

*ELEMENTS OF ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN*

ARCH 614

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SPRING 2014

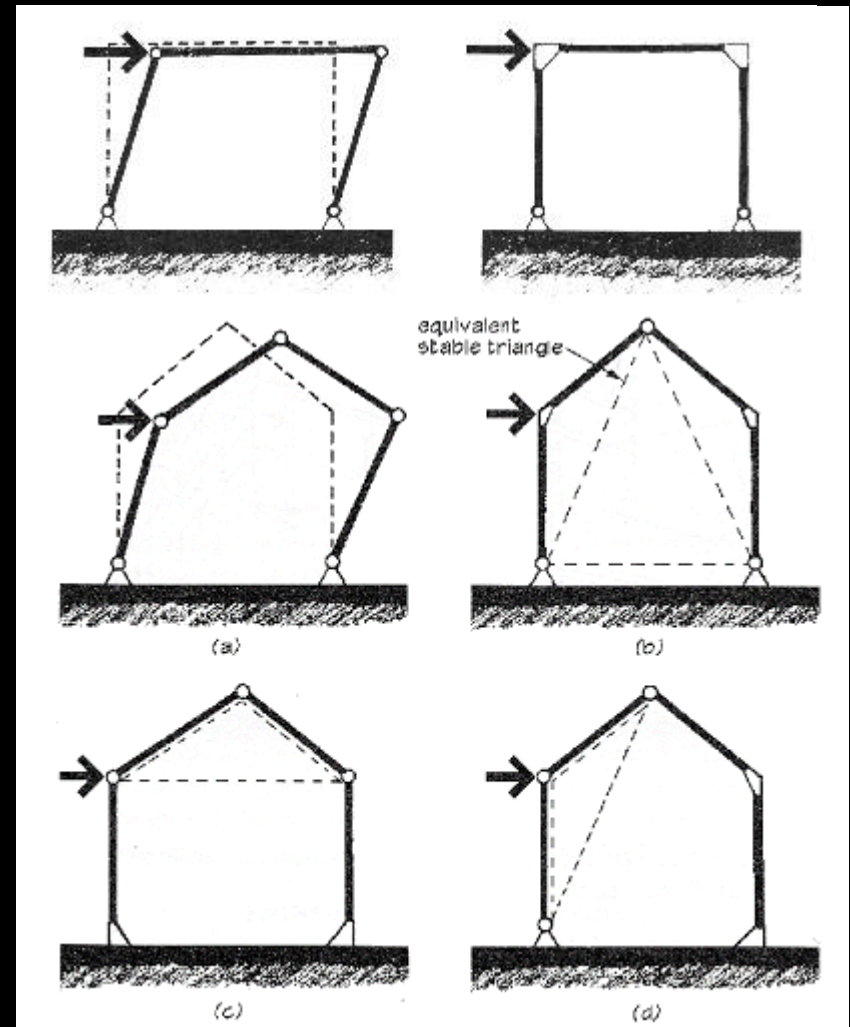
lecture
*elev*en

***rigid frames:
compression & buckling***



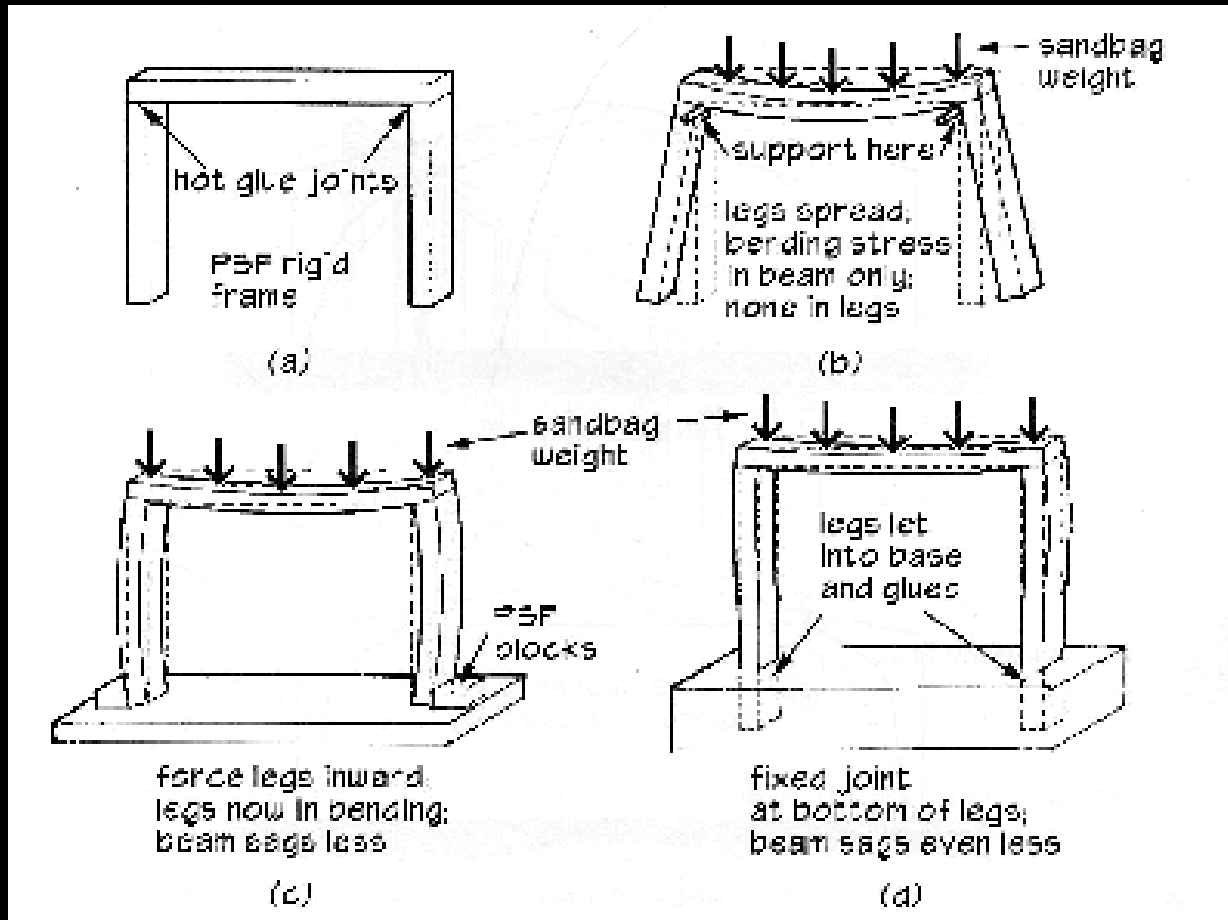
Rigid Frames

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



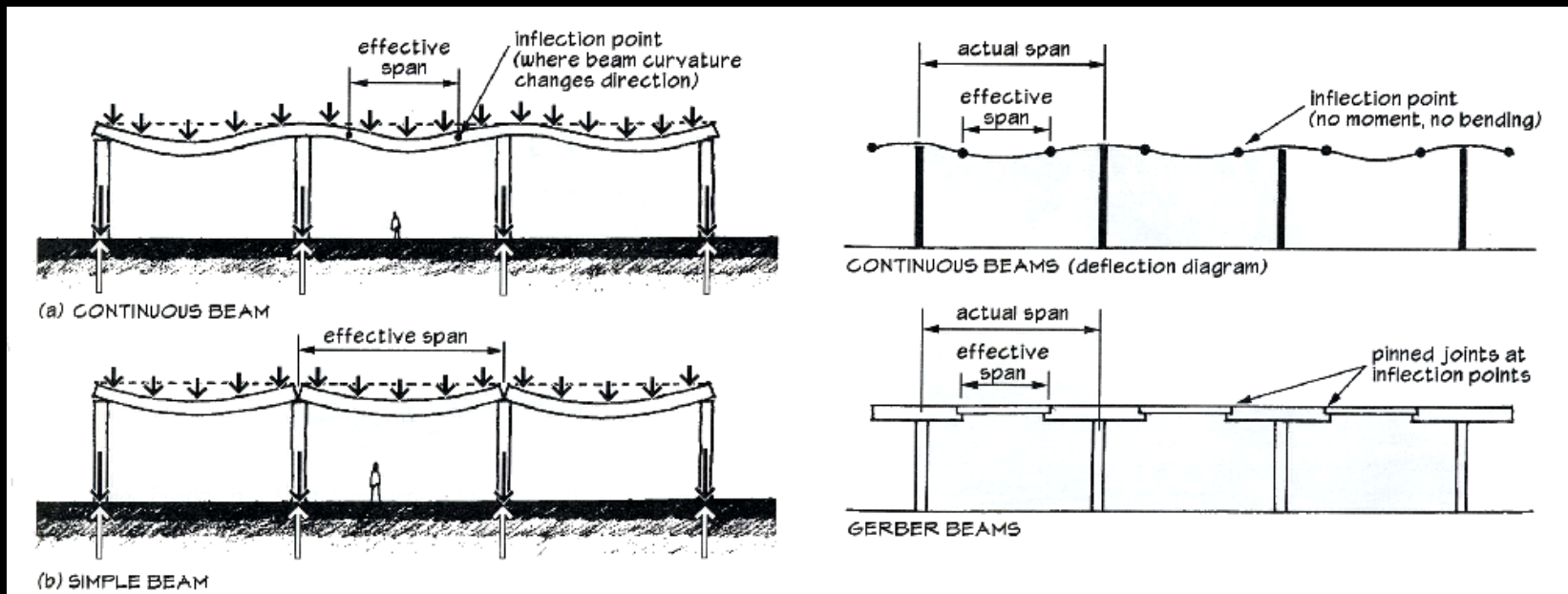
Rigid Frames

- behavior



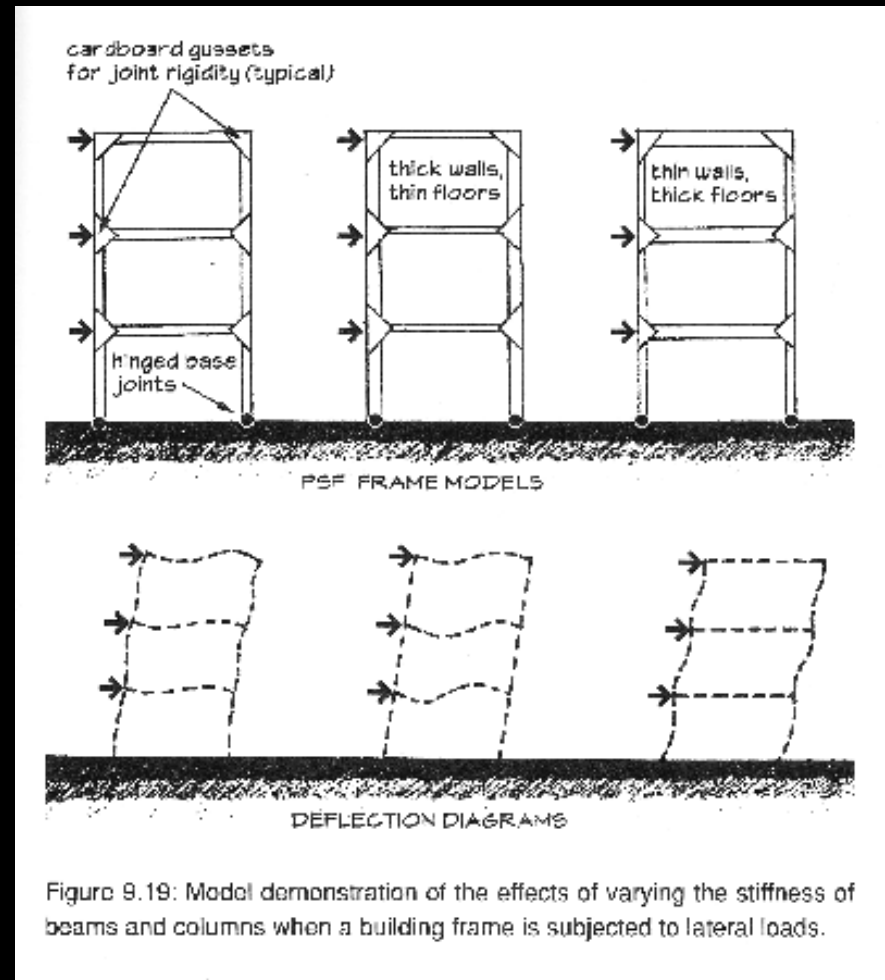
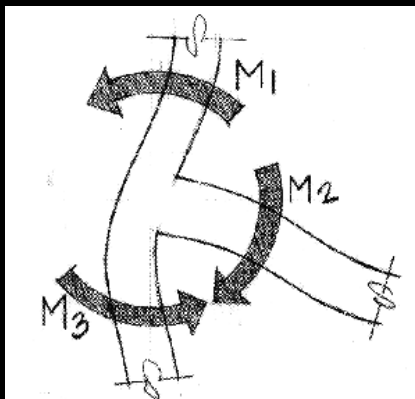
Rigid Frames

- moments get redistributed
- deflections are smaller
