Concrete construction: columns & frames
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

\[ \Psi = \frac{\sum EI}{l_c} / \frac{\sum EI}{l_b} \]
Column Behavior

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

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

$C_1 = 0.85 f'_c (A_g - A_{st})$

$C_2 = f_y A_1$

$C_3 = f_y A_2$

$P_0$ is located colinearly with the resultant of $C_1$, $C_2$, and $C_3$ at the plastic centroid.
Columns with Bending

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

**Figure 10.6** Considerations for development of bending in steel columns; (a) bending induced by eccentric load, (b) bending transferred to column in a rigid frame, and (c) combined loading condition, separately producing axial compression and bending.
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 \( M \)
Columns with Bending

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

Figure 5-3 Transition Stages on Interaction Diagram
Design Methods

- **calculation intensive**
  - handbook charts
  - computer programs
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