ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 331
HÜDAVERDİ TOZAN
SPRING 2013

lecture
seven

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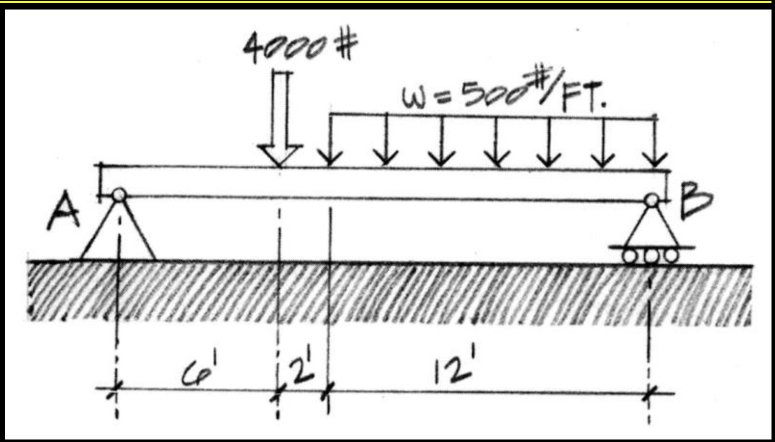
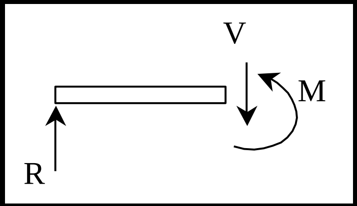
beams – internal forces

Beams

- *span horizontally*
  - *floors*
  - *bridges*
  - *roofs*

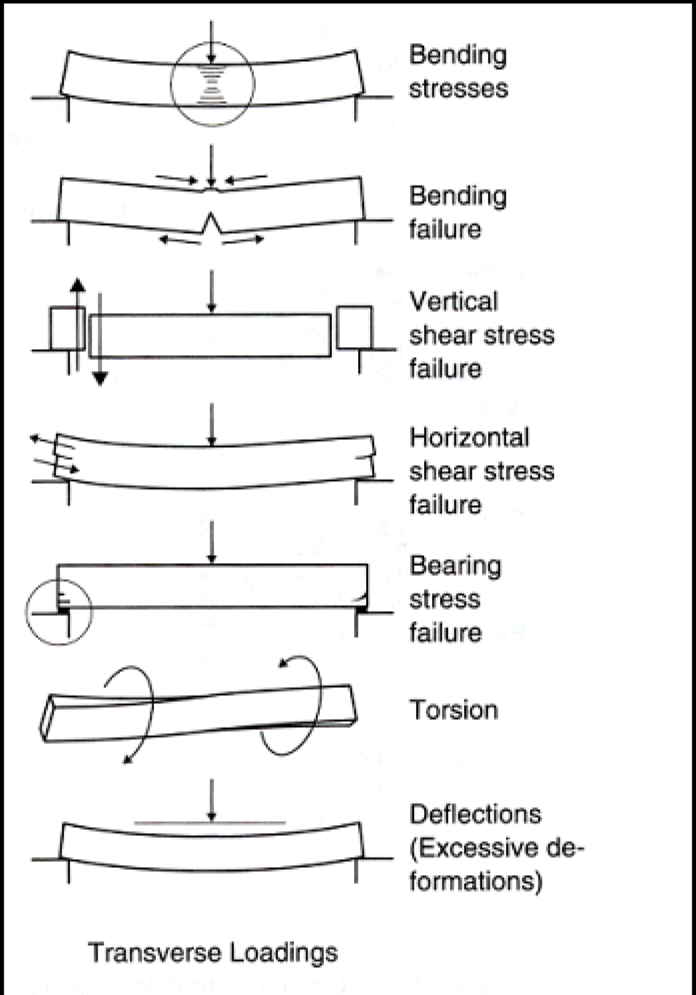


- *loaded transversely by gravity loads*
- *may have internal axial force*
- *will have internal shear force*
- *will have internal moment (bending)*



