### EXAMPLE E.1A W-SHAPE COLUMN DESIGN WITH PINNED ENDS

### Given:

Select a W-shape column to carry the loading as shown in Figure E.1A. The column is pinned top and bottom in both axes. Limit the column size to a nominal 14-in. shape. A column is selected for both ASTM A992 and ASTM A913 Grade 65 material.

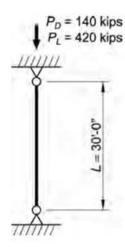


Fig. E.1A. Column loading and bracing.

## $1.2 \cdot 140 \ kip + 1.6 \cdot 420 \ kip = 840 \ kip$

### W14x132

$$h := 14.7 \ in$$
  
 $b_f := 14.7 \ in$   
 $t_f := 1.03 \ in$   
 $t_w := 0.645 \ in$   
 $k := 1.63 \ in$ 

$$A_g \coloneqq 2 \cdot t_f \cdot b_f + \left(h - 2 \cdot t_f\right) \cdot t_w = 38.435 \ \boldsymbol{in}^2$$

$$I_{x}\!\coloneqq\!\left(\!2\boldsymbol{\cdot}\!\left(\!b_{f}\boldsymbol{\cdot}\frac{t_{f}^{\;3}}{12}\!+\!b_{f}\boldsymbol{\cdot}t_{f}\boldsymbol{\cdot}\!\left(\!\frac{\left(\!h\!-\!2\boldsymbol{\cdot}t_{f}\!\right)}{2}\!+\!\frac{t_{f}}{2}\!\right)^{\!2}\right)\!+t_{w}\boldsymbol{\cdot}\frac{\left(\!h\!-\!2\boldsymbol{\cdot}t_{f}\!\right)^{\;3}}{12}\!\right)\!=\!\left(\!1.526\boldsymbol{\cdot}10^{3}\right)\,\boldsymbol{in}^{\,4}$$

$$S_x \coloneqq \frac{I_x}{\left(\frac{h}{2}\right)} = 207.608 \; in^3$$

$$Z_x \coloneqq b_f \cdot t_f \cdot \left( h - t_f \right) + \frac{1}{4} \cdot \left( h - 2 \ t_f \right)^2 \cdot t_w = 232.74 \ \textbf{in}^3$$

$$r_x := \sqrt{\frac{I_x}{A_a}} = 6.301 \ \emph{in}$$

$$I_y := 2 \cdot \left(t_f \cdot \frac{b_f^3}{12}\right) + \left(h - 2 \cdot t_f\right) \cdot \frac{t_w^3}{12} = 545.586 \ in^4$$

$$S_y \coloneqq \frac{I_y}{\frac{b_f}{2}} = 74.229 \; \emph{in}^3$$

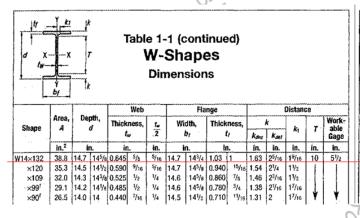
$$egin{aligned} Z_y \coloneqq & rac{1}{2} \cdot b_f^{\ 2} \cdot t_f + rac{1}{4} \cdot ig( h - 2 \cdot t_f ig) \cdot t_w^{\ 2} = 112.601 \,\, m{i}m{n}^3 \ & r_y \coloneqq & \sqrt{rac{I_y}{A_g}} = 3.768 \,\, m{i}m{n} \end{aligned}$$

$$r_y = \sqrt{rac{I_y}{A_g}} = 3.768 \; in$$

$$c_w \! \coloneqq \! rac{\left(h \! - \! t_f
ight)^2 \cdot b_f^{\phantom{-}3} \cdot t_f}{24} \! = \! \left(2.548 \cdot 10^4
ight) \, m{in}^6$$

$$J \coloneqq \frac{2 \cdot b_f \cdot {t_f}^3 + (h - t_f) \cdot {t_w}^3}{3} = 11.931 \; m{in}^4 \ r_{ts} \coloneqq \sqrt{\frac{\sqrt{I_y \cdot c_w}}{S_x}} = 4.238 \; m{in}$$

