Architectural Structures: Form, Behavior, and Design
ARCH 331
Dr. Anne Nichols
Spring 2015

Lecture twenty one

Steel Construction: Bolted & Welded Connections
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
    \[
    R_a \leq \frac{R_n}{\Omega} \quad R_u \leq \phi_v R_n
    \]
    \[
    \phi_v = 0.75
    \]
  - double shear
    \[
    R_n = F_n A_b
    \]
    \[
    R_n = F_n 2A_b
    \]
### Table 7-1
Available Shear Strength of Bolts, kips

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter, d, in.</th>
<th>$f_{sb}$/kips</th>
<th>$f_{sb}$/kips</th>
<th>$f_{sb}$/kips</th>
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<tbody>
<tr>
<td>Nominal Bolt Area, in.$^2$</td>
<td>0.307</td>
<td>0.442</td>
<td>0.601</td>
<td>0.785</td>
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<tr>
<td><strong>ASTM Design.</strong></td>
<td><strong>Thread Cond.</strong></td>
<td><strong>F$_{cm}$/kips</strong></td>
<td><strong>F$_{cm}$/kips</strong></td>
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### Table 7-2
Available Tensile Strength of Bolts, kips

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<tr>
<th>Nominal Bolt Diameter, d, in.</th>
<th>$f_{sb}$/kips</th>
<th>$f_{sb}$/kips</th>
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<td>0.307</td>
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<td><strong>ASTM Design.</strong></td>
<td><strong>Thread Cond.</strong></td>
<td><strong>F$_{cm}$/kips</strong></td>
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<td><strong>Nominal Bolt Area, in.$^2$</strong></td>
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</tbody>
</table>

For end loaded connections greater than 30 in., see ASC Specification Table J2 footnote b.
Bolts

• bearing

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

\(\phi = 0.75\)

– deformation is concern

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

– deformation isn’t concern

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

– long slotted holes

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

\(L_c\) – clear length to edge or next hole (ex. 1\(\frac{1}{4}\)”, 3”)
Bolts

**Table 7-3 (continued)**

Slip-Critical Connections
Available Shear Strength, kips
(Class A Faying Surface, \( \mu = 0.30 \))

<table>
<thead>
<tr>
<th>Hole Type</th>
<th>Loading</th>
<th>Group B Bolts</th>
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<tbody>
<tr>
<td>STD/SSLT</td>
<td>S</td>
<td>Minimum Group B Bolt Pretension, kips</td>
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<tr>
<td>OVS/SSLT</td>
<td>D</td>
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<tr>
<td>LSL</td>
<td>S</td>
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</table>

<table>
<thead>
<tr>
<th>Hole Type</th>
<th>Loading</th>
<th>1 1/8</th>
<th>1 1/4</th>
<th>1 1/2</th>
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<tbody>
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<td>34.6</td>
<td>23.1</td>
<td>14.0</td>
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<td>ASD</td>
<td>57.1</td>
<td>39.3</td>
<td>25.9</td>
<td>15.4</td>
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<td>46.9</td>
<td>30.8</td>
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</tbody>
</table>

**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.

See ASTM Specification Sections J3.8 and J5 for provisions when fillers are present.

---

**Available Bearing Strength at Bolt Holes Based on Edge Distance**

<table>
<thead>
<tr>
<th>Hole Type</th>
<th>Edge Distance ( L_e ), in.</th>
<th>( F_p ), ksi</th>
<th>( F_p/\Omega )</th>
<th>( \phi_{tp} )</th>
<th>( \phi_{tp}/\Omega )</th>
<th>( \phi_{fp} )</th>
<th>( \phi_{fp}/\Omega )</th>
<th>( \phi_{bf} )</th>
<th>( \phi_{bf}/\Omega )</th>
<th>( \phi_{bf}/\Omega )</th>
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<td>31.5</td>
<td>47.3</td>
<td>29.4</td>
<td>44.0</td>
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<td>40.8</td>
<td>25.0</td>
<td>37.5</td>
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<tr>
<td>LSL</td>
<td>1/4</td>
<td>58</td>
<td>31.7</td>
<td>47.5</td>
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<td>34.7</td>
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<tr>
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<td>45.7</td>
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<td>39.6</td>
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<tr>
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<td>1/4</td>
<td>58</td>
<td>36.3</td>
<td>53.4</td>
<td>35.9</td>
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<td>45.7</td>
<td>27.4</td>
<td>39.6</td>
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</tbody>
</table>
Welded Connection Design

- considerations
  - shear stress
  - yielding
  - rupture
Welded Connection Design

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

- **field welding**

- **shop welding**

(AISC - Steel Structures of the Everyday)
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 1/4 (6) inclusive</td>
<td>1/8 (3)</td>
</tr>
<tr>
<td>Over 1/4 (6) to 1/2 (13)</td>
<td>3/16 (5)</td>
</tr>
<tr>
<td>Over 1/2 (13) to 5/8 (19)</td>
<td>1/4 (6)</td>
</tr>
<tr>
<td>Over 5/8 (19)</td>
<td>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

• shear

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

\[ R_u \leq \phi R_n \]

\[ \phi = 0.75 \]

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

area

– table for \( \phi \)S

| Available Strength of Fillet Welds per inch of weld (\( \phi \$ \)) |
|-----------------|---------|---------|
| Weld Size       | E60XX   | E70XX   |
| (in.)           | (k/in.) | (k/in.) |
| \( \frac{3}{16} \) | 3.58    | 4.18    |
| \( \frac{1}{4} \)  | 4.77    | 5.57    |
| \( \frac{5}{32} \) | 5.97    | 6.96    |
| \( \frac{3}{8} \)  | 7.16    | 8.35    |
| \( \frac{7}{32} \) | 8.35    | 9.74    |
| \( \frac{1}{2} \)  | 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
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

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

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

\( \phi = 0.75 \)

**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

The Royal Ontario Museum  Toronto, Canada
Daniel Libeskind
(AISC - Steel Structures of the Everyday)

Steel Bolts & Welding 27
Lecture 21

Architectural Structures
ARCH 331

http://courses.civil.ualberta.ca
S2015abn
Other Connections

- rigid frame knees
- gussets & joints
Other Connections

• base plates
  – anchor bolts
  – bearing on steel
  – bending of plate