Check flange slenderness.

$$\lambda_{rf} = 1.0\sqrt{\frac{E}{F_y}}$$ from AISC *Specification* Table B4.1b Case 10

$$= 1.0\sqrt{\frac{29{,}000 \text{ ksi}}{50 \text{ ksi}}}$$
$$= 24.1$$

$$\lambda = \frac{b_f}{2t_f}$$
$$= 9.43 < \lambda_{rf}$$; therefore, the flange is not slender

For a WT with a noncompact flange, the nominal flexural strength due to flange local buckling is:

$$M_n = \left[M_p - \left(M_p - 0.7F_yS_{xc}\right)\left(\frac{\lambda - \lambda_{pf}}{\lambda_{rf} - \lambda_{pf}}\right)\right] \le 1.6M_y \qquad \text{(Spec. Eq. F9-6)}$$
$$= \left\{110 \text{ kip-in.} - \left[110 \text{ kip-in.} - 0.7\left(50 \text{ ksi}\right)\left(3.20 \text{ in.}^3\right)\right]\left(\frac{9.43 - 9.15}{24.1 - 9.15}\right)\right\} \le 97.6 \text{ kip-in.}$$
$$= 110 \text{ kip-in.} > 97.6 \text{ kip-in.}$$

Therefore use:

M_n = 97.6 kip-in. or 8.13 kip-ft

$M_n = M_p$
= 8.13 kip-ft **yielding limit state controls** (*Spec*. Eq. F9-1)

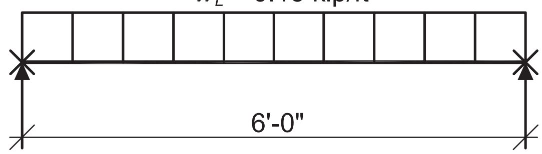
From AISC *Specification* Section F1, the available flexural strength is:

LRFD	ASD
$\phi_b = 0.90$ $\phi_b M_n = 0.90\left(8.13 \text{ kip-ft}\right)$ $= 7.32 \text{ kip-ft} > 2.16 \text{ kip-ft}$ **o.k.**	$\Omega_b = 1.67$ $\frac{M_n}{\Omega_b} = \frac{8.13 \text{ kip-ft}}{1.67}$ $= 4.87 \text{ kip-ft} > 1.44 \text{ kip-ft}$ **o.k.**

EXAMPLE F.11A SINGLE ANGLE FLEXURAL MEMBER

Given:

Select an ASTM A36 single angle with a simple span of 6 ft. The vertical leg of the single angle is up and the toe is in compression. The vertical loads are a uniform dead load of 0.05 kip/ft and a uniform live load of 0.15 kip/ft. There are no horizontal loads. There is no deflection limit for this angle. The angle is braced at the end points only. Assume bending about the geometric *x-x* axis and that there is no lateral-torsional restraint.



Beam Loading & Bracing Diagram
(*braced at end points only*)

Solution:

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

ASTM A36
F_y = 36 ksi
F_u = 58 ksi

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

LRFD	ASD
$w_{ux} = 1.2(0.05\text{ kip/ft}) + 1.6(0.15\text{ kip/ft})$ $= 0.300\text{ kip/ft}$ $M_{ux} = \dfrac{0.300\text{ kip/ft}(6\text{ ft})^2}{8}$ $= 1.35\text{ kip-ft}$	$w_{ax} = 0.05\text{ kip/ft} + 0.15\text{ kip/ft}$ $= 0.200\text{ kip/ft}$ $M_{ax} = \dfrac{0.200\text{ kip/ft}(6\text{ ft})^2}{8}$ $= 0.900\text{ kip-ft}$

Try a L4×4×¼.

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

L4×4×¼
S_x = 1.03 in.^{3}

Nominal Flexural Strength, M_n

Flexural Yielding

From AISC *Specification* Section F10.1, the nominal flexural strength due to the limit state of flexural yielding is:

$$\begin{aligned} M_n &= 1.5M_y \qquad \text{(Spec. Eq. F10-1)} \\ &= 1.5F_yS_x \\ &= 1.5(36\text{ ksi})(1.03\text{ in.}^3) \\ &= 55.6\text{ kip-in.} \end{aligned}$$

Lateral-Torsional Buckling

From AISC *Specification* Section F10.2, for single angles bending about a geometric axis with no lateral-torsional restraint, M_y is taken as 0.80 times the yield moment calculated using the geometric section modulus.

$$\begin{aligned} M_y &= 0.80F_yS_x \\ &= 0.80(36\text{ ksi})(1.03\text{ in.}^3) \\ &= 29.7\text{ kip-in.} \end{aligned}$$

Determine M_e.

