Girder Properties & Proportion Checks

$E \equiv 29000\ ksi$

$F_y \equiv 50\ ksi$

$t_w \equiv 0.5\ in$

$t_{topflange} \equiv 1.50\ in$

$t_{bottomflange} \equiv 1.75\ in$

$b_f \equiv 16\ in$

$h \equiv 55\ in$

$3.76 \cdot \sqrt{\left(\frac{E}{F_y}\right)} = 90.553$

$5.70 \cdot \sqrt{\left(\frac{E}{F_y}\right)} = 137.274$

$I_x \equiv 64985.015\ in^4$

$c_{xc} \equiv 13.772\ in$

$c_{xt} \equiv 17.522\ in$

$S_{xc} \equiv \frac{I_x}{c_{xc}} = 4718.633\ in^3$

$S_{xt} \equiv \frac{I_x}{c_{xt}} = 3708.767\ in^3$

$\frac{S_{xt}}{S_{xc}} = 0.786$

$I_{yc} \equiv 21196.632\ in^4$

$I_{yt} \equiv 20282.677\ in^4$

AASHTO Section 6.10 Checks

$\frac{b_f}{2\ t_{topflange}} = 5.333$ $\quad 5.333 \le 12$ Ok!

$\frac{b_f}{2 \cdot t_{bottomflange}} = 4.571$ $\quad 4.571 \le 12$ Ok!

$1.1 \cdot t_w = 0.55\ in$ $\quad 1.50 \ge 0.55$ $\quad 1.75 \ge 0.55$ Ok!

$\frac{h}{6} = 9.167\ in$ $\quad 16 \ge 9.167$ Ok!

$\frac{I_{yc}}{I_{yt}} = 1.045$ $\quad 0.1 \le 1.045 \le 10$ Ok!

$\frac{h}{t_w} = 110$ $\quad 110 \le 150$ Ok!

Moment Capacity Calculations

$M_U \equiv (1.25 \cdot (2525.39\ ft \cdot kip + 488.28\ ft \cdot kip)) + (1.50 \cdot 416.02\ ft \cdot kip) + (1.75 \cdot 3328.29\ ft \cdot kip) = 10215.625\ ft \cdot kip$

-Plastic Moment Calculations (*AASHTO Table D6.1-1*) $\quad f'_c \equiv 4\ ksi \quad t_s \equiv 8\ in \quad b_s \equiv 88\ in$

$P_s \equiv 0.85\ f'_c \cdot b_s \cdot t_s = 2393.6\ kip$

$P_c \equiv F_y \cdot b_f \cdot t_{topflange} = 1200\ kip$

$P_w \equiv F_y \cdot h \cdot t_w = 1375\ kip$

$P_t \equiv F_y \cdot b_f \cdot t_{bottomflange} = 1400\ kip$

$P_c + P_w + P_t = 3975\ kip$ $\quad P_s < (P_c + P_w + P_t)$

AASHTO Case I: $\quad (P_t + P_w) \ge (P_c + P_s)$

$P_t + P_w = 2775\ kip$ $\quad P_c + P_s = 3593.6\ kip$ $\quad 2775\ kip < 3593.6\ kip$ **INVALID**

AASHTO Case II: $\quad (P_t + P_w + P_c) \ge P_s$

$P_t + P_w + P_c = 3975\ kip$ $\quad P_s = 2393.6\ kip$ $\quad 3975\ kip > 2393.6\ kip$ **VALID**

Therefore, the Plastic Neutral Axis (PNA) is located in the top flange of the beam.

$$Y_{bar} \equiv \left(\frac{t_{topflange}}{2}\right) \left(\frac{P_w + P_t - P_s}{P_c} + 1\right) = 0.988\ in$$

$$haunch \equiv 2\ in$$

$$d_s \equiv \left(\frac{t_s}{2} + \left(haunch - t_{topflange}\right) + Y_{bar}\right) = 5.488\ in$$

$$D_t \equiv h + haunch + t_{bottomflange} + t_s = 66.75\ in$$

$$D_p \equiv t_s + haunch - t_{topflange} + Y_{bar} = 9.488\ in$$

$$d_w \equiv \frac{h}{2} + \left(t_{topflange} - Y_{bar}\right) = 28.012\ in$$

$$d_t \equiv \frac{t_{bottomflange}}{2} + h + \left(t_{topflange} - Y_{bar}\right) = 56.387\ in$$

$$M_p \equiv \left(\frac{P_c}{2 \cdot t_{topflange}}\right) \left(Y_{bar}^{\ 2} + \left(t_{topflange} - Y_{bar}\right)^2\right) + \left(\left(P_s \cdot d_s\right) + \left(P_w \cdot d_w\right) + \left(P_t \cdot d_t\right)\right) = 10924.141\ ft \cdot kip$$

AASHTO 6.10.7.1.2

$0.1\ D_t = 6.675\ in$ $\quad D_p \le 0.1\ Dt$ $\quad 9.488 > 6.675$ $\quad$ **INVALID**

$D_p = 9.488\ in$

$$M_n \equiv \left(M_p\right) \left(1.07 - 0.7 \left(\frac{D_p}{D_t}\right)\right) = 10601.84\ ft \cdot kip$$

$\phi_M := 1.0$

$\phi_M M_n := \phi_M \cdot M_n = 10601.84\ ft \cdot kip$

$\phi M_n \ge M_U$

$10601.84\ ft \cdot kip > 10215.625\ ft \cdot kip$ $\quad$ **VALID**

Girder Performance Ratio

$\frac{M_U}{M_n} = 96.36\%$ $\quad$ **GOOD**

Shear Capacity Calculations

$$V_U := (1.25 \cdot 80.81\ kip) + (1.50 \cdot 13.31\ kip) + (1.75 \cdot 122.35\ kip) = 335.09\ kip$$

$$1.12 \cdot \sqrt{\frac{(29000 \cdot 5)}{50}} = 60.314 \qquad k := 5$$

$$\frac{85.3}{1.12} \cdot 1.4 = 106.625$$

$$C := \frac{1.57}{\left(110^2\right)} \cdot \left(\frac{29000 \cdot 5}{50}\right) = 0.376$$

$$V_p \equiv 0.58\ (50\ ksi \cdot 55\ in \cdot 0.5\ in) = 797.5\ kip$$

$$V_p \cdot C = 300.084\ kip$$

$$797.5 \cdot 0.376 = 299.86$$

$$V_n := 797.5\ kip\ \left(C + \frac{0.87 \cdot (1 - C)}{1 + \sqrt{2}}\right) = 479.336\ kip$$

$$\phi_V := 1.0$$

$$\phi_V \cdot V_n = 479.336\ kip$$

$$\phi_V \cdot V_n \geq V_U$$

$479.336\ kip > 335.09\ kip$ **VALID**

Therefore, use one 1/2" thick shear stiffener located 55" away from abutments on each girder.