

ELEMENTS OF ARCHITECTURAL STRUCTURES:  
FORM, BEHAVIOR, AND DESIGN

ARCH 614

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SPRING 2013

lecture  
eleven

rigid frames:  
compression & bending

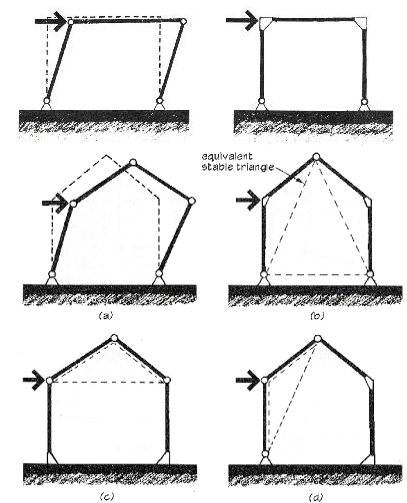


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Rigid Frames

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



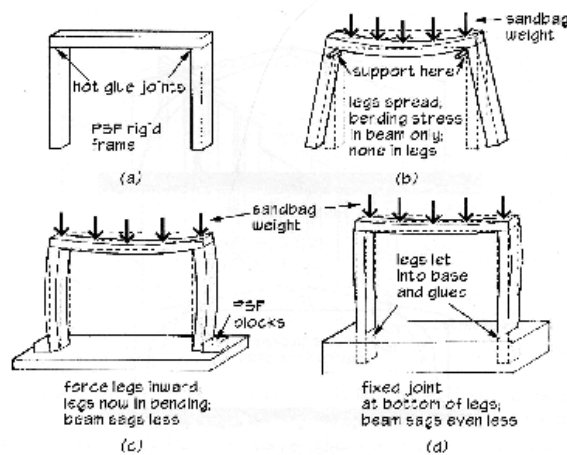
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Rigid Frames

- behavior



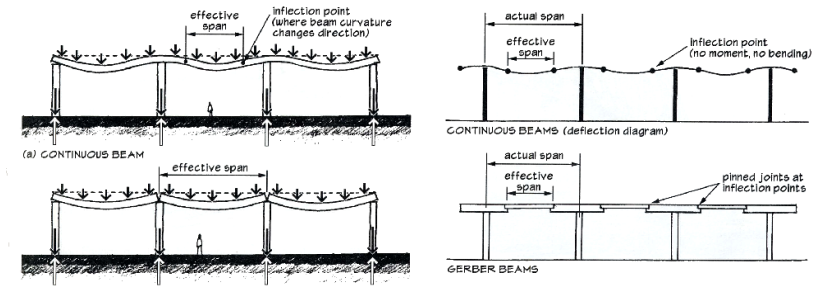
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Rigid Frames

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



(b) SIMPLE BEAM  
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# Rigid Frames

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

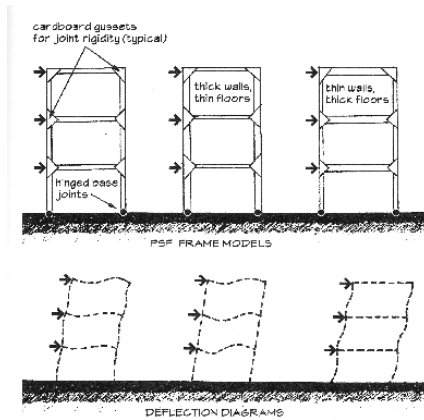
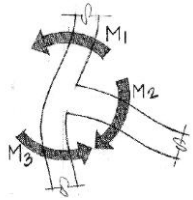


Figure 9.19: Modal demonstration of the effects of varying the stiffness of beams and columns when a building frame is subjected to lateral loads.

