

**ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN**

ARCH 331

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FALL 2013

**lecture
seven**

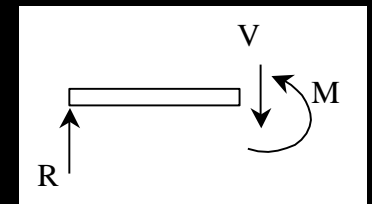
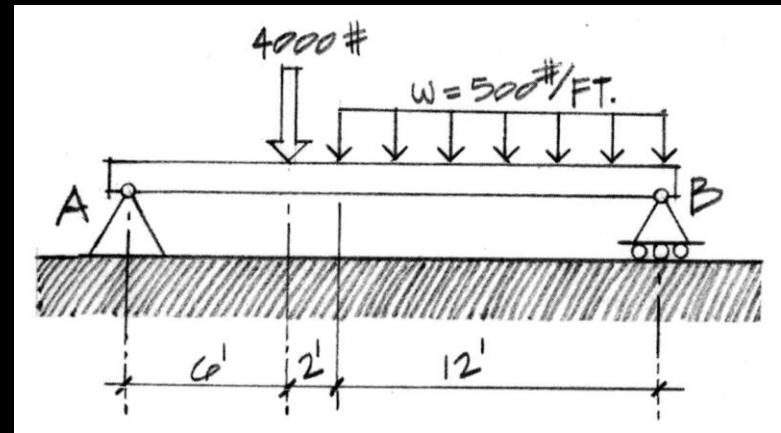


<http://nisee.berkeley.edu/godden>

**beams –
internal forces**

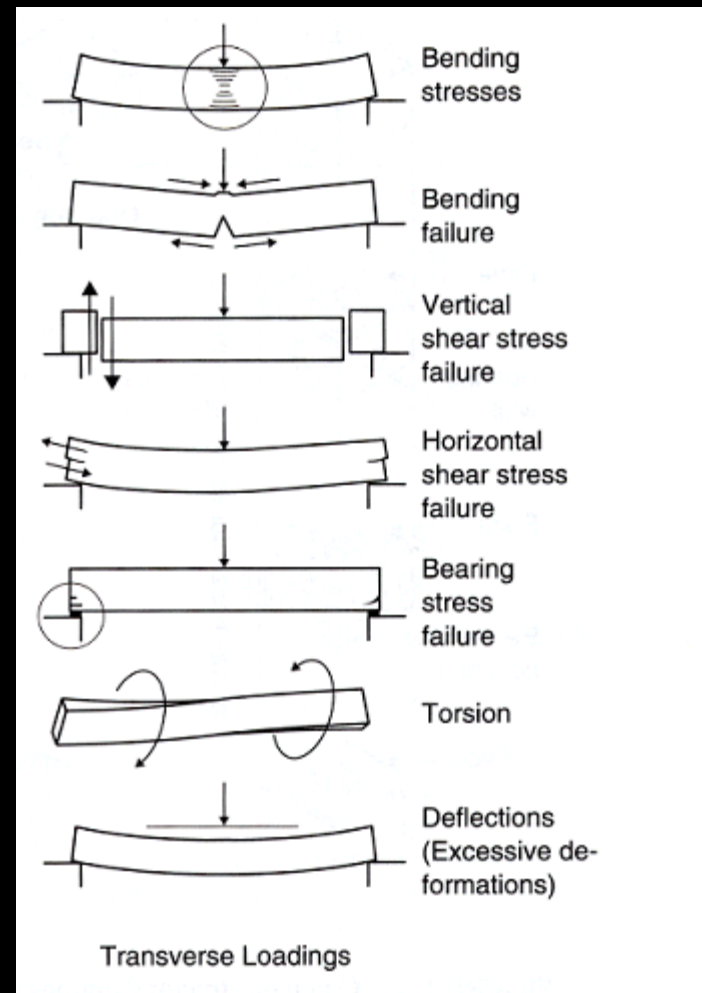
Beams

- *span horizontally*
 - floors
 - bridges
 - roofs
- *loaded transversely by gravity loads*
- *may have internal axial force*
- *will have internal shear force*
- *will have internal moment (bending)*



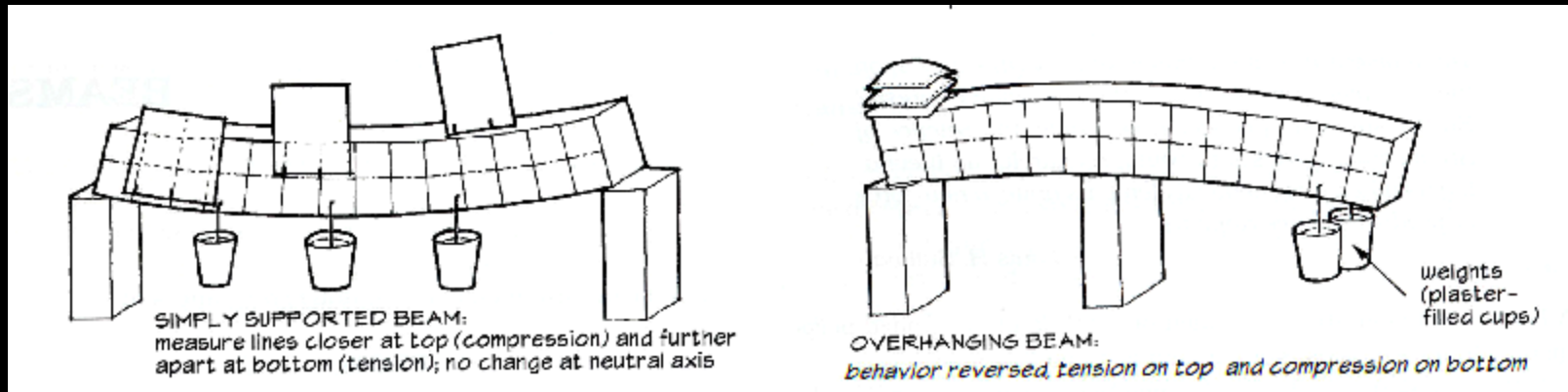
Beams

- *transverse loading*
- *sees:*
 - *bending*
 - *shear*
 - *deflection*
 - *torsion*
 - *bearing*
- *behavior depends on cross section shape*



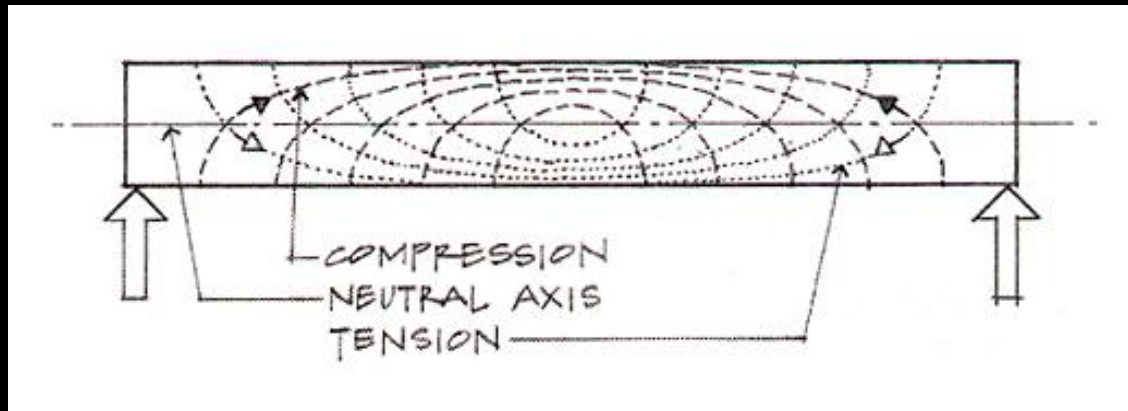
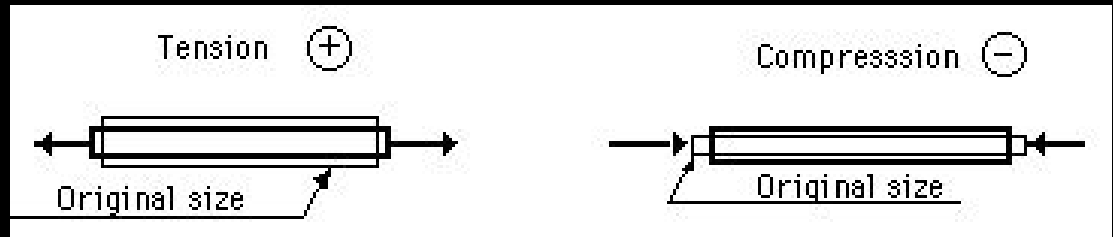
Beams

- *bending*
 - *bowing of beam with loads*
 - *one edge surface stretches*
 - *other edge surface squishes*

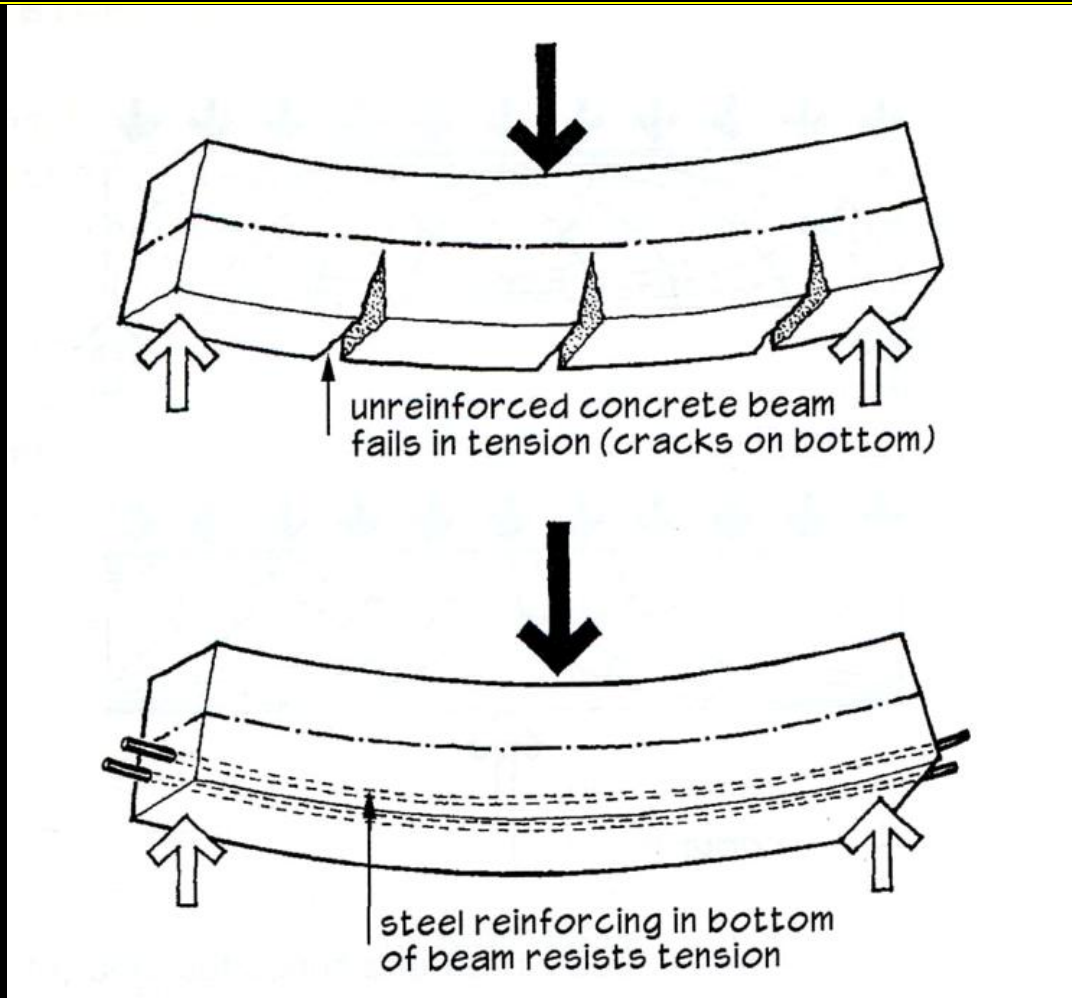


Beam Stresses

- *stress = relative force over an area*
 - *tensile*
 - *compressive*
 - *bending*
 - *tension and compression + ...*

