

**ELEMENTS OF ARCHITECTURAL STRUCTURES:**

**FORM, BEHAVIOR, AND DESIGN**

**ARCH 614**

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**SPRING 2013**

*lecture*  
**twenty five**



Brenton Hardee

***concrete construction:  
columns & frames***

# *Concrete in Compression*

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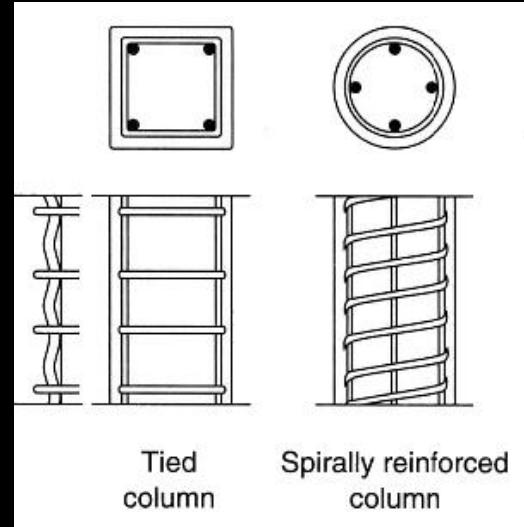
- *crushing*
- *vertical cracking*
  - *tension*
- *diagonal cracking*
  - *shear*
- $f'_c$



<http://www.bam.de>

# *Columns Reinforcement*

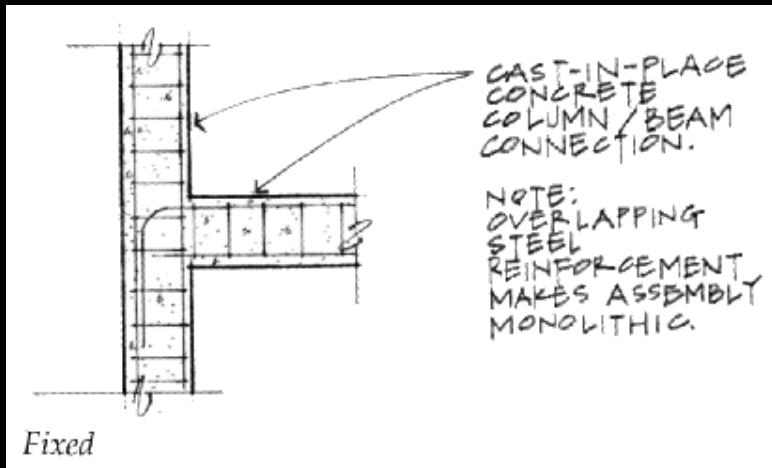
- *columns require*
  - *ties or spiral reinforcement* to “confine” concrete (#3 bars minimum)
  - *minimum amount of longitudinal steel* (#5 bars minimum: 4 with ties, 5 with spiral)



# Slenderness

- *effective length in monolithic with respect to stiffness of joint:  $\Psi$  &  $k$*
- *not slender when*

