w = \) Horizontal force in the web.
Design Procedure - Overview

Horizontal Web Force

• Composite Section in Positive Bending

Horizontal Force \( (H_w) \)
\[
H_w = \frac{\text{Web Moment}}{A_w}
\]

• Composite Section in Negative Bending

Horizontal Force \( (H_w) \)
\[
H_w = \frac{\text{Web Moment}}{D/4}
\]

• Non-Composite Section

Horizontal Force \( (H_w) \)
\[
A_w = \frac{D}{2} + t_{\text{haunch}} + \frac{t_s}{2}
\]
Design Procedure - Overview

Web Splice Bolts

Minimum Number of Bolts:

\[ N_{\text{min}} = \frac{\text{Web Design Force}}{R_r} \]

Nominal Shear Resistance (Included):

\[ R_n = 0.45A_b f_{ub} N_S \quad \text{(6.13.2.7-1)} \]

Factored Shear Resistance:

\[ R_r = \phi_s R_n \]

Where:
- \( \text{Web Design Force} = V_r \) or \( R \).
- \( R_r \) = Factored shear resistance of the bolts.
- \( \phi_s \) = Resistance factor for shear of bolt (0.80).

Anticipated Effect

- Slight increase in flange splice bolts.
- Significant decrease in web splice bolts.
- Overall simplification in the design procedure.
- Easier interpretation of the provisions.
- Faster and more efficient design of field splices.
- More consistent and cost-effective designs.
Design Procedure - Overview

<table>
<thead>
<tr>
<th></th>
<th>7th Edition</th>
<th>8th Edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Flange</td>
<td>24</td>
<td>20</td>
</tr>
<tr>
<td>Web</td>
<td>102</td>
<td>70</td>
</tr>
<tr>
<td>Bottom Flange</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Total – Per Side</td>
<td>154</td>
<td>118</td>
</tr>
</tbody>
</table>

Bolts Saved: 72x$20= $1,440
Labor Saved: 72x10 min= 12 field hours each splice

Basics of Bolted Field Splice Design

Case Study Bridge - Background
Bolted Field Splice – Case Study Bridge

Five Field Sections

Tip – Field sections should take into consideration common fabrication weight and length capabilities along with shipping and construction limitations. Reference AASHTO/NSBA Steel Bridge Collaboration “G12.1 Guidelines to Design for Constructability”.

Bolted Field Splice – Case Study Bridge

Four Bolted Field Splices

Tip – Marking field splices as “optional” gives fabricators the discretion of fabricating and shipping less pieces to the field.
Bolted Field Splice – Case Study Bridge (Flanges)

<table>
<thead>
<tr>
<th>Material</th>
<th>Grade 50W</th>
</tr>
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<tbody>
<tr>
<td>Thickness (in)</td>
<td>1</td>
</tr>
<tr>
<td>Width (in)</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>HPS Grade 70W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (in)</td>
<td>1</td>
</tr>
<tr>
<td>Width (in)</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Grade 50W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (in)</td>
<td>1/2</td>
</tr>
<tr>
<td>Depth (in)</td>
<td>69</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Grade 50W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (in)</td>
<td>3/8</td>
</tr>
<tr>
<td>Width (in)</td>
<td>18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>HPS Grade 70W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (in)</td>
<td>9/16</td>
</tr>
<tr>
<td>Depth (in)</td>
<td>69</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Grade 50W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (in)</td>
<td>1</td>
</tr>
<tr>
<td>Width (in)</td>
<td>20</td>
</tr>
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</table>
**Bolted Field Splice – Flange Splice Design**

### Unfactored Design Moments

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Moment (kip-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-composite Dead Load (DC₁)</td>
<td>248.00</td>
</tr>
<tr>
<td>Superimposed Composite Dead Load (DC₂)</td>
<td>50.00</td>
</tr>
<tr>
<td>Future Wearing Surface (DW)</td>
<td>52.00</td>
</tr>
<tr>
<td>Positive Live Load plus Impact (LL⁺ + I)</td>
<td>2,469.00</td>
</tr>
<tr>
<td>Negative Live Load plus Impact (LL⁻ + I)</td>
<td>-1,754.00</td>
</tr>
<tr>
<td>Deck Casting</td>
<td>1,300.00</td>
</tr>
</tbody>
</table>

### Factored Moments

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Moment (kip-ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Casting</td>
<td>1,820.00</td>
</tr>
<tr>
<td>Strength I - Positive</td>
<td>4,771.25</td>
</tr>
<tr>
<td>Strength I - Negative</td>
<td>-2,767.50</td>
</tr>
<tr>
<td>Service II - Positive</td>
<td>3,559.70</td>
</tr>
<tr>
<td>Service II - Negative</td>
<td>-1,930.20</td>
</tr>
</tbody>
</table>
### Bolted Field Splice – Flange Splice Design

