ELEMENTS OF ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 614

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SPRING 2014

lecture

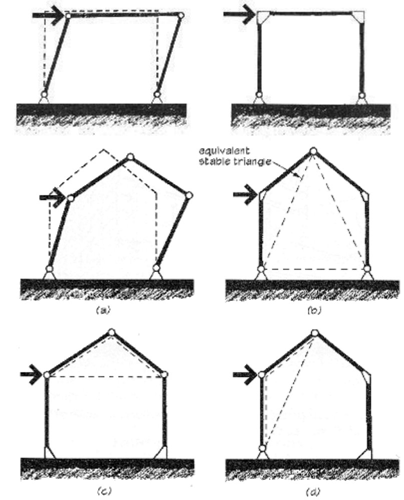
eleven

rigid frames: compression & buckling

http:// nisee.berkeley.edu/godden

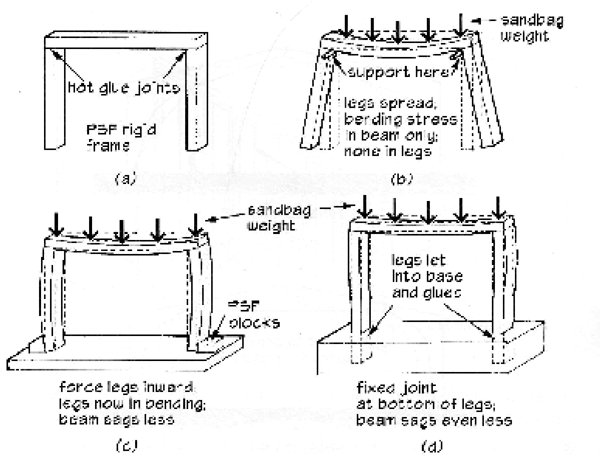
Rigid Frames

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



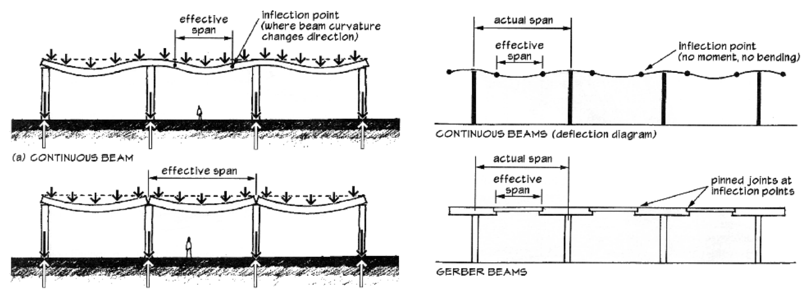
Rigid Frames

- 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*

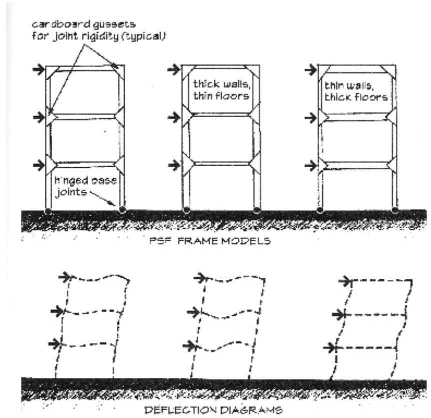
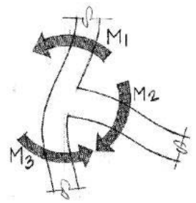
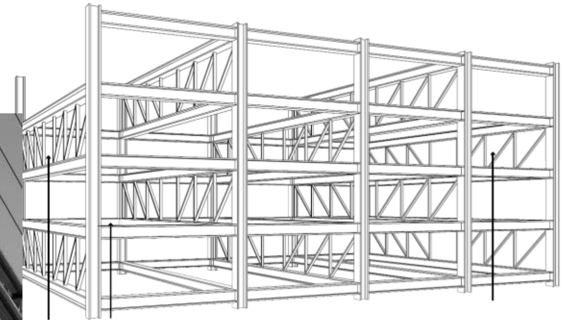


Figure 9.19: Model demonstration of the effects of varying the stiffness of beams and columns when a building frame is subjected to lateral loads.



