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

• relative rotation

$$\Psi = \frac{\sum EI}{l_c - \sum EI/l_b}$$

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 $0.003$
  - 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