$Z = 98.208\ in^3$

MEMBER: WT 10.5 x 91

$KL = 18\ ft$
$f_y = 50\ ksi$
$A_g = 26.8\ in^2$
$r_x = 3.07\ in$
$r_y = 3.00\ in$

X-AXIS

$$\frac{KL}{r_x} = \frac{(18)(12)}{3.07} = 70.358$$

$$F_{e_x} = \frac{\pi^2 E}{(KL/r)_x^2} = \frac{\pi^2(29000\,ksi)}{(70.358)^2} = 57.819\ ksi$$

$$4.71\sqrt{\frac{E}{F_y}} = 4.71\sqrt{\frac{29000}{50}} = 113.43$$

$$113.43 > 70.358 \quad \text{USE : } F_{cr} = \left[0.658^{(f_y/F_e)}\right] f_y$$

$$F_{cr_x} = \left[0.658^{(50/57.819)}\right](50) = 34.816\ ksi$$

$$P_{n_x} = F_{cr_x}(A_g) = (34.816)(26.8) = 933.07\ kips$$

FROM TABLE 4-7 $\phi P_n = 841\ kip \Rightarrow P_n = \frac{841^k}{0.9} = 934.44\ k$

$933.07^k \approx 934.44 \quad \therefore$ OK

Y-Z AXIS

$$\frac{KL}{r_y} = \frac{(18)(12)}{(3.00)} = 72$$

$$F_{e_y} = \frac{\pi^2 E}{(KL/r)_y^2} = \frac{\pi^2(29000)}{72^2} = 55.212\ ksi$$

$$(KL/r)_y = 72 < 4.71\sqrt{\frac{E}{f_y}} = 113$$

$$F_{cr_y} = 0.658^{(50/55.212)}(50) = 34.226\ ksi$$

$$F_{cr_z} = \frac{GJ}{A_g \bar{r}_o^2} \Rightarrow \frac{(11266)(15.3)}{(26.8)(21.46)} = 297.95$$

$G = 11200$
$J = 15.3$
$\bar{y} = 2.48\ in$
$t_f = 1.48\ in$
$I_x = 253\ in^4$
$I_y = 241\ in^4$

$$x_o = 0 \qquad y_o = \bar{y} - \frac{t_f}{2} = 2.48 - \frac{1.48}{2} = 1.74\ in$$

$$\bar{r}_o^2 = x_o^2 + y_o^2 + \frac{I_x + I_y}{A_g}$$

$$= 0^2 + 1.74^2 + \frac{253 + 241}{26.8} = 21.46\ in^2$$

$$H = 1 - \frac{x_o^2 + y_o^2}{\bar{r}_o^2} = 1 - \frac{0^2 + (1.74)^2}{21.46} = 0.65892$$

$$F_{cr} = \left(\frac{F_{cry} + F_{crz}}{2H}\right)\left[1 - \sqrt{1 - \frac{4F_{cry}F_{crz}H}{(F_{cry}+F_{crz})^2}}\right]$$

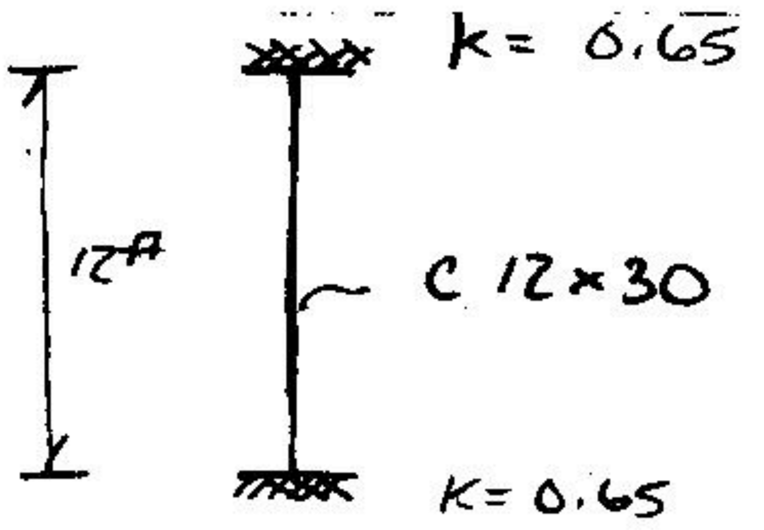
$$= \left(\frac{34.226 + 297.95}{2(0.65892)}\right)\left[1 - \sqrt{1 - \frac{4(34.226)(297.95)(0.65892)}{(34.226 + 297.95)^2}}\right] = 33.62\ ksi$$

$$P_{n_{yz}} = (33.62)(26.8) = 901.02\ kips$$

FROM TABLE 4-7 $\phi P_n = 811\ kips \Rightarrow P_n = \frac{811}{0.9} = 901.11\ k$