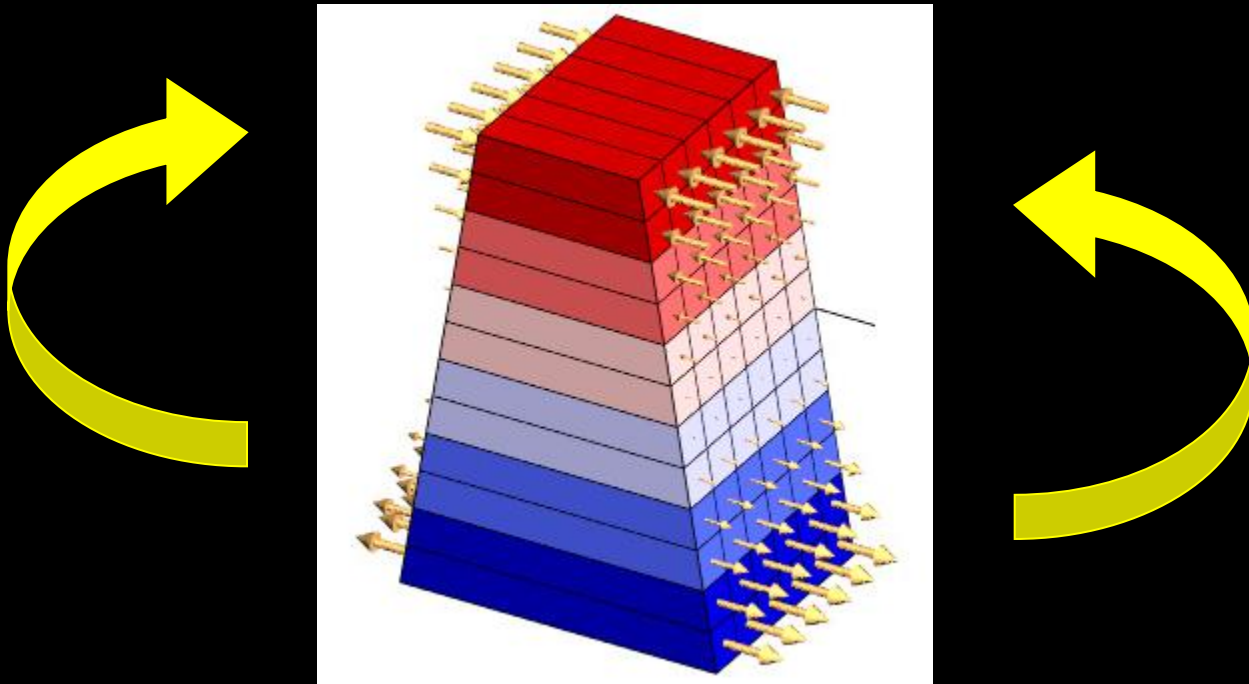


Beam Stresses



Beam Stresses

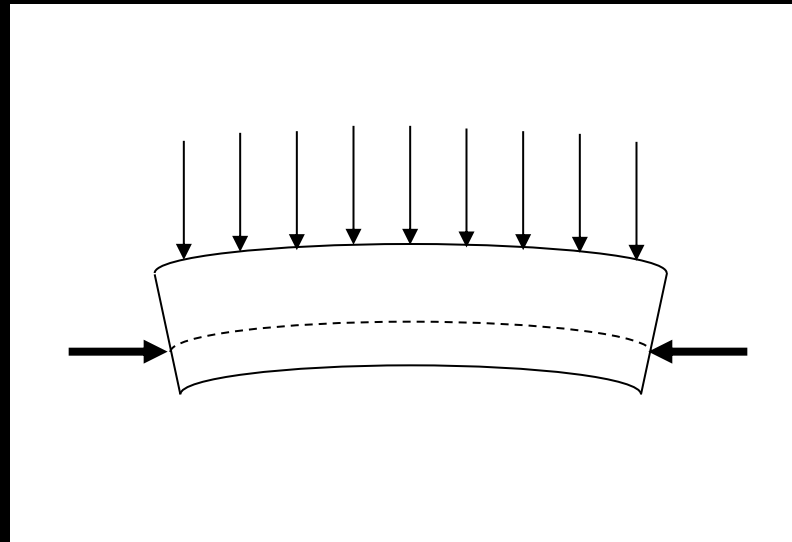
- *tension and compression*
 - *causes moments*



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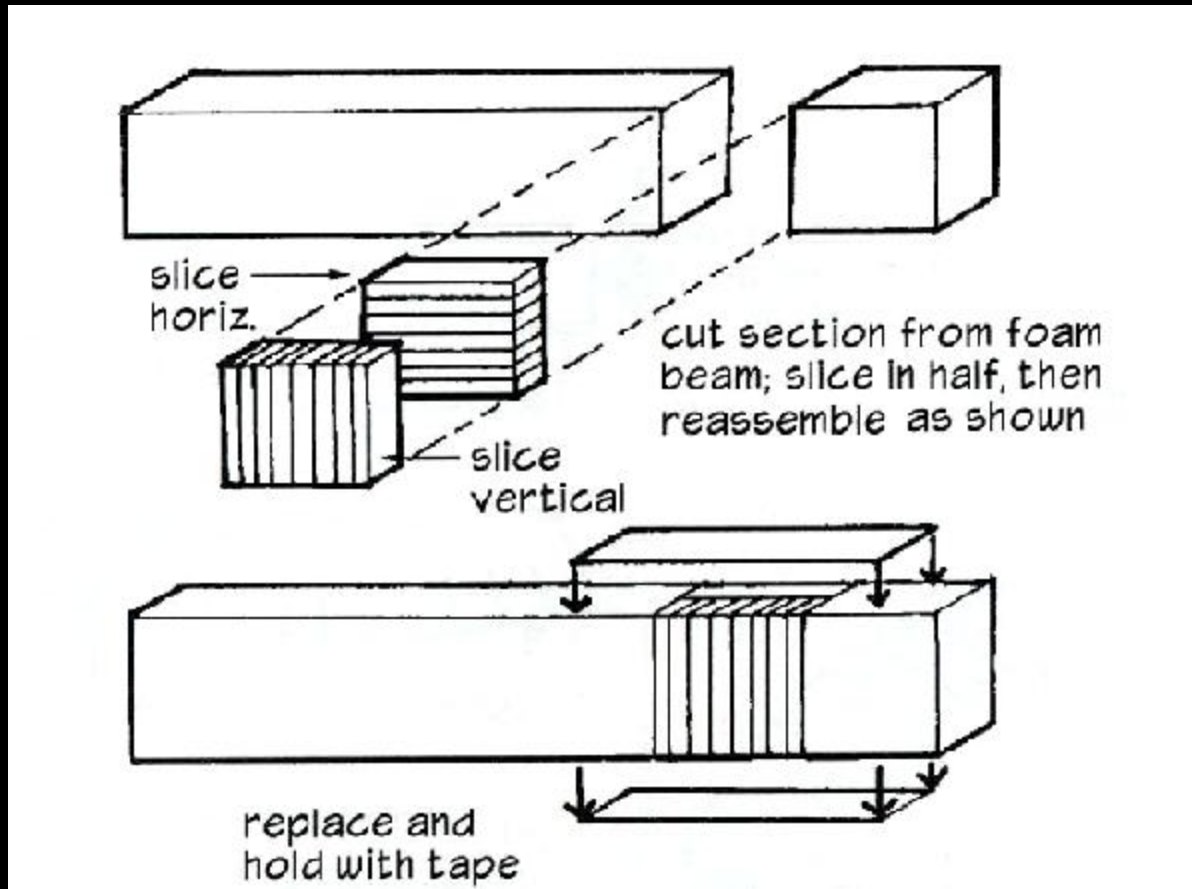
Beam Stresses

- *prestress or post-tensioning*
 - *put stresses in tension area to “pre-compress”*



