APPLIED ARCHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS
ARCH 631
DR. ANNE NICHOLS
FALL 2012

lecture
seven

http:// nisee.berkeley.edu/godden

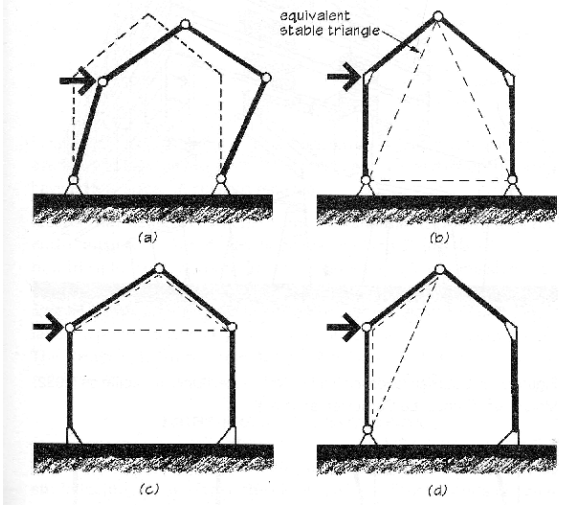
rigid frames: analysis & design

Rigid Frames

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

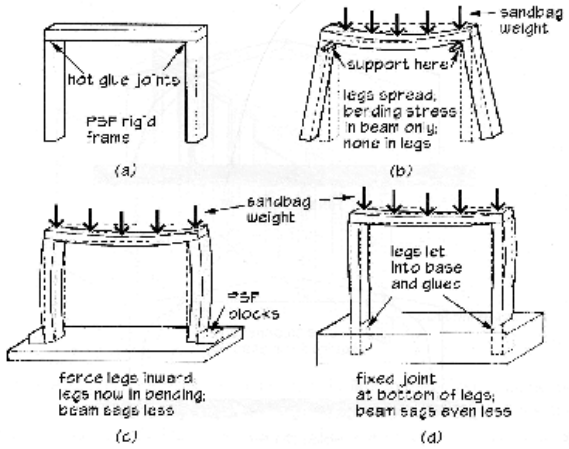
Rigid Frames

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



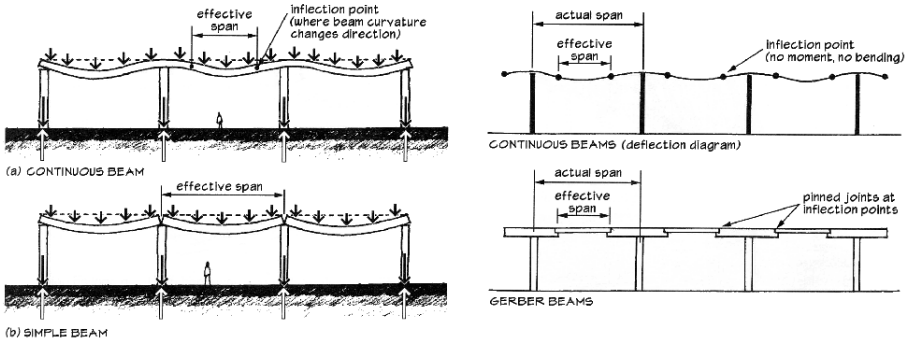
Rigid Frames

- *behavior*



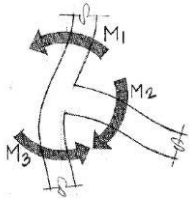
Rigid Frames

- *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*



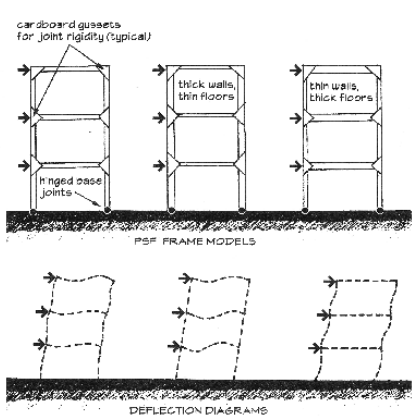
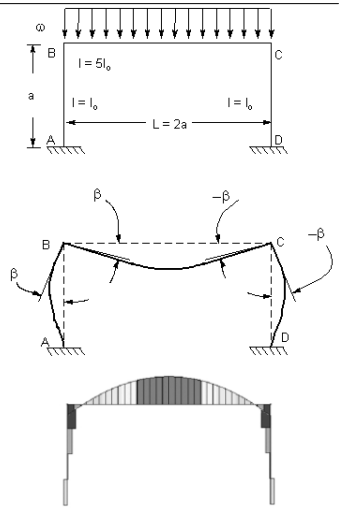


Figure 9.19: Model demonstration of the effects of varying the stiffness of beams and columns when a building frame is subjected to lateral loads.