$901.02^k \cong 901.11^k \quad \therefore$ OK

$Z = 98.208\ in^3$



$F_y = 50$ ksi
$A_g = 8.81\ in^2$
$r_x = 4.29$ in
$r_y = 0.762$ in

Buckling strength about y-axis

$$\left(\frac{KL}{r}\right)_y = \frac{(0.65)(12)(12)}{0.762} = 122.83 \quad \Rightarrow \left(\frac{KL}{r}\right)_y > 4.71\sqrt{\frac{E}{F_y}}$$

$$F_{ey} = \frac{\pi^2(E)}{(KL/r)_y^2} = \frac{\pi^2(29000)}{112.83^2} = 18.97 \text{ ksi}$$

$$F_{cry} = 0.877\ F_e = 0.877(18.97) = 16.636 \text{ ksi}$$

$$P_n = F_{cry}(A_g) = 16.636(8.81) = \underline{\underline{146.57}} \text{ kips}$$

Flexural - torsional buckling about the y and z axes

$$\left(\frac{KL}{r}\right)_x = \frac{(0.65)(12)(12)}{4.29} = 21.818 \quad \Rightarrow \left(\frac{KL}{r}\right)_x < 4.71\sqrt{\frac{E}{F_y}}$$

$$F_{ex} = \frac{\pi^2(E)}{(KL/r)_x^2} = \frac{\pi^2(29000)}{(21.818)^2} = 601.26 \text{ ksi}$$

$$F_{ez} = \left(\frac{\pi^2 E C_w}{(K_z L)^2} + GJ\right)\frac{1}{A_g \bar{r}_o^2}$$

$$= \left\{\frac{\pi^2(29000)(151)}{[(0.65)(12)(12)]^2} + 11200(0.861)\right\}\frac{1}{(8.81)(4.54)^2}$$

$$= 86.271 \text{ ksi}$$

$C_w = 151\ in^6$
$\bar{r}_o = 4.54$ in
$H = 0.919$
$G = 11{,}200$ ksi
$J = 0.861\ in^4$

$$F_e = \left(\frac{F_{ey} + F_{ez}}{2H}\right)\left[1 - \sqrt{1 - \frac{4F_{ey}F_{ez}H}{(F_{ey}+F_{ez})^2}}\right]$$

$$= \left(\frac{601.26 + 86.271}{(2)(0.919)}\right)\left[1 - \sqrt{1 - \frac{4(601.26)(86.271)(0.919)}{(601.26 + 86.271)^2}}\right]$$

$$= 79.295 \text{ ksi}$$

$$F_{cr} = 0.658^{(50/79.295)}(50) = 38.462$$

$$P_n = F_{cr}(A_g) = (38.462)(8.81) = 338.32^{K}$$

(4.9-10) 2L6 x 4 x 5/8 LLBB , $\frac{3}{8}$ in spacing between them,
F_y = 50 Ksi , KL = 18' in every axis, two intermediate fully tightened bolts. A_g = 11.7 in²

1. Buckling about x-axis:

$r_x = 1.89$ in

$$\frac{KL}{r_x} = \frac{18 \times 12 in}{1.89 in} = 114.29 > 113$$

$$F_e = \frac{\pi^2 \times 29000 Ksi}{(KL/r_x)^2} = \frac{\pi^2 \times 29000 Ksi}{(114.29)^2}$$

$$= 21.91 Ksi$$

$$\Rightarrow F_{cr} = 0.877 \times F_e$$

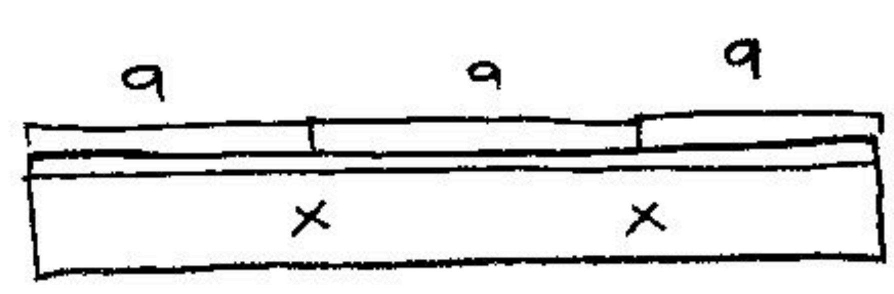
$$= 19.23 Ksi$$

$$\phi P_n = 0.9 \times 11.7 in^2 \times 19.23 Ksi = \boxed{202.33 Kips}$$

2. Flexural-Torsional Buckling:

$r_y = 1.66$ in

$$\frac{KL}{r_y} = \frac{18 \times 12 in}{1.66 in} = 130.12$$



$$3a = KL \Rightarrow a = \frac{18 \times 12 in}{3} = 72 in$$

$r_z = 0.859$ in
(single angle)

