

lecture
seven

**rigid frames:
analysis & design**



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

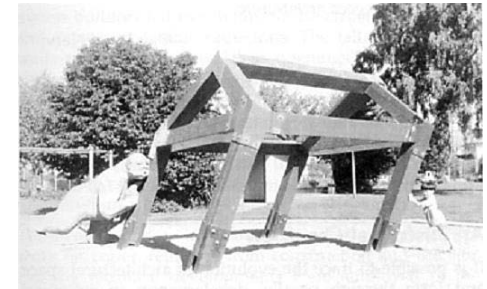
Rigid Frames 1
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Rigid Frames

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



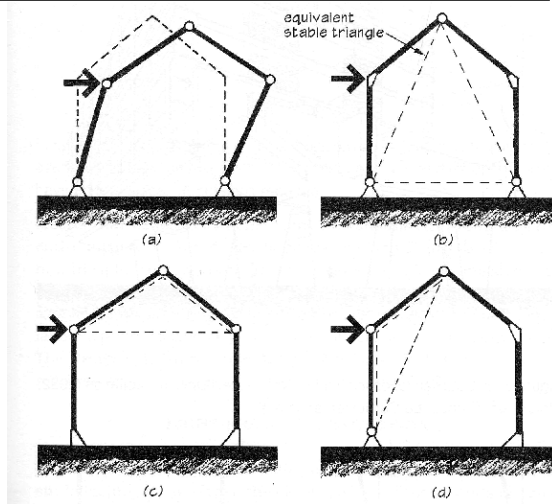
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Rigid Frames

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



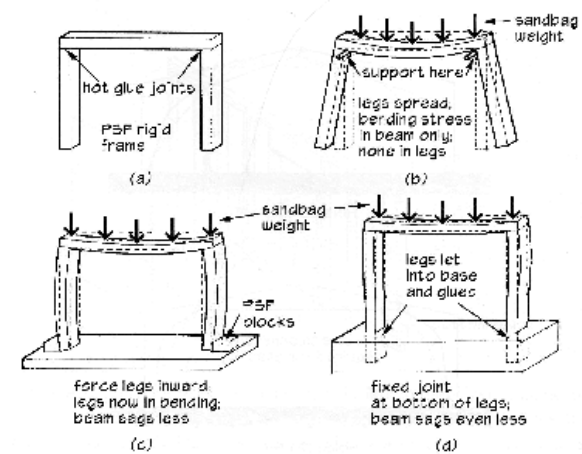
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Rigid Frames

- behavior



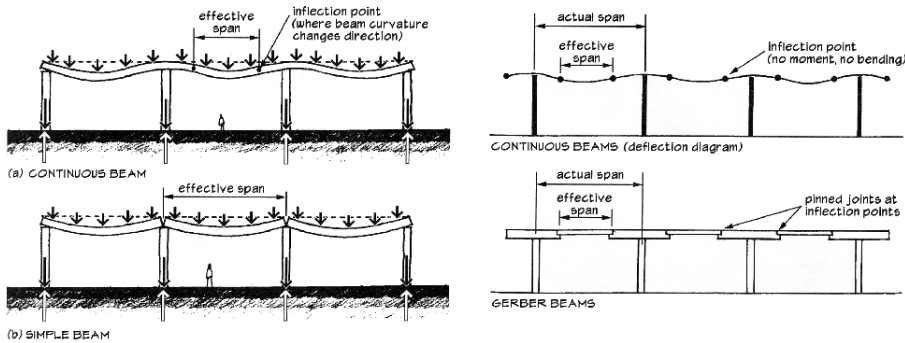
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Rigid Frames

- moments get redistributed
- deflections are smaller
- effective column lengths are shorter



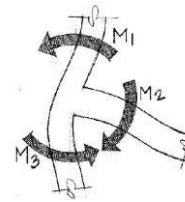
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Rigid Frames

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



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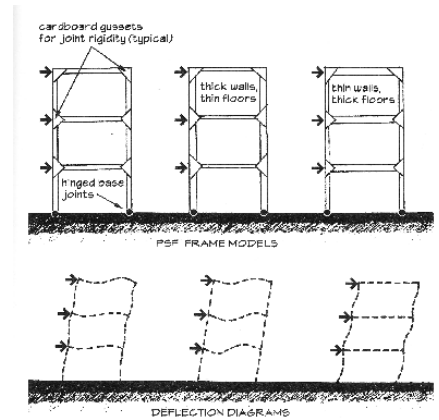
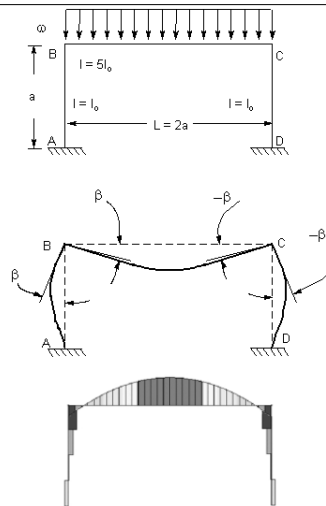


Figure 9.19: Model demonstration of the effects of varying the stiffness of beams and columns when a building frame is subjected to lateral loads.