Rigid Frames

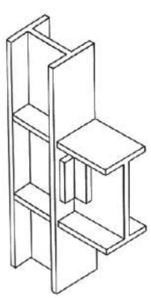
- *staggered truss*
  - *rigidity*
  - *clear stories*

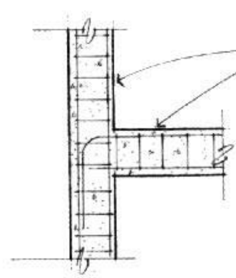


www.arcchicago.blogspot.com

Rigid Frames

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





Fixed

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Braced Frames

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

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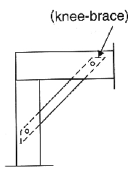
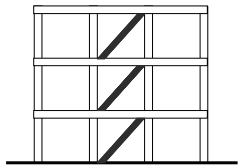
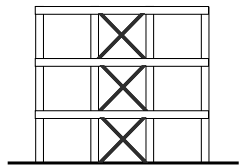
Braced Frames

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

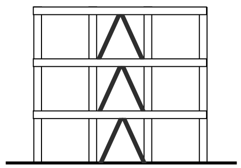




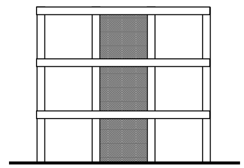
diagonal



X



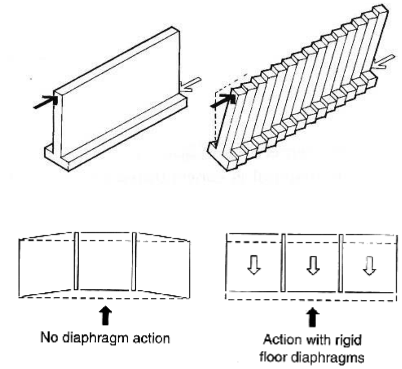
K (chevron)

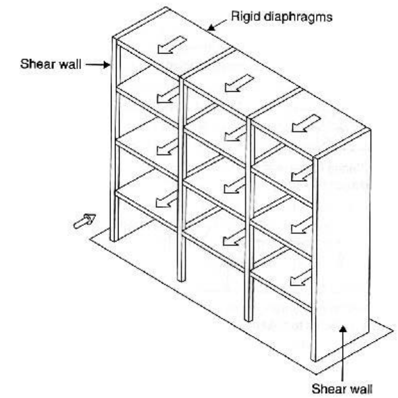


shear walls

Shear Walls

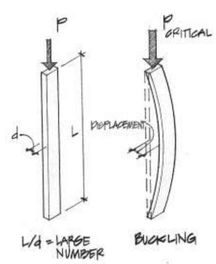
- resist lateral load in plane with wall





Compression Members

- designed for strength & stresses
- designed for serviceability & deflection
- need to design for <u>stability</u>
  - – 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

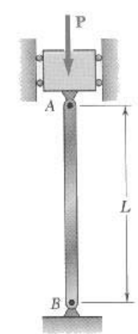
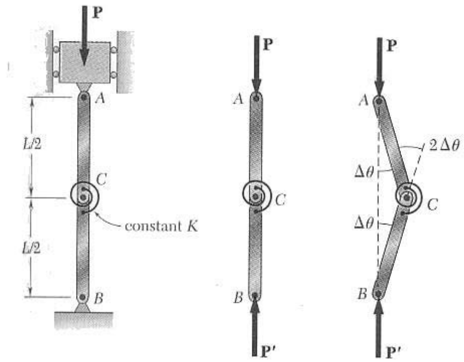


