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

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

- relative rotation

\[ \Psi = \frac{\sum EI}{\sum EI} \frac{l_c}{l_b} \]
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: \( P_n = 0.8 P_o \)
  – 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 \((P-\Delta)\)

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 \( M \)

Figure 13.6.1 Typical strength interaction diagram for axial compression and bending moment about one axis. Transition zone is where \( \epsilon_{ij} \leq \epsilon_t \leq 0.005 \).
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

Figure 5-17 12 × 12 in. Column Design Chart
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