Steel construction: bolts, welds & light gages
Connections

• **needed to:**
  – support beams by columns
  – connect truss members
  – splice beams or columns

• **transfer load**

• **subjected to**
  – tension or compression
  – shear
  – bending
Bolts

- **bolted steel connections**
Welds

• welded steel connections
Bolts

- **types**
  - **materials**
    - high strength
    - A307, A325, A490
  - **location of threads**
    - included - N
    - excluded - X
  - **friction or bearing (SC)**
    - always tightened
Bolted Connection Design

- considerations
  - bearing stress
    - yielding
  - shear stress
    - single & double
  - member
    - rupture
Bolts

• rarely fail in bearing
• holes considered 1/8” larger
• shear & tension
  – single shear or tension
    \[ R_a \leq \frac{R_n}{\Omega} \]
    \[ R_{u} \leq \phi_v R_n \]
    \[ \phi_v = 0.75 \]
  – double shear
    \[ R_n = F_n A_b \]
    \[ R_n = F_n 2 A_b \]
# Bolts

## Table 7-1 Available Shear Strength of Bolts, kips

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter, d, in.</th>
<th>3/8</th>
<th>3/4</th>
<th>7/8</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nominal Bolt Area, in.²</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.307</td>
<td>0.442</td>
<td>0.601</td>
<td>0.785</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASTM Design.</th>
<th>Thread Cond.</th>
<th>F_s (ksi)</th>
<th>( \phi_F )</th>
<th>F_t (ksi)</th>
<th>( \phi_T )</th>
<th>F_a (ksi)</th>
<th>( \phi_A )</th>
<th>F_w (ksi)</th>
<th>( \phi_W )</th>
<th>F_p (ksi)</th>
<th>( \phi_P )</th>
<th>F_y (ksi)</th>
<th>( \phi_Y )</th>
<th>F_d (ksi)</th>
<th>( \phi_D )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASD</strong></td>
<td><strong>LRFD</strong></td>
<td></td>
<td></td>
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<tr>
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<td>N</td>
<td>27.0</td>
<td>40.5</td>
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<td></td>
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<td>51.0</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>N</td>
<td>34.0</td>
<td>51.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>X</td>
<td>42.0</td>
<td>63.0</td>
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</tr>
</tbody>
</table>

## Table 7-2 Available Tensile Strength of Bolts, kips

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter, d, in.</th>
<th>1/8</th>
<th>1/4</th>
<th>3/8</th>
<th>1/2</th>
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<tr>
<td><strong>Nominal Bolt Area, in.²</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>0.307</td>
<td>0.442</td>
<td>0.601</td>
<td>0.785</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ASTM Design.</th>
<th>Thread Cond.</th>
<th>F_s (ksi)</th>
<th>( \phi_F )</th>
<th>F_t (ksi)</th>
<th>( \phi_T )</th>
<th>F_a (ksi)</th>
<th>( \phi_A )</th>
<th>F_w (ksi)</th>
<th>( \phi_W )</th>
<th>F_p (ksi)</th>
<th>( \phi_P )</th>
<th>F_y (ksi)</th>
<th>( \phi_Y )</th>
<th>F_d (ksi)</th>
<th>( \phi_D )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASD</strong></td>
<td><strong>LRFD</strong></td>
<td></td>
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<tr>
<td>Group A</td>
<td>N</td>
<td>27.0</td>
<td>40.5</td>
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<td></td>
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<tr>
<td></td>
<td>X</td>
<td>34.0</td>
<td>51.0</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Group B</td>
<td>N</td>
<td>34.0</td>
<td>51.0</td>
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<tr>
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<td>63.0</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **ASD**       | **LRFD**    |          |        |          |        |          |        |          |        |          |        |          |        |          |          |
| Omega (\( \Omega \)) | 2.00 | \( \phi = 0.75 \) |          |        |          |        |          |        |          |        |          |        |          |          |

*For end loaded connections greater than 30 in, see AISC Specification Table J3.2 footnote b.*

---

Steel Bolts & Welding 8
Lecture 18

Architectural Structures
ARCH 331

http://www.fastenal.com

Su2014abn
Bolts

• bearing

\[ R_a \leq \frac{R_n}{\Omega} \]

\[ R_u \leq \phi R_n \]

\[ \phi = 0.75 \]

– deformation is concern

\[ R_n = 1.2 L_c t F_u \leq 2.4 d t F_u \]

– deformation isn’t concern

\[ R_n = 1.5 L_c t F_u \leq 3.0 d t F_u \]

