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
  $$\frac{kL_u}{r} < 22$$
  *not braced
Effective Length (revisited)

- relative rotation

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

Column Behavior

• 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
  \[ C_t = 0.85 f'_c (A_g - A_{st}) \]

Columns with Bending

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

Figure 13.3.2 Sprayed reinforced column behavior. (Courtesy of Portland Cement Association.)

Figure 13.3.3 Tied column behavior. (Courtesy of Portland Cement Association.)
**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