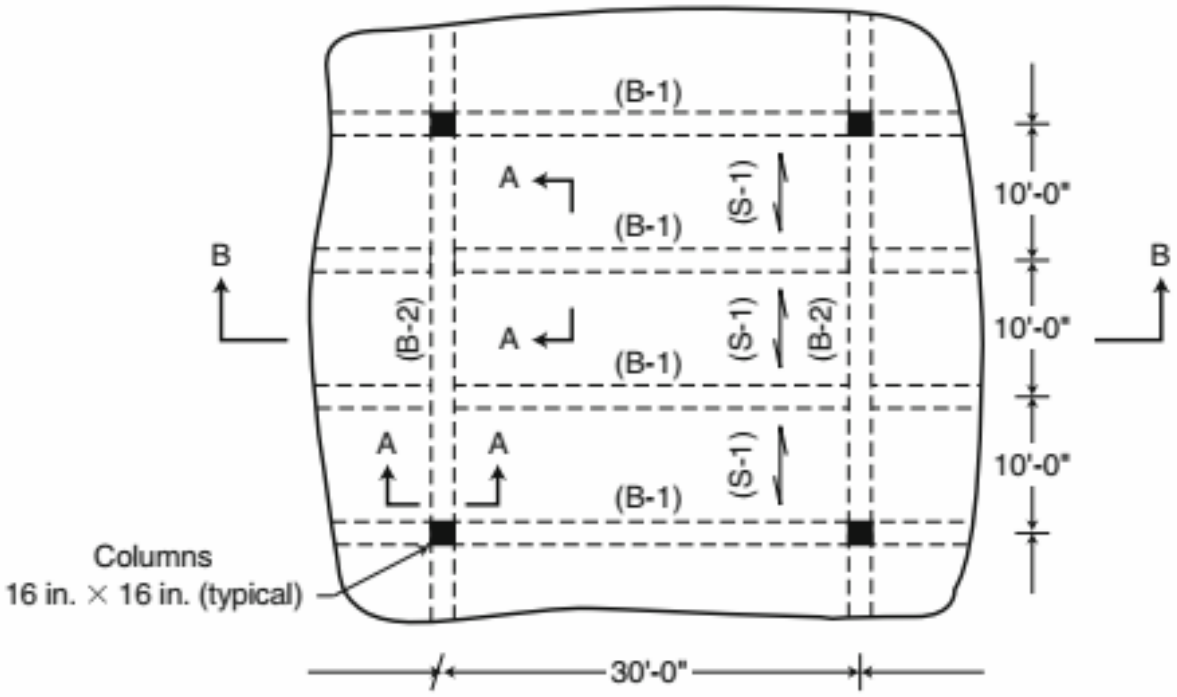
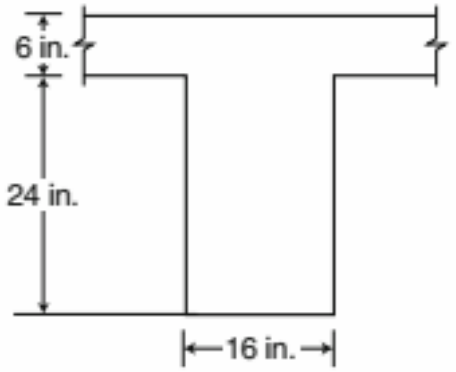
PROBLEM 3