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

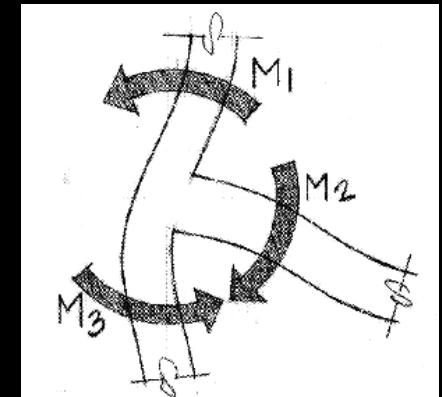
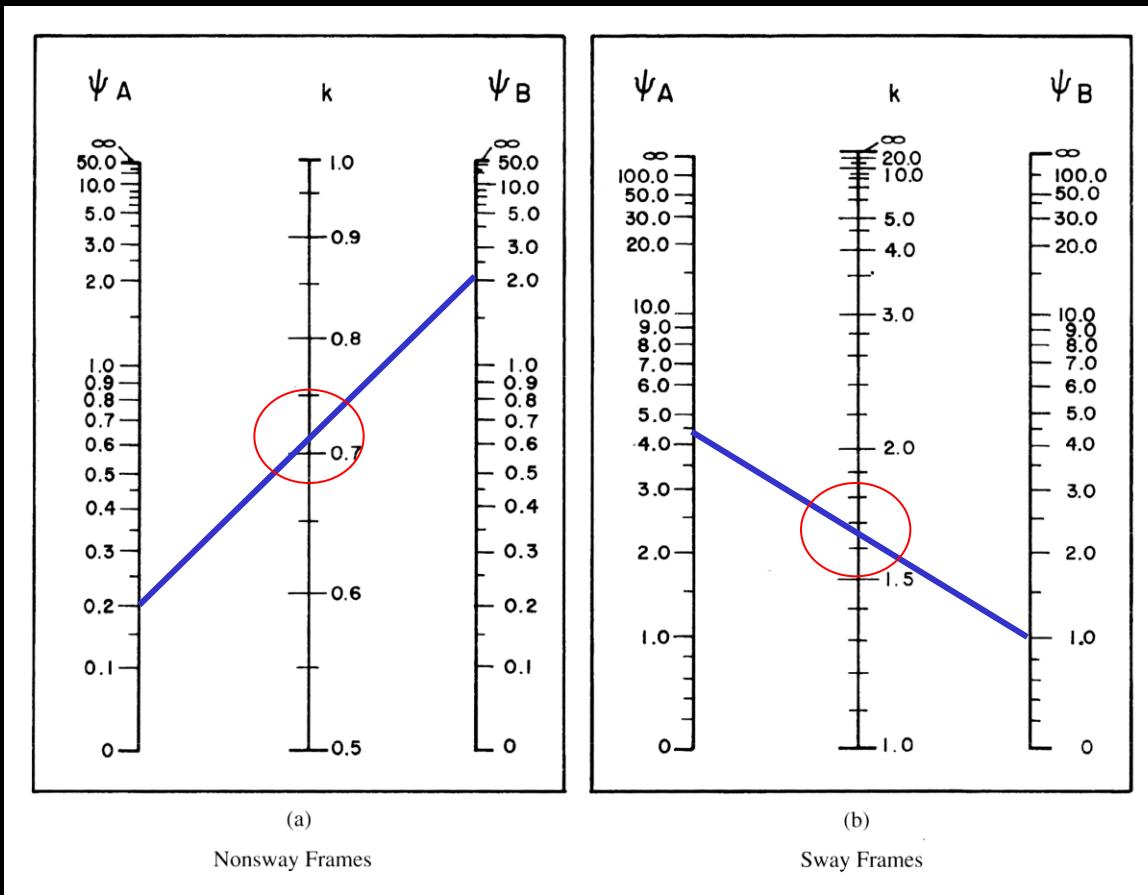


8 bars	All. hook 90° (typ.)	Preassembled Cages	All. hooks (typ.)
	Column ≤ 18 in.	Preassembled Cages	Field Erection
12 bars			20 in., 22 in., and 24 in. columns
	Lap splice ≥ greater of $\frac{1.9d}{12''}$	Field Erection	All 12 bar arrangements
16 bars		Preassembled Cages	Field Erection
		All 16 bar arrangements	