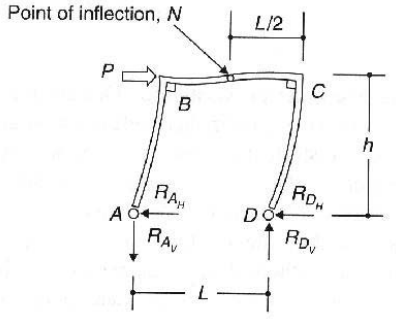
Rigid Frame Analysis

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



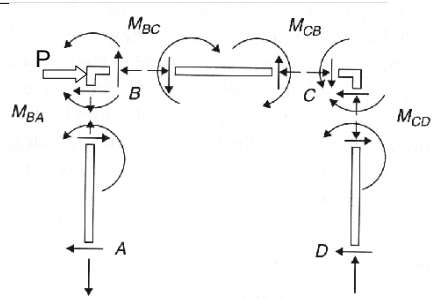
Rigid Frame Analysis

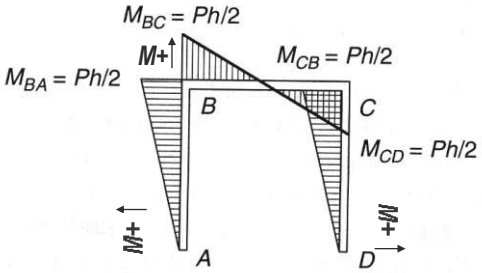
- *need support reactions*
- *free body diagram each member*
- *end reactions are equal and opposite on next member*
- *"turn" member like beam*
- *draw V & M*



Rigid Frame Analysis

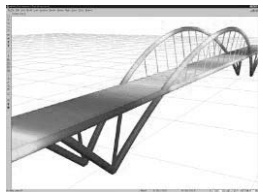
- *FBD & M*
  - *opposite end reactions at joints*





Analysis Methods

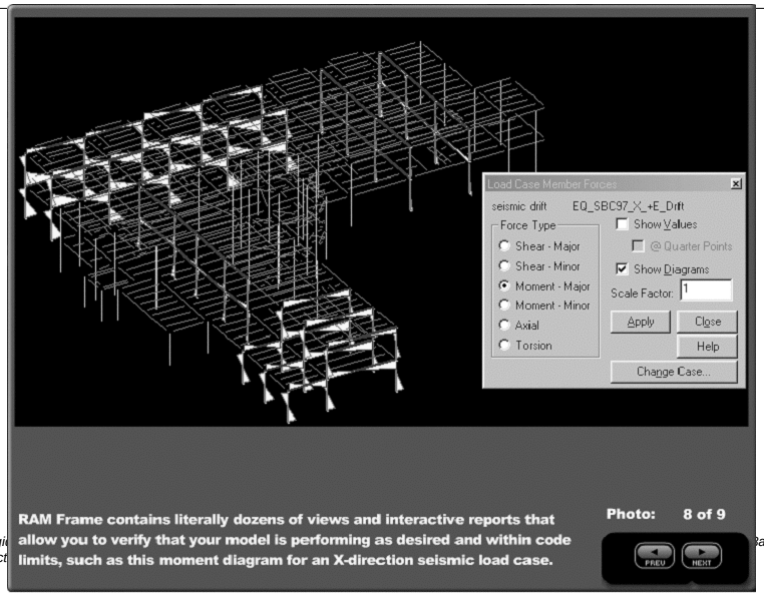
- *computer-based*
  - *matrix analysis or finite element analysis*
  - *equilibrium*
  - *support conditions*
  - *joint locations*
  - *relative stiffness of members*
  - *output*
    - *deflections*
    - *member forces*



