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 (4 bars minimum)

Slenderness

- effective length in monolithic with respect to stiffness of joint: $\Psi$ & $k$
- not slender when
  
  \[
  \frac{kL_u}{r} \leq 22
  \]
  *not braced*
Effective Length (revisited)

- relative rotation

\[ \Psi = \frac{\sum EI}{l_e} = \frac{\sum EI}{l_b} \]

Column Behavior

Column Design

- \( \phi_c = 0.65 \) for ties, \( \phi_c = 0.70 \) 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: \( P_n = 0.8 P_o \)
  - spiral: \( P_n = 0.85 P_o \)
- nominal axial capacity:
  - presumes steel yields
  - concrete at ultimate stress

Columns with Bending

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

![Interaction diagram for axial compression and bending moment about one axis. Transition zone is where $\varepsilon_c = \varepsilon_s = 0.003$.](image1)

Design Methods

• calculation intensive
  – handbook charts
  – computer programs

![Interaction diagram for axial compression and bending moment about one axis. Transition zone is where $\varepsilon_c = \varepsilon_s = 0.003$.](image2)

Columns with Bending

• need to consider combined stresses
  • linear strain
  • steel stress at or below $f_y$
  • plot interaction diagram

![Interaction diagram for axial compression and bending moment about one axis. Transition zone is where $\varepsilon_c = \varepsilon_s = 0.003$.](image3)

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

![Interaction diagram for axial compression and bending moment about one axis. Transition zone is where $\varepsilon_c = \varepsilon_s = 0.003$.](image4)