APPLIED ARCHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS

ARCH 631

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FALL 2013

lecture
seven

rigid frames: analysis & design

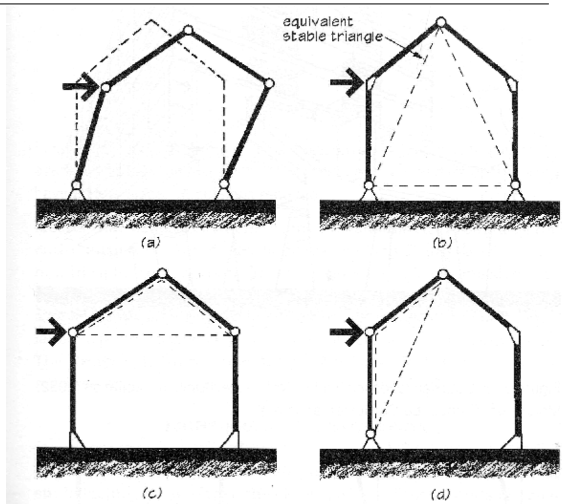
http:// nisee.berkeley.edu/godden

Rigid Frames

- *composed of linear elements*
- *member geometry fixed at joints*
  - *no relative rotation*
- *statically indeterminate*
- *see*
  - *shear*
  - *axial forces*
  - *bending moments*

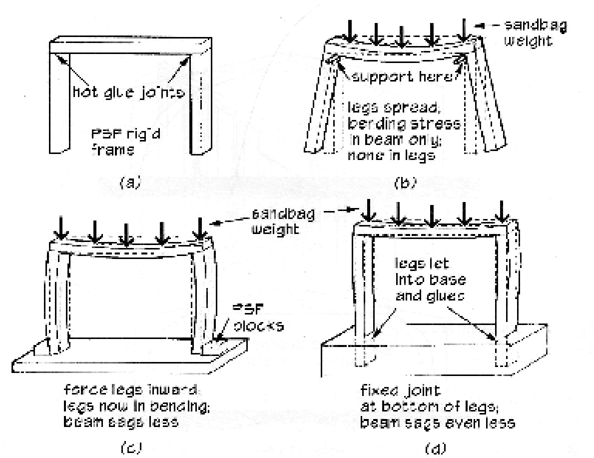
Rigid Frames

- *rigidity*
- *end constraints*
- *smaller horizontal members*
- *larger vertical members*



Rigid Frames

- *behavior*

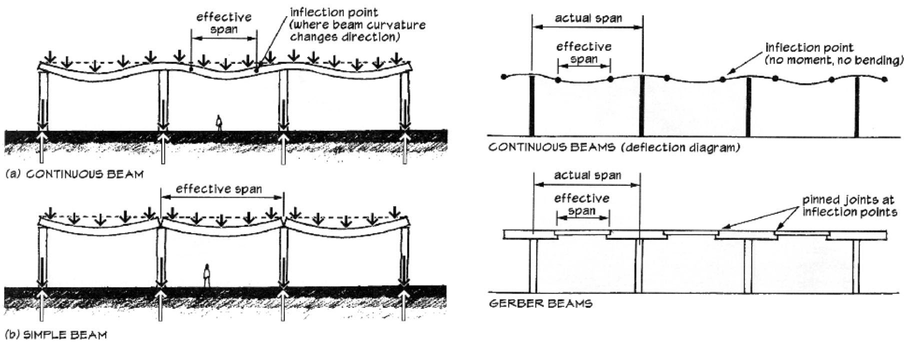


Rigid Frames

– *moments get redistributed*

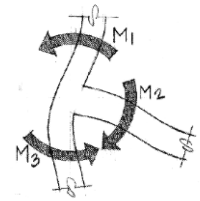
– *deflections are smaller*

– *effective column lengths are shorter*



Rigid Frames

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



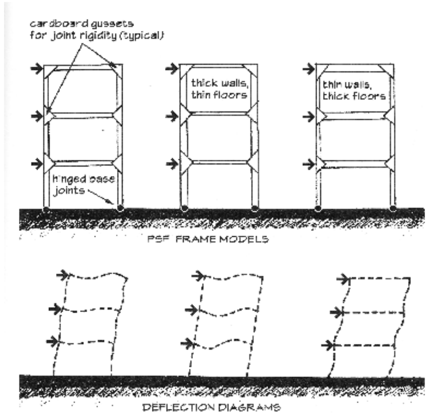
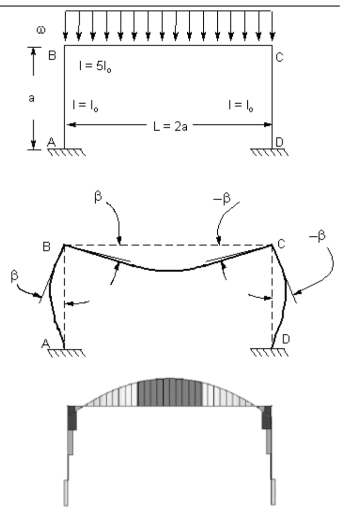