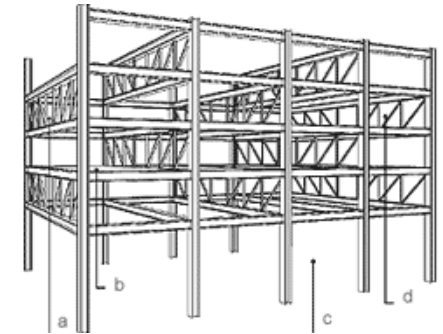
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# Rigid Frames

- staggered truss
  - rigidity
  - clear stories



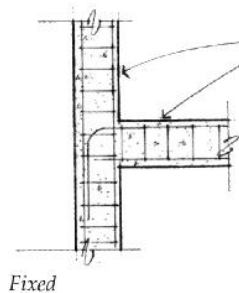
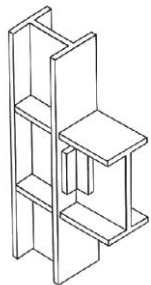
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# Rigid Frames

- connections
  - steel
  - concrete



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# Braced Frames

- pin connections
- bracing to prevent lateral movements



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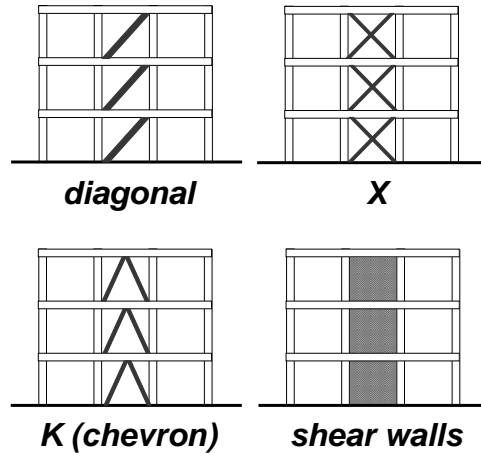
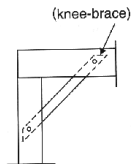
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## Braced Frames

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



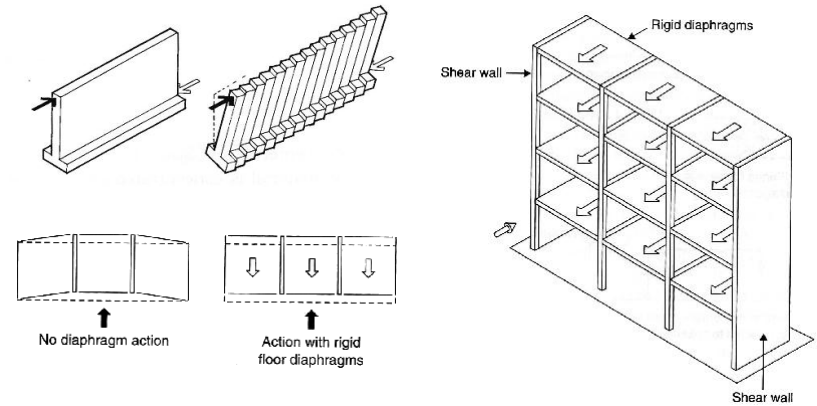
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## Shear Walls

- resist lateral load in plane with wall



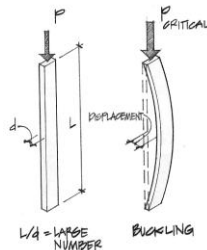
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## Compression Members

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



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## Column Buckling

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



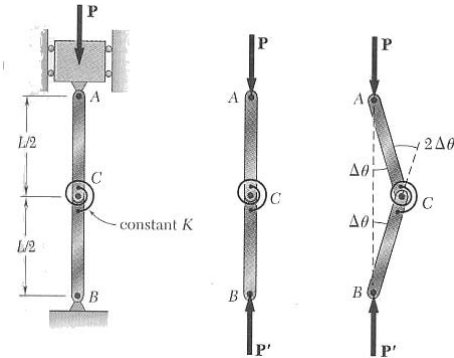
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# Modeling

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



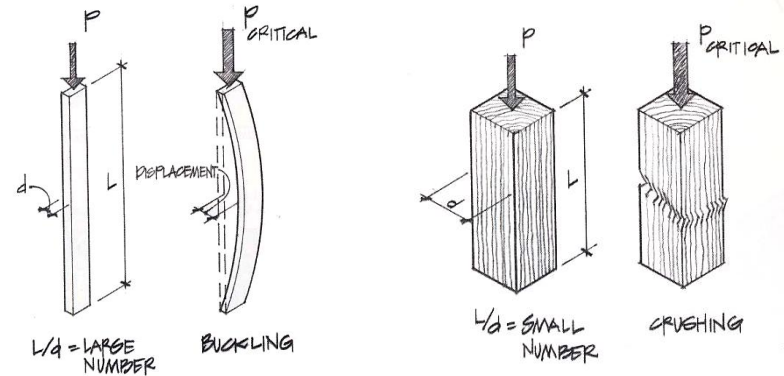
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# Effect of Length

- long & slender
- short & stubby



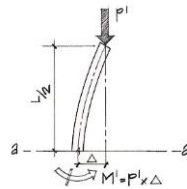
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# Buckling Load

- 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).