Fig. 10.1

Fig. 10.2

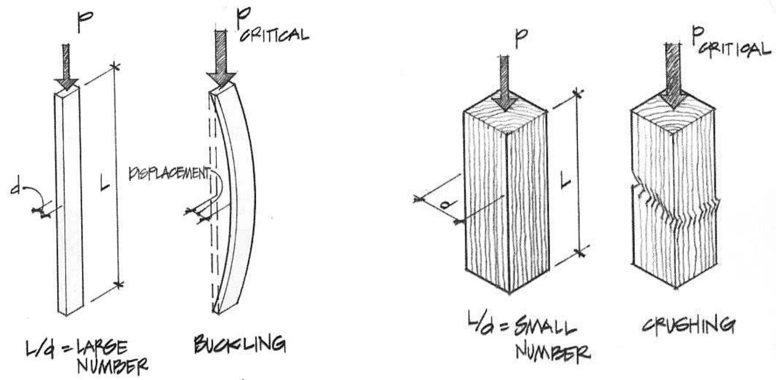
Modeling

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



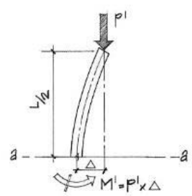
Effect of Length

- long & slender
- short & stubby



Buckling Load

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



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

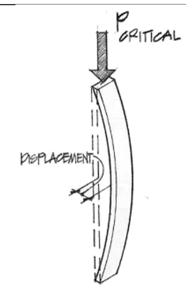
Figure 9.3 Leonhard Euler (1707–1783).

Critical Stress

- short columns

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

- slenderness ratio = L_e/r (L/d)
- radius of gyration = $r = \sqrt{\frac{I}{A}}$

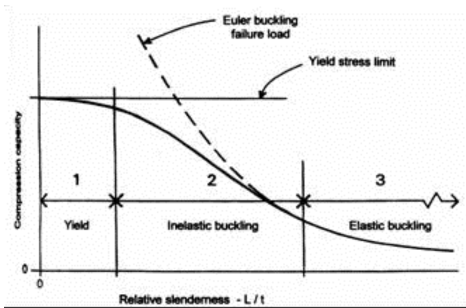


weak axis

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

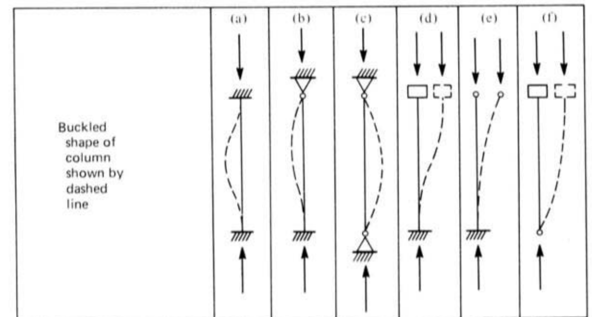
Critical Stresses

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



Effective Length

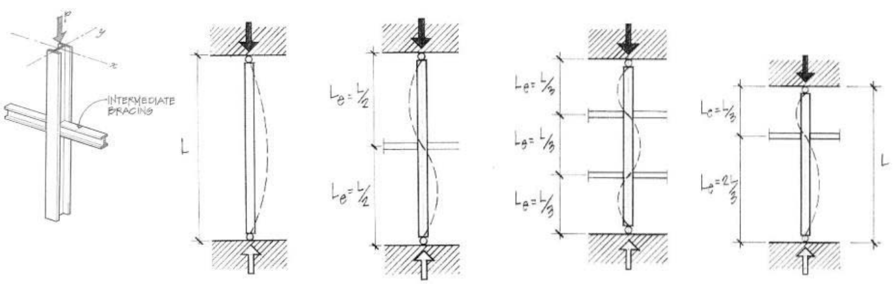
- *end conditions affect shape*
- *effective length factor, K* $L_e = K \cdot L$



	(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

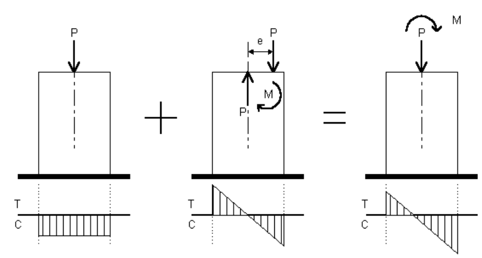
- *bracing affects shape of buckle in one direction*
- *both should be checked!*

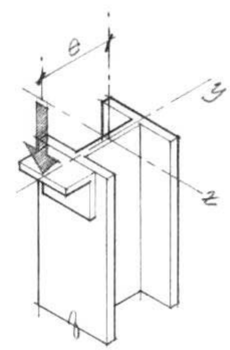


(a) No bracing. *(b) Braced at midpoint.* *(c) Third-point bracing.* *(d) Asymmetric bracing.*

