axis, $(KL/r)_y$, governs, the available axial strength values tabulated in *AISC Manual* Table 4-1 may be utilized directly. When the slenderness ratio about the major axis, $(KL/r)_x$, governs, the effective length about the major axis is divided by r_x/r_y to give an equivalent effective length about the minor axis, which has the same load carrying capacity as the actual effective length about the major axis. *AISC Manual* Table 4-1 may then be used to obtain the available design strength of the member in compression by the equivalent length $(KL)_x/(r_x/r_y)$.

Equivalent Effective Length

When the effective lengths of a column about the x- and y-axes are different, the strength of the column must be investigated with respect to both axes. Dividing the effective length about the x-axis by the ratio r_x/r_y provides an equivalent effective length about the y-axis.

Example 5.18

Determine the available axial strength of a W12 × 106 grade 50 column that is 12 ft high, pinned at each end, and braced at midheight about the y-axis.

Solution

The effective length about the y-axis is

$$(KL)_y = 6\text{ ft}$$

The effective length about the x-axis is

$$(KL)_x = 12\text{ ft}$$

From *AISC Manual* Table 4-1, a W12 × 106 column has a value of

$$\frac{r_x}{r_y} = 1.76$$

The equivalent effective length about the major axis with respect to the y-axis is

$$\begin{aligned}(KL_y)_{\text{equiv}} &= \frac{(KL)_x}{\frac{r_x}{r_y}} = \frac{12\text{ ft}}{1.76}\\ &= 6.8\text{ ft} \quad [\text{governs}]\\ &> (KL)_y\end{aligned}$$

LRFD Method

From *AISC Manual* Table 4-1, a W12 × 106 column with an effective length, $(KL_y)_{\text{equiv}}$, of 6.8 ft has a design axial strength of

$$\phi_c P_n = 1334\text{ kips}$$

ASD Method

From *AISC Manual* Table 4-1, a W12 × 106 column with an effective length, $(KL_y)_{\text{equiv}}$, of 6.8 ft has an allowable axial strength of

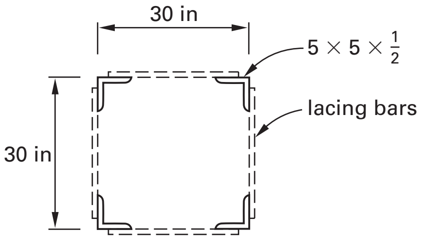
$$\frac{P_n}{\Omega_c} = 887\text{ kips}$$

Built-Up Sections

For built-up sections and laced compression members, *AISC Manual* Table 4-22 tabulates $\phi_c F_{cr}$ and F_{cr}/Ω_c against KL/r for steel with yield stresses of 35 kips/in^2, 36 kips/in^2, 42 kips/in^2, 46 kips/in^2, and 50 kips/in^2, respectively.

Example 5.19

A laced column consisting of four 5 × 5 × ½ angles of grade A36 steel is shown. The column may be considered a single integral member and is 20 ft high with pinned ends. Determine the maximum design axial load.



Solution

The relevant properties of a 5 × 5 × ½ angle are

$$\begin{aligned}A &= 4.79\text{ in}^2\\ I &= 11.3\text{ in}^4\\ y &= 1.42\text{ in}\end{aligned}$$

The relevant properties of the laced column are

$$\begin{aligned}\sum A &= 4A\\ &= (4)(4.79\text{ in}^2)\\ &= 19.16\text{ in}^2\\ \sum I &= 4I + \sum A\left(\frac{d}{2} - y\right)^2\\ &= (4)(11.3\text{ in}^4) + (19.16\text{ in}^2)\Big(\overset{\boxed{\text{15 in}}}{\cancel{30\text{ in}^2}} - 1.42\text{ in}^{\cancel{2}}\Big)^2\\ &= 3579\text{ in}^4\end{aligned}$$

