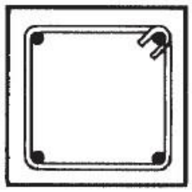
Axial load capacity of pile

At failure, the theoretical ultimate strength or nominal strength of a short axially loaded pile is quite accurately determined by the expression that follows, in which A_g is the gross concrete area and A_{st} is the total cross-sectional area of longitudinal reinforcement, including bars and steel shapes:



$$P_n = 0.85f_C'(A_g - A_{st}) + f_y A_{st}$$

In today's code, minimum eccentricities are not specified, but the same objective is accomplished by requiring that theoretical axial load capacities be multiplied by a factor sometimes called α, which is equal to 0.85 for spiral columns and 0.80 for tied columns.

$$\emptyset P_n(Max) = 0.8\emptyset[0.85f_C'(A_g - A_{st}) + f_y A_{st}]$$

For tied columns (ϕ = 0.65)

It is to be clearly understood that the preceding expressions are to be used only when the moment is quite small or when there is no calculated moment.

Design of Axially Loaded Columns

As a brief introduction to columns, the design of three axially loaded short columns is presented in this section and the next. Moment and length effects are completely neglected. Examples .1 and 3 present the design of axially loaded square tied columns, while Example.2 illustrates the design of a similarly loaded round spiral column.

Example 1

Design a square tied column to support an axial dead load D of 600 KN and an axial live load L of 800 kN. Initially assume that 2% longitudinal steel is desired, fc= 20 MPa and fy = 425kN.

Ans:

$$P_U = 1.2 * 600 + 1.6 * 800 = 2000\ KN$$

Selecting Column Dimensions

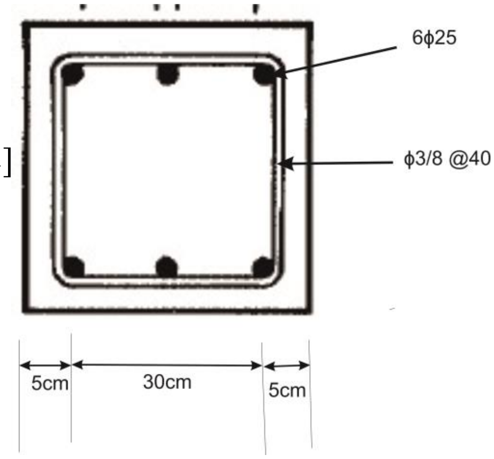
$\emptyset P_n = 0.8\emptyset[0.85f_C'(A_g - A_{st}) + f_y A_{st}]$

$2000 = 0.8 * 0.65[0.85 * 20 * 1000(A_g - 0.02A_g) + 425 * 1000 * 0.02A_g]$

$2 = 0.8 * 0.65[0.85 * 20(A_g - 0.02A_g) + 425 * 0.02A_g]$

3.846 = 16.66 A_g +8.5 A_g, $A_g = 0.15286m2,$ use 0.4cm *0.4 cm ($A_g = 0.16m2$)

Selecting Longitudinal Bars



$2000 = 0.8 * 0.65[0.85 * 20 * 1000(0.16 - A_{st}) + 425 * 1000 * A_{st}]$

$3.846 = 2.72 - 17A_{st} + 425A_{st}$

$1.126 = 408A_{st}$, $A_{st} = 2{,}759.8mm2$, use 6∅25

Design of Ties (Assuming #3/8" Bars = 9.375mm)

Use ∅3

Example 2

Design a round spiral column to support an axial dead load P_D of 1000 kN and an axial live load P_L of1360 kN. Initially assume that approximately 2% longitudinal steel is desired, f_C = 20 psi, and f_y =425 KN.

$$P_U = 1.2 * 100 + 1.6 * 1360 = 3{,}376\ KN$$

Selecting Column Dimensions

$\emptyset P_n = 0.85\emptyset[0.85f_C'(A_g - A_{st}) + f_y A_{st}]$

$3{,}376\ KN = 0.85 * 0.75[0.85 * 20 * 1000(A_g - 0.02A_g) + 425 * 1000 * 0.02A_g]$

$3.376 = 0.8 * 0.65[0.85 * 20(A_g - 0.02A_g) + 425 * 0.02A_g]$

5.295 = 16.66 A_g +8.5 A_g, $A_g = 0.21m2$, use 0. 5m diameter ($A_g = 0.196m2$)

Using a column diameter with a gross area less than the calculated gross area 0.196m2 <0.21m2) results in a higher percentage of steel than originally assumed.

$3{,}376 = 0.85 * 0.75[0.85 * 20 * 1000(0.196 - A_{st}) + 425 * 1000 * A_{st}]$

$5.295 = 3.332 - 17A_{st} + 425A_{st}$

$1.963 = 408A_{st}$, $A_{st} = 4{,}811.27mm2$, use 10∅25

Design of spiral

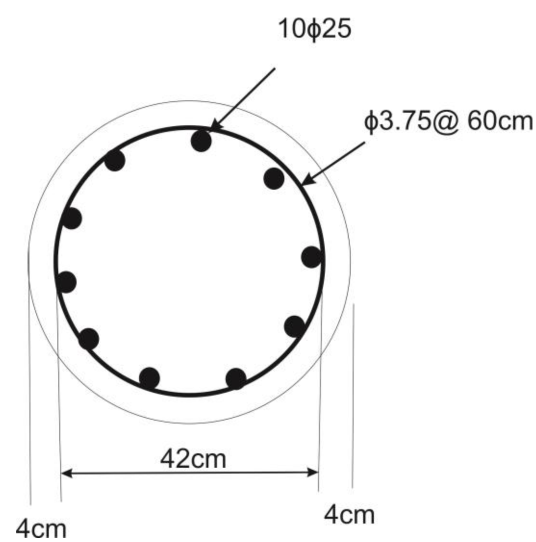
$\boldsymbol{A_C = \frac{\pi(0{,}42)^2}{4} = 0.1385m2}$