Centric & Eccentric Loading

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



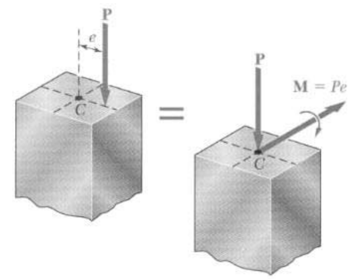


Combined Stresses

– *axial + bending*

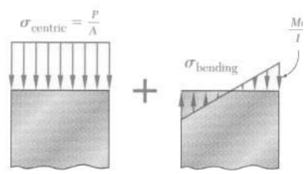
$$f_{max} = \frac{P}{A} + \frac{Mc}{I}$$

$$M = P \cdot e$$



– *design*

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



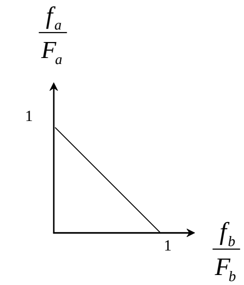
Stress Limit Conditions

– *ASD interaction formula*

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

– *with biaxial bending*

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



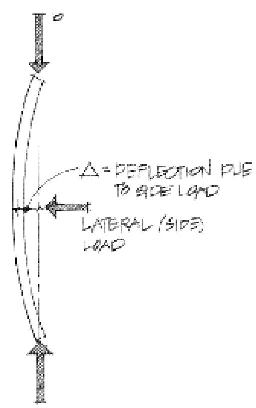
interaction diagram

Stress Limit Conditions

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

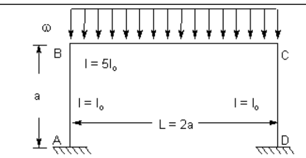
– *P-Δ effect*

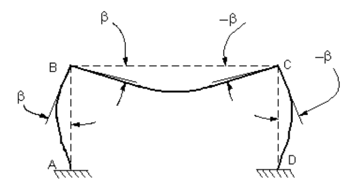
$$\frac{f_a}{F_a} + \frac{f_b \times (Magnification\ \ factor)}{F_{bx}} \le 1.0$$

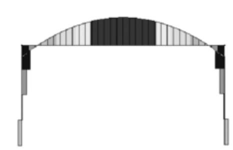


Rigid Frame Analysis

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







Rigid Frame Analysis

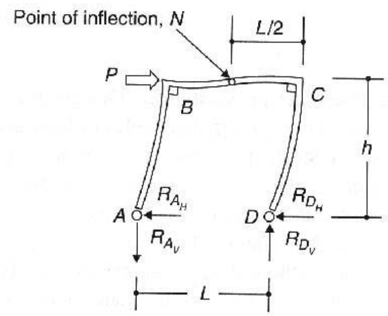
– need support reactions

– free body diagram each member

– end reactions are <u>equal and opposite</u> on next member

– "turn" member like beam

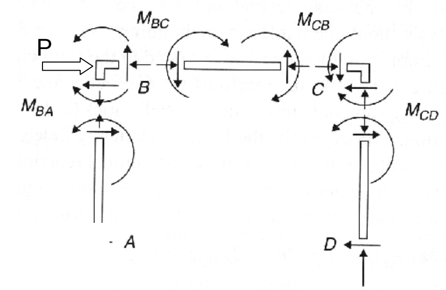
– draw V & M

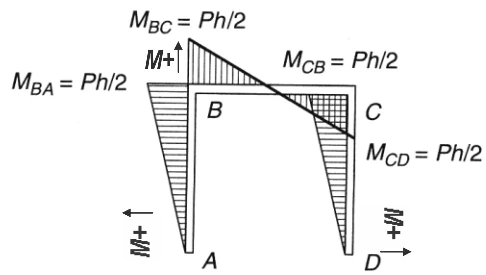


Rigid Frame Analysis

– FBD & M

• opposite end reactions at joints



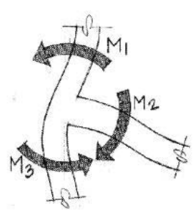


Rigid Frame Design

• columns in frames

– ends can be "flexible"