http://eng.midasuser.com

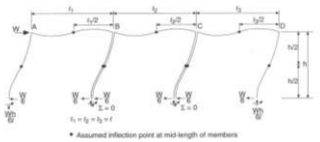
Analysis Methods

-



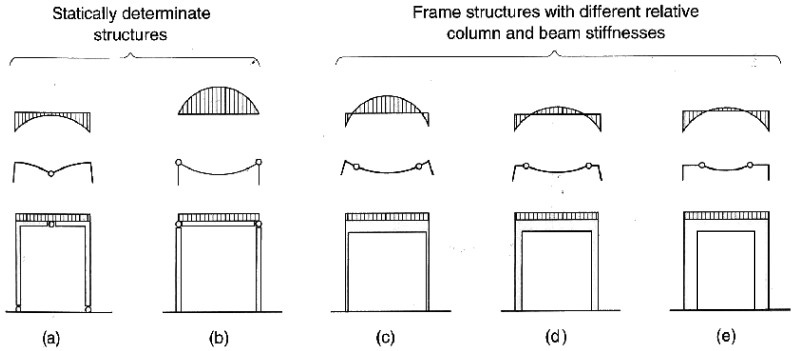
Analysis Methods

- *approximate methods*
  - *presume where inflection points occur in deformed shape*
  - *these points have zero moment*
  - *“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*