Figure 5-7 Column Tie Details

# *Effective Length (revisited)*

- *relative rotation*

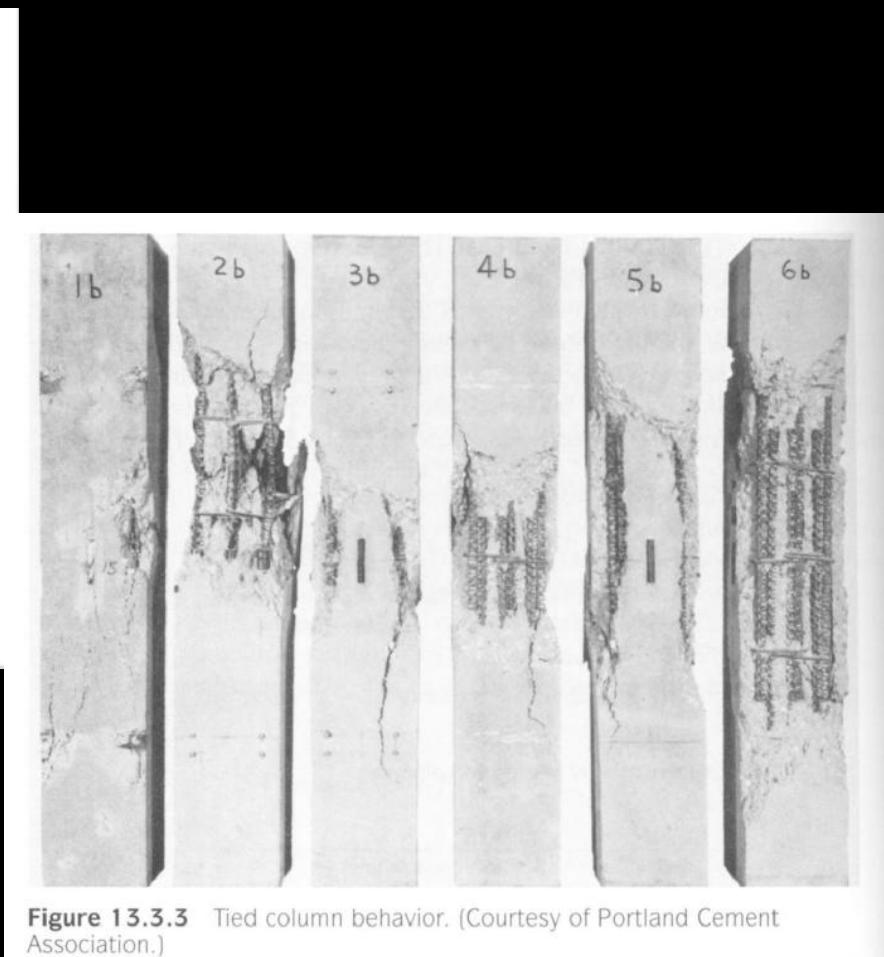


$$\Psi = \frac{\sum EI/l_c}{\sum EI/l_b}$$

# *Column Behavior*



**Figure 13.3.2** Spirally reinforced column behavior. (Courtesy of Portland Cement Association.)



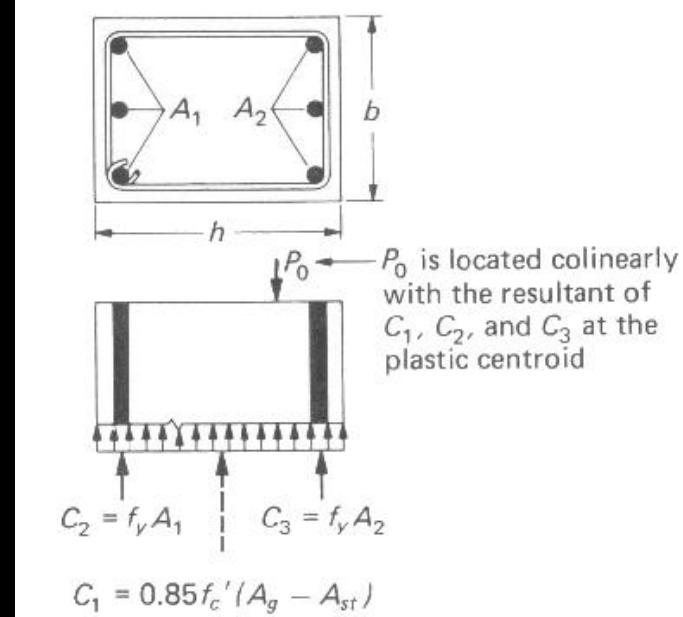
**Figure 13.3.3** Tied column behavior. (Courtesy of Portland Cement Association.)

