Concrete construction: columns & frames
Concrete in Compression

- crushing
- vertical cracking
  - tension
- diagonal cracking
  - shear
- $f'_c$

http://www.bam.de
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

\[ \Psi = \frac{\sum EI / l_c}{\sum EI / l_b} \]
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 $M$

![Diagram](image_url)

**Figure 13.6.1** Typical strength interaction diagram for axial compression and bending moment about one axis. Transition zone is where $\epsilon_c \leq \epsilon_t \leq 0.005$. 
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
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