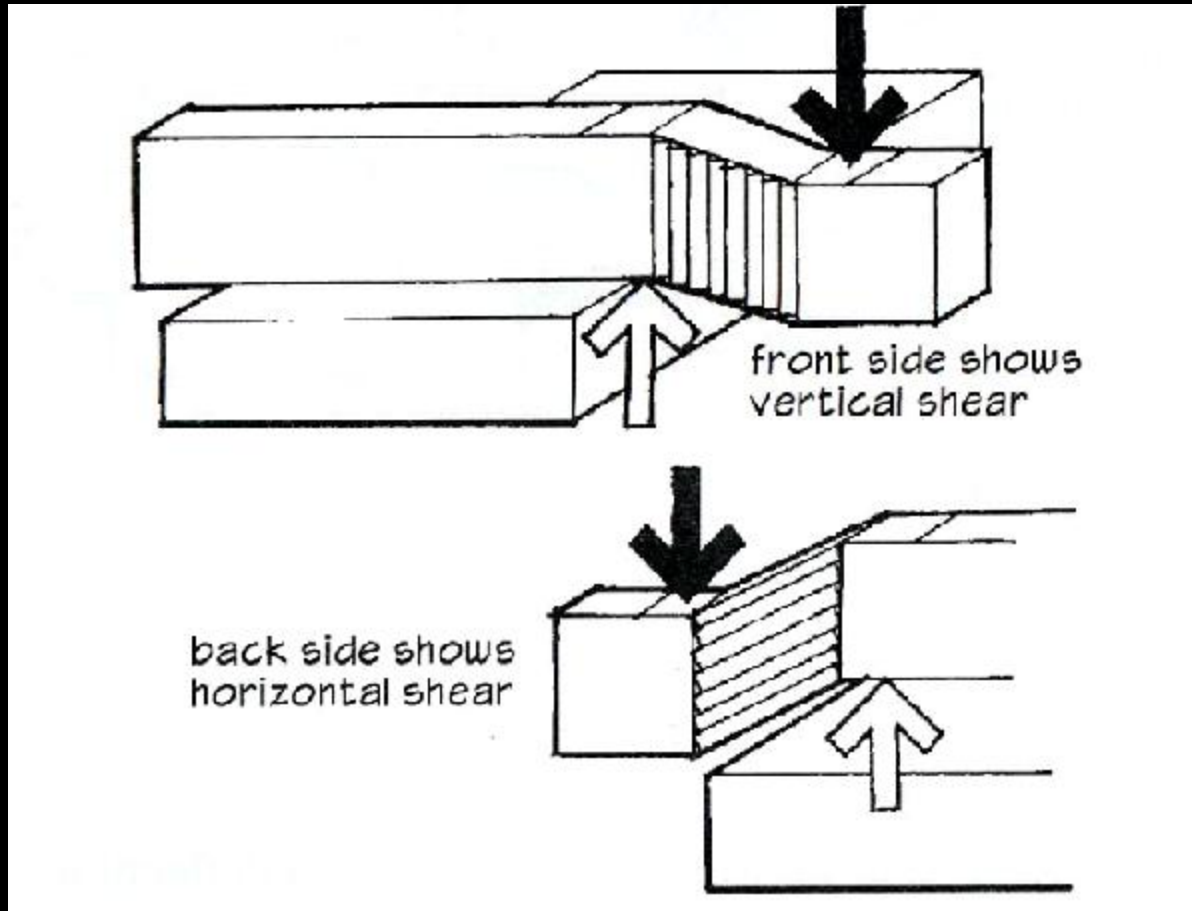
Beam Stresses

- *shear – horizontal & vertical*



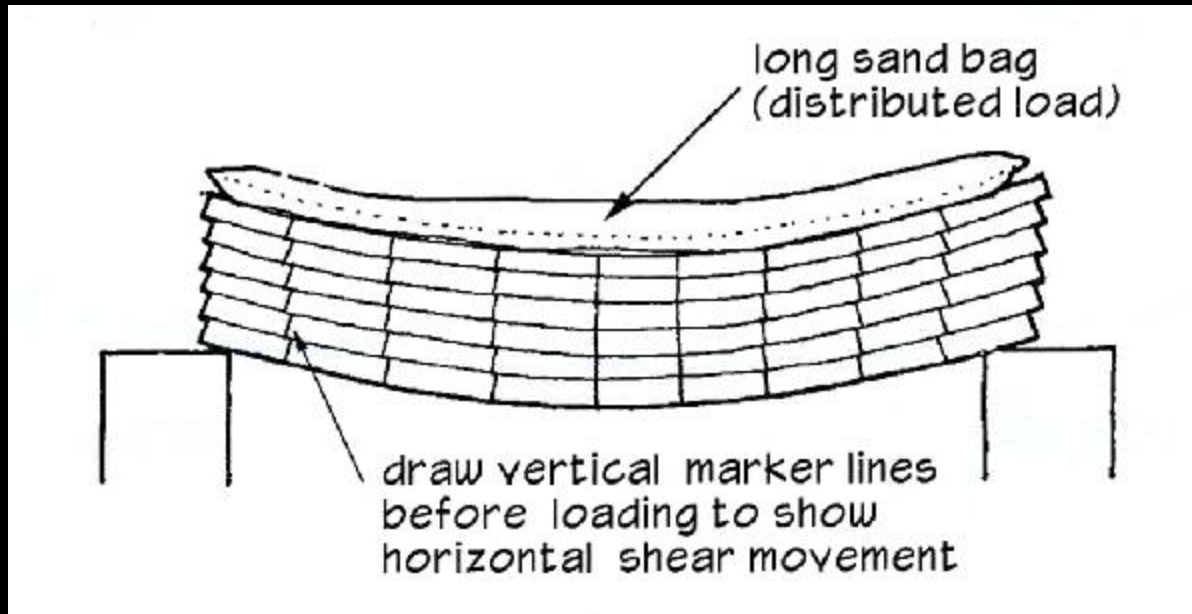
Beam Stresses

- *shear – horizontal & vertical*



Beam Stresses

- *shear – horizontal*



Beam Deflections

- *depends on*
 - *load*
 - *section*
 - *material*

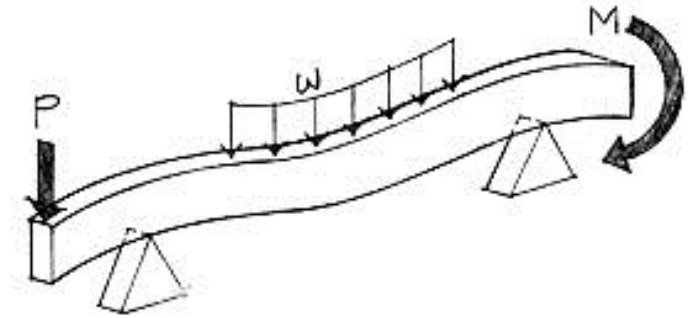
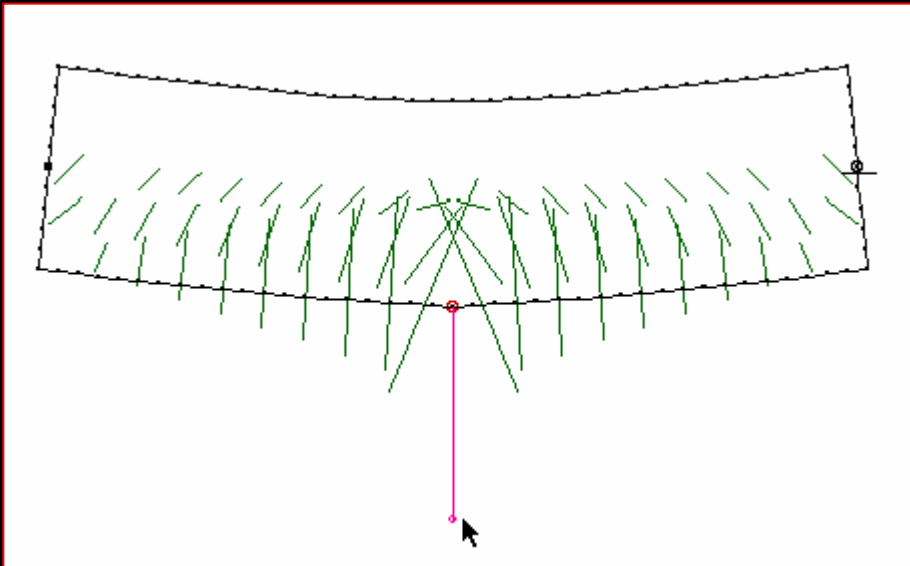
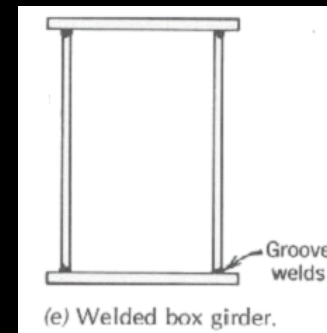
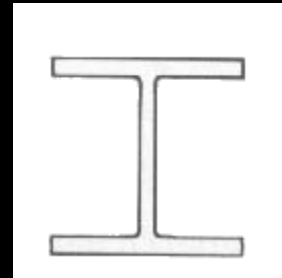
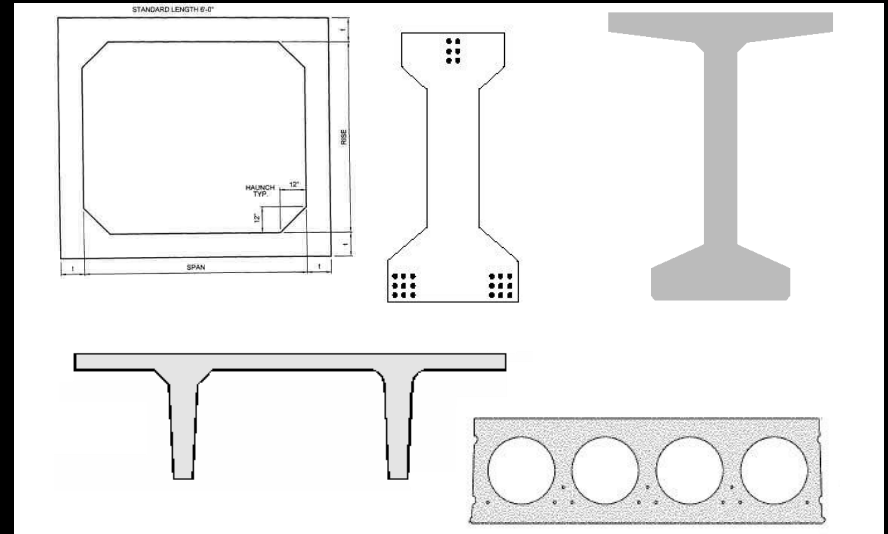
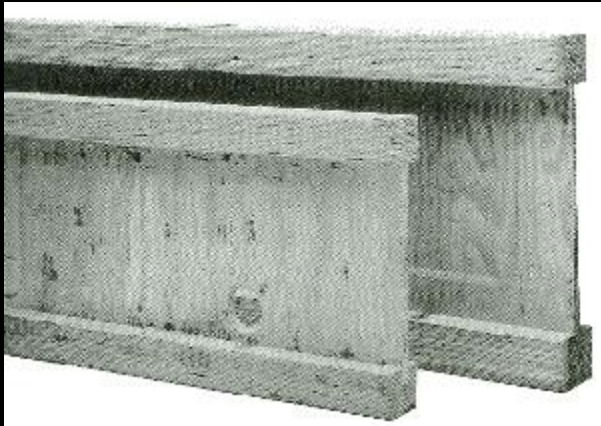


Figure 5.4 Bending (flexural) loads on a beam.



Beam Deflections

- “moment of inertia”