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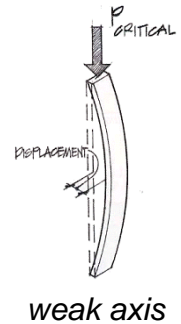
# Critical Stress

- short columns

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

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

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



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

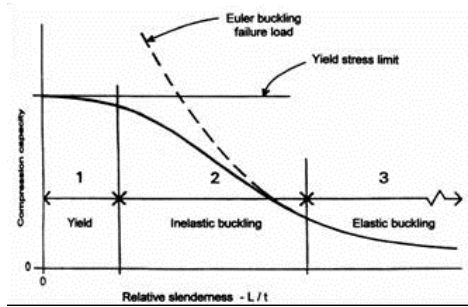
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# Critical Stresses

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



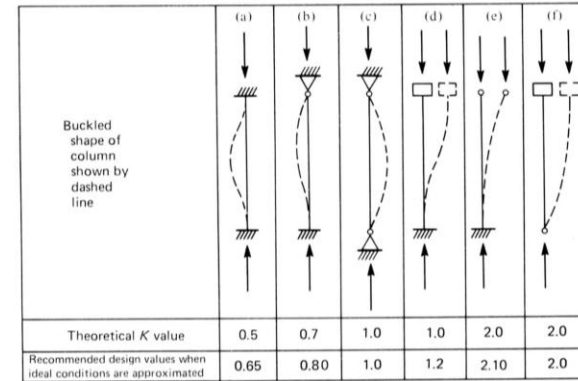
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# Effective Length

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



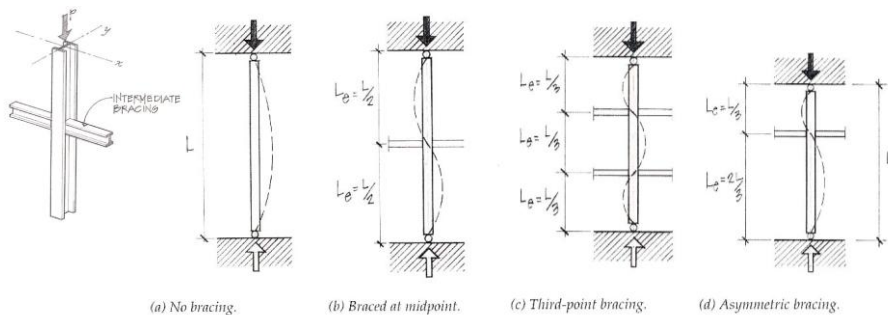
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# Bracing

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



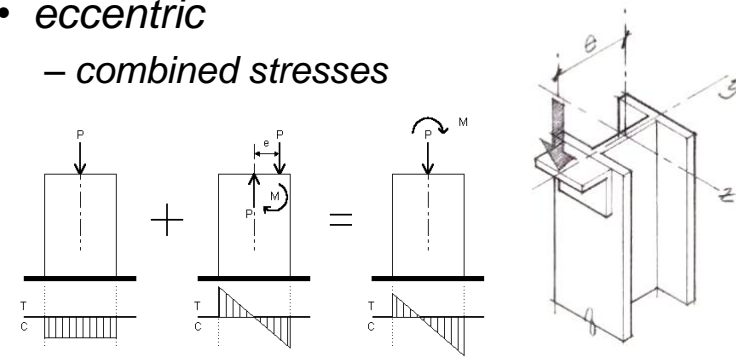
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# Centric & Eccentric Loading

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



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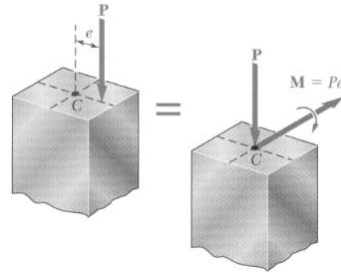
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## Combined Stresses