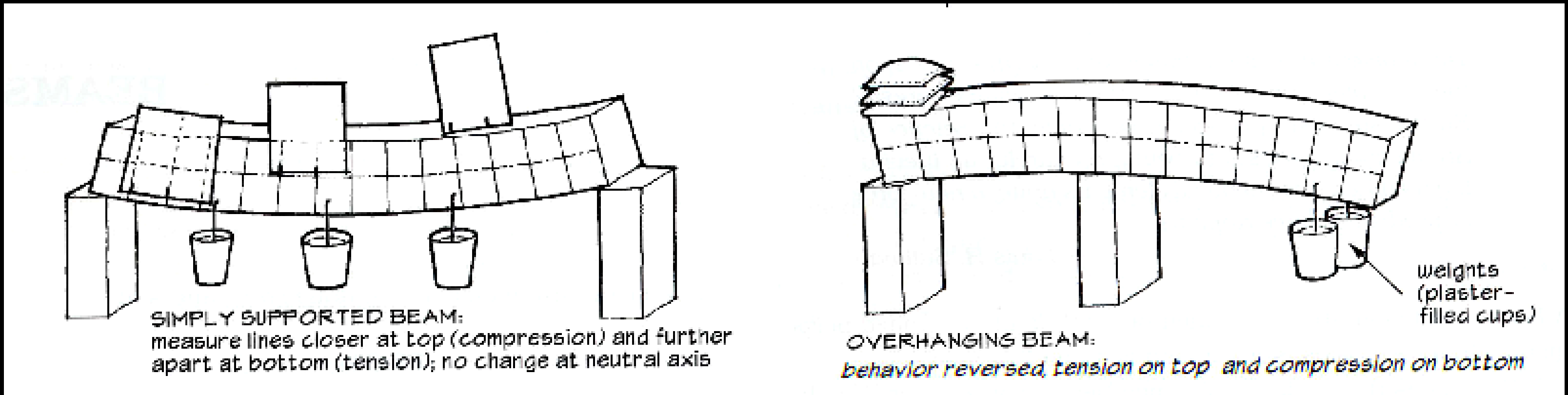
Beams

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



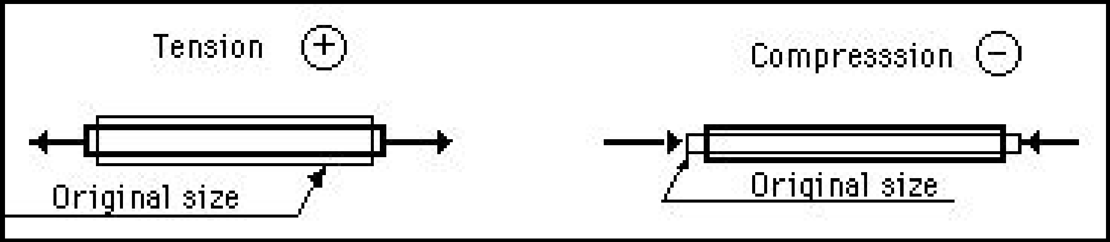
Beams

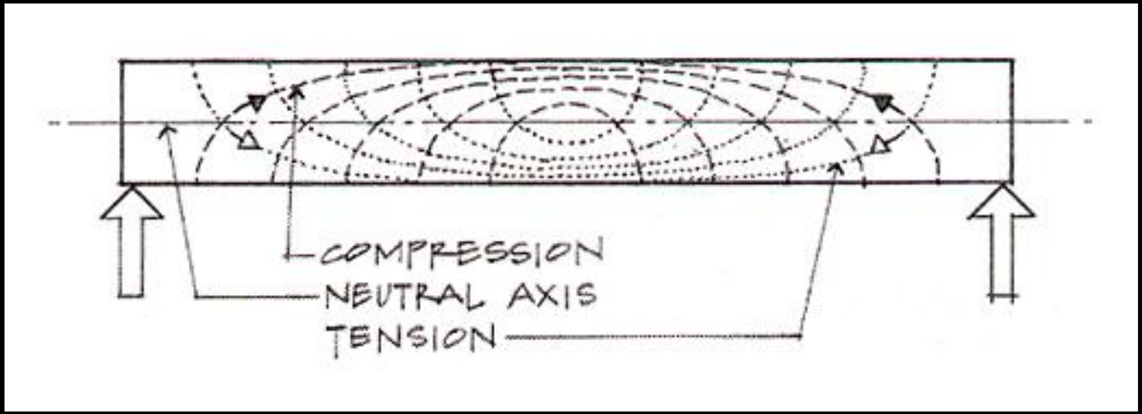
- *bending*
  - *bowing of beam with loads*
  - *one edge surface stretches*
  - *other edge surface squishes*