Minimum $\boldsymbol{\rho_s = 0.45\left(\frac{A_g}{A_C} - 1\right)\frac{f_C}{f_y} = 0.45\left(\frac{0.196}{0.1385} - 1\right)\frac{20}{425} = 0.00879}$

Use ∅3, d_b=9.375mm $\boldsymbol{a_S = 69mm2}$

$$\boldsymbol{\rho_s = \frac{4a_s(D_C - d_b)}{S(D_C)^2}}$$

$\boldsymbol{0.00879 = \frac{4*69(42-9.375)}{S(42)^2}}$, $\boldsymbol{S = 580mm}$ **say S = 60 cm**



Design an axially loaded short square tied column for $P_u = 2600$ kN if $f'_c = 28$ MPa and $f_y = 350$ MPa. Initially assume $\rho = 0.02$.

SOLUTION

Selecting Column Dimensions

$$\phi P_n = \phi 0.80[0.85 f'_c (A_g - A_{st}) + f_y A_{st}] \qquad \text{(ACI Equation 10-2)}$$

$$2600 \text{ kN} = (0.65)(0.80)[(0.85)(28 \text{ MPa})(A_g - 0.02A_g) + (350 \text{ MPa})(0.02A_g)]$$

$$A_g = 164\ 886 \text{ mm}^2$$

Use 400 mm × 400 mm ($A_g = 160\ 000$ mm^2)

Selecting Longitudinal Bars

$$2600 \text{ kN} = (0.65)(0.80)[(0.85)(28 \text{ MPa})(160\ 000 \text{ mm}^2 - A_{st}) + (350 \text{ MPa})A_{st}]$$

$$A_{st} = 3654 \text{ mm}^2$$

Use 6 #29 (3870 mm^2)

Design of Ties (Assuming #10 SI Ties)

(a) 16 mm × 28.7 mm = 459.2 mm
(b) 48 mm × 9.5 mm = 456 mm
(c) Least col. dim. = 400 mm ← Use #10 ties @ 400 mm

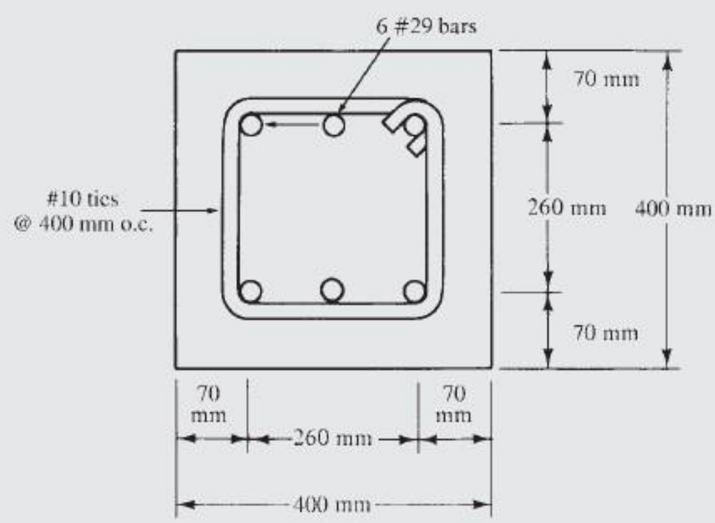


FIGURE 9.7 Final design for Example 9.3.

Problem 9.10 Square tied column: $P_D = 280$ k, $P_L = 500$ k, $f'_c = 4000$ psi, and $f_y = 60{,}000$ psi. Initially assume $\rho_g = 2\%$.

Problem 9.11 Repeat Problem 9.10 if ρ_g is to be 4% initially. (*One ans.* 20-in. × 20-in. column with 10 #11 bars)

Problem 9.12 Round spiral column: $P_D = 300$ k, $P_L = 400$ k, $f'_c = 3500$ psi, and $f_y = 60{,}000$ psi. Initially assume $\rho_g = 4\%$.

Problem 9.13 Round spiral column: $P_D = 400$ k, $P_L = 250$ k, $f'_c = 4000$ psi, $f_y = 60{,}000$ psi, and p_g initially assumed = 2%. (*One ans.* 20-in. diameter column with 6 #9 bars)

Problem 9.14 Smallest possible square tied column: $P_D = 200$ k, $P_L = 300$ k, $f'_c = 4000$ psi, and $f_y = 60{,}000$ psi.

Problem 9.15 Design a rectangular tied column with the long side equal to two times the length of the short side. $P_D = 650$ k, $P_L = 400$ k, $f'_c = 3000$ psi, and $f_y = 60{,}000$ psi. Initially assume that $p_g = 2\%$. (*One ans.* 20-in. × 40-in. column with 8 #11 bars)