- effective column lengths are shorter
- very sensitive to settling



Rigid Frames

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

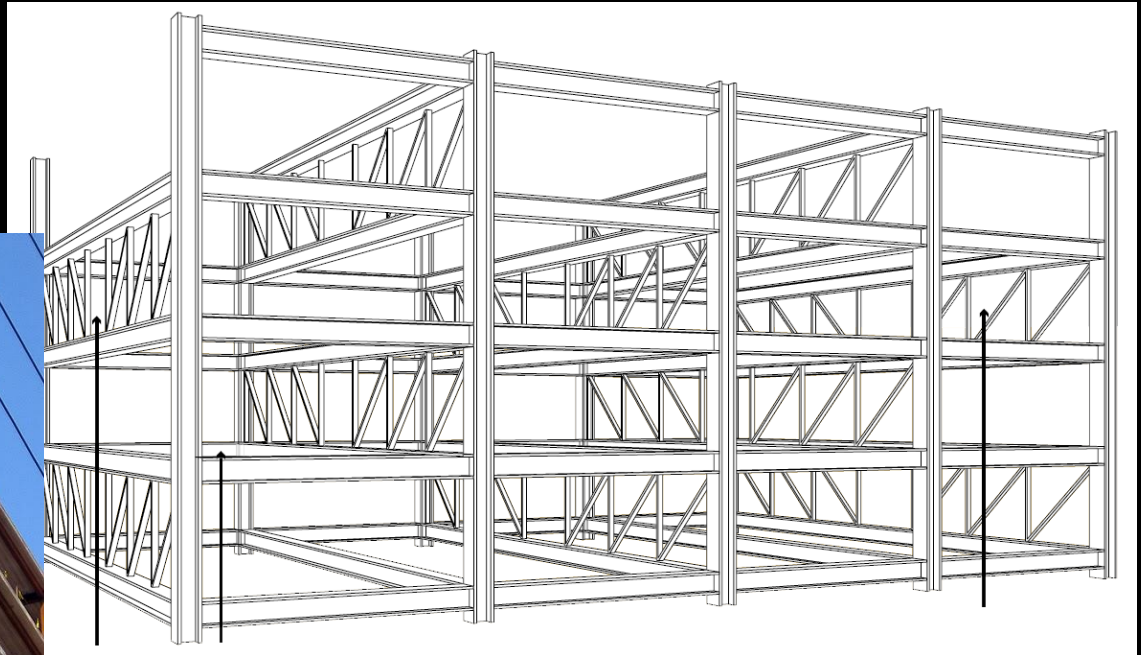


Rigid Frames

- *staggered truss*
 - *rigidity*
 - *clear stories*

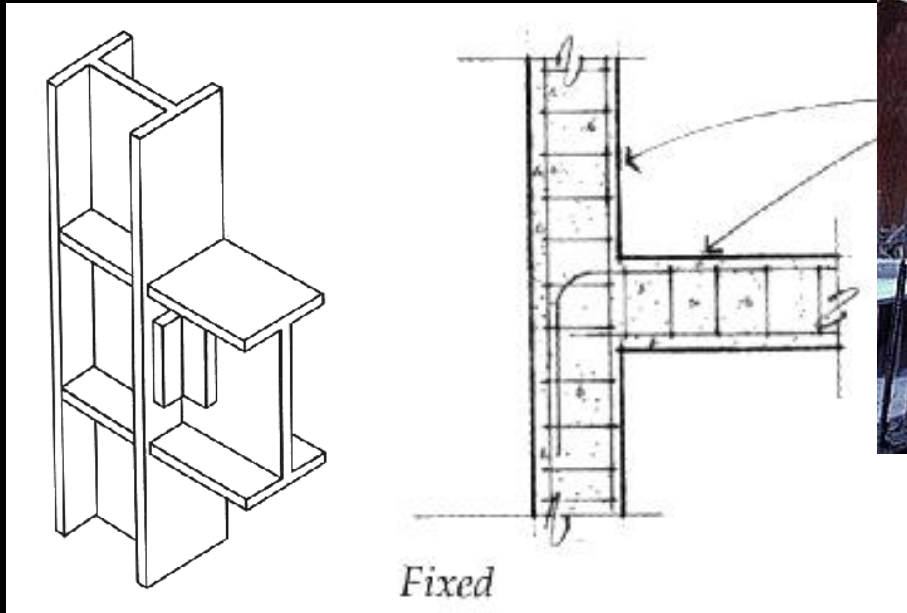


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Rigid Frames

- *connections*
 - *steel*
 - *concrete*



<http://nisee.berkeley.edu/godden>

Braced Frames

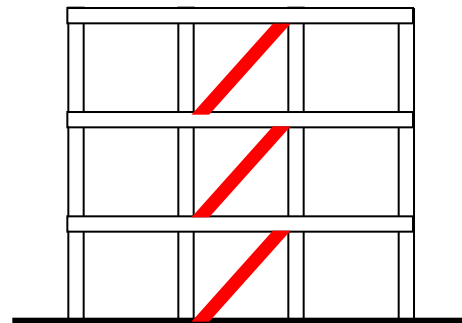
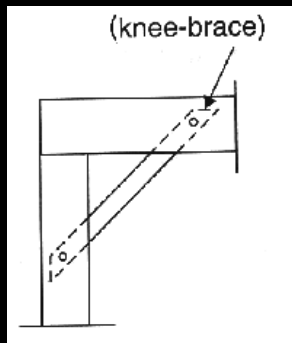
- *pin connections*
- *bracing to prevent lateral movements*



