lecture
twenty six

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
Bolted Connection Design

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

### Bolted Connection Design

#### ASD steel

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

#### Table: Bearing Allowable Loads in kips

<table>
<thead>
<tr>
<th>Material Thickness</th>
<th>Bearing for Various Stress Levels</th>
<th>Bearing for Various Stress Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$F_u = 58$ ksi Bolt dia.</td>
<td>$F_u = 65$ ksi Bolt dia.</td>
</tr>
<tr>
<td>1/16</td>
<td>6.5</td>
<td>7.6</td>
</tr>
<tr>
<td>1/8</td>
<td>9.8</td>
<td>11.4</td>
</tr>
<tr>
<td>1/4</td>
<td>13.1</td>
<td>15.2</td>
</tr>
<tr>
<td>3/32</td>
<td>18.3</td>
<td>19.0</td>
</tr>
<tr>
<td>1/32</td>
<td>22.8</td>
<td>26.6</td>
</tr>
<tr>
<td>1/16</td>
<td>26.1</td>
<td>30.5</td>
</tr>
<tr>
<td>1/8</td>
<td>29.4</td>
<td>34.3</td>
</tr>
<tr>
<td>3/32</td>
<td>32.8</td>
<td>38.1</td>
</tr>
<tr>
<td>1/16</td>
<td>41.5</td>
<td>47.5</td>
</tr>
<tr>
<td>1/8</td>
<td>45.7</td>
<td>52.2</td>
</tr>
<tr>
<td>3/32</td>
<td>55.6</td>
<td>60.8</td>
</tr>
<tr>
<td>1/16</td>
<td>60.9</td>
<td>69.6</td>
</tr>
</tbody>
</table>

F2007Tabn
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 \( \phi_t = 0.9 \) \( P_n = F_y A_g \)
  2. rupture* \( \phi_t = 0.75 \) \( P_n = F_u A_e \)

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

- **considerations**
  - shear stress
  - yielding
  - rupture

![Diagram of welded connection](image)
Welded Connection Design

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

• weld materials
  – E60XX
  – E70XX
  $F_{EXX} = 70$ ksi

<table>
<thead>
<tr>
<th>TABLE J2.4 Minimum Size of Fillet Welds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Thickness of Thicker Part Joined, in. (mm)</td>
</tr>
<tr>
<td>To $\frac{1}{4}$ (6) Inclusive</td>
</tr>
<tr>
<td>Over $\frac{1}{4}$ (6) to $\frac{1}{2}$ (13)</td>
</tr>
<tr>
<td>Over $\frac{1}{2}$ (13) to $\frac{3}{8}$ (19)</td>
</tr>
<tr>
<td>Over $\frac{3}{8}$ (19)</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 \( f_v \leq F_v \)
    - \( F_v = 0.30F_{weld} \)
  - 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** Allowable loads in kips

<table>
<thead>
<tr>
<th>$L$</th>
<th>$L'$</th>
<th>$n$</th>
<th>$F$, Ks</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>23</td>
<td>4</td>
<td>21.0</td>
</tr>
<tr>
<td>26</td>
<td>25</td>
<td>6</td>
<td>28.0</td>
</tr>
<tr>
<td>22</td>
<td>21</td>
<td>7</td>
<td>30.0</td>
</tr>
<tr>
<td>19</td>
<td>18</td>
<td>9</td>
<td>40.0</td>
</tr>
</tbody>
</table>

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** Bolt Shear

For bolts in bearing-type connections with standard or bolted holes.

<table>
<thead>
<tr>
<th>Bolt Type</th>
<th>A325-N</th>
<th>A490-N</th>
<th>A325-X</th>
<th>A490-X</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_r$, Ks</td>
<td>21.0</td>
<td>28.0</td>
<td>30.0</td>
<td>40.0</td>
</tr>
<tr>
<td>Angle Leg Thickness, $t$, in.</td>
<td>1/16</td>
<td>1/16</td>
<td>1/16</td>
<td>1/16</td>
</tr>
<tr>
<td>$L$, in.</td>
<td>$L'$, in.</td>
<td>$n$</td>
<td>$F_r$, Ks</td>
<td>$F_r$, Ks</td>
</tr>
<tr>
<td>29/31</td>
<td>10</td>
<td>186</td>
<td>253</td>
<td>330</td>
</tr>
<tr>
<td>26/28</td>
<td>9</td>
<td>167</td>
<td>227</td>
<td>267</td>
</tr>
<tr>
<td>23/25</td>
<td>8</td>
<td>148</td>
<td>202</td>
<td>264</td>
</tr>
<tr>
<td>20/22</td>
<td>7</td>
<td>130</td>
<td>177</td>
<td>231</td>
</tr>
<tr>
<td>17/19</td>
<td>6</td>
<td>111</td>
<td>152</td>
<td>198</td>
</tr>
<tr>
<td>14/16</td>
<td>5</td>
<td>92.8</td>
<td>128</td>
<td>185</td>
</tr>
<tr>
<td>11/13</td>
<td>4</td>
<td>74.2</td>
<td>101</td>
<td>132</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