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

**Equation:**

\[ R_a \leq \frac{R_n}{\phi_v} \]
\[ R_u \leq \phi_v R_n \]

- single shear or tension
  \[ \phi_v = 0.75 \]

- double shear
  \[ R_n = F_n A_h \]
  \[ R_n = F_n 2A_h \]

---

**Table 7-1**

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter, d, in</th>
<th>Available Shear Strength of Bolts, kips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
</tbody>
</table>

**Table 7-2**

<table>
<thead>
<tr>
<th>Nominal Bolt Diameter, d, in</th>
<th>Available Tensile Strength of Bolts, kips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>T1</td>
</tr>
</tbody>
</table>

[http://www.fastenal.com](http://www.fastenal.com)
Bolts

- bearing \( R_u \leq \frac{R_n}{\phi} \) \( \phi = 0.75 \)
  - deformation is concern \( R_n = 1.2L_c t F_u \leq 2.4dt F_u \)
  - deformation isn’t concern \( R_n = 1.5L_c t F_u \leq 3.0dt F_u \)
  - long slotted holes \( R_n = 1.0L_c t F_u \leq 2.0dt F_u \)
  
  \( L_c \) – clear length to edge or next hole (ex. 1¼", 3")

Welded Connection Design

- considerations
  - shear stress
  - yielding
  - rupture

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Welded Connection Design

- weld terms
  - butt weld
  - fillet weld
  - plug weld
  - throat
- field welding
- shop welding

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**Welded Connection Design**

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

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

**Welded Connection Design**

- **minimum**
  - table

- **maximum**
  - material thickness (to $\frac{1}{4}$")
  - $1/16"$ less

- **min. length**
  - $4 \times$ size min.
  - $\geq 1 \frac{1}{2}$

**Table 2.4:** Minimum Size of Fillet Welds

<table>
<thead>
<tr>
<th>Material Thickness of Thicker Part Jointed, in (mm)</th>
<th>Minimum Size of Weld Electrode Size, in (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{6}$</td>
<td>$\frac{1}{4}$</td>
</tr>
<tr>
<td>$\frac{1}{4}$</td>
<td>$\frac{3}{8}$</td>
</tr>
</tbody>
</table>

*Note: Single pass welds must be used.*

**Welded Connection Design**

- **shear**

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

\[ R_u \leq \phi R_n \]

\[ R_n = 0.6 F_{EXX} T l = S l \]

- **shear failure assumed**
- **throat**
  - $T = 0.707 \times$ weld size
- **area**
  - $A = T \times$ length of weld
- **weld metal generally stronger than base metal** (ex. $F_y = 50$ ksi)

**Available Strengths of Fillet Welds per inch of weld (g)**

<table>
<thead>
<tr>
<th>Weld Size (in)</th>
<th>$F_{EXX}$ (ksi)</th>
<th>$E_{LOOK}$ (ksi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{6}$</td>
<td>3.50</td>
<td>4.10</td>
</tr>
<tr>
<td>$\frac{1}{4}$</td>
<td>4.77</td>
<td>5.57</td>
</tr>
<tr>
<td>$\frac{3}{8}$</td>
<td>5.97</td>
<td>6.96</td>
</tr>
<tr>
<td>$\frac{1}{2}$</td>
<td>7.16</td>
<td>8.35</td>
</tr>
<tr>
<td>$\frac{1}{4}$</td>
<td>8.35</td>
<td>9.74</td>
</tr>
<tr>
<td>$\frac{3}{8}$</td>
<td>9.55</td>
<td>11.14</td>
</tr>
<tr>
<td>$\frac{1}{2}$</td>
<td>13.32</td>
<td>13.92</td>
</tr>
<tr>
<td>$\frac{3}{4}$</td>
<td>14.52</td>
<td>16.70</td>
</tr>
</tbody>
</table>

*Not considering increase in stress with submerged arc weld process*
Framed Beam Connections

• angles
  – bolted
  – welded

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Framed Beam Connections

• terms
  – coping

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Framed Beam Connections

• tables for standard bolt sizes & spacings
• # bolts
• bolt diameter, angle leg thickness
• bearing on beam web

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Framed Beam Connections

• welded example (shear)

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ARCH 331
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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

Other Connections

- seated beam
- continuous
  - beam to column
  - beam to beam

Other Connections

- splices

- rigid frame knees
- gussets & joints

\[ \phi = 0.75 \]
Other Connections

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