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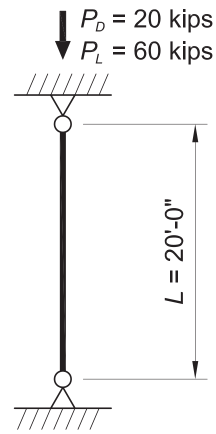
EXAMPLE E.7 WT COMPRESSION MEMBER WITHOUT SLENDER ELEMENTS

Given:

Select an ASTM A992 nonslender WT-shape compression member with a length of 20 ft to support a dead load of 20 kips and live load of 60 kips in axial compression. The ends are pinned.



Solution:

From AISC *Manual* Table 2-4, the material properties are as follows:

ASTM A992
$F_y = 50$ ksi
$F_u = 65$ ksi

From Chapter 2 of ASCE/SEI 7, the required compressive strength is:

LRFD	ASD
$P_u = 1.2(20 \text{ kips}) + 1.6(60 \text{ kips})$ $= 120 \text{ kips}$	$P_a = 20 \text{ kips} + 60 \text{ kips}$ $= 80.0 \text{ kips}$

Table Solution

From AISC *Specification* Commentary Table C-A-7.1, for a pinned-pinned condition, $K = 1.0$.

Therefore, $(KL)_x = (KL)_y = 20.0$ ft.

Select the lightest nonslender member from AISC *Manual* Table 4-7 with sufficient available strength about both the *x-x* axis (upper portion of the table) and the *y-y* axis (lower portion of the table) to support the required strength.

Try a WT7×34.

The available strength in compression is:

LRFD	ASD
$\phi_c P_{nx} = 128 \text{ kips} > 120 \text{ kips}$ **controls** **o.k.**	$\dfrac{P_{nx}}{\Omega_c} = 85.5 \text{ kips} > 80.0 \text{ kips}$ **controls** **o.k.**
$\phi_c P_{ny} = 221 \text{ kips} > 120 \text{ kips}$ **o.k.**	$\dfrac{P_{ny}}{\Omega_c} = 147 \text{ kips} > 80.0 \text{ kips}$ **o.k.**

The available strength can be easily determined by using the tables of the AISC *Manual*. Available strength values can be verified by hand calculations, as follows.

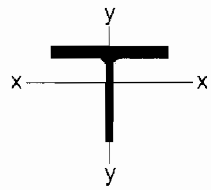
Calculation Solution

From AISC *Manual* Table 1-8, the geometric properties are as follows.

WT7×34

F_y = 50 ksi

Table 4–7 (continued)
Available Strength in Axial Compression, kips
WT Shapes



WT7

Shape		WT7×											
Wt/ft		37		34		30.5[c]		26.5[c]		24[c]		21.5[c]	
Design		P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD
Effective length *KL* (ft) with respect to indicated axis													
X-X Axis	0	326	490	299	450	261	392	223	336	187	281	147	220
	10	237	356	217	326	190	285	168	253	143	216	116	174
	12	206	310	188	283	165	248	148	223	128	192	104	157
	14	175	262	159	239	140	210	128	192	111	167	92.5	139
	16	144	217	131	197	116	174	108	162	95.0	143	80.3	121
	18	116	174	105	158	93.2	140	88.8	133	79.4	119	68.5	103
	20	93.9	141	85.2	128	75.5	113	72.0	108	64.9	97.5	57.3	86.1
	22	77.6	117	70.4	106	62.4	93.7	59.5	89.4	53.6	80.6	47.3	71.1
	24	65.2	98.0	59.2	88.9	52.4	78.8	50.0	75.1	45.1	67.7	39.8	59.8
	26	55.6	83.5	50.4	75.8	44.7	67.1	42.6	64.0	38.4	57.7	33.9	50.9
	28	47.9	72.0	43.5	65.3	38.5	57.9	36.7	55.2	33.1	49.8	29.2	43.9
	30	41.7	62.7	37.9	56.9	33.5	50.4	32.0	48.1	28.8	43.3	25.4	38.2
Y-Y Axis	0	326	490	299	450	261	392	223	336	187	281	147	220
	10	269	404	245	368	212	318	166	250	140	211	112	169
	12	250	375	227	342	199	299	148	222	126	189	102	154
	14	229	344	208	313	183	275	128	193	111	166	91.3	137
	16	207	311	188	283	165	249	109	164	95.0	143	79.8	120
	18	184	277	168	252	147	222	90.8	136	79.9	120	68.4	103
	20	162	244	147	221	130	195	74.1	111	65.8	98.9	57.6	86.5
	22	141	211	128	192	112	169	61.4	92.3	54.6	82.0	47.8	71.8
	24	120	180	109	164	95.9	144	51.7	77.7	46.0	69.1	40.3	60.6
	26	102	154	92.9	140	81.9	123	44.1	66.3	39.3	59.0	34.4	51.7
	28	88.5	133	80.2	121	70.8	106	38.1	57.3	33.9	50.9	29.7	44.7
	30	77.1	116	69.9	105	61.7	92.8	33.2	49.9	29.6	44.4	25.9	39.0
	32	67.8	102	61.5	92.4	54.3	81.6	29.2	43.9				
	34	60.1	90.4	54.5	81.9	48.2	72.4						
	36	53.6	80.6	48.7	73.1	43.0	64.6						
	40	43.5	65.4	39.4	59.3	34.9	52.4						
Properties													
A_g (in.^{2})		10.9		9.99		8.96		7.80		7.07		6.31	
r_x (in.)		1.82		1.81		1.80		1.88		1.88		1.86	
r_y (in.)		2.48		2.46		2.45		1.92		1.91		1.89	