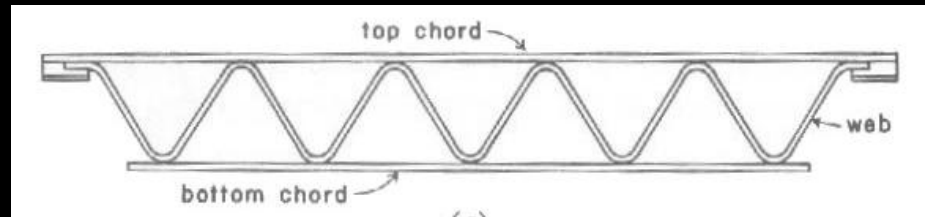


Beam Styles

- *vierendeel*
- *open web joists*
- *manufactured*

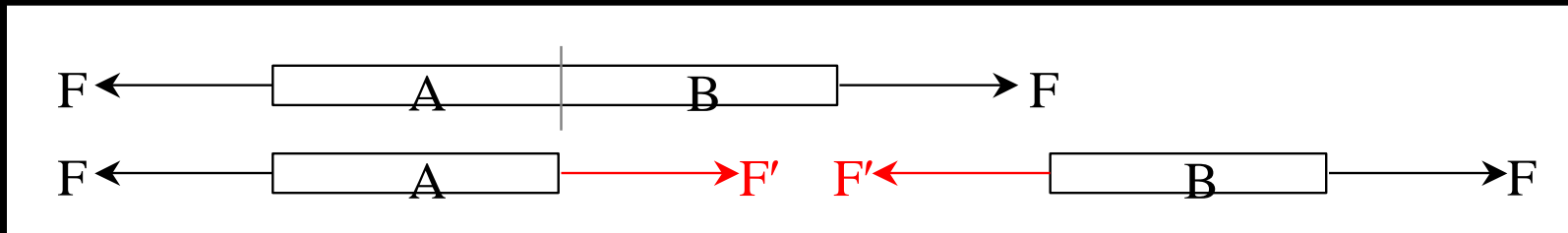


<http://nisee.berkeley.edu/godden>

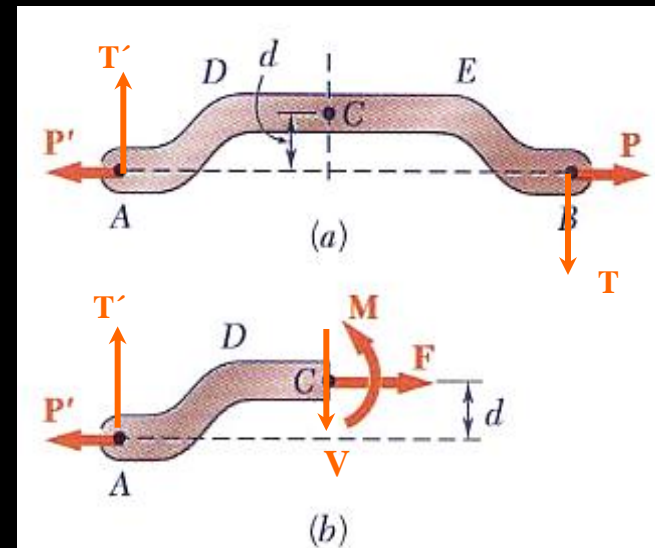


Internal Forces

- *trusses*
 - *axial only, (compression & tension)*

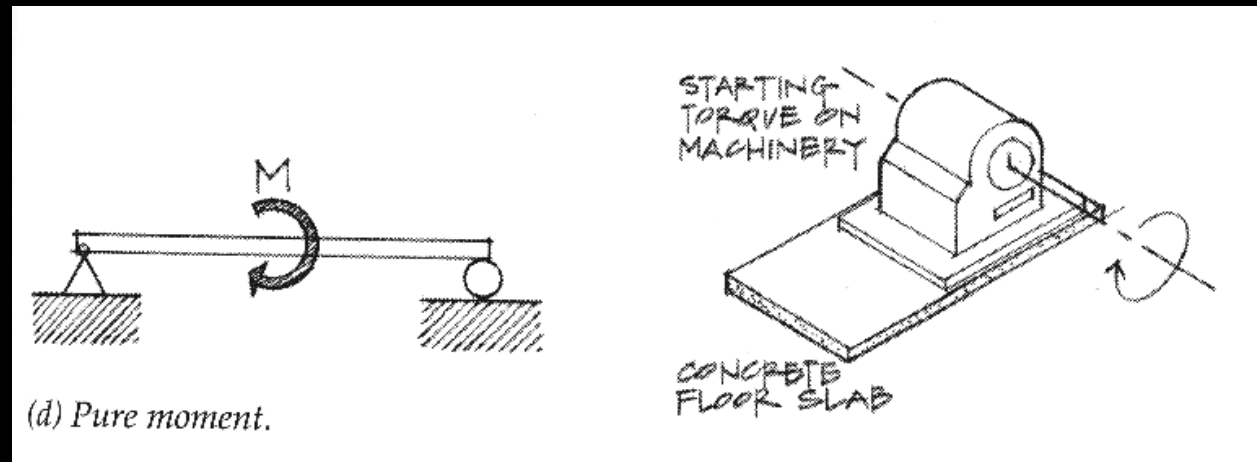
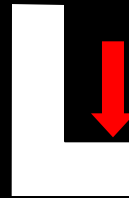


- *in general*
 - *axial force*
 - *shear force, V*
 - *bending moment, M*



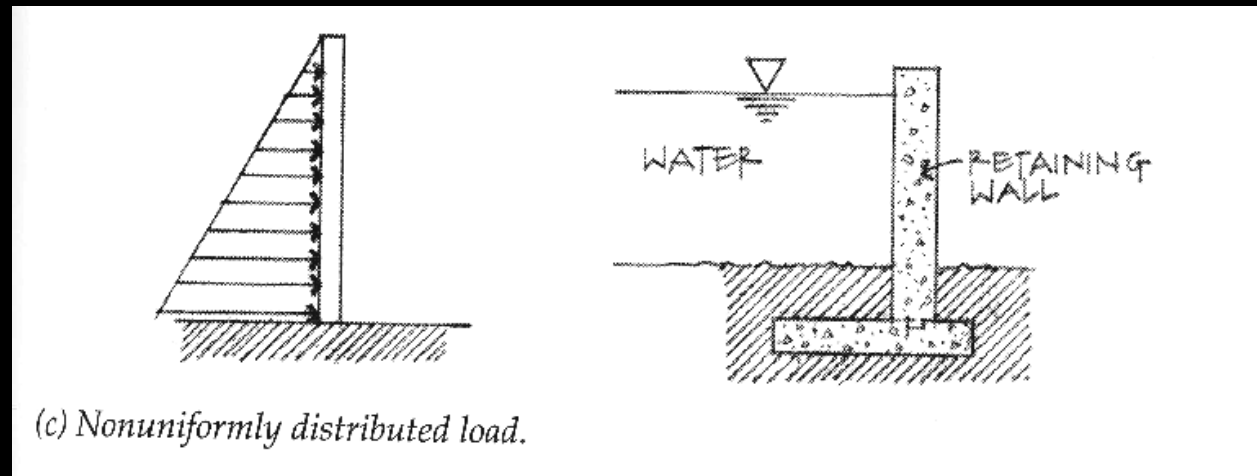
Beam Loading

- concentrated force
- concentrated moment
 - spandrel beams



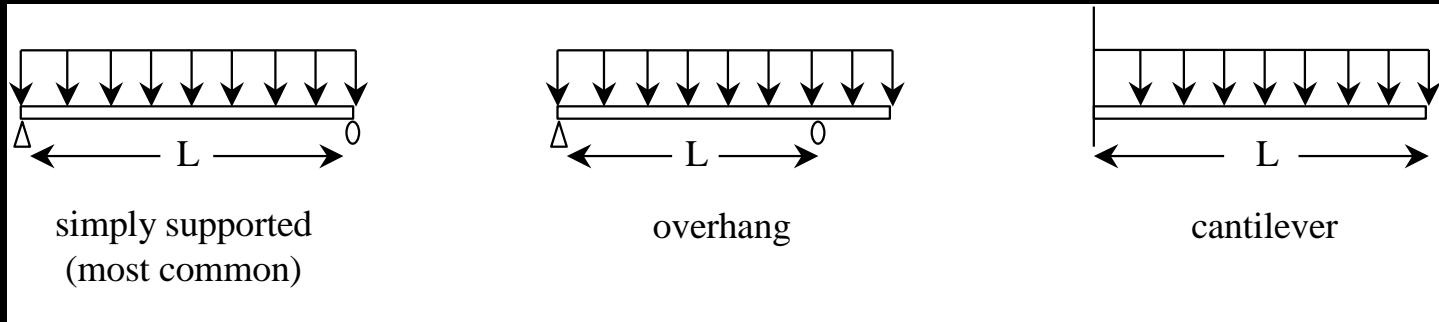
Beam Loading

- *uniformly distributed load (line load)*
- *non-uniformly distributed load*
 - *hydrostatic pressure = γh*
 - *wind loads*

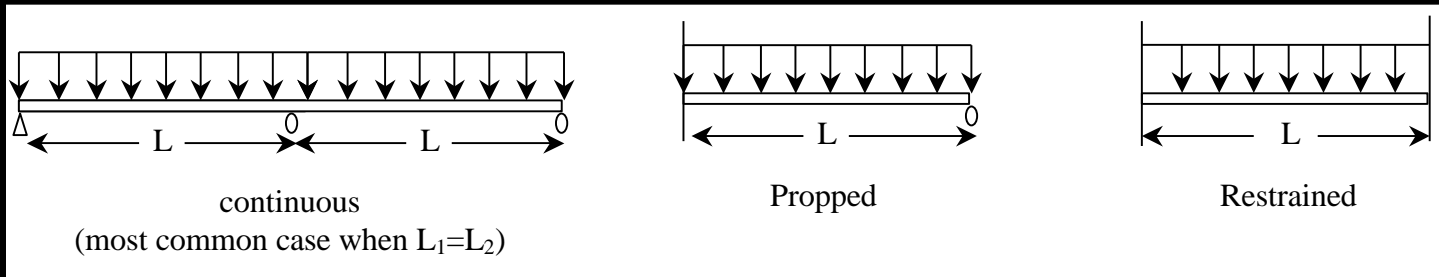


Beam Supports

- *statically determinate*

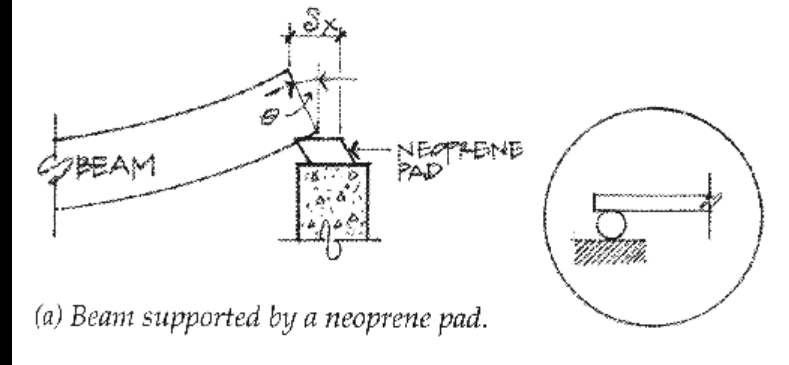
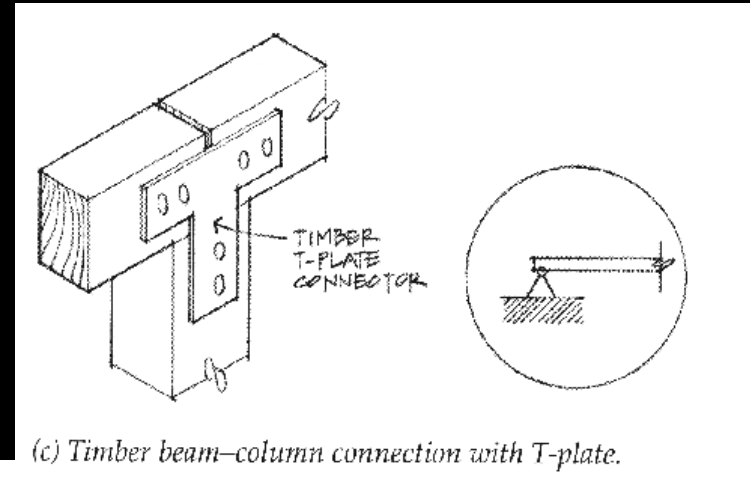
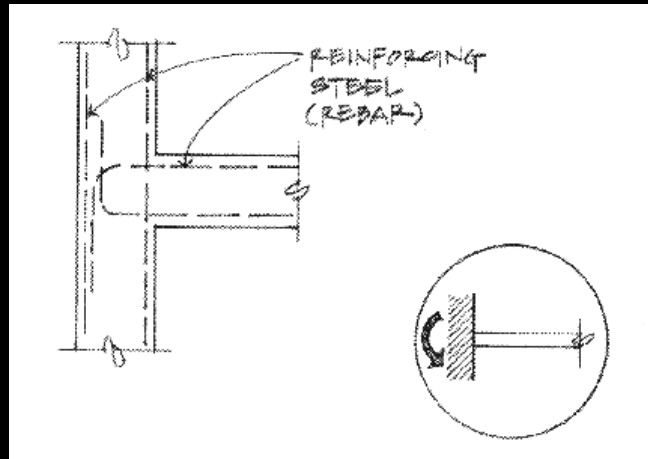