$$r_{ts}\!\coloneqq\!\sqrt{rac{\sqrt{I_y\!\cdot\! c_w}}{S_x}}\!=\!4.238$$
 in



| Table 1-1 (continued)  W-Shapes  Properties  W14-W12 |      |                |       |      |       |      |          |      |      |                 |                |                      |      |                  |
|--|------|----------------|-------|------|-------|------|----------|------|------|-----------------|----------------|----------------------|------|------------------|
| Nom-   |      |                |       | Axis | х-х   |      | Axis Y-Y |      |      | r <sub>ts</sub> | ħ <sub>e</sub> | Torsional Properties |      |                  |
| Wt.  | br   | h              | 1.    | S    | r     | Z    | 1        | S    | r    | Z               |                |                      | J    | C <sub>w</sub>   |
| lb/ft  | 21,  | t <sub>w</sub> | ín.4  | ìn.3 | ín.   | ín.³ | in.4     | in.3 | in.  | in,3            | in.            | in.                  | in.4 | ìn. <sup>6</sup> |
| 132  | 7.15 | 17.7           | 1530  | 209  | 6.28  | 234  | 548      | 74.5 | 3.76 | 113             | 4.23           | 13,7                 | 12.3 | 25500            |
| 120  | 7.80 | 19.3           | 1380  | 190  | 6.24  | 212  | 495      | 67.5 | 3.74 | 102             | 4.20           | 13.6                 | 9.37 | 22700            |
| 109  | 8.49 | 21.7           | 1240  | 173  | 6.22  | 192  | 447      | 61.2 | 3.73 | 92.7            | 4.17           | 13.4                 | 7.12 | 20200            |
|  | 004  | 22 5           | 1110  | 157  | 6.17  | 173  | 402      | 55.2 | 3.71 | 83.6            | 4.14           | 13.4                 | 5.37 | 18000            |
| 99   | 9.34 | 23.5           | 11110 | 13/  | 0.171 | 170  |          |      |      |                 |                |                      |      |                  |

$$E = 29000 \ ksi = (1.999 \cdot 10^5) \ MPa$$

$$F_y = 50 \ ksi = 344.738 \ MPa$$

$$\frac{b_f}{2 \cdot t_f} = 7.136$$

$$0.56 \cdot \sqrt{\frac{E}{F_y}} = 13.487$$

$$\frac{(h-2\cdot(k))}{t_w} = 17.736 \qquad 1.49 \cdot \sqrt{\frac{E}{F_y}} = 35.884$$

$$1.49 \cdot \sqrt{\frac{E}{F_y}} = 35.884$$

$$L_c = 30 \; ft = 360 \; in$$

$$4.71 \cdot \sqrt{\frac{E}{F_y}} = 113.432$$

$$\frac{L_c}{r_x} = 57.135$$

$$\frac{L_c}{r_u} = 95.551$$

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$$F_e \coloneqq \frac{oldsymbol{\pi}^2 \cdot E}{\left(rac{L_c}{r_x}
ight)^2} = 87.68 \,\, oldsymbol{ksi}$$

$$\mathbf{F_{cr}}\!\coloneqq\!\mathbf{if}\!\left(\!\frac{L_{e}}{r_{x}}\!\!>\!4.71\boldsymbol{\cdot}\sqrt{\frac{E}{F_{y}}}\,,0.877\boldsymbol{\cdot}F_{e}\,,0.658^{\frac{F_{y}}{F_{e}}}\boldsymbol{\cdot}F_{y}\!\right)\!\!=\!39.383~\textit{ksi}$$

$$F_e \coloneqq rac{oldsymbol{\pi}^2 \cdot E}{\left(rac{L_c}{r_y}
ight)^2} = 31.35 \; oldsymbol{ksi}$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left( \frac{L_c}{r_y} \right)^2$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left( \frac{L_c}{r_y} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 25.648 \text{ ksi}$$

$$F_e \coloneqq \frac{\pi^2 \cdot E}{\mathbf{F_{cr}}} = 31.35 \text{ ksi}$$

$$F_e \coloneqq \frac{oldsymbol{\pi}^2 oldsymbol{\cdot} E}{\left( \max \left( rac{L_c}{r_x}, rac{L_c}{r_y} 
ight) 
ight)^2} = 31.35 \; oldsymbol{ksi}$$