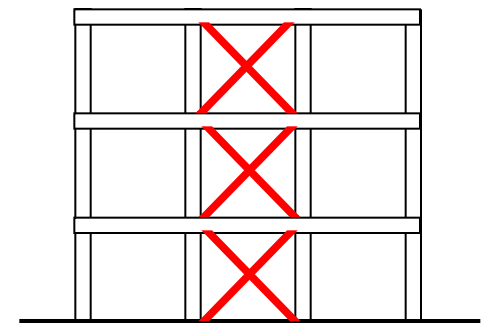
<http://nisee.berkeley.edu/godden>

Braced Frames

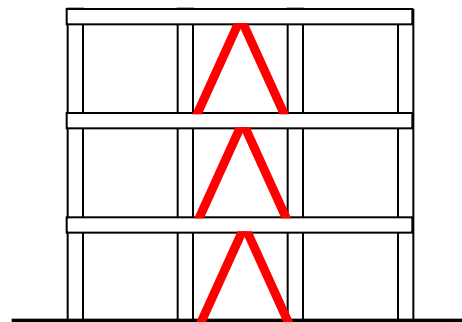
- *types of bracing*
 - *knee-bracing*
 - *diagonal*
 - *X*
 - *K or chevron*
 - *shear walls*



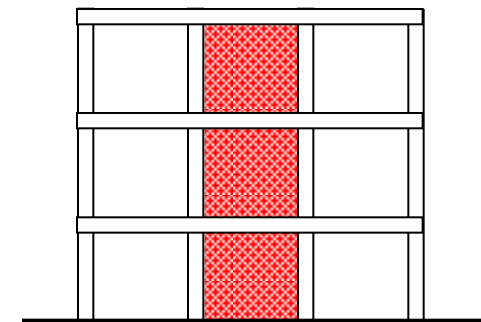
diagonal



X



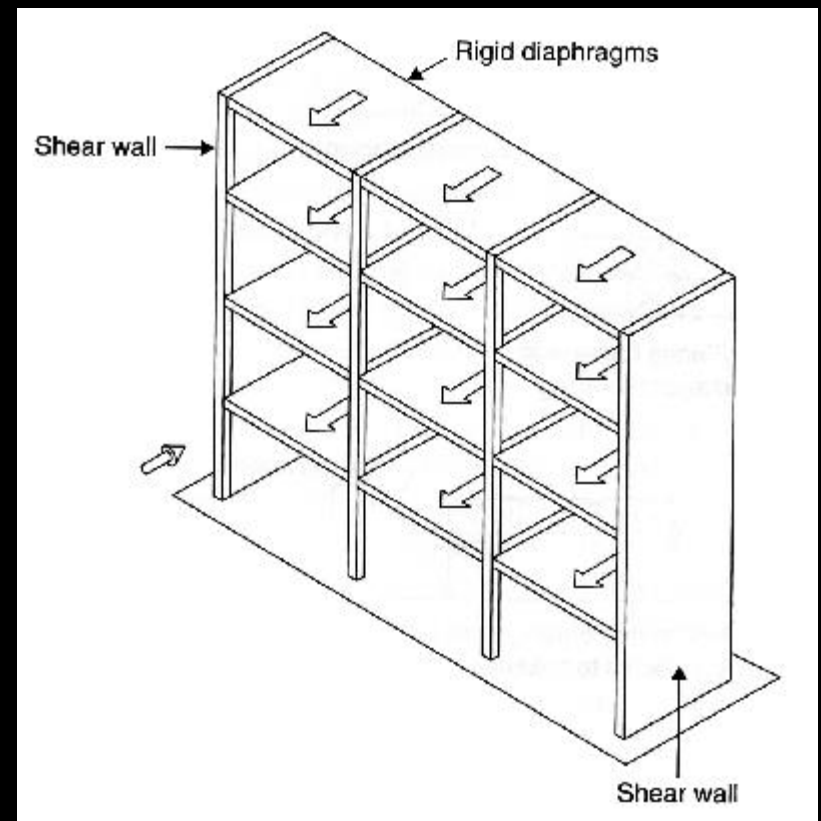
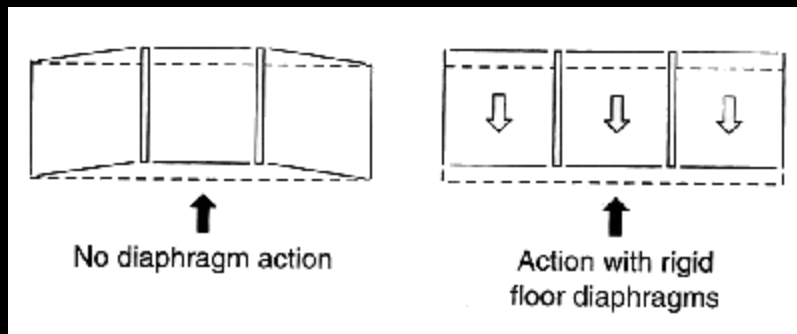
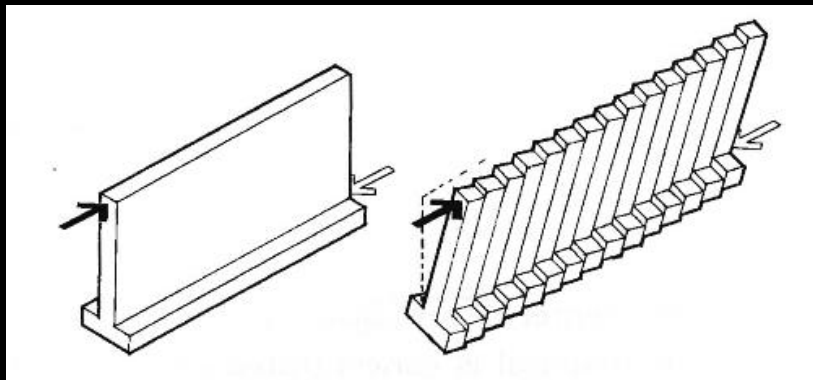
K (chevron)



