

Footing Reinforcing Design (F-1):

$$f'_c := 3000 \text{ psi} \quad E := 29000 \text{ ksi} \quad \lambda := 1.0 \quad F_y := 60 \text{ ksi}$$

$$W := 6 \text{ ft} \quad L := 4 \text{ ft} \quad T := 10 \text{ in} \quad C_{top} := 2 \cdot \text{in} \quad C_{bottom} := 3 \text{ in}$$

$$Base_W := 12 \text{ in} \quad Base_L := 12 \text{ in}$$

Loading:

$$P_{Dead} := 15 \text{ kip} \quad P_{Self} := 145 \text{ pcf} \cdot W \cdot L \cdot T = 2.9 \text{ kip} \quad P_{Snow} := 15 \text{ kip}$$

Check Soil Bearing:

$$\sigma_{max} := 3000 \text{ psf}$$

$$maxBearingCapacity := \sigma_{max} \cdot W \cdot L = 72 \text{ kip}$$

$$P_{asd} := \max \left(\begin{array}{l} P_{Dead} + P_{Self} \\ P_{Dead} + P_{Self} + P_{Snow} \end{array} \right) = 32.9 \text{ kip}$$

$$bearingDesignRatio := \frac{P_{asd}}{maxBearingCapacity} = 0.457$$

Footing Reinforcing:

Reinforcing Top:

$$Bar_W := 4 \quad A_{s_W} := A_{bar}(Bar_W) = 0.2 \text{ in}^2 \quad N_{bars_W} := 5 \quad Bar_Spacing(W, N_{bars_W}) = 16.5 \text{ in}$$

$$Bar_L := 4 \quad A_{s_L} := A_{bar}(Bar_L) = 0.2 \text{ in}^2 \quad N_{bars_L} := 4 \quad Bar_Spacing(L, N_{bars_L}) = 14 \text{ in}$$

Reinforcing Bottom:

$$Bar_W := 4 \quad A_{s_W} := A_{bar}(Bar_W) = 0.2 \text{ in}^2 \quad N_{bars_W} := 5 \quad Bar_Spacing(W, N_{bars_W}) = 16.5 \text{ in}$$

$$Bar_L := 4 \quad A_{s_L} := A_{bar}(Bar_L) = 0.2 \text{ in}^2 \quad N_{bars_L} := 4 \quad Bar_Spacing(L, N_{bars_L}) = 14 \text{ in}$$

Steel Depths:

$$\text{Top:} \quad d_W := C_{top} + D_{bar}(Bar_L) + \frac{D_{bar}(Bar_W)}{2} = 2.75 \text{ in}$$

$$d_L := C_{top} + D_{bar}(Bar_W) + \frac{D_{bar}(Bar_L)}{2} = 2.75 \text{ in}$$

$$\text{Bottom:} \quad d_W := T - \left(C_{bottom} + D_{bar}(Bar_L) + \frac{D_{bar}(Bar_W)}{2} \right) = 6.25 \text{ in}$$

$$d_L := T - \left(C_{bottom} + D_{bar}(Bar_W) + \frac{D_{bar}(Bar_L)}{2} \right) = 6.25 \text{ in}$$

Steel Ratios: $SteelCheck(\rho_w) := \text{if}(\rho_w > 0, \text{if}(\rho_w > 0.0018, \text{"OK"}, \text{"Not Enough"}), \text{"NA"})$

Top: $\rho_{W_top} := \frac{A_{s_W} \cdot N_{bars_W}}{W \cdot (T - d'_W)} = 0.002$ $SteelCheck(\rho_{W_top}) = \text{"OK"}$

$\rho_{L_top} := \frac{A_{s_L} \cdot N_{bars_L}}{L \cdot (T - d'_L)} = 0.002$ $SteelCheck(\rho_{L_top}) = \text{"OK"}$

Bottom: $\rho_{W_bottom} := \frac{A_{s_W} \cdot N_{bars_W}}{W \cdot d_W} = 0.0022$ $SteelCheck(\rho_{W_bottom}) = \text{"OK"}$

$\rho_{L_bottom} := \frac{A_{s_L} \cdot N_{bars_L}}{L \cdot d_L} = 0.0027$ $SteelCheck(\rho_{L_bottom}) = \text{"OK"}$

Single Shear: $V_n(f'_c, b, d, \rho_w) := \begin{cases} \text{if } \rho_w \geq 0.0018 \\ \left| \begin{array}{l} V_{c1} \leftarrow 2 \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi \cdot b \cdot d \\ V_{c2} \leftarrow 8 \cdot \lambda \cdot (\rho_w)^{\frac{1}{3}} \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi \cdot b \cdot d \\ \text{return } \min(\max(V_{c1}, V_{c2}), 5 \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi \cdot b \cdot d) \end{array} \right. \\ \text{else} \\ \left| \text{return } 0 \text{ kip} \right. \end{cases}$

$V_{n_W} := V_n(f'_c, W, d_W, \rho_{W_bottom}) = 49.295 \text{ kip}$ $\phi V_{n_W} := 0.75 \cdot V_{n_W} = 36.971 \text{ kip}$