Figure 9.19: Model demonstration of the effects of varying the stiffness of beams and columns when a building frame is subjected to lateral loads.

Rigid Frame Analysis

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



Rigid Frame Analysis

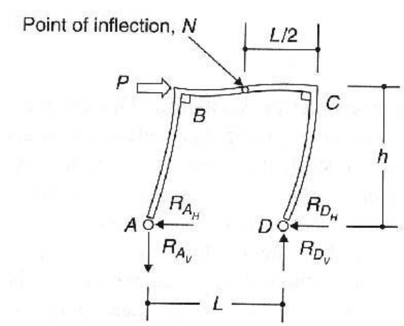
– *need support reactions*

– *free body diagram each member*

– *end reactions are equal and opposite on next member*

– *"turn" member like beam*

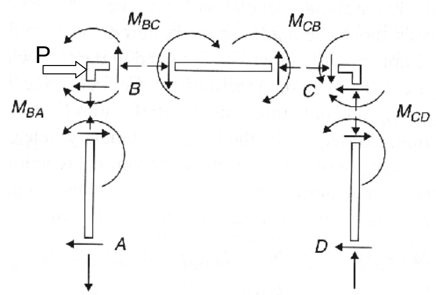
– *draw V & M*

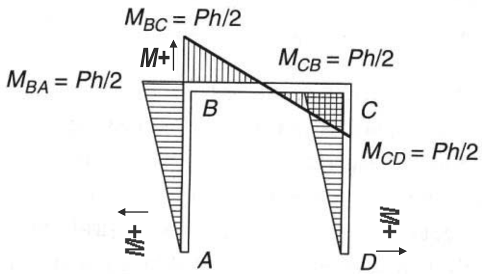


Rigid Frame Analysis

– FBD & M

- opposite end reactions at joints





Analysis Methods

- computer-based
  - <u>matrix analysis</u> or <u>finite element analysis</u>
  - equilibrium
  - support conditions
  - joint locations
  - relative stiffness of members
  - output
    - deflections
    - member forces

http://eng.midasuser.com

Analysis Methods

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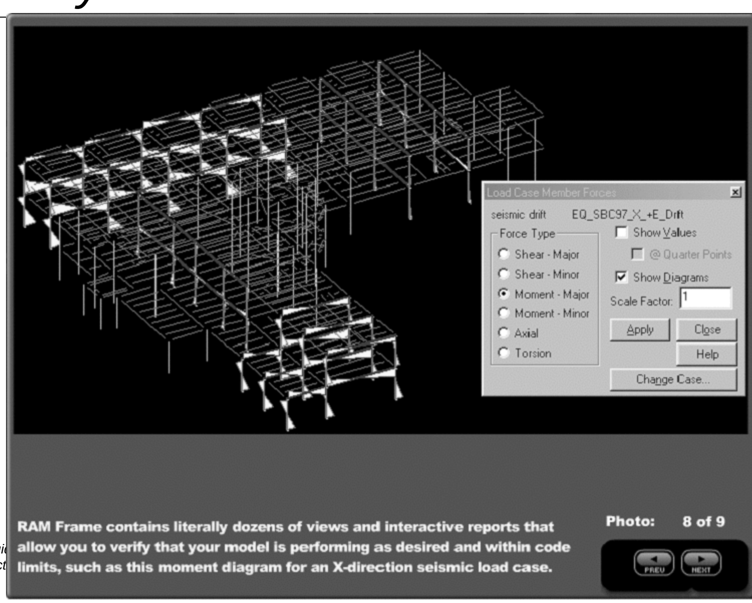
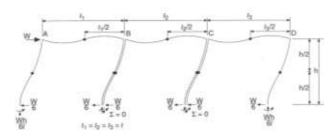


