ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 331

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FALL 2013

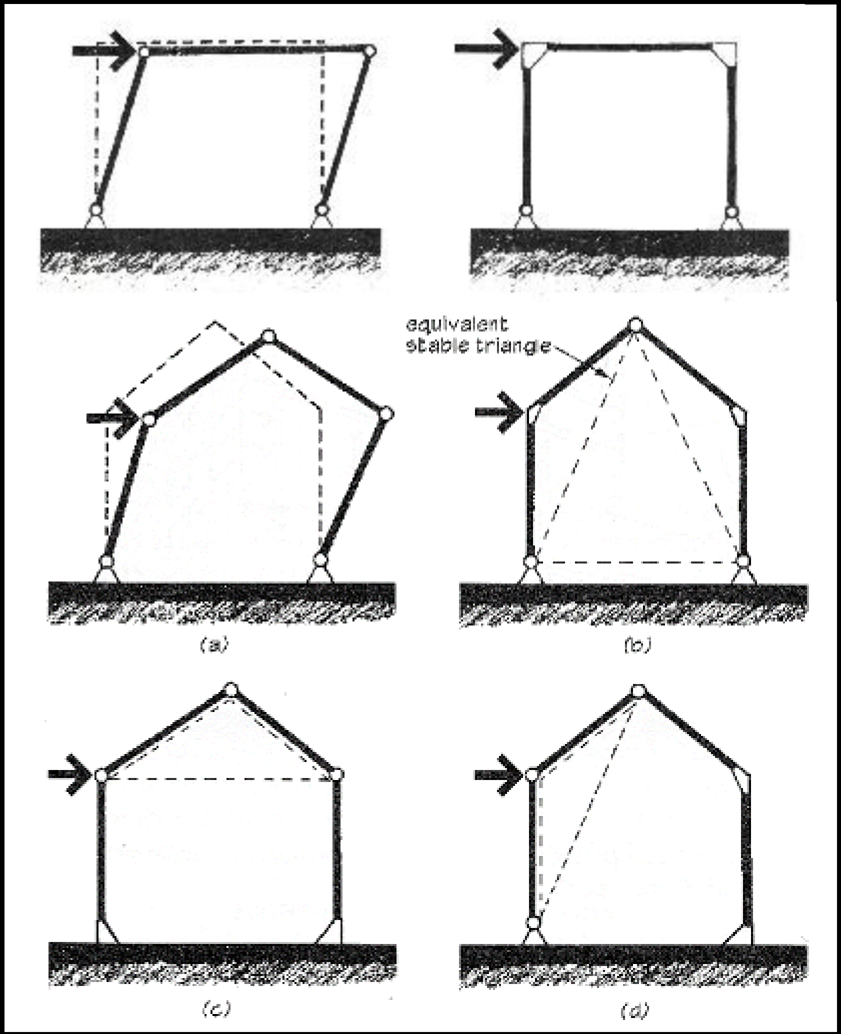
lecture
twelve

rigid frames: compression & buckling

http:// nisee.berkeley.edu/godden

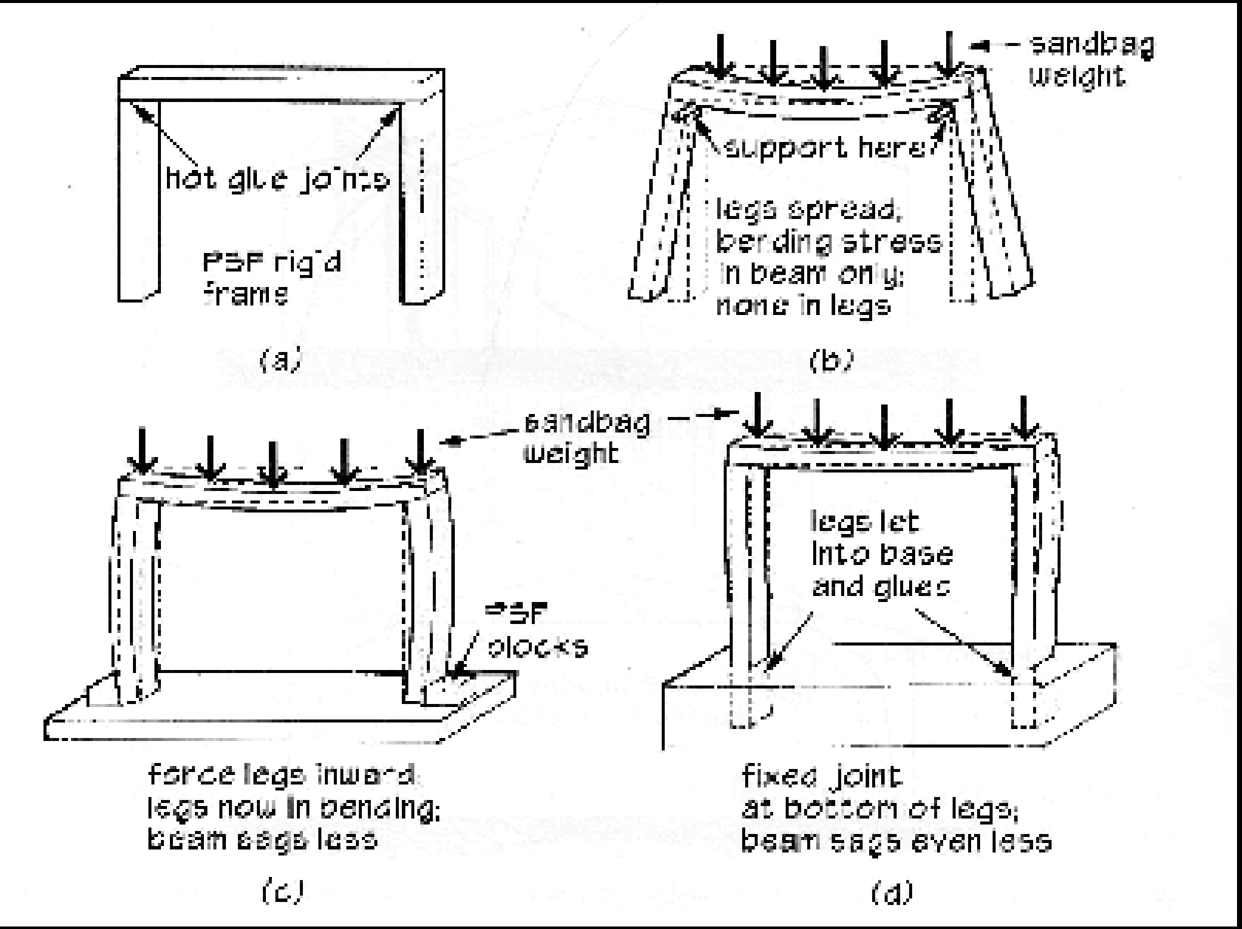
Rigid Frames

- *rigid frames have no pins*
- *frame is all one body*
- *joints transfer moments and shear*
- *typically statically indeterminate*
- *types*
  - *portal*
  - *gable*



Rigid Frames

- *behavior*



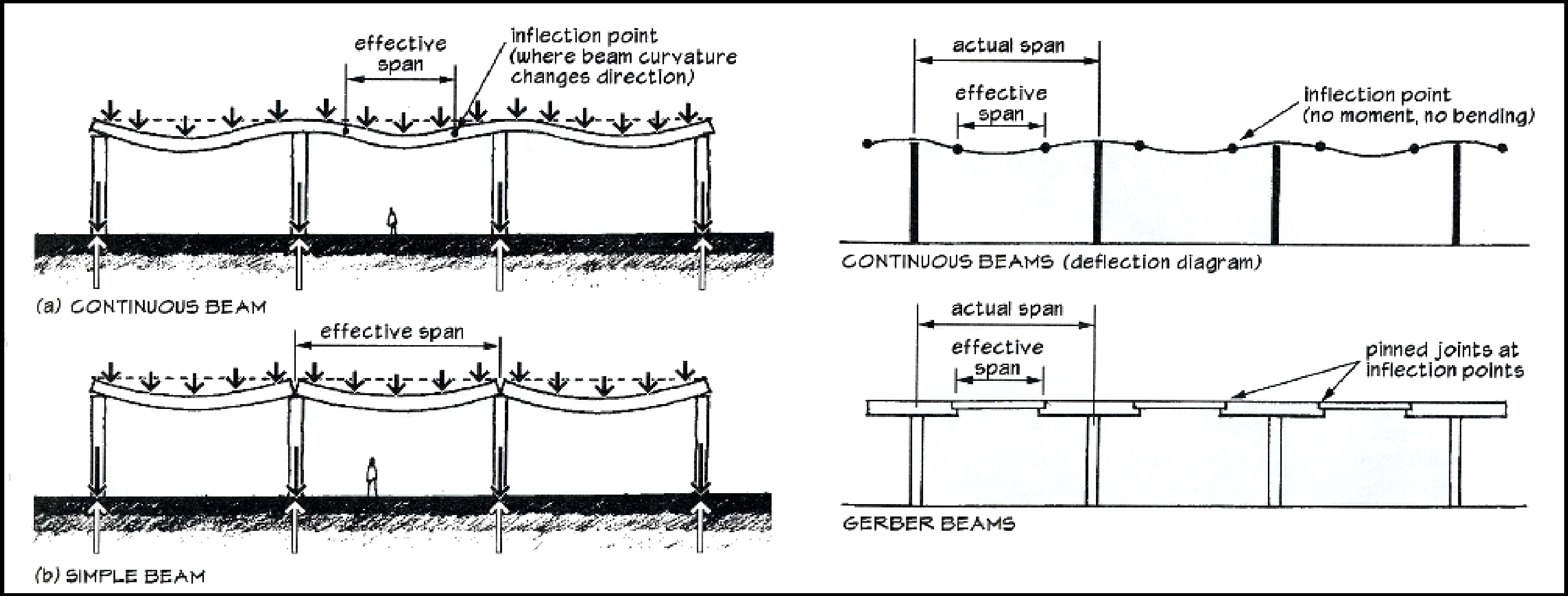
Rigid Frames

– *moments get redistributed*

– *deflections are smaller*

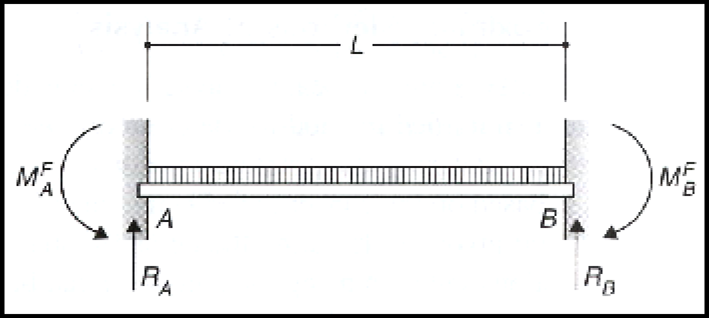
– *effective column lengths are shorter*