For bending moment about one of the geometric axes of an equal-leg angle with no axial compression, with no lateral-torsional restraint, and with maximum compression at the toe, use AISC *Specification* Section F10.2(b)(iii)(a)(i), Equation F10-6a.

C_b = 1.14 from AISC *Manual* Table 3-1

$$M_e = \frac{0.66Eb^4tC_b}{L_b^2}\left(\sqrt{1+0.78\left(\frac{L_bt}{b^2}\right)^2}-1\right) \quad (Spec.\text{ Eq. F10-6a})$$

$$= \frac{0.66(29{,}000\text{ ksi})(4.00\text{ in.})^4(\text{¼ in.})(1.14)}{(72.0\text{ in.})^2}\left(\sqrt{1+0.78\left(\frac{(72.0\text{ in.})(\text{¼ in.})}{(4.00\text{ in.})^2}\right)^2}-1\right)$$

= 110 kip-in. > 29.7 kip-in.; therefore, AISC *Specification* Equation F10-3 is applicable

$$M_n = \left(1.92-1.17\sqrt{\frac{M_y}{M_e}}\right)M_y \le 1.5M_y \quad (Spec.\text{ Eq. F10-3})$$

$$= \left(1.92-1.17\sqrt{\frac{29.7\text{ kip-in.}}{110\text{ kip-in.}}}\right)29.7\text{ kip-in.} \le 1.5(29.7\text{ kip-in.})$$

$= 39.0$ kip-in. ≤ 44.6 kip-in.; therefore, M_n = 39.0 kip-in.

Leg Local Buckling

AISC *Specification* Section F10.3 applies when the toe of the leg is in compression.

Check slenderness of the leg in compression.

$$\begin{aligned} \lambda &= \frac{b}{t} \\ &= \frac{4.00\text{ in.}}{\text{¼ in.}} \\ &= 16.0 \end{aligned}$$

Determine the limiting compact slenderness ratios from AISC *Specification* Table B4.1b Case 12.

$$\lambda_p = 0.54\sqrt{\frac{E}{F_y}}$$

$$= 0.54\sqrt{\frac{29{,}000\text{ ksi}}{36\text{ ksi}}}$$
$$= 15.3$$

Determine the limiting noncompact slenderness ratios from AISC *Specification* Table B4.1b Case 12.

$$\lambda_r = 0.91\sqrt{\frac{E}{F_y}}$$
$$= 0.91\sqrt{\frac{29{,}000\text{ ksi}}{36\text{ ksi}}}$$
$$= 25.8$$

$\lambda_p < \lambda < \lambda_r$, therefore, the leg is noncompact in flexure

$$M_n = F_y S_c\left(2.43 - 1.72\left(\frac{b}{t}\right)\sqrt{\frac{F_y}{E}}\right) \qquad \text{(\textit{Spec}. Eq. F10-7)}$$

$$S_c = 0.80S_x$$
$$= 0.80\left(1.03\text{ in.}^3\right)$$
$$= 0.824\text{ in.}^3$$

$$M_n = 36\text{ ksi}\left(0.824\text{ in.}^3\right)\left(2.43 - 1.72(16.0)\sqrt{\frac{36\text{ ksi}}{29{,}000\text{ ksi}}}\right)$$
$$= 43.3\text{ kip-in.}$$

The lateral-torsional buckling limit state controls.

M_n = 39.0 kip-in. or 3.25 kip-ft

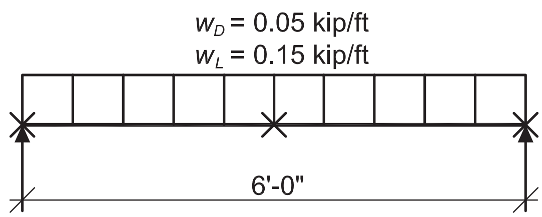
From AISC *Specification* Section F1, the available flexural strength is:

LRFD	ASD
$\phi_b = 0.90$ $\phi_b M_n = 0.90(3.25\text{ kip-ft})$ $= 2.93\text{ kip-ft} > 1.35\text{ kip-ft}$ **o.k.**	$\Omega_b = 1.67$ $\dfrac{M_n}{\Omega_b} = \dfrac{3.25\text{ kip-ft}}{1.67}$ $= 1.95\text{ kip-ft} > 0.900\text{ kip-ft}$ **o.k.**

EXAMPLE F.11B SINGLE ANGLE FLEXURAL MEMBER

Given:

Select an ASTM A36 single angle with a simple span of 6 ft. The vertical leg of the single angle is up and the toe is in compression. The vertical loads are a uniform dead load of 0.05 kip/ft and a uniform live load of 0.15 kip/ft. There are no horizontal loads. There is no deflection limit for this angle. The angle is braced at the end points and at the midspan. Assume bending about the geometric *x-x* axis and that there is lateral-torsional restraint at the midspan and ends only.



