concrete construction: columns & frames

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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

$$\frac{kL}{r} < 22$$
Effective Length (revisited)

- relative rotation

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

\[ \frac{1}{\sum EI/\ell_b} \]
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
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 \( \epsilon_y \leq \epsilon_f \leq 0.005 \).
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