#### Bolts: F3125 Grade A325

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (in)</td>
<td>7/8</td>
<td></td>
</tr>
<tr>
<td>Area (sq-in)</td>
<td>0.6013</td>
<td></td>
</tr>
<tr>
<td>$P_t$ (kip)</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Standard Hole Diameter (in)</td>
<td>15/16</td>
<td></td>
</tr>
<tr>
<td>Minimum Edge and End Distance (in)</td>
<td>1 1/8</td>
<td></td>
</tr>
</tbody>
</table>

#### Splice Plates – Top Flange

<table>
<thead>
<tr>
<th>Splice Plate Material</th>
<th>Inner</th>
<th>Outer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splice Plate Thickness (in)</td>
<td>11/16</td>
<td>5/8</td>
</tr>
<tr>
<td>Splice Plate Width (in)</td>
<td>7</td>
<td>16</td>
</tr>
<tr>
<td>$A_{gross}$ (sq-in)</td>
<td>9.62</td>
<td>10.00</td>
</tr>
<tr>
<td>% Difference $A_g$ Inner/Outer Area</td>
<td>3.82%</td>
<td></td>
</tr>
<tr>
<td>Shear Planes per Bolt ($N_s$)</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

**Tip** – Where the areas of the inside and outside flange splice plates do not differ by more than 10 percent, the connections may then be proportioned for the total flange design force assuming double shear.
Bolted Field Splice – Flange Splice Design

Flange Design Yield Resistance – Top Flange

Design Yield Resistance: \[ P_{fy} = F_{yf}A_e \] 6.13.6.1.3b-1

Effective Flange Area: \[ A_e = \left( \frac{\phi_uF_u}{\phi_yF_{yf}} \right) A_n \leq A_g \] 6.13.6.1.3b-2

\[ A_e = \left( \frac{0.80(70.0)}{0.95(50.0)} \right) \left[ 16 - 4 \left( \frac{15}{16} \right) \right] (1.0) = 14.41 \text{ in}^2 \]

\[ A_g = [16.0(1.0)] = 16.0 \text{ in}^2 \quad \therefore A_e = 14.41 \text{ in}^2 \]

\[ P_{fy} = 50.0(14.41) = 720.50 \text{ kips} \]

Tip – Left side of the splice has the smaller design yield resistance (i.e., the top flange on the left side has a smaller area and lower yield strength).

Bolted Field Splice – Flange Splice Design

Number of Bolts Required (Strength) – Top Flange

Nominal Shear Resistance (Excluded): \[ R_n = 0.56A_pF_{ub}N_S \] 6.13.2.7-1

Factored Shear Resistance:

\[ R_r = \phi_sR_n \]

Bolts Required:

\[ N = \frac{P_{fy}}{R_r} \]

\[ R_n = 0.56(0.6013)(120)(2) = 80.81 \text{ kip} \]

\[ R_r = 0.80(80.81) = 64.65 \text{ kip} \]

\[ N = \frac{720.5}{64.65} = 11.14 \]

\[ \therefore \text{Use 4 Rows with 3 Bolts Per Row Per Side} \]
Bolted Field Splice – Flange Splice Design

Splice Plates – Bottom Flange

<table>
<thead>
<tr>
<th></th>
<th>Inner</th>
<th>Outer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splice Plate Material</td>
<td>Grade 50W</td>
<td></td>
</tr>
<tr>
<td>Splice Plate Thickness (in)</td>
<td>7/8</td>
<td>3/4</td>
</tr>
<tr>
<td>Splice Plate Width (in)</td>
<td>8</td>
<td>18</td>
</tr>
<tr>
<td>Total $A_{gross}$ (sq-in)</td>
<td>14.00</td>
<td>13.50</td>
</tr>
<tr>
<td>% Difference $A_g$ Inner/Outer Area</td>
<td>3.64%</td>
<td></td>
</tr>
<tr>
<td>Shear Planes per Bolt ($N_s$)</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Tip – The width of the outside splice plate should be at least as wide as the width of the narrowest flange at the splice.