Beam Loading & Bracing Diagram
(*braced at end points and midspan*)

Solution:

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

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

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

LRFD	ASD
$w_{ux} = 1.2(0.05\text{ kip/ft}) + 1.6(0.15\text{ kip/ft})$ $= 0.300\text{ kip/ft}$ $M_{ux} = \dfrac{0.300\text{ kip/ft}\left(6\text{ ft}\right)^2}{8}$ $= 1.35\text{ kip-ft}$	$w_{ax} = 0.05\text{ kip/ft} + 0.15\text{ kip/ft}$ $= 0.200\text{ kip/ft}$ $M_{ax} = \dfrac{0.200\text{ kip/ft}\left(6\text{ ft}\right)^2}{8}$ $= 0.900\text{ kip-ft}$

Try a L4×4×¼.

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

L4×4×¼
$S_x = 1.03\text{ in.}^3$

Nominal Flexural Strength, M_n

Flexural Yielding

From AISC *Specification* Section F10.1, the nominal flexural strength due to the limit state of flexural yielding is:

$$M_n = 1.5M_y \qquad (Spec.\ \text{Eq. F10-1})$$
$$= 1.5F_yS_x$$

$$= 1.5(36\text{ ksi})(1.03\text{ in.}^3)$$
$$= 55.6\text{ kip-in.}$$

Lateral-Torsional Buckling

From AISC *Specification* Section F10.2(b)(iii)(b), for single angles with lateral-torsional restraint at the point of maximum moment, M_y is taken as the yield moment calculated using the geometric section modulus.

$$M_y = F_y S_x$$
$$= 36\text{ ksi}(1.03\text{ in.}^3)$$
$$= 37.1\text{ kip-in.}$$

Determine M_e.

For bending moment about one of the geometric axes of an equal-leg angle with no axial compression, with lateral-torsional restraint at the point of maximum moment only (at midspan in this case), and with maximum compression at the toe, M_e shall be taken as 1.25 times M_e computed using AISC *Specification* Equation F10-6a.

C_b = 1.30 from AISC *Manual* Table 3-1

$$M_e = 1.25\left(\frac{0.66Eb^4tC_b}{L_b^2}\right)\left(\sqrt{1+0.78\left(\frac{L_bt}{b^2}\right)^2}-1\right) \qquad (\textit{Spec}.\text{ Eq. F10-6a})$$

$$= 1.25\left[\frac{0.66(29{,}000\text{ ksi})(4.00\text{ in.})^4(\tfrac{1}{4}\text{ in.})(1.30)}{(36.0\text{ in.})^2}\right]\left(\sqrt{1+0.78\left(\frac{(36.0\text{ in.})(\tfrac{1}{4}\text{ in.})}{(4.00\text{ in.})^2}\right)^2}-1\right)$$

= 179 kip-in. > 37.1 kip-in., therefore, AISC *Specification* Equation F10-3 is applicable

$$M_n = \left(1.92-1.17\sqrt{\frac{M_y}{M_e}}\right)M_y \le 1.5M_y \qquad (\textit{Spec}.\text{ Eq. F10-3})$$

$$= \left(1.92-1.17\sqrt{\frac{37.1\text{ kip-in.}}{179\text{ kip-in.}}}\right)37.1\text{ kip-in.} \le 1.5(37.1\text{ kip-in.})$$

= 51.5 kip-in. ≤ 55.7 kip-in., therefore, M_n = 51.5 kip-in.

Leg Local Buckling

M_n = 43.3 kip-in. from Example F.11A.

The leg local buckling limit state controls.

M_n = 43.3 kip-in. or 3.61 kip-ft

From AISC *Specification* Section F1, the available flexural strength is:

LRFD	ASD
$\phi_b = 0.90$ $\phi_b M_n = 0.90(3.61 \text{ kip-ft})$ $= 3.25 \text{ kip-ft} > 1.35 \text{ kip-ft}$ **o.k.**	$\Omega_b = 1.67$ $\dfrac{M_n}{\Omega_b} = \dfrac{3.61 \text{ kip-ft}}{1.67}$ $= 2.16 \text{ kip-ft} > 0.900 \text{ kip-ft}$ **o.k.**