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.

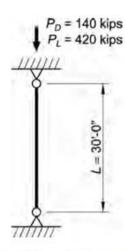


Fig. E.1A. Column loading and bracing.

$$1.2 \cdot 140 \ kip + 1.6 \cdot 420 \ kip = (3.737 \cdot 10^3) \ kN$$

W14x132

$$h \coloneqq 14.7 \; in = 373.38 \; mm$$

 $b_f \coloneqq 14.7 \; in = 373.38 \; mm$
 $t_f \coloneqq 1.03 \; in = 26.162 \; mm$
 $t_w \coloneqq 0.645 \; in = 16.383 \; mn$

$$A_g := 2 \cdot t_f \cdot b_f + (h - 2 \cdot t_f) \cdot t_w = (2.48 \cdot 10^4) \, \boldsymbol{mm}^2$$

$$\begin{aligned} &h \coloneqq 1.2 \cdot 140 \ kip + 1.6 \cdot 420 \ kip = \left(3.737 \cdot 10^3\right) \ kN \\ &M14 \times 132 \\ &h \coloneqq 14.7 \ in = 373.38 \ mm \\ &b_f \coloneqq 14.7 \ in = 373.38 \ mm \\ &t_f \coloneqq 1.03 \ in = 26.162 \ mm \\ &t_g \coloneqq 0.645 \ in = 16.383 \ mm \\ &k \coloneqq 1.63 \ in = 41.402 \ mm \end{aligned}$$

$$&A_g \coloneqq 2 \cdot t_f \cdot b_f + \left(h - 2 \cdot t_f\right) \cdot t_w = \left(2.48 \cdot 10^4\right) \ mm^2$$

$$&I_x \coloneqq \left(2 \cdot \left(b_f \cdot \frac{t_f^3}{12} + b_f \cdot t_f \cdot \left(\frac{\left(h - 2 \cdot t_f\right)}{2} + \frac{t_f}{2}\right)^2\right) + t_w \cdot \frac{\left(h - 2 \cdot t_f\right)^3}{12}\right) = \left(6.351 \cdot 10^8\right) \ mm^4$$

$$&S_x \coloneqq \frac{I_x}{\left(\frac{h}{2}\right)} = \left(3.402 \cdot 10^6\right) \ mm^3$$

$$&Z_x \coloneqq b_f \cdot t_f \cdot \left(h - t_f\right) + \frac{1}{4} \cdot \left(h - 2 \cdot t_f\right)^2 \cdot t_w = \left(3.814 \cdot 10^6\right) \ mm^3$$

$$&T_x \coloneqq \sqrt{\frac{I_x}{A_g}} = 160.043 \ mm$$

$$&I_y \coloneqq 2 \cdot \left(t_f \cdot \frac{b_f^3}{12}\right) + \left(h - 2 \cdot t_f\right) \cdot \frac{t_w^3}{12} = \left(2.271 \cdot 10^8\right) \ mm^4$$

$$&S_y \coloneqq \frac{I_y}{b_f} = \left(1.216 \cdot 10^6\right) \ mm^3$$

$$S_x \coloneqq \frac{I_x}{\left(\frac{h}{2}\right)} = \left(3.402 \cdot 10^6\right) \ m{mm}^3$$

$$Z_x := b_f \cdot t_f \cdot (h - t_f) + \frac{1}{4} \cdot (h - 2 t_f)^2 \cdot t_w = (3.814 \cdot 10^6) \ mm^3$$

$$r_x = \sqrt{\frac{I_x}{A_a}} = 160.043$$
 mm

$$I_y := 2 \cdot \left(t_f \cdot \frac{b_f^3}{12}\right) + \left(h - 2 \cdot t_f\right) \cdot \frac{t_w^3}{12} = \left(2.271 \cdot 10^8\right) \ \boldsymbol{mm}^4$$

$$S_y := \frac{I_y}{\frac{b_f}{2}} = (1.216 \cdot 10^6) \ \textit{mm}^3$$

$$Z_y \coloneqq \frac{1}{2} \cdot b_f^2 \cdot t_f + \frac{1}{4} \cdot (h - 2 \cdot t_f) \cdot t_w^2 = (1.845 \cdot 10^6) \ m{mm}^3$$
 $r_y \coloneqq \sqrt{\frac{I_y}{A_g}} = 95.698 \ m{mm}$