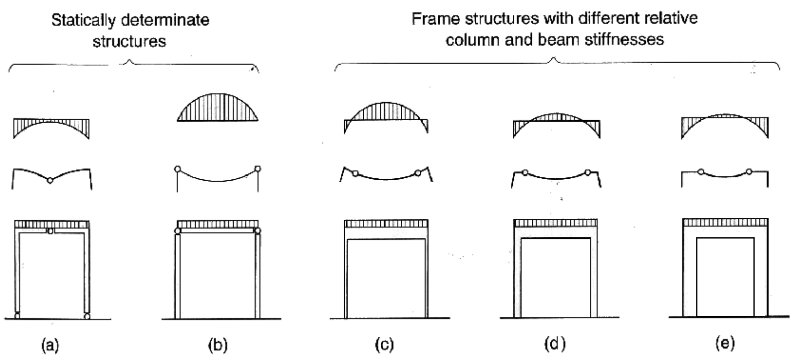
Analysis Methods

- approximate methods
  - presume where <u>inflection points</u> occur in deformed shape
  - these points have <u>zero moment</u>
  - "portal method"
    - hinge is placed at the center of each girder
    - hinge is placed at the center of each column
    - shear at interior columns is twice that of exterior columns



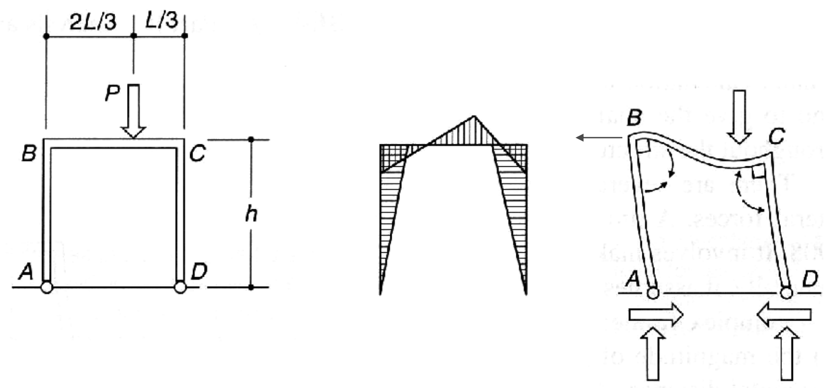
Rigid Frames

- member sizes do affect behavior
- location of inflection points critical



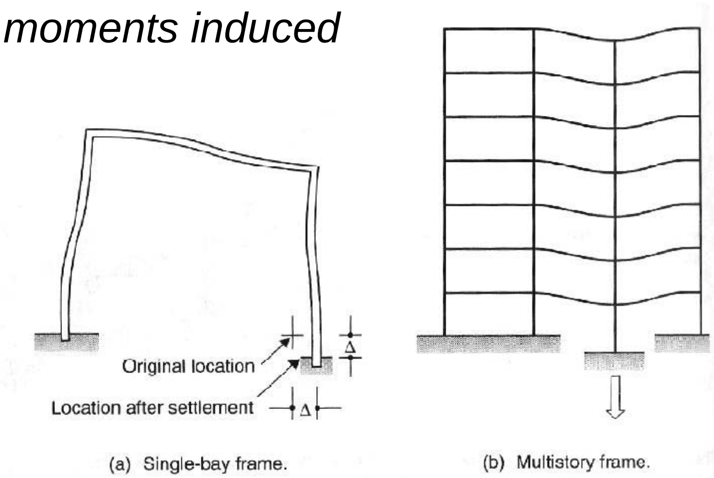
Sidesway

- translation with vertical load



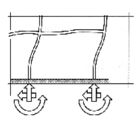
Support Settlements

- moments induced



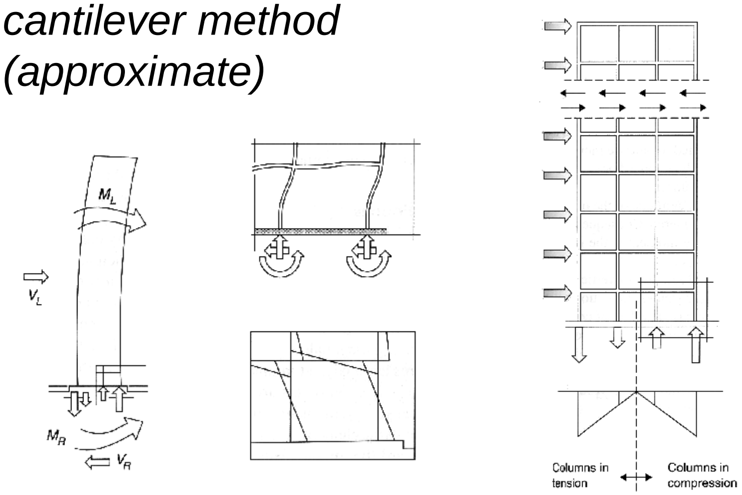
Multistory Frame Analysis

- cantilever method (approximate)
  - point of inflection at midspan of each beam