$V_{n_L} := V_n(f'_c, L, d_L, \rho_{L_bottom}) = 32.863 \text{ kip}$ $\phi V_{n_L} := 0.75 \cdot V_{n_L} = 24.648 \text{ kip}$

Double Shear: $V_{c_punching} := \begin{cases} d \leftarrow \min(d_W, d_L) \\ \beta \leftarrow \frac{\max(W, L)}{\min(W, L)} \\ b_{o_w} \leftarrow \text{if}(Base_L + d \geq L, 0 \text{ in}, Base_W + d) \\ b_{o_l} \leftarrow \text{if}(Base_W + d \geq W, 0 \text{ in}, Base_L + d) \\ b_o \leftarrow 2 \cdot b_{o_w} + 2 \cdot b_{o_l} \\ \text{if } b_o > 0 \text{ in} \\ \left| \begin{array}{l} \alpha_s \leftarrow 40 \\ \text{return } \min \left(\begin{array}{l} 4 \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi \\ \left(2 + \frac{4}{\beta}\right) \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi \\ \left(\frac{\alpha_s \cdot d}{b_o} + 2\right) \cdot \lambda \cdot \sqrt{\frac{f'_c}{psi}} \cdot psi \end{array} \right) \cdot b_o \cdot d \end{array} \right. \\ \text{else} \\ \left| \text{return } 0 \text{ kip} \right. \end{cases} = 99.959 \text{ kip}$

$\phi V_{c_punching} := 0.75 \cdot V_{c_punching} = 74.97 \text{ kip}$

Calculate Moment Capacity:

$$M_n(A_{bottom}, N_{bottom}, A_{top}, N_{top}, b, T, d, d', F_y, f_c, E) := \begin{cases} \beta_1 \leftarrow \text{if } f'_c \leq 4000 \text{ psi} \\ \quad \left\| \begin{array}{l} 0.85 \\ \text{else if } f'_c \leq 8000 \text{ psi} \\ \quad \left\| \begin{array}{l} 0.85 - 0.05 \cdot \frac{(f'_c - 4000 \text{ psi})}{1000 \text{ psi}} \\ \text{else} \\ \quad \left\| 0.65 \end{array} \right. \end{array} \right. \\ A_s \leftarrow A_{bottom} \cdot N_{bottom} \\ A'_s \leftarrow A_{top} \cdot N_{top} \\ \rho \leftarrow \frac{A_s}{b \cdot d} \\ \rho' \leftarrow \frac{A'_s}{b \cdot (T - d')} \\ \text{if } \rho \geq 0.0018 \\ \quad \left\| \begin{array}{l} \text{if } \rho - \rho' \geq \frac{\beta_1 \cdot 0.85 \cdot f'_c \cdot d'}{F_y \cdot d} \cdot \frac{87000 \text{ psi}}{87000 \text{ psi} - F_y} \\ \quad \left\| \begin{array}{l} c \leftarrow \frac{(A_s - A'_s) \cdot F_y}{0.85 \cdot \beta_1 \cdot b \cdot f'_c} \\ a \leftarrow \beta_1 \cdot c \\ M_n \leftarrow A'_s \cdot F_y \cdot (d - d') + (A_s - A'_s) \cdot F_y \cdot \left(d - \frac{a}{2}\right) \end{array} \right. \\ \text{else} \\ \quad \left\| \begin{array}{l} c \leftarrow \frac{\sqrt{9 \cdot E^2 \cdot A_s'^2 - 6000 \cdot E \cdot A_s \cdot F_y \cdot A'_s + 10200 \cdot b \cdot d' \cdot \beta_1 \cdot f'_c \cdot E \cdot A'_s + 1000000 \cdot A_s^2 \cdot F_y^2 - 3 \cdot E \cdot A'_s + 1000 \cdot A_s \cdot F_y}}{1700 \cdot b \cdot \beta_1 \cdot f'_c} \\ a \leftarrow \beta_1 \cdot c \\ M_n \leftarrow 0.85 \cdot f'_c \cdot b \cdot \beta_1 \cdot c \cdot \left(d - \frac{a}{2}\right) \\ \quad + A'_s \cdot E \cdot 0.003 \cdot \left(\frac{c - d'}{c}\right) \cdot (d - d') \end{array} \right. \\ \text{else} \\ \quad \left\| M_n \leftarrow 0 \text{ kip} \cdot \text{ft} \end{array} \right. \\ \text{return } M_n \end{cases}$$

$$M_{n_W} := M_n(A_{s_W}, N_{bars_W}, A'_{s_W}, N'_{bars_W}, W, T, d_W, d'_W, F_y, f'_c, E) = 51.427 \text{ kip} \cdot \text{ft}$$

$$M_{n_L} := M_n(A_{s_L}, N_{bars_L}, A'_{s_L}, N'_{bars_L}, L, T, d_L, d'_L, F_y, f'_c, E) = 38.141 \text{ kip} \cdot \text{ft}$$

