Steel Connections: bolts, welds & tension members
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
Fasteners

- wood connections
Bolted Connection Design

- considerations
  - bearing stress
    - yielding
  - shear stress
    - single & double
  - member
    - rupture
Bolted Connection Design

- **ASD steel**
  - shear:
    \[ f_v \leq F_v \]
  - bolt strengths
  - single & double
- **Bolt types**
  - A325-SC, A490-SC
  - A325-N, A490-N
  - A325-X, A490-X

### Table: Shear

<table>
<thead>
<tr>
<th>Nominal Diameter d, in.</th>
<th>3/8</th>
<th>7/32</th>
<th>1/4</th>
<th>1/2</th>
<th>3/4</th>
<th>1</th>
<th>1 1/4</th>
<th>1 1/2</th>
<th>1 3/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area (Based on Normal Diameter in.)</td>
<td>in.²</td>
<td>3/8</td>
<td>7/32</td>
<td>1/4</td>
<td>1/2</td>
<td>3/4</td>
<td>1</td>
<td>1 1/4</td>
<td>1 1/2</td>
</tr>
<tr>
<td>3/8</td>
<td>STD</td>
<td>0.36</td>
<td>0.19</td>
<td>0.14</td>
<td>0.18</td>
<td>0.25</td>
<td>0.32</td>
<td>0.46</td>
<td>0.61</td>
</tr>
<tr>
<td>3/8</td>
<td>A325</td>
<td>0.46</td>
<td>0.28</td>
<td>0.22</td>
<td>0.29</td>
<td>0.41</td>
<td>0.55</td>
<td>0.82</td>
<td>1.09</td>
</tr>
<tr>
<td>3/8</td>
<td>A490</td>
<td>0.56</td>
<td>0.32</td>
<td>0.25</td>
<td>0.34</td>
<td>0.49</td>
<td>0.68</td>
<td>0.97</td>
<td>1.30</td>
</tr>
<tr>
<td>3/8</td>
<td>A502/1</td>
<td>0.66</td>
<td>0.39</td>
<td>0.31</td>
<td>0.42</td>
<td>0.61</td>
<td>0.86</td>
<td>1.25</td>
<td>1.68</td>
</tr>
<tr>
<td>3/8</td>
<td>A502-2</td>
<td>0.77</td>
<td>0.44</td>
<td>0.36</td>
<td>0.48</td>
<td>0.70</td>
<td>1.01</td>
<td>1.47</td>
<td>2.02</td>
</tr>
<tr>
<td>3/8</td>
<td>A36</td>
<td>1.06</td>
<td>0.60</td>
<td>0.48</td>
<td>0.66</td>
<td>0.96</td>
<td>1.38</td>
<td>2.00</td>
<td>2.90</td>
</tr>
<tr>
<td>3/8</td>
<td>X-STD</td>
<td>1.33</td>
<td>0.76</td>
<td>0.60</td>
<td>0.84</td>
<td>1.22</td>
<td>1.78</td>
<td>2.63</td>
<td>3.90</td>
</tr>
</tbody>
</table>
Bolted Connection Design

- ASD steel
  - bearing:
    - bolts rarely fail by bearing
    - other part fails first
Tension Members

- steel members can have holes
- reduced area
- increased stress
Effective Net Area

- likely path to “rip” across
- bolts divide transferred force too
ASD – Tension Members

- non-pin connected members:
  - $F_t = 0.60F_y$ on gross area
  - $F_t = 0.50F_u$ on net area

- pin connected members:
  - $F_t = 0.45F_y$ on net area

- threaded rods of approved steel:
  - $F_t = 0.33F_u$ on major diameter
  - (for static loading only)
LRFD - Tension Members

- limit states for failure
  
  \[ P_u \leq \phi_t P_n \]

  1. yielding
    \[ \phi_t = 0.9 \quad P_n = F_y A_g \]

  2. rupture*
    \[ \phi_t = 0.75 \quad P_n = F_u A_e \]

\[ A_g - \text{gross area} \]

\[ A_e - \text{effective net area} \]

\[ F_u - \text{tensile strength of the steel (ultimate)} \]
Welded Connection Design

• considerations
  – shear stress
  – yielding
  – rupture
Welded Connection Design

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

- **weld materials**
  - E60XX
  - E70XX
  - $F_{EXX} = 70$ ksi

<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 $\frac{1}{4}$ (6) Inclusive</td>
<td>$\frac{1}{8}$ (3)</td>
</tr>
<tr>
<td>Over $\frac{1}{4}$ (6) to $\frac{1}{2}$ (13)</td>
<td>$\frac{1}{8}$ (5)</td>
</tr>
<tr>
<td>Over $\frac{1}{2}$ (13) to $\frac{3}{4}$ (19)</td>
<td>$\frac{1}{8}$ (6)</td>
</tr>
<tr>
<td>Over $\frac{3}{4}$ (19)</td>
<td>$\frac{3}{8}$ (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

- **ASD**
  - shear \( f_v \leq F_v \)
    - \( F_v = 0.30F_{\text{weld}} \)
  - throat
    - \( T = 0.707 \times \text{weld size} \)
  - area
    - \( A = T \times \text{length of weld} \)
  - weld metal generally stronger than base metal (ex. \( F_y = 50 \text{ ksi} \))
Framed Beam Connections

• angles
  – bolted
  – welded
Framed Beam Connections

• terms
  – coping
Framed Beam Connections

- tables for standard bolt holes & spacings
- \( n = \# \) bolts
- angle leg thickness
- length needed

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Bolt Shear(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolt Type</td>
<td>A325-N</td>
</tr>
<tr>
<td>( F_s, \text{ Ksi} )</td>
<td>21.0</td>
</tr>
<tr>
<td>Bolt Dia, ( d ) in.</td>
<td>( \frac{1}{4} )</td>
</tr>
<tr>
<td>Angle Thickness</td>
<td>( \frac{1}{8} )</td>
</tr>
<tr>
<td>( L ) in.</td>
<td>( L' ) in.</td>
</tr>
<tr>
<td>25%</td>
<td>10</td>
</tr>
<tr>
<td>25%</td>
<td>9</td>
</tr>
<tr>
<td>25%</td>
<td>8</td>
</tr>
<tr>
<td>22%</td>
<td>7</td>
</tr>
<tr>
<td>19%</td>
<td>6</td>
</tr>
<tr>
<td>15%</td>
<td>5</td>
</tr>
<tr>
<td>11%</td>
<td>4</td>
</tr>
<tr>
<td>( ^)</td>
<td></td>
</tr>
</tbody>
</table>
Beam Connections

- LRFD provisions
  - shear yielding
  - shear rupture
  - block shear rupture
  - tension yielding
  - tension rupture
  - local web buckling
  - lateral torsional buckling
Beam Connections

- block shear rupture
- tension rupture