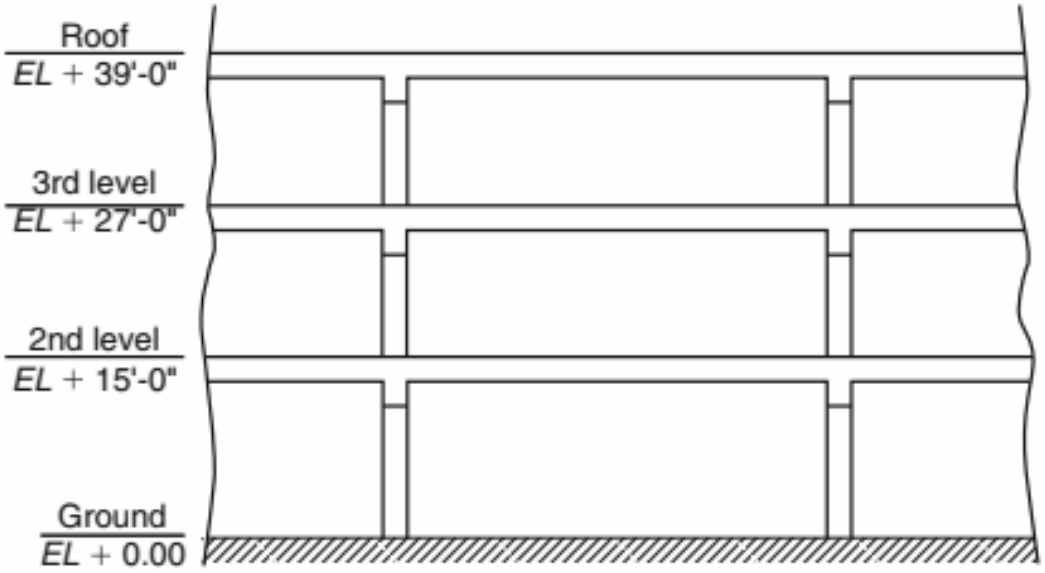
Figure below shows the typical partial floor plan and sections of a three story reinforced concrete office building. The mechanical and electrical systems for the floor and the roofing and insulation weigh 5 psf. The weight of the partitions is 15 psf. The floor live load is 50 psf and the roof environmental load is 30 psf. Assume = 4 ksi and = 60 ksi. Design the square 16 inch x 16 inch tied interior columns between the Ground and Second Levels. Moment acting on the column is not significant. Assume the unit weight of the concrete is 150 pcf. Neglect the self weight of the column.



Typical partial framing plan



Section A-A



Section B-B

Step 1. Determine the loads acting on the columns:

Floor Loads

$$\text{Weight of concrete slab} = 150\left(\tfrac{6}{12}\right) = 75 \text{ psf}$$

$$\text{Mechanical and electrical} = 5 \text{ psf}$$

$$\text{Partitions} = 15 \text{ psf}$$

$$\text{Floor dead load} = 95 \text{ psf}$$

The tributary area for the columns is $30 \text{ ft} \times 30 \text{ ft} = 900 \text{ ft}^2$. In addition to supporting the slab, the columns also support beams B-1 and B-2.

$$P_{D,\text{floor}} = \overbrace{\frac{95}{1{,}000}(900)}^{\text{Slab}} + \overbrace{\frac{150}{1{,}000}\left(\frac{24}{12}\times\frac{16}{12}\times 3\times 30\right)}^{\text{B-1}} + \overbrace{\frac{150}{1{,}000}\left(\frac{24}{12}\times\frac{16}{12}\times 30\right)}^{\text{B-2}}$$

$$P_{D,\text{floor}} = 85.5 + 36 + 12.0 = 133.5\,\text{kip}$$

$$P_{L,\text{floor}} = \frac{50}{1{,}000}(900) = 45\,\text{kip}$$

Roof Loads

$$\text{Weight of concrete slab} = 150\left({}^{6}/_{12}\right) = 75\ \text{psf}$$

$$\text{Roofing and insulation} = \ 5\ \text{psf}$$

$$\text{Roof dead load} = 80\ \text{psf}$$

The tributary area of the columns at roof level is the same as that of a floor (900 ft^2). Therefore

$$P_{D,\text{roof}} = \overbrace{\frac{80}{1{,}000}(900)}^{\text{Slab}} + \overbrace{\frac{150}{1{,}000}\left(\frac{24}{12}\times\frac{16}{12}\times 3\times 30\right)}^{\text{B-1}} + \overbrace{\frac{150}{1{,}000}\left(\frac{24}{12}\times\frac{16}{12}\times 30\right)}^{\text{B-2}}$$

$$P_{D,\text{roof}} = 72.0 + 36.0 + 12.0 = 120.0\,\text{kip}$$

$$P_{L,\text{roof}} = \text{snow load} = \frac{30}{1{,}000}(900) = 27.0\ \text{kip}$$