$$r_y = \sqrt{\frac{I_y}{A_g}} = 95.698 \; mm$$

$$c_{w}\!\coloneqq\!\frac{\left(\!h\!-\!t_{\!f}\!\right)^{^{2}}\!\cdot\! b_{\!f}^{\;3}\cdot\! t_{\!f}}{24}\!=\!\left(\!6.841\cdot\!10^{12}\!\right)\,\boldsymbol{mm}^{6}$$

$$\begin{split} J \coloneqq & \frac{2 \cdot b_f \cdot t_f^{\ 3} + \left(h - t_f\right) \cdot t_w^{\ 3}}{3} = \left(4.966 \cdot 10^6\right) \ \textit{mm}^4 \\ r_{ts} \coloneqq & \sqrt{\frac{\sqrt{I_y \cdot c_w}}{S_x}} = 107.636 \ \textit{mm} \end{split}$$

$$r_{ts} \coloneqq \sqrt{\frac{\sqrt{I_y \cdot c_w}}{S_x}} = 107.636$$
 mm

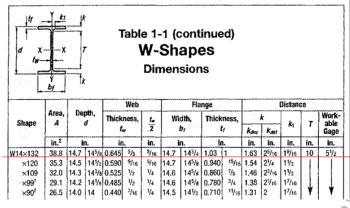


		Table 1-1 (continued) W-Shapes Properties Non Compact Section Axis X-X Axis Y-Y											Tors			
	l	W.	br	h	1.	S	r	Z	1	S	1	Z		L	J	G _W
Wit.	l	lb/ft	24	t _w	in.4	ìn.³	in.	ín.³	in.4	in.3	in.	in,3	in.	in.	in,4	ìn. ⁶
b ₁ b 1 S r Z 1 S r Z		132	7.15	17.7	1530	209	6.28	234	548	74.5	3.76	113	4.23	13.7	12.3	25500
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	ſ	120	7.80	19.3	1380	190	6.24	212	495	67.5	3.74	102	4.20	13.6	9.37	22700
	1	109	8.49	21.7	1240	173	6.22	192	447	61.2	3.73	92.7	4.17	13.4	7.12	20200
	н		004	22.5	1110	157	6 17	173	402	55.2	3.71	83.6	4.14	13.4	5.37	18000
	ı	99	9.34	23.5	1110	137	0.17	170								

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

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

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

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

$$\frac{(h-2\cdot(k))}{t_{ov}} = 17.736 \qquad 1.49 \cdot \sqrt{\frac{E}{F_{ov}}} = 35.884$$

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

Non-Slender Web Como Hoppin Hitted History

$$L_c = 30 \; ft = (9.144 \cdot 10^3) \; mm$$

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

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

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

$$F_e \coloneqq \frac{oldsymbol{\pi}^2 \cdot E}{\left(\frac{L_c}{r_x}\right)^2} = 604.53 \; MPa$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left(\frac{L_c}{r_x} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 271.538 \; \mathbf{MPa}$$

$$F_e \coloneqq rac{oldsymbol{\pi}^2 ullet E}{\left(rac{L_c}{r_y}
ight)^2} = 216.147 \; oldsymbol{MPa}$$

$$\begin{aligned} &\left(\frac{c}{r_y}\right) \\ &\mathbf{F_{cr}} \coloneqq \mathbf{if} \left(\frac{L_c}{r_y} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y\right) = 176.837 \; \mathbf{MPa} \end{aligned}$$

$$F_e \coloneqq \frac{\boldsymbol{\pi}^2 \cdot E}{\left(\max \left(\frac{L_c}{r_x}, \frac{L_c}{r_y} \right) \right)^2} = 216.147 \; \boldsymbol{\mathit{MPa}}$$