shear walls

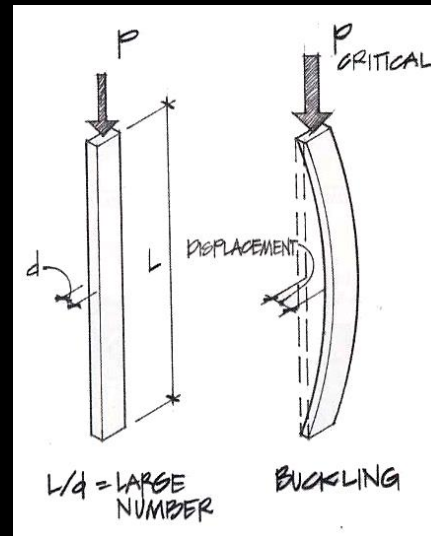
Shear Walls

- *resist lateral load in plane with wall*



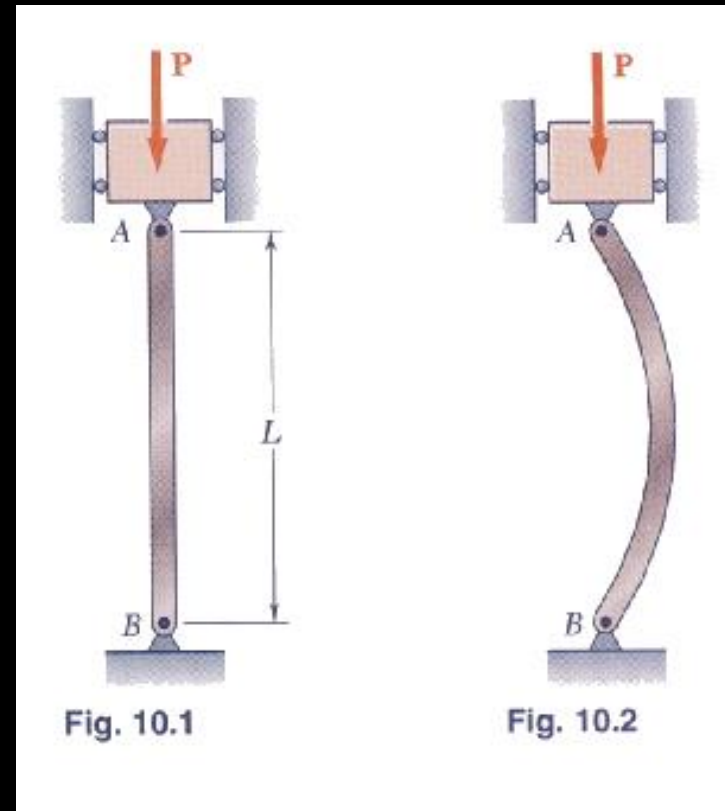
Compression Members

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



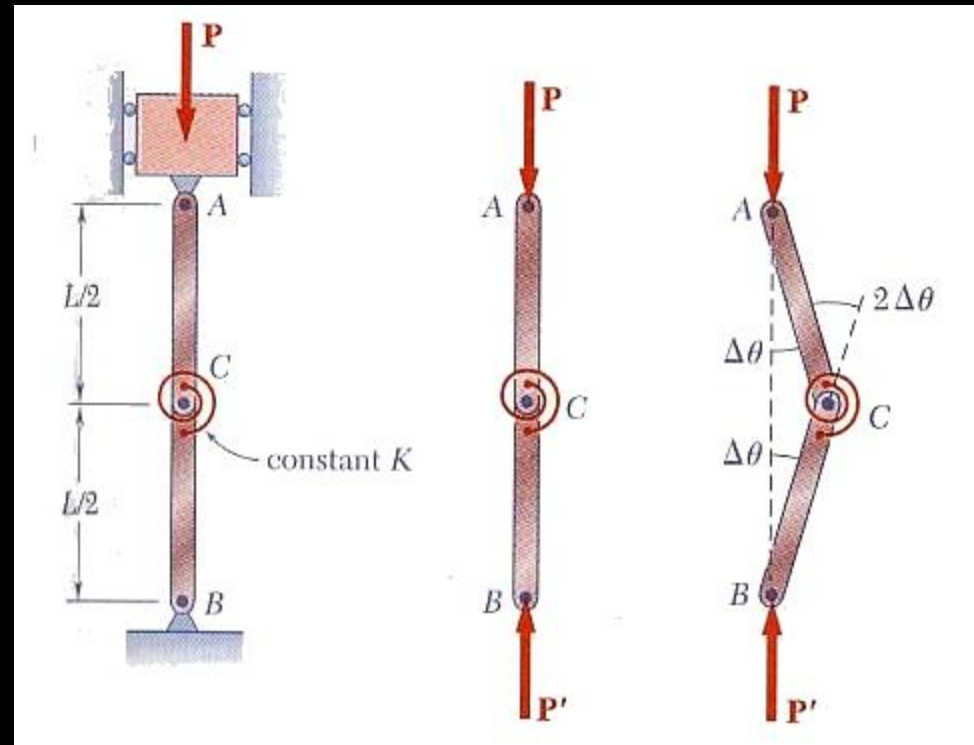
Column Buckling

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



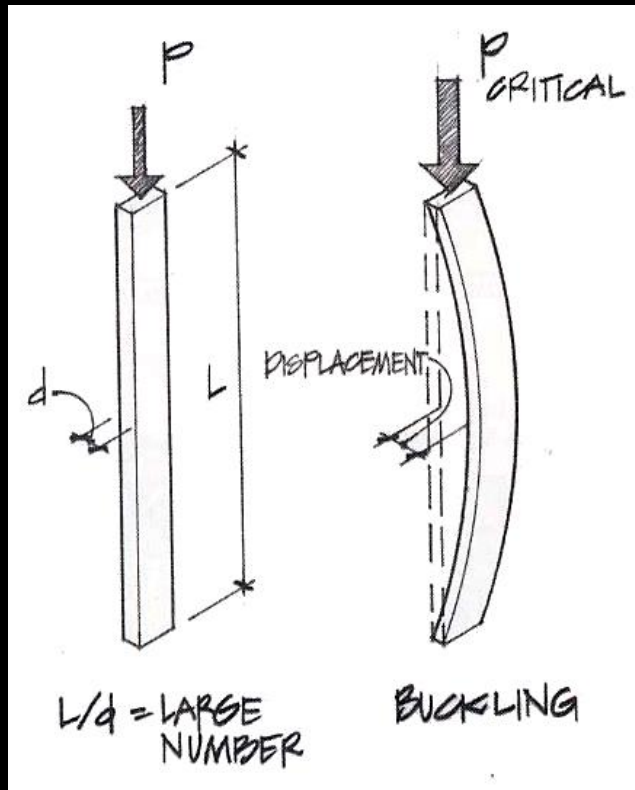
Modeling

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

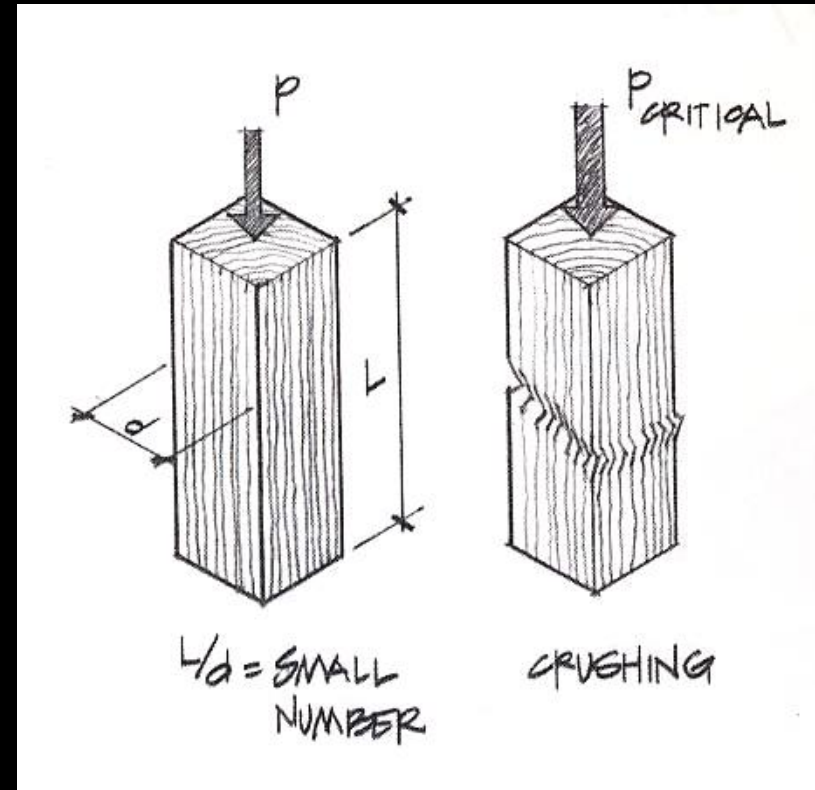


Effect of Length

- long & slender



- short & stubby



Buckling Load

- related to deflected shape ($P\Delta$)
- shape of sine wave
- Euler's Formula
- smallest I governs

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

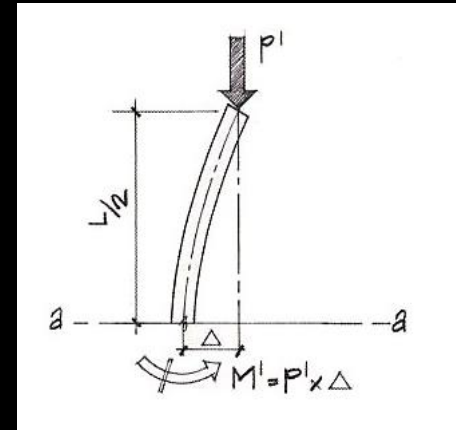


Figure 9.3 Leonhard Euler (1707–1783).