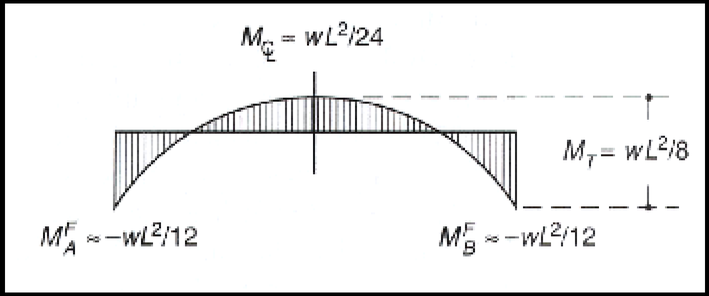
– *very sensitive to settling*



Moment Redistribution

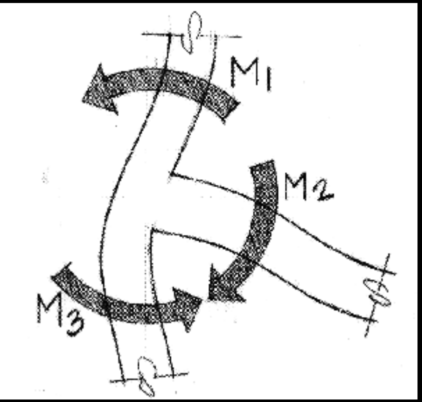
- *continuous slabs & beams with uniform loading*
  - *joints similar to fixed ends, but can rotate*
- *change in moment to center =* $\dfrac{wL^2}{8}$
  - *M_{max} for simply supported beam*





Rigid Frames

- *resists lateral loadings*
- *shape depends on stiffness of beams and columns*
- *90° maintained*



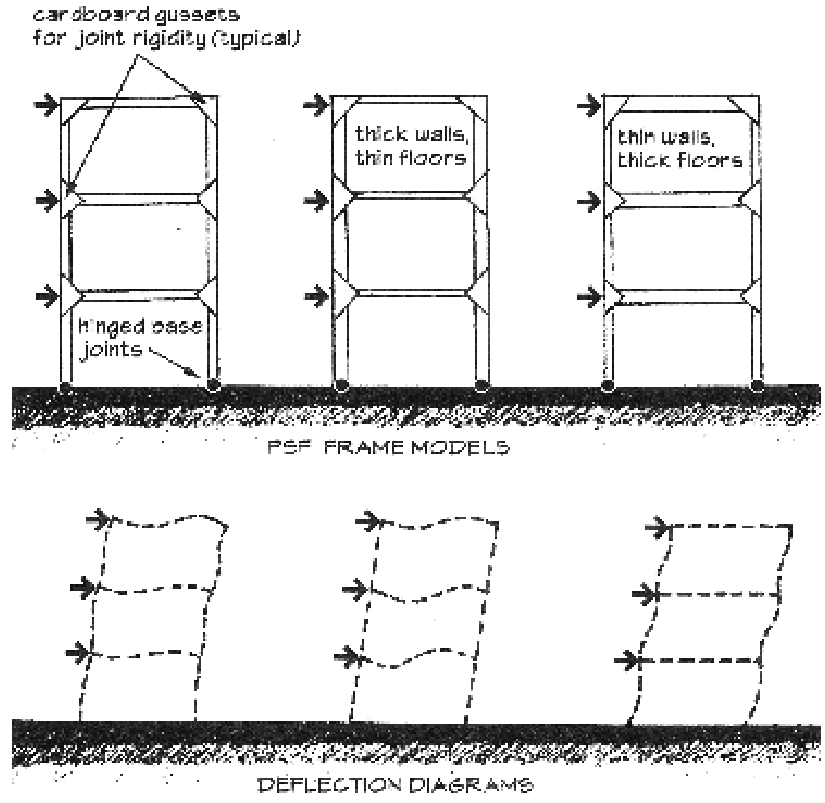
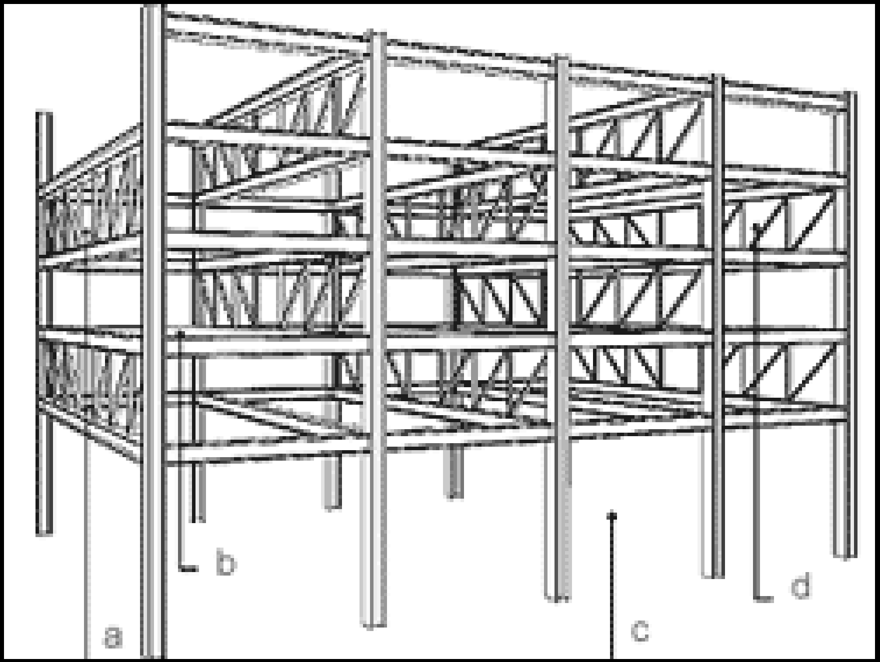


Figure 9.19: Model demonstration of the effects of varying the stiffness of beams and columns when a building frame is subjected to lateral loads.

Rigid Frames

- staggered truss
  - rigidity
  - clear stories



Rigid Frames

- connections
  - steel
  - concrete

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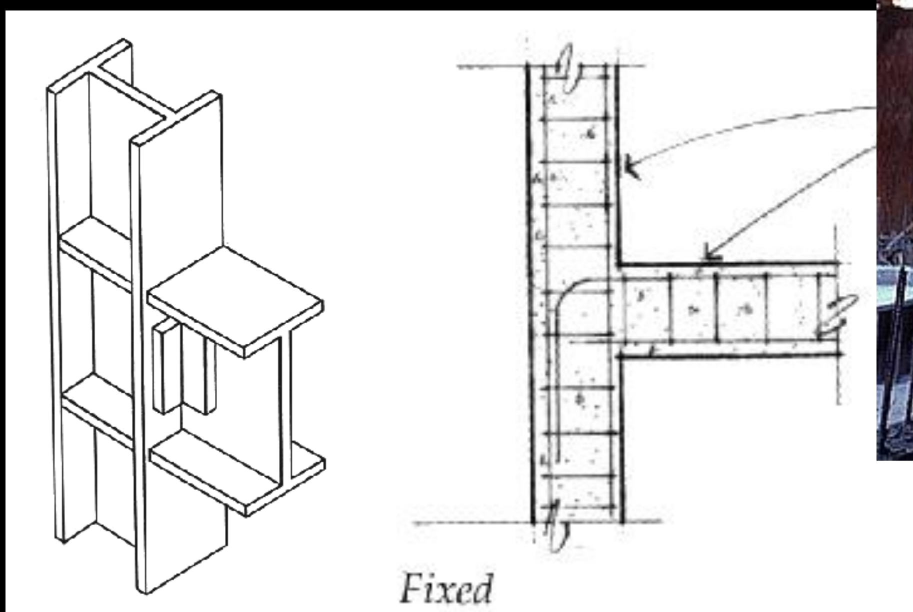

Braced Frames

- *pin connections*
- *bracing to prevent lateral movements*

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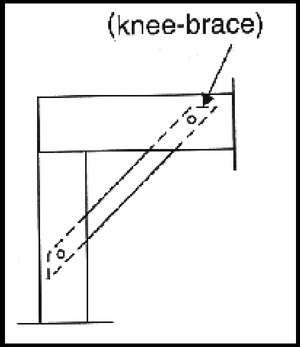
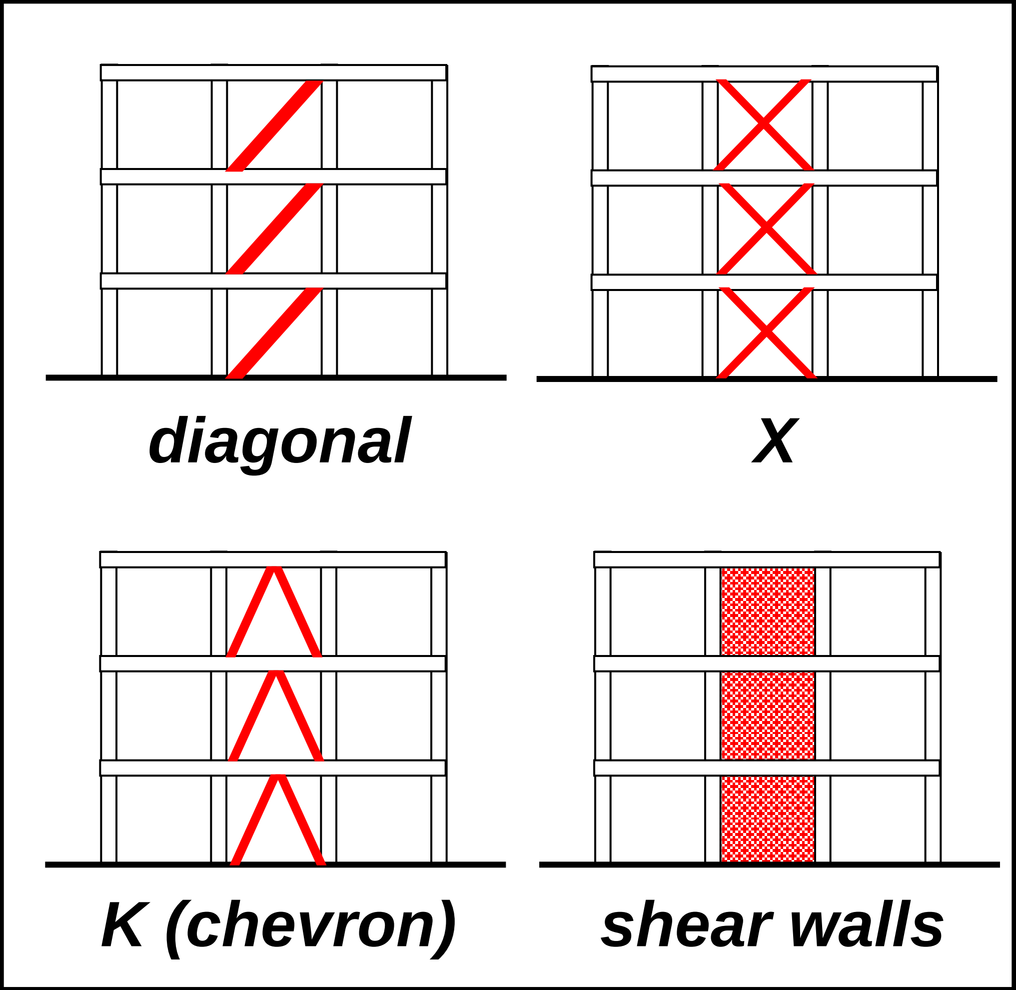
Braced Frames