ASD	LRFD
$\Omega_c = 1.67$	$\phi_c = 0.90$

[c] Shape is slender for compression with F_y = 50 ksi.
Note: Heavy line indicates Kl/r equal to or greater than 200.

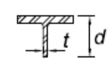
$A_g = 10.0 \text{ in.}^2$
$r_x = 1.81 \text{ in.}$
$r_y = 2.46 \text{ in.}$
$J = 1.50 \text{ in.}^4$
$\bar{y} = 1.29 \text{ in.}$
$I_x = 32.6 \text{ in.}^4$
$I_y = 60.7 \text{ in.}^4$
$d = 7.02 \text{ in.}$
$t_w = 0.415 \text{ in.}$
$b_f = 10.0 \text{ in.}$
$t_f = 0.720 \text{ in.}$

Stem Slenderness Check

$$\lambda = \frac{d}{t_w}$$
$$= \frac{7.02 \text{ in.}}{0.415 \text{ in.}}$$
$$= 16.9$$

Determine the stem limiting slenderness ratio, λ_r, from AISC *Specification* Table B4.1a Case 4

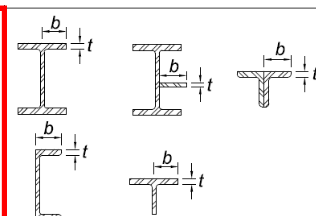
$$\lambda_r = 0.75\sqrt{\frac{E}{F_y}}$$
$$= 0.75\sqrt{\frac{29{,}000 \text{ ksi}}{50 \text{ ksi}}}$$
$$= 18.1$$

4	Stems of tees	d/t	$\boxed{0.75\sqrt{\frac{E}{F_y}}}$	

$\lambda < \lambda_r$; therefore, the stem is not slender

Flange Slenderness Check

$$\lambda = \frac{b_f}{2t_f}$$
$$= \frac{10 \text{ in.}}{2(0.720 \text{ in.})}$$
$$= 6.94$$

1	Flanges of rolled I-shaped sections, plates projecting from rolled I-shaped sections, outstanding legs of pairs of angles connected with continuous contact, flanges of channels, and flanges of tees	b/t	$0.56\sqrt{\frac{E}{F_y}}$	

Determine the flange limiting slenderness ratio, λ_r, from AISC *Specification* Table B4.1a Case 1

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

$\lambda < \lambda_r$; therefore, the flange is not slender

There are no slender elements.

For compression members without slender elements, AISC *Specification* Sections E3 and E4 apply. The nominal compressive strength, P_n, shall be determined based on the limit states of flexural, torsional and flexural-torsional buckling.

Flexural Buckling About the *x-x* Axis

$$\frac{KL}{r_x} = \frac{1.0(20.0\text{ ft})(12\text{ in./ft})}{1.81\text{ in.}}$$
$$= 133$$

$$4.71\sqrt{\frac{E}{F_y}} = 4.71\sqrt{\frac{29{,}000\text{ ksi}}{50\text{ ksi}}}$$
$$= 113 < 133\text{, therefore, AISC } \textit{Specification} \text{ Equation E3-3 applies}$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$ (*Spec*. Eq. E3-4)

$$= \frac{\pi^2(29{,}000\text{ ksi})}{(133)^2}$$
$$= 16.2\text{ ksi}$$

$$F_{cr} = 0.877F_e$$ (*Spec*. Eq. E3-3)

$$= 0.877(16.2\text{ ksi})$$
$$= 14.2\text{ ksi}$$ **controls**

Torsional and Flexural-Torsional Buckling

Because the WT7×34 section does not have any slender elements, AISC *Specification* Section E4 will be applicable for torsional and flexural-torsional buckling. F_{cr} will be calculated using AISC *Specification* Equation E4-2.

