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

\[
\Psi = \frac{\sum EI}{l_b} - \frac{\sum EI}{l_c}
\]

**Column Behavior**

**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: \( P_n = 0.8 P_o \)
  
  - 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 $M$

Design Methods

- calculation intensive
  - handbook charts
  - computer programs

Columns with Bending

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

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