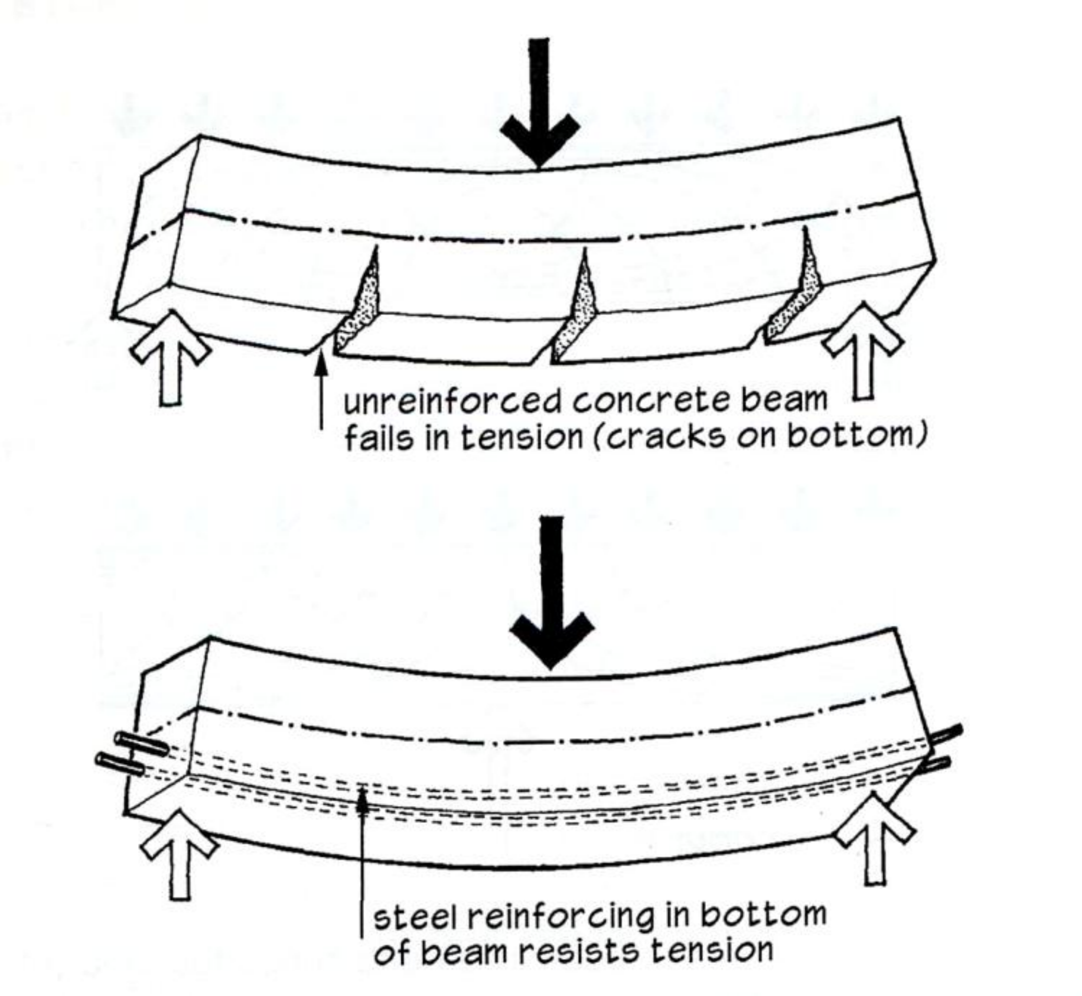
Beam Stresses

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



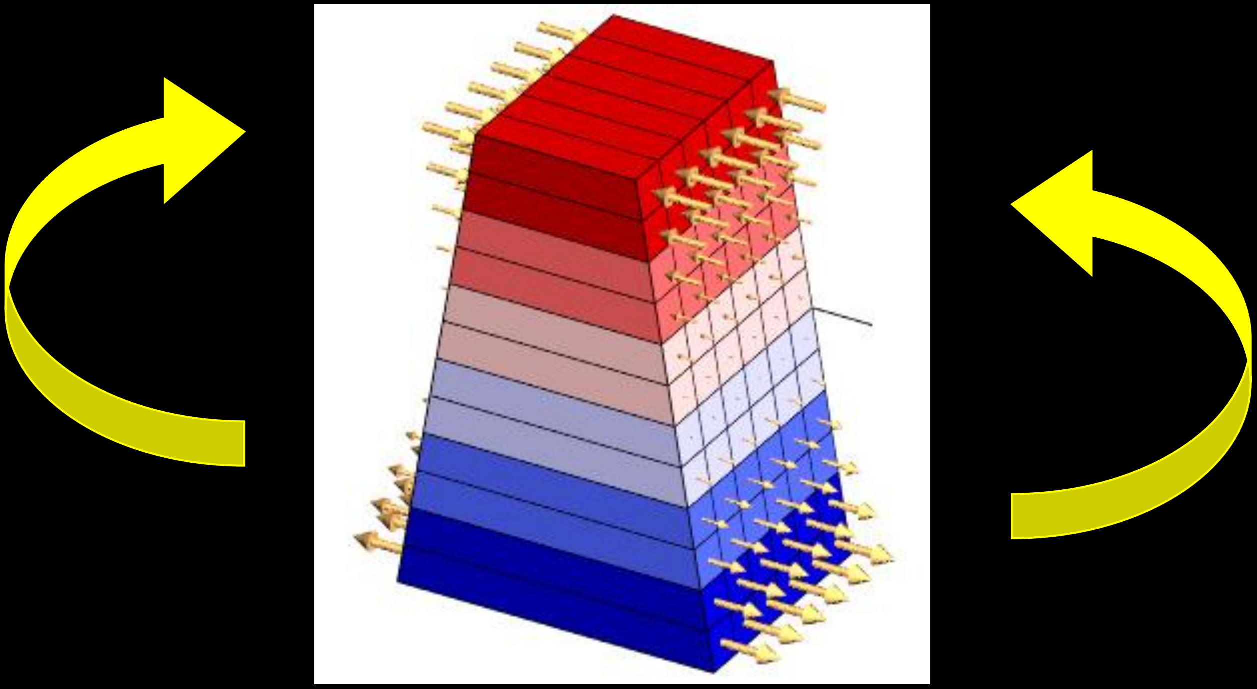


Beam Stresses



Beam Stresses

- tension and compression
  - causes moments



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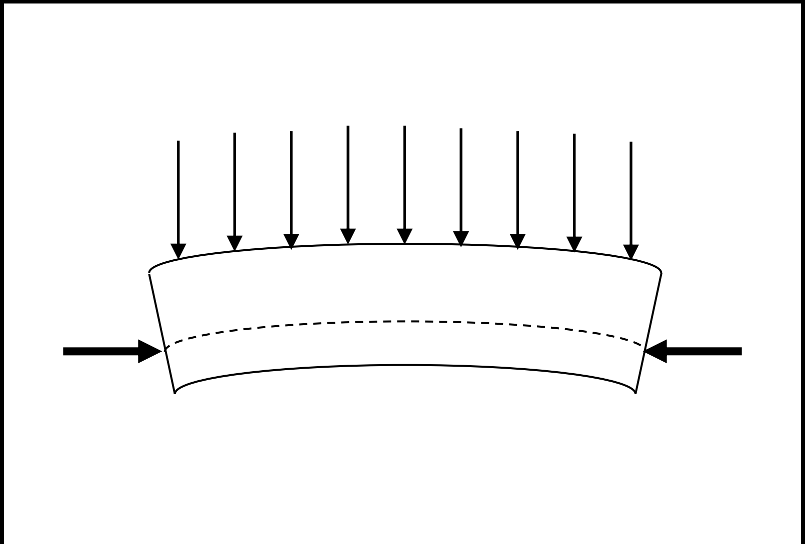
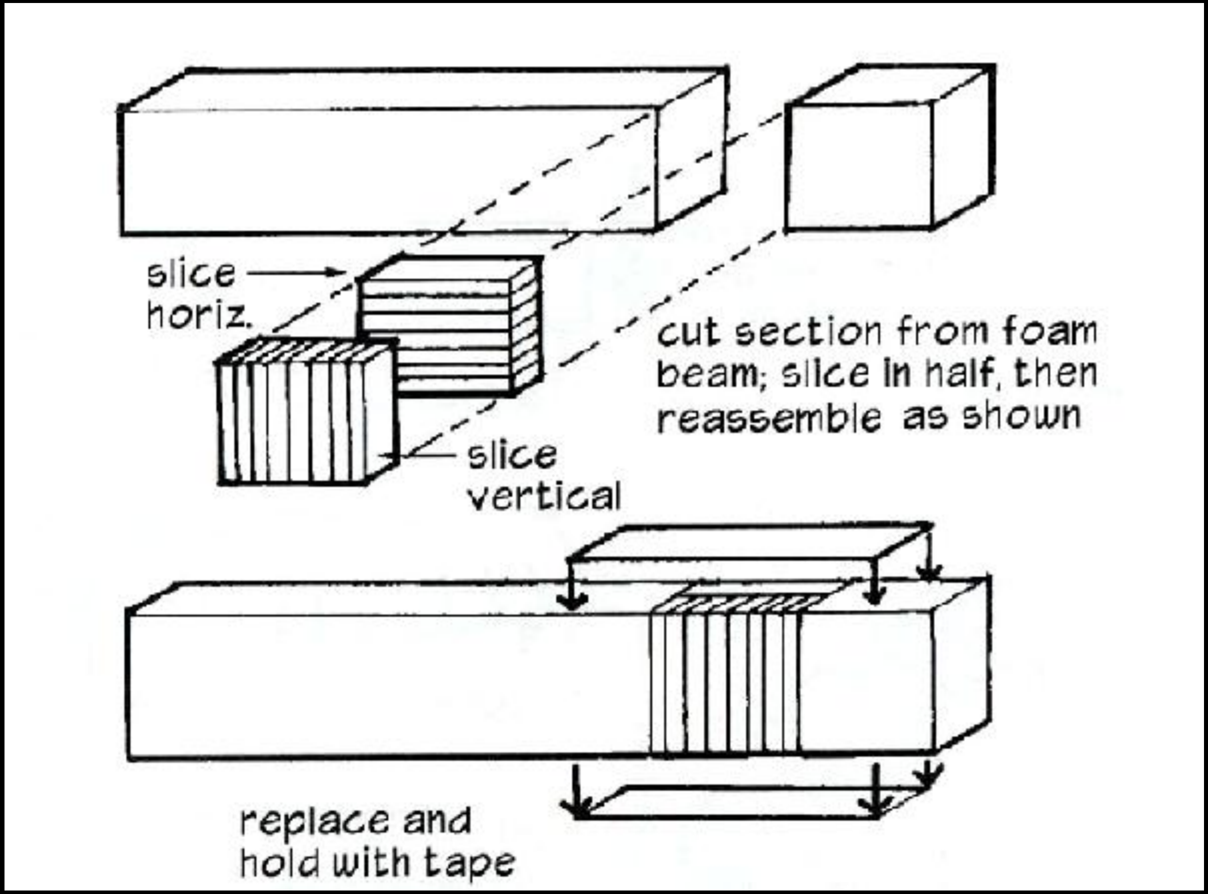
Beam Stresses