# Column Design

- $\phi_c = 0.65$  for ties,  $\phi_c = 0.75$  for spirals
- $P_o$  – no bending

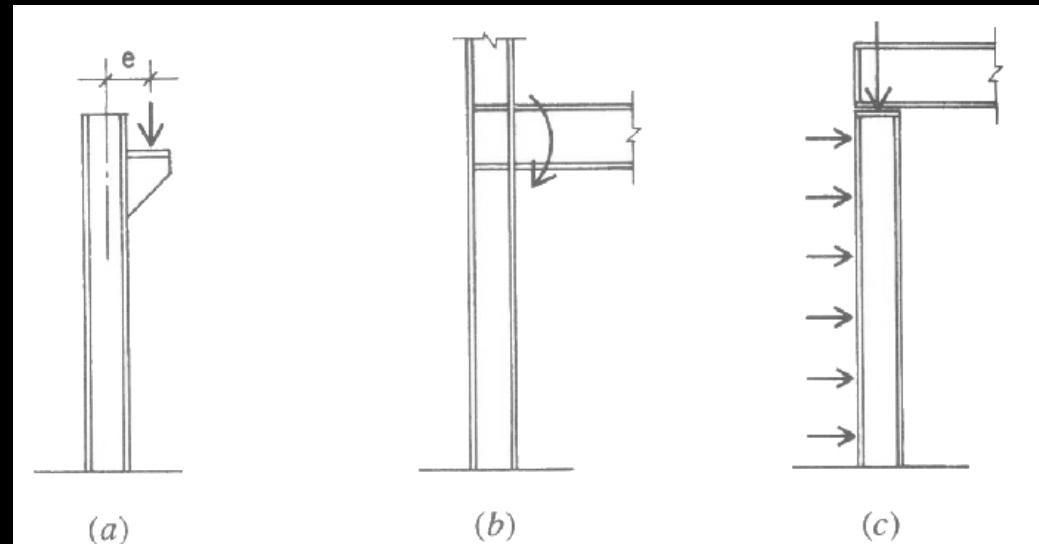
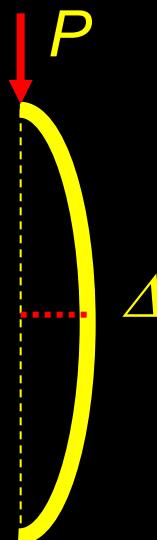
$$P_o = 0.85 f'_c (A_g - A_{st}) + f_y A_{st}$$

- $P_u \leq \phi_c P_n$ 
  - ties:  $P_n = 0.8P_o$
  - spiral:  $P_n = 0.85P_o$
- nominal axial capacity:
  - presumes steel yields
  - concrete at ultimate stress



# Columns with Bending

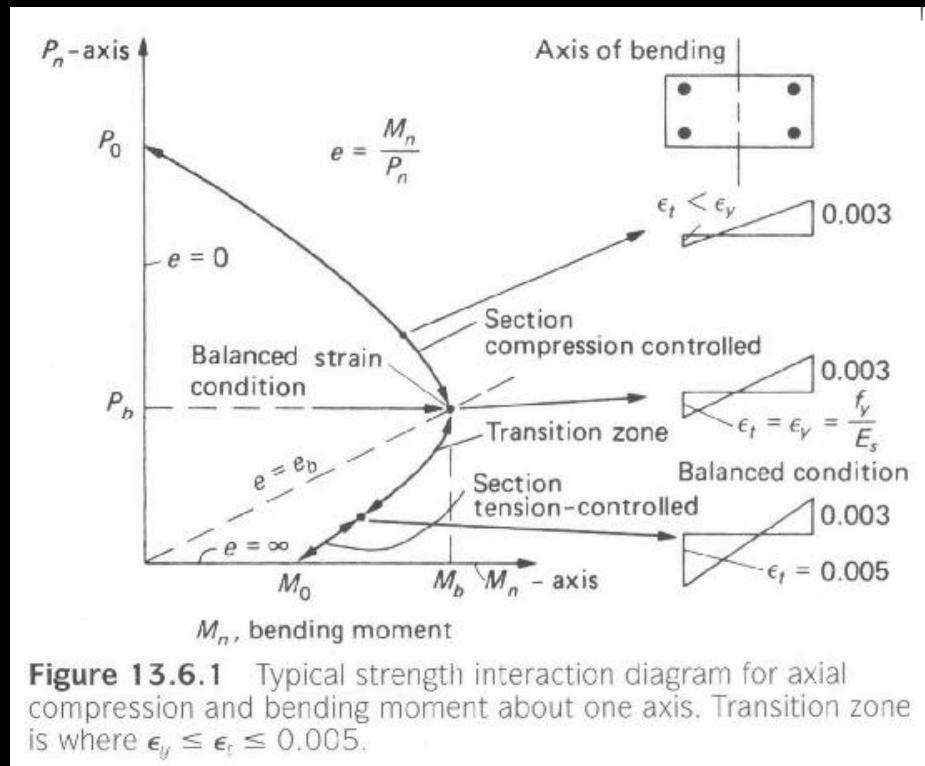
- eccentric loads can cause moments
- moments can change shape and induce more deflection ( $P-\Delta$ )



**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  $M$



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

# *Columns with Bending*

- *need to consider combined stresses*
- *linear strain*
- *steel stress at or below  $f_y$*
- *plot interaction diagram*