$$\begin{split} F_e &\coloneqq \frac{\pi^2 \cdot E}{\left(\max\left(\frac{L_c}{r_x}, \frac{L_c}{r_y}\right)\right)^2} = 216.147 \, \textit{MPa} \\ &\mathbf{F_{cr}} \coloneqq \mathbf{if} \left(\max\left(\frac{L_c}{r_x}, \frac{L_c}{r_y}\right) > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y\right) = 176.837 \, \textit{MPa} \\ &\phi \coloneqq 0.9 \\ &\phi P_n \coloneqq \phi \cdot \mathbf{F_{cr}} \cdot A_g = \left(3.946 \cdot 10^3\right) \, \textit{kN} \\ &1.2 \cdot 140 \, \textit{kip} + 1.6 \cdot 420 \, \textit{kip} = \left(3.737 \cdot 10^3\right) \, \textit{kN} \end{split}$$

$$\phi := 0.9$$

$$\phi P_n := \phi \cdot \mathbf{F_{cr}} \cdot A_q = (3.946 \cdot 10^3) \text{ kN}$$

$$1.2 \cdot 140 \ kip + 1.6 \cdot 420 \ kip = (3.737 \cdot 10^3) \ kN$$

LRFD	ASD
$\phi_c P_n = 893 \text{ kips} > 840 \text{ kips}$ o.k.	$\frac{P_n}{\Omega_c}$ = 594 kips > 560 kips 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.

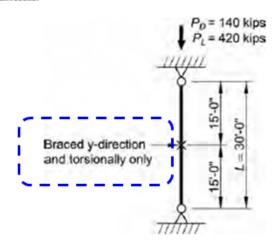


Fig. E.1B. Column loading and bracing.

W14x132

$$h := 14.7 \ in = 373.38 \ mm$$

 $b_f := 14.7 \ in = 373.38 \ mm$
 $t_f := 1.03 \ in = 26.162 \ mm$
 $t_w := 0.645 \ in = 16.383 \ mm$
 $k := 1.63 \ in = 41.402 \ mm$

$$A_g \coloneqq 2 \boldsymbol{\cdot} t_f \boldsymbol{\cdot} b_f + \left(h - 2 \boldsymbol{\cdot} t_f\right) \boldsymbol{\cdot} t_w = \left(2.48 \boldsymbol{\cdot} 10^4\right) \ \boldsymbol{mm}^2$$

$$I_{x}\!:=\!\left(\!2\boldsymbol{\cdot}\!\left(\!b_{f}\boldsymbol{\cdot}\!\frac{t_{f}^{\;3}}{12}\!+\!b_{f}\boldsymbol{\cdot}\!t_{f}\boldsymbol{\cdot}\!\left(\!\frac{\left(\!h\!-\!2\boldsymbol{\cdot}\!t_{f}\!\right)}{2}\!+\!\frac{t_{f}}{2}\!\right)^{\!2}\right)\!+t_{w}\boldsymbol{\cdot}\!\frac{\left(\!h\!-\!2\boldsymbol{\cdot}\!t_{f}\!\right)^{\;3}}{12}\!\right)\!=\!\left(\!6.351\boldsymbol{\cdot}\!10^{8}\right)\;\boldsymbol{mm}^{4}$$

$$S_x := \frac{I_x}{\left(\frac{h}{2}\right)} = \left(3.402 \cdot 10^6\right) \ \emph{mm}^3$$

$$Z_x\!\coloneqq\!b_f\!\cdot\!t_f\!\cdot\!\left(h\!-\!t_f\!\right)\!+\!\frac{1}{4}\!\cdot\!\left(h\!-\!2\ t_f\!\right)^2\cdot\!t_w\!=\!\left(3.814\cdot10^6\right)\,\pmb{mm}^3$$

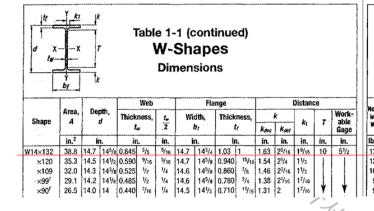
$$r_x\!\coloneqq\!\sqrt{\frac{I_x}{A_g}}\!=\!160.043~{\it mm}$$

$$I_y := 2 \cdot \left(t_f \cdot \frac{{b_f}^3}{12} \right) + \left(h - 2 \cdot t_f \right) \cdot \frac{{t_w}^3}{12} = \left(2.271 \cdot 10^8 \right) \ \boldsymbol{mm}^4$$