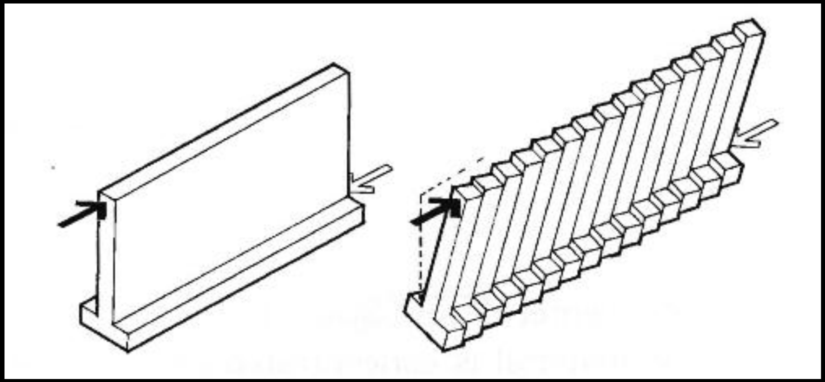
- types of bracing
  - knee-bracing
  - diagonal
  - X
  - K or chevron
  - shear walls

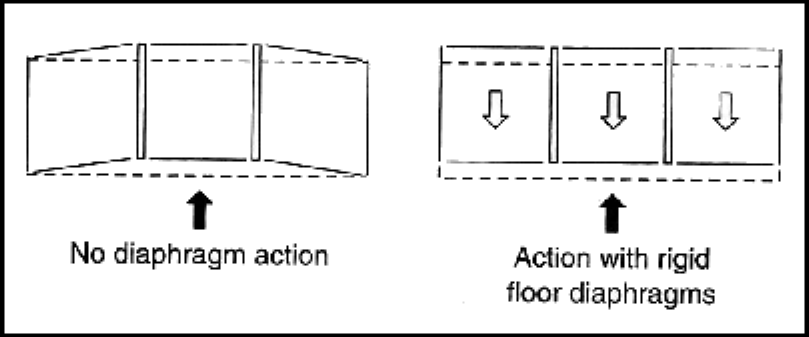


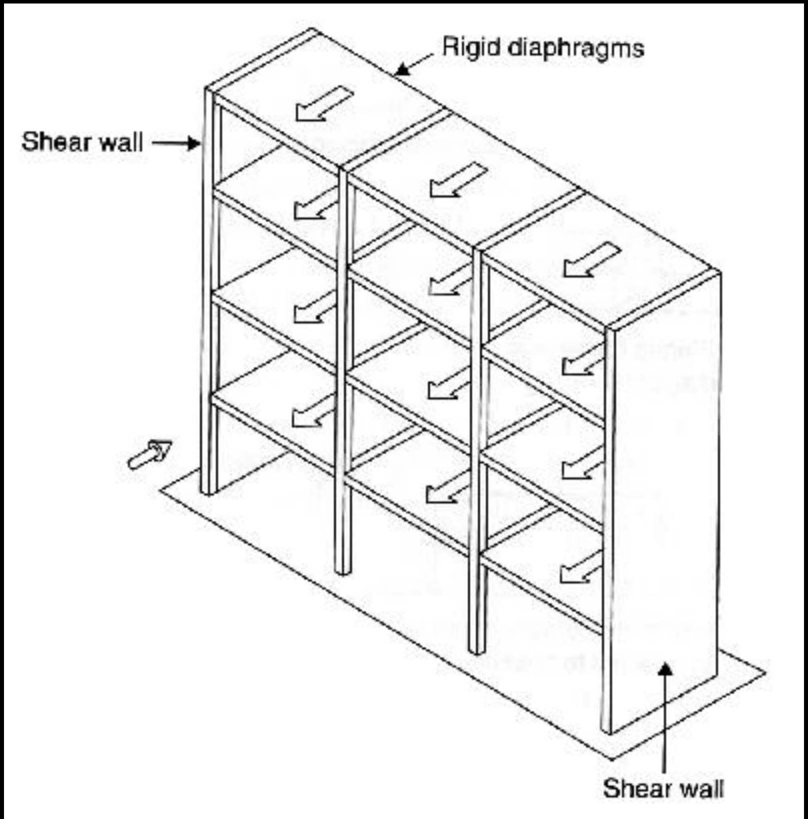


Shear Walls

- *resist lateral load in plane with wall*

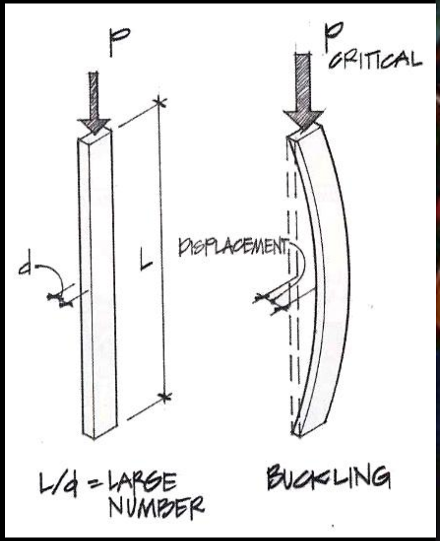






Compression Members

- *designed for strength & stresses*
- *designed for serviceability & deflection*
- *need to design for <u>stability</u>*
  - *ability to support a specified load without sudden or unacceptable deformations*



Column Buckling

- axially loaded columns
- long & slender
  - unstable equilibrium = buckling
  - sudden and not good

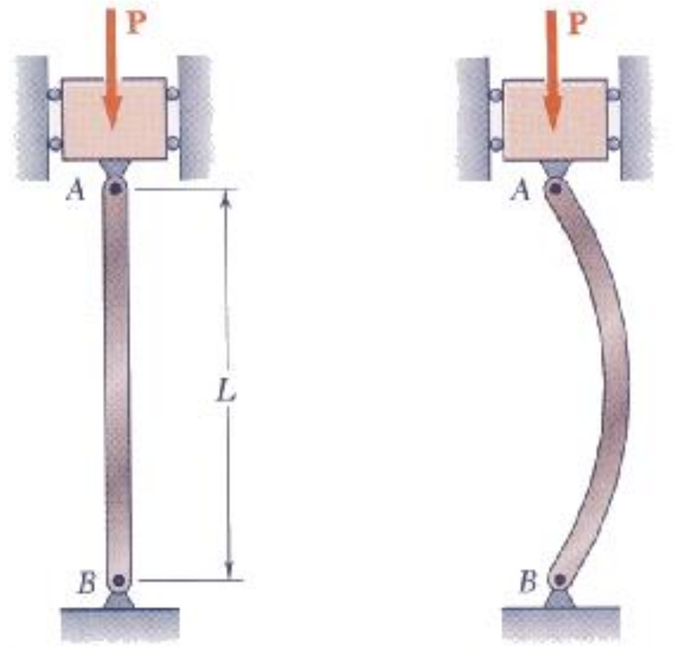
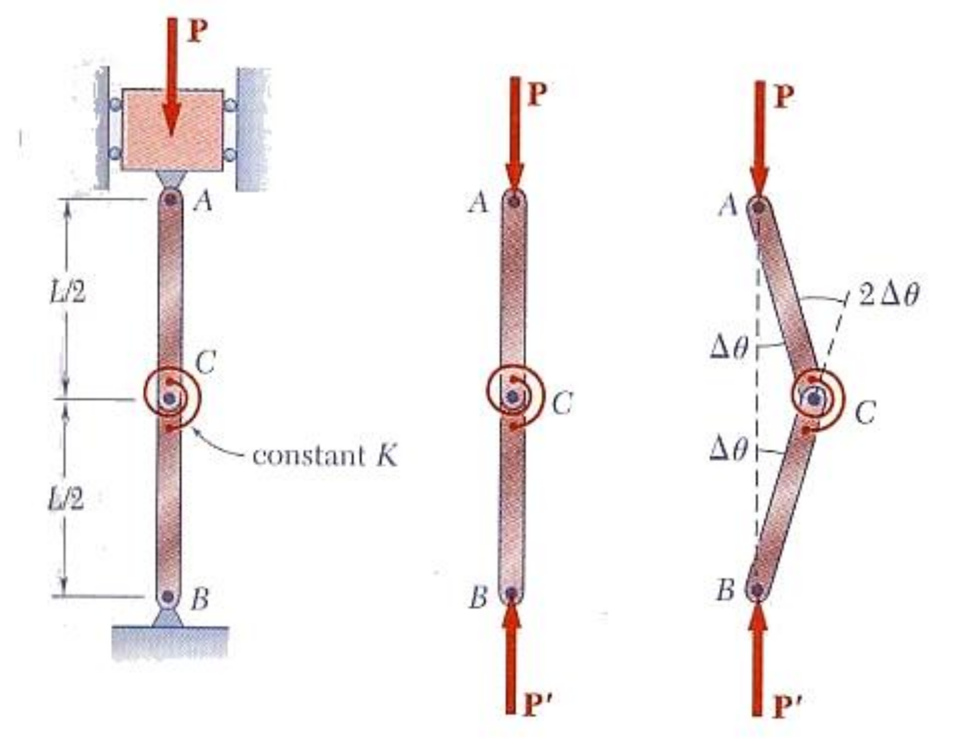