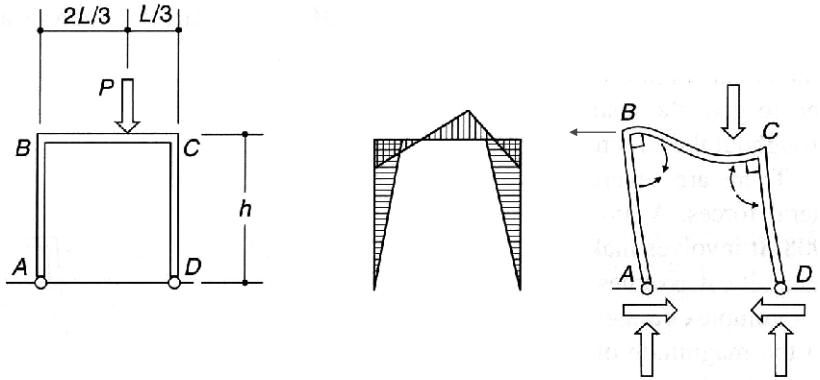
Rigid Frames

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



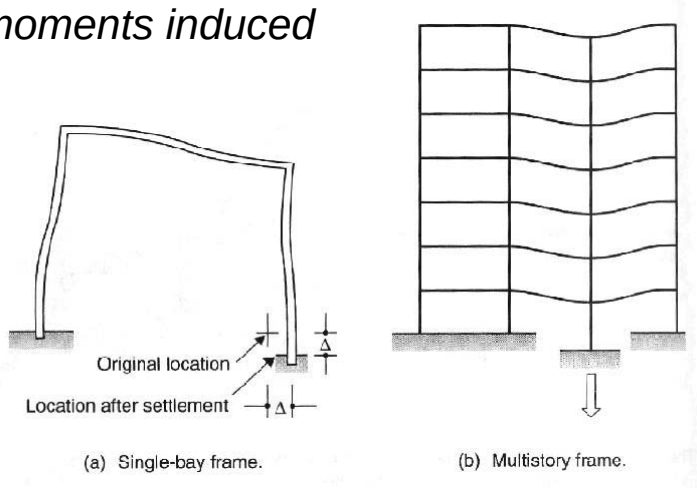
Sidesway

- *translation with vertical load*



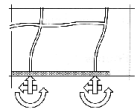
Support Settlements

- *moments induced*



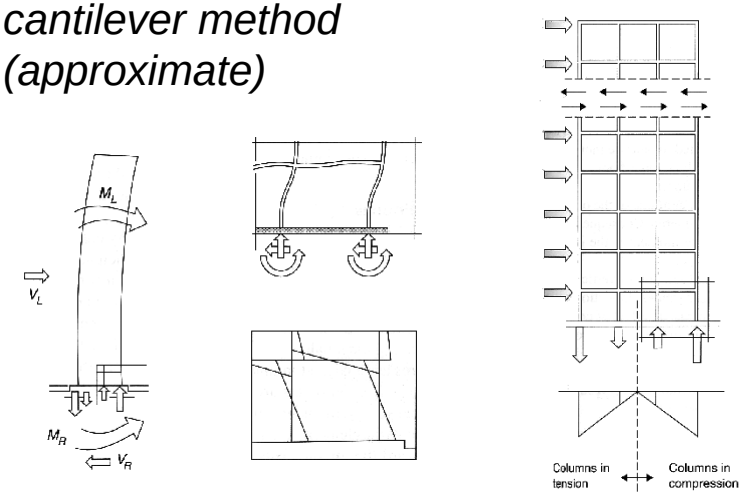
Multistory Frame Analysis

- *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*
  - *<u>centroids</u> are "average" locations*

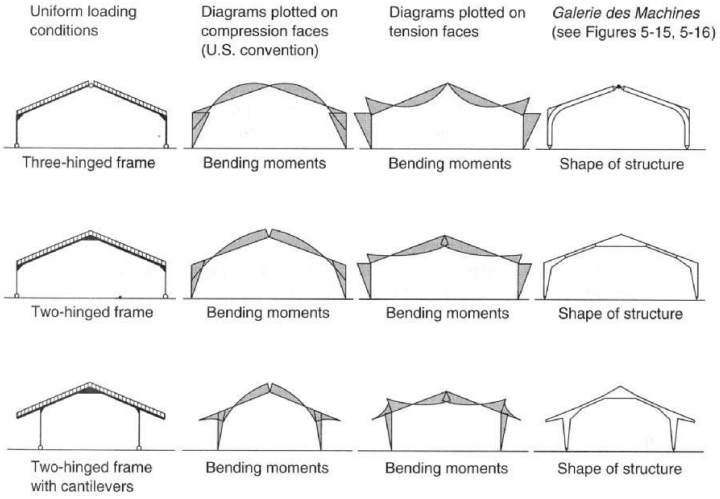


Multistory Frame Analysis

- *cantilever method (approximate)*

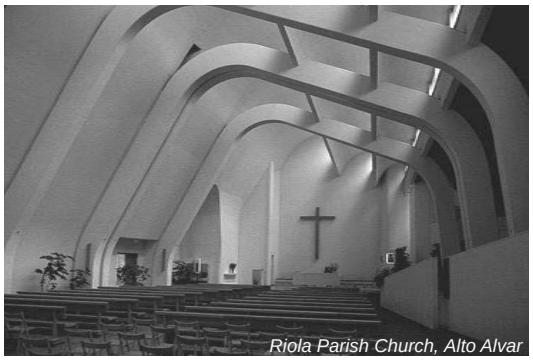


Rigid Frame Design - Types



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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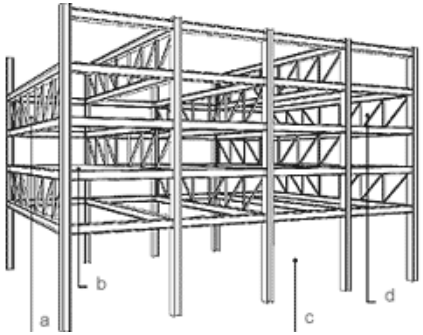
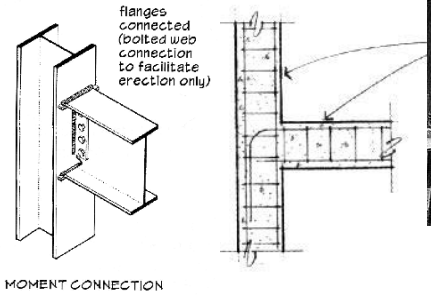
Rigid Frame Design