Bolted Field Splice – Flange Splice Design

Flange Design Yield Resistance – Bottom Flange

Left Side

\[
A_e = \left( \frac{0.8(70.0)}{0.95(50.0)} \right) \left[ 18 - 4\left( \frac{15}{16} \right) \right] (1.375) = 23.10 \text{ in}^2
\]

\[
A_g = [18.0(1.375)] = 24.75 \text{ in}^2 \quad \therefore A_e = 23.10 \text{ in}^2
\]

\[
P_{f_y} = 50.0(23.10) = 1,155.00 \text{ kips}
\]

Right Side

\[
A_e = \left( \frac{0.8(85.0)}{0.95(70.0)} \right) \left[ 20 - 4\left( \frac{15}{16} \right) \right] (1.0) = 16.61 \text{ in}^2
\]

\[
A_g = [20.0(1.0)] = 20.00 \text{ in}^2 \quad \therefore A_e = 16.61 \text{ in}^2
\]

\[
P_{f_y} = 70.0(16.61) = 1,162.70 \text{ kips}
\]

Tip – Filler plates are typical where adjoining plates at the point of splice are different. A reduction factor is applied to the bolt shear resistance where filler is \( \frac{1}{4} \) in or greater (6.13.6.1.4).
Bolted Field Splice – Flange Splice Design

Filler Plate Reduction – Bottom Flange

_Filler Thickness_ = (69.0 + 1.0 + 1.375) – (69.0 + 1.0 + 1.0) = 0.375 in

Filler Plate Reduction Factor:

\[ R_f = \left( \frac{1 + \gamma}{1 + 2\gamma} \right) \]

6.13.6.1.4-1

\[ \gamma = \frac{A_f}{A_p} = \frac{18.0(0.375)}{20.0(1.0)} = 0.338 \]

\[ R_f = \left[ \frac{(1 + 0.338)}{(1 + 2(0.338))} \right] = 0.798 \]

Tip – Adjacent girders are web centered, so the filler plate is the difference in height. If the girders were aligned differently, inner and outer filler plates may be necessary.

Bolted Field Splice – Flange Splice Design

Number of Bolts Required (Strength) – Bottom Flange

\[ R_n = 0.56(0.6013)(120)(2) = 80.81 \text{ kip} \]

\[ R_r = 0.80(80.81) = 64.65 \text{ kip} \]

\[ R_f = 0.798 \]

\[ N = \frac{P_{fy}}{R_f(R_r)} = \frac{1155.00}{0.798(64.65)} = 22.39 \]

\[ \therefore \text{Use 4 Rows with 6 Bolts Per Row Per Side} \]
Bolted Field Splice – Flange Splice Design

Moment Resistance - Positive

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

\[ 69.00 + \frac{1.375}{2} + 3.5 + \frac{9.0}{2} = 77.69 \text{ in} \]

\[ P_{fy}(\text{bottom}) = 1,155 \text{ kips} \]

\[ M_{\text{flange}} = P_{fy} \left(\frac{A}{12}\right) > |\text{Strength I - Positive (kip-ft)}| \]

\[ 1,155(77.69/12) = 7,477 \text{ kip-ft} > |4,771 \text{ kip-ft}| \]

Bolted Field Splice – Flange Splice Design

Moment Resistance - Negative

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

\[ 69.00 + \frac{1.0}{2} + \frac{1.375}{2} = 70.19 \text{ in} \]

\[ P_{fy}(\text{top}) = 720.50 \text{ kips} \]

\[ P_{fy}(\text{bottom}) = 1,155.00 \text{ kips} \]

\[ M_{\text{flange}} = P_{fy} \left(\frac{A}{12}\right) > |\text{Strength I - Negative (kip-ft)}| \]

\[ 720(70.19/12) = 4,211 \text{ kip-ft} > |2,767 \text{ kip feet}| \]
Bolted Field Splice – Flange Splice Design

Summary

<table>
<thead>
<tr>
<th>Flange</th>
<th>Bolt Rows (Per Side)</th>
<th>Total Bolts (Per Side)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Bottom</td>
<td>4</td>
<td>24</td>
</tr>
</tbody>
</table>

Additional Considerations

- Factored Yield Resistance - Tension
- Net Section to Gross Section Check - Tension
- Net Section Fracture Resistance - Tension
- Block Shear Rupture Resistance – Splice Plates
- Block Shear Rupture Resistance – Girder
- Bearing Resistance Check
- Slip Resistance
- Entering and Tightening Clearances

Basics of Bolted Field Splice Design

Case Study Bridge – Web Bolt Design
Bolted Field Splice – Case Study Bridge (Web)

Material | Grade 50W | Thickness (in) | 1
Width (in) | 16

Material | HPS Grade 70W | Thickness (in) | 1
Width (in) | 18

Material | Grade 50W | Thickness (in) | 1/2
Depth (in) | 69

Material | Grade 50W | Thickness (in) | 9/16
Depth (in) | 69

Material | Grade 50W | Thickness (in) | 1 3/8
Width (in) | 18

Material | HPS Grade 70W | Thickness (in) | 1
Width (in) | 20

Unfactored Design Shears

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Shear (kip)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-composite Dead Load (DC₁)</td>
<td>-82.00</td>
</tr>
<tr>
<td>Superimposed Composite Dead Load (DC₂)</td>
<td>-12.00</td>
</tr>
<tr>
<td>Future Wearing Surface (DW)</td>
<td>-11.00</td>
</tr>
<tr>
<td>Positive Live Load plus Impact (LL⁺ + I)</td>
<td>19.00</td>
</tr>
<tr>
<td>Negative Live Load plus Impact (LL⁻ + I)</td>
<td>-112.00</td>
</tr>
<tr>
<td>Deck Casting</td>
<td>-82.00</td>
</tr>
</tbody>
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Bolted Field Splice – Web Splice Design

