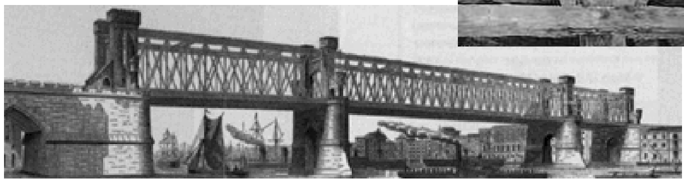
APPLIED ARCHITECTURAL STRUCTURES:
STRUCTURAL ANALYSIS AND SYSTEMS
ARCH 631
DR. ANNE NICHOLS
FALL 2013

lecture
five

trusses & columns

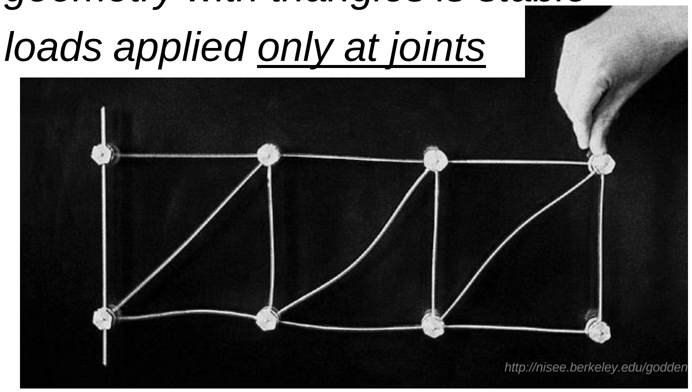
Trusses

- ancient (?) wood
- 1800's analysis
- efficient
- long spans



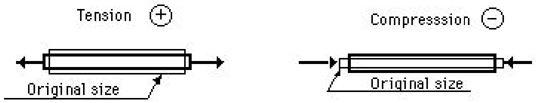
Trusses

- comprised of straight members
- geometry with triangles is stable
- loads applied <u>only at joints</u>



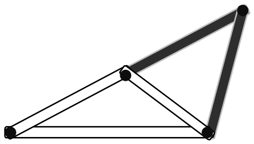
Trusses

- 2 force members
  - compression
  - tension



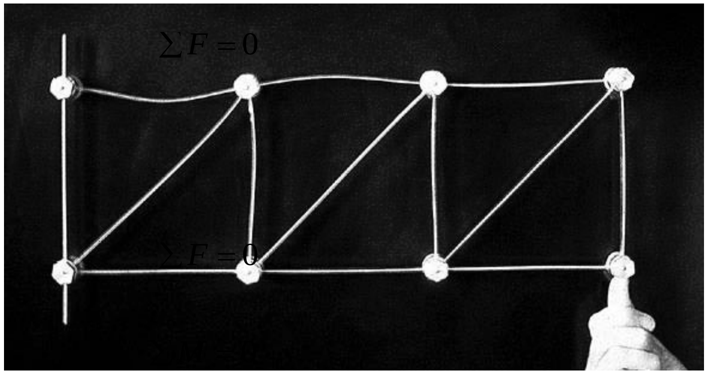
- 3 members connected by 3 joints
- 2 more members need 1 more joint

$$b = 2n - 3$$
$$(n = 2j - 3)$$



Truss Analysis

- *visualize compression and tension from deformed shape*



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Truss Analysis

- *Method of Joints*
  - $\Sigma F = 0$
- *Method of Sections*
  - $\Sigma F = 0$
  - $\Sigma M = 0$
- *Graphical Methods*
- *all rely on equilibrium*
  - *of bodies*
  - *internal equilibrium*

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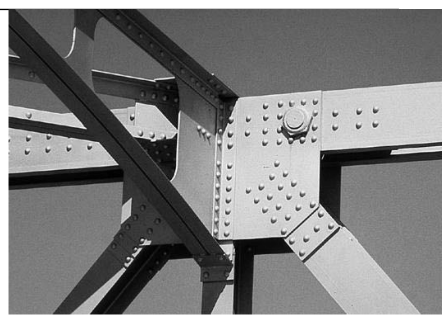
Truss Connections

- *"pins"*
  - *can't resist rotation*



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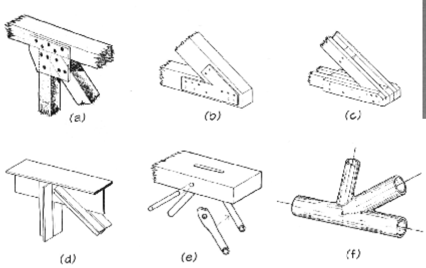

Figure 4.8: Truss joints.

