Sample Calculations – Connection 2

Connection Description

Connection number two consists of a W-section that is welded to an angle on each side of the web, and then bolted to the web of another W-section. There is only one bolt in each angle connection, and the welds run the full length of all three sides of the angle that are in contact with the W-section. For this connection, we have A992 steel for our two 6 x 12 W-sections and A36 steel for our L 4 x 3 x ¼ angle. A ¾” A325N Hex bolt was used, along with an E-70 electrode weld that was applied using the Shield Metal Arc Welding (SMAW) technique.

Limit States

The limit states that will be looked at for this connection are as follows:

1.) Bolt Bearing
2.) Bolt Shear Rupture
3.) Block Shear
4.) Weld Strength

Analysis

The following equations were used to evaluate each limit state

**Bolt Bearing:**

\[ \phi R_n = \min \{ \phi (1.2L_c t F_u); \phi (2.4d t F_u) \} \]

\[ \phi = \text{Resistance factor} = 0.75 \]

\[ F_u = \text{Ultimate tensile strength of the connected material, in ksi} \]

\[ L_c = \text{Clear distance, in the direction of the force, between the edge of the hole and the edge of the material, in inches} \]

\[ L_e' = \text{effective length from center of bolt hole to rolled edge} \]

\[ L_e = \text{effective length from center of bolt hole to cut edge} \]

\[ t = \text{Thickness of the connected material, in inches} \]

\[ d = \text{Nominal bolt diameter, in inches} \]

\[ R_n = \min \{ [1.2 * (2”-0.5 * (0.375”)) * (0.25”) * (58ksi)] \]

\[ [2.4 * (0.875”) * (0.25”) * (58ksi)] \} \]
Bolt Shear Rupture:

\[ \varphi R_n = \varphi F_n A_b \]

\( \varphi = \) Resistance factor = 0.75

\( F_n = \) Nominal shear strength \( F_v \) tabulated in AISC/LRFD Manual Table J3.2, ksi

\( A_b = \) Nominal unthreaded body area of the bolt, in\(^2\)

\[ \varphi R_n = (0.75) \times (48 \text{ksi}) \times (3/4")^2 \times (\pi/4) = 15.91k \]
Block Shear on Angle:

Block shear on W-section will not control because of the two flanges.

\[ \psi_P = \min \{ \psi \left[ 0.6 \times F_u \times A_{nv} + U_{bs} \times F_u \times A_{nt} \right] \}
\]

\[ \psi \left[ (0.6 \times F_y) \times A_{gvd} + U_{bs} \times F_u \times A_{nt} \right] \}
\]

\[ \psi = \text{Resistance factor} = 0.75 \]

\[ A_{gvd} = \text{Gross area subjected to shear, in}^2 \]

\[ A_{nv} = \text{Net area subjected to shear, in}^2 \]

\[ A_{gtd} = \text{Gross area subjected to tension, in}^2 \]

\[ A_{nt} = \text{Net area subjected to tension, in}^2 \]

\[ U_{bs} = 1.0 \text{ since tension stress is uniform} \]

\[ F_y = \text{Minimum yield stress, ksi} \]

\[ F_u = \text{Tensile stress, ksi} \]

\[ A_{gvd} = 3'' \times 0.25'' = 0.75\text{in}^2 \]

\[ A_{nv} = 0.75\text{in}^2 - 1 \times (\frac{1}{4}'' + \frac{1}{16}'' + \frac{1}{16}'' \times \frac{1}{4}'' = 0.656\text{in}^2 \]

\[ A_{gtd} = 2'' \times 0.25'' = 0.5\text{in}^2 \]

\[ A_{nt} = 0.5\text{in}^2 - 0 = 0.5\text{in}^2 \]

\[ \psi_P = \min \{ [0.75 \times (0.6 \times 36\text{ksi}) \times (0.5\text{in}^2) + (58\text{ksi}) \times (0.5\text{in}^2)] \]

\[ [0.75 \times (0.6 \times 58\text{ksi}) \times (0.656\text{in}^2) + (58\text{ksi}) \times (0.5\text{in}^2)] \}

\[ = \min \{ 29.85 \text{ k}, 38.87 \text{ k} \} \]