$$S_y \coloneqq \frac{I_y}{\frac{b_f}{2}} = (1.216 \cdot 10^6) \ \boldsymbol{mm}^3$$

$$Z_y := \frac{1}{2} \cdot b_f^2 \cdot t_f + \frac{1}{4} \cdot (h - 2 \cdot t_f) \cdot t_w^2 = (1.845 \cdot 10^6) \ mm^3$$

$$r_y := \sqrt{rac{I_y}{A_g}} = 95.698 \ m{mm}$$
 $c_w := rac{\left(h - t_f
ight)^2 \cdot b_f^3 \cdot t_f}{24} = \left(6.841 \cdot 10^{12}
ight) \ m{mm}^6$
 $J := rac{2 \cdot b_f \cdot t_f^3 + \left(h - t_f
ight) \cdot t_w^3}{3} = \left(4.966 \cdot 10^6
ight) \ m{mm}^4$
 $r_{ts} := \sqrt{rac{\sqrt{I_y \cdot c_w}}{S_x}} = 107.636 \ m{mm}$



	Та		1-1 (d -Sh Prope	apo	es	ed)			
xis	X-X			Axis	Y-Y		r _{ts}	ft.	· T
Š	r	Z	1	S	1	Z	*65	"	J
1.3	in.	ín.3	in.4	in.3	in.	in,3	in.	in.	in,4

ìn.6

25500 22700

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

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

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

$$\frac{b_f}{2 \cdot t_f} = 7.136 \qquad 0.56 \cdot \sqrt{\frac{E}{F_y}} = 13.487$$

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

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

Non-Slender Fla.
Non-Slender Web

$$L_{cx} = 30 \; ft = (9.144 \cdot 10^3) \; mm$$

$$L_{cy} = 15 \; ft = (4.572 \cdot 10^3) \; mm$$

$$4.71 \cdot \sqrt{\frac{E}{F_{yy}}} = 113.432$$

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

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

$$F_e \coloneqq \frac{\boldsymbol{\pi}^2 \cdot E}{\left(\frac{L_{cx}}{r_x}\right)^2} = 604.53 \; \boldsymbol{MPa}$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left(\frac{L_{cx}}{r_x} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 271.538 \ \textbf{\textit{MPa}}$$

$$F_e \coloneqq \frac{\pi^2 \cdot E}{\left(\frac{L_{cy}}{r_y}\right)^2} = 864.59 \ \textbf{\textit{MPa}}$$

$$F_e \coloneqq \frac{\boldsymbol{\pi}^2 \cdot E}{\left(\frac{L_{cy}}{r_y}\right)^2} = 864.59 \; \boldsymbol{MPa}$$

$$\mathbf{F_{cr}}\!\coloneqq\!\mathbf{if}\!\left(\!\frac{L_{cy}}{r_{y}}\!>\!4.71\!\cdot\!\sqrt{\frac{E}{F_{y}}},0.877\!\cdot\!F_{e},0.658^{\frac{F_{y}}{F_{e}}}\!\cdot\!F_{y}\!\right)\!=\!291.75\;\mathbf{MPa}$$

$$F_e \coloneqq \frac{oldsymbol{\pi}^2 \cdot E}{\left(\max\left(rac{L_{cx}}{r_x}, rac{L_{cy}}{r_y}
ight)
ight)^2} = 604.53 \ extbf{\textit{MPa}}$$

$$\left(\max\left(\frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y}\right)\right)$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if}\left(\max\left(\frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y}\right) > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y\right) = 271.538 \, \mathbf{MPa}$$

$$\phi \coloneqq 0.9$$

$$\phi P_n \coloneqq \phi \cdot \mathbf{F_{cr}} \cdot A_g = \left(6.06 \cdot 10^3\right) \, \mathbf{kN}$$

$$1.2 \cdot 140 \, \mathbf{kip} + 1.6 \cdot 420 \, \mathbf{kip} = \left(3.737 \cdot 10^3\right) \, \mathbf{kN}$$

$$\phi = 0.9$$

$$\phi P_n := \phi \cdot \mathbf{F_{cr}} \cdot A_q = (6.06 \cdot 10^3) \, \mathbf{kN}$$

