

Concrete footing for concentric steel column

General information and acting loads:

Considering the load from the central shade roof and column self weight.

Loads determination:

$DL_r := 10 \text{ psf}$	$LL_r := 20 \text{ psf}$	Roof dead and live load
$B_r := 18.9 \text{ ft}$	$L_r := 27.5 \text{ ft}$	Roof tributary width and length
$A_r := B_r \cdot L_r = 519.8 \text{ ft}^2$		Roof tributary area
$b_c := 14 \text{ in}$	$L_c := 14 \text{ ft}$	Column width and length
$\omega_c := 145 \text{ pcf}$		Concrete unit weight
$P_s := (DL_r + LL_r) \cdot A_r + b_c \cdot b_c \cdot L_c \cdot \omega_c = 18.4 \text{ kip}$ Service load on column		
$P_u := 1.2 \cdot (DL_r \cdot A_r + b_c \cdot b_c \cdot L_c \cdot \omega_c) + 1.6 \cdot LL_r \cdot A_r = 26.2 \text{ kip}$ Ultimate load on column		

Considering square footing, 66" x 66" x 12" concrete footing, 3000 psi, with (4) #5 bottom in both directions.

Existing footing data:

$q_a := 2500 \text{ psf}$	Allowable soil bearing pressure
$c := 14 \text{ in}$	Square column
$D_f := 12 \text{ in}$	Footing depth and width
$B_f := 3 \text{ ft}$	Footing base area
$A_f := B_f^2 = 9 \text{ ft}^2$	Concrete strength and lightweight factor
$f'_c := 3000 \text{ psi}$	Strength of reinforcement steel
$\lambda := 1$	Depth of soil over footing and unit weight of soil
$f_y := 60 \text{ ksi}$	Concrete cover to rebar centroid
$h_{soil} := 0 \text{ in}$	No. of rebars and rebar size
$\gamma_{soil} := 110 \text{ pcf}$	Depth to concrete cover
$\text{cover} := 3 \text{ in}$	
$N := 4$	
$\text{rebar\#} := 4$	
$d := D_f - \text{cover} = 9 \text{ in}$	

$$A_{s1} := \frac{\pi \cdot \left(\frac{\text{rebar\#}}{8} \text{ in} \right)^2}{4} = 0.2 \text{ in}^2$$

Area for one rebar

$$A_s := N \cdot A_{s1} = 0.8 \text{ in}^2$$

Rebar area in one direction

$$\rho := \frac{A_s}{B_f \cdot d} = 0.0024$$

Reinforcement ratio

Soil bearing capacity

$$q := \frac{P_s}{A_f} = 2039.506 \text{ psf}$$

Acting soil pressure

$$\text{if } (q < q_a, \text{"OK"}, \text{"NOT OK"}) = \text{"OK"}$$

$$\frac{q}{q_a} = 0.8$$

Ultimate soil pressure

$$q_u := \frac{P_u}{A_f} = 2909.4 \text{ psf}$$

Ultimate soil pressure for conc. capacity calculations

One-way Shear capacity

$$V_u := \left(\frac{B_f}{2} - \frac{c}{2} - d \right) \cdot B_f \cdot q_u = 1.5 \text{ kip}$$

Required one-way shear strength

$$V_c := 2 \cdot \sqrt{\frac{f'_c}{\text{psi}}} \cdot \frac{B_f}{\text{in}} \cdot \frac{d}{\text{in}} \cdot \text{lbf} = 35.5 \text{ kip}$$

Concrete shear strength

$$V_s := 0 \text{ lbf}$$

Assuming no shear reinforcement

$$\phi_s := 0.75$$

Reduction factor for shear

$$\phi V_n := \phi_s \cdot (V_c + V_s) = 26.6 \text{ kip}$$

Design one way shear strength

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

$$\frac{V_u}{\phi V_n} = 0.1$$

Two-way Shear capacity

$$V_u := q_u \cdot (B_f^2 - (c + d)^2) = 15.497 \text{ kip}$$

two-way shear required strength

$$b_o := (c + d) + 2 \cdot \left(c + \frac{d}{2} + 4 \text{ in} \right) = 68 \text{ in}$$

Critical two way shear perimeter

$$\alpha_s := 40$$

Column position factor

$$u_c := \min \left(4 \cdot 1 \cdot \sqrt{\frac{f'_c}{\text{psi}}}, \left(2 + \frac{4}{1} \right) \cdot 1 \cdot \sqrt{\frac{f'_c}{\text{psi}}}, \left(\frac{\alpha_s \cdot d}{b_o} + 2 \right) \lambda \cdot \sqrt{\frac{f'_c}{\text{psi}}} \right) \text{ psi} = 219.1 \text{ psi}$$

two way shear stress

$$V_c := u_c \cdot b_o \cdot d = 134.082 \text{ kip}$$

Concrete shear strength

$$V_s := 0 \text{ lbf}$$

Assuming no shear reinforcement

$$\phi_s := 0.75$$

Reduction factor for shear

$$\phi V_n := \phi_s \cdot (V_c + V_s) = 100561.862 \text{ lbf}$$

Design two-way shear strength

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

$$\frac{V_u}{\phi V_n} = 0.2$$

Flexure capacity

$$\rho = 0.0024$$

$$\rho_{\min} := 0.0018$$

if ($\rho > \rho_{\min}$, "OK", "NOT OK") = "OK"

$$M_u := \frac{q_u \cdot \left(\frac{B_f - c}{2} \right)^2 \cdot B_f}{2} = 3.7 \text{ kip} \cdot \text{ft}$$

Reinforcement ratio

Minimum reinf. ratio

Required bending strength

$$a := \frac{A_s \cdot f_y}{0.85 f'_c \cdot B_f} = 0.5 \text{ in}$$

Equivalent compression block depth

$$M_n := A_s \cdot f_y \cdot \left(d - \frac{a}{2} \right) = 34.3 \text{ kip} \cdot \text{ft}$$

Nominal bending strength

$$\phi_b := 0.9$$

Reduction factor for bending

$$\phi M_n := \phi_b \cdot M_n = 30.9 \text{ kip} \cdot \text{ft}$$

Design bending strength

if ($\phi M_n > M_u$, "OK", "NOT OK") = "OK"

$$\frac{M_u}{\phi M_n} = 0.1$$

Bearing capacity

$$A_1 := 6 \text{ in} \cdot 6 \text{ in} = 0.3 \text{ ft}^2$$

Bearing plate area

$$A_2 := A_f = 9 \text{ ft}^2$$

Footer area

$$B_n := \min \left(\sqrt{\frac{A_2}{A_1}} \cdot 0.85 \cdot f'_c \cdot A_1, 2 \cdot 0.85 f'_c \cdot A_1 \right) = 183.6 \text{ kip}$$

Nominal bearing strength

$$\phi_{\text{bearing}} := 0.65$$

$$\phi B_n := \phi_{\text{bearing}} \cdot B_n = 119.34 \text{ kip}$$

Design bearing strength

if ($\phi B_n > P_u$, "OK", "NOT OK") = "OK"

$$\frac{P_u}{\phi B_n} = 0.2$$