Because the column self-weight is small compared to the applied loads, we neglect the column weight. The columns between the ground and second levels carry two floor loads and one roof load:

$$P_D = 2P_{D,\text{floor}} + P_{D,\text{roof}}$$

$$P_D = 2(133.5) + 120.0 = 387.0\ \text{kip}$$

$$P_L = 2P_{L,\text{floor}}$$

$$P_L = 2(45)$$

$$P_L = 90.0\ \text{kip}$$

$$P_{Lr} = 27.0\ \text{kip}$$

Since $1.83P_{Lr} = 1.83(27) = 49.4$ kip $< P_L = 90$ kip, therefore,

$$P_u = 1.2P_D + 1.6P_L + 0.5P_{Lr}$$
$$P_u = 1.2(387) + 1.6(90) + 0.5(27)$$
$$P_u = 621.9 \text{ kip}$$

A safe column requires that:

$$P_R = \phi P_n \geq P_u$$

The load capacity of a tied column is given by

$$P_R = 0.8\phi\left[0.85f_c'\left(A_g - A_{st}\right) + f_y A_{st}\right]$$

The useful capacity of the column (P_R) must be at least equal to the factored load on the column (P_U). Thus,

$$P_u = 0.8\phi \left[0.85 f_c' \left(A_g - A_{st}\right) + f_y A_{st}\right]$$

Because the area of concrete (A_g) is known we can solve the above equation for the area of steel (A_{st}):

$$A_{st}\left[0.8\phi\left(f_y - 0.85 f_c'\right)\right] = P_u - 0.8\phi\left(0.85 f_c' A_g\right)$$

$$\phi = 0.65$$

$$A_{st} = \frac{P_u - 0.8\phi\left(0.85 f_c' A_g\right)}{0.8\phi\left(f_y - 0.85 f_c'\right)}$$

Similarly, the required area of steel, A_{st}, for spiral columns is:

$$\phi = 0.75$$

$$A_{st} = \frac{P_u - 0.85\phi\left(0.85f_c' A_g\right)}{0.85\phi\left(f_y - 0.85f_c'\right)}$$

Note that if the numerator (top of a fraction) in Equations results in a negative value, the column requires only 1% longitudinal reinforcement (ρ_{min}).

Step 2. Determine the required area of steel, A_{st}:

$$A_{st} = \frac{P_u - 0.8\phi\left[0.85f_c' A_g\right]}{0.8\phi\left[f_y - 0.85f_c'\right]}$$

$$A_{st} = \frac{621.9 - 0.8(0.65)[0.85(4.0)(16 \times 16)]}{0.8(0.65)[60 - 0.85(4.0)]}$$

$$A_{st} = 5.75 \text{ in.}^2$$

Step 3. Using Table A2.9, select 8 #8 bars ($A_s = 6.32$ in^2). Based on Table A5.1, the maximum number of #8 bars for a 16 in. × 16 in. column is 12. Therefore, 8 #8 bars are ok. The provided column steel ratio, ρ_g, is:

$$\rho_g = \frac{A_{st}}{A_g} = \frac{6.32}{16 \times 16} = 0.0247$$

$$0.01 < \rho_g = 0.0247 < 0.08 \quad \therefore \text{ ok}$$

Step 4. Design ties:

Use #3 ties for #8 longitudinal bars. The maximum tie spacing, s_{max}, is:

