Columns

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Your hero is spider who?
Axial load column strength

- Axial load capacity of a column
- $f'c$ derives from short term failure of concrete cylinders
- The usable compressive strength for long-term axial load is NOT $f'c$
- Thus
- $P_n = 0.85 f'c (A_g - A_{st}) + f_y A_{st}$

Lateral reinforcement

SPIRAL
Continuous bar not less that 3/8 in. diameter
Clear spacing < 3 in.
Clear spacing > 1 in.

$S <= \min \{16d_b, 48d_t, b_{min}\}$
ACI column design

- To allow for accidental eccentricities not considered in the analysis apply reduction factors
- Axial load capacity of columns with spiral reinforcement
  - $\phi = 0.7$
  - $P_0 = 0.85 \phi [0.85f'_c (A_g-A_{st}) + f_y A_{st}]$
- Axial load capacity tied columns
  - $\phi = 0.65$
  - $P_0 = 0.80 \phi [0.85f'_c (A_g-A_{st}) + f_y A_{st}]$

RC column behavior

- Load-deformation curves

![Diagram of load-deformation curves for different types of spiral columns and their failure modes.](image)
Strain compatibility

- Eccentrically loaded column

Equilibrium

- Sum \( F_y = 0 \)

\[ P_n = 0.85 f_c' ab + A_s f_s' - A_s f_s \]

- Sum \( M_{\text{about centroid}} = 0 \)

\[ M_n = P_n e = 0.85 f_c' ab \left( \frac{h}{2} - \frac{a}{2} \right) + A_s f_s' \left( \frac{h}{2} - d' \right) + A_s f_s \left( d - \frac{h}{2} \right) \]
1. Select values of \( c \), then compute

2. Use strain compatibility to find strains, stresses, and compressive block depth

   a. Strain and stress in tension steel

   \[
   \varepsilon_s = \varepsilon_u \frac{d - c}{c} \quad f_s = \varepsilon_u E_s \frac{d - c}{c} \leq f_y
   \]

   b. Strain and stress in compression steel

   \[
   \varepsilon'_s = \varepsilon_u \frac{c - d'}{c} \quad f'_s = \varepsilon_u E_s \frac{c - d'}{c} \leq f_y
   \]

   c. Depth of equivalent rectangular stress block

   \[
   a = \beta c \leq h
   \]
Interaction diagram

3. Find $P_n$ and $M_n$

\[ P_n = 0.85 f'_c ab + A'_s f'_s - A_s f_s \]

\[ M_n = P_n e = 0.85 f'_c ab \left( \frac{h}{2} - \frac{a}{2} \right) + A'_s f'_s \left( \frac{h}{2} - d' \right) - A_s f_s \left( d - \frac{h}{2} \right) \]

4. Plot them on the interaction diagram

Balanced failure

1. Find neutral axis depth

\[ c_b = d \frac{\varepsilon_u}{\varepsilon_u + \varepsilon_y} \]

2. Find depth of equivalent rectangular stress block

\[ a = \beta_i c_b \]

3. Find $P_n$ and $M_n$ again

4. Plot them
ACI interaction diagrams

Ties: $\phi = 0.65; \alpha = 0.80$
Spirals: $\phi = 0.70; \alpha = 0.85$

Column design charts
Use of column design charts

1. Select trial cross section $b$ and $h$
2. Calculate the ratio $\gamma$
3. Select the proper design chart
4. Compute $K_n = \frac{P_u}{(\phi f'_c A_g)}$ and $R_n = \frac{P_{ue}}{(\phi f'_c A_g h)}$
5. Use $K_n$ and $R_n$ to find $\rho_g$
6. Compute the steel area $A_s = \rho_g bh$

Example

Selection of reinforcement for column of given size. In a three-story structure, an exterior column is to be designed for a service dead load of 222 kips, maximum live load of 333 kips, dead load moment of 162 ft-kips, and live load moment of 232 ft-kips. The minimum live load compatible with the full live load moment is 166 kips, obtained when no live load is placed on the roof but a full live load is placed on the second floor. Architectural considerations require that a rectangular column be used, with dimensions $b = 20$ in. and $h = 25$ in.

(a) Find the required column reinforcement for the condition that the full live load acts.
(b) Check to ensure that the column is adequate for the condition of no live load on the roof.

Material strengths are $f'_c = 4000$ psi and $f_y = 60,000$ psi.

Solution.

(a) The column will be designed initially for full load, then checked for adequacy when live load is partially removed. According to the ACI safety provisions, the column must be designed for a factored load $P_u = 1.2 \times 222 + 1.6 \times 333 = 799$ kips and a factored moment $M_u = 1.2 \times 162 + 1.6 \times 232 = 566$ ft-kips. A column $20 \times 25$ in. is specified, and reinforcement distributed around the column perimeter will be used. Bar cover is estimated to be 2.5 in. from the column face to the steel centerline for each bar. The column parameters (assuming bending about the strong axis) are
Example

\[ K_e = \frac{P_e}{\delta f/A_k} = \frac{799}{0.65 \times 4 \times 500} = 0.615 \]

\[ R_e = \frac{M_e}{\delta f/A_k h} = \frac{566 \times 12}{0.65 \times 4 \times 500 \times 25} = 0.209 \]

With 2.5 in. cover, the parameter \( \gamma = (25 - 5)/25 = 0.80 \). For this column geometry and material strengths, Graph A.7 of Appendix A applies. From this figure, with the calculated values of \( K_e \) and \( R_e \), \( \rho_e = 0.034 \). Thus, the required reinforcement is \( A_e = 0.024 \times 500 = 12.00 \text{ in.}^2 \). Twelve No. 9 (No. 29) bars will be used, one at each corner and two evenly spaced along each face of the column, providing \( A_e = 12.00 \text{ in.}^2 \).

(b) With the roof live load absent, the column will carry a factored load \( P_e = 2 \times 222 = 1.6 \times 166 = 332 \text{ kips} \) and factored moment \( M_e = 566 \text{ ft-kips} \), as before. Thus, the column parameters for this condition are

\[ K_e = \frac{P_e}{\delta f/A_k} = \frac{332}{0.65 \times 4 \times 500} = 0.409 \]

\[ R_e = \frac{M_e}{\delta f/A_k h} = \frac{566 \times 12}{0.65 \times 4 \times 500 \times 25} = 0.209 \]

and \( \gamma = 0.80 \) as before. From Graph A.7 it is found that a reinforcement ratio of \( \rho_e = 0.016 \) is sufficient for this condition, less than that required in part (a), so no modification is required.

Selecting No. 3 (No. 10) ties for trial, the maximum tie spacing must not exceed \( 48 \times 0.375 = 18 \text{ in.} \), \( 16 \times 1.128 = 18.05 \text{ in.} \), or 20 in. Spacing is controlled by the diameter of the ties, and No. 3 (No. 10) ties will be used at 18 in. spacing, in the pattern shown in Fig. 8.2d.