Trusses

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- *require lateral bracing*
- *consider buckling*
- *indeterminate trusses*
  - *extra members*
  - *solvable with statics*
    - *cables can't hold compression*
  - *displacement methods*
    - *elastic elongation*
  - *too few members, unstable*

Space Trusses

- pyramid
- tetrahedron

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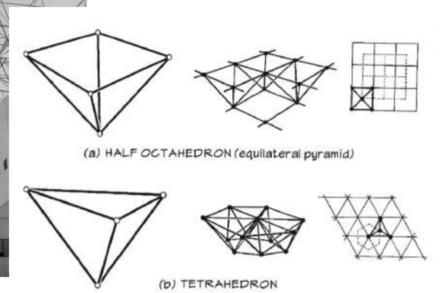
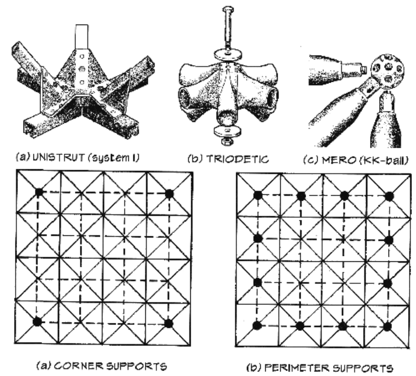
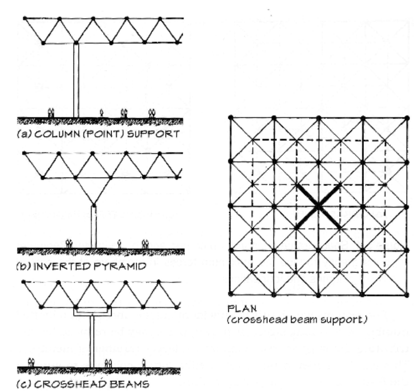


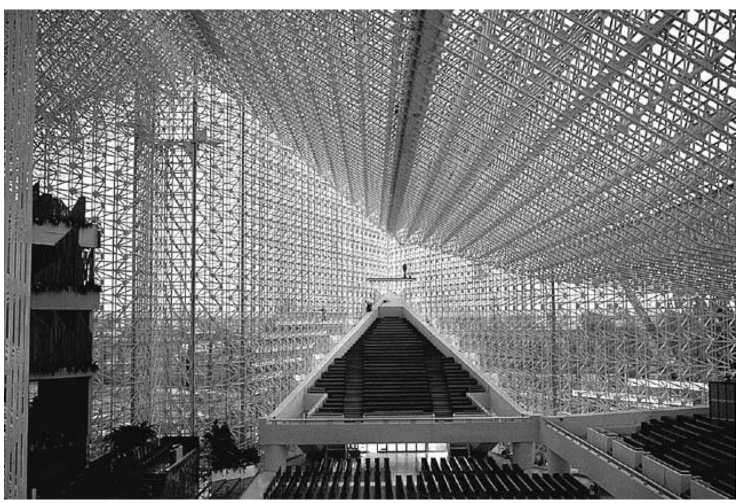
Space Trusses

- connections
- supports





Crystal Cathedral, Johnson 1980



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Expo 70 Festival Plaza

- Tange & Kamiya 1970

Jacob K. Javits Convention Center

- *I.M. Pei 1980*

Jacob K. Javits Convention Center

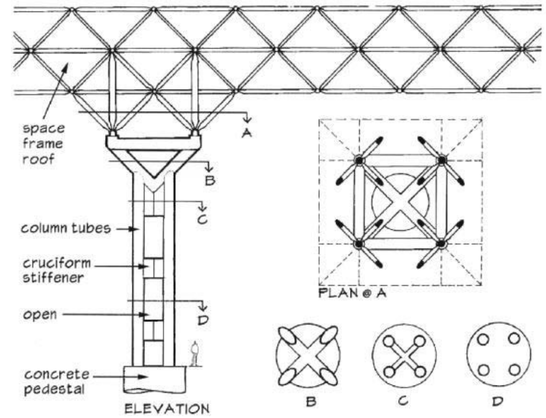


Figure 5.10: Javits Center, column details: (a) elevation, and (b through d) plan sections.