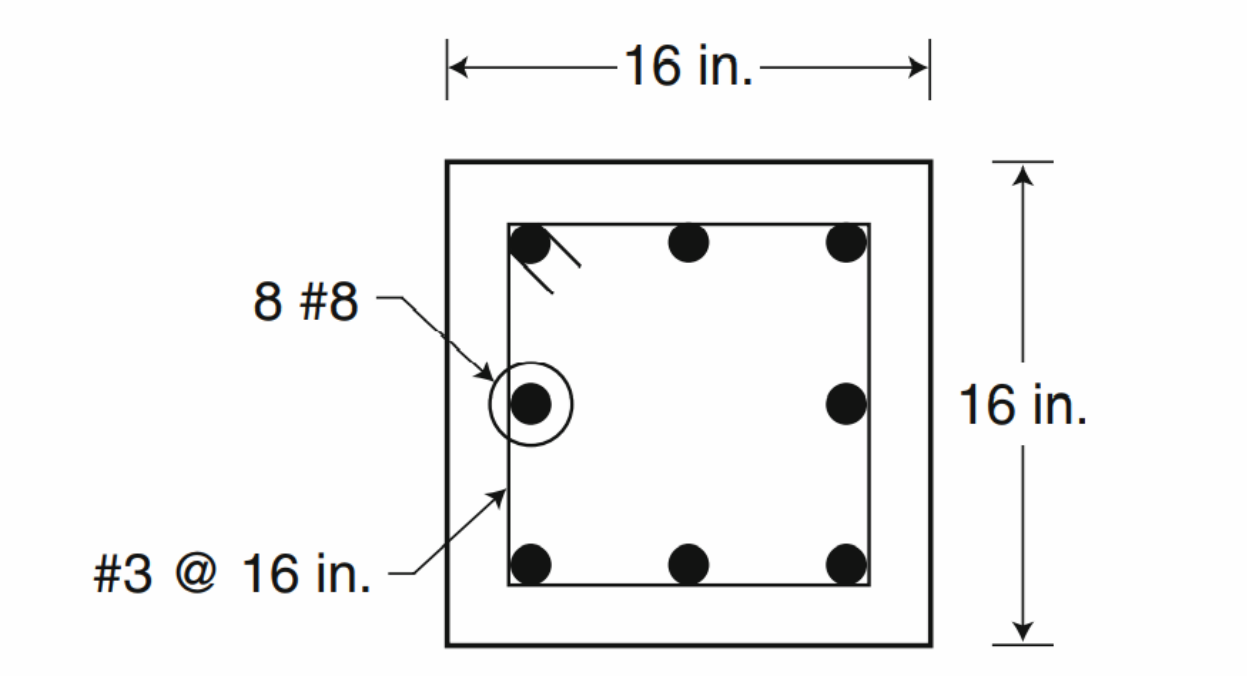
$$s_{max} = \min\{16d_b, 48d_t, b_{min}\}$$
$$s_{max} = \min\{16(1.0), 48(3/8), 16\}$$
$$s_{max} = \{16.0, 18.0, 16.0\}$$
$$s_{max} = 16.0 \text{ in.}$$