  - point of inflection at midheight of each column
  - axial force in each column proportional to the horizontal distance of that column from the centroid of all columns in the story
  - centroids are "average" locations

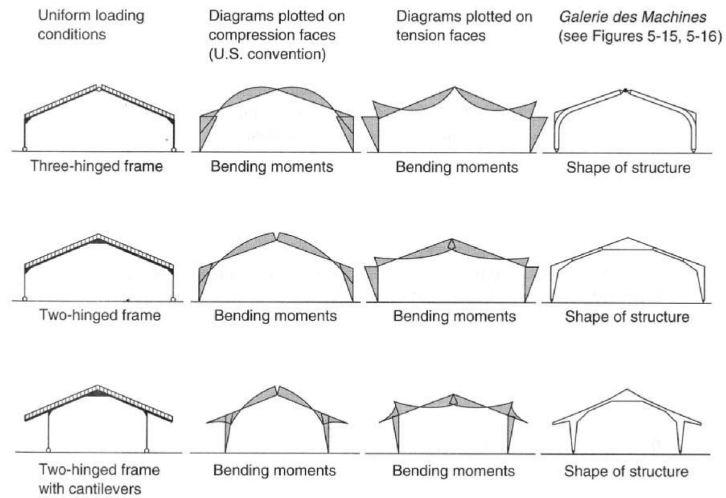


Multistory Frame Analysis

- *cantilever method (approximate)*

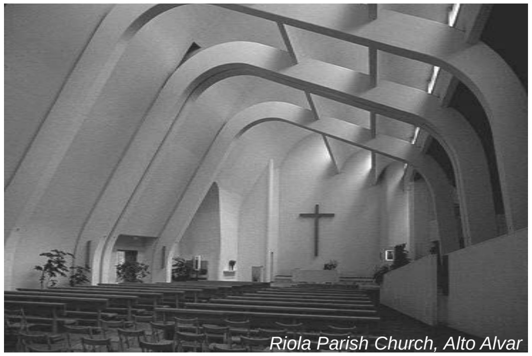


Rigid Frame Design - Types



Rigid Frame Design

- *materials*
  - *steel*
  - *monolithic concrete*
  - *laminated wood*
- *forms*
  - *small*
    - *single story, gabled frame, portal, hinged...*
  - *large - multistory*



Riola Parish Church, Alto Alvar
www.greatbuildings.com

Rigid Frame Design

- *forms*
  - *small*
  - *large*

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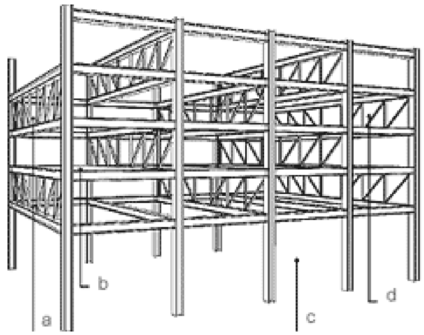
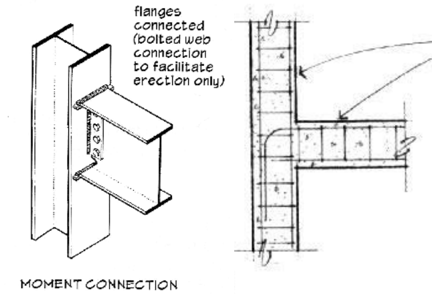
Rigid Frame Design