Fig. 10.1 Fig. 10.2

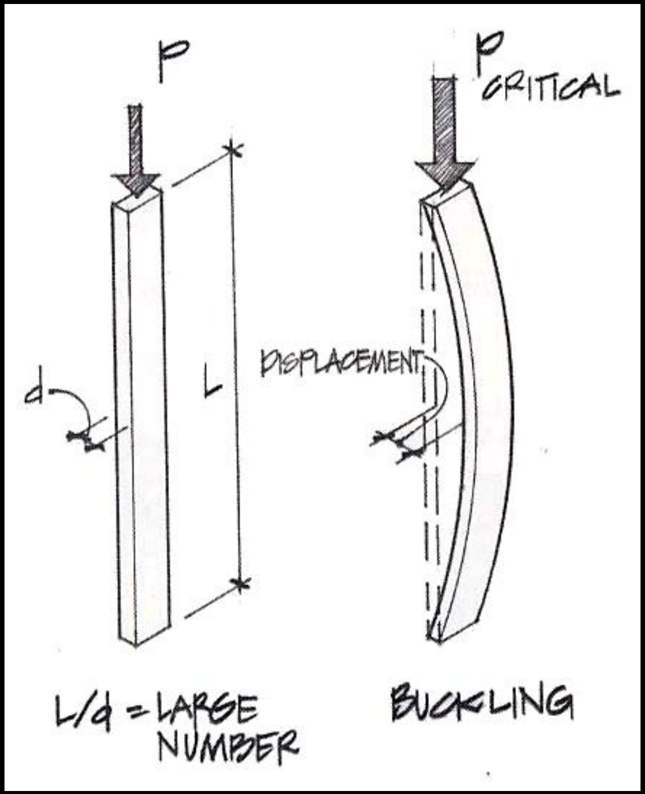
Modeling

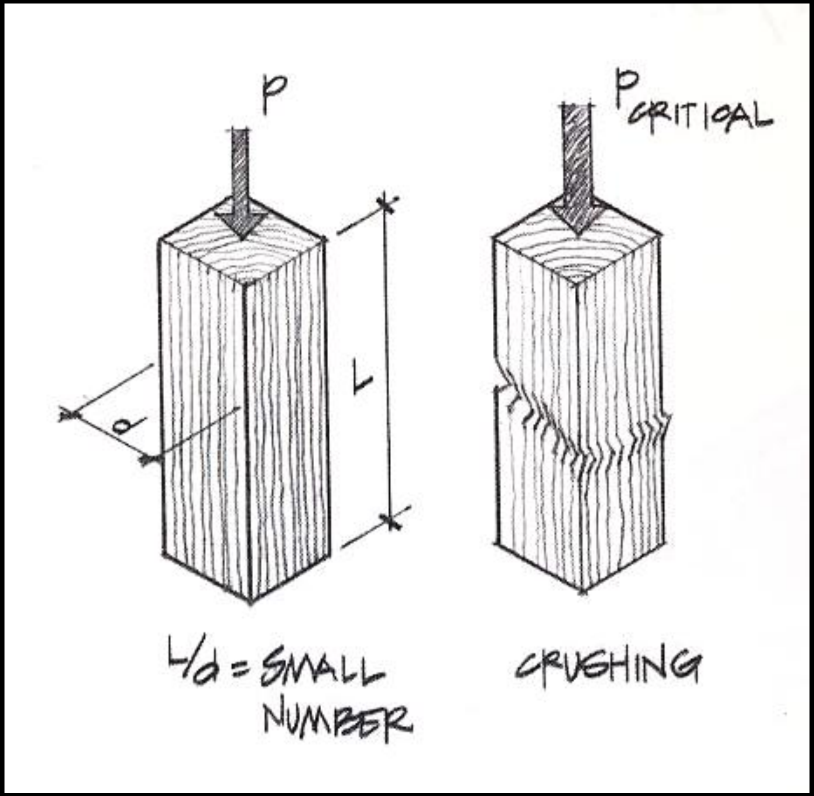
- can be modeled with a spring at mid-height
- when moment from deflection exceeds the spring capacity ... “boing”
- critical load P



Effect of Length

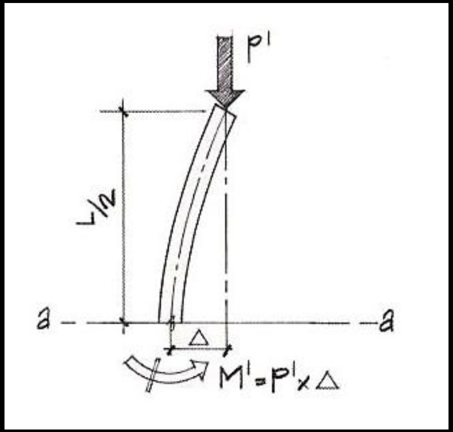
- *long & slender*
- *short & stubby*





Buckling Load

- *related to deflected shape (PΔ)*
- *shape of sine wave*
- *Euler's Formula*
- *smallest I governs*



$$P_{critical} = \frac{\pi^2 EI}{(L)^2}$$

Figure 9.3 Leonhard Euler (1707–1783).

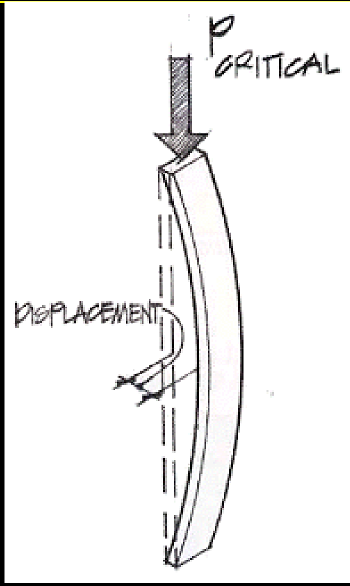
Critical Stress

- short columns

$$f_{critical} = \frac{P_{actual}}{A} < F_a$$

- slenderness ratio = L_e/r (L/d)

- radius of gyration = $r = \sqrt{\frac{I}{A}}$



weak axis

$$f_{critical} = \frac{P_{critical}}{A} = \frac{\pi^2 E A r^2}{A(L_e)^2} = \frac{\pi^2 E}{\left(\frac{L_e}{r}\right)^2} \qquad P_{critical} = \frac{\pi^2 E A}{\left(\frac{L_e}{r}\right)^2}$$

Critical Stresses

- *when a column gets stubby, F_y will limit the load*
- *real world has loads with eccentricity*
- *C_c for steel and allowable stress*

$$L_e/r > C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$$

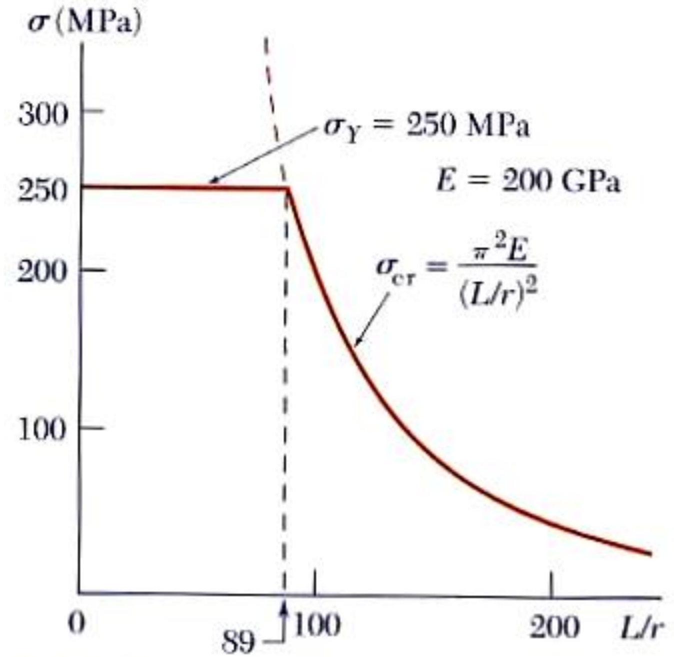
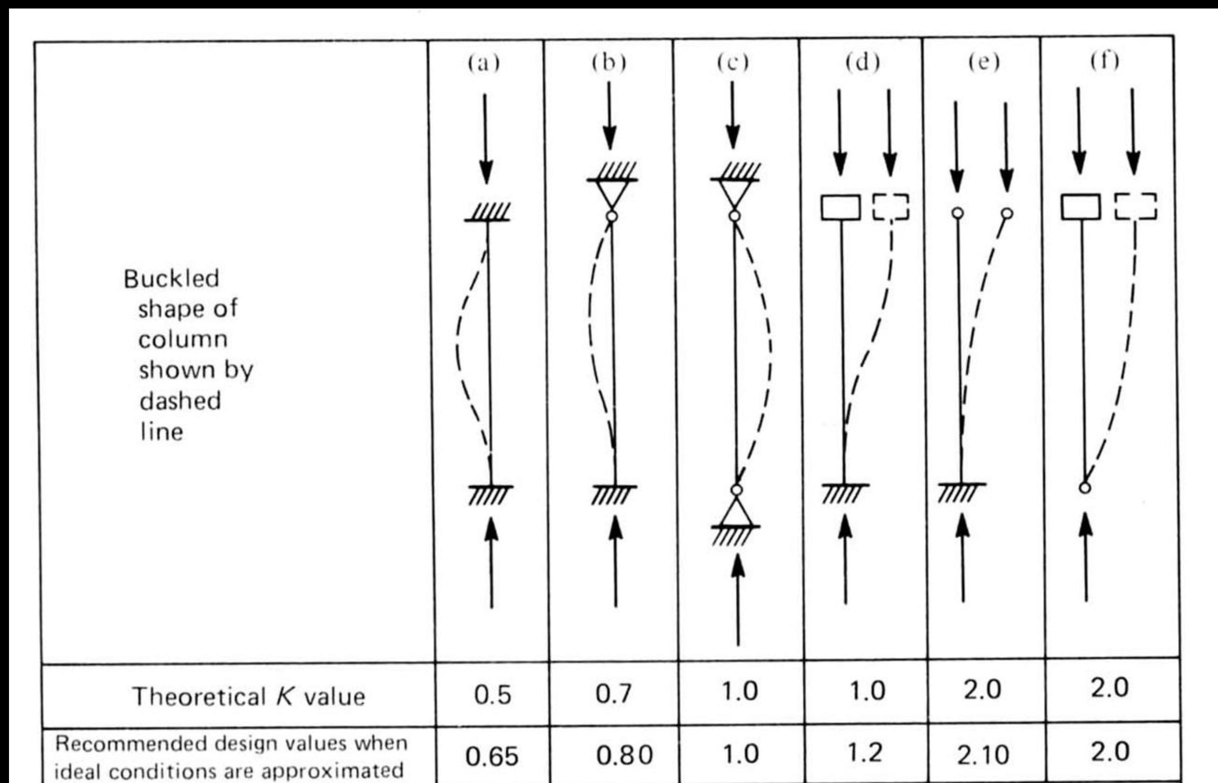