- *statically indeterminate*



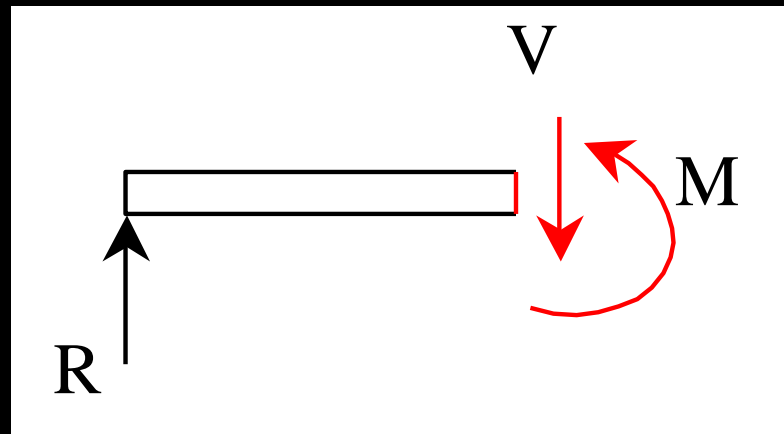
Beam Supports

- *in the real world, modeled type*



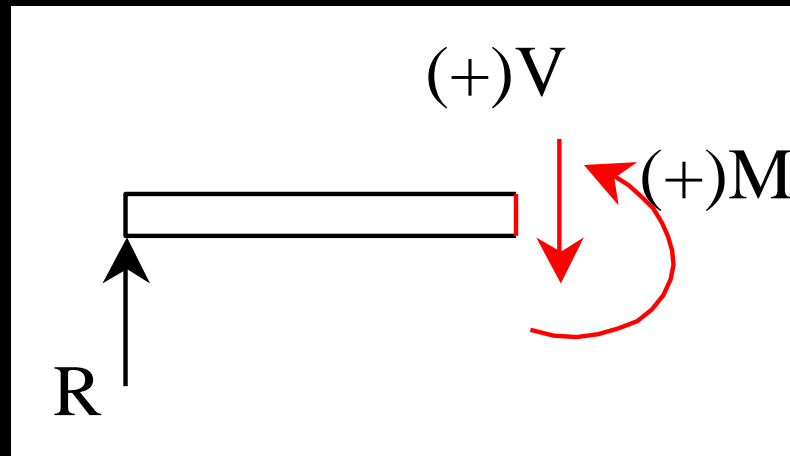
Internal Forces in Beams

- *like method of sections / joints*
 - *no axial forces*
- *section must be in equilibrium*
- *want to know where biggest internal forces and moments are for designing*



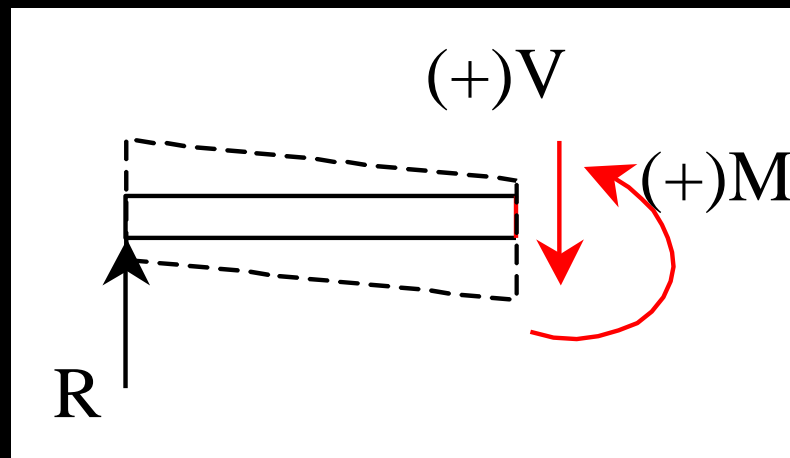
V & M Diagrams

- *tool to locate V_{max} and M_{max} (at $V = 0$)*
- *necessary* for designing
- *have a different sign convention than external forces, moments, and reactions*

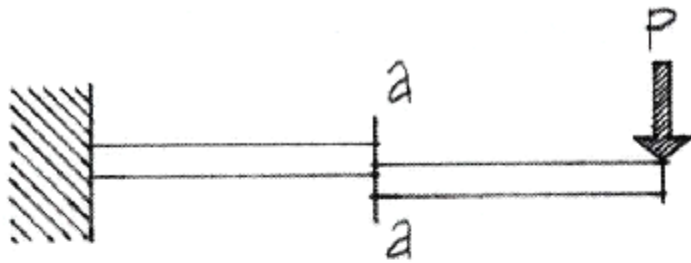


Sign Convention

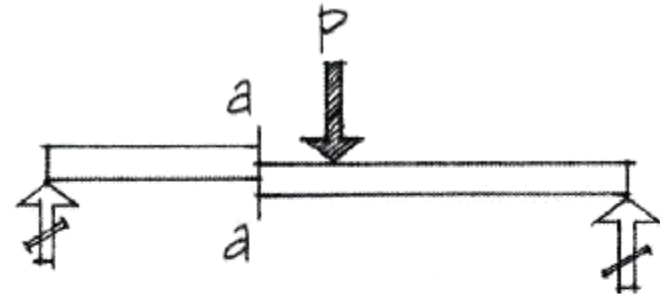
- *shear force, V :*
 - *cut section to LEFT*
 - *if $\sum F_y$ is positive by statics, V acts down and is POSITIVE*
 - *beam has to resist shearing apart by V*



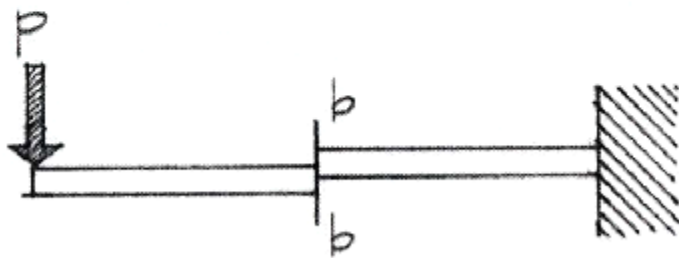
Shear Sign Convention



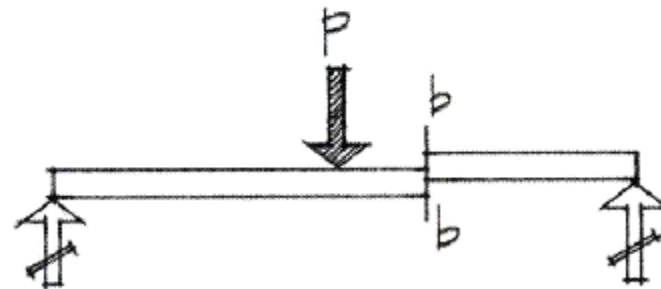
(+) Shear.



(+) Shear.



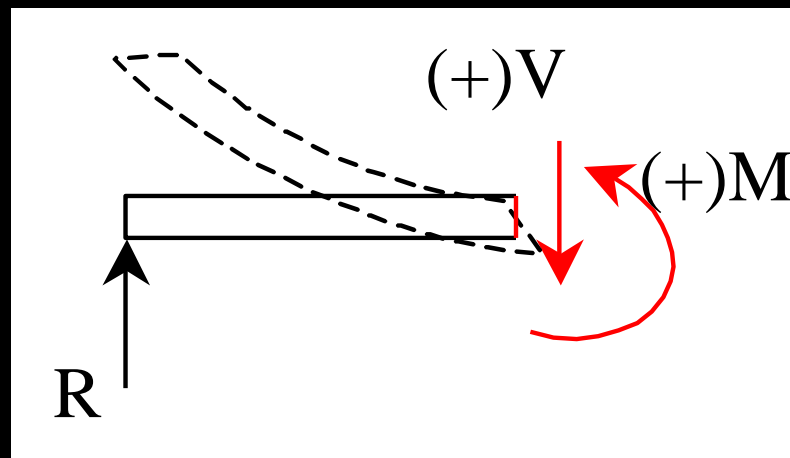
(-) Shear.



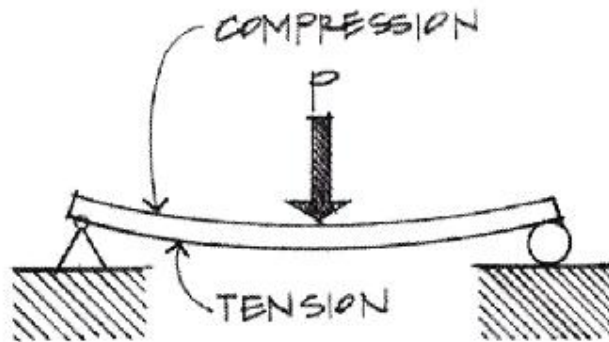
(-) Shear.

Sign Convention

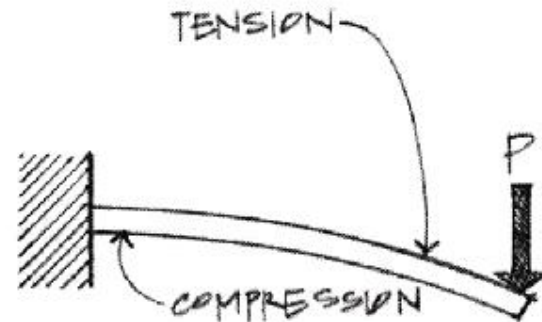
- *bending moment, M :*
 - *cut section to LEFT*
 - *if $\sum M_{cut}$ is clockwise, M acts ccw and is **POSITIVE** – flexes into a “smiley” beam*
 - has to resist bending apart by M*



Bending Moment Sign Convention



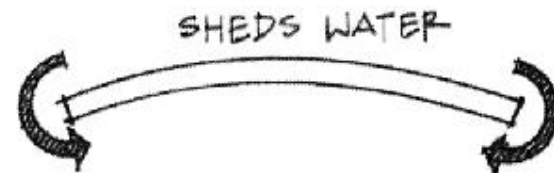
(+) Moment.



(-) Moment.

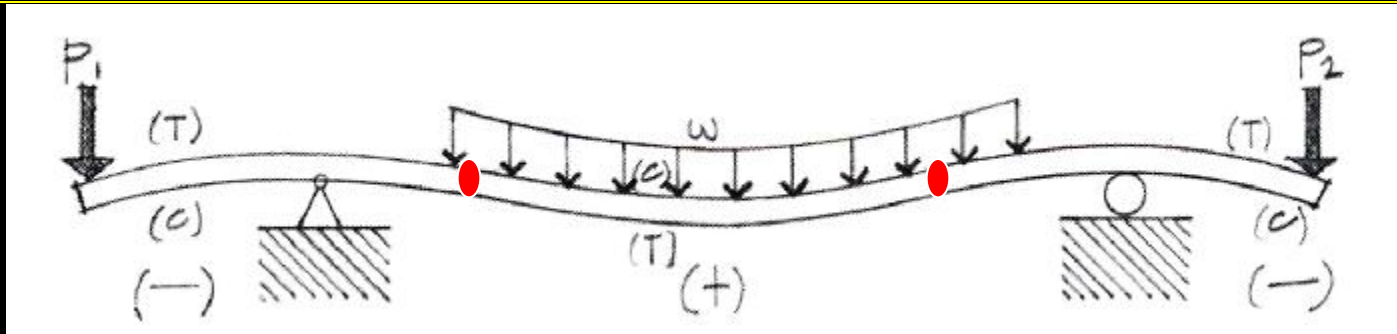


(+) Moment.