The radius of gyration of the laced column is

$$\begin{aligned}r &= \sqrt{\frac{\sum I}{\sum A}} = \sqrt{\frac{3579\text{ in}^4}{19.16\text{ in}^2}}\\ &= 13.67\text{ in}\end{aligned}$$

When $f_v > F_{vm}$, shear reinforcement is provided to carry the residual shear stress. The area of shear reinforcement required is given by TMS 402 Eq. ~~3-30~~ 8-30 as

$$F_{vs} = 0.5\left(\frac{A_v F_s d_v}{A_{nv} s}\right)$$

For a solid grouted masonry beam, the net shear area of the beam is

$$A_{nv} = bd_v$$

For a solid grouted beam in accordance with TMS 402 Eq. 8-25, the shear stress resisted by the masonry and the shear stress resisted by the shear reinforcement are additive to give a combined allowable shear stress of

$$F_v = F_{vm} + F_{vs}$$

The allowable shear stress, when $M/(Vd_v) \leq 0.25$, is limited by TMS 402 Eq. 8-26 to

$$F_v \leq 3\sqrt{f'_m}$$

The allowable shear stress, when $M/(Vd_v) \geq 1.0$, is limited by TMS 402 Eq. 8-27 to

$$F_v \leq 2\sqrt{f'_m}$$

To simplify the procedure, TMS 402 Comm. Sec. 8.3.5.1.2 permits $M/(Vd_v)$ to be 1.0 in TMS 402 Eq. 8-29 and Sec. 8.3.5.1.2.

SD Method

The nominal shear strength of a beam without shear reinforcement is given by TMS 402 Eq. 9-24 as

$$V_{nm} = \left(4.0 - 1.75\left(\frac{M_u}{V_u d_v}\right)\right)A_{nv}\sqrt{f'_m} + 0.25P_u$$

The nominal shear strength provided by shear reinforcement is given by TMS 402 Eq. 9-25 as

$$V_{ns} = 0.5\left(\frac{A_v}{s}\right)f_y d_v$$

For a solid grouted masonry beam, the net shear area of the beam is

$$A_{nv} = bd_v$$

For a solid grouted masonry beam in accordance with TMS 402 Eq. 9-21, the nominal shear strength provided by the masonry and the nominal shear strength provided by the shear reinforcement are additive to give a combined nominal shear strength of

$$V_n = V_{nm} + V_{ns}$$

For a solid grouted masonry beam the nominal shear strength, when $M_u/(V_u d_v) \leq 0.25$, is limited by TMS 402 Eq. 9-22 to

$$V_n \leq 6A_{nv}\sqrt{f'_m}$$

For a solid grouted masonry beam the nominal shear strength, when $M_u/(V_u d_v) \geq 1.0$, is limited by TMS 402 Eq. 9-23 to

$$V_n \leq 4A_{nv}\sqrt{f'_m}$$

To simplify the procedure, TMS 402 Comm. Sec. 9.3.4.1.2 permits $M_u/(V_u d_v)$ to be 1.0 in TMS 402 Eq. 9-24, Sec. 9.3.4.1.2, and Sec. 9.3.4.1.2.1.

Example 7.7

For the masonry beam of Ex. 7.5, determine whether the shear reinforcement provided is adequate.

Solution

ASD Method

The maximum permitted shear stress, assuming $M/Vd_v = 1$, is given by TMS 402 Eq. 8-27 as

$$\begin{aligned} F_v &= 2\sqrt{f'_m} \\ &= 2\sqrt{1500\ \frac{\text{lbf}}{\text{in}^2}} \\ &= 77.5\ \text{lbf/in}^2 \end{aligned}$$

The shear force at a distance of $d/2$ from each support is given by

$$\begin{aligned} V &= \frac{w(l-d)}{2} + W \\ &= \frac{\left(276\ \frac{\text{lbf}}{\text{ft}}\right)\left(11\ \text{ft} - \left(\frac{45\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right)\right)}{(2)\left(1000\ \frac{\text{lbf}}{\text{kip}}\right)} + 20\ \text{kips} \\ &= 21.0\ \text{kips} \end{aligned}$$