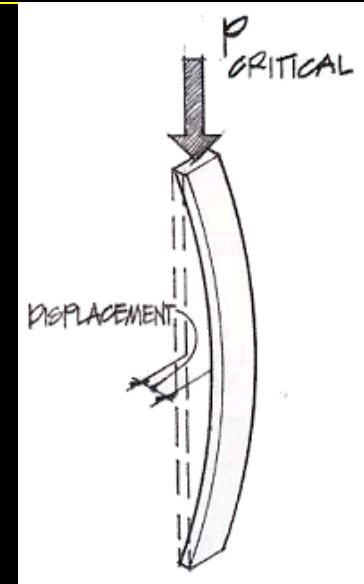
Critical Stress

- short columns

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

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

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



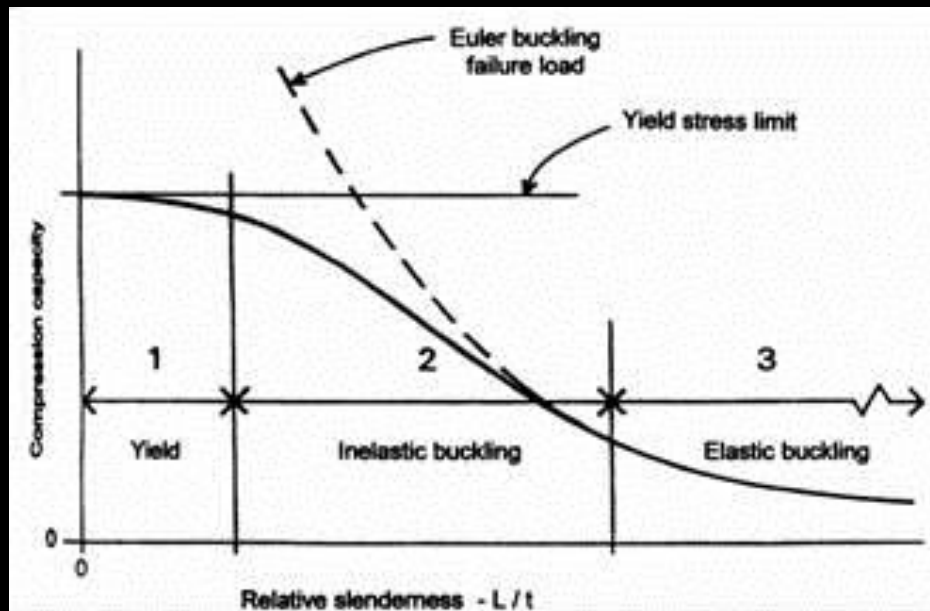
weak axis

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

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

Critical Stresses

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



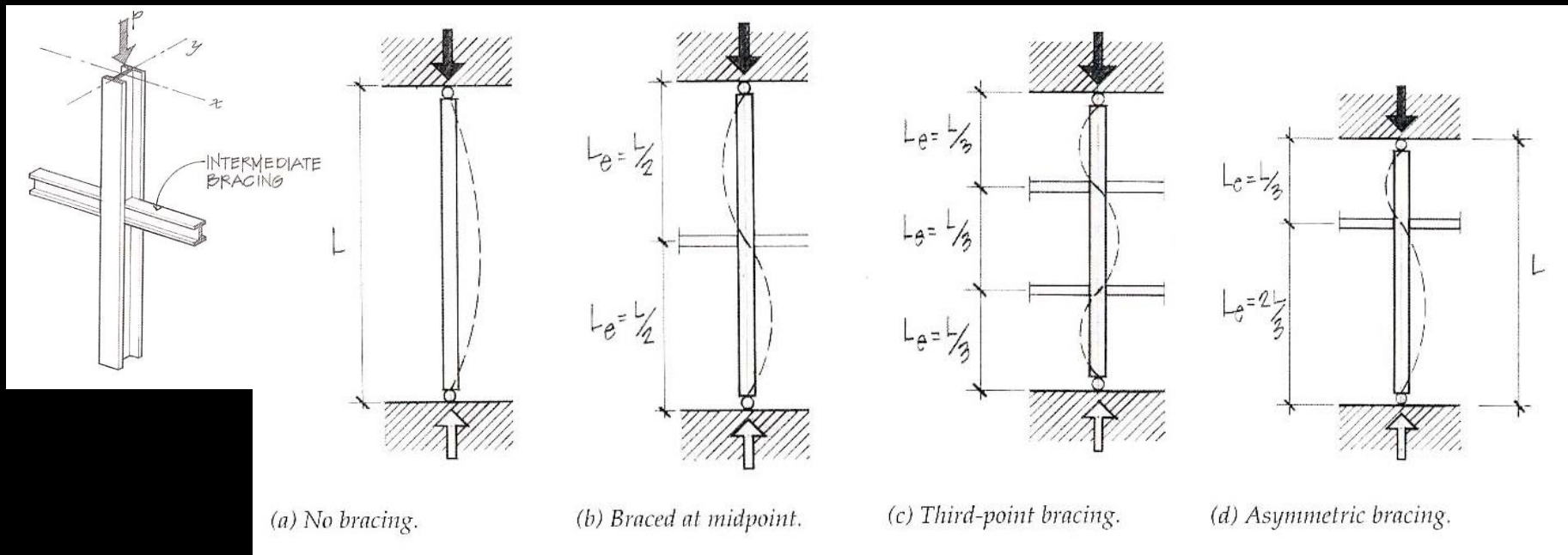
Effective Length

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

Buckled shape of column shown by dashed line	(a)	(b)	(c)	(d)	(e)	(f)
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

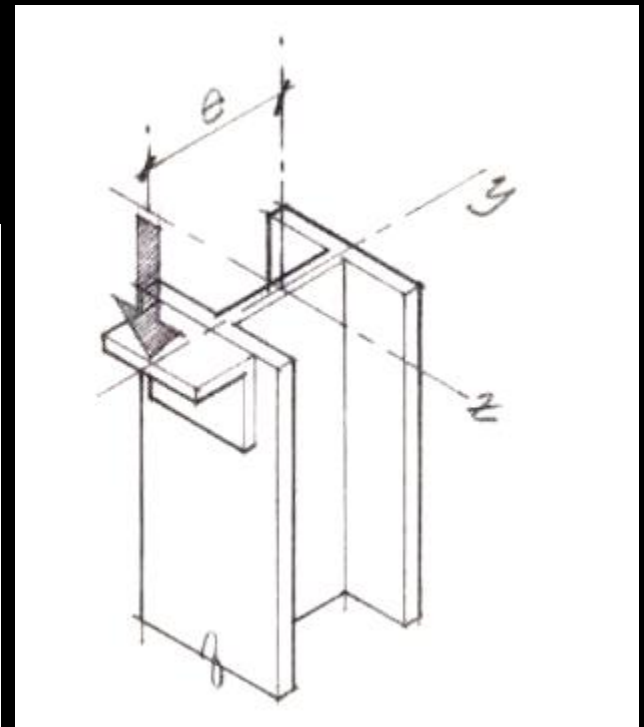
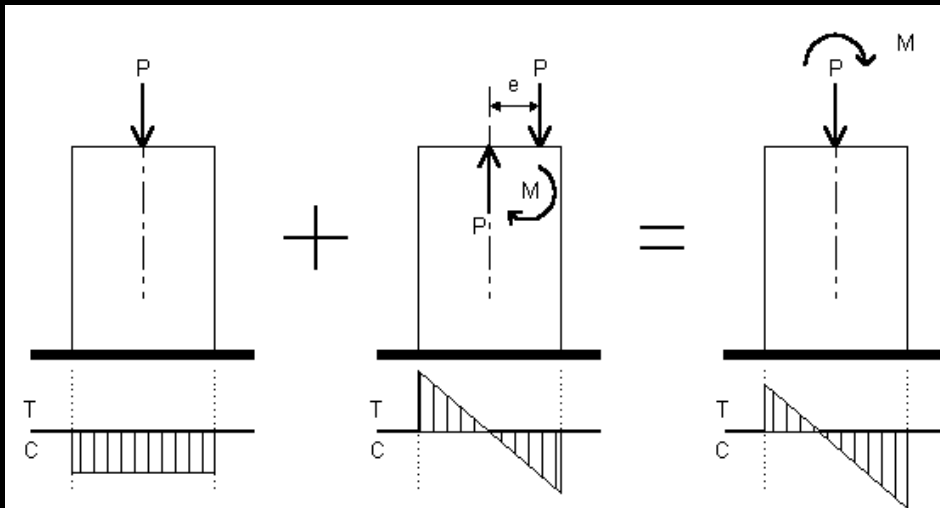
Bracing