- staggered truss
  - rigidity
  - clear stories



Rigid Frame Design

- connections
  - steel
  - concrete



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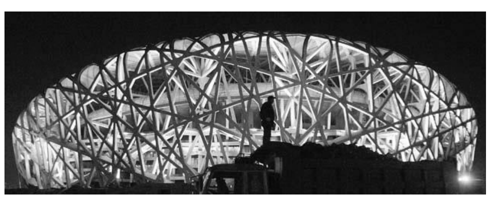
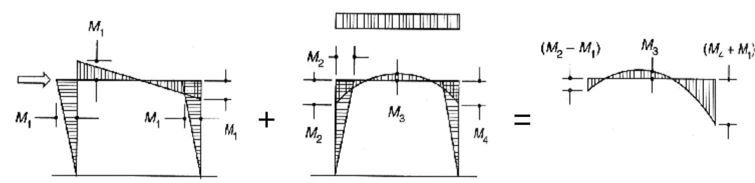
Rigid Frame Design

- considerations
  - need frame?
  - minimize moment (affects member size)
  - increasing stiffness
    - redistributes moments
    - limits deflections
  - joint rigidity
  - support types



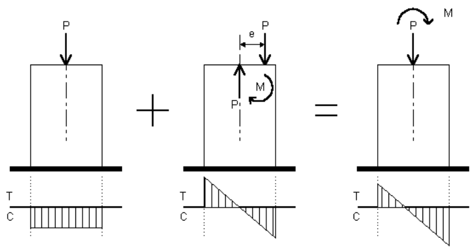
Rigid Frame Design

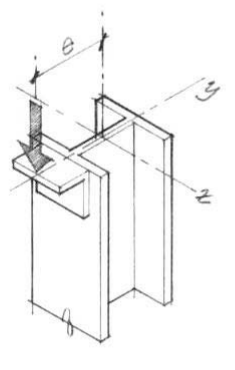
- load combinations
  - worst case for largest moments...
  - wind direction can increase moments



Combined Stresses

- *beam-columns have moments at end*
- *often due to eccentric load*



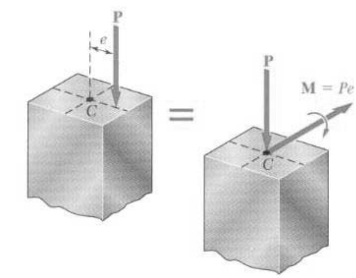


Combined Stresses & Design

– *axial + bending*

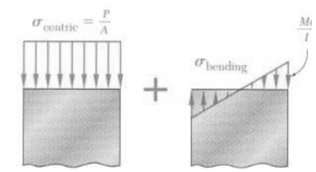
$$f_{\max} = \frac{P}{A} + \frac{Mc}{I}$$

$$M = P \cdot e$$



– *design*

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

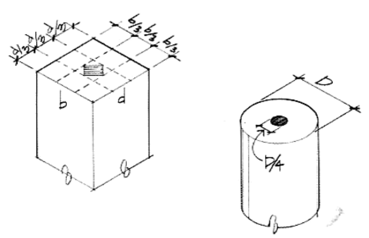


Eccentric Loading

– *find e such that the minimum stress = 0*

$$f_{\min} = \frac{P}{A} - \frac{(Pe)c}{I} = 0$$

– *area defined by e from centroid is the* *<u>kern</u>*



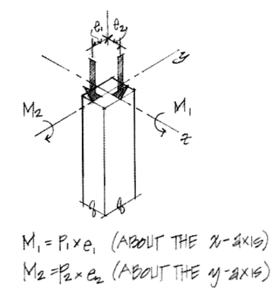
Biaxial Bending

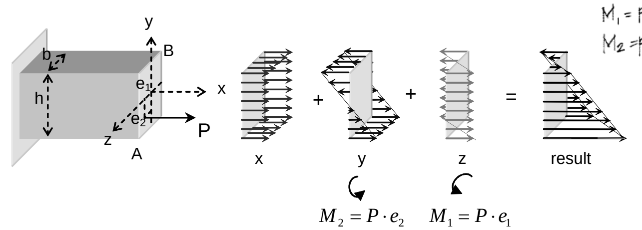
– *when there is moment in two directions*