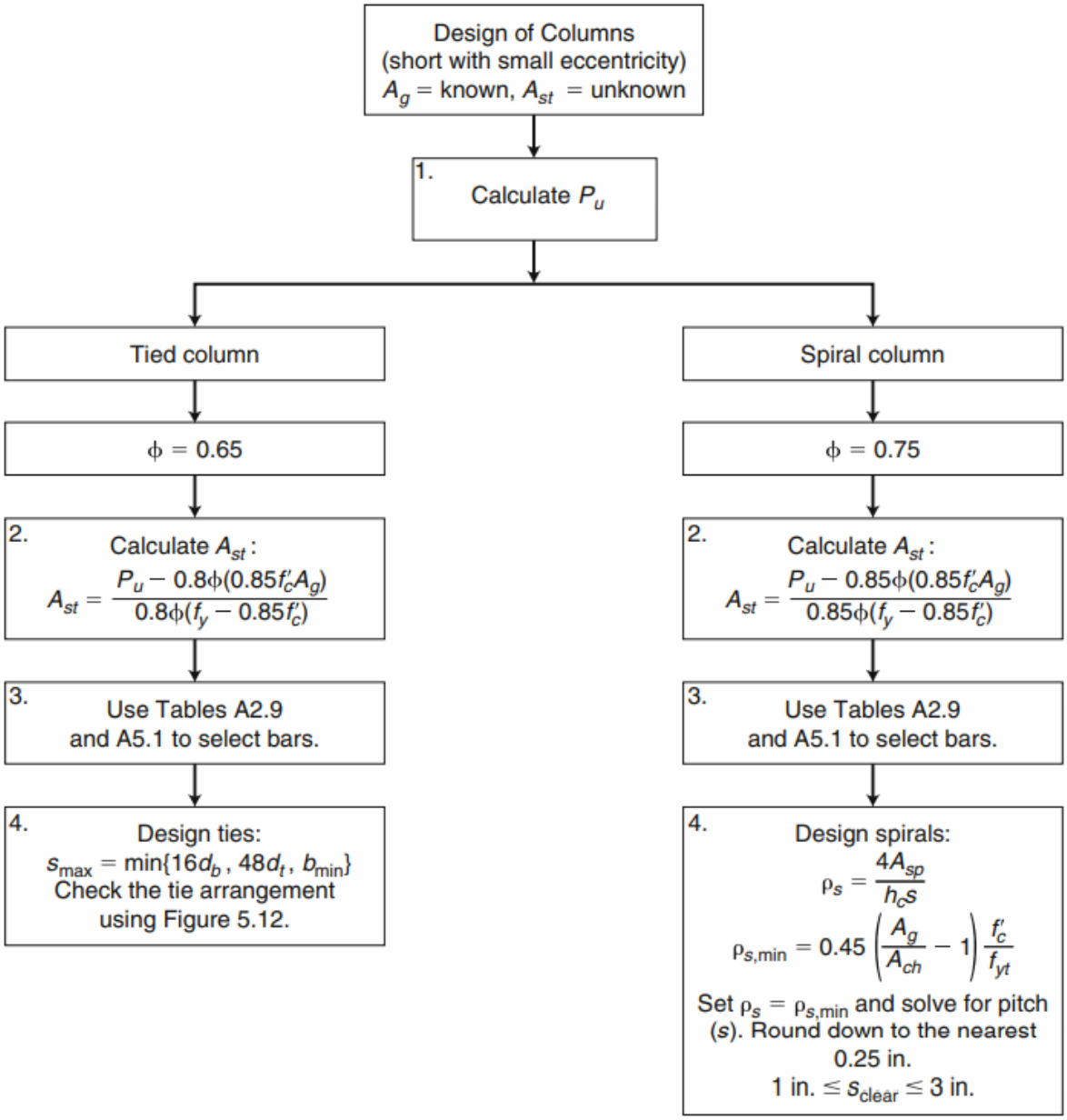
Check the tie arrangement based on Figure below:

$$\text{Clear space} = \frac{16 - 2(1.5) - 2(3/8) - 3(1.0)}{2}$$

$$\text{Clear space} = 4.6 \text{ in.} < 6 \text{ in.} \quad \therefore \quad \text{One tie per set}$$

Figure below shows the cross section of the designed column.




Design of Columns
(short with small eccentricity)
A_g = known, A_{st} = unknown
1.
Calculate P_u
Tied column
$\phi = 0.65$
2.
Calculate A_{st}:
$A_{st} = \frac{P_u - 0.8\phi(0.85f'_cA_g)}{0.8\phi(f_y - 0.85f'_c)}$
3.
Use Tables A2.9
and A5.1 to select bars.
4.
Design ties:
$s_{max} = \min\{16d_b, 48d_t, b_{min}\}$
Check the tie arrangement
using Figure 5.12.
Spiral column
$\phi = 0.75$
2.
Calculate A_{st}:
$A_{st} = \frac{P_u - 0.85\phi(0.85f'_cA_g)}{0.85\phi(f_y - 0.85f'_c)}$
3.
Use Tables A2.9
and A5.1 to select bars.
4.
Design spirals:
$\rho_s = \frac{4A_{sp}}{h_cs}$
$\rho_{s,min} = 0.45\left(\frac{A_g}{A_{ch}} - 1\right)\frac{f'_c}{f_{yt}}$
Set $\rho_s = \rho_{s,min}$ and solve for pitch
(s). Round down to the nearest
0.25 in.
1 in. $\leq s_{clear} \leq$ 3 in.