Louvre Museum Addition, Pei 1989

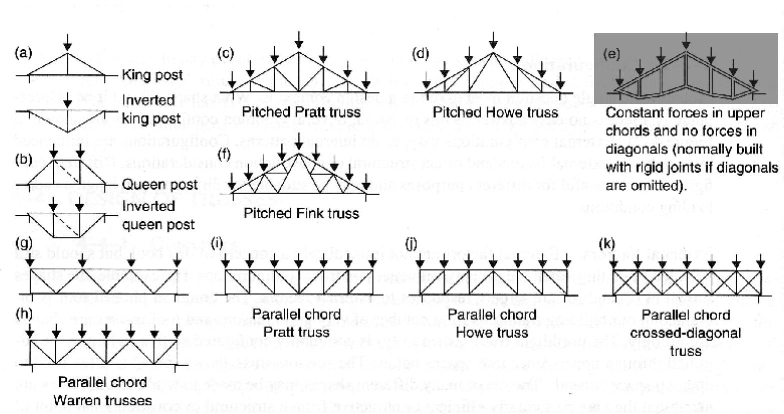
Louvre Museum Addition, Pei 1989

Truss Design

- *variables*
  - *spans*
  - *depths*
  - *length of members*
  - *spacing*
  - *transverse beam spacing*
  - *pattern*
  - *materials; size & strength efficiency*

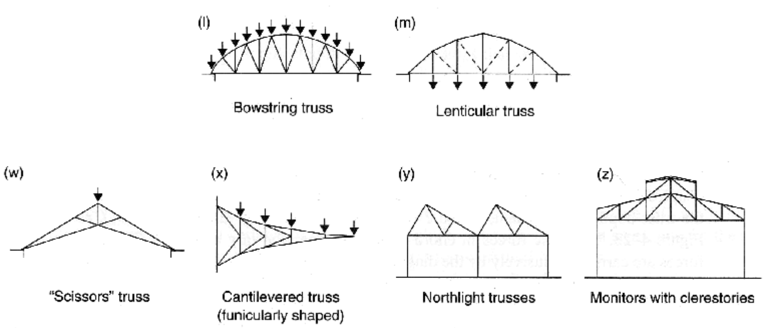
Trusses

- *common designs*



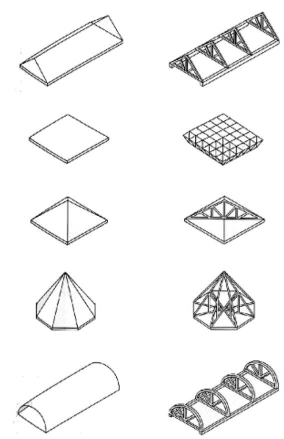
Trusses

- *common designs*



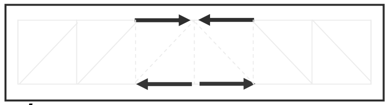
Truss Configurations

- *external factors*
  - *roof form*
  - *openings*
- *basic forms*
  - *symmetrical loading*
  - *maximum bending*
  - *cables in tension only*



Truss Configurations

- *parallel chords*
  - *verticals common*
  - *longer members in tension*
  - *often cross members - indeterminate*



- *funicular shapes*
  - *efficient*
  - *similar sized forces*
  - *some zero force*

Truss Configurations

- *special shapes*
  - *Vierendeel*
  - *"frame"*
- *depth*
  - *depends on loads, span*
  - *rules of thumb, charts*
- *structurally*
  - *tension members can have holes!*
  - *compression members can buckle*
  - *3D trusses stable*