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



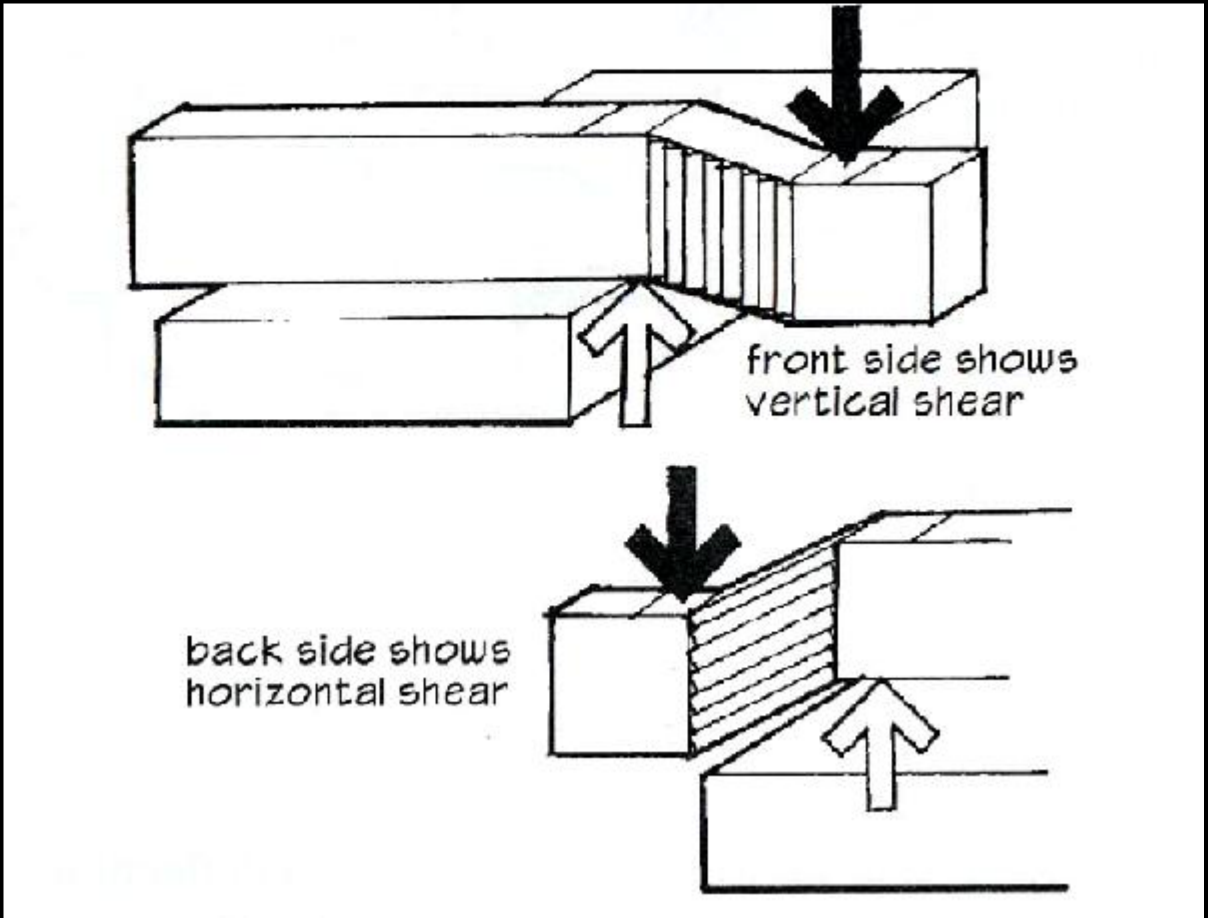
Beam Stresses

- *shear – horizontal & vertical*



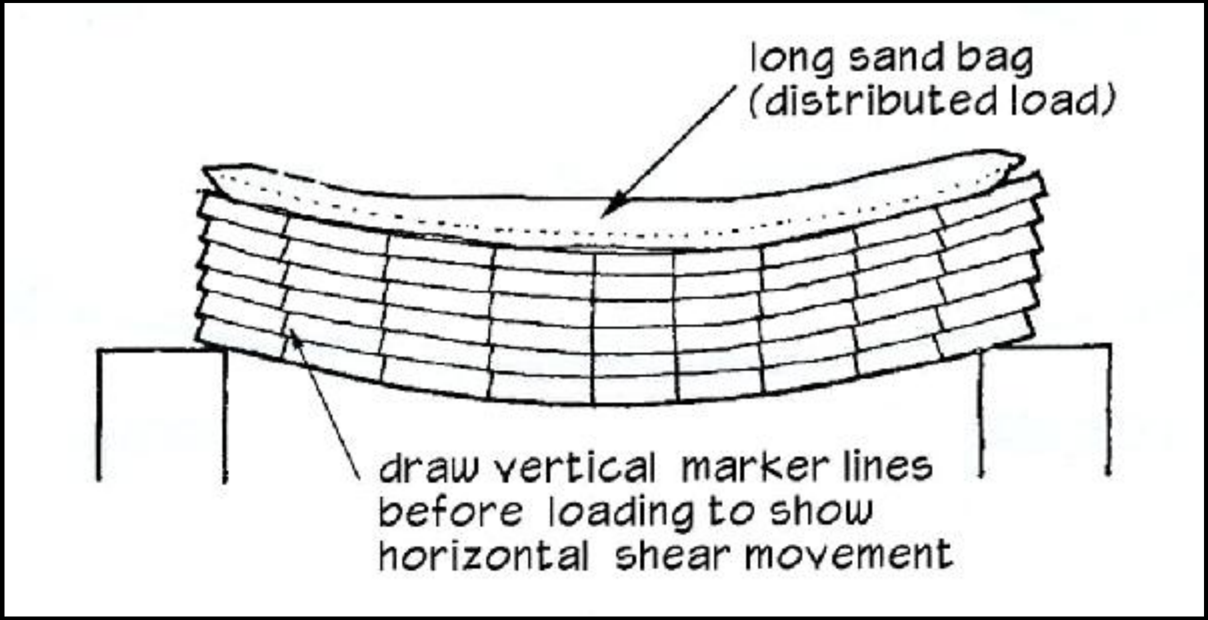
Beam Stresses

- *shear – horizontal & vertical*



Beam Stresses

- *shear – horizontal*



Beam Deflections

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

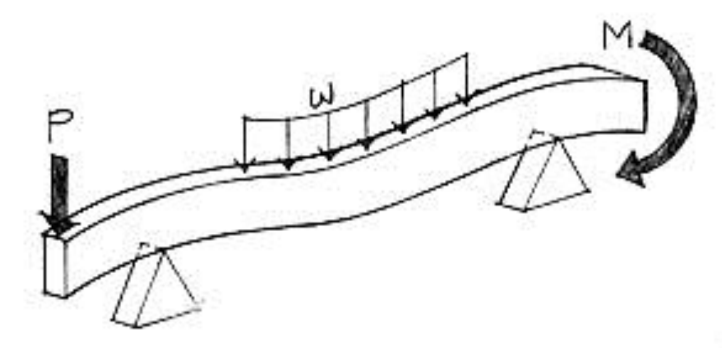
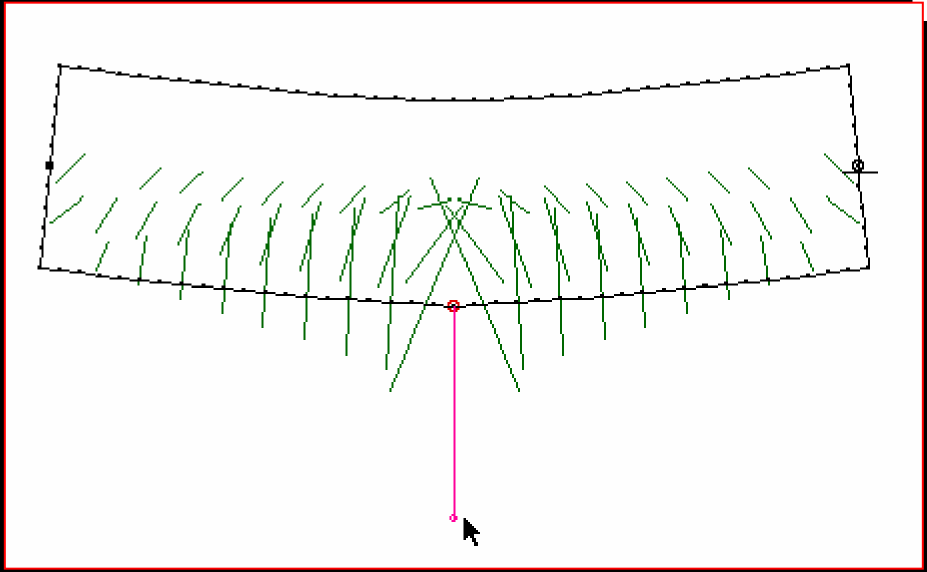