$$1.2 \cdot 140 \ kip + 1.6 \cdot 420 \ kip = (3.737 \cdot 10^3) \ kN$$

$$h \coloneqq 14 \ \textit{in} = 355.6 \ \textit{mm}$$
 $b_f \coloneqq 14.5 \ \textit{in} = 368.3 \ \textit{mm}$
 $t_f \coloneqq 0.71 \ \textit{in} = 18.034 \ \textit{mm}$
 $t_w \coloneqq 0.44 \ \textit{in} = 11.176 \ \textit{mm}$
 $k \coloneqq 1.31 \ \textit{in} = 33.274 \ \textit{mm}$

$$A_g\!:=\!2 \cdot t_f \cdot b_f \!+\! \left(h \!-\! 2 \cdot t_f\right) \cdot t_w \!=\! \left(1.685 \cdot 10^4\right) \; \pmb{mm}^2$$

$$I_{x} \coloneqq \left(2 \cdot \left(b_{f} \cdot \frac{t_{f}^{\ 3}}{12} + b_{f} \cdot t_{f} \cdot \left(\frac{\left(h - 2 \cdot t_{f}\right)}{2} + \frac{t_{f}}{2}\right)^{2}\right) + t_{w} \cdot \frac{\left(h - 2 \cdot t_{f}\right)^{3}}{12}\right) = \left(4.092 \cdot 10^{8}\right) \ \textit{mm}^{4}$$

$$S_x := \frac{I_x}{\left(\frac{h}{2}\right)} = \left(2.301 \cdot 10^6\right) \, mm^3$$

$$I_{x} \coloneqq \left(2 \cdot \left\lfloor b_{f} \cdot \frac{J}{12} + b_{f} \cdot t_{f} \cdot \left(\frac{J}{2} + \frac{J}{2}\right) \right) + t_{w} \cdot \frac{J}{12}$$

$$S_{x} \coloneqq \frac{I_{x}}{\left(\frac{h}{2}\right)} = \left(2.301 \cdot 10^{6}\right) \, \boldsymbol{mm}^{3}$$

$$Z_{x} \coloneqq b_{f} \cdot t_{f} \cdot \left(h - t_{f}\right) + \frac{1}{4} \cdot \left(h - 2 \cdot t_{f}\right)^{2} \cdot t_{w} = \left(2.527 \cdot 10^{6}\right) \, \boldsymbol{mm}^{3}$$

$$r_{x} \coloneqq \sqrt{\frac{I_{x}}{A_{g}}} = 155.808 \, \boldsymbol{mm}$$

$$r_x := \sqrt{\frac{I_x}{A_q}} = 155.808 \ \textit{mm}$$

$$r_x := \sqrt{\frac{I_x}{A_g}} = 155.808 \ mm$$
 $I_y := 2 \cdot \left(t_f \cdot \frac{b_f^3}{12} \right) + \left(h - 2 \cdot t_f \right) \cdot \frac{t_w^3}{12} = \left(1.502 \cdot 10^8 \right) \ mm^4$
 $S_y := \frac{I_y}{\frac{b_f}{2}} = \left(8.156 \cdot 10^5 \right) \ mm^3$

$$S_y := \frac{I_y}{\frac{b_f}{2}} = (8.156 \cdot 10^5) \ \textit{mm}^3$$

$$Z_{y}\!\coloneqq\!\frac{\overline{\frac{2}{2}}}{2}\!\cdot\!b_{f}^{\;2}\cdot\!t_{f}\!+\!\frac{1}{4}\!\cdot\!\left(\!h\!-\!2\cdot\!t_{f}\!\right)\!\cdot\!t_{w}^{\;2}\!=\!\left(1.233\cdot10^{6}\right)\;\boldsymbol{mm}^{3}$$

$$r_y := \sqrt{\frac{I_y}{A_g}} = 94.398 \ \textit{mm}$$

$$c_w \coloneqq \frac{\left(h - t_f\right)^2 \cdot b_f^3 \cdot t_f}{24} = \left(4.278 \cdot 10^{12}\right) \ \boldsymbol{mm}^6$$

$$J := \frac{2 \cdot b_f \cdot t_f^3 + (h - t_f) \cdot t_w^3}{3} = (1.597 \cdot 10^6) \ \boldsymbol{mm}^4$$

