Example 1 (LRFD Steel Design, Third Edition by William T. Segui, page 95.)

Compute the design compressive strength of a W14 × 74 with a length of 20 feet and pinned ends. A992 steel is used.

Slenderness ratio:

$$\text{Maximum } \frac{KL}{r} = \frac{KL}{r_y} = \frac{1.0(20 \times 12)}{2.48} = 96.77 < 200 \qquad \text{(OK)}$$

$$\lambda_c = \frac{KL}{r\pi}\sqrt{\frac{F_y}{E}} = \frac{96.77}{\pi}\sqrt{\frac{50}{29{,}000}} = 1.279$$

$$\lambda_c < 1.5 \therefore \text{ use AISC Equation E2-2.}$$

$$F_{cr} = (0.658^{\lambda_c^2})F_y = (0.658)^{(1.279)^2}(50) = 25.21 \text{ ksi}$$

$$P_n = A_g F_{cr} = 21.8(25.21) = 549.6 \text{ kips}$$

$$\phi_c P_n = 0.85(549.6) = 467 \text{ kips}$$

Design compressive strength = 467 kips. ■

Example 2 (LRFD Manual, page 4-7, 4-8.)

W-shape compression member design (braced frame).

Determine the design strength of an ASTM A992 W14×132 that is part of a braced frame.

$$F_y = 50\text{ ksi} \qquad A_g = 38.8\text{ in.}^2$$
$$F_u = 65\text{ ksi} \qquad r_x = 6.28\text{ in.}$$
$$r_y = 3.76\text{ in.}$$

a) Assume the physical length $L = 30$ ft, the ends are pinned and the column is braced at the ends only for both the X-X and Y-Y axes. Also, calculate at what length this compression member would cease to satisfy the slenderness limitation in LRFD Specification Section B7.

b) Assume the physical length $L = 30$ ft, the ends are pinned, and the column is braced at the ends only for the X-X axis and braced at the ends and mid-height for the Y-Y axis.

From Table 1-1, the width-thickness ratio for the flanges is

$$\lambda = \frac{b_f}{2t_f} = 7.15$$

and the width-thickness ratio for the web is

$$\lambda = \frac{h}{t_w} = 17.7$$

From LRFD Specification Section B5.1, for flange compactness

$$\lambda_r = 0.56\sqrt{\frac{E}{F_y}} = 0.56\sqrt{\frac{29{,}000\text{ ksi}}{50\text{ ksi}}} = 13.5$$

Since $\lambda < \lambda_r$, the flanges are not slender. From LRFD Specification Section B5.1, for web compactness

$$\lambda_r = 1.49\sqrt{\frac{E}{F_y}} = 1.49\sqrt{\frac{29{,}000\text{ ksi}}{50\text{ ksi}}} = 35.9$$

Since $\lambda < \lambda_r$, the web is not slender. Since neither the flanges nor the web are slender, the W14×132 can be designed per LRFD Specification Section E2.

From LRFD Specification Section C2.1 and Commentary Table C-C2.1, $K = 1.0$ for both the X-X axis and the Y-Y axis.

$$\frac{Kl_x}{r_x} = \frac{1.0(30\text{ ft} \times 12\text{ in./ft})}{6.28\text{ in.}}$$
$$= 57.3$$
$$\frac{Kl_y}{r_y} = \frac{1.0(30\text{ ft} \times 12\text{ in./ft})}{3.76\text{ in.}}$$
$$= 95.7$$

Since $Kl_y/r_y > Kl_x/r_x$, buckling about the Y-Y axis controls. From LRFD Specification Section E2,

$$\lambda_c = \frac{Kl}{r\pi}\sqrt{\frac{F_y}{E}}$$
$$= \frac{95.7}{\pi}\sqrt{\frac{50\text{ ksi}}{29{,}000\text{ ksi}}}$$
$$= 1.26$$

Since $\lambda_c < 1.5$,

$$\phi_c P_n = \phi_c F_{cr} A_g$$
$$= \phi_c \left(0.658^{\lambda_c^2}\right) F_y A_g$$
$$= 0.85 \left(0.658^{(1.26)^2}\right) (50\text{ ksi}) \left(38.8\text{ in.}^2\right)$$
$$= 844\text{ kips}$$

Per LRFD Specification Section B7,

$$L_{\max} = \frac{200r}{K}$$
$$= \frac{200(3.76\text{ in.})}{1.0(12\text{ in./ft})}$$
$$= 62.7\text{ ft}$$

Thus, the W14×132 compression member satisfies the slenderness requirements up to a 62.7-ft length.