– long slotted holes

\[ R_n = 1.0 L_c t F_u \leq 2.0 d t F_u \]

\( L_c \) – clear length to edge or next hole (ex. 1¼”, 3”)

\( \Omega \) – factor of safety

\( d \) – diameter of bolt

\( t \) – thickness of element

\( F_u \) – ultimate tensile strength
### Table 7-5
Available Bearing Strength at Bolt Holes Based on Edge Distance (kips/in. thickness)

<table>
<thead>
<tr>
<th>Hole Type</th>
<th>Edge Distance</th>
<th>$F_a$ ksi</th>
<th>Nominal Bolt Diameter, $d$, in.</th>
<th>$F_b/\Omega$</th>
<th>$F_d/\Omega$</th>
<th>$F_f/\Omega$</th>
<th>$F_f/\Omega$</th>
<th>$F_i/\Omega$</th>
<th>$F_i/\Omega$</th>
<th>$F_i/\Omega$</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>$L_e$, in.</td>
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<td></td>
<td>ASD</td>
<td>LRFD</td>
<td>ASD</td>
<td>LRFD</td>
<td>ASD</td>
<td>LRFD</td>
<td>ASD</td>
</tr>
<tr>
<td>STD SSLT</td>
<td>1 1/4</td>
<td>58</td>
<td>31.5</td>
<td>47.3</td>
<td>23.9</td>
<td>40.8</td>
<td>27.3</td>
<td>13.3</td>
<td>51.1</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>65</td>
<td>35.3</td>
<td>50.6</td>
<td>27.9</td>
<td>42.0</td>
<td>24.7</td>
<td>14.2</td>
<td>56.1</td>
<td>24.7</td>
</tr>
<tr>
<td>SSLP</td>
<td>1 1/4</td>
<td>58</td>
<td>28.3</td>
<td>42.4</td>
<td>23.9</td>
<td>40.8</td>
<td>27.3</td>
<td>13.3</td>
<td>51.1</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>65</td>
<td>31.7</td>
<td>47.3</td>
<td>27.9</td>
<td>42.0</td>
<td>24.7</td>
<td>14.2</td>
<td>56.1</td>
<td>24.7</td>
</tr>
<tr>
<td>OVS</td>
<td>1 1/4</td>
<td>58</td>
<td>26.3</td>
<td>44.0</td>
<td>26.1</td>
<td>40.8</td>
<td>24.7</td>
<td>14.2</td>
<td>51.1</td>
<td>23.3</td>
</tr>
<tr>
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<td>65</td>
<td>28.8</td>
<td>50.6</td>
<td>27.9</td>
<td>42.0</td>
<td>24.7</td>
<td>14.2</td>
<td>56.1</td>
<td>24.7</td>
</tr>
<tr>
<td>LSLP</td>
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<td>58</td>
<td>24.3</td>
<td>52.2</td>
<td>27.9</td>
<td>42.0</td>
<td>24.7</td>
<td>14.2</td>
<td>44.0</td>
<td>27.9</td>
</tr>
<tr>
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<td>24</td>
<td>65</td>
<td>26.8</td>
<td>54.3</td>
<td>27.9</td>
<td>42.0</td>
<td>24.7</td>
<td>14.2</td>
<td>49.3</td>
<td>27.9</td>
</tr>
</tbody>
</table>

### Table 7-3 (continued)
Slip-Critical Connections
Available Shear Strength, kips (Class A Faying Surface, $\mu = 0.30$)

<table>
<thead>
<tr>
<th>Group B Bolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Bolt Diameter, $d$, in.</td>
</tr>
<tr>
<td>$F_b/\Omega$</td>
</tr>
<tr>
<td>ASD</td>
</tr>
<tr>
<td>STD SSLT</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>OVS SSLP</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>LSL</td>
</tr>
<tr>
<td>S</td>
</tr>
<tr>
<td>D</td>
</tr>
</tbody>
</table>

STD = standard hole
SSLT = short-slotted hole oriented transverse to the line of force
SSLP = short-slotted hole oriented parallel to the line of force
OVS = oversized hole
LSL = long-slotted hole oriented parallel or transverse to the line of force

Note: Slip-critical bolt values assume no more than one filler has been provided or bolts have been added to distribute loads in the fillers.
Welded Connection Design

- shear stress
- yielding
- rupture
Welded Connection Design

- **weld terms**
  - butt weld
  - fillet weld
  - plug weld
  - throat

- **field welding**
- **shop welding**
Welded Connection Design

• **weld process**
  – melting of material
  – melted filler - electrode
  – shielding gas / flux
  – potential defects