- axial + bending

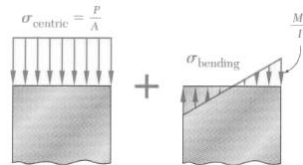
$$f_{\max} = \frac{P}{A} + \frac{Mc}{I}$$

$$M = P \cdot e$$



- design

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



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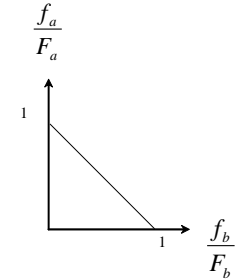
## Stress Limit Conditions

- ASD interaction formula

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

- with biaxial bending

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



interaction diagram

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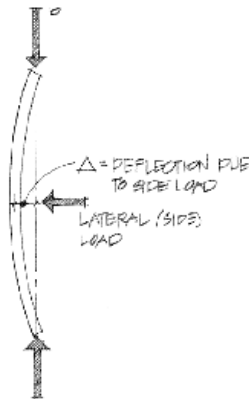
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## Stress Limit Conditions

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

- P-Δ effect

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



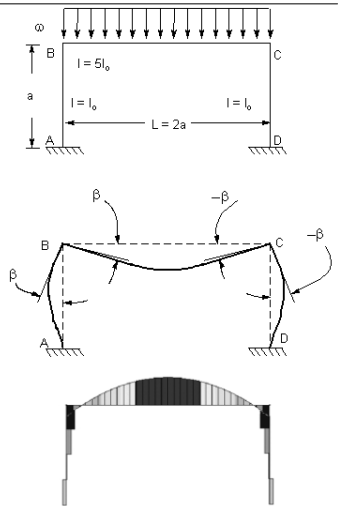
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## Rigid Frame Analysis

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



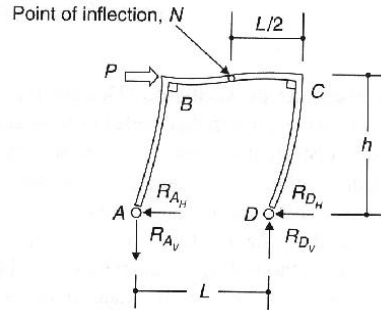
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# Rigid Frame Analysis

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



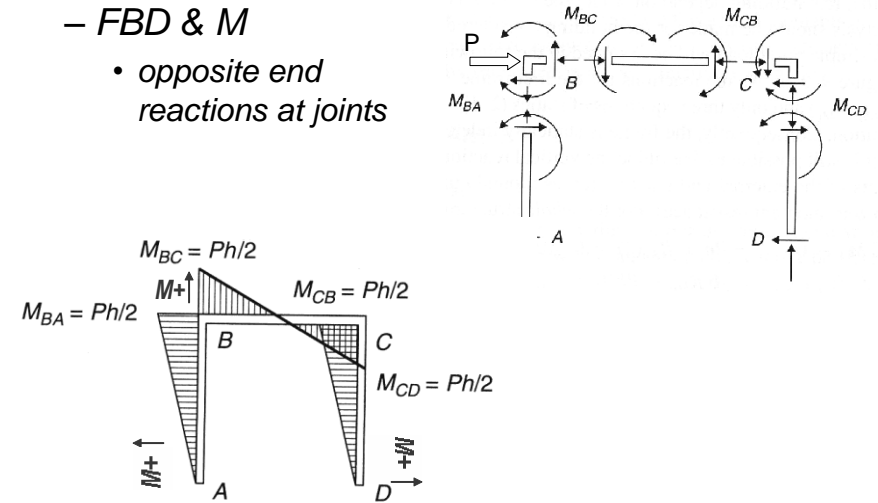
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# Rigid Frame Analysis

- FBD & M
- opposite end reactions at joints



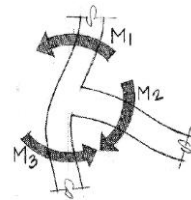
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# Rigid Frame Design