Rigid Frame Analysis

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



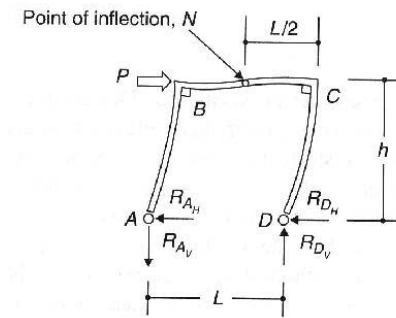
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Rigid Frame Analysis

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



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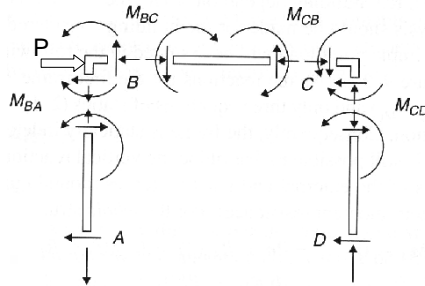
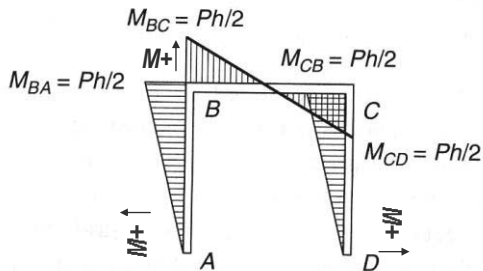
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Rigid Frame Analysis

- FBD & M

- opposite end reactions at joints



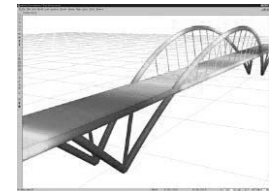
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Analysis Methods

- 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>

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Analysis Methods

RAM Frame contains literally dozens of views and interactive reports that allow you to verify that your model is performing as desired and within code limits, such as this moment diagram for an X-direction seismic load case.

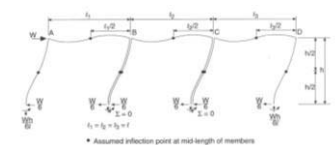
Photo: 8 of 9

Rigid
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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



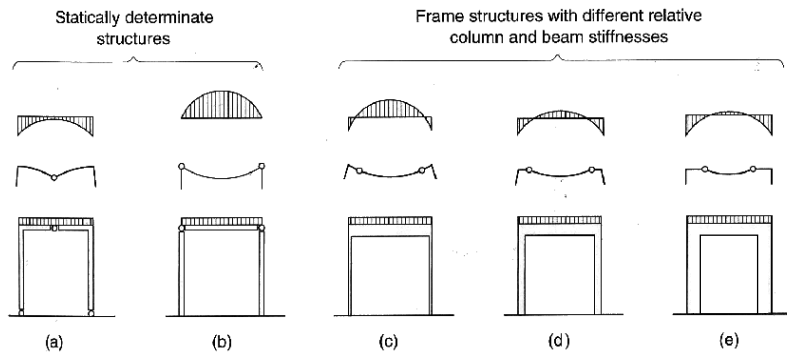
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Rigid Frames

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



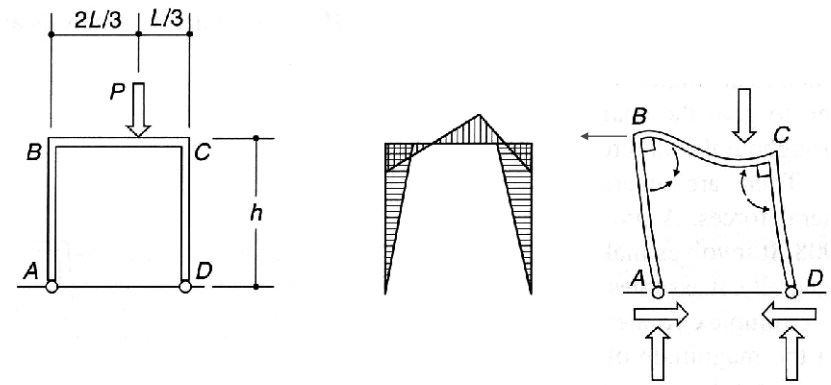
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Sidesway