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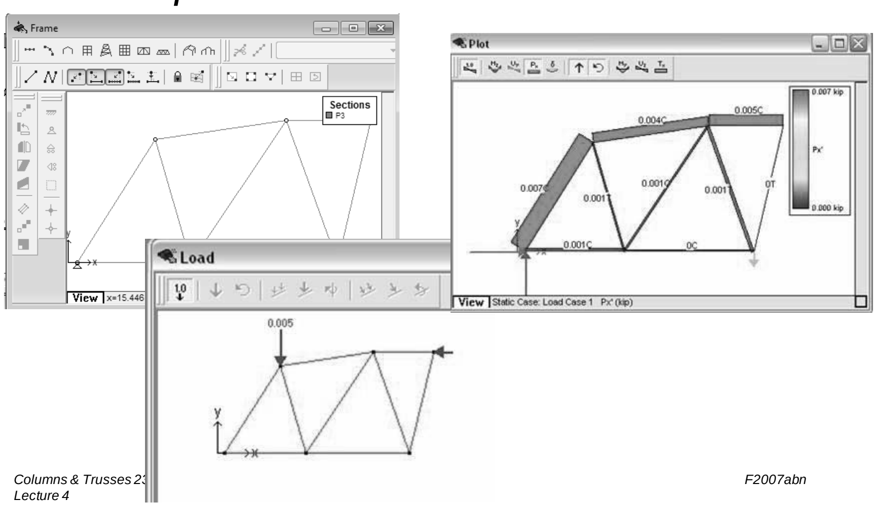
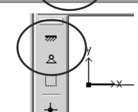
Tools – Multiframe

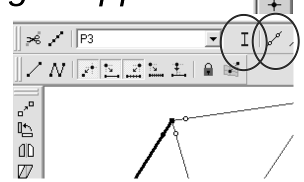
- *in computer lab*

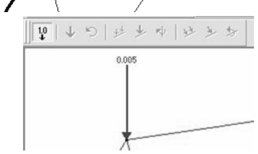


Tools – Multiframe

- *frame window*
  - *define truss members*
    - *or pre-defined truss*
  - *select points, assign supports*
  - *select members, assign section & assign pin ends*
- *load window*
  - *select points, add point load*

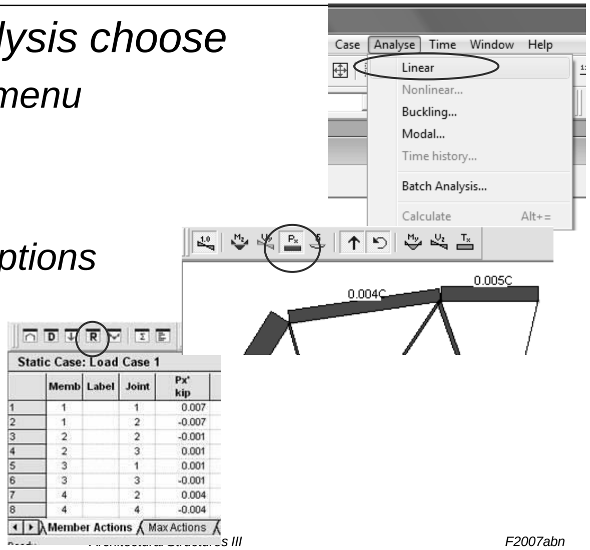






Tools – Multiframe

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



	Memb	Label	Joint	Px' kip
1	1		1	0.007
2	1		2	-0.007
3	2		2	-0.001
4	2		3	0.001
5	3		1	0.001
6	3		3	-0.001
7	4		2	0.004
8	4		4	-0.004

Columns

- compression members
- column behavior is length dependant
  - short: crush
  - long: buckle (sudden) in slender direction
  - end restraints
- bearing walls
  - continuous in one direction
  - can resist lateral forces

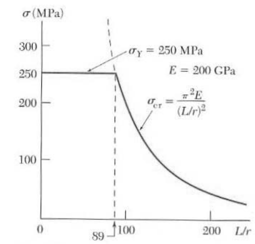
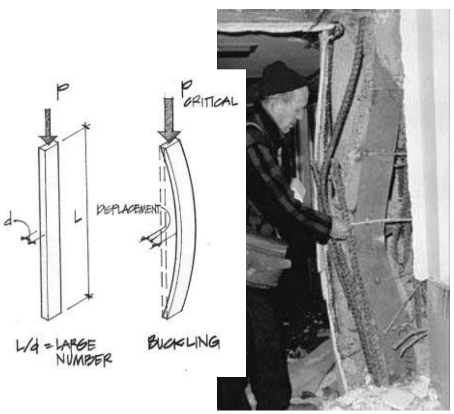