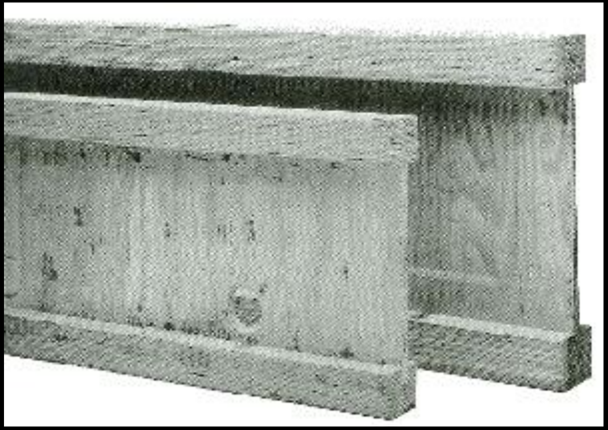


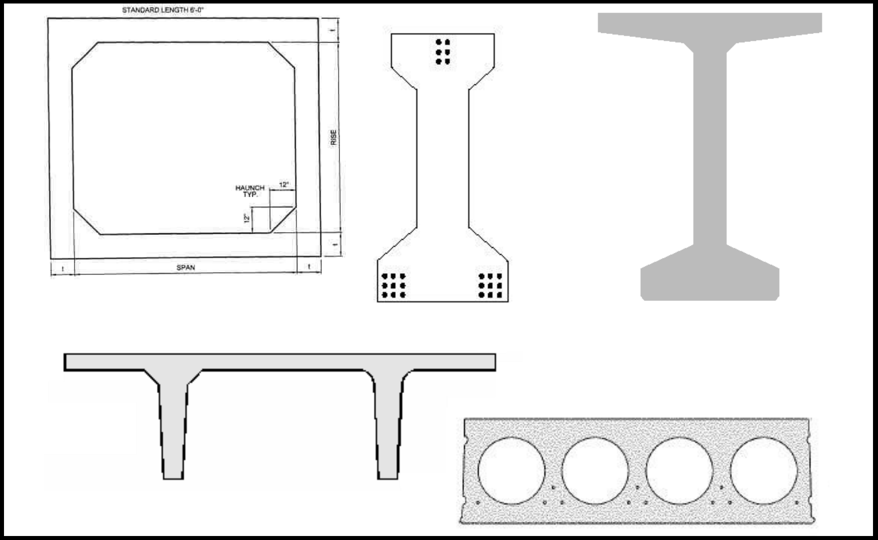
Figure 5.4 Bending (flexural) loads on a beam.

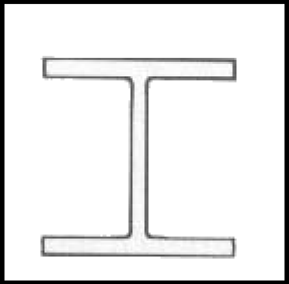


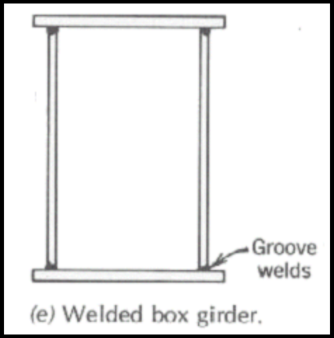
Beam Deflections

- *"moment of inertia"*









Beam Styles

- vierendeel

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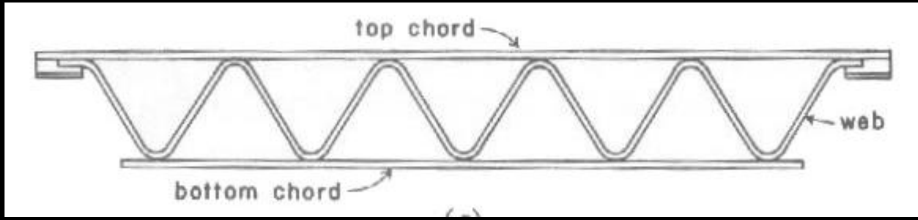
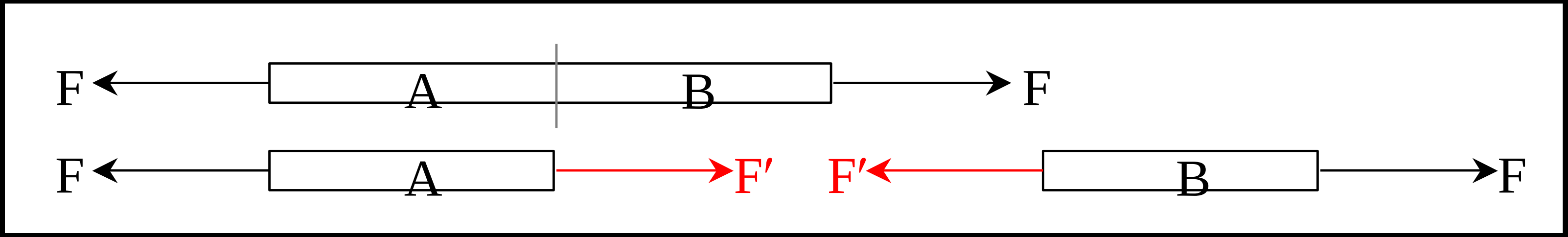
- open web joists
- manufactured