$$\phi M_{n_W} := 0.9 \cdot M_{n_W} = 46.284 \text{ kip} \cdot \text{ft}$$

$$\phi M_{n_L} := 0.9 \cdot M_{n_L} = 34.327 \text{ kip} \cdot \text{ft}$$

Calculating Single Shear Demand:

$$P_u := \max \left(\left[\begin{array}{l} 1.4 \cdot (P_{Dead} + P_{Self}) \\ 1.2 \cdot (P_{Dead} + P_{Self}) + 1.6 \cdot P_{Snow} \end{array} \right] \right) = 45.48 \text{ kip}$$

$$V_{u_W} := \text{if } \frac{Base_L}{2} + d_W < \frac{L}{2} \quad = 11.133 \text{ kip} \quad V_{u_L} := \text{if } \frac{Base_W}{2} + d_L < \frac{W}{2} \quad = 15.002 \text{ kip}$$

$$\left\| \frac{P_u \cdot \left(\frac{L}{2} - \left(\frac{Base_L}{2} + d_L \right) \right)}{L} \right\| \quad \left\| \frac{P_u \cdot \left(\frac{W}{2} - \left(\frac{Base_W}{2} + d_W \right) \right)}{W} \right\|$$

$$\text{else} \quad \text{else}$$

$$\left\| 0 \text{ kip} \right\| \quad \left\| 0 \text{ kip} \right\|$$

Calculate Punching Shear Demand:

$$V_{u_Punching} := \left\| \begin{array}{l} d \leftarrow \min(d_W, d_L) \\ b_{o_W} \leftarrow \min(Base_W + d, W) \\ b_{o_L} \leftarrow \min(Base_L + d, L) \\ \text{if } b_{o_W} \cdot b_{o_L} > 0 \text{ in}^2 \\ \left\| \text{return } P_u - \frac{P_u}{W \cdot L} \cdot (b_{o_W} \cdot b_{o_L}) \right\| \\ \text{else} \\ \left\| \text{return } 0 \text{ kip} \right\| \end{array} \right\| = 41.097 \text{ kip}$$

Calculate Factored Moment Demand:

$$M_{u_W} := \frac{P_u \cdot \left(\frac{L}{2} - \frac{Base_L}{2} \right)^2}{2 \cdot L} = 12.791 \text{ kip} \cdot \text{ft} \quad M_{u_L} := \frac{P_u \cdot \left(\frac{W}{2} - \frac{Base_W}{2} \right)^2}{2 \cdot W} = 23.688 \text{ kip} \cdot \text{ft}$$

Check Footing Shear Capacity:

$$V_{u_W} = 11.133 \text{ kip} \quad V_{u_L} = 15.002 \text{ kip} \quad V_{u_Punching} = 41.097 \text{ kip}$$

$$\phi V_{n_W} = 36.971 \text{ kip} \quad \phi V_{n_L} = 24.648 \text{ kip} \quad \phi V_{c_punching} = 74.97 \text{ kip}$$

$$\frac{V_{u_W}}{\phi V_{n_W}} = 0.301 \quad \frac{V_{u_L}}{\phi V_{n_L}} = 0.609 \quad \frac{V_{u_Punching}}{\phi V_{c_punching}} = 0.548$$

$$shearDesignRatio := \max \left(\frac{V_{u_W}}{\phi V_{n_W}}, \frac{V_{u_L}}{\phi V_{n_L}}, \frac{V_{u_Punching}}{\phi V_{c_punching}} \right) = 0.609$$

Check Footing Moment Capacity:

$$M_{u_W} = 12.791 \text{ kip}\cdot\text{ft}$$

$$M_{u_L} = 23.688 \text{ kip}\cdot\text{ft}$$

$$\phi M_{n_W} = 46.284 \text{ kip}\cdot\text{ft}$$

$$\phi M_{n_L} = 34.327 \text{ kip}\cdot\text{ft}$$

$$\frac{M_{u_W}}{\phi M_{n_W}} = 0.276$$

$$\frac{M_{u_L}}{\phi M_{n_L}} = 0.69$$

$$\text{momentDesignRatio} := \max\left(\frac{M_{u_W}}{\phi M_{n_W}}, \frac{M_{u_L}}{\phi M_{n_L}}\right) = 0.69$$

Bearing Check:

Max Bearing Force: $P_{asd} = 32.9 \text{ kip}$

Footing Bearing Capacity: $\text{maxBearingCapacity} = 72 \text{ kip}$

Bearing Unity Check: $\text{bearingDesignRatio} = 0.457$

Footing Bearing Analysis:

Bearing Code Check = 0.46

P = 32.90 kips vs 72.00 kips

For Dead + Snow

Footing Shear Analysis:

Shear Code Check = 0.61

Vu = 15.00 kips vs 24.65 kips

For 1.2 Dead + 1.6 Snow

Footing Moment Analysis:

Moment Code Check = 0.69

Mu = 23.69 kip-ft vs 34.33 kip-ft

For 1.2 Dead + 1.6 Snow