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



Centric & Eccentric Loading

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



Combined Stresses

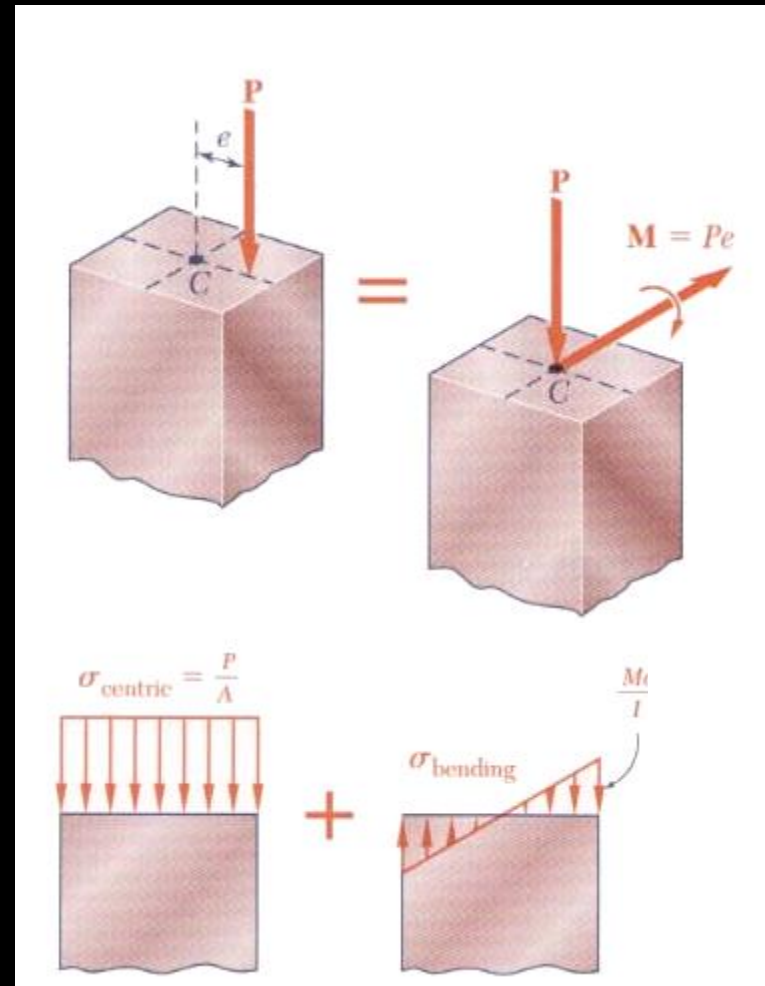
– axial + bending

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

$$M = P \cdot e$$

– design

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



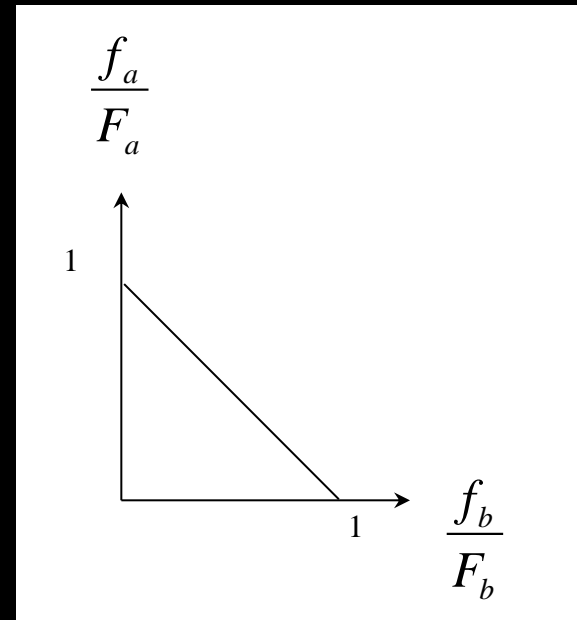
Stress Limit Conditions

– ASD interaction formula

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

– with biaxial bending

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



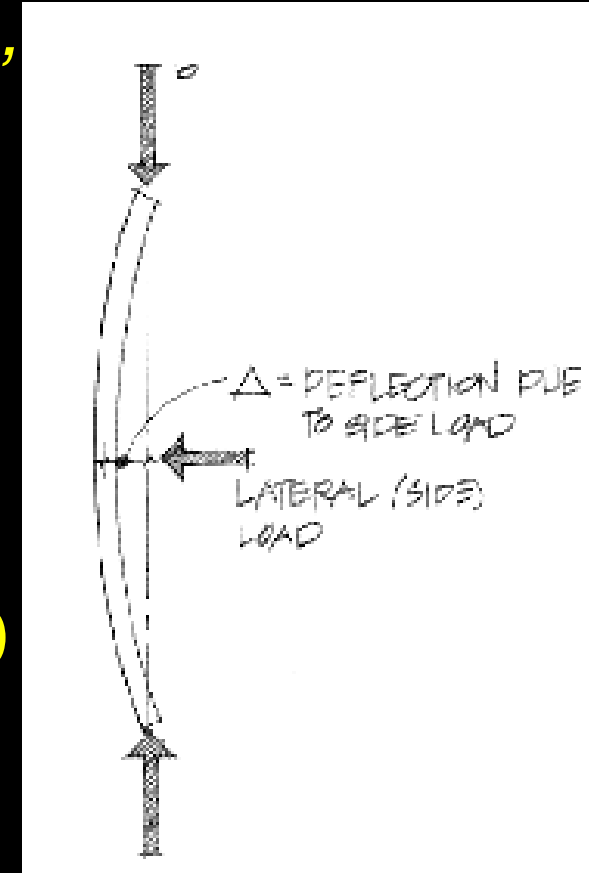
interaction diagram

Stress Limit Conditions

– in reality, as the column flexes,
the moment increases

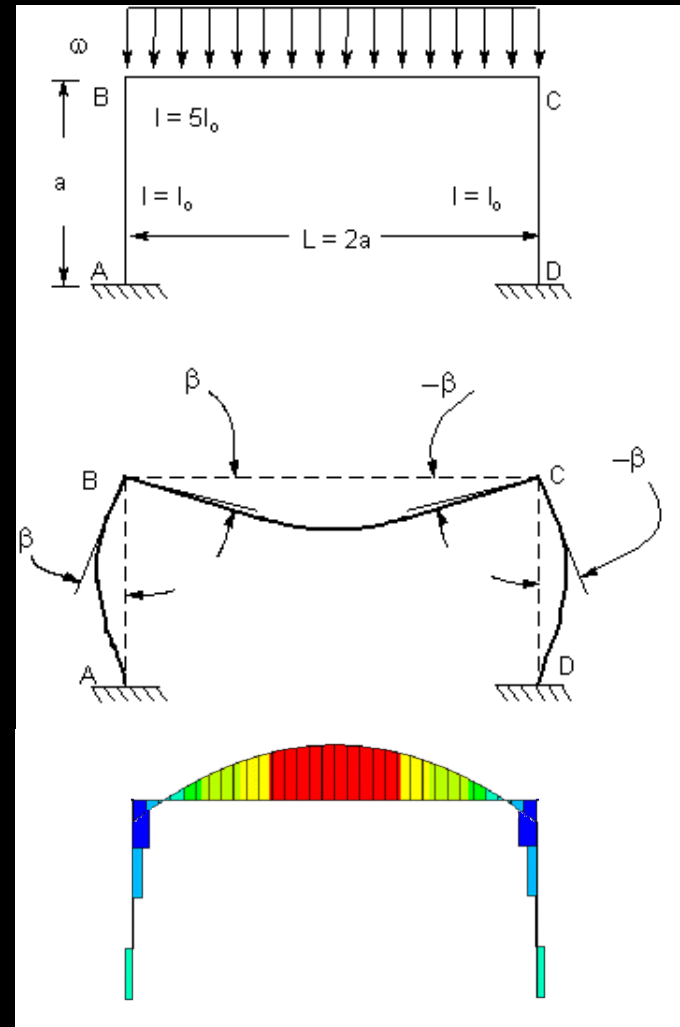
– P-Δ effect

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



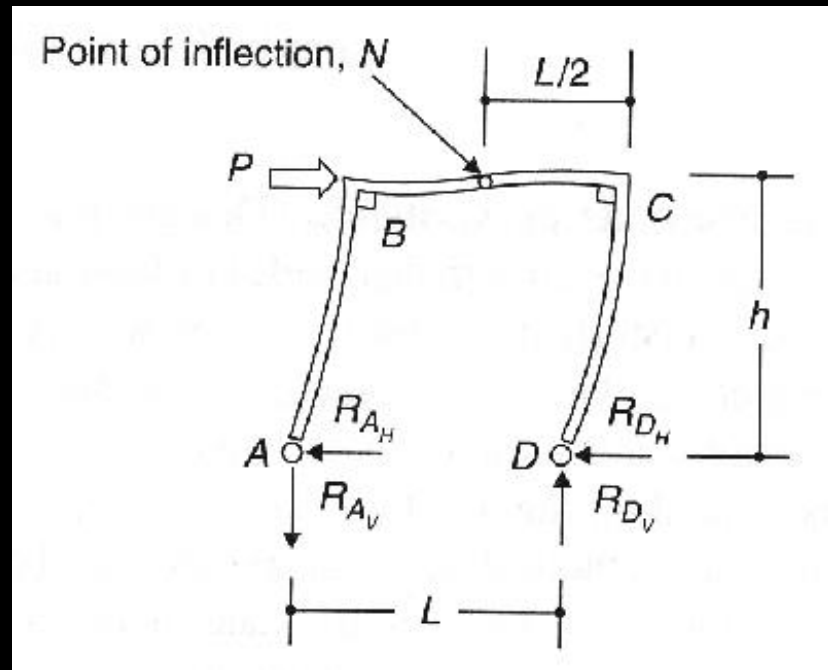
Rigid Frame Analysis

- *members see*
 - *shear*
 - *axial force*
 - *bending*
- *V & M diagrams*
 - *plot on “outside”*