- 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

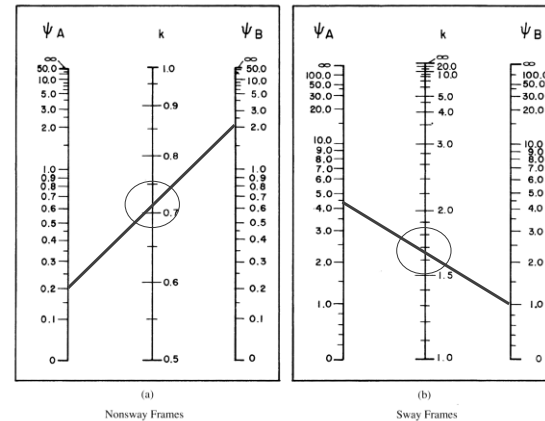
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# Rigid Frame Design

- column effective length,  $k$

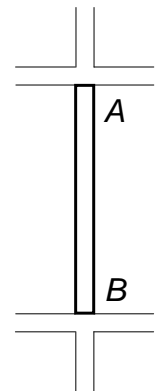


(a) Nonsway Frames

(b) Sway Frames

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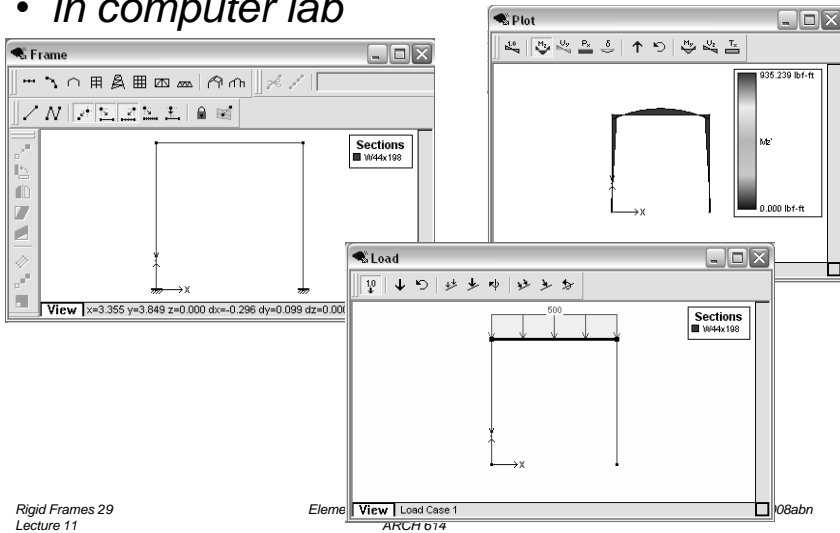
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## Tools – Multiframe

- in computer lab

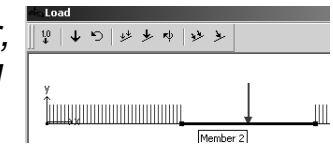
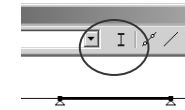
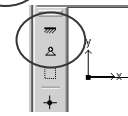
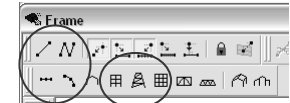


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Elernel View Load Case 1 ARCH 614 08abn

## 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



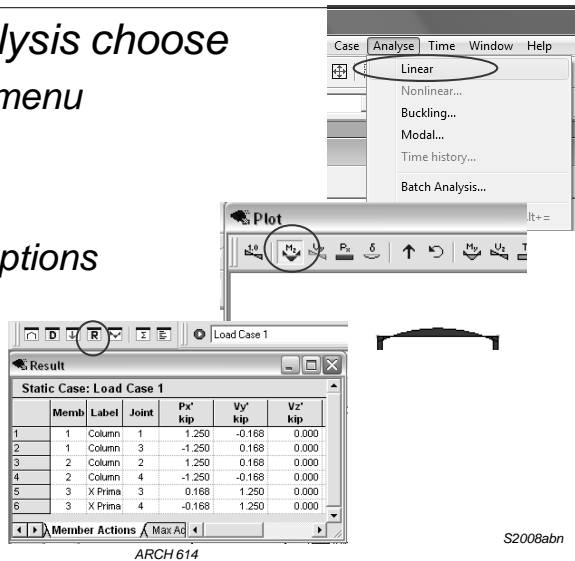
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## Tools – Multiframe

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



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