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

$$\frac{kL_u}{r} < 22$$ *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

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

**Column Behavior**

**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
  \( (P-\Delta) \)
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 \( M \)

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