– stiffness affected by beams <u>and</u> column = EI/L



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

– for the joint

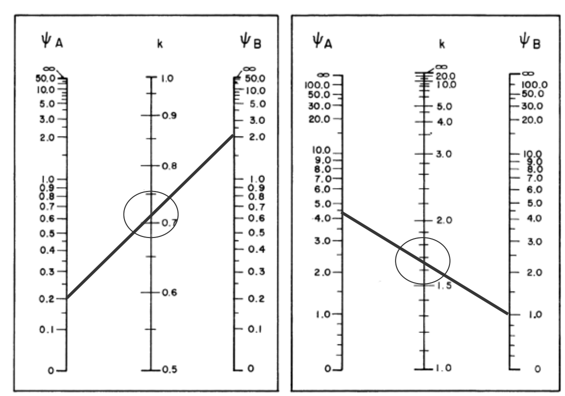
• l_c is the column length of each column

• l_b is the beam length of each beam

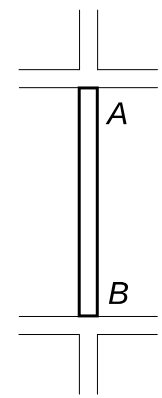
• measured center to center

Rigid Frame Design

• column effective length, k

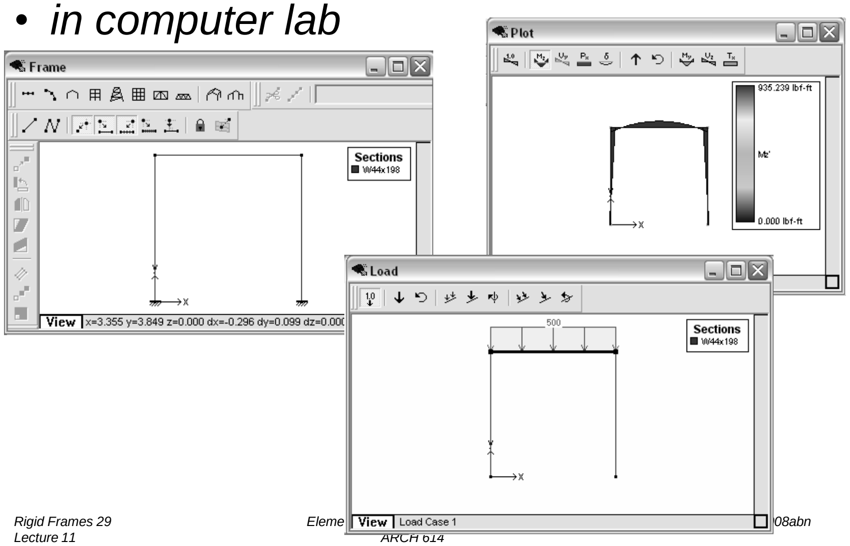


(a) Nonsway Frames (b) Sway Frames



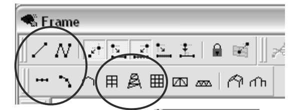
Tools – Multiframe

- *in computer lab*

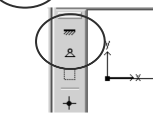


Tools – Multiframe

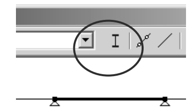
- *frame window*
  - *define frame members*



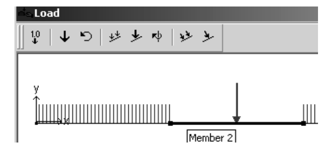
    - *or pre-defined frame*



  - *select points, assign supports*
  - *select members, assign <u>section</u>*

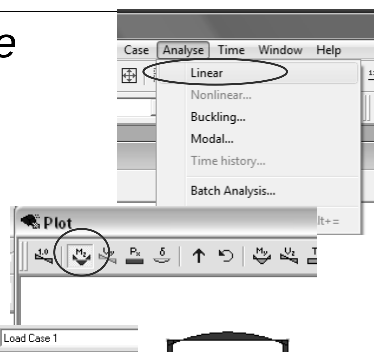


  - *load window*
  - *select point or member, add point or distributed loads*

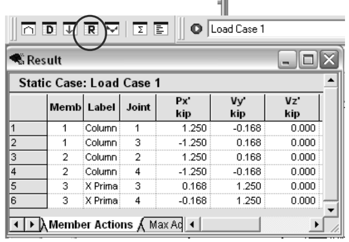


Tools – Multiframe

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



- *results*
  - *choose options*



	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