

Steel beam design

Analysis for steel beam supporting existing concrete beam underside through pockets on the masonry wall. Steel beam will be supported at its end with steel shore posts.

Loads determination:

$$DL := 40 \text{ psf} \quad SDL := 15 \text{ psf}$$

$$LL := 20 \text{ psf}$$

$$L_T := 5 \text{ ft}$$

$$L_b := 5 \text{ ft}$$

Roof dead load and superimposed dead load

Roof live load

Beam length

Beam unbraced length

$$S_x := 6.25 \text{ ft} \quad S_y := 16 \text{ ft}$$

$$A_t := S_x \cdot S_y = 100 \text{ ft}^2$$

Roof tributary width in X and Y

Roof tributary area

$$P := (DL + SDL + LL) \cdot A_t = 7500 \text{ lbf}$$

Point load on beam center

$$M := \frac{P \cdot L_T}{4} = 9.375 \text{ kip} \cdot \text{ft}$$

Moment demand on steel beam

$$V := \frac{P}{2} = 3.75 \text{ kip}$$

Shear demand on steel beam

Material properties

$$E := 29000 \text{ ksi} \quad F_y := 50 \text{ ksi}$$

Steel young modulus and yield strength

Section properties

$$\text{Section} := \text{Section: W6X8.5} \quad \text{v}$$

Steel section

$$d = 5.875 \text{ in}$$

$$b = 4 \text{ in}$$

Section depth and flange width

$$t_f = 0.188 \text{ in}$$

$$t_w = 0.188 \text{ in}$$

Flange thickness and web thickness

$$A = 5.83 \text{ in}^2$$

Section area

$$r_y = 0.89 \text{ in}$$

Radius of gyration about Y

$$S_x = 5.1 \text{ in}^3$$

$$Z_x = 5.73 \text{ in}^3$$

Elastic and plastic modulus about X

$$S_y = 1.01 \text{ in}^3$$

$$Z_y = 1.56 \text{ in}^3$$

Elastic and plastic modulus about Y

$$h_o = 5.64 \text{ in}$$

$$J = 0.033 \text{ in}^4$$

Distance between flange centroids and torsional constant

$$I_x = 14.9 \text{ in}^4$$

$$I_y = 1.99 \text{ in}^4$$

Inertia modulus about X and Y

$$\lambda = 29.1$$

Web Slenderness ratio

Bending about major axis

$$L_p := 1.76 \cdot r_y \cdot \sqrt{\frac{E}{F_y}} = 37.7 \text{ in}$$

Limiting unbraced length for yielding

$$C_b := 1$$

C_b factor

$$c := 1$$

Coefficient c for I shapes

$$r_{ts} := \sqrt{\frac{I_y \cdot h_o}{2 \cdot S_x}} = 1.05 \text{ in}$$

Effective radius of gyration

$$L_r := 1.95 r_{ts} \cdot \frac{E}{0.7 F_y} \cdot \sqrt{\frac{J \cdot c}{S_x \cdot h_o} + \sqrt{\left(\frac{J \cdot c}{S_x \cdot h_o}\right)^2 + 6.76 \cdot \left(\frac{0.7 \cdot F_y}{E}\right)^2}} = 9.48 \text{ ft}$$

$$L_r = 9.48 \text{ ft}$$

Limiting unbraced length for inelastic torsional buckling

$$F_{cr} := \frac{C_b \cdot \pi^2 \cdot E}{\left(\frac{L_b}{r_{ts}}\right)^2} \cdot \sqrt{1 + 0.078 \cdot \frac{J \cdot c}{S_x \cdot h_o} \cdot \left(\frac{L_b}{r_{ts}}\right)^2}$$

$$F_{cr} = 99.57 \text{ ksi}$$

Critical stress for lateral torsional buckling

$$M_p := F_y \cdot Z_x = 23.88 \text{ kip} \cdot \text{ft}$$

Plastic moment

$$M_{nLTB} := \text{if} \left(L_b < L_p, M_p, \text{if} \left(L_b < L_r, C_b \cdot \left(M_p - (M_p - 0.7 F_y \cdot S_x) \cdot \left(\frac{L_b - L_p}{L_r - L_p} \right) \right), F_{cr} \cdot S_x \right) \right) = 21.24 \text{ kip} \cdot \text{ft}$$

$$M_p = 23.9 \text{ kip} \cdot \text{ft}$$

Yielding flexural strength

$$M_{nLTB} = 21.2 \text{ kip} \cdot \text{ft}$$

Lateral torsional buckling flexural strength

$$\phi := 0.9$$

Bending reduction factor

$$M_n := \min(M_p, M_{nLTB}) = 21.2 \text{ kip} \cdot \text{ft}$$

Nominal bending capacity

$$\phi M_n := \phi \cdot M_n = 19.1 \text{ kip} \cdot \text{ft}$$

Design bending capacity

$$\text{if} (\phi M_n > M, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$$

$$\frac{M}{\phi M_n} = 0.49$$

Shear of web

$$A_w := d \cdot t_w = 1.102 \text{ in}^2$$

Area of web

$$\lambda_{lim} := 2.24 \cdot \sqrt{\frac{E}{F_y}} = 53.946$$

Limiting web slenderness

$$k_v := 5.34$$

Web plate shear buckling coefficient

$$C_{v1} := \text{if} \left(\lambda \leq 1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}}, 1, \frac{1.10 \cdot \sqrt{k_v \cdot \frac{E}{F_y}}}{\lambda} \right) = 1$$

$$C_{v1} = 1$$

Web shear strength coefficient

$$\phi_v := \text{if} \left(\lambda \leq 2.24 \cdot \sqrt{\frac{E}{F_y}}, 1, 0.9 \right) = 1$$

Shear reduction factor

$$\phi V_n := \phi_v \cdot 0.6 \cdot F_y \cdot A_w \cdot C_{v1} = 33.047 \text{ kip}$$

Design shear capacity

$$\text{if} (\phi V_n > V, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$$

$$\frac{V}{\phi V_n} = 0.113$$

Deflection

$$\delta_{max} := \frac{L_T}{240} = 0.25 \text{ in}$$

Maximum allowed deflection

$$\delta := \frac{1}{48} \cdot \frac{P \cdot L_T^3}{E \cdot I_x} = 0.078 \text{ in}$$

Expected deflection

$$\text{if} (\delta_{max} > \delta, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$$

$$\frac{\delta}{\delta_{max}} = 0.312$$