$$F_e \coloneqq \frac{\pi^2 \cdot E}{\left(\max\left(\frac{L_c}{r_x}, \frac{L_c}{r_y}\right)\right)^2} = 31.35 \text{ ksi}$$

$$\mathbf{F}_{cr} \coloneqq \mathbf{if} \left(\max\left(\frac{L_c}{r_x}, \frac{L_c}{r_y}\right) > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y\right) = 25.648 \text{ ksi}$$

$$\phi \coloneqq 0.9$$

$$\phi P_n \coloneqq \phi \cdot \mathbf{F}_{cr} \cdot A_g = 887.201 \text{ kip}$$

$$1.2 \cdot 140 \text{ kip} + 1.6 \cdot 420 \text{ kip} = 840 \text{ kip}$$

$$\phi := 0.9$$

$$\phi P_n := \phi \cdot \mathbf{F_{cr}} \cdot A_q = 887.201 \ kip$$

| LRFD   | ASD   |
|--|---|
| $\phi_c P_n = 893 \text{ kips} > 840 \text{ kips}$ <b>o.k.</b> | $\frac{P_n}{\Omega_c} = 594 \text{ kips} > 560 \text{ kips}  \textbf{o.k.}$ |

### Given:

Verify a W14×90 is adequate to carry the loading as shown in Figure E.1B. The column is pinned top and bottom in both axes and braced at the midpoint about the y-y axis and torsionally. The column is verified for both ASTM A992 and ASTM A913 Grade 65 material.

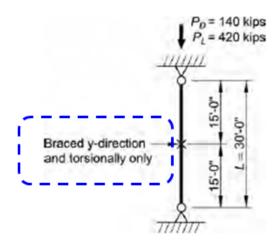


Fig. E.1B. Column loading and bracing.

### W14x132

$$h := 14.7 \ in$$
  
 $b_f := 14.7 \ in$   
 $t_f := 1.03 \ in$   
 $t_w := 0.645 \ in$   
 $k := 1.63 \ in$ 

$$A_a := 2 \cdot t_f \cdot b_f + (h - 2 \cdot t_f) \cdot t_w = 38.435 \ in^{3}$$

$$\begin{split} A_g &\coloneqq 2 \cdot t_f \cdot b_f + \left(h - 2 \cdot t_f\right) \cdot t_w = 38.435 \ \textbf{in}^2 \\ I_x &\coloneqq \left(2 \cdot \left(b_f \cdot \frac{t_f^{\ 3}}{12} + b_f \cdot t_f \cdot \left(\frac{\left(h - 2 \cdot t_f\right)}{2} + \frac{t_f}{2}\right)^2\right) + t_w \cdot \frac{\left(h - 2 \cdot t_f\right)^3}{12}\right) = \left(1.526 \cdot 10^3\right) \ \textbf{in}^4 \end{split}$$

$$S_x \coloneqq \frac{I_x}{\left(\frac{h}{2}\right)} = 207.608 \ \emph{in}^3$$

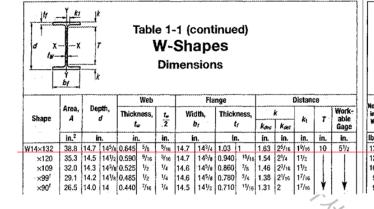
$$Z_x\!:=\!b_f\!\cdot\!t_f\!\cdot\!\left(\!h\!-\!t_f\!\right)\!+\!\frac{1}{4}\!\cdot\!\left(\!h\!-\!2\ t_f\!\right)^2\cdot\!t_w\!=\!232.74\ \pmb{in}^3$$

$$r_x \! \coloneqq \! \sqrt{rac{I_x}{A_g}} \! = \! 6.301 \; m{in}$$

$$I_y := 2 \cdot \left( t_f \cdot \frac{{b_f}^3}{12} \right) + \left( h - 2 \cdot t_f \right) \cdot \frac{{t_w}^3}{12} = 545.586 \ \emph{in}^4$$

$$S_y \coloneqq \frac{I_y}{\frac{b_f}{2}} = 74.229 \ \emph{in}^3$$
 
$$Z_y \coloneqq \frac{1}{2} \cdot b_f^2 \cdot t_f + \frac{1}{4} \cdot (h - 2 \cdot t_f) \cdot t_w^2 = 112.601 \ \emph{in}^3$$

