5.2-3

For the centroid of half of a W18 × 50, use the centroid of a WT9 × 25:

\[ a = d - 2(2.12) = 18.00 - 2(2.12) = 13.76 \text{ in.} \]

\[ Z_x = \frac{A \cdot a}{2} = \left( \frac{14.7}{2} \right)(13.76) = 101.1 \text{ in.}^3 \]

\[ Z_x = 101 \text{ in.}^3 \]
(a) The flange is noncompact for flexure when

\[ 0.38 \frac{E}{F_y} < \frac{b_f}{2t_f} \leq 1.0 \frac{E}{F_y} \]

\[ 0.38 \frac{29,000}{60} < \frac{b_f}{2t_f} \leq 1.0 \frac{29,000}{60} \Rightarrow 8.35 < \frac{b_f}{2t_f} \leq 22.0 \]

The following shapes meet these criteria and are noncompact for \( F_y = 60 \) ksi:

W30 x 90, W24 x 104, W21 x 48, W14 x 109, W14 x 99, W14 x 90, W14 x 30,
W12 x 72, W12 x 65, W12 x 53, W12 x 26, W12 x 14, W10 x 49, W10 x 33,
W10 x 12, W8 x 31, W8 x 10, W6 x 15, W6 x 9, W6 x 8.5, M12 x 10, M4 x 6,
M4 x 3.45, M4 x 3.2, and M3 x 2.9

The web is noncompact for flexure when

\[ 0.376 \frac{E}{F_y} < \frac{h}{t_w} \leq 5.70 \frac{E}{F_y} \]

\[ 0.376 \frac{29,000}{60} < \frac{h}{t_w} \leq 5.70 \frac{29,000}{60} \Rightarrow 82.7 < \frac{h}{t_w} \leq 125 \]

No shapes are noncompact because of the web.

(b) The flange is slender for flexure when \( \frac{b_f}{2t_f} > 1.0 \frac{E}{F_y} = 22.0 \)

and the web is slender when \( \frac{h}{t_w} > 5.70 \frac{E}{F_y} = 125 \)

No W, M, or S shapes in Part 1 of the Manual are slender.
5.5-3

Verify that this shape is compact. For the flange,

\[ \lambda_p = 0.38 \sqrt{\frac{29,000}{50}} = 9.15, \quad \lambda = \frac{b_f}{2t_f} = 6.89 < \lambda_p \therefore \text{flange is compact} \]

For the web, \[ \lambda_p = 3.76 \sqrt{\frac{29,000}{50}} = 90.6, \quad \lambda = \frac{h_w}{t_w} = 49.6 < \lambda_p \therefore \text{web is compact, and the shape is compact.} \]

\[ M_n = F_y Z_x = \frac{50(346)}{12} = 1442 \text{ ft-kips} \]

(a) Load combination 2 controls:
Design strength = $\phi_b M_n = 0.90(1442) = 1298$ ft-kips

$M_u = 118(15.91) - 4.4(15.91)^2/2 - 48(0.9091)$

= 1277 ft-kips < 1298 ft-kips (OK)

A W30 × 108 is adequate.

(b) ASD load combination 2 controls:
Allowable strength = \( \frac{M_n}{\Omega_b} = \frac{1442}{1.67} = 864 \text{ ft-kips} \)

\( M_n = 85(15) - 3(15)^2/2 = 938 \text{ ft-kips} > 864 \text{ ft-kips} \) (N.G.)

A W30 x 108 is not adequate.
Verify that this shape is compact. For the flange,

\[ \lambda_p = 0.38 \sqrt{\frac{29,000}{50}} = 9.15, \quad \lambda = \frac{b_t}{2t_f} = 5.44 < \lambda_p \quad \therefore \text{flange is compact} \]

\[ \frac{h}{t_w} < 3.76 \sqrt{\frac{F_t}{F_y}} \quad \text{(for all shapes in the Manual for } F_y \leq 65 \text{ ksi)}, \text{ so the web is compact, and the shape is compact.} \]

\[ M_n = F_y Z_x = \frac{50(123)}{12} = 512.5 \text{ ft-kips} \]