Fig. 10.9

Effective Length

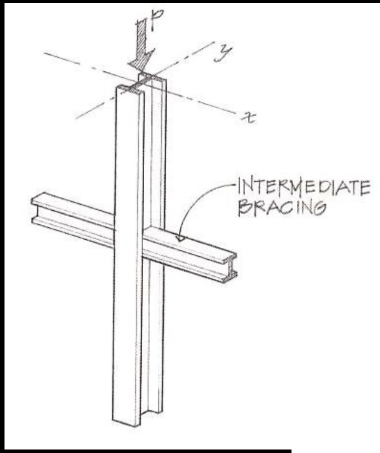
- *end conditions affect shape*
- *effective length factor, K* $L_e = K \cdot L$

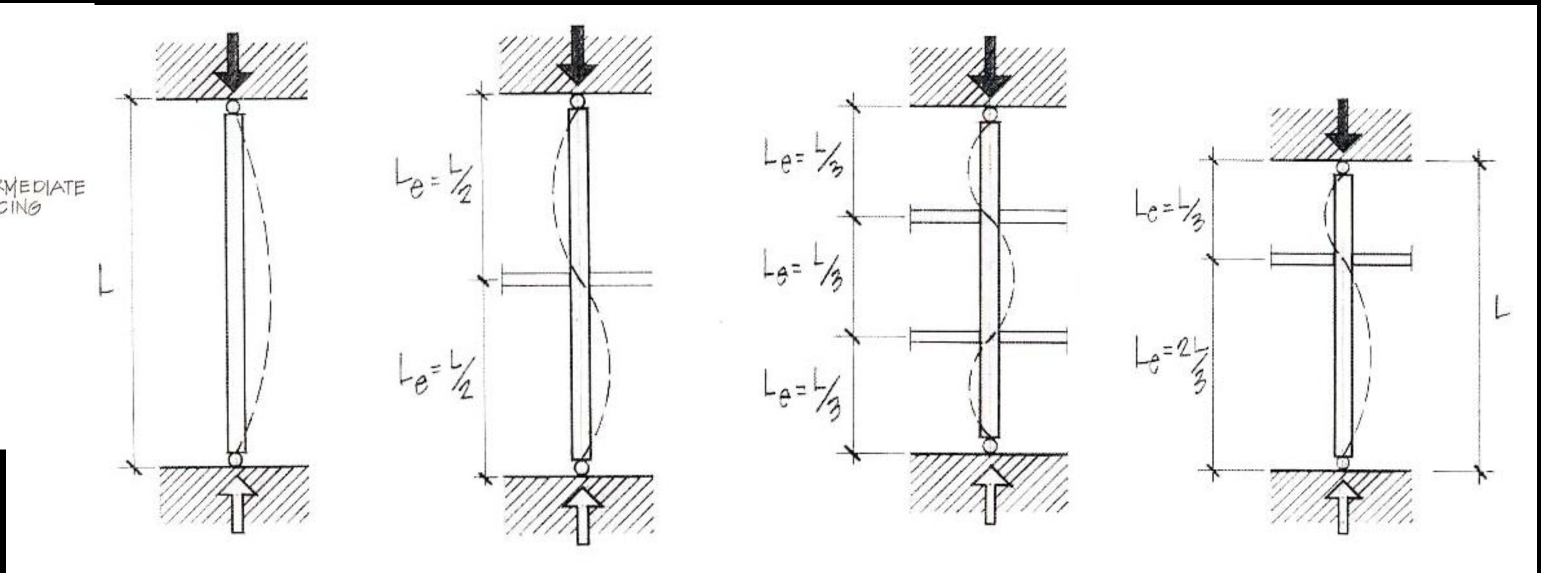


	(a)	(b)	(c)	(d)	(e)	(f)
Buckled shape of column shown by dashed line						
Theoretical *K* value	0.5	0.7	1.0	1.0	2.0	2.0
Recommended design values when ideal conditions are approximated	0.65	0.80	1.0	1.2	2.10	2.0

Bracing

- *bracing affects shape of buckle in one direction*
- *both should be checked!*

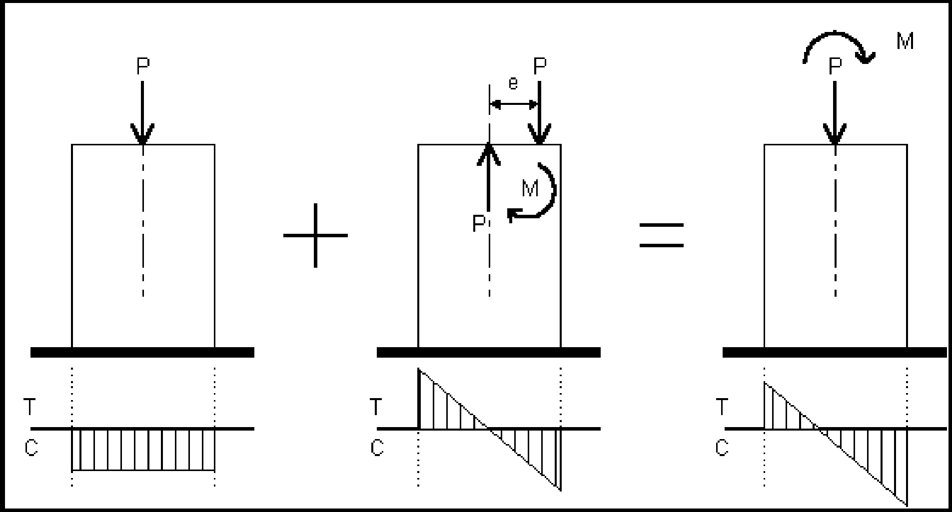


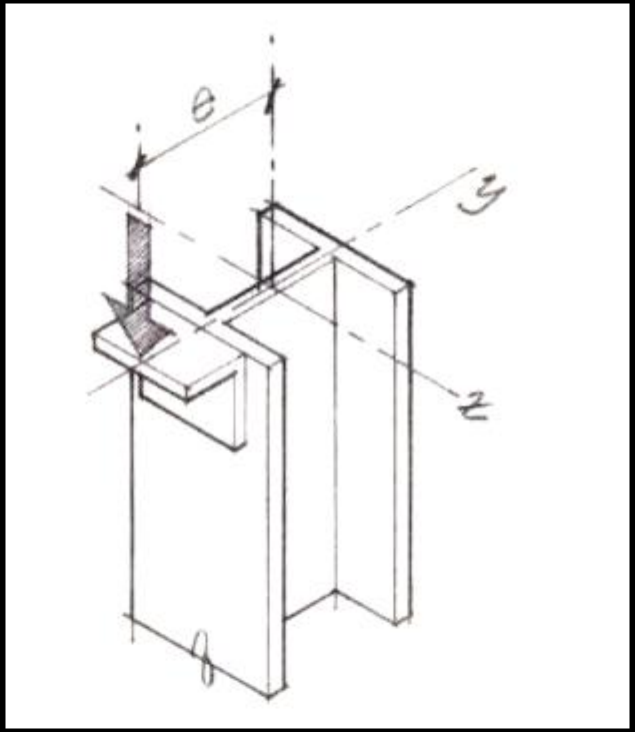


(a) No bracing. (b) Braced at midpoint. (c) Third-point bracing. (d) Asymmetric bracing.

Centric & Eccentric Loading

- centric
  - allowable stress from strength or buckling
- eccentric
  - combined stresses