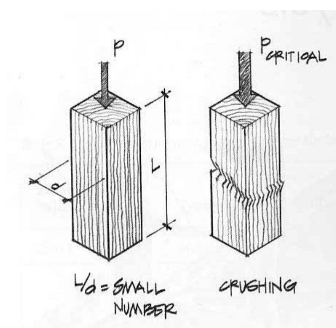
Fig. 10.9

Columns

- column buckling

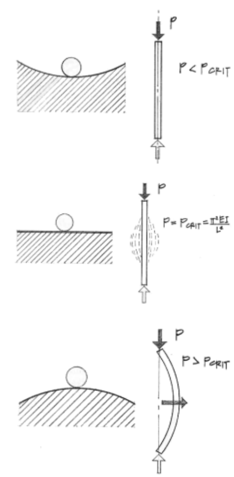
crushing





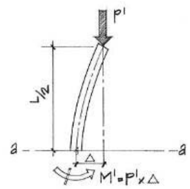
Columns

- stability
  - stable equilibrium
    - $P < P_{cr}$
  - neutral equilibrium
    - $P = P_{cr}$
  - unstable equilibrium
    - $P > P_{cr}$



Buckling Load

- *related to deflected shape (PΔ)*
- *shape of sine wave*
- *Euler's Formula*
- *I minimum*



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

Figure 9.3 Leonhard Euler (1707–1783).

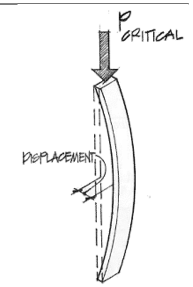
- *stiffness related to E, I, & L*

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

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

Critical Stresses

- *when a column gets stubby, F_y will limit the load*
- *real world has loads with eccentricity*
- *buckling for steel when $F_e < 0.44F_y$*

$$\frac{KL}{r} > 4.71\sqrt{\frac{E}{F_y}}$$

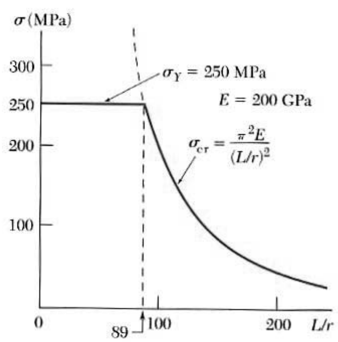
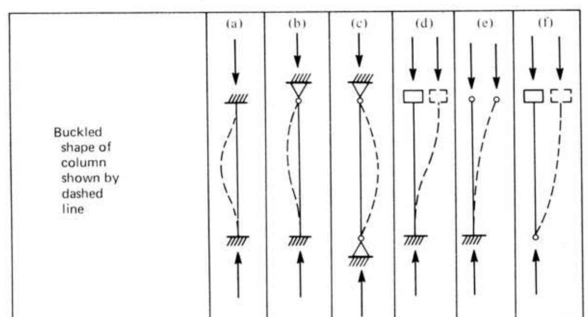


Fig. 10.9

Columns

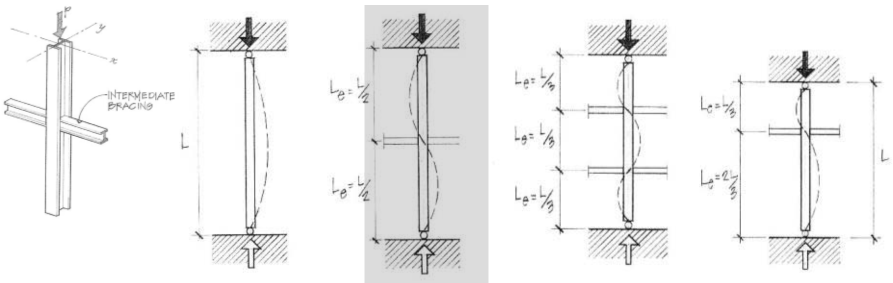
- *end conditions affect shape*
- *effective length factor, k*