(a) Factored loads, including beam weight:

\[ 1.2(0.060) = 0.072 \text{ kips/ft,} \quad 1.6(12) = 19.2 \text{ kips,} \quad 1.6(8) = 12.8 \text{ kips} \]
Reaction at $C$:

$$\sum M_D = -10.61(56) - 12.8(42) - 12.8(14) + R_C(28) - 0.072(56)^2/2 = 0$$

$$R_C = 50.85 \text{ kips}$$

Shear diagram:

Maximum moment occurs at $C$. Using the free-body diagram of $BCD$,

$$M_C = -10.61(28) - 12.8(14) - 0.072(28)^2/2 = -505 \text{ ft-kips}$$

Design strength $= \phi_b M_n = 0.90(512.5) = 461 \text{ ft-kips}$

[5-10]
\[ M_u = 505 \text{ ft-kips} > \phi_b M_n = 461 \text{ ft-kips} \text{ (N.G.)} \]

A W18 x 60 is not adequate.

(b) Service loads:

Reaction at C:

\[
\sum M_D = -6.84(56) - 8(42) - 8(14) + R_C(28) - 0.060(56)^2/2 = 0
\]

\[ R_C = 33.04 \text{ kips} \]

Shear diagram:

Maximum moment occurs at C. Refer to the free-body diagram of BCD.

\[ \text{[5-11]} \]
\[ M_a = M_C = -6.84(28) - 8(14) - 0.060(28)^2/2 = -327 \text{ ft-kips} \]

Allowable strength \[ \frac{M_a}{\Omega_b} = \frac{512.5}{1.67} = 307 \text{ ft-kips} \]

\[ M_a = 327 \text{ ft-kips} > 307 \text{ ft-kips (N.G.)} \]

A W18 \times 60 is not adequate.
Check for compactness. For the flange,

\[ \lambda_p = 0.38 \sqrt{\frac{29,000}{50}} = 9.152, \quad \lambda_r = 1.0 \sqrt{\frac{29,000}{50}} = 24.08 \]

\[ \lambda = \frac{b_f}{2t_f} = 9.34, \quad \lambda_p < \lambda < \lambda_r \therefore \text{flange is noncompact} \]

(In the Dimensions and Properties tables, there is a footnote indicating that the flange of a W14 \times 99 is noncompact.) The web is compact for all shapes in Part 1 of the Manual for \( F_y \leq 65 \) ksi.

Compute the strength based on the limit state of flange local buckling.

\[ M_p = F_yZ_x = 50(173) = 8650 \text{ in.-kips} \]

\[ M_n = M_p - (M_p - 0.7F_yS_x)\left( \frac{\lambda - \lambda_p}{\lambda_r - \lambda_p} \right) \]

\[ = 8650 - (8650 - 0.7 \times 50 \times 157)\left( \frac{9.34 - 9.152}{24.08 - 9.152} \right) \]

\[ = 8610 \text{ in.-kips} = 717.5 \text{ ft-kips} \]

Check for lateral-torsional buckling. From the \( Z_x \) table, \( L_p = 13.5 \) ft. Since \( L_b = 10 \) ft < \( L_b \), lateral-torsional buckling does not have to be investigated.

\[ M_n = 718 \text{ ft-kips} \]
For an M12 \times 11.8 (t_f = 0.225 \text{ in.}) of A242 steel, F_y = 50 \text{ ksi}

\[ \frac{h}{t_w} = 62.5, \quad 2.24 \sqrt{\frac{E}{F_y}} = 2.24 \sqrt{\frac{29,000}{50}} = 53.95 \]

Since \[ \frac{h}{t_w} > 2.24 \sqrt{\frac{E}{F_y}} \], AISC Section G2.1(b) applies.

\[ 1.10 \sqrt{\frac{k_s E}{F_y}} = 1.10 \sqrt{\frac{5(29,000)}{50}} = 59.24 \]
$$1.37 \sqrt{\frac{k_y E}{F_y}} = 1.37 \sqrt{\frac{5(29,000)}{50}} = 73.78$$

$$59.24 < \frac{h}{t_w} < 73.78, \Rightarrow C_v = \frac{1.10 \sqrt{\frac{k_y E}{F_y}}}{h/t_w} = \frac{59.24}{62.5} = 0.9478$$

$$V_n = 0.6 F_y A_w C_v = 0.6(50)(12.0 \times 0.177)(0.9478) = 60.39 \text{ kips}$$

$$V_n = 60.4 \text{ kips}$$