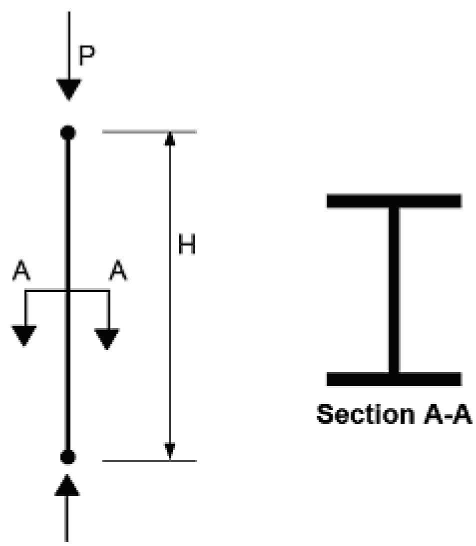
AISC LRFD-93 Example 002

WIDE FLANGE MEMBER UNDER COMBINED COMPRESSION & BIAXIAL BENDING

EXAMPLE DESCRIPTION

A check of the column adequacy is checked for combined axial compression and flexural loads. The column is 14 feet tall and loaded with an axial load, $\boldsymbol{P_u} = 1400\,\text{kips}$ and bending, $\boldsymbol{M_{ux}}, \boldsymbol{M_{uy}}$ = 200k-ft and 70k-ft, respectively. It is assumed that there is reverse-curvature bending with equal end moments about both axes and no loads along the member. The column demand/capacity ratio is checked against the results of Example 6.2 in the 3rd Edition, *LRFD Manual of Steel Construction*, pages 6-6 to 6-8.

GEOMETRY, PROPERTIES AND LOADING



Member Properties	Loading	Geometry
W14X176	P_u = 1,400 kips	H = 14.0 ft
E = 29000 ksi	M_{ux} = 200 kip-ft	
F_y = 50 ksi	M_{uy} = 70 kip-ft	

TECHNICAL FEATURES TESTED

- Section compactness check (compression)
- Member compression capacity
- Member bending capacity
- Demand/capacity ratio, D/C

RESULTS COMPARISON

Independent results are hand calculated and compared with the results from Example 6.2 in the 3rd Edition, *LRFD Manual of Steel Construction*, pages 6-6 to 6-8.

Output Parameter	SAP2000	Independent	Percent Difference
Compactness	Compact	Compact	0.00%
$\phi_c P_n$ (kips)	1937.84	1937.84	0.00%
$\phi_b M_{nx}$ (k-ft)	1200	1200	0.00%
$\phi_b M_{ny}$ (k-ft)	600.478	600.478	0.00%
D/C	0.974	0.974	0.00%

COMPUTER FILE: AISC LRFD-93 EX002

CONCLUSION

The results show an exact comparison with the independent results.

HAND CALCULATION

Properties:

Material: ASTM A992 Grade 50 Steel

F_y = 50 ksi, E = 29,000 ksi

Section: W14x176

A = 51.8 in^2,

b_f = 15.7 in, t_f = 1.31 in, d = 15.2 in, t_w = 0.83 in

$h_c = d - 2t_f = 15.2 - 2 \bullet 1.31 = 12.58\, in$

I_x = 2,140 in^4, I_y = 838 in^4, r_x = 6.4275 in, r_y = 4.0221 in

S_x = 281.579 in^3, S_y = 106.7516 in^3, Z_x = 320.0 in^3, Z_y = 163.0 in^3.

Member:

$K_x = K_y = 1.0$

$L = L_b$ = 14 ft

Other

$\phi_c = 0.85$

$\phi_b = 0.9$

Loadings:

P_u = 1400 kips

M_{ux} = 200 k-ft

M_{uy} = 70 k-ft

Section Compactness:

Localized Buckling for Flange:

$$\lambda = \frac{(b_f / 2)}{t_f} = \frac{(15.7 / 2)}{1.31} = 5.99$$

$$\lambda_p = \frac{65}{\sqrt{F_y}} = \frac{65}{\sqrt{50}} = 9.19$$

$\lambda < \lambda_p$, No localized flange buckling

Flange is Compact.

Localized Buckling for Web:

$$\lambda = \frac{h_c}{t_w} = \frac{12.58}{0.83} = 15.16$$

$$\phi_b P_y = \phi_b A_g F_y = 0.9 \bullet 51.8 \bullet 50 = 2331 \text{ kips}$$

$$\frac{P_u}{\phi_b P_y} = \frac{1400}{2331} = 0.601$$

Since $\frac{P_u}{\phi_b P_y} = 0.601 > 0.125$

$$\lambda_p = \frac{191}{\sqrt{F_y}}\left(2.33 - \frac{P_u}{\phi_b P_y}\right) \geq \frac{253}{\sqrt{F_y}}$$

$$\lambda_p = \frac{191}{\sqrt{50}}\left(2.33 - 0.601\right) = 46.714 \geq \frac{253}{\sqrt{50}} = 35.780$$

$\lambda < \lambda_p$, No localized web buckling

Web is Compact.