- translation with vertical load



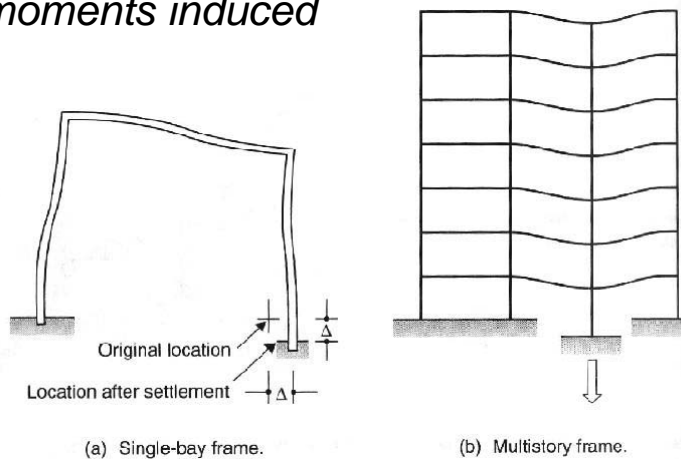
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Support Settlements

- moments induced



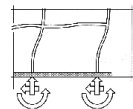
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Multistory Frame Analysis

- 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



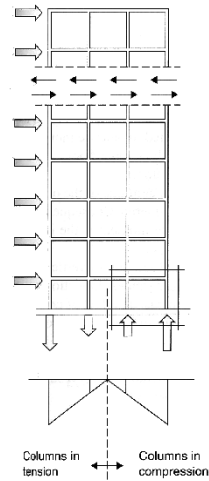
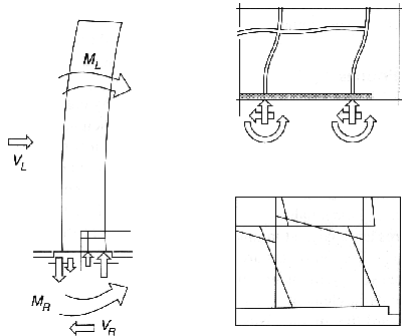
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Multistory Frame Analysis

- cantilever method (approximate)

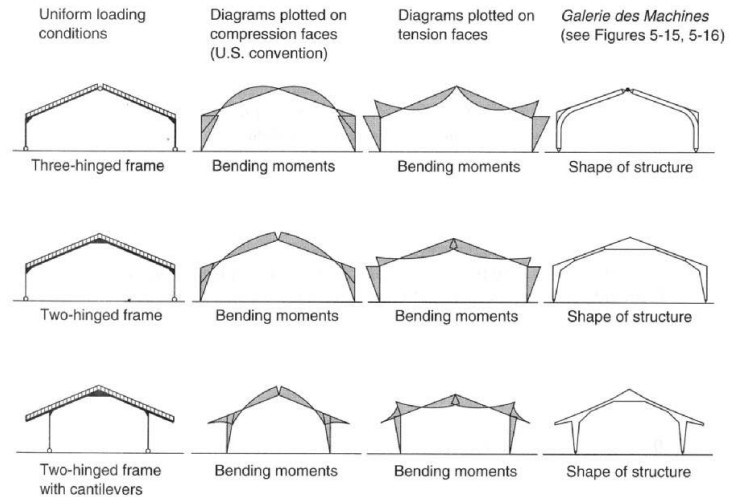


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Rigid Frame Design - Types



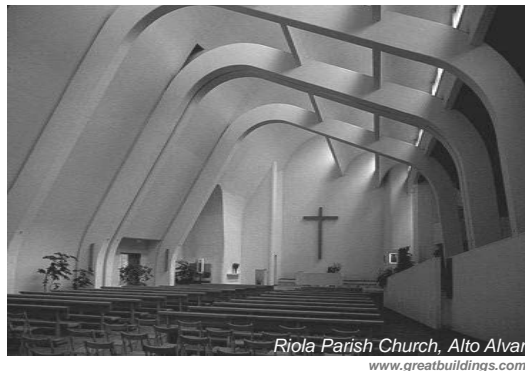
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Rigid Frame Design