	(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

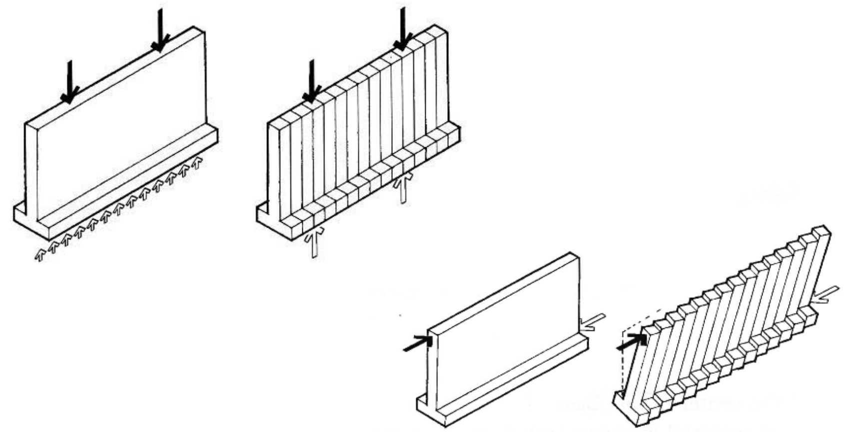
- bracing affects shape of buckle in one direction
- both directions should be checked!



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

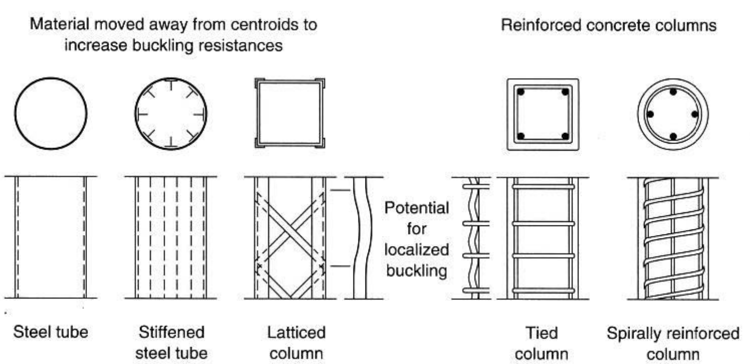
Columns and Walls

- bearing & shear



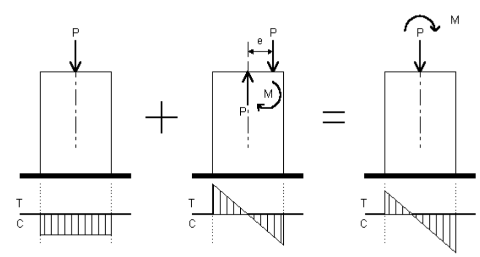
Columns

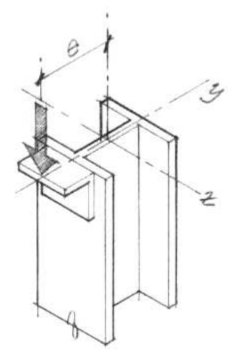
- typical cross sections



Centric & Eccentric Loading

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



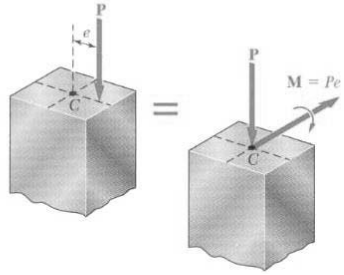


Combined Stresses

– *axial + bending*

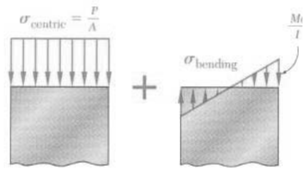
$$f_{\max} = \frac{P}{A} + \frac{Mc}{I}$$

$$M = P \cdot e$$



– *design*

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



Column Materials

- *wood*
- *steel*
  - *W sections can buckle about both axes*
- *concrete & masonry*
  - *compression primarily in concrete*
  - *reinforcement for bending*