Rigid Frame Analysis

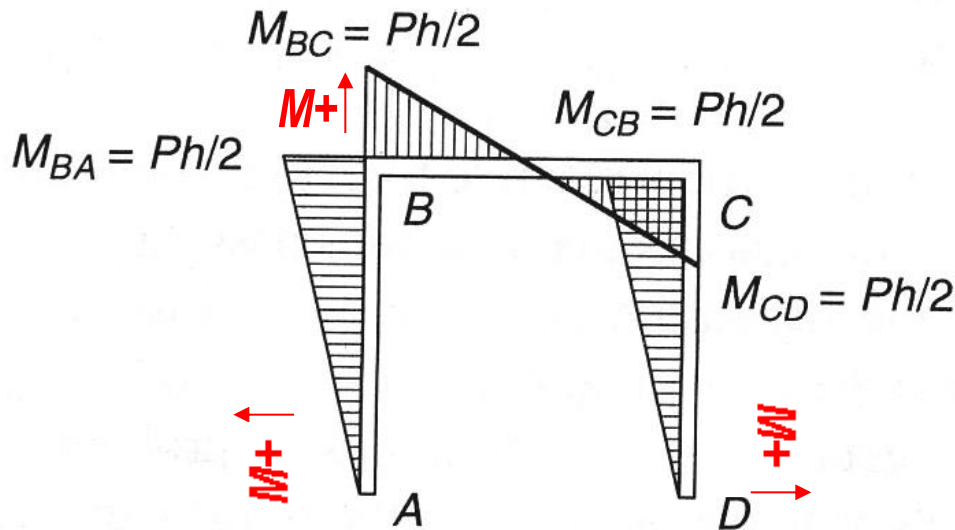
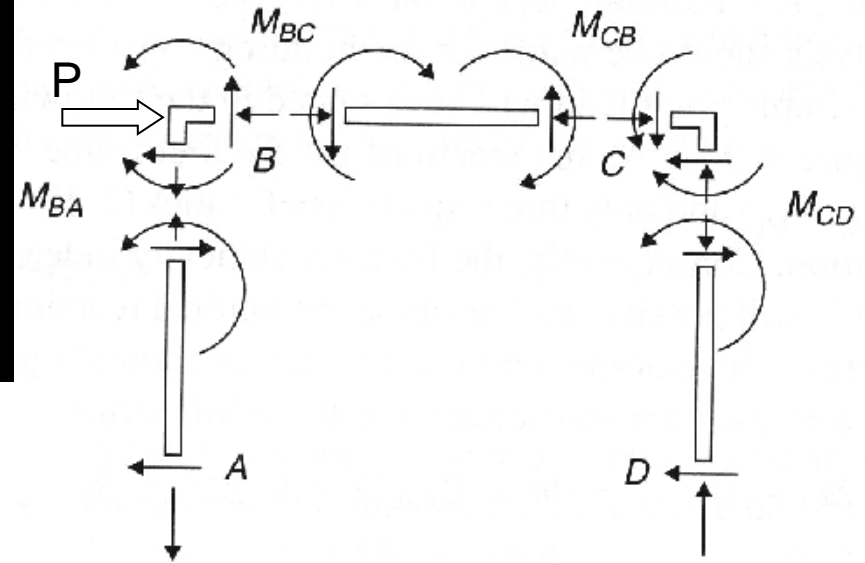
- need support reactions
- free body diagram each member
- end reactions are equal and opposite on next member
- “turn” member like beam
- draw V & M



Rigid Frame Analysis

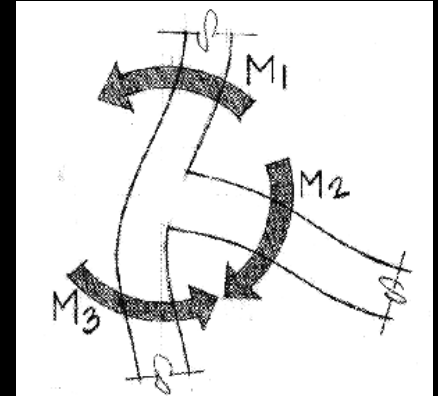
– FBD & M

- opposite end reactions at joints



Rigid Frame Design

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

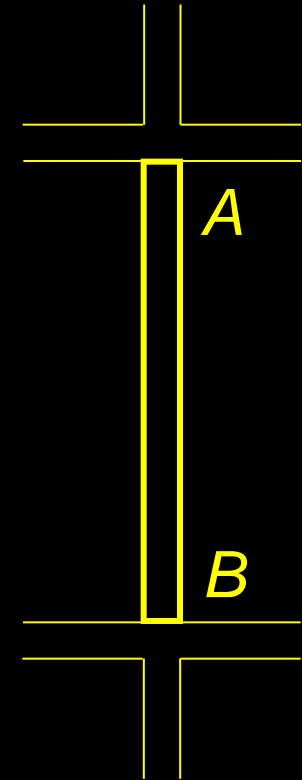
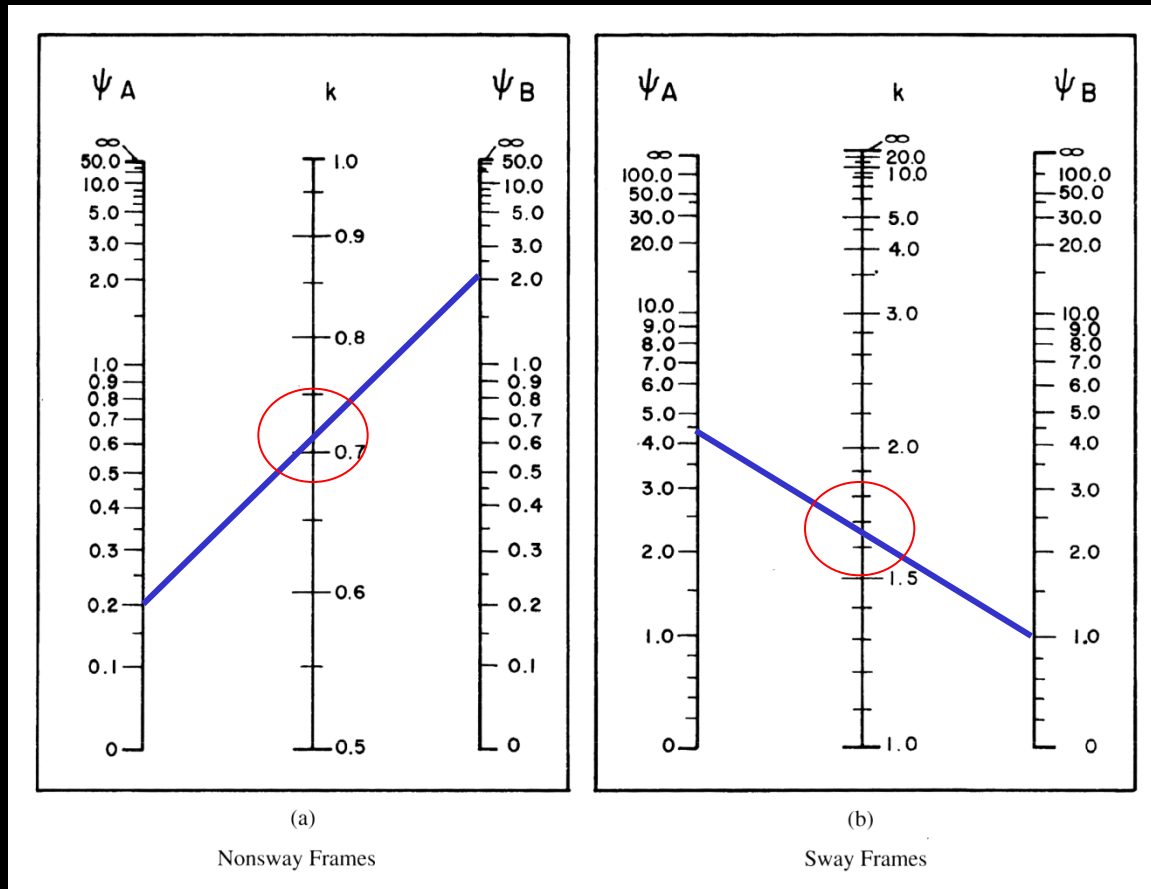