(-) Moment.

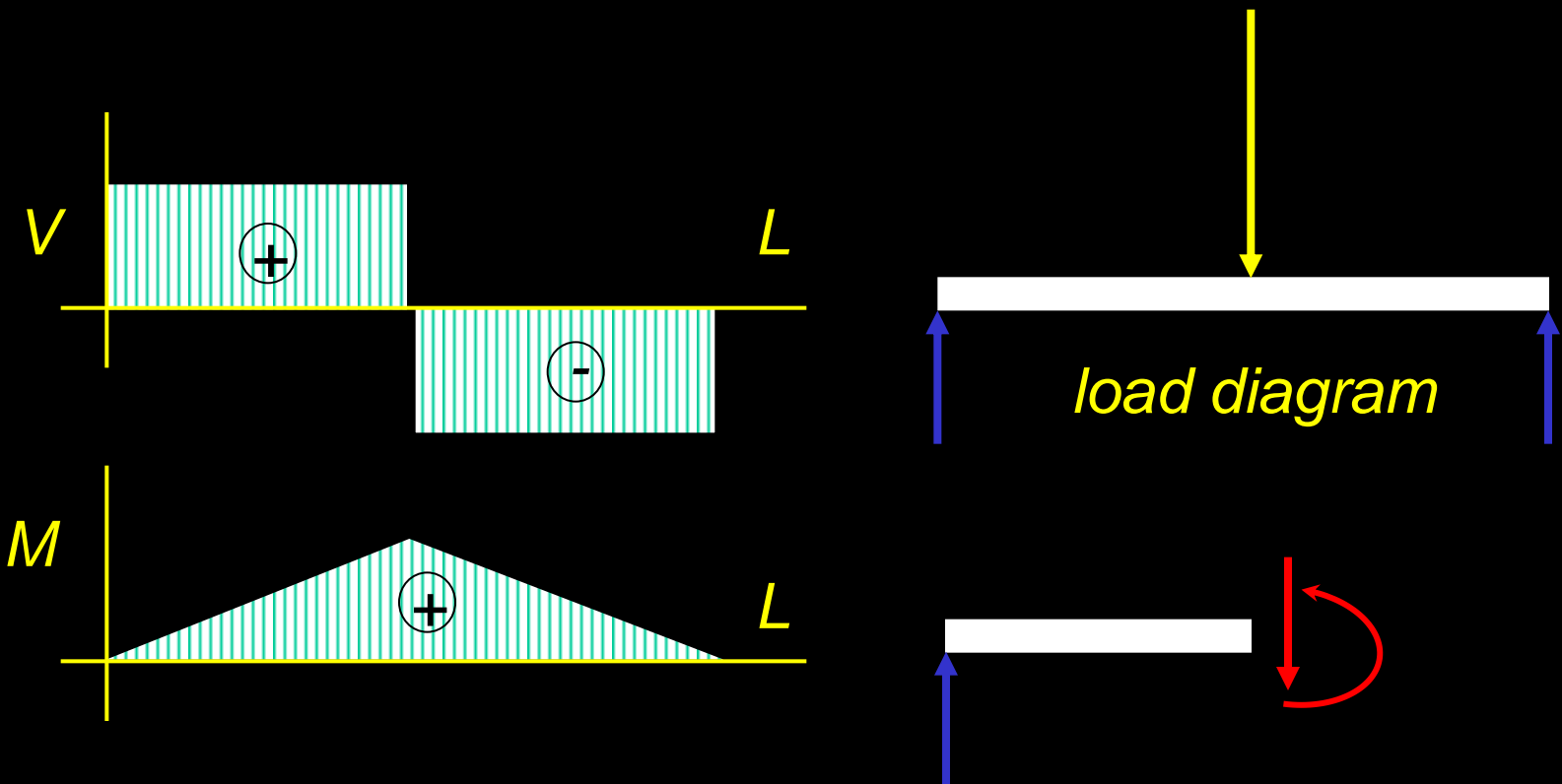
Deflected Shape



- *positive bending moment*
 - *tension in bottom, compression in top*
- *negative bending moment*
 - *tension in top, compression in bottom*
- *zero bending moment*
 - *inflection point*

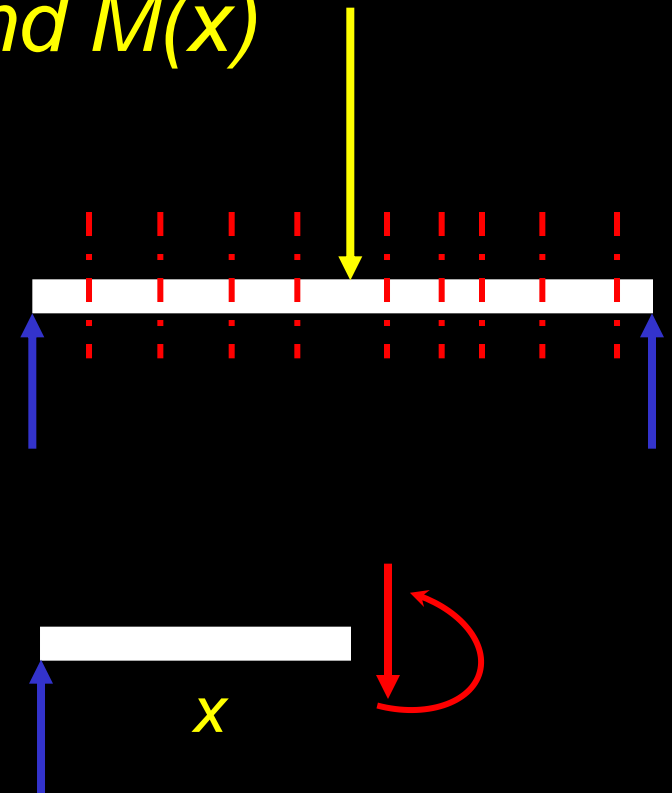
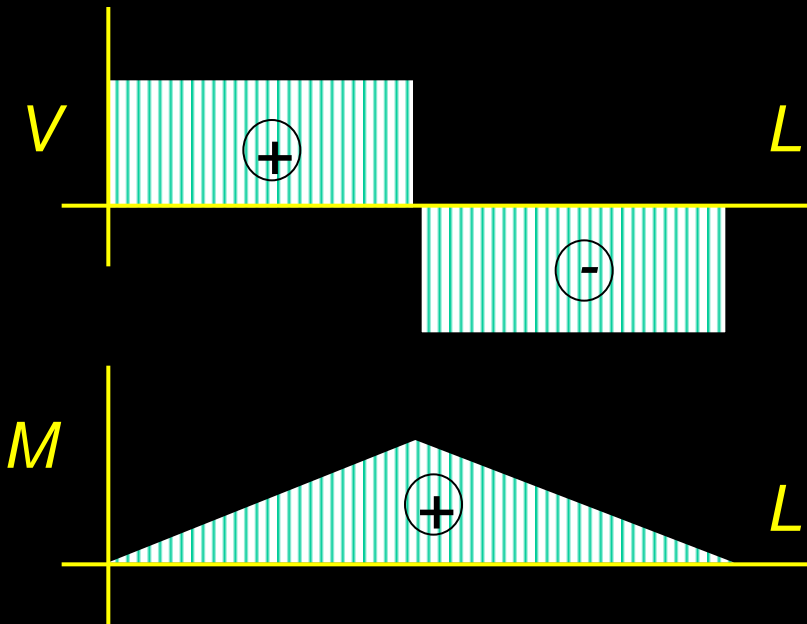
Constructing V & M Diagrams

- along the beam length, plot V, plot M



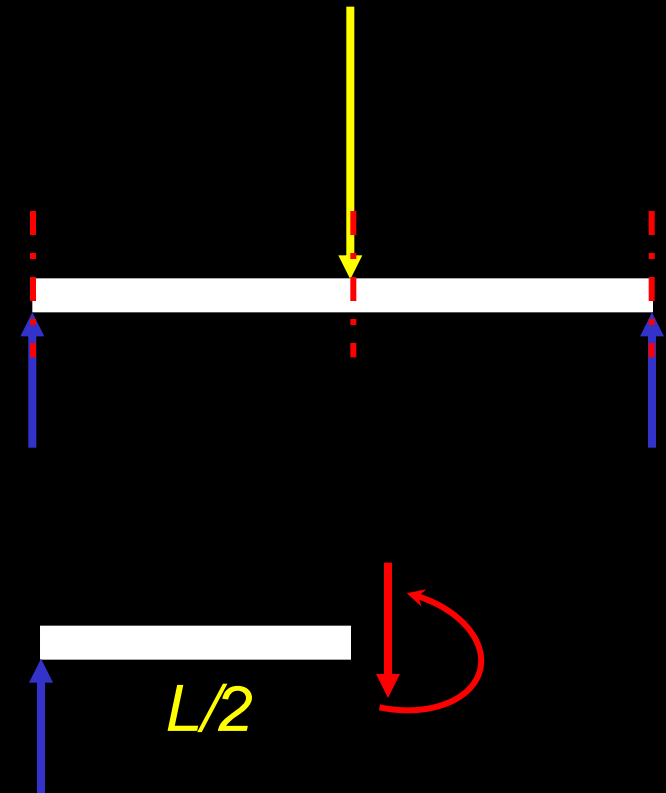
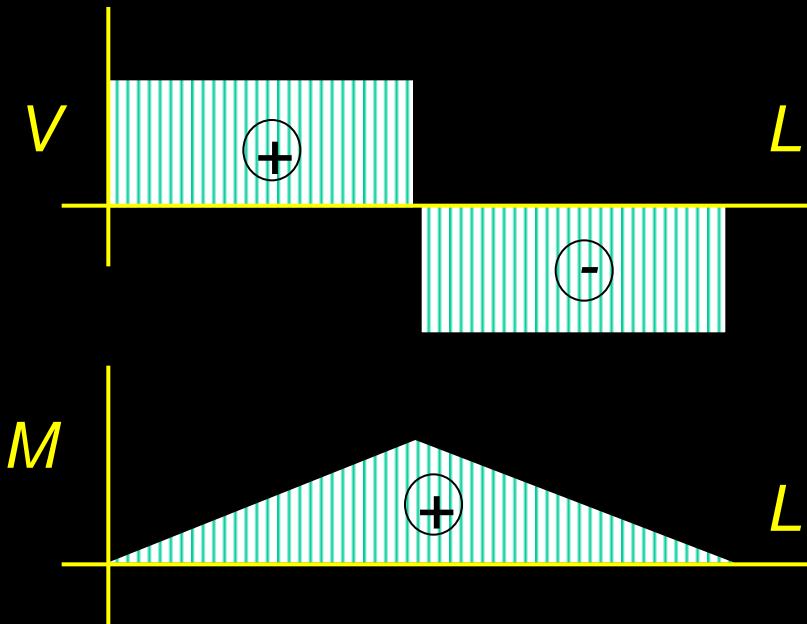
Mathematical Method