Factored Shears

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Shear (kip)</th>
</tr>
</thead>
<tbody>
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<td>Deck Casting</td>
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<tr>
<td>Service II - Positive</td>
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<tr>
<td>Service II - Negative</td>
<td>-250.60</td>
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Bolted Field Splice – Web Splice Design

Bolts: F3125 Grade A325

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (in)</td>
<td>7/8</td>
</tr>
<tr>
<td>Area (sq-in)</td>
<td>0.6013</td>
</tr>
<tr>
<td>$P_t$ (kip)</td>
<td>39</td>
</tr>
<tr>
<td>Standard Hole Diameter</td>
<td>15/16</td>
</tr>
<tr>
<td>Minimum Edge and End</td>
<td>1 1/8</td>
</tr>
<tr>
<td>Distance (in)</td>
<td></td>
</tr>
</tbody>
</table>
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Number of Bolts Required (Strength)

Factored Shear Resistance: \( V_r = \phi_v V_n \)

Web Depth: 69 in
Left Web Thickness: 1/2 in
\( A_{\text{gross}} = 34.50 \text{ sq-in} \)
\( E = 29,000 \text{ ksi} \)
\( F_y = 50 \text{ ksi} \)
Transverse-stiffener spacing: 17’ – 3”

\[ V_r = 1.0(468) = 468 \text{ kips} \]

\[ R = \sqrt{(V_r)^2 + (H_w)^2} = 468 \text{ kips} \]

Design Procedure - Web Splice Design

Number of Bolts Required (Strength)

Nominal Shear Resistance (Included): \( R_n = 0.45A_p F_{ub} N_S \)
Factored Shear Resistance: \( R_r = \phi_s R_n \)

Bolts Required: \( N = \frac{V_r}{R_r} \)

Are we done?

\( R_n = 0.45(0.6013)(120)(2) = 64.94 \text{ kip} \)
\( R_r = 0.80(64.94) = 51.95 \text{ kip} \)

\[ N = \frac{V_r}{R_r} = \frac{468}{51.95} = 9.00 \]

∴ Use 2 Rows with 5 Bolts Per Row Per Side
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Number of Bolts Required (Seal)

\[
t_{splice} \geq \left( \frac{t_w}{2} \right) + \frac{1}{16} = \frac{1}{2} \left( \frac{1}{2} \right) + \frac{1}{16} = \frac{5}{16} \text{ in}
\]

\[
s_{max} \leq 4.0 + 4 \left[ \frac{5}{16} \right] = 5.25 \text{ in}
\]

\[
N_{min} = 1 + \left[ \frac{69 - 2 (3)}{5.25} \right] = 13 \text{ (per row)}
\]

∴ Use 2 Rows with 13 Bolts Per Row Per Side
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Summary

<table>
<thead>
<tr>
<th>Bolt Rows (Per Side)</th>
<th>Total Bolts (Per Side)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>26</td>
</tr>
</tbody>
</table>

Additional Considerations

- Factored Shear Yielding Resistance
- Factored Shear Rupture Resistance
- Block Shear Rupture Resistance - Splice Plates
- Bearing Resistance
- Slip Resistance
- Entering and Tightening Clearances
### Designer Resources – Excel Spreadsheet

#### New Feature - Results Override

<table>
<thead>
<tr>
<th>Miscellaneous Properties</th>
<th>Drilled - Full Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splice Plate Hole Method</td>
<td>17.2500</td>
</tr>
<tr>
<td>Transverse Stiffener Spacing (d,) (b)</td>
<td></td>
</tr>
<tr>
<td>Alignment Mode</td>
<td>Web Center</td>
</tr>
</tbody>
</table>

**Bolt Count Overrides**

<table>
<thead>
<tr>
<th>Count Override Status</th>
<th>Bolt Count - Calculated</th>
<th>Bolt Count - User Specified</th>
<th>Valid Override</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Flange Bolt Count Override</td>
<td>User Specified</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Web Bolt Count Override</td>
<td>Spreadsheet Calculated</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>Bottom Flange Bolt Count Override</td>
<td>Spreadsheet Calculated</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>
Designer Resources – Design Guide

www.steelbridges.org/nsbas splice