Concrete in Compression

- crushing
- vertical cracking
  - tension
- diagonal cracking
  - shear
- $f'_c$

Columns Reinforcement

- columns require
  - ties or spiral reinforcement to “confine” concrete (#3 bars minimum)
  - minimum amount of longitudinal steel (#5 bars minimum: 4 with ties, 5 with spiral)

Slenderness

- effective length in monolithic with respect to stiffness of joint: $\Psi$ & $k$
- not slender when

\[
\frac{kL_u}{r} < 22
\]
Effective Length (revisited)

- relative rotation

\[
\Psi = \frac{\Sigma EI}{\Sigma EI/l_b}
\]

Column Behavior

Columns with Bending

- eccentric loads can cause moments
- moments can change shape and induce more deflection (P-\(\Delta\))

Column Design

- \(\phi_c = 0.65\) for ties, \(\phi_c = 0.75\) for spirals
- \(P_o\) – no bending

\[
P_o = 0.85 f'_c (A_g - A_{st}) + f_y A_{st}
\]

- \(P_u \leq \phi_c P_n\)
  - ties: \(P_n = 0.8P_o\)
  - spiral: \(P_n = 0.85P_o\)
- nominal axial capacity:
  - presumes steel yields
  - concrete at ultimate stress

\[\psi_n = \frac{M_1}{M_2}\]

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Columns with Bending

- for ultimate strength behavior, ultimate strains can’t be exceeded
  - concrete 0.003
  - steel \( \frac{f_y}{E_s} \)
- \( P \) reduces with \( M \)

![Diagram illustrating typical strength interaction diagram for axial compression and bending moment about one axis. Transition zone is where \( \varepsilon_c = \varepsilon_t \approx 0.003 \).](image)

Design Considerations

- bending at both ends
  - \( P - \Delta \) maximum
- biaxial bending
- walls
  - unit wide columns
  - “deep” beam shear
- detailing
  - shorter development lengths
  - dowels to footings

![Diagram illustrating biaxial interaction surface.](image)

Design Methods

- calculation intensive
  - handbook charts
  - computer programs

![Diagram illustrating design methods.](image)