Example 3.2 Solution

Design a double angle tension member and a gusset plated bolted connection system to carry a factored load of 100 kips. Assume A36 (36 ksi yield stress) material for the double angles and the gusset plate. Assume A325 bolts. Note that you have to design the double angle member sizes, the gusset plate thickness, the bolt diameter, numbers, and spacing.

Solution

Step I. Design and select a trial tension member

- See Table 5-8 on page 5-49 of the AISC manual.
  - Select 2L 3 x 2 x 3/8 with $\phi P_n = 112$ kips (yielding) and 113 kips (fracture)
  - While selecting a trial tension member check the fracture strength with the load.

Step II. Select size and number of bolts

The bolts are in double shear for this design (may not be so for other designs)

- See Table 7-1 on page 7-22 in the AISC manual
  
  Use four 3/4 in. A325 bolts in double shear
  
  $\phi R_n = 35.8 \times 4 = 143.2$ kips
  
  - shear strength of bolts from Table 7-1

Step III. Design edge distance and bolt spacing

- See Table J3.4
  
  - The minimum edge distance = 1 in. for 3/4 in. diameter bolts in rolled edges.
  
  - Select edge distance = 1.25 in.

- See specification J3.5
  
  - Minimum spacing = $2.67 d_b = 2.0$ in.
  
  - Preferred spacing = $3.0 d_b = 2.25$ in.
- Select spacing = 3.0 in., which is greater than preferred or minimum spacing

**Step IV.** Check the bearing strength at bolt holes in angles

- Bearing strength at bolt holes in angles
  - Angle thickness = 3/8 in.
  - See **Table 7-5** for the bearing strength per in. thickness at the edge holes
  - Bearing strength at the edge holes \((L_e = 1.25\text{ in.}) = \phi R_n = 44.0 \times 3/8 = 16.5\text{ k}\)
  - See **Table 7-4** for the bearing strength per in. thickness based on bolt spacing
  - Bearing strength at non-edge holes \((s = 3\text{ in.}) = \phi R_n = 78.3 \times 3/8 = 29.4\text{ k}\)
  - **Bearing strength at bolt holes in each angle** = \(16.5 + 3 \times 29.4 = 104.7\text{ kips}\)
  - **Bearing strength of double angles** = \(2 \times 104.7\text{ kips} = 209.4\text{ kips}\)

**Step V.** Check the fracture and block shear strength of the tension member

**Net Section Fracture**

\[
A_g = 3.5\text{ in}^2 \\
A_n = A_g - (2\text{ members}) \times t \times d_hole = 3.5\text{ in}^2 - 2 \times (3/8\text{ in.})(3/4\text{ in.} + 1/16\text{ in.} + 1/16\text{ in.}) = 2.84\text{ in}^2 \\
U = 1 - (x \text{ bar})/l = 1 - (0.535\text{ in.})/9\text{ in.} = 0.941 \\
A_e = U \times A_n = (0.941)(2.84\text{ in}^2) = 2.68\text{ in}^2 \\
\text{Net section fracture strength} = (0.75)(2.68\text{ in}^2)(58\text{ ksi}) = 116.6\text{ kips}
\]
\[ A_{gv} = (2 \text{ members}) \times (3 \text{ in.} + 3 \text{ in.} + 3 \text{ in.} + 1.25 \text{ in.}) \times (3/8 \text{ in.}) = 7.69 \text{ in}^2 \]
\[ A_{nv} = A_{gv} - (2 \text{ members}) \times 3.5 \times d_{\text{hole}} = 7.69 \text{ in}^2 - 2 \times 3.5 \times (3/4 \text{ in.} + 1/16 \text{ in.} + 1/16 \text{ in.}) = 5.39 \text{ in}^2 \]
\[ A_{nt} = (2 \text{ members}) \times t \times (1.25 \text{ in.} - 0.5 \times d_{\text{hole}}) = 2 \times (3/8 \text{ in.}) \times (1.25 \text{ in.} - 0.5 \times (3/4 \text{ in.} + \ldots 1/16 \text{ in.} + 1/16 \text{ in.}) = 0.61 \text{ in}^2 \]

Block shear strength = 0.75 \times (0.6 \times F_u \times A_{nv} + F_u \times A_{nt}) = 167 \text{ kips} \\
or 0.75 \times (0.6 \times F_y \times A_{gv} + F_u \times A_{nt}) = 151 \text{ kips} \\

**Step VI. Design the gusset plate**

- See specification J4.1 for designing gusset plates. These plates must be designed for the limit states of yielding and rupture

  - Limit state of yielding
    - \( \phi R_n = 0.9 A_g F_y > 100 \text{ kips} \)
    - Therefore, \( A_g = L \times t > 3.09 \text{ in}^2 \)
    - Assume \( t = \frac{1}{2} \text{ in.} \); Therefore \( L > 6.18 \text{ in.} \)
    - Design gusset plate = 6.5 x \( \frac{1}{2} \text{ in.} \)
    - Yield strength = \( \phi R_n = 0.9 \times 6.5 \times 0.5 \times 36 = 105.3 \text{ kips} \)

  - Limit state for fracture
    - \( A_n = A_g - (d_h + 1/8) \times t \)
    - \( A_n = 6.5 \times 0.5 - (3/4 + 1/8) \times 0.5 = 2.81 \text{ in}^2 \)
    - \textbf{But,} \( A_n \leq 0.85 A_g = 0.85 \times 3.25 = 2.76 \text{ in}^2 \)
- \( \phi R_n = 0.75 \times A_n \times F_u = 0.75 \times 2.76 \times 58 = 120 \text{ kips} \)

- Design gusset plate = 6.5 x 0.5 in.

- **Step VII.** Bearing strength at bolt holes in gusset plates

Assume \( L_e = 1.25 \text{ in.} \) (same as double angles)

- Plate thickness = 1/2 in.

- Bearing strength at the edge holes = \( \phi R_n = 44.0 \times 1/2 = 22.0 \text{ k} \)

- Bearing strength at non-edge holes = \( \phi R_n = 78.3 \times 1/2 = 39.15 \text{ k} \)

- *Bearing strength at bolt holes in gusset plate* = \( 22.0 + 3 \times 39.15 = 139.5 \text{ kips} \)

### Summary of Member and Connection Strength

<table>
<thead>
<tr>
<th>Connection</th>
<th>Member</th>
<th>Gusset Plate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shear strength = 143.2 kips</td>
<td>Yielding = 112 kips</td>
<td>Yielding = 105.3 kips</td>
</tr>
<tr>
<td>Bearing strength = 209.4 kips (angles)</td>
<td>Fracture = 116.6 kips</td>
<td>Fracture = 120 kips</td>
</tr>
<tr>
<td>Bearing Strength = 139.5 (gusset)</td>
<td>Block Shear = 151 kips</td>
<td></td>
</tr>
</tbody>
</table>

- Overall Strength is the smallest of all these numbers = 105.3 kips
- Gusset plate yielding controls
- Resistance > Factored Load (100 kips).
- Design is acceptable