$$r_y \coloneqq \sqrt{rac{I_y}{A_g}} = 3.768 \; m{in}$$
  $c_w \coloneqq rac{\left(h - t_f
ight)^2 \cdot b_f^{\; 3} \cdot t_f}{24} = \left(2.548 \cdot 10^4
ight) \; m{in}^6$   $J \coloneqq rac{2 \cdot b_f \cdot t_f^{\; 3} + \left(h - t_f
ight) \cdot t_w^{\; 3}}{3} = 11.931 \; m{in}^4$   $r_{ts} \coloneqq \sqrt{rac{\sqrt{I_y \cdot c_w}}{S_x}} = 4.238 \; m{in}$ 



| Table 1-1 (continued) W-Shapes Properties  W14-W12 |      |      |      |          |      |      |      |      |      |                         |                |  |
|--|------|------|------|----------|------|------|------|------|------|-------------------------|----------------|--|
| Axis X-X   |      |      |      | Axis Y-Y |      |      |      | Fis  | h.   | Torsional<br>Properties |                |  |
|  | 5    | r    | Z    | 1        | S    | 1    | Z    |      |      | J                       | C <sub>w</sub> |  |
|  | in.3 | ín.  | ín.³ | in.4     | in.3 | in.  | in,3 | in.  | in.  | in.4                    | in.6           |  |
|  | 209  | 6.28 | 234  | 548      | 74.5 | 3.76 | 113  | 4.23 | 13.7 | 12.3                    | 25500          |  |
|  | 190  | 6.24 | 212  | 495      | 67.5 | 3.74 | 102  | 4.20 | 13.6 | 9.37                    | 22700          |  |
| ı  | 173  | 6.22 | 192  | 447      | 61.2 | 3.73 | 92.7 | 4.17 | 13.4 | 7.12                    | 20200          |  |
|  | 157  | 6.17 | 173  | 402      | 55.2 | 3.71 | 83.6 | 4.14 | 13.4 | 5.37                    | 18000          |  |
|  |      |      |      |          |      |      |      |      |      |                         |                |  |

$$E = 29000 \ ksi = (1.999 \cdot 10^5) \ MPa$$

$$F_y = 50 \ ksi = 344.738 \ MPa$$

$$\frac{b_f}{2 \cdot t_f} = 7.136$$

$$0.56 \cdot \sqrt{\frac{E}{F_y}} = 13.487$$

$$\frac{\left(h - 2 \cdot (k)\right)}{t_w} = 17.736 \qquad 1.49 \cdot \sqrt{\frac{E}{F_y}} = 35.884$$

$$1.49 \cdot \sqrt{\frac{E}{F_y}} = 35.884$$

$$L_{cx} = 30 \; ft = 360 \; in$$

$$L_{cy} = 15 \; ft = 180 \; in$$

$$4.71 \cdot \sqrt{\frac{E}{F_y}} = 113.432$$

$$\frac{L_{cx}}{r_x} = 57.135$$

$$\frac{L_{cy}}{r_y} = 47.775$$

$$F_e \coloneqq \frac{\boldsymbol{\pi}^2 \cdot E}{\left(\frac{L_{cx}}{r_x}\right)^2} = 87.68 \ \boldsymbol{ksi}$$

$$\begin{aligned} \mathbf{F_{cr}} &\coloneqq \mathbf{if} \left( \frac{L_{cx}}{r_x} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 39.383 \ \textit{ksi} \end{aligned}$$

$$F_e &\coloneqq \frac{\pi^2 \cdot E}{\left( \frac{L_{cy}}{r_y} \right)^2} = 125.398 \ \textit{ksi}$$

$$F_e \coloneqq rac{\pi^2 \cdot E}{\left(rac{L_{cy}}{r_y}
ight)^2} = 125.398 \,\, extbf{ksi}$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left( \frac{L_{cy}}{r_y} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 42.315 \ \mathbf{\textit{ks}}$$

