EXAMPLE D.1 W-SHAPE TENSION MEMBER

Given:

Select an ASTM A992 W-shape with 8 in. nominal depth to carry a dead load of 30 kips and a live load of 90 kips in tension. The member is 25.0 ft long. Verify the member strength by both LRFD and ASD with the bolted end connection as shown in Figure D.1-1. Verify that the member satisfies the recommended slenderness limit. Assume that connection limit states do not govern.

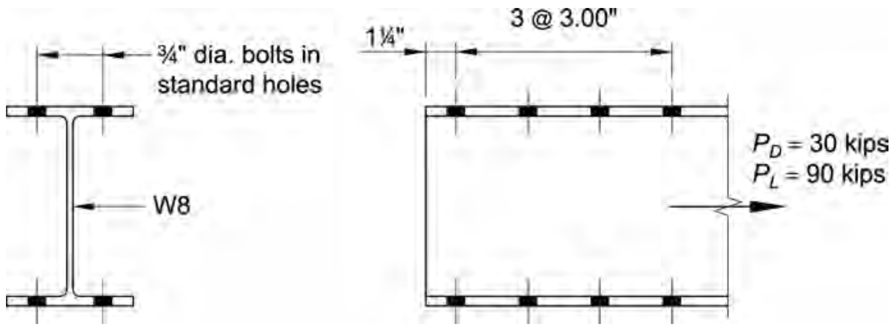

Fig D.1-1. Connection geometry for Example D.1.

Solution:

From Chapter 2 of ASCE/SEI 7, the required tensile strength is:

LRFD	ASD
$P_u = 1.2(30\text{ kips}) + 1.6(90\text{ kips})$ $= 180\text{ kips}$	$P_a = 30\text{ kips} + 90\text{ kips}$ $= 120\text{ kips}$

From AISC *Manual* Table 5-1, try a W8×21.

From AISC *Manual* Table 2-4, the material properties are as follows:

ASTM A992
F_y = 50 ksi
F_u = 65 ksi

From AISC *Manual* Table 1-1, the geometric properties are as follows:

W8×21
A_g = 6.16 in.^{2}
b_f = 5.27 in.
t_f = 0.400 in.
d = 8.28 in.
r_y = 1.26 in.

The WT-shape corresponding to a W8×21 is a WT4×10.5. From AISC *Manual* Table 1-8, the geometric properties are as follows:

WT4×10.5
$\bar{y}$ = 0.831 in.

Tensile Yielding

From AISC *Manual* Table 5-1, the available tensile yielding strength of a W8×21 is:

LRFD	ASD
$\phi_t P_n = 277 \text{ kips} > 180 \text{ kips}$ **o.k.**	$\dfrac{P_n}{\Omega_t} = 184 \text{ kips} > 120 \text{ kips}$ **o.k.**

Tensile Rupture

Verify the table assumption that $A_e/A_g \geq 0.75$ for this connection.

From the description of the element in AISC *Specification* Table D3.1, Case 7, calculate the shear lag factor, U, as the larger of the values from AISC *Specification* Section D3, Table D3.1 Case 2 and Case 7.

From AISC *Specification* Section D3, for open cross sections, U need not be less than the ratio of the gross area of the connected element(s) to the member gross area.

$$
\begin{aligned}
U &= \frac{2b_f t_f}{A_g} \\
&= \frac{2(5.27 \text{ in.})(0.400 \text{ in.})}{6.16 \text{ in.}^2} \\
&= 0.684
\end{aligned}
$$

Case 2: Determine U based on two WT-shapes per AISC *Specification* Commentary Figure C-D3.1, with $\bar{x} = \bar{y} = 0.831 \text{ in.}$ and where l is the length of connection.

$$
\begin{aligned}
U &= 1 - \frac{\bar{x}}{l} \\
&= 1 - \frac{0.831 \text{ in.}}{9.00 \text{ in.}} \\
&= 0.908
\end{aligned}
$$

Case 7:

$$
\begin{aligned}
b_f &= 5.27 \text{ in.} \\
\frac{2}{3}d &= \frac{2}{3}(8.28 \text{ in.}) \\
&= 5.52 \text{ in.}
\end{aligned}
$$

Because the flange is connected with three or more fasteners per line in the direction of loading and $b_f < \dfrac{2}{3}d$:

$U = 0.85$

Therefore, use the larger $U = 0.908$.