Combined Stresses

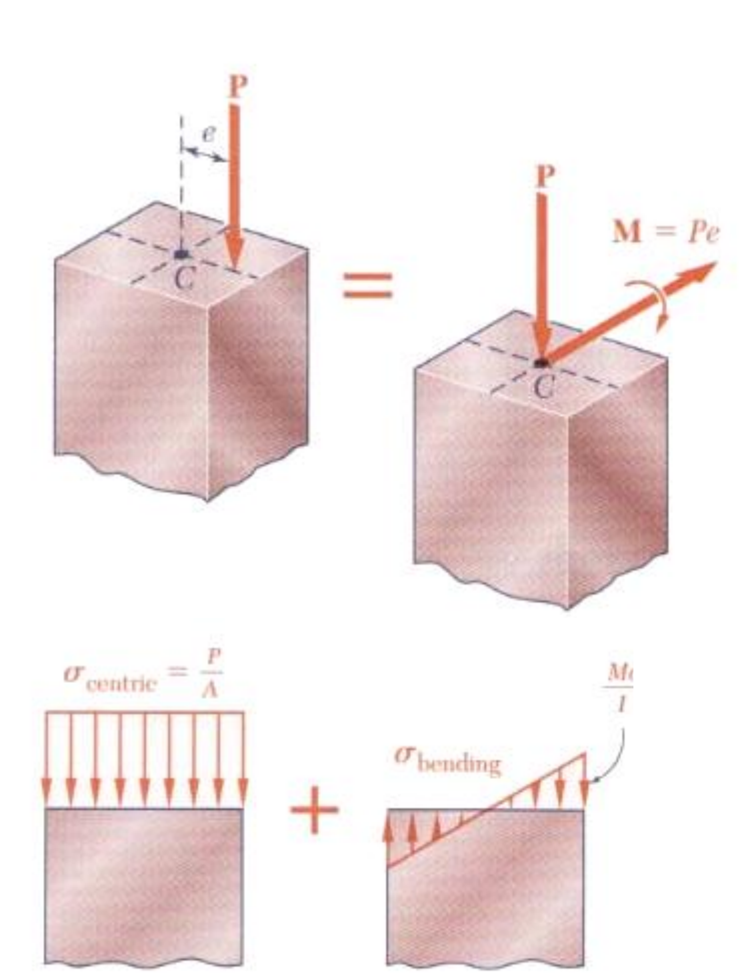
– axial + bending

$$f_{max} = \frac{P}{A} + \frac{Mc}{I}$$

$$M = P \cdot e$$

– design

$$f_{max} \le F_{cr} = \frac{f_{cr}}{F.S.}$$



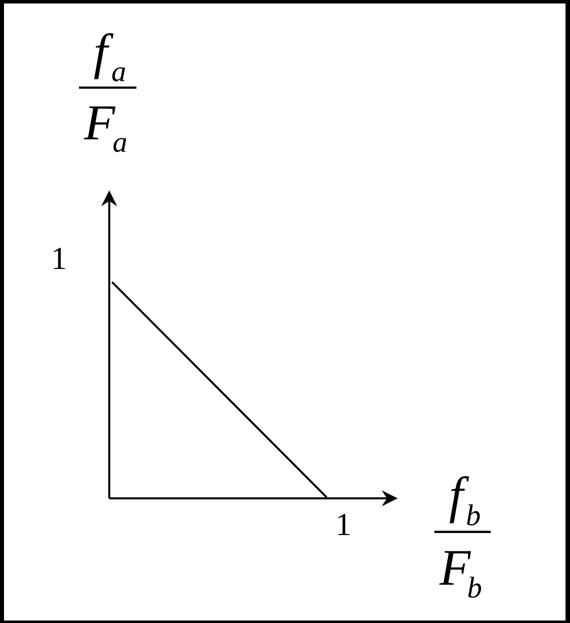
Stress Limit Conditions

– ASD interaction formula

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1.0$$

– with biaxial bending

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0$$

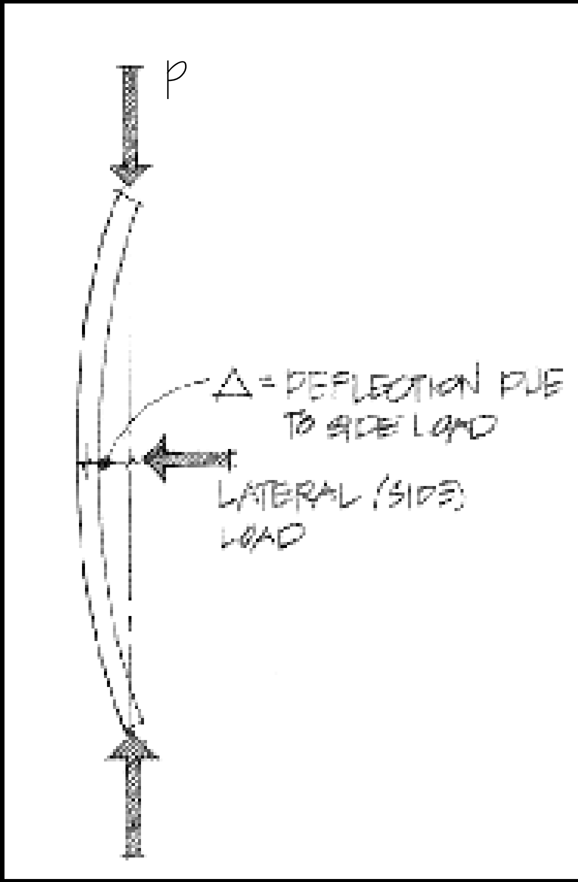


interaction diagram

Stress Limit Conditions

- *in reality, as the column flexes, the moment increases*

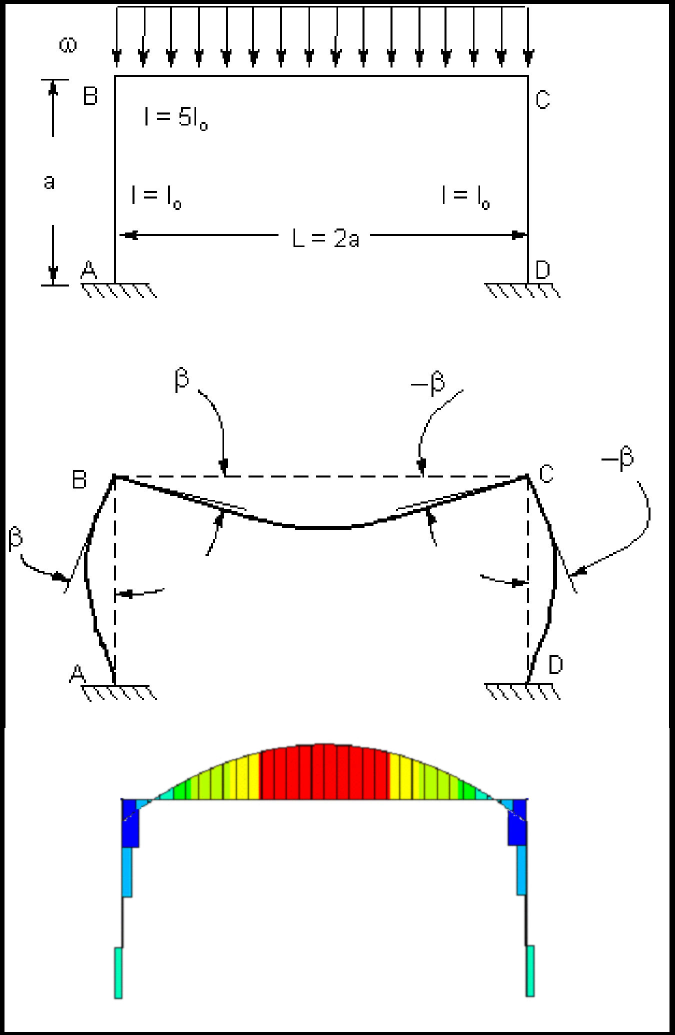
- *P-Δ effect*



$$\frac{f_a}{F_a} + \frac{f_b \times (Magnification\ \ factor)}{F_{bx}} \le 1.0$$

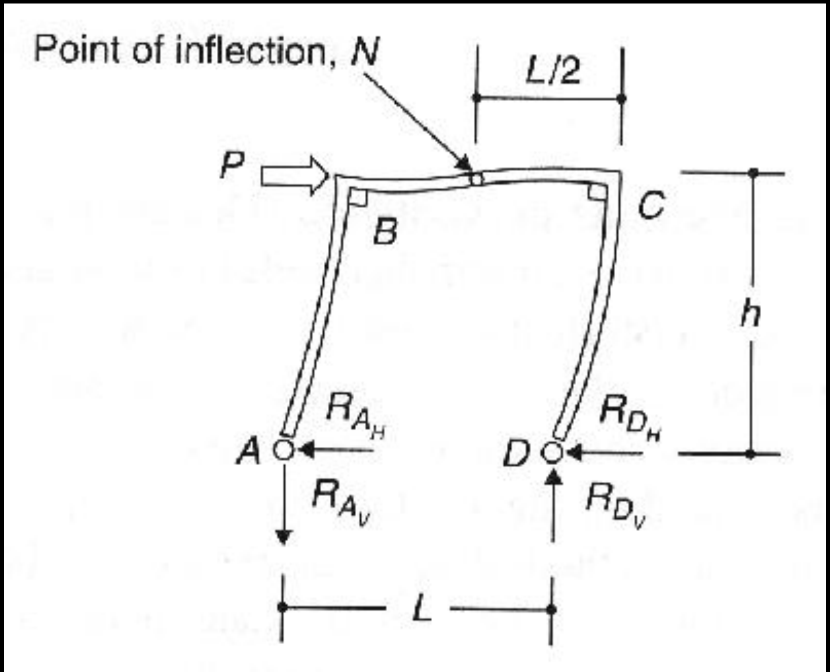
Rigid Frame Analysis

- members see
  - shear
  - axial force
  - bending
- V & M diagrams
  - plot on "outside"



Rigid Frame Analysis

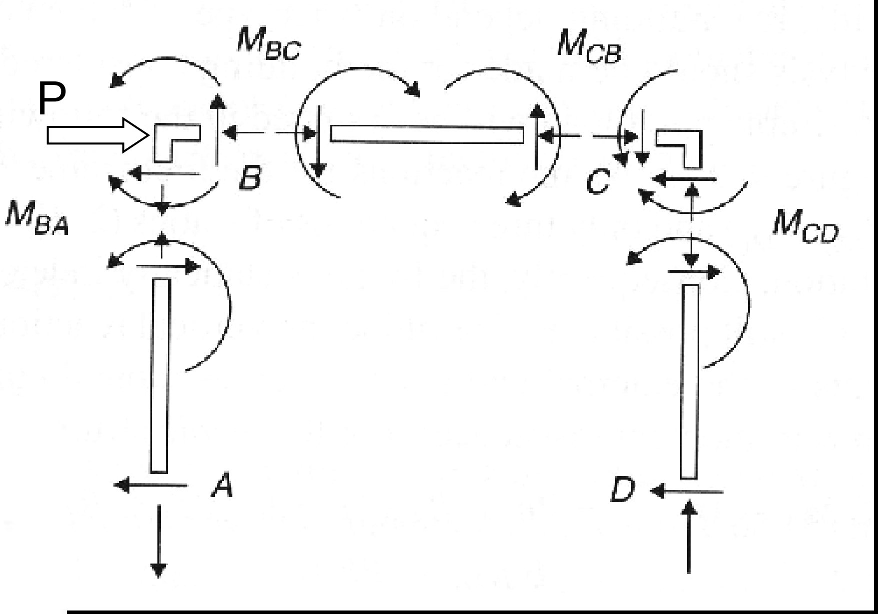
- *need support reactions*
- *free body diagram each member*
- *end reactions are <u>equal and opposite</u> on next member*
- *"turn" member like beam*
- *draw V & M*