$$F_e \coloneqq \frac{oldsymbol{\pi}^2 oldsymbol{\cdot} E}{\left( \max \left( rac{L_{cx}}{r_x}, rac{L_{cy}}{r_y} 
ight) 
ight)^2} = 87.68 \,\, extbf{ extit{ksi}}$$

$$\begin{split} \mathbf{F}_{cr} &= \mathbf{H} \left( \frac{L_{cr}}{r_{x}} > 4.71 \cdot \sqrt{\frac{E}{F_{y}}}, 0.877 \cdot F_{e}, 0.658^{\frac{e}{I_{x}}} \cdot F_{g} \right) = 39.383 \text{ ksi} \\ F_{cr} &= \mathbf{H} \left( \frac{L_{cr}}{r_{y}} > 4.71 \cdot \sqrt{\frac{E}{F_{y}}}, 0.877 \cdot F_{e}, 0.658^{\frac{e}{I_{x}}} \cdot F_{g} \right) = 42.315 \text{ ksi} \\ F_{cr} &= \mathbf{H} \left( \max \left( \frac{L_{cr}}{r_{x}}, \frac{L_{cg}}{r_{y}} \right) > 4.71 \cdot \sqrt{\frac{E}{F_{y}}}, 0.877 \cdot F_{e}, 0.658^{\frac{F_{x}}{I_{x}}} \cdot F_{y} \right) = 39.383 \text{ ksi} \\ \phi &= 0.9 \\ \phi P_{u} &= \phi \cdot \mathbf{F}_{cr} \cdot A_{g} = \left( 1.362 \cdot 10^{2} \right) \text{ kip} \\ 1.2 \cdot 140 \text{ kip} + 1.6 \cdot 420 \text{ kip} = 840 \text{ kip} \end{split}$$

$$\phi = 0.9$$

$$\phi P_n := \phi \cdot \mathbf{F_{cr}} \cdot A_q = (1.362 \cdot 10^3)$$
 kip

$$1.2.140 \, kin + 1.6.420 \, kin - 840 \, kin$$

$$h \coloneqq 14 \; in$$
 $b_f \coloneqq 14.5 \; in$ 
 $t_f \coloneqq 0.71 \; in$ 
 $t_w \coloneqq 0.44 \; in$ 
 $k \coloneqq 1.31 \; in$ 

$$A_g\!:=\!2 \cdot t_f \cdot b_f \!+\! \left(h\!-\!2 \cdot t_f\right) \cdot t_w \!=\! 26.125 \ \pmb{in}^2$$

$$I_{x} \coloneqq \left(2 \cdot \left(b_{f} \cdot \frac{t_{f}^{3}}{12} + b_{f} \cdot t_{f} \cdot \left(\frac{(h-2 \cdot t_{f})}{2} + \frac{t_{f}}{2}\right)^{2}\right) + t_{w} \cdot \frac{(h-2 \cdot t_{f})^{3}}{12}\right) = 983.036 \ in^{4}$$

$$S_{x} \coloneqq \frac{I_{x}}{\left(\frac{h}{2}\right)} = 140.434 \ in^{3}$$

$$Z_{x} \coloneqq b_{f} \cdot t_{f} \cdot (h-t_{f}) + \frac{1}{4} \cdot (h-2 \cdot t_{f})^{2} \cdot t_{w} = 154.229 \ in^{3}$$

$$r_{x} \coloneqq \sqrt{\frac{I_{x}}{A_{g}}} = 6.134 \ in$$

$$I_{y} \coloneqq 2 \cdot \left(t_{f} \cdot \frac{b_{f}^{3}}{12}\right) + (h-2 \cdot t_{f}) \cdot \frac{t_{w}^{3}}{12} = 360.843 \ in^{4}$$

$$S_{y} \coloneqq \frac{I_{y}}{b_{f}} = 49.771 \ in^{3}$$

$$S_x \coloneqq \frac{I_x}{\left(\frac{h}{2}\right)} = 140.434 \; \emph{in}^3$$

$$Z_x := b_f \cdot t_f \cdot (h - t_f) + \frac{1}{4} \cdot (h - 2 t_f)^2 \cdot t_w = 154.229 \ in^3$$

