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

| ASNV | Connection Type | Hole Dia. | Lead | \( P_{in} \) | \( P_{out} \) | \( P_{in} \) | \( P_{out} \) | \( P_{in} \) | \( P_{out} \) | \( P_{in} \) | \( P_{out} \) | \( P_{in} \) | \( P_{out} \) | \( P_{in} \) | \( P_{out} \) |
|------|-----------------|----------|------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| 3/8  | STD             | 10.6     | D    | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        |
| 5/8  | STD             | 12.1     | D    | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        |
| 7/8  | STD             | 15.7     | D    | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        |
| 1"   | STD             | 21.0     | D    | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        |
| 1 1/4 | STD           | 30.0     | D    | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        | 0.1         | 0.45        |

### BOLTS, THREADED PARTS AND RIVETS

#### Shear

**Allowable load in kips**
Bolted Connection Design

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

---

### BOLTS AND THREADED PARTS Bearing

**Allowable loads in kips**

#### TABLE BEARING

<table>
<thead>
<tr>
<th>Material Thickness</th>
<th>( F_u = 58 , \text{ksi} ) Bolt dia.</th>
<th>( F_u = 65 , \text{ksi} ) Bolt dia.</th>
<th>( F_u = 70 , \text{ksi} ) Bolt dia.</th>
<th>( F_u = 100 , \text{ksi} ) Bolt dia.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{3}{8} )</td>
<td>6.5</td>
<td>7.6</td>
<td>9.7</td>
<td>7.3</td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>9.8</td>
<td>11.4</td>
<td>13.1</td>
<td>11.0</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>13.1</td>
<td>15.2</td>
<td>17.4</td>
<td>14.6</td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>18.3</td>
<td>21.0</td>
<td>23.9</td>
<td>18.9</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>18.6</td>
<td>22.0</td>
<td>26.1</td>
<td>21.9</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>22.8</td>
<td>26.6</td>
<td>30.5</td>
<td>25.6</td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>28.1</td>
<td>30.5</td>
<td>34.8</td>
<td>29.3</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>29.4</td>
<td>34.3</td>
<td>39.2</td>
<td>32.9</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>32.5</td>
<td>38.1</td>
<td>43.6</td>
<td>36.3</td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>41.5</td>
<td>47.9</td>
<td>53.8</td>
<td>46.9</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>45.7</td>
<td>52.2</td>
<td>59.6</td>
<td>53.5</td>
</tr>
<tr>
<td>( \frac{3}{4} )</td>
<td>55.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \frac{1}{2} )</td>
<td>60.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>52.2</td>
<td>60.9</td>
<td>69.6</td>
<td>58.5</td>
</tr>
</tbody>
</table>
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**
  - 1. **yielding**
    \[ P_u \leq \phi_t P_n \]
    \[ \phi_t = 0.9 \quad P_n = F_y A_g \]
  - 2. **rupture**
    \[ \phi_t = 0.75 \quad P_n = F_u A_e \]

\( A_g \) - gross area
\( A_e \) - effective net area
\( F_u \) - tensile strength of the steel (ultimate)
Welded Connection Design

- shear stress
- yielding
- rupture
Welded Connection Design

• weld terms
  – butt weld
  – fillet weld
  – plug weld
  – throat

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

![Diagram of weld connections]

### 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 ( \frac{1}{4} ) (6) Inclusive&lt;br&gt;Over ( \frac{1}{4} ) (6) to ( \frac{1}{2} ) (13)&lt;br&gt;Over ( \frac{1}{2} ) (13) to ( \frac{3}{4} ) (19)&lt;br&gt;Over ( \frac{3}{4} ) (19)</td>
<td>( \frac{1}{8} ) (3)&lt;br&gt;( \frac{3}{8} ) (5)&lt;br&gt;( \frac{1}{4} ) (6)&lt;br&gt;( \frac{5}{16} ) (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 \( f_v \leq F_v \)
    - \( F_v = 0.30 F_{weld} \)
  - 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

---

Framed Beam Connections

Bolted

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Allowable loads in kips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

STAGGERED BOLT ALTERNATE

Note: For $L = 2\frac{1}{2}$ use one half the tabular load value shown for $L = 5\frac{1}{2}$, for the same bolt type, diameter, and thickness.

---

<table>
<thead>
<tr>
<th>TABLE</th>
<th>Bolt Shear</th>
<th>For bolts in bearing-type connections with standard or slotted holes.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A325-N</td>
</tr>
<tr>
<td>$F_c$, Ks</td>
<td>21.0</td>
<td>28.0</td>
</tr>
<tr>
<td>Bolt Dia, $d$, in.</td>
<td>1/8</td>
<td>1/4</td>
</tr>
<tr>
<td>Angle Thickness</td>
<td>1/16</td>
<td>3/32</td>
</tr>
<tr>
<td>$L$, in.</td>
<td>$L'$, in.</td>
<td>$n$</td>
</tr>
<tr>
<td>29/31</td>
<td>10</td>
<td>186</td>
</tr>
<tr>
<td>26/28</td>
<td>9</td>
<td>167</td>
</tr>
<tr>
<td>23/25</td>
<td>8</td>
<td>148</td>
</tr>
<tr>
<td>20/22</td>
<td>7</td>
<td>130</td>
</tr>
<tr>
<td>17/19</td>
<td>6</td>
<td>111</td>
</tr>
<tr>
<td>14/16</td>
<td>5</td>
<td>92.8</td>
</tr>
<tr>
<td>11/13</td>
<td>4</td>
<td>74.2</td>
</tr>
<tr>
<td>8/10</td>
<td>3</td>
<td>55.7</td>
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<tr>
<td>6/8</td>
<td>2</td>
<td>37.2</td>
</tr>
<tr>
<td>4/6</td>
<td>1</td>
<td>18.7</td>
</tr>
</tbody>
</table>

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Connections 18
Lecture 26

ENDS 231
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