$$r_{ts} \coloneqq \sqrt{rac{\sqrt{I_y \cdot c_w}}{S_x}} = 104.949 \ \emph{mm}$$



Table 1-1 (continued) W-Shapes

Dimensions

		Area, Depth,		Web			i	Fla	nge			- 1	Distano	ce .		
Shape				Thick	ness,	t.	Wi	dth,	Thick	ness,		k	k ₁	7.	Work- able	
				į t		.2	,	p,		t,	Køes	Køet	"	١.	Gage	
	in.2	Ír	ín.		in.		in.		in.		ín.	in.	in.	in.	in.	
W14×132	38.8	14.7	14 ⁵ /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	145/8	0.940	15/16	1,54	21/4	11/2	1	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 ^r	26.5	14.0	14	0.440	7/16	1/4	14,5	141/2	0.710	11/16	1.31	2	17/16	۱Ÿ	*	

Table 1-1 (continued) W-Shapes

Properties

	L
W14	-W12

Nom-	Com Sec Crit			Axis.	х-х			Axis	Y-Y		res	ħ,	Torsional Properties			
Wt.	br	h	1	S	r	Z	 ,	5	1	Z			j	C _w		
lb/ft	21,	t,	in.4	in.3	ín.	ín.³	in.4	in.3	in.	in.3	in.	in.	in,4	ìn. ⁶		
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		
99	9.34	23.5	1110	157	6.17	173	402	55.2	3.71	83.6	4.14	13.4	5.37	18000		
90	10.2	25.9	999	143	6.14	157	362	49.9	3.70	75.6	4.10	13.3	4.06	16000		

$$E \coloneqq 29000 \ \textit{ksi} = (1.999 \cdot 10^5) \ \textit{MPa}$$

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

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

$$0.56 \cdot \sqrt{\frac{E}{F_y}} = 13.487$$
 $1.49 \cdot \sqrt{\frac{E}{F_y}} = 35.884$

Non-Slender Flange

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

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

Non-Slender Web

$$L_{cx} = 30 \; ft = (9.144 \cdot 10^3) \; mm$$

$$L_{cy} = 15 \; ft = (4.572 \cdot 10^3) \; mm$$

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

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

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

$$F_e \coloneqq \frac{\boldsymbol{\pi}^2 \cdot E}{\left(\frac{L_{cx}}{r_x}\right)^2} = 572.956 \; \boldsymbol{MPa}$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left(\frac{L_{cx}}{r_x} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 267.99 \; \mathbf{MPa}$$

$$F_e \coloneqq \frac{\boldsymbol{\pi}^2 \cdot E}{\left(\frac{L_{cy}}{r_y}\right)^2} = 841.261 \; \boldsymbol{MPa}$$

$$\begin{aligned} \mathbf{F_{cr}} &\coloneqq \mathbf{if} \left(\frac{L_{cy}}{r_y} > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 290.402 \ \textit{MPa} \\ F_e &\coloneqq \frac{\pi^2 \cdot E}{\left(\max \left(\frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y} \right) \right)^2} = 572.956 \ \textit{MPa} \end{aligned}$$

$$F_e \coloneqq \frac{\pi^2 \cdot E}{\left(\max\left(\frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y}\right)\right)^2} = 572.956 \; MPa$$

$$\mathbf{F_{cr}} \coloneqq \mathbf{if} \left(\max \left(\frac{L_{cx}}{r_x}, \frac{L_{cy}}{r_y} \right) > 4.71 \cdot \sqrt{\frac{E}{F_y}}, 0.877 \cdot F_e, 0.658^{\frac{F_y}{F_e}} \cdot F_y \right) = 267.99 \ \mathbf{MPa}$$

$$\phi = 0.9$$

$$\phi\!\coloneqq\!0.9$$

$$\phi P_n\!\coloneqq\!\phi\!\cdot\!\mathbf{F_{cr}}\!\cdot\!A_g\!=\!\left(4.065\!\cdot\!10^3\right)\,\mathbf{\textit{kN}}$$

$$1.2 \cdot 140 \ kip + 1.6 \cdot 420 \ kip = (3.737 \cdot 10^3) \ kN$$

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

OTHER WANN, MARKED COMPONENT HORSE