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



Riola Parish Church, Alvaro Siza
www.greatbuildings.com

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Rigid Frame Design

- forms
 - small
 - large



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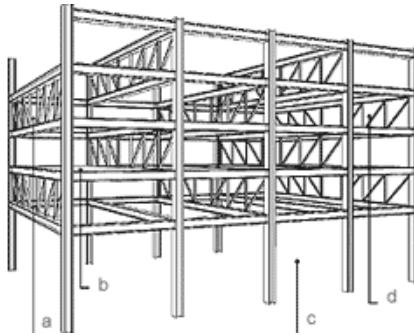
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Rigid Frame Design

- staggered truss
 - rigidity
 - clear stories



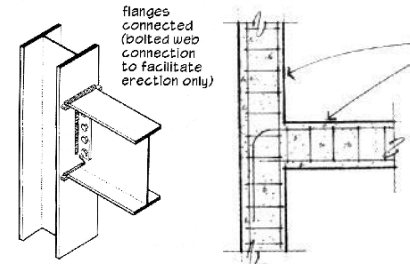
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Rigid Frame Design

- connections
 - steel
 - concrete



MOMENT CONNECTION



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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



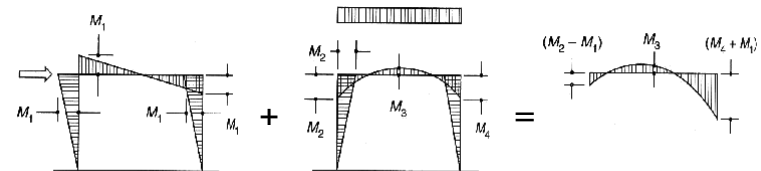
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Rigid Frame Design

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



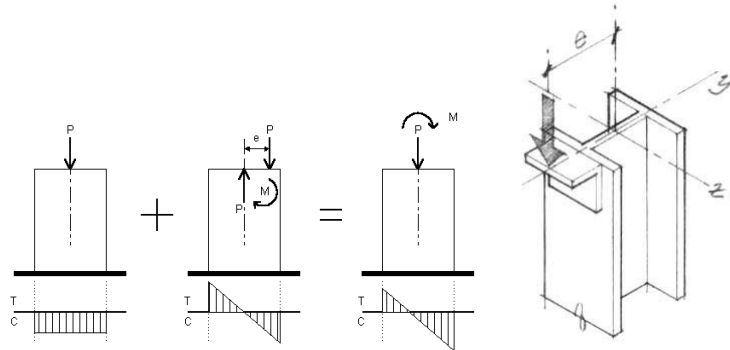
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Combined Stresses

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



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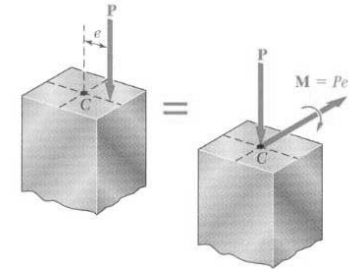
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Combined Stresses & Design

- axial + bending

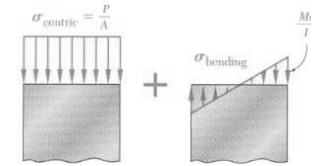
$$f_{\max} = \frac{P}{A} + \frac{Mc}{I}$$

$$M = P \cdot e$$



- design

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



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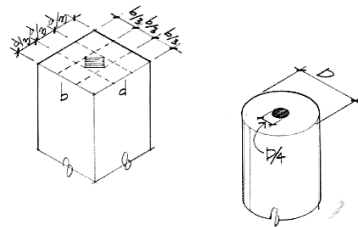
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Eccentric Loading

- 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 kern



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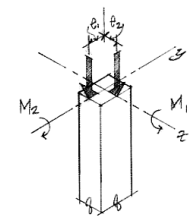
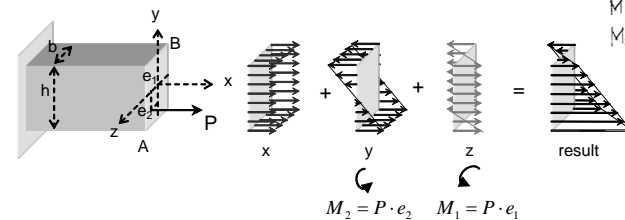
Biaxial Bending

- when there is moment in two directions

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

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

- biaxial bending



$$M_1 = P \cdot e_1 \quad (\text{ABOUT THE } x\text{-axis})$$

$$M_2 = P \cdot e_2 \quad (\text{ABOUT THE } z\text{-axis})$$

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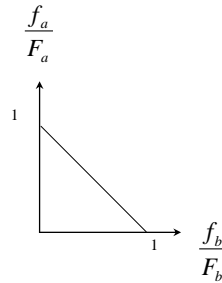
Stress Limit Conditions