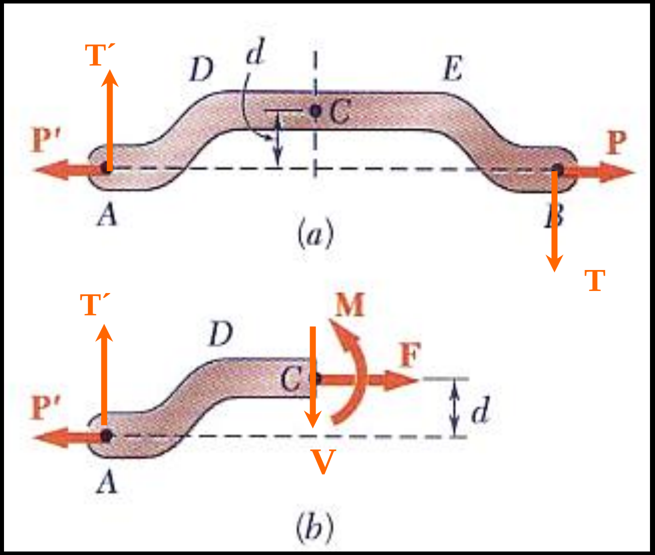


Internal Forces

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

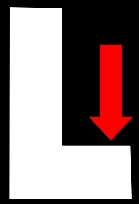


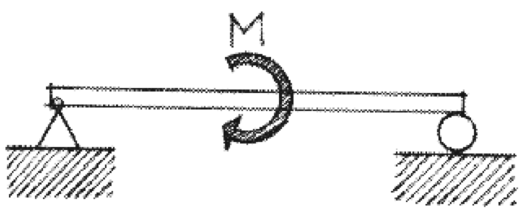
- *in general*
  - *axial force*
  - *shear force, V*
  - *bending moment, M*



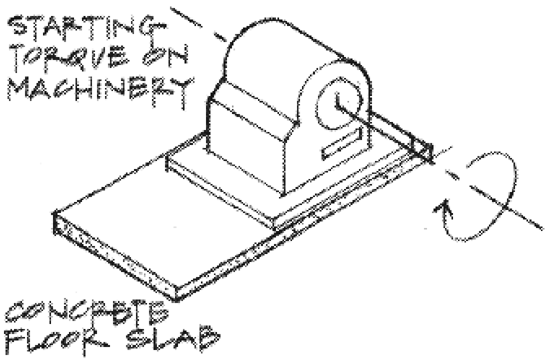
Beam Loading

- *concentrated force*
- *concentrated <u>moment</u>*
  - *spandrel beams*



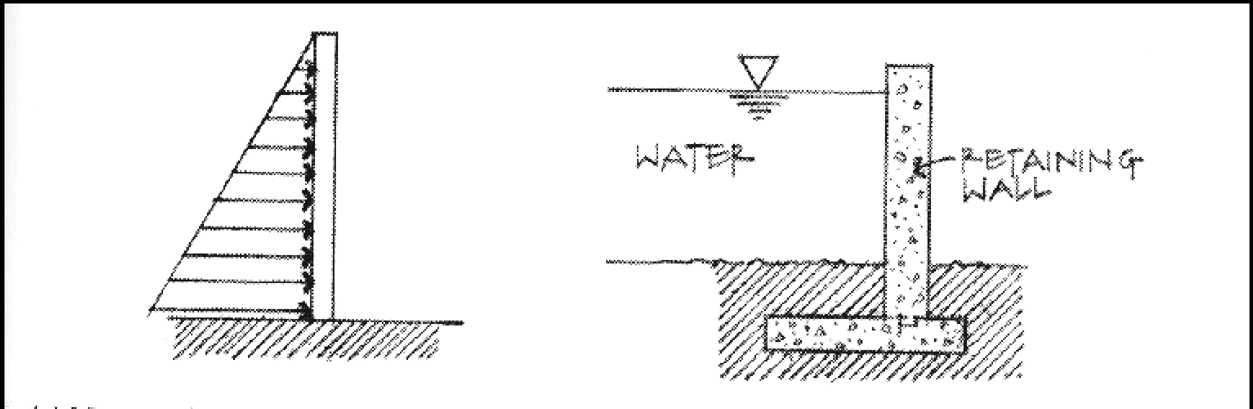


(d) Pure moment.



Beam Loading

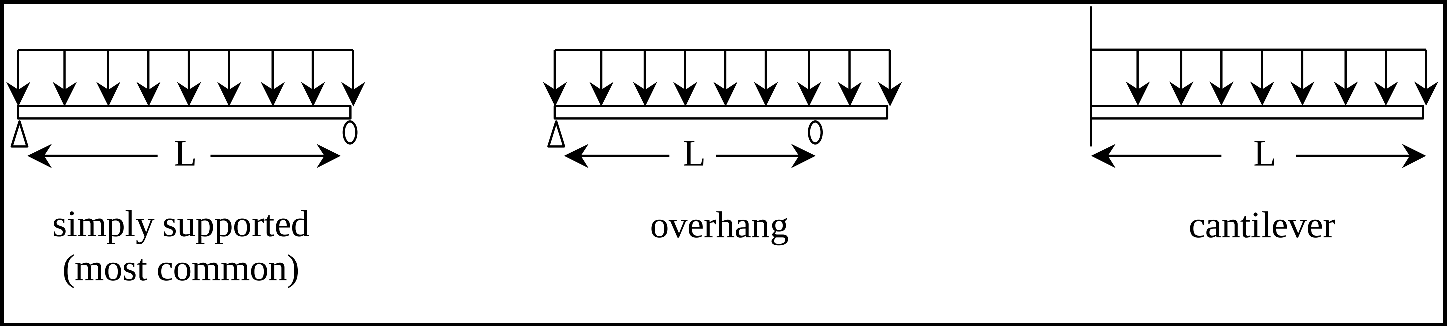
- *uniformly distributed load (line load)*
- *non-uniformly distributed load*
  - *hydrostatic pressure = γh*
  - *wind loads*



