Concrete in Compression

- crushing
- vertical cracking
  - tension
- diagonal cracking
  - shear
- $f_c'$

Slenderness

- effective length in monolithic with respect to stiffness of joint: $\Psi$ & $k$
- not slender when
  \[
  \frac{kL_u}{r} \leq 22
  \]
  *not braced*

Columns Reinforcement

- columns require
  - ties or spiral reinforcement to “confine” concrete (#3 bars minimum)
  - minimum amount of longitudinal steel (4 bars minimum)
Effective Length (revisited)

- relative rotation

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

Column Design

- \( \phi_c = 0.65 \) for ties, \( \phi_c = 0.70 \) 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
  \( (P-\Delta) \)
Columns with Bending

- for ultimate strength behavior, ultimate strains can't be exceeded
  - concrete \( \varepsilon_{u,\text{concrete}} = 0.003 \)
  - steel \( \varepsilon_{u,\text{steel}} = \frac{f_y}{E_y} \)

- \( P \) reduces with \( M \)

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

Columns with Bending

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