$$\frac{Ka}{r_z} = \frac{72 in}{0.859 in} = 83.82 < 0.75 \times \left(\frac{KL}{r_y}\right) = 97.56 \checkmark$$

$$\left(\frac{KL}{r}\right)_m = \sqrt{\left(\frac{KL}{r_y}\right)^2 + \left(\frac{a}{r_z}\right)^2} = \sqrt{(130.12)^2 + (83.82)^2}$$

$$= 154.78.$$

- $F_e = \dfrac{\pi^2 E}{\left(\frac{KL}{r}\right)_m^2} = \dfrac{\pi^2 \times 29000}{(154.78)^2}\ \text{ksi} = 11.94\ \text{ksi} < 0.44\,F_y$

$\Rightarrow F_{cry} = 0.877 \times F_e = 10.48\ \text{ksi}$

- $F_{crz} = \dfrac{GJ}{A_g \bar{r}_o^2} = \dfrac{11200 \times 2 \times 0.775}{11.7 \times (3.05)^2}\ \text{ksi}$

$\bar{r}_o = 3.05$ in

$J = 2 \times 0.775\ \text{in}^4$

$H = 0.684$ in

$= 159.5$ ksi

$$\Rightarrow F_{cr} = \frac{F_{cry} + F_{crz}}{2H}\left(1 - \sqrt{1 - \frac{4 F_{cry} F_{crz} H}{(F_{cry} + F_{crz})^2}}\right)$$

$$= \frac{10.48 + 159.5}{2 \times 0.684}\left(1 - \sqrt{1 - \frac{4 \times 10.48 \times 159.5 \times 0.684}{(10.48 + 159.5)^2}}\right)$$

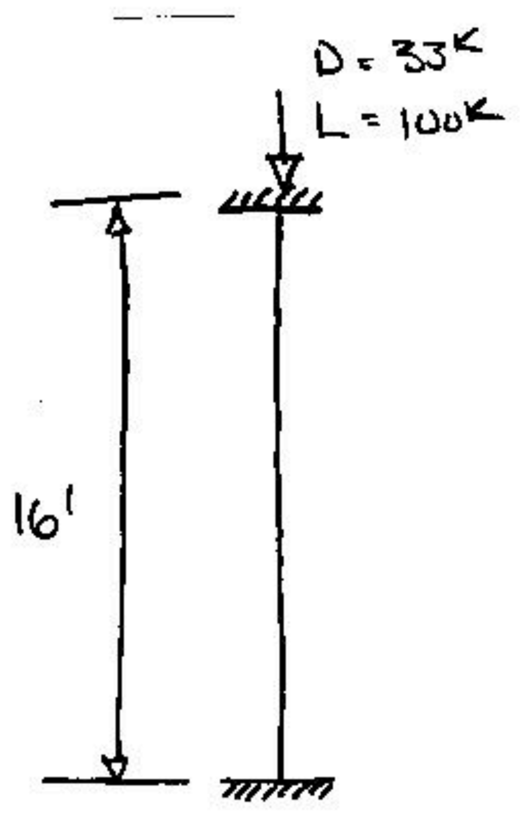
$= 10.26$ ksi

$\Rightarrow P_n = F_{cr} \times A_g = 10.26\ \text{ksi} \times 11.7\ \text{in}^2 = 120$ kips

$\phi P_n = 0.9 \times 120$ kips $= 108$ kips

So it has more strength for x-axis buckling than for flexural torsional buckling.

We can't compare with the table 4-9 because it is for $f_y = 36$ ksi.



GIVEN: Column as shown, A36 steel.

REQUIRED: Design a double angle section (gusset plate = 3/8") for the column and specify # of intermediate connectors

SOLUTION: <u>Loading</u>

$$P = 1.2D + 1.6L$$
$$= 1.2(33) + 1.6(100)$$
$$= 199.6\ K$$

<u>Design</u>

$$(KL)_x = (KL)_y = (16')(0.65) = 10.4$$

From Table 4-9 (4-133)
2L5 × 3½ × 5/8
KL X-X . 10 ⇒ 234 K
12 ⇒ 204 K

<u>X-axis Strength Check</u>

$$\left(\frac{KL}{r}\right)_x = \frac{(10.4)(12^{in}/_{ft})}{1.56} = 80$$

$$F_e = \frac{\pi^2\, 29000}{(80)^2} = 44.72$$

$$F_{cr} = 0.658^{\,50/44.72}\ 50$$

$$= 31.31\ \text{ksi}$$

$$\phi P_n = \phi A_g F_{cr} = 0.9(2 \times 4.92)(31.31)$$

$$= 277.31\ \text{Kips}$$