$$r_x \! \coloneqq \! \sqrt{rac{I_x}{A_g}} \! = \! 6.134 \; m{in}$$

$$I_y \coloneqq 2 \cdot \left( t_f \cdot \frac{b_f^3}{12} \right) + \left( h - 2 \cdot t_f \right) \cdot \frac{t_w^3}{12} = 360.843 \ in^4$$

$$S_y \coloneqq \frac{I_y}{b_f} = 49.771 \; in^3$$

$$Z_y := \frac{1}{2} \cdot b_f^2 \cdot t_f + \frac{1}{4} \cdot (h - 2 \cdot t_f) \cdot t_w^2 = 75.248 \ in^3$$

$$r_y\!:=\!\sqrt{rac{I_y}{A_g}}\!=\!3.716$$
 in

$$c_w \! \coloneqq \! rac{\left(h \! - \! t_f
ight)^2 \! \cdot \! b_f^{\; 3} \cdot \! t_f}{24} \! = \! \left(1.593 \! \cdot \! 10^4
ight) \, m{in}^6$$

$$J := \frac{2 \cdot b_f \cdot t_f^3 + (h - t_f) \cdot t_w^3}{3} = 3.837 \ in^4$$

$$r_{ts} \coloneqq \sqrt{rac{\sqrt{I_y \cdot c_w}}{S_x}} = 4.132$$
 in



Table 1-1 (continued) W-Shapes

**Dimensions** 

|                  | T     |                  |                    |            | Web  |           | Γ      | Fla                | nge        |       |      |                         | Distano | 8   |       |
|------------------|-------|------------------|--------------------|------------|------|-----------|--------|--------------------|------------|-------|------|-------------------------|---------|-----|-------|
| Shape            | Area, | Area, Depth, A d |                    | Thickness, |      | <u>t.</u> | Width, |                    | Thickness, |       | k    |                         | k1      | 7   | Work- |
| onape            | , "   |                  |                    |            |      |           |        |                    |            |       | Køes | <i>k</i> <sub>det</sub> | "       | '   | Gage  |
|                  | in.2  | Ír               | ٦.                 | in         | ۱.   | in.       | i      | n.                 | ir         | l     | ín.  | in.                     | in.     | in. | in.   |
| W14×132          | 38.8  | 14.7             | 14 <sup>5</sup> /8 | 0.645      | 5/8  | 5/16      | 14.7   | 143/4              | 1.03       | 1     | 1.63 | 25/16                   | 19/16   | 10  | 51/2  |
| ×120             | 35.3  | 14.5             | 141/2              | 0.590      | 9/16 | 5/16      | 14.7   | 14 <sup>5</sup> /8 | 0.940      | 15/16 | 1.54 | 21/4                    | 11/2    | 1   |       |
| ×109             | 32.0  | 14.3             | 143/8              | 0.525      | 1/2  | 1/4       | 14.6   | 145/8              | 0.860      | 7/8   | 1.46 | 23/16                   | 11/2 .  |     |       |
| ×991             | 29.1  | 14.2             | 141/8              | 0.485      | 1/2  | 1/4       | 14.6   | 145/8              | 0.780      | 3/4   | 1.38 | 21/16                   | 17/16   |     |       |
| ×90 <sup>r</sup> | 26.5  | 14.0             | 14                 | 0.440      | 7/16 | 1/4       | 14,5   | 141/2              | 0.710      | 11/16 | 1.31 | 2                       | 17/16   | Ý   | *     |

# Table 1-1 (continued) W-Shapes

**Properties** 

Axis Y-Y

74.5 3.76 11.5 67.5 3.74 102 61.2 3.73 92.7 55.2 3.71 83.6 2.70 75.6

|    |      | W14    | -W12           |  |
|----|------|--------|----------------|--|
| ts | ft.  | · Tors |                |  |
|    |      | J      | C <sub>w</sub> |  |
| 1. | in.  | in.4   | in.6           |  |
| 23 | 13.7 | 12.3   | 25500          |  |
| 20 | 13.6 | 9.37   | 22700          |  |
| 17 | 13.4 | 7.12   | 20200          |  |
|    |      |        |                |  |