Calculate F_{cry}.

F_{cry} is taken as F_{cr} from AISC *Specification* Section E3, where $KL/r = KL/r_y$.

$$\frac{KL}{r_y} = \frac{1.0(20.0\text{ ft})(12\text{ in./ft})}{2.46\text{ in.}}$$
$$= 97.6 \le 113\text{, therefore, AISC } \textit{Specification} \text{ Equation E3-2 applies}$$

$$F_e = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$ (*Spec*. Eq. E3-4)

$$= \frac{\pi^2(29{,}000\text{ ksi})}{(97.6)^2}$$
$$= 30.0\text{ ksi}$$

$$F_{cry} = F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right]F_y \qquad \text{(}\textit{Spec}\text{. Eq. E3-2)}$$

$$= \left[0.658^{\frac{50.0\,\text{ksi}}{30.0\,\text{ksi}}}\right]50.0\,\text{ksi}$$

$$= 24.9\text{ ksi}$$

The shear center for a T-shaped section is located on the axis of symmetry at the mid-depth of the flange.

$$x_o = 0.0\text{ in.}$$

$$y_o = \bar{y} - \frac{t_f}{2}$$

$$= 1.29\text{ in.} - \frac{0.720\text{ in.}}{2}$$

$$= 0.930\text{ in.}$$

$$\bar{r}_o^2 = x_o^2 + y_o^2 + \frac{I_x + I_y}{A_g} \qquad \text{(}\textit{Spec}\text{. Eq. E4-11)}$$

$$= (0.0\text{ in.})^2 + (0.930\text{ in.})^2 + \frac{32.6\text{ in.}^4 + 60.7\text{ in.}^4}{10.0\text{ in.}^2}$$

$$= 10.2\text{ in.}^2$$

$$\bar{r}_o = \sqrt{\bar{r}_o^2}$$

$$= \sqrt{10.2\text{ in.}^2}$$

$$= 3.19\text{ in.}$$

$$H = 1 - \frac{x_o^2 + y_o^2}{\bar{r}_o^2} \qquad \text{(}\textit{Spec}\text{. Eq. E4-10)}$$

$$= 1 - \frac{(0.0\text{ in.})^2 + (0.930\text{ in.})^2}{10.2\text{ in.}^2}$$

$$= 0.915$$

$$F_{crz} = \frac{GJ}{A_g \bar{r}_o^2} \qquad \text{(}\textit{Spec}\text{. Eq. E4-3)}$$

$$= \frac{(11{,}200\text{ ksi})(1.50\text{ in.}^4)}{(10.0\text{ in.}^2)(10.2\text{ in.}^2)}$$

$$= 165\text{ ksi}$$

$$F_{cr} = \left(\frac{F_{cry} + F_{crz}}{2H}\right)\left[1 - \sqrt{1 - \frac{4F_{cry}F_{crz}H}{(F_{cry} + F_{crz})^2}}\right] \qquad \text{(}\textit{Spec}\text{. Eq. E4-2)}$$

$$= \left(\frac{24.9\text{ ksi} + 165\text{ ksi}}{2(0.915)}\right)\left[1 - \sqrt{1 - \frac{4(24.9\text{ ksi})(165\text{ ksi})(0.915)}{(24.9\text{ ksi} + 165\text{ ksi})^2}}\right]$$

$= 24.5\text{ ksi}$ **does not control**

x-*x* axis flexural buckling governs, therefore,

$$P_n = F_{cr}A_g \qquad \text{(}\textit{Spec}\text{. Eq. E3-1)}$$

$$= 14.2\text{ ksi}\left(10.0\text{ in.}^2\right)$$

$$= 142\text{ kips}$$

From AISC *Specification* Section E1, the available compressive strength is:

LRFD	ASD
$\phi_c P_n = 0.90(142\text{ kips})$ $= 128\text{ kips} > 120\text{ kips}$ **o.k.**	$\dfrac{P_n}{\Omega_c} = \dfrac{142\text{ kips}}{1.67}$ $= 85.0\text{ kips} > 80.0\text{ kips}$ **o.k.**