Calculate A_n using AISC *Specification* Section B4.3b.

$$A_n = A_g - 4\left(d_h + \tfrac{1}{16}\text{ in.}\right)t_f$$
$$= 6.16\text{ in.}^2 - 4\left(\tfrac{13}{16}\text{ in.} + \tfrac{1}{16}\text{ in.}\right)\left(0.400\text{ in.}\right)$$
$$= 4.76\text{ in.}^2$$

Calculate A_e using AISC *Specification* Section D3.

$$A_e = A_n U \qquad \text{(}\textit{Spec}\text{. Eq. D3-1)}$$
$$= \left(4.76\text{ in.}^2\right)\left(0.908\right)$$
$$= 4.32\text{ in.}^2$$

$$\frac{A_e}{A_g} = \frac{4.32\text{ in.}^2}{6.16\text{ in.}^2}$$
$$= 0.701 < 0.75$$

Because A_e/A_g < 0.75, the tensile rupture strength from AISC *Manual* Table 5-1 is not valid. The available tensile rupture strength is determined using AISC *Specification* Section D2 as follows:

$$P_n = F_u A_e \qquad \text{(}\textit{Spec}\text{. Eq. D2-2)}$$
$$= \left(65\text{ ksi}\right)\left(4.32\text{ in.}^2\right)$$
$$= 281\text{ kips}$$

From AISC *Specification* Section D2, the available tensile rupture strength is:

LRFD	ASD
$\phi_t = 0.75$ $\phi_t P_n = 0.75\left(281\text{ kips}\right)$ $= 211\text{ kips} > 180\text{ kips} \quad \textbf{o.k.}$	$\Omega_t = 2.00$ $\dfrac{P_n}{\Omega_t} = \dfrac{281\text{ kips}}{2.00}$ $= 141\text{ kips} > 120\text{ kips} \quad \textbf{o.k.}$

Note that the W8×21 available tensile strength is governed by the tensile rupture limit state at the end connection versus the tensile yielding limit state.

See Chapter J for illustrations of connection limit state checks.

Check Recommended Slenderness Limit

$$\frac{L}{r} = \frac{\left(25.0\text{ ft}\right)\left(12\text{ in./ft}\right)}{1.26\text{ in.}}$$
$$= 238 < 300 \text{ from AISC } \textit{Specification} \text{ Section D1} \quad \textbf{o.k.}$$

EXAMPLE D.2 SINGLE-ANGLE TENSION MEMBER

Given:

Verify the tensile strength of an ASTM A36 L4×4×½ with one line of four ¾-in.-diameter bolts in standard holes, as shown in Figure D.2-1. The member carries a dead load of 20 kips and a live load of 60 kips in tension. Additionally, calculate at what length this tension member would cease to satisfy the recommended slenderness limit. Assume that connection limit states do not govern.

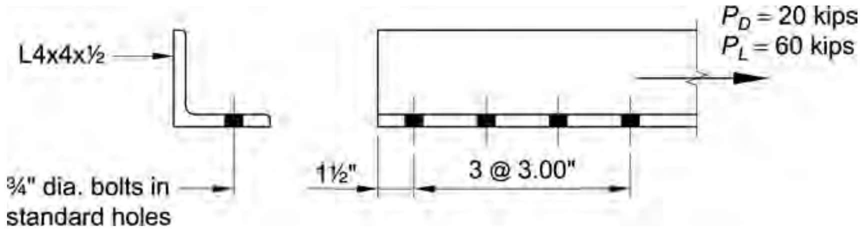

Fig. D.2-1. Connection geometry for Example D.2.

Solution:

From AISC *Manual* Table 2-4, the material properties are as follows:

ASTM A36
$F_y = 36$ ksi
$F_u = 58$ ksi

From AISC *Manual* Table 1-7, the geometric properties are as follows:

L4×4×½
$A_g = 3.75$ in.^{2}
$r_z = 0.776$ in.
$\bar{x} = 1.18$ in.