$$M_1 = P \cdot e_1 \qquad M_2 = P \cdot e_2$$

$$f_{\max} = \frac{P}{A} + \frac{M_1 y}{I} + \frac{M_2 z}{I}$$

– *<u>biaxial bending</u>*





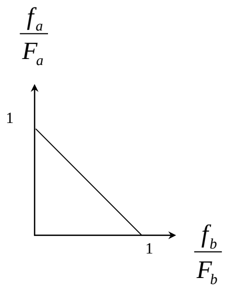
Stress Limit Conditions

– *ASD interaction formula*

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

– *with biaxial bending*

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

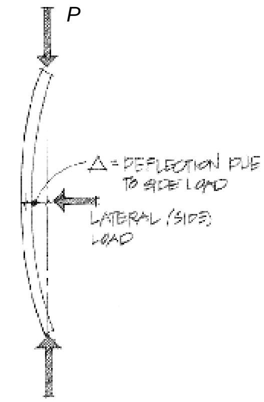


Stress Limit Conditions

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

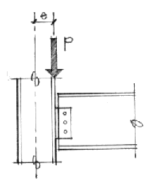
– *P-Δ effect*

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

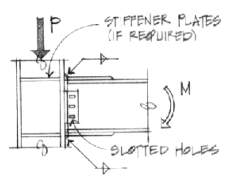


Design for Combined Stress

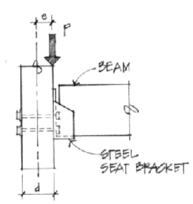
- *satisfy*
  - *strength*
  - *stability*
- *pick*
  - *section*



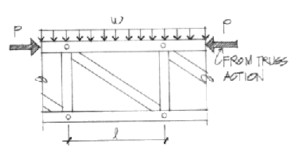
(a) Framed beam (shear) connection.
e = *Eccentricity*; M = P × e



(b) Moment connection (rigid frame).
M = *Moment due to beam bending*



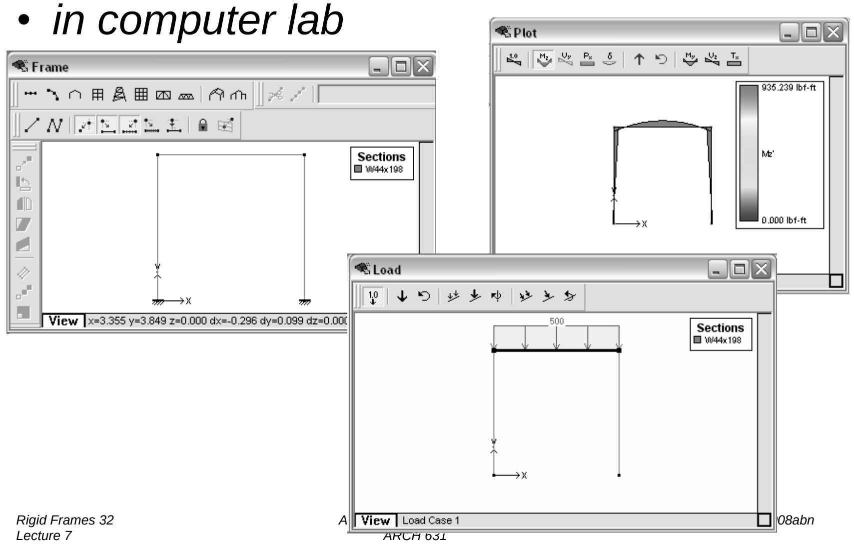
(c) Timber beam–column connection.
e = d/2 = *eccentricity*; M = P × e



(d) Upper chord of a truss—compression plus bending.
$M = \frac{\omega l^2}{8}$

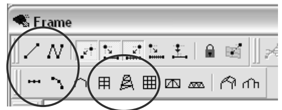
Tools – Multiframe4D

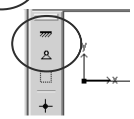
- *in computer lab*

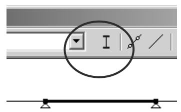


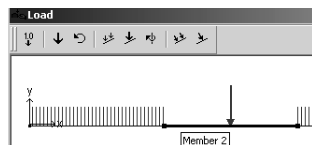
Tools – Multiframe4D

- *frame window*
  - *define frame members*
    - *or pre-defined frame*
  - *select points, assign supports*
  - *select members, assign <u>section</u>*
  - *load window*
  - *select point or member, add point or distributed loads*



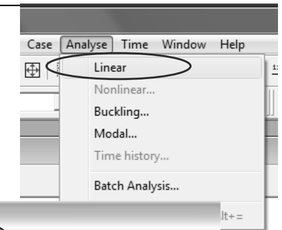


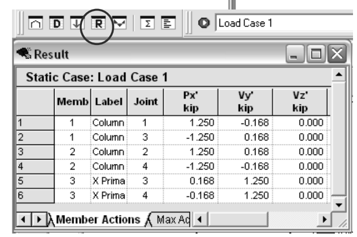




Tools – Multiframe4D

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





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