<u>Classroom Problem 5.5-3</u>: Determine the flexural strength of a **W16 x 100** of **A572 Grade 50** steel (F_y = 50 *ksi*; F_u = 65 *ksi*) subject to: a) continuous lateral support, b) an unbraced length of 30 ft. with C_b = 1.0, and c) an unbraced length of 40 ft. with C_b = 1.0.

* TABLE 1-1 (1-22)

$A = 29.4\,in^2$ $h/t = 24.3$ $b/2t = 5.29$ $Z_x = 198\,in^3$

$S_x = 175\,in^3$ $r_y = 2.51\,in$ $r_{st} = 2.92\,in$ $h_o = 16\,in$ $J = 7.73\,in^4$

* CHECK FOR COMPACTNESS

$b/2t < 0.38\sqrt{E/F_y} = 9.15$ COMPACT

$h/t < 3.76\sqrt{E/F_y} = 90.55$ COMPACT

PART a) $M_n = M_p = F_y Z = 50ksi(198\,in^3) = 9{,}900\,k \cdot in = 825\,k \cdot ft$

$\phi_b M_n = 0.90(825\,kft) = 742.5\,kft$

PART b) $L_b = 30\text{ ft} = 30\text{ ft}(12\text{ in}/\text{ft}) = 360\text{ in.}$ $\quad C_b = 1.0$

$$L_p = 1.76 r_y \sqrt{E/F_y} = 1.76(2.51\text{ in})\sqrt{\frac{29{,}000\text{ ksi}}{50\text{ ksi}}} = 106.39\text{ in.}$$

$$L_r = 1.95 r_{ts} \frac{E}{0.7F_y}\sqrt{\frac{J_c}{S_x h_o} + \sqrt{\left(\frac{J_c}{S_x h_o}\right)^2 + 6.76\left(\frac{0.7F_y}{E}\right)^2}}$$

$$\frac{J_c}{S_x h_o} = \frac{7.73\text{ in}^4(1)}{175\text{ in}^3(16\text{ in})} = 0.002761$$

$$L_r = 1.95(2.92\text{ in})\frac{29{,}000\text{ ksi}}{0.7(50\text{ ksi})}\sqrt{0.002761 + \sqrt{(0.002761)^2 + 6.76\left(\frac{0.7(50\text{ ksi})}{29000\text{ ksi}}\right)^2}}$$

$$= 393.04\text{ in} > L_b = 360\text{ in} \quad \therefore \text{ USE EQ. F2-2}$$

$$M_n = C_b\left[M_p - (M_p - \underbrace{0.7F_y S_x}_{M_r})\left[\frac{L_b - L_p}{L_r - L_p}\right]\right] \leq M_p$$

$$M_n = \left[9{,}900\,k\cdot in - (9{,}900\,k\cdot in - 0.7(50\,ksi)175\,in^3)\left[\frac{360 - 106.39}{393.04 - 106.39}\right]\right] \le M_p$$

$$= 6{,}560.8\ k\cdot in = 546.67\ kft \qquad \phi_b M_n = 0.90(546.67\,kft)$$

$$= \underline{\underline{492.01\ kft}}$$

PART c) $L_b = 40\,ft = 40\,ft(12\,in/ft) = 480\,in > L_r \quad \therefore$ USE $\left[\begin{array}{l} F2\text{-}3 \\ F2\text{-}4 \end{array}\right.$

$$F_{CR} = \frac{C_b \pi^2 E}{(L_b/r_{ts})^2}\sqrt{1 + 0.078\frac{J_c}{S_x h_o}\left(\frac{L_b}{r_{ts}}\right)^2}$$

$$= \frac{\pi^2(29{,}000\,ksi)}{(480\,in/2.92\,in)^2}\sqrt{1 + 0.078(0.002761)\left(\frac{480\,in}{2.92\,in}\right)^2} = 27.66\,ksi$$

$$M_n = F_{CR} S_x = 27.66\,ksi(175\,in^3) = 4{,}840.3\,k\cdot in = 403.36\,k\cdot ft < M_p$$

$$\phi_b M_n = 0.90(403.36\,kft) = \underline{\underline{363.02\,kft}}$$