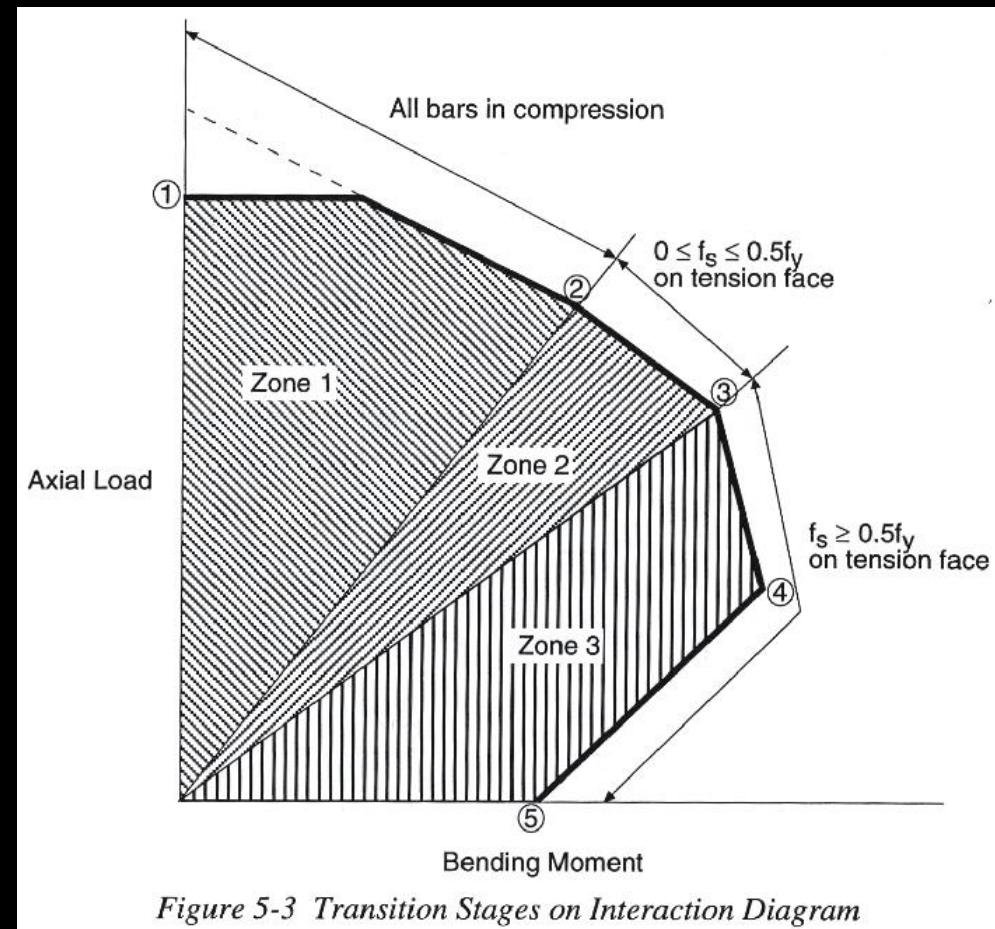


Figure 5-3 Transition Stages on Interaction Diagram

# Design Methods

- *calculation intensive*
  - *handbook charts*
  - *computer programs*

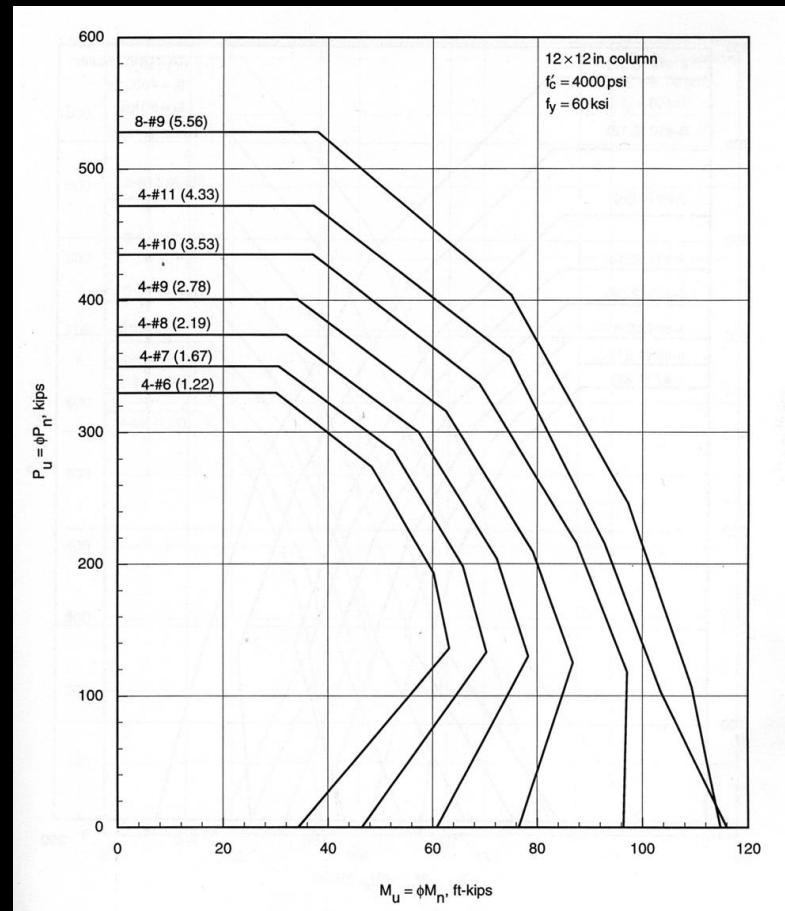