18000

$$E := 29000 \ ksi = (1.999 \cdot 10^5) \ MPa$$

$$F_y = 50 \ ksi = 344.738 \ MPa$$

$$\frac{b_f}{2 \cdot t_f} = 10.211$$

$$\frac{\left(h-2\cdot(k)\right)}{t_{w}}=25.864$$

$$0.56 \cdot \sqrt{\frac{E}{F_y}} = 13.487$$

Compact Section Criteria

7.80 19.3 8.49 21.7

1530 1380 1240 209 190 173

$$1.49 \cdot \sqrt{\frac{E}{F_y}} = 35.884$$

6.28 234 6.24 212 6.22 192 6.17 173 6.14 157

$$L_{cx} = 30 \; ft = 360 \; in$$

$$L_{cy} = 15 \; ft = 180 \; in$$

$$4.71 \cdot \sqrt{\frac{E}{F_y}} = 113.432$$

$$\frac{L_{cx}}{r_x} = 58.688$$

$$\frac{L_{cy}}{r_{y}}$$
 = 48.433

$$F_e \coloneqq rac{oldsymbol{\pi}^2 oldsymbol{\cdot} E}{\left(rac{L_{cx}}{r_x}
ight)^2} = 83.1 \; oldsymbol{ksi}$$

$$E \coloneqq 29000 \; ksi = (1.999 \cdot 10^3) \; MPa$$
 
$$F_y \coloneqq 50 \; ksi = 344.738 \; MPa$$
 
$$\frac{b_f}{2 \cdot t_f} = 10.211 \qquad 0.56 \cdot \sqrt{\frac{E}{F_y}} = 13.487 \qquad \text{Non-Slender Flange}$$
 
$$\frac{(h-2 \cdot (k))}{t_w} = 25.864 \qquad 1.49 \cdot \sqrt{\frac{E}{F_y}} = 35.884 \qquad \text{Non-Slender Web}$$
 
$$L_{cx} \coloneqq 30 \; ft = 360 \; in$$
 
$$L_{cy} \coloneqq 15 \; ft = 180 \; in$$
 
$$4.71 \cdot \sqrt{\frac{E}{F_y}} = 113.432$$
 
$$\frac{L_{cx}}{r_x} = 58.688$$
 
$$\frac{L_{cy}}{r_y} = 48.433$$
 
$$F_e \coloneqq \frac{\pi^2 \cdot E}{\left(\frac{L_{cx}}{r_x}\right)^2} = 83.1 \; ksi$$
 
$$F_{ct} \coloneqq \text{If} \left(\frac{L_{cx}}{r_x}\right) \times 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_c, 0.658 \cdot \frac{r_s}{r_s} \cdot F_y \right) = 38.869 \; ksi$$
 
$$F_c \coloneqq \frac{\pi^2 \cdot E}{\left(\frac{L_{cy}}{r_y}\right)^2} = 122.015 \; ksi$$

$$F_e\!\coloneqq\!rac{oldsymbol{\pi}^2oldsymbol{\cdot} E}{\left(rac{L_{cy}}{r_y}
ight)^2}\!=\!122.015$$
 ksi

$$\begin{aligned} \mathbf{F_{cr}} &\coloneqq \mathbf{if} \left( \frac{L_{cy}}{r_y} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 42.119 \ \textit{ksi} \\ F_e &\coloneqq \frac{\pi^2 \cdot E}{\left( \max \left( \frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y} \right) \right)^2} = 83.1 \ \textit{ksi} \end{aligned}$$

$$F_e \coloneqq \frac{\pi^2 \cdot E}{\left(\max\left(\frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y}\right)\right)^2} = 83.1 \text{ ksi}$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left( \max \left( \frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y} \right) > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 38.869 \text{ ksi}$$

$$\phi = 0.9$$

$$\phi\!\coloneqq\!0.9$$
 
$$\phi P_n\!\coloneqq\!\phi\!\cdot\!\mathbf{F_{cr}}\!\cdot\!A_g\!=\!913.907\;\pmb{kip}$$

$$1.2 \cdot 140 \ kip + 1.6 \cdot 420 \ kip = 840 \ kip$$

| LRFD   | ASD  |
|--|--|
| $\phi_c P_n = 903 \text{ kips} > 840 \text{ kips}$ <b>o.k.</b> | $\frac{P_n}{\Omega_c}$ = 601 kips > 560 kips <b>o.k.</b> |

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