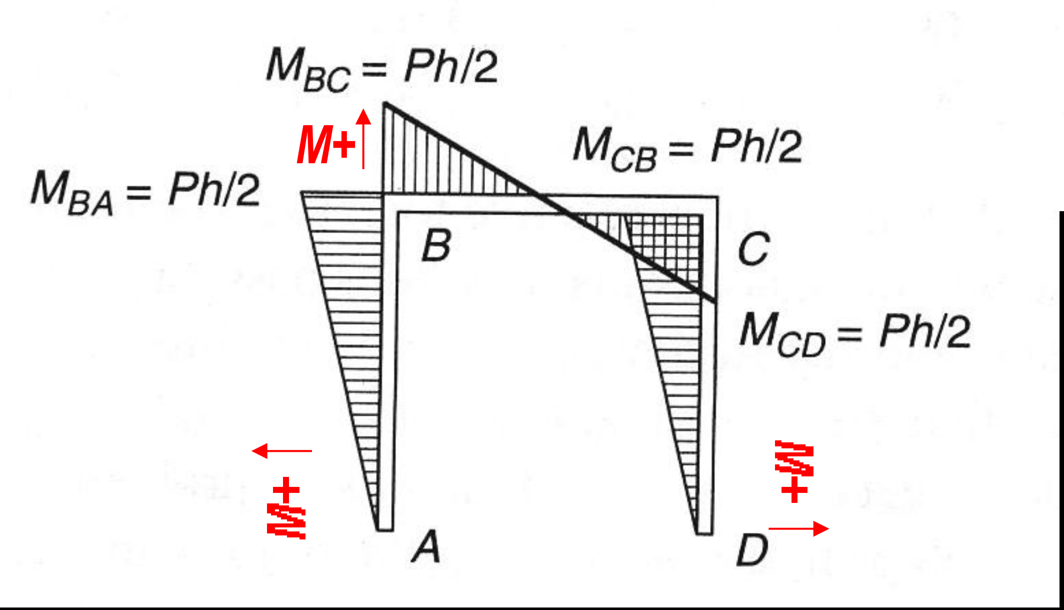


Rigid Frame Analysis

– FBD & M

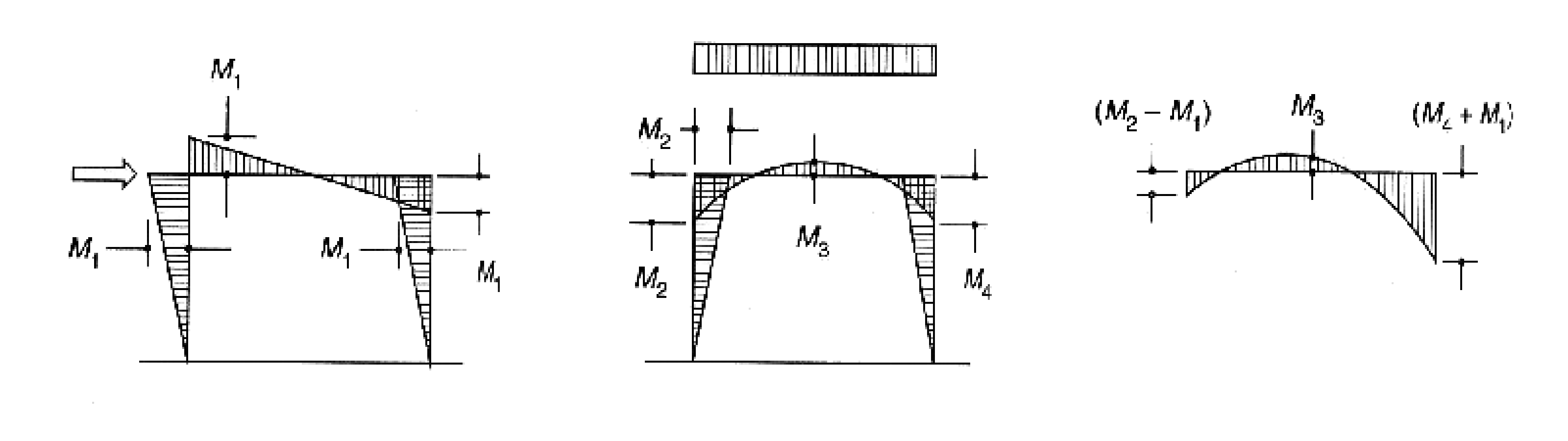
- opposite end reactions at joints





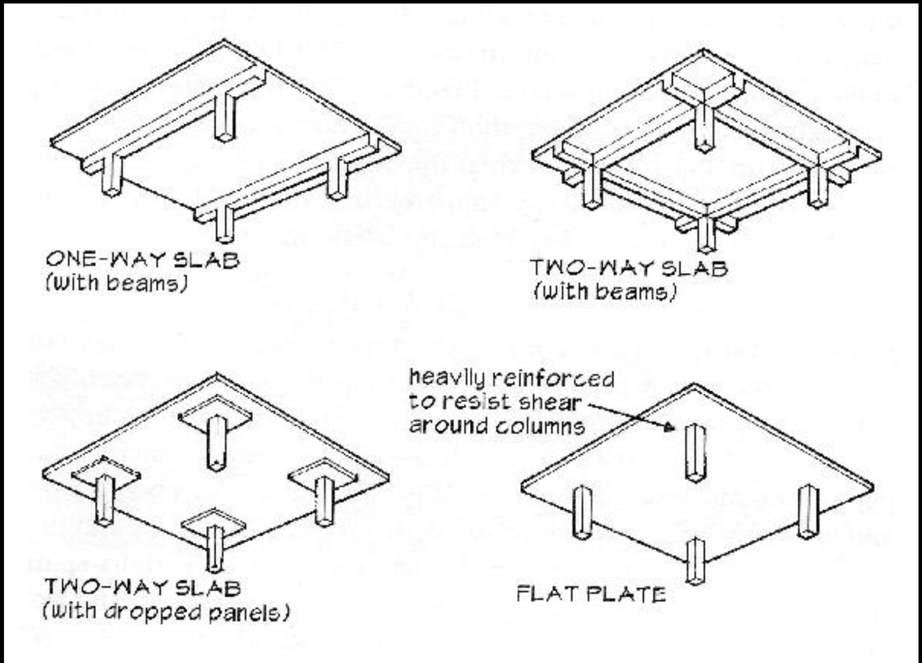
Rigid Frame Design

- loads and combinations
  - usually uniformly distributed gravity loads
  - worst case for largest moments...
  - wind direction can increase moments



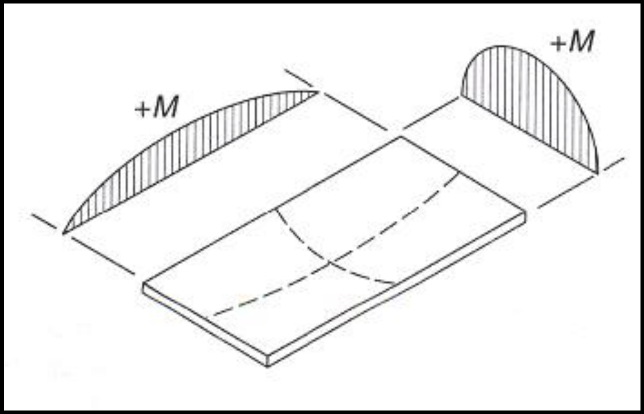
Rigid Frame Design

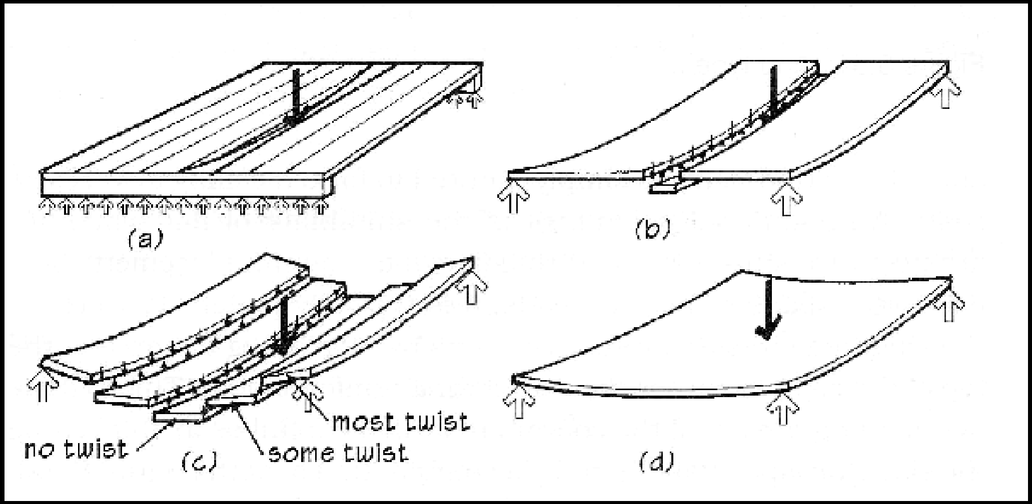
- *frames & floors*
  - *rigid frame can have slab floors or slab with connecting beams*
- *other*
  - *slabs or plates on columns*



Rigid Frame Design

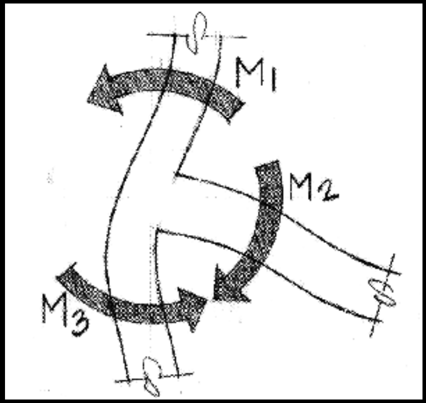
- *floors – plates & slabs*
  - *one-way behavior*
    - *side ratio > 1.5*
    - *"strip" beam*
  - *two-way behavior*
    - *more complex*





Rigid Frame Design

- *columns in frames*
  - *ends can be "flexible"*
  - *stiffness affected by beams* *and column = EI/L*