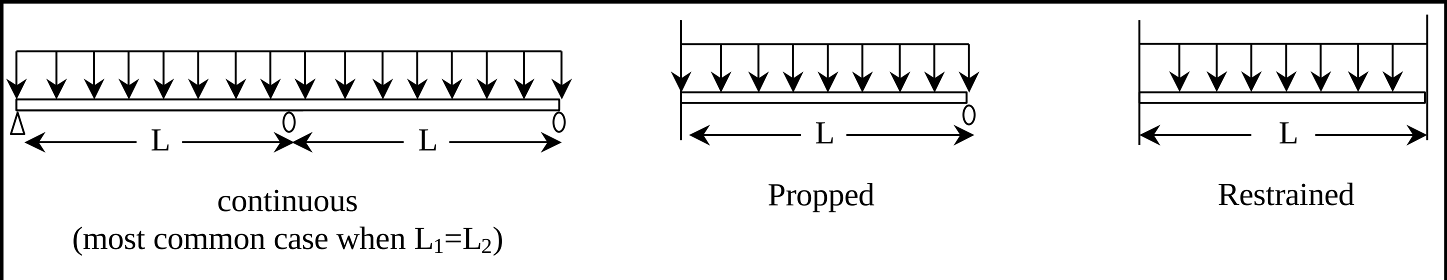
(c) Nonuniformly distributed load.

Beam Supports

- *statically determinate*

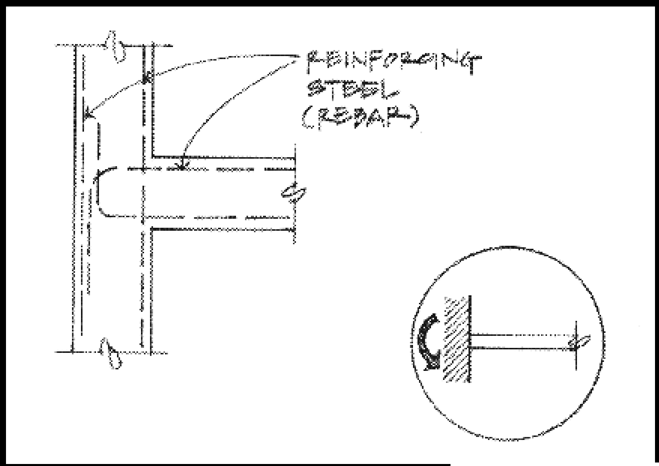


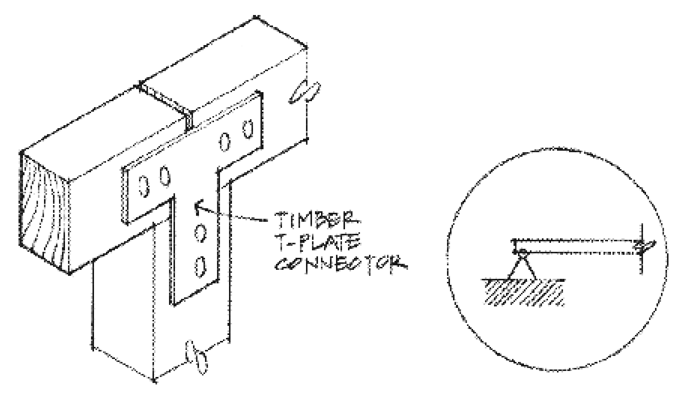
- *statically indeterminate*



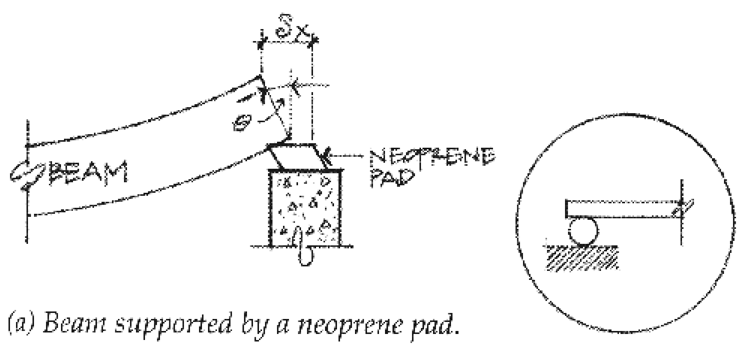
Beam Supports

- *in the real world, modeled type*





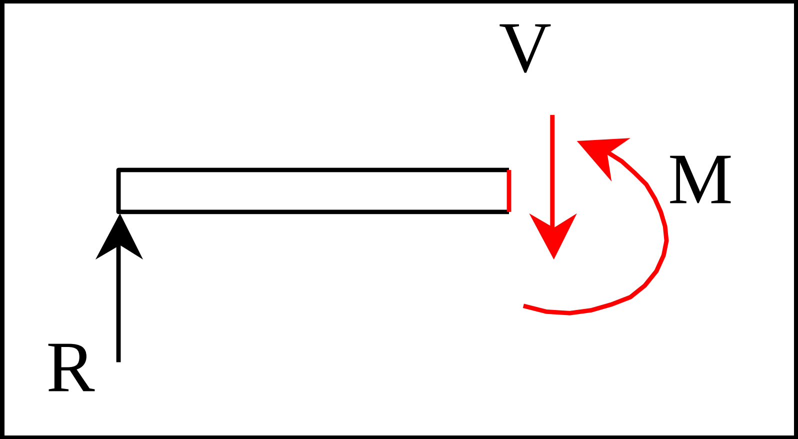
(c) Timber beam–column connection with T-plate.



(a) Beam supported by a neoprene pad.