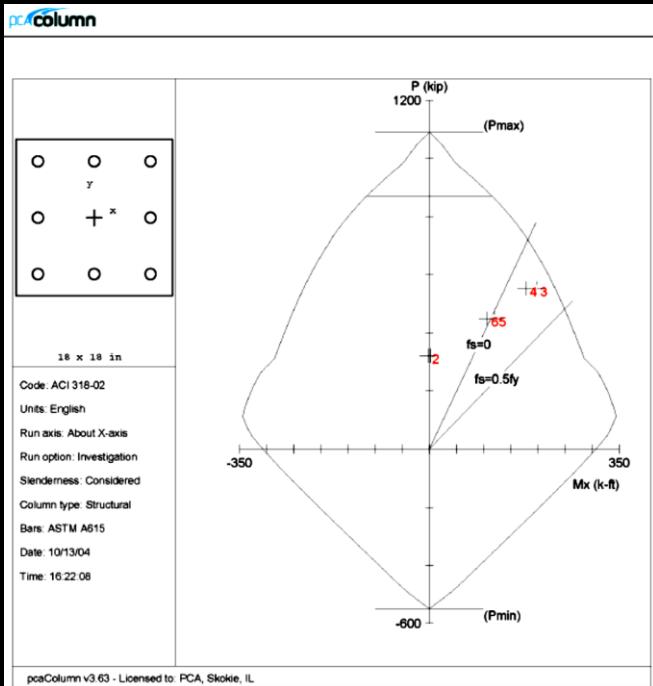


Figure 5-17 12 × 12 in. Column Design Chart

# *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

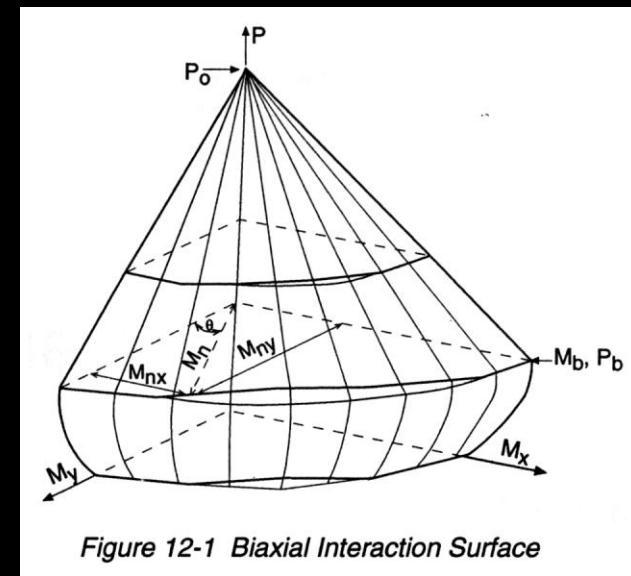
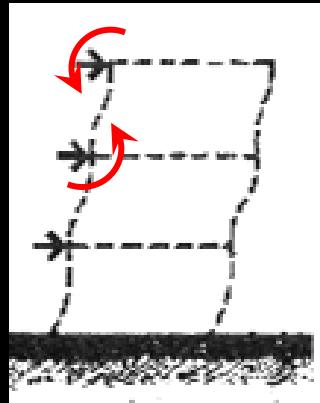


Figure 12-1 Biaxial Interaction Surface