– ASD interaction formula

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

– with biaxial bending

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

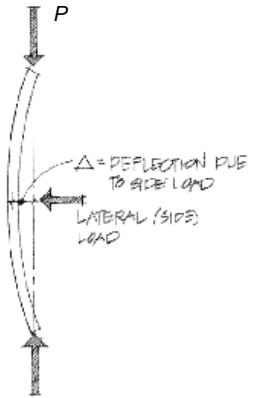


Stress Limit Conditions

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

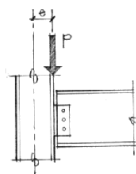
– P-Δ effect

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

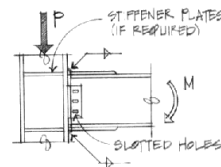


Design for Combined Stress

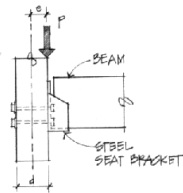
- satisfy
 - strength
 - stability
- pick
 - section



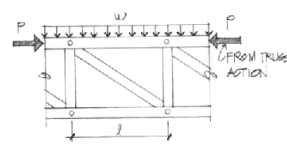
(a) Framed beam (shear) connection.
 $e = \text{Eccentricity}; M = P \times e$



(b) Moment connection (rigid frame).
 $M = \text{Moment due to beam bending}$



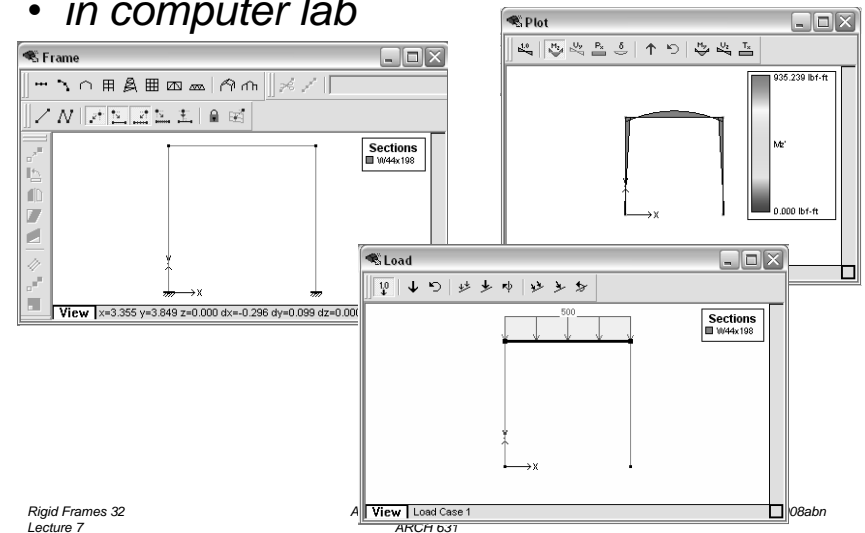
(c) Timber beam-column connection.
 $e = d/2 = \text{eccentricity}; M = P \times e$



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

Tools – Multiframe4D

- in computer lab



Tools – Multiframe4D

- *frame window*

- *define frame members*

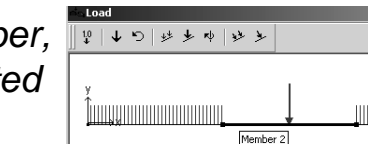
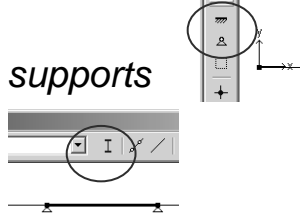
- *or pre-defined frame*

- *select points, assign supports*

- *select members, assign section*

- *load window*

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



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Tools – Multiframe4D

- *to run analysis choose*

- *Analyze menu*

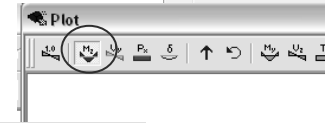
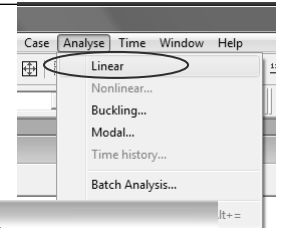
- *Linear*

- *plot*

- *choose options*

- *results*

- *choose options*

| Member | 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 | X Prima | 3 | 0.168 | 1.250 | 0.000 |
| 6 | X Prima | 4 | -0.168 | 1.250 | 0.000 |

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