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



Rigid Frame Design

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



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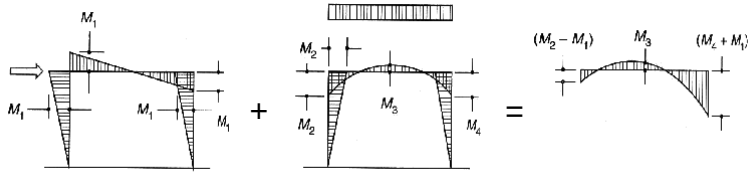
Rigid Frame Design

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

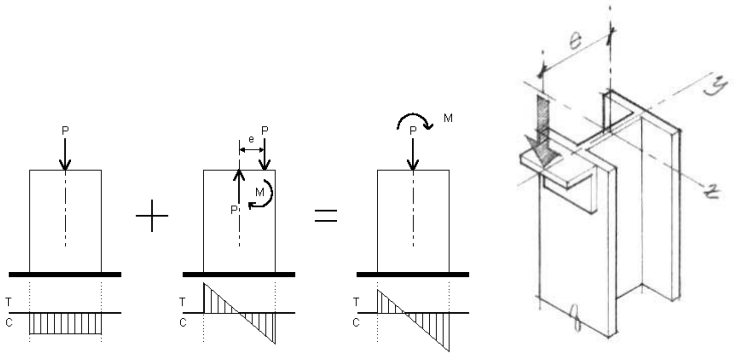
Rigid Frame Design

- *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*

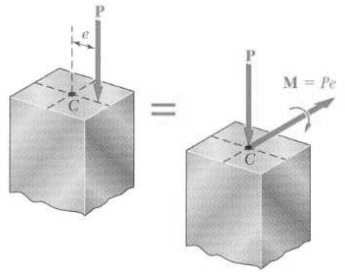


Combined Stresses & Design

– *axial + bending*

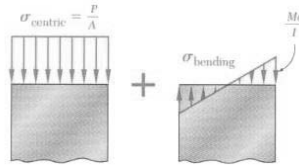
$$f_{\max} = \frac{P}{A} + \frac{Mc}{I}$$

$$M = P \cdot e$$



– *design*

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

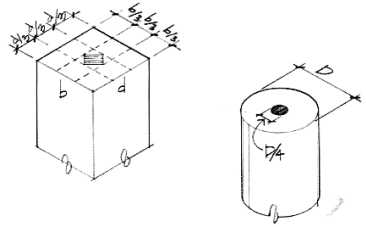


Eccentric Loading

– *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>*



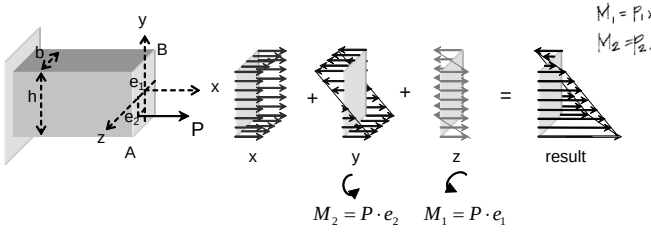
Biaxial Bending

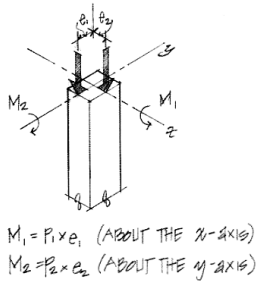
– *when there is moment in two directions*