- cut sections with x as width
- write functions of $V(x)$ and $M(x)$



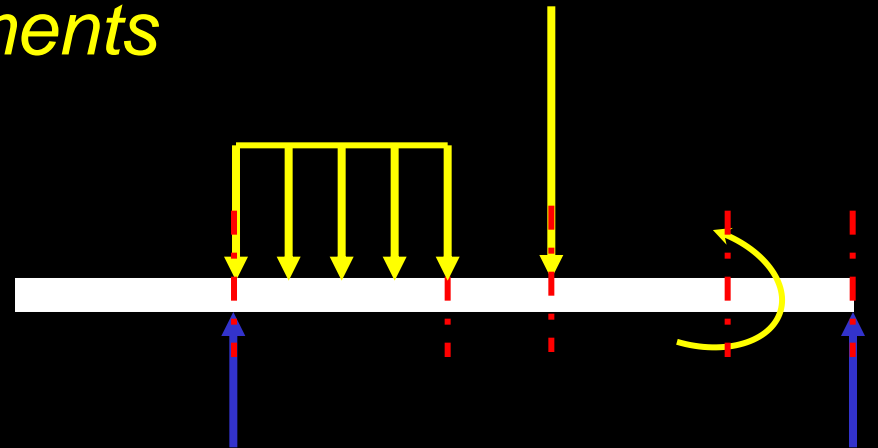
Method 1: Equilibrium

- *cut sections at important places*
- *plot V & M*



Method 1: Equilibrium

- *important places*
 - *supports*
 - *concentrated loads*
 - *start and end of distributed loads*
 - *concentrated moments*
- *free ends*
 - *zero forces*



Method 2: Semigraphical

- *by knowing*
 - *area under loading curve = change in V*
 - *area under shear curve = change in M*
 - *concentrated forces cause “jump” in V*
 - *concentrated moments cause “jump” in M*

$$V_D - V_C = - \int_{x_C}^{x_D} w dx \quad M_D - M_C = \int_{x_C}^{x_D} V dx$$

Method 2

- relationships

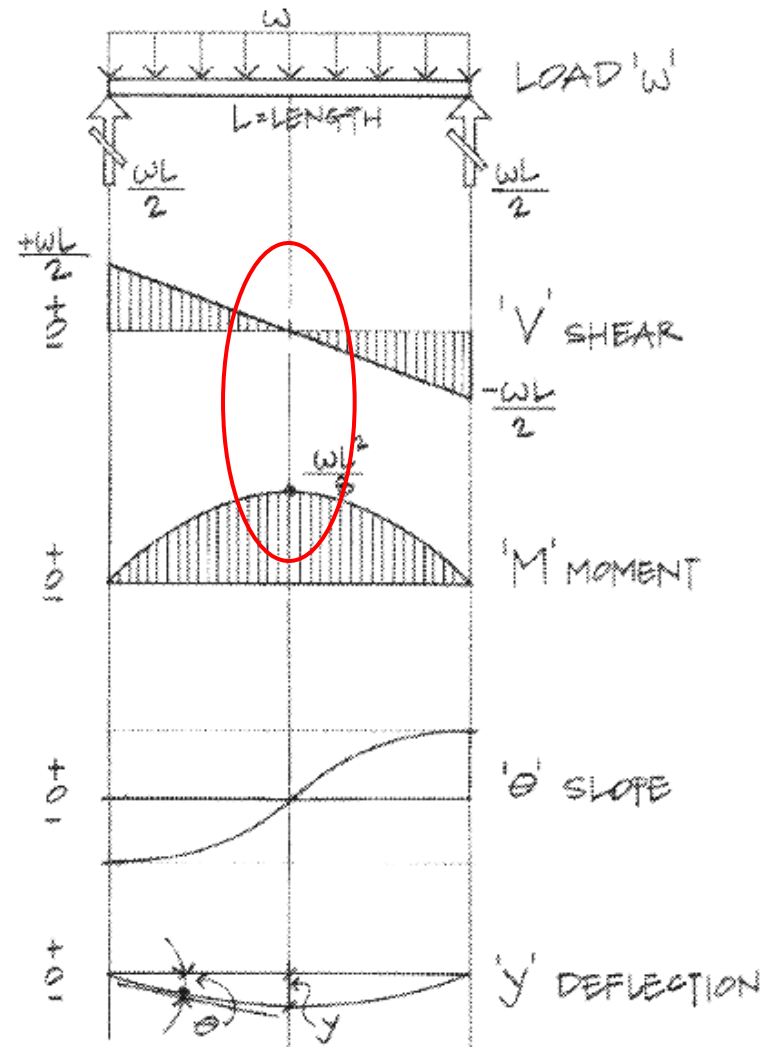
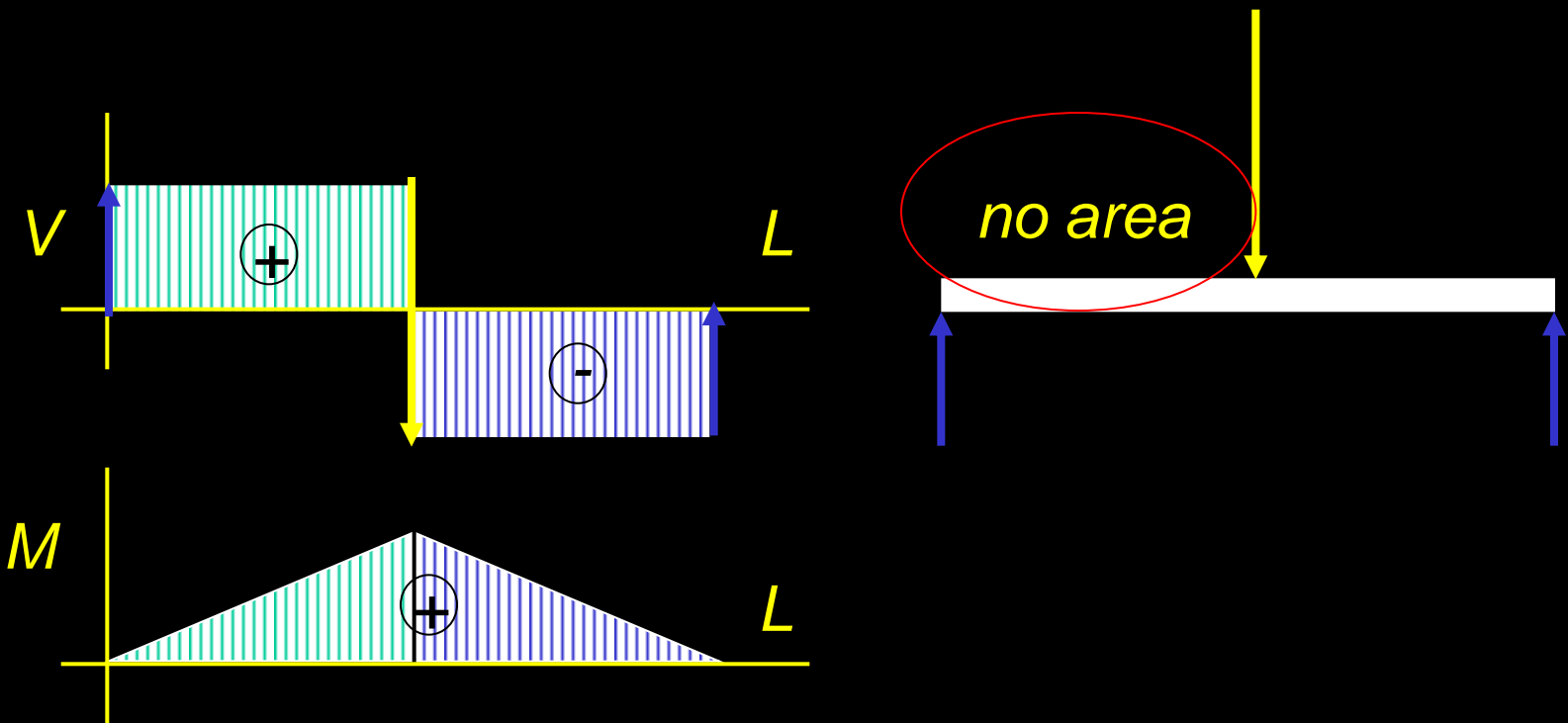


Figure 7.11 Relationship of load, shear, moment, slope, and deflection diagrams.

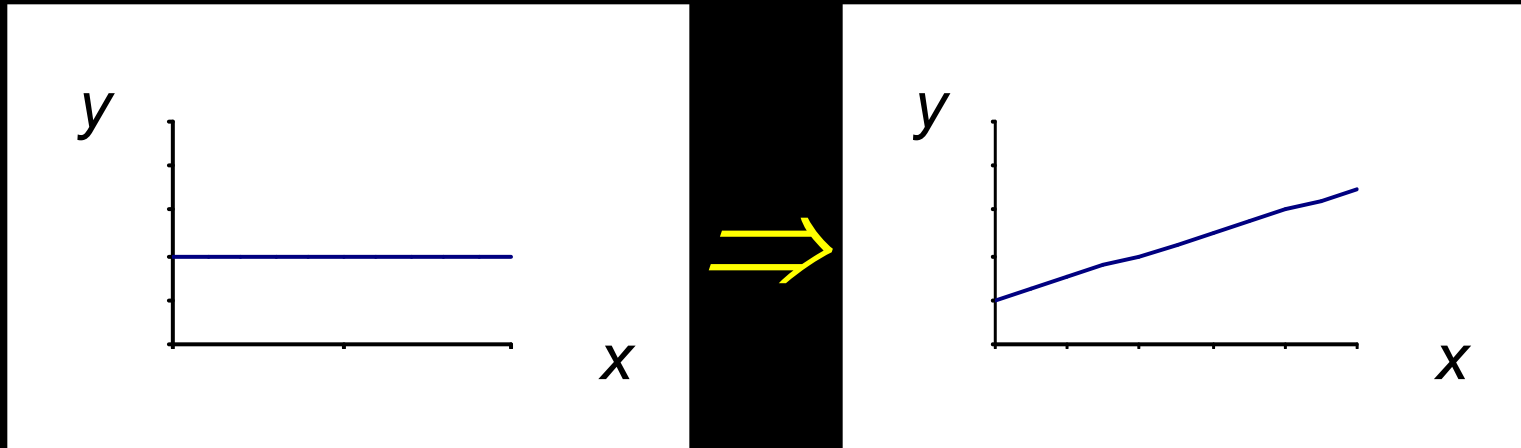
Method 2: Semigraphical

- M_{max} occurs where $V = 0$ (calculus)



