Elements of Architectural Structures: Form, Behavior, and Design
ARCH 614
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Lecture twenty five

Concrete construction: columns & frames
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

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