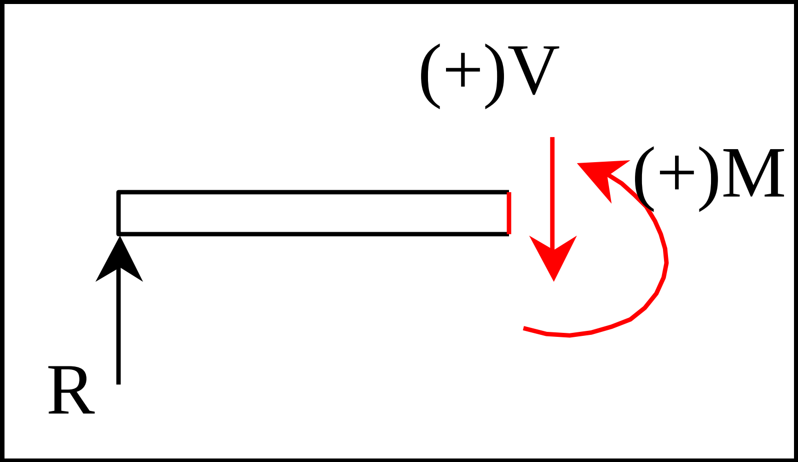
Internal Forces in Beams

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



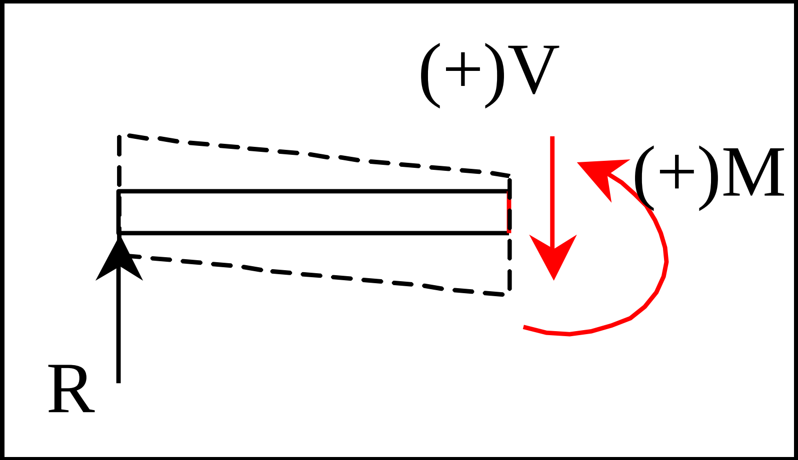
V & M Diagrams

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

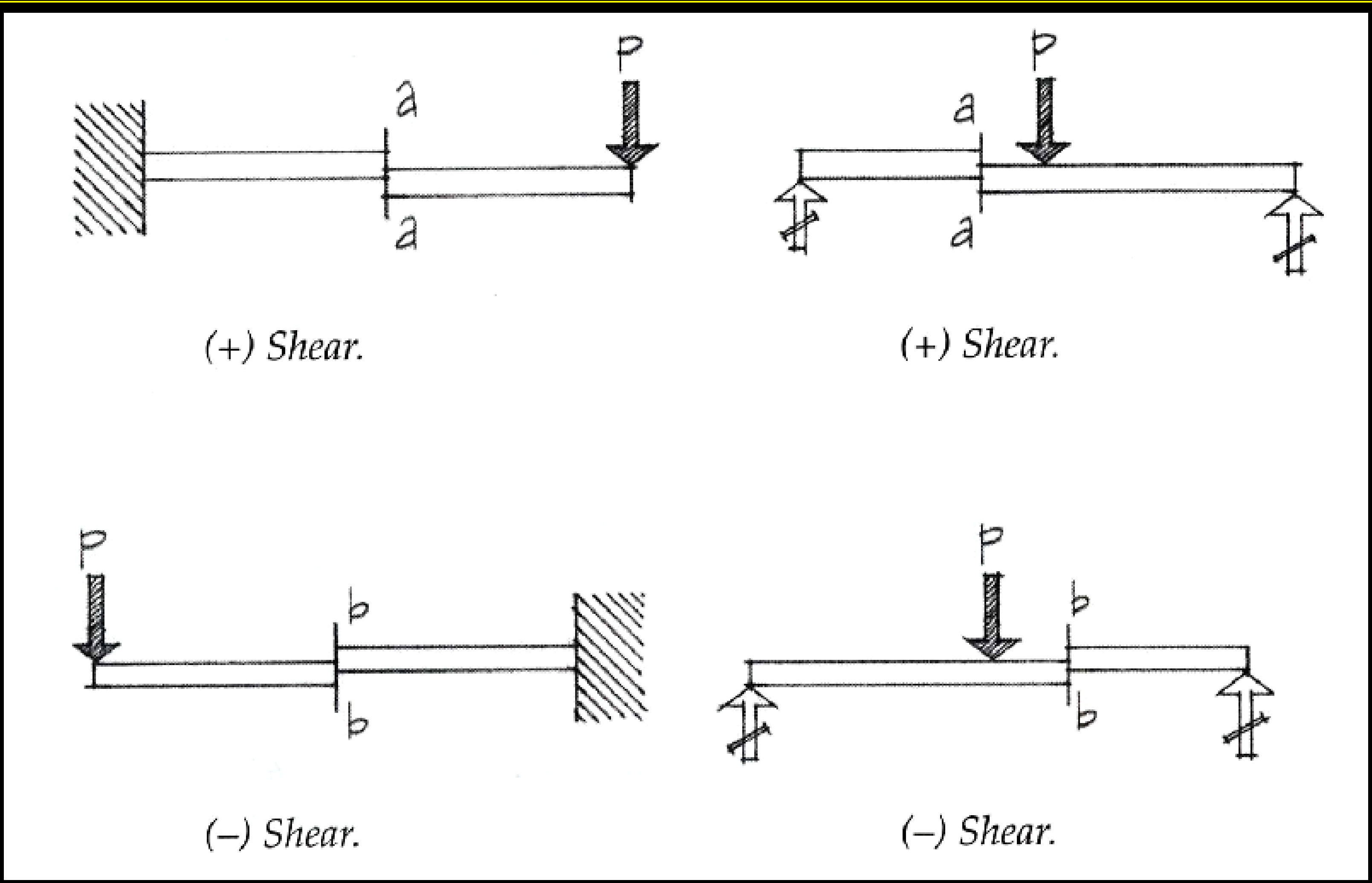


Sign Convention

- *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*

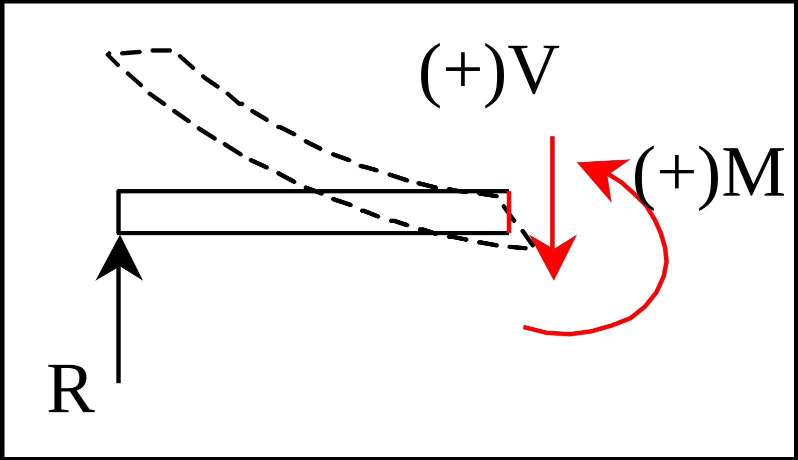


Shear Sign Convention