$$G = \Psi = \frac{\sum EI / l_c}{\sum EI / l_b}$$

- 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

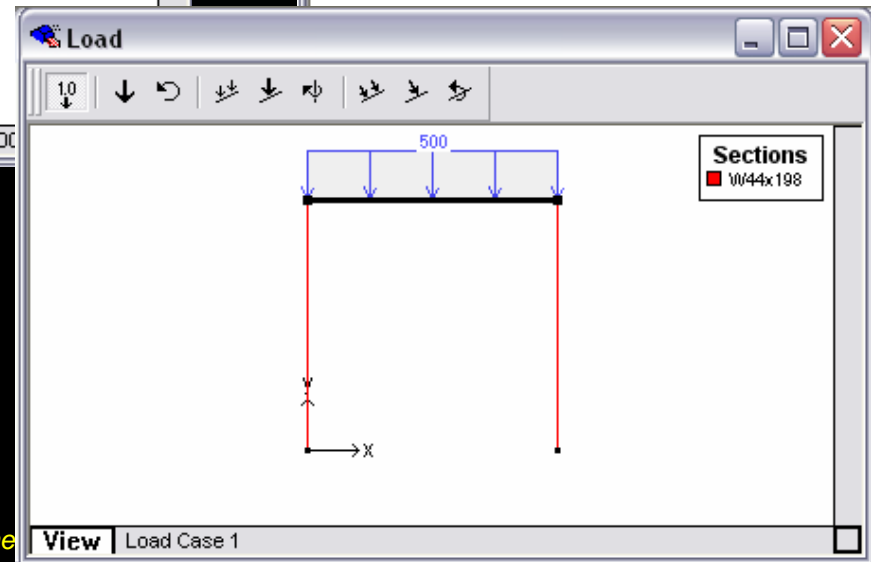
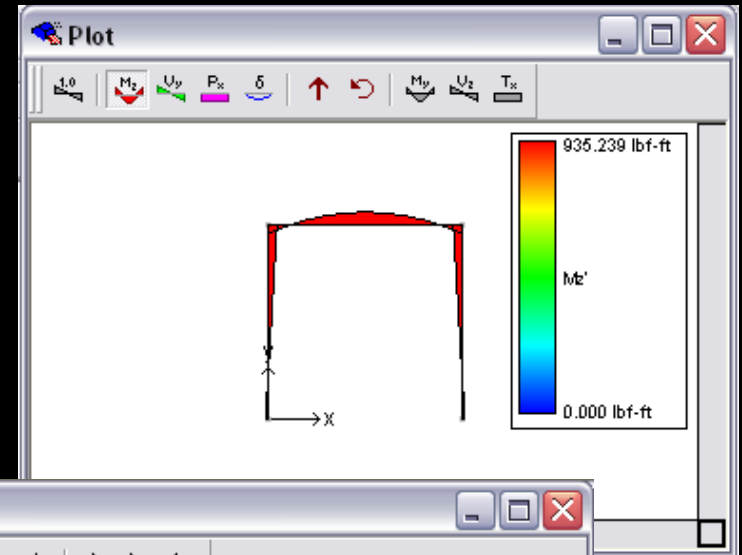
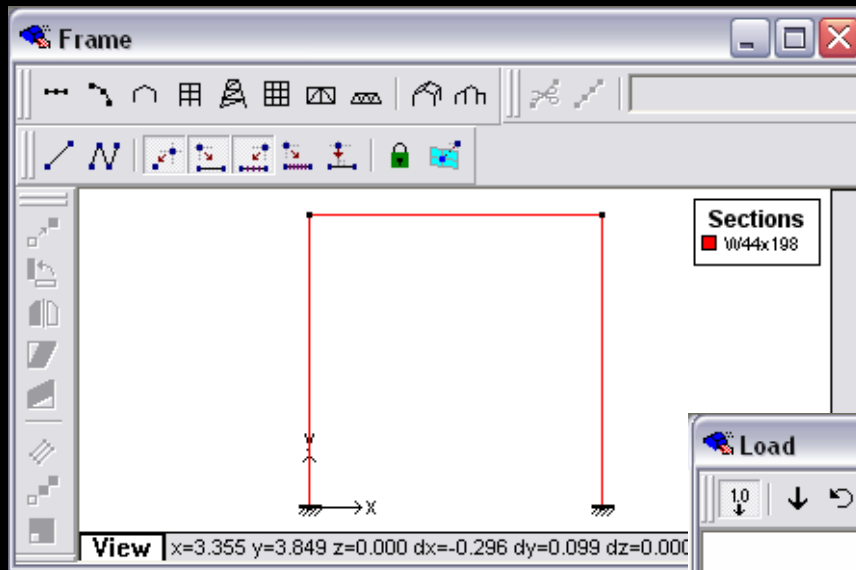
Rigid Frame Design

- column effective length, k



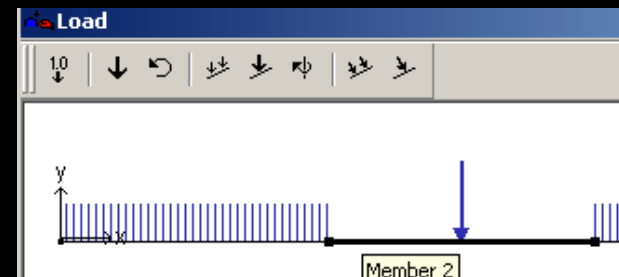
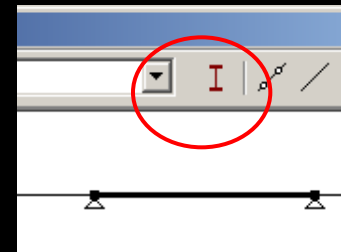
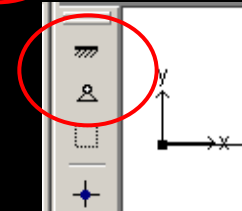
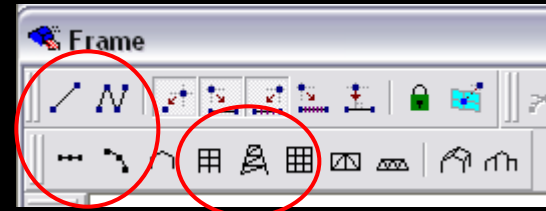
Tools – Multiframe

- *in computer lab*



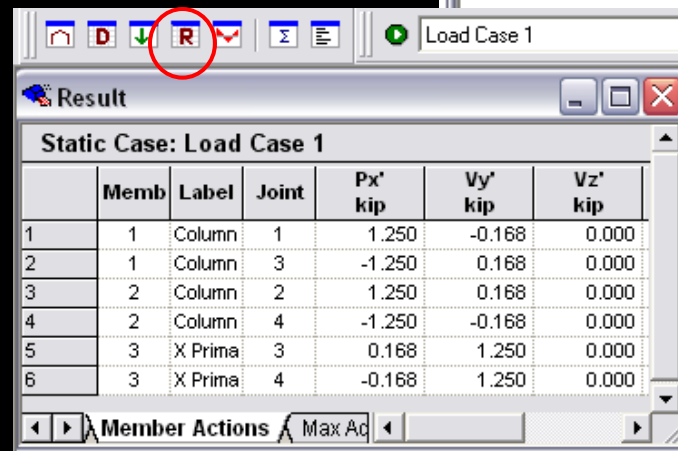
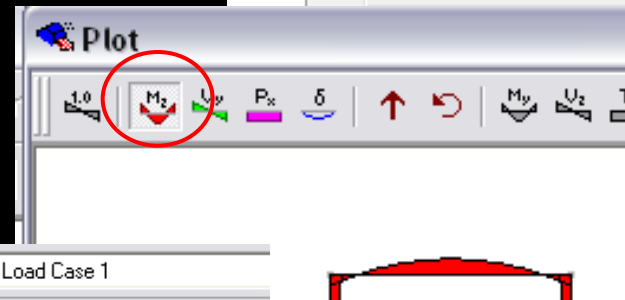
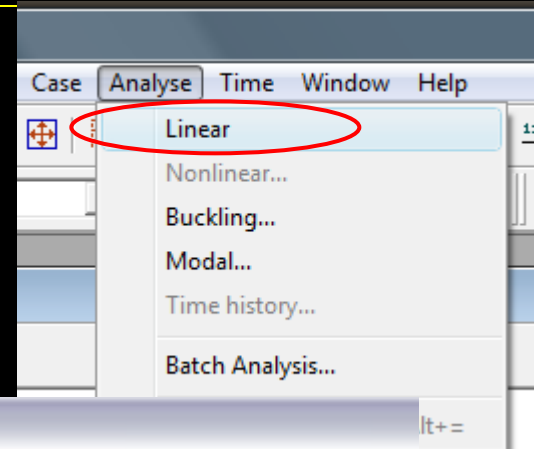
Tools – Multiframe

- *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*



A screenshot of the 'Result' window in a software application. The 'R' icon in the toolbar is circled in red. The window displays a table of results for 'Static Case: Load Case 1'.

	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