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

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

– *<u>biaxial bending</u>*

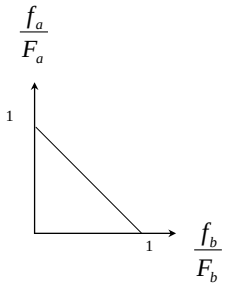




Stress Limit Conditions

– *ASD interaction formula*

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



– *with biaxial bending*

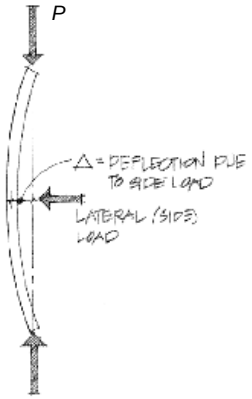
$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \le 1.0$$

Stress Limit Conditions

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

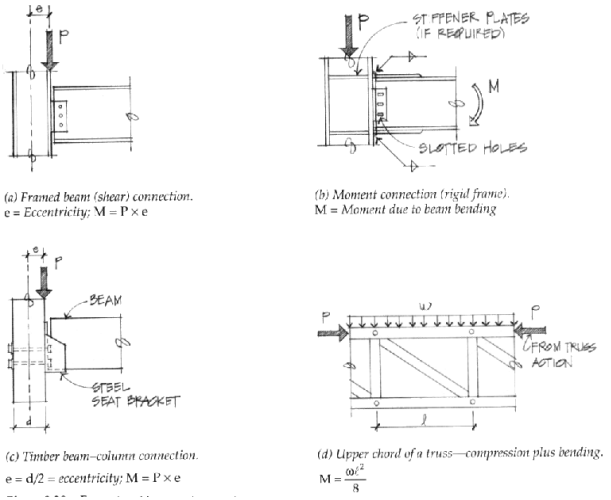
– *<u>P-Δ effect</u>*

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



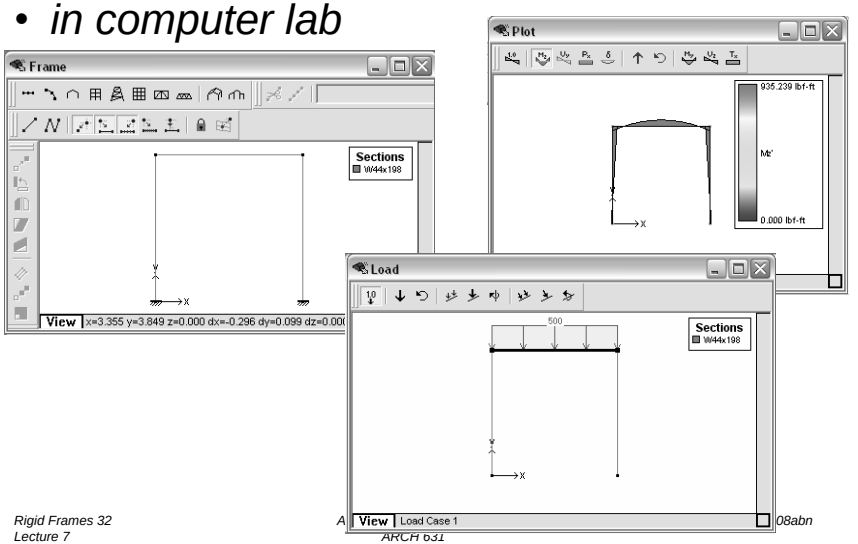
Design for Combined Stress

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



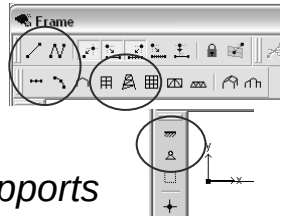
Tools – Multiframe4D

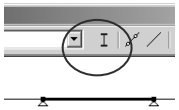
- *in computer lab*

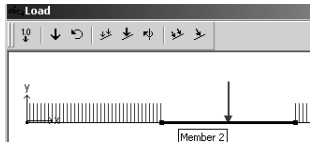


Tools – Multiframe4D

- *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 – Multiframe4D

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