• **weld materials**
  – E60XX
  – E70XX
  \[ F_{EXX} = 70 \text{ ksi} \]
Welded Connection Design

• shear failure assumed
• throat
  – \( T = 0.707 \times \text{weld size} \)
• area
  – \( A = T \times \text{length of weld} \)
• weld metal generally stronger than base metal (ex. \( F_y = 50 \text{ ksi} \))
Welded Connection Design

- **minimum**
  - table
- **maximum**
  - material thickness (to ¼”)
  - 1/16” less
- **min. length**
  - 4 x size min.
  - ≥ 1 ½”

---

**TABLE J2.4**
Minimum Size of Fillet Welds

<table>
<thead>
<tr>
<th>Material Thickness of Thicker Part Joined, in. (mm)</th>
<th>Minimum Size of Fillet Weld[a] in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>To 1/8 (6) inclusive</td>
<td>1/16 (3)</td>
</tr>
<tr>
<td>Over 1/8 (6) to 1/4 (13)</td>
<td>3/32 (5)</td>
</tr>
<tr>
<td>Over 1/4 (13) to 5/32 (19)</td>
<td>1/32 (6)</td>
</tr>
<tr>
<td>Over 5/32 (19)</td>
<td>3/64 (8)</td>
</tr>
</tbody>
</table>

[a] Leg dimension of fillet welds. Single pass welds must be used.
[b] See Section J2.25 for maximum size of fillet welds.
Welded Connection Design

- shear

\[ R_a \leq \frac{R_n}{\Omega} \]
\[ R_u \leq \phi R_n \]
\[ \phi = 0.75 \]

\[ R_n = 0.6F_{EXX} Tl = Sl \]

- table for \( \phi \)S

| Available Strength of Fillet Welds per inch of weld (\( \phi \)S) |
|-----------------|-----------------|-----------------|
| Weld Size (in.) | E60XX (k/in.)   | E70XX (k/in.)   |
| \( \frac{3}{8} \) | 3.58            | 4.18            |
| \( \frac{1}{4} \) | 4.77            | 5.57            |
| \( \frac{5}{32} \) | 5.97            | 6.96            |
| \( \frac{3}{32} \) | 7.16            | 8.35            |
| \( \frac{1}{16} \) | 8.35            | 9.74            |
| \( \frac{1}{8} \) | 9.55            | 11.14           |
| \( \frac{5}{16} \) | 11.93           | 13.92           |
| \( \frac{3}{4} \) | 14.32           | 16.70           |

(not considering increase in throat with submerged arc weld process)
Framed Beam Connections

- **angles**
  - bolted
  - welded
Framed Beam Connections

- terms
  - coping

(AISC - Steel Structures of the Everyday)
Framed Beam Connections

- tables for standard bolt sizes & spacings
- # bolts
- bolt diameter, angle leg thickness
- bearing on beam web
Framed Beam Connections

- welded example (shear)

(AISC - Steel Structures of the Everyday)
Framed Beam Connections

• welded moment example

(AISC - Steel Structures of the Everyday)
Framed Beam Connections

• welded/bolted moment example

(AISC - Steel Structures of the Everyday)
Framed Beam Connections

• welded/bolted moment example

(AISC - Steel Structures of the Everyday)
Beam Connections

• LRFD provisions
  – shear yielding
  – shear rupture
  – block shear rupture
  – tension yielding
  – tension rupture
  – local web buckling
  – lateral torsional buckling
Beam Connections \( \phi = 0.75 \)

\[ R_n = 0.6F_u A_{nv} + U_{bs} F_u A_{nt} \leq 0.6F_y A_{gv} + U_{bs} F_u A_{nt} \]

– where \( U_{bs} \) is 1 for uniform tensile stress

Figure 2-1. Block Shear Rupture Limit State
(Photo by J.A. Swanson and R. Leon, courtesy of Georgia Institute of Technology)

Figure 2-14. Tension Fracture Limit State
(Photo by J.A. Swanson and R. Leon, courtesy of Georgia Institute of Technology)

block shear rupture

tension rupture
Other Connections

• seated beam
• continuous
  – beam to column
  – beam to beam
Other Connections

- splices
Other Connections

- rigid frame knees
- gussets & joints

(AISC - Steel Structures of the Everyday)
Other Connections

- base plates
  - anchor bolts
  - bearing on steel
  - bending of plate

http://courses.civil.ualberta.ca