Therefore, \( \psi_P = 29.85 \text{ k} \)
**Weld strength:**

\[ \varnothing R_n = \min \{ \varnothing F_w A_w; \varnothing F_{bm} A_{bm} \} \]

\[ \varnothing F_w A_w = \varnothing (0.6F_{EXX}) \times (L_w) \times (t_w) \]

\[ t_w = 0.707 \times D_w \]

\[ \varnothing F_{bm} A_{bm} = \min \{ 0.75 \times t_{bm} \times L_w \times (0.6F_u); \]

\[ \quad 0.75 \times U \times A_n \times F_u; \]

\[ \quad 1.0 \times A_g \times (0.6F_y) \} \]

\[ \varnothing = \text{Resistance factor} = 0.75 \]

\[ R_n = \text{Nominal strength of weld design material, kips} \]

\[ F_{bm} = \text{Nominal strength of the base material, ksi} \]

\[ F_y = \text{Tensile yield of base material, ksi} \]

\[ F_{EXX} = \text{Tensile strength of electrode material, ksi} \]

\[ A_w = \text{Effective cross-sectional area of the weld, in}^2 \]

\[ A_g = \text{Gross cross-sectional area of base material, in}^2 \]

\[ t_w = \text{Effective throat dimension, in} \]

\[ L_w = \text{Length of weld, nominal value, in} \]

\[ t_w = 0.707 \times \frac{1}{4}" = 0.177" \]

\[ \varnothing F_w A_w = 0.75 \times (0.6 \times 70 \text{ ksi}) \times 9" \times 0.177" = 50.18 \text{ k} \]

**Angle Section**

\[ \varnothing F_{bm} A_{bm} = \min \{ 0.75 \times 0.25" \times 9" \times (0.6 \times 58 \text{ ksi}); \]

\[ 0.75 \times 1.0 \times 1.69 \text{ in}^2 \times 58 \text{ ksi}; \]

\[ 1.0 \times 1.69 \text{ in}^2 \times (0.6 \times 36 \text{ ksi}) \} = \min \{ 58.73 \text{ k}, 73.52 \text{ k}, 36.50 \text{ k} \}

Therefore, \( \varnothing F_{bm} A_{bm} \) (Angle) = 36.50 k

\[ \varnothing F_{bm} A_{bm} = \min \{ 0.75 \times 0.230" \times 9" \times (0.6 \times 65 \text{ ksi}); \]

\[ 0.75 \times 1.0 \times 3.55 \text{ in}^2 \times 65 \text{ ksi}; \]

\[ 1.0 \times 3.55 \text{ in}^2 \times (0.6 \times 50 \text{ ksi}) \} = \min \{ 60.55 \text{ k}, 173.06 \text{ k}, 106.50 \text{ k} \}

Therefore, \( \varnothing F_{bm} A_{bm} \) (W-section) = 60.55 k

\[ \varnothing R_n = \min \{ 50.18 \text{ k}, 36.50 \text{ k}, 60.55 \text{ k} \} \]

Therefore, \( \varnothing R_n = 36.50 \text{ k} \)
CONTROLLING $\mathcal{O}P_n$

Once we have all of our values calculated, we need to compare them all to find out which value is the controlling value for our connection.

The final values are:

$$\mathcal{O}P_n = \min \{22.84 \text{ k}, 15.91 \text{ k}, 29.85 \text{ k}, 36.50 \text{ k}\}$$

$$\mathcal{O}P_n = 15.91 \text{ k}$$

Therefore, our controlling value for this connection comes from the block shear rupture on the angle bracket.