Section is Compact.

Member Compression Capacity:

For braced frames, K = 1.0 and $K_xL_x = K_yL_y$ = 14.0 ft, From AISC Table 4-2,

$$\phi_c P_n = 1940 \text{ kips}$$

Or by hand,

$$\lambda_c = \frac{K_y L}{r_y \pi}\sqrt{\frac{F_y}{E}} = \frac{1.0 \bullet 14 \bullet 12}{4.022 \bullet \pi}\sqrt{\frac{50}{29000}} = 0.552$$

Since $\lambda_c < 1.5$,

$$F_{cr} = F_y\left(0.658^{\lambda_c^2}\right) = 50 \bullet 0.658^{0.552^2} = 44.012 \text{ ksi}$$

$$\phi_c P_n = \phi_c F_{cr} A_g = 0.85 \bullet 44.012 \bullet 51.8$$

$$\boxed{\phi_c P_n = 1937.84 \text{ kips}}$$

From LRFD Specification Section H1.2,

$$\frac{P_u}{\phi_c P_n} = \frac{1400}{1937.84} = 0.722 > 0.2$$

Therefore, LRFD Specification Equation H1-1a governs.

Section Bending Capacity

$$M_{px} = F_y Z_x = \frac{50 \bullet 310}{12} = 1333.333 \text{ k-ft}$$

$$M_{py} = F_y Z_y$$

However, $\frac{Z_y}{S_y} = \frac{163}{106.7516} = 1.527 > 1.5$,

So

$$Z_y = 1.5 S_y = 1.5 \bullet 106.7516 = 160.1274 \text{in}^3$$

$$M_{py} = \frac{50 \bullet 160.1274}{12} = 667.198 \text{k-ft}$$

Member Bending Capacity

From LRFD Specification Equation F1-4,

$$L_p = 1.76 r_y \sqrt{\frac{E}{F_{yf}}}$$

$$L_p = 1.76 \bullet 4.02 \sqrt{\frac{29000}{50}} \bullet 1/12 = 14.2 \text{ft} > L_b = 14 \text{ft}$$

$$\phi_b M_{nx} = \phi_b M_{px}$$

$$\phi_b M_{nx} = 0.9 \bullet 1333.333$$

$$\boxed{\phi_b M_{nx} = 1200 \text{k-ft}}$$

$$\phi_b M_{ny} = \phi_b M_{py}$$

$$\phi_b M_{ny} = 0.9 \bullet 667.198$$

$$\boxed{\phi_b M_{ny} = 600.478 \text{ k-ft}}$$

Interaction Capacity: Compression & Bending

From LRFD Specification section C1.2, for a braced frame, $M_{lt} = 0$.

$$M_{ux} = B_{1x} M_{ntx}, \text{ where } M_{ntx} = 200 \text{ kip-ft; and}$$
$$M_{uy} = B_{1y} M_{nty}, \text{ where } M_{nty} = 70 \text{ kip-ft}$$

$$B_1 = \frac{C_m}{\left(1 - \frac{P_u}{P_{e1}}\right)} \geq 1$$

For reverse curvature bending and equal end moments:

$$\frac{M_1}{M_2} = +1.0$$

$$C_m = 0.6 - 0.4\left(\frac{M_1}{M_2}\right)$$
$$C_m = 0.6 - 0.4(1.0) = 0.2$$
$$p_{e1} = \frac{\pi^2 EI}{(KL)^2}$$

$$p_{e1x} = \frac{\pi^2 \bullet 29000 \bullet 2140}{(14.0 \bullet 12)^2} = 21,702\, kips$$
$$p_{e1y} = \frac{\pi^2 \bullet 29000 \bullet 838}{(14.0 \bullet 12)^2} = 8,498$$

$$B_{1x} = \frac{C_{mx}}{\left(1 - \frac{P_u}{P_{e1x}}\right)} \geq 1$$
$$B_{1x} = \frac{0.2}{\left(1 - \frac{1400}{21702}\right)} = 0.214 \geq 1$$

$$B_{1x} = 1$$

$$B_{1y} = \frac{C_{my}}{\left(1 - \dfrac{P_u}{P_{e1y}}\right)} \geq 1$$

$$B_{1y} = \frac{0.2}{\left(1 - \dfrac{1400}{8498}\right)} = 0.239 \geq 1$$

$$B_{1y} = 1$$

$$M_{ux} = 1.0 \bullet 200 = 200 \text{ kip-ft;}$$

and

$$M_{uy} = 1.0 \bullet 70 = 70 \text{ kip-ft}$$

From LRFD Specification Equation H1-1a,

$$\frac{1400}{1940} + \frac{8}{9}\left(\frac{200}{1200} + \frac{70}{600.478}\right) = 0.974 < 1.0 \text{, OK}$$

$$\boxed{\frac{D}{C} = 0.974}$$