From Chapter 2 of ASCE/SEI 7, the required tensile strength is:

LRFD	ASD
$P_u = 1.2(20 \text{ kips}) + 1.6(60 \text{ kips})$ $= 120 \text{ kips}$	$P_a = 20 \text{ kips} + 60 \text{ kips}$ $= 80.0 \text{ kips}$

Tensile Yielding

$$P_n = F_y A_g \quad (\textit{Spec}.\ \text{Eq. D2-1})$$
$$= (36 \text{ ksi})(3.75 \text{ in.}^2)$$
$$= 135 \text{ kips}$$

From AISC *Specification* Section D2, the available tensile yielding strength is:

LRFD	ASD
$\phi_t = 0.90$ $\phi_t P_n = 0.90(135 \text{ kips})$ $= 122 \text{ kips} > 120 \text{ kips}$ **o.k.**	$\Omega_t = 1.67$ $\dfrac{P_n}{\Omega_t} = \dfrac{135 \text{ kips}}{1.67}$ $= 80.8 \text{ kips} > 80.0 \text{ kips}$ **o.k.**

Tensile Rupture

From the description of the element in AISC *Specification* Table D3.1 Case 8, calculate the shear lag factor, U, as the larger of the values from AISC *Specification* Section D3, Table D3.1 Case 2 and Case 8.

From AISC *Specification* Section D3, for open cross sections, U need not be less than the ratio of the gross area of the connected element(s) to the member gross area. Half of the member is connected, therefore, the minimum value of U is:

$$U = 0.500$$

Case 2, where l is the length of connection and $\bar{y} = \bar{x}$:

$$\begin{aligned} U &= 1 - \frac{\bar{x}}{l} \\ &= 1 - \frac{1.18 \text{ in.}}{9.00 \text{ in.}} \\ &= 0.869 \end{aligned}$$

Case 8, with four or more fasteners per line in the direction of loading:

$$U = 0.80$$

Therefore, use the larger $U = 0.869$.

Calculate A_n using AISC *Specification* Section B4.3b.

$$\begin{aligned} A_n &= A_g - (d_h + \tfrac{1}{16} \text{ in.})t \\ &= 3.75 \text{ in.} - (\tfrac{13}{16} \text{ in.} + \tfrac{1}{16} \text{ in.})(\tfrac{1}{2} \text{ in.}) \\ &= 3.31 \text{ in.}^2 \end{aligned}$$

Calculate A_e using AISC *Specification* Section D3.

$$\begin{aligned} A_e &= A_n U \\ &= (3.31 \text{ in.}^2)(0.869) \\ &= 2.88 \text{ in.}^2 \end{aligned}$$ (*Spec*. Eq. D3-1)

$$\begin{aligned} P_n &= F_u A_e \\ &= (58 \text{ ksi})(2.88 \text{ in.}^2) \\ &= 167 \text{ kips} \end{aligned}$$ (*Spec*. Eq. D2-2)

From AISC *Specification* Section D2, the available tensile rupture strength is:

LRFD	ASD
$\phi_t = 0.75$ $\phi_t P_n = 0.75(167 \text{ kips})$ $= 125 \text{ kips} > 120 \text{ kips}$ **o.k.**	$\Omega_t = 2.00$ $\dfrac{P_n}{\Omega_t} = \dfrac{167 \text{ kips}}{2.00}$ $= 83.5 \text{ kips} > 80.0 \text{ kips}$ **o.k.**

The L4×4×½ available tensile strength is governed by the tensile yielding limit state.

LRFD	ASD
$\phi_t P_n = 122 \text{ kips} > 120 \text{ kips}$ **o.k.**	$\dfrac{P_n}{\Omega_t} = 80.8 \text{ kips} > 80.0 \text{ kips}$ **o.k.**

Recommended L_{max}

Using AISC *Specification* Section D1:

$$
\begin{aligned}
L_{max} &= 300 r_z \\
&= 300\left(\frac{0.776 \text{ in.}}{12 \text{ in./ft}}\right) \\
&= 19.4 \text{ ft}
\end{aligned}
$$

Note: The *L/r* limit is a recommendation, not a requirement.

See Chapter J for illustrations of connection limit state checks.