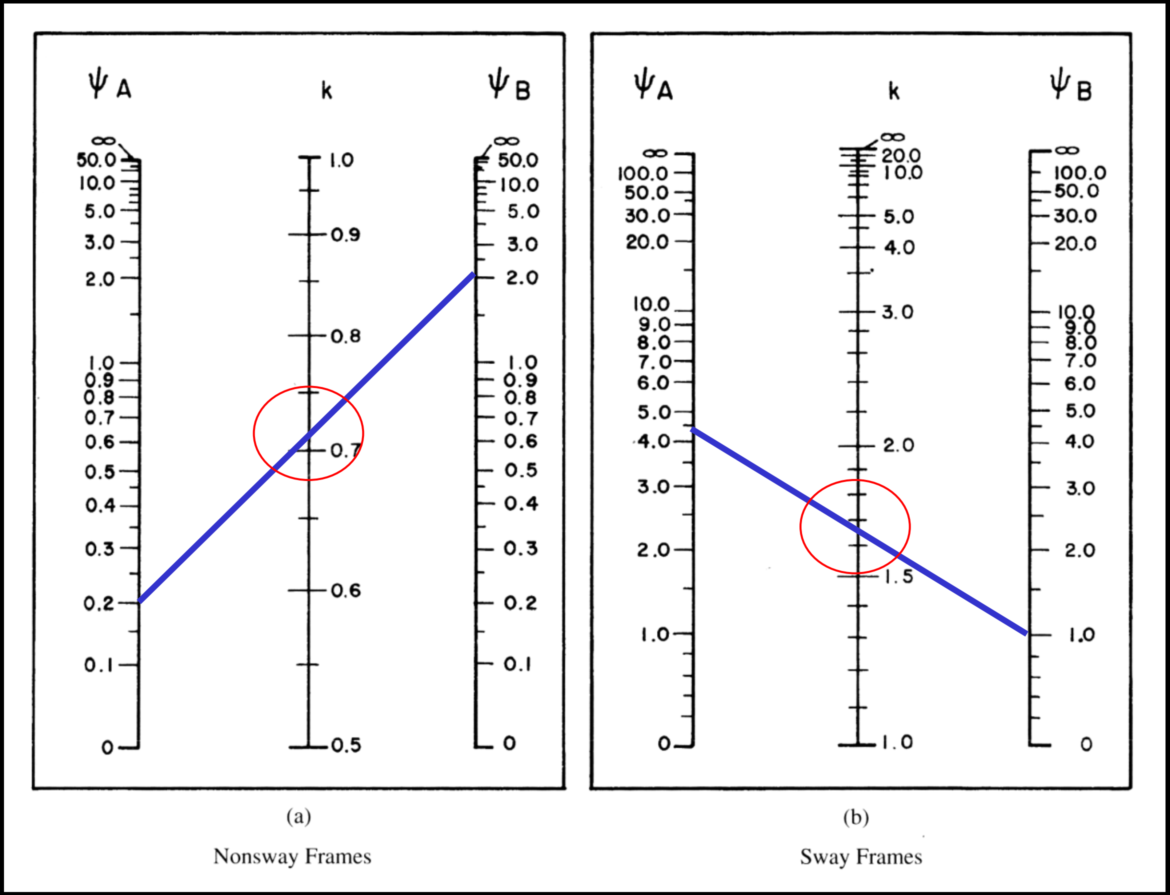


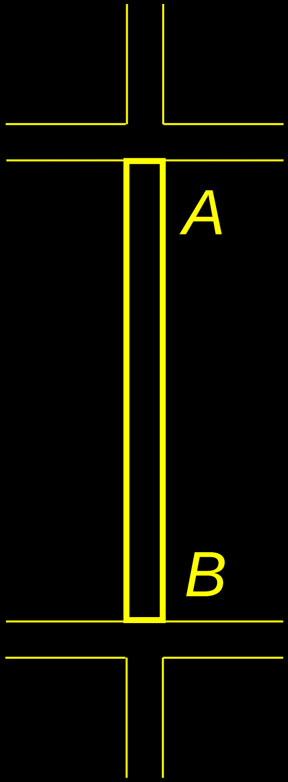
$$G = \Psi = \frac{\sum EI/l_c}{\sum EI/l_b}$$

  - *for the joint*
    - *l_c is the column length of each column*
    - *l_b is the beam length of each beam*
    - *measured center to center*

Rigid Frame Design

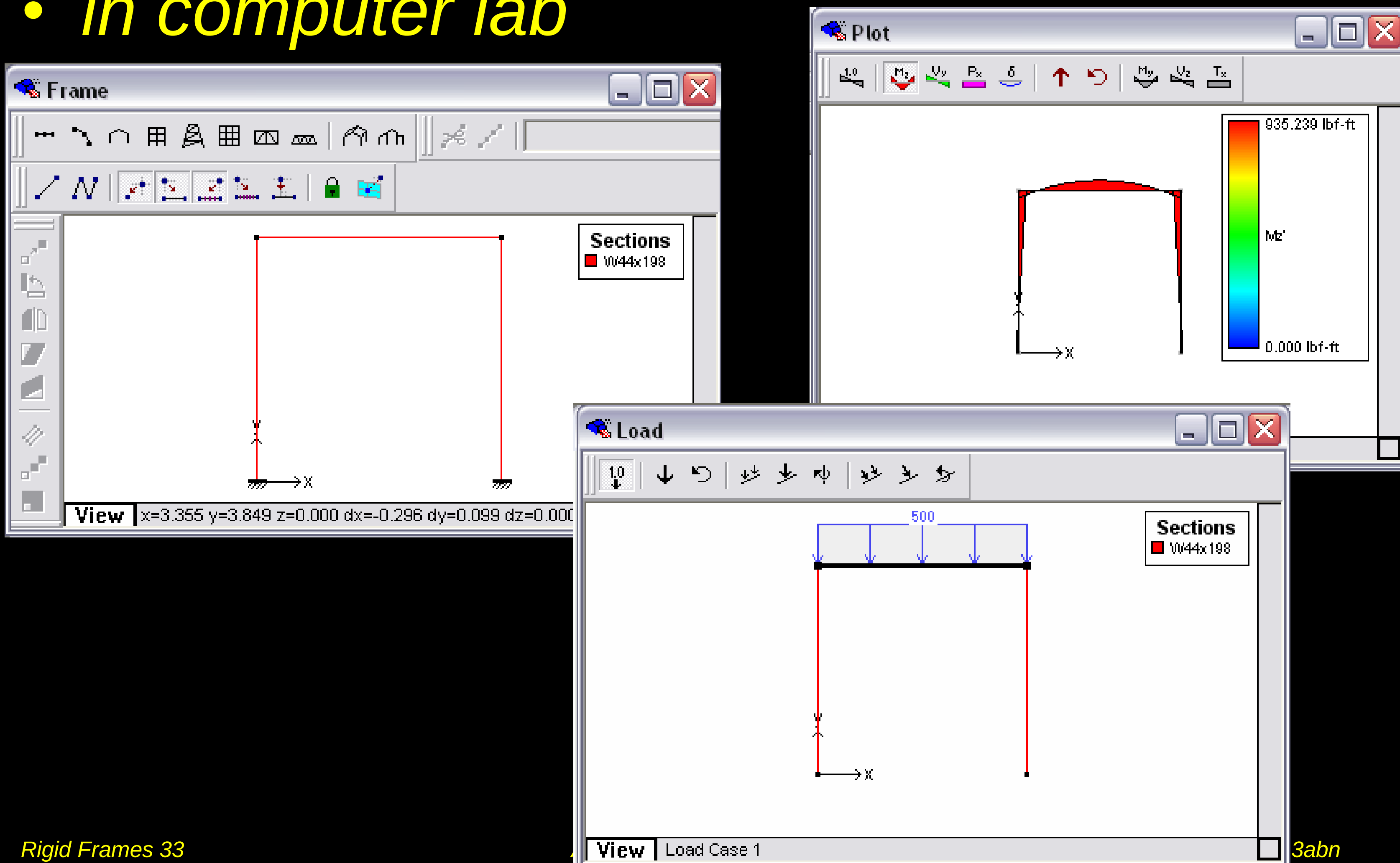
- *column effective length, k*



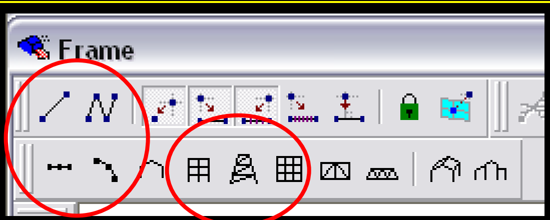


Tools – Multiframe

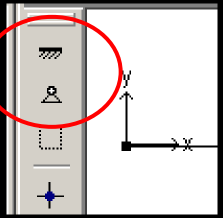
- in computer lab



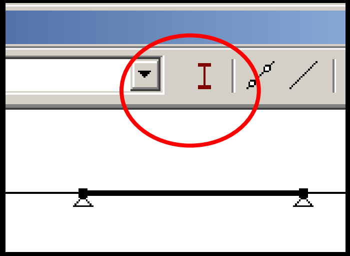
Tools – Multiframe



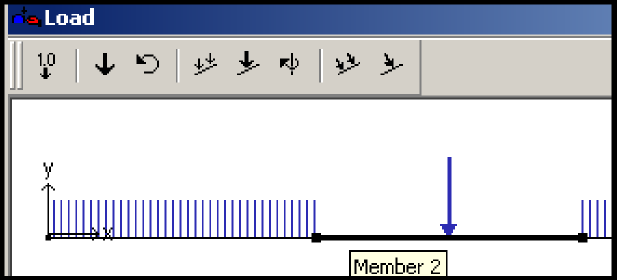
- *frame window*
  - *define frame members*
    - *or pre-defined frame*
  - *select points, assign supports*



  - *select members, assign section*

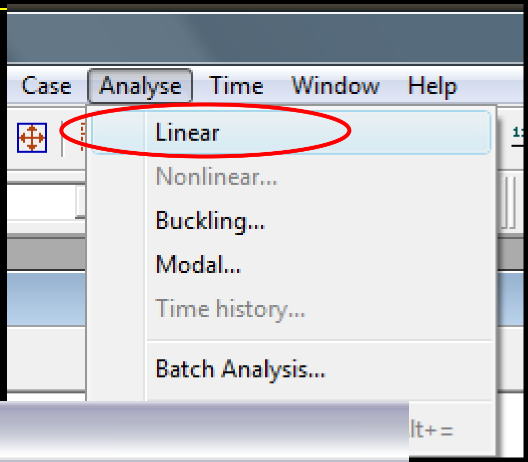


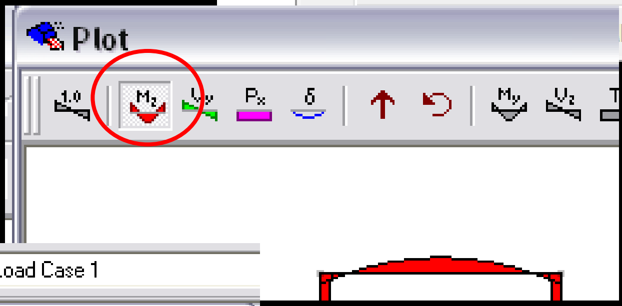
  - *load window*
  - *select point or member, add point or distributed loads*

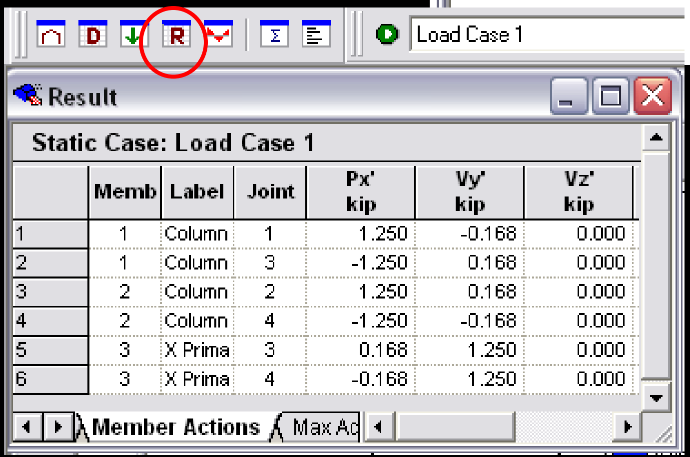


Tools – Multiframe

- to run analysis choose
  - Analyze menu
    - Linear
- plot
  - choose options
- results
  - choose options







	Memb	Label	Joint	Px' kip	Vy' kip	Vz' kip
1	1	Column	1	1.250	-0.168	0.000
2	1	Column	3	-1.250	0.168	0.000
3	2	Column	2	1.250	0.168	0.000
4	2	Column	4	-1.250	-0.168	0.000
5	3	X Prima	3	0.168	1.250	0.000
6	3	X Prima	4	-0.168	1.250	0.000