Curve Relationships

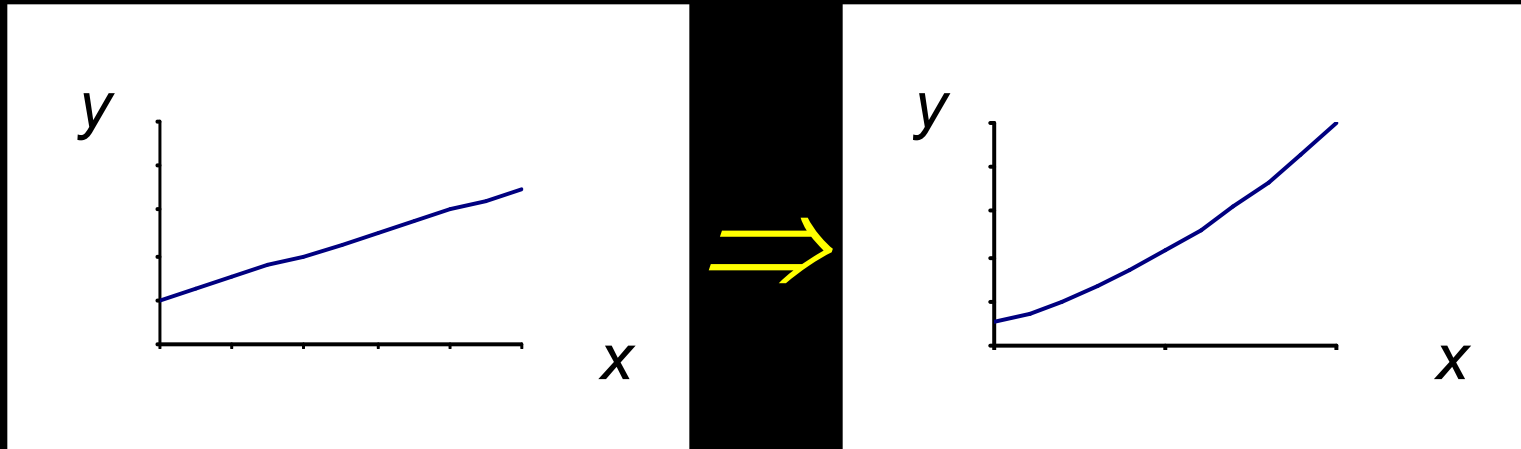
- *integration of functions*
- *line with 0 slope, integrates to sloped*



- *ex: load to shear, shear to moment*

Curve Relationships

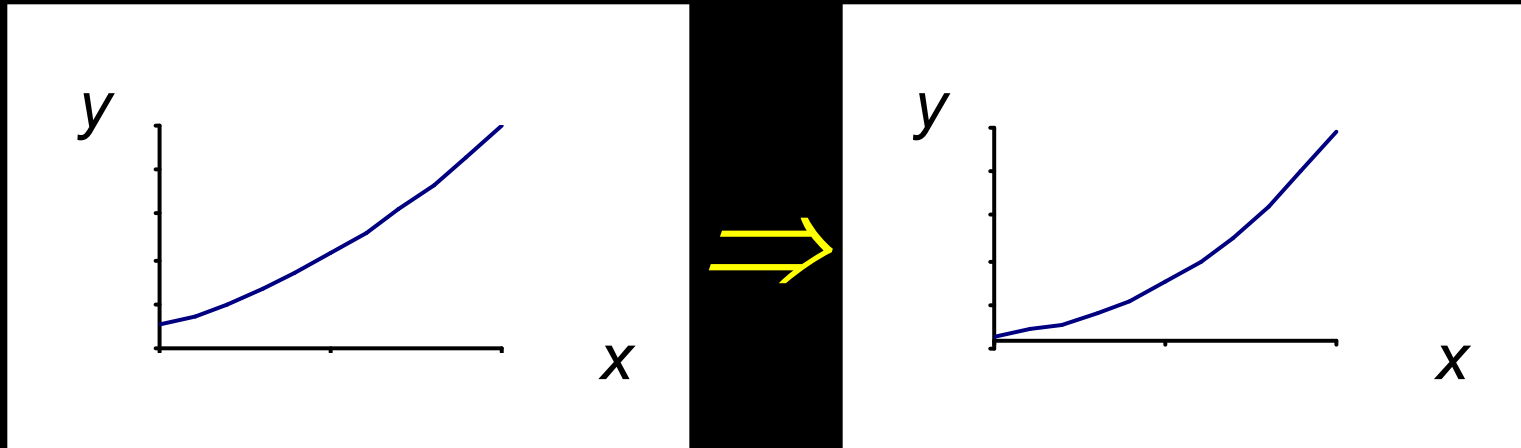
- *line with slope, integrates to parabola*



- *ex: load to shear, shear to moment*

Curve Relationships

- *parabola, integrates to 3rd order curve*



- *ex: load to shear, shear to moment*

Basic Procedure

- 1. Find reaction forces & moments
Plot axes, underneath beam load diagram*
- V:*
- 2. Starting at left*
 - 3. Shear is 0 at free ends*
 - 4. Shear has 2 values at point loads*
 - 5. Sum vertical forces at each section*

Basic Procedure

M:

6. Starting at left

7. Moment is 0 at free ends

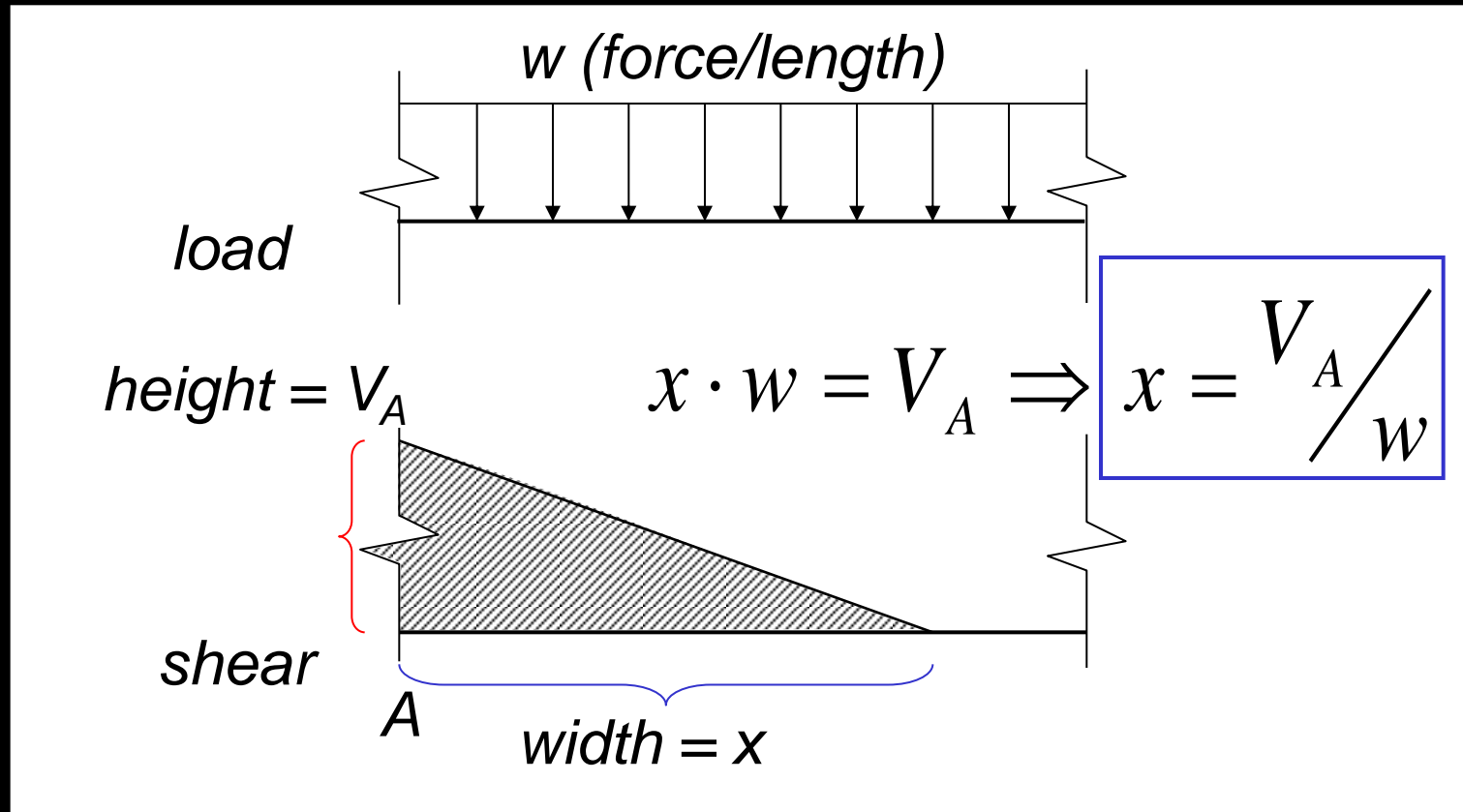
8. Moment has 2 values at moments

9. Sum moments at each section

*10. Maximum moment is where shear = 0!
(locate where $V = 0$)*

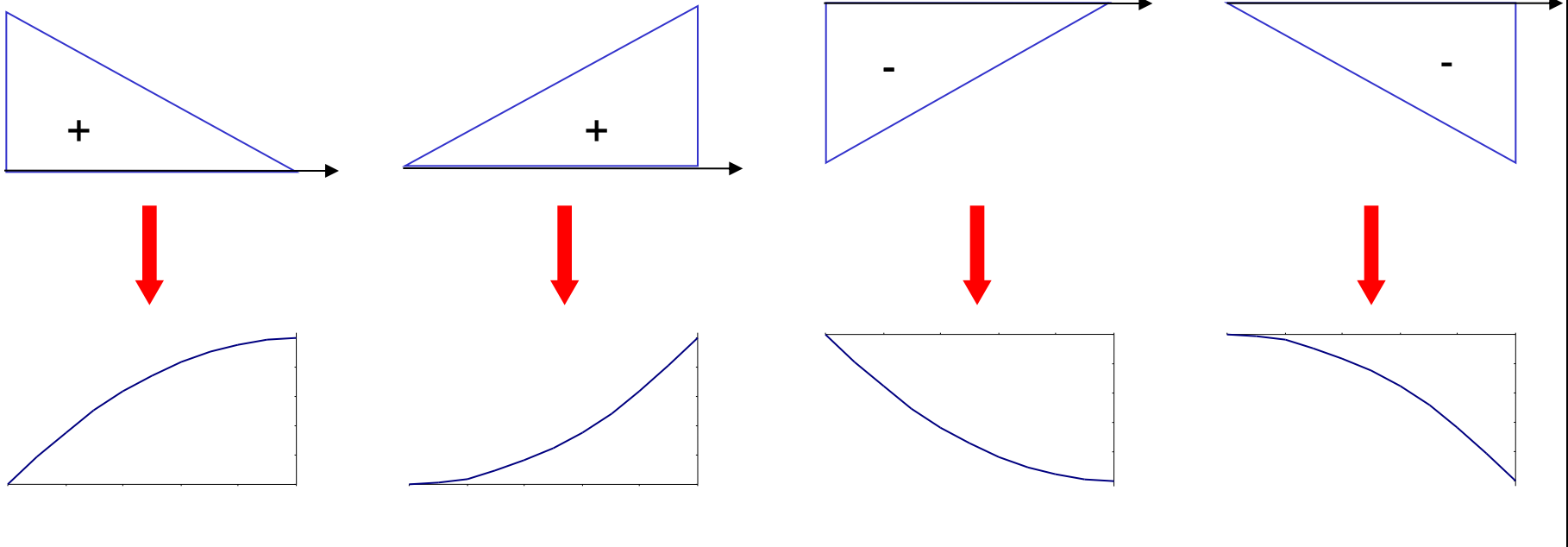
Shear Through Zero

- slope of V is w ($-w:1$)



Parabolic Shapes

- cases



*up fast,
then slow*

*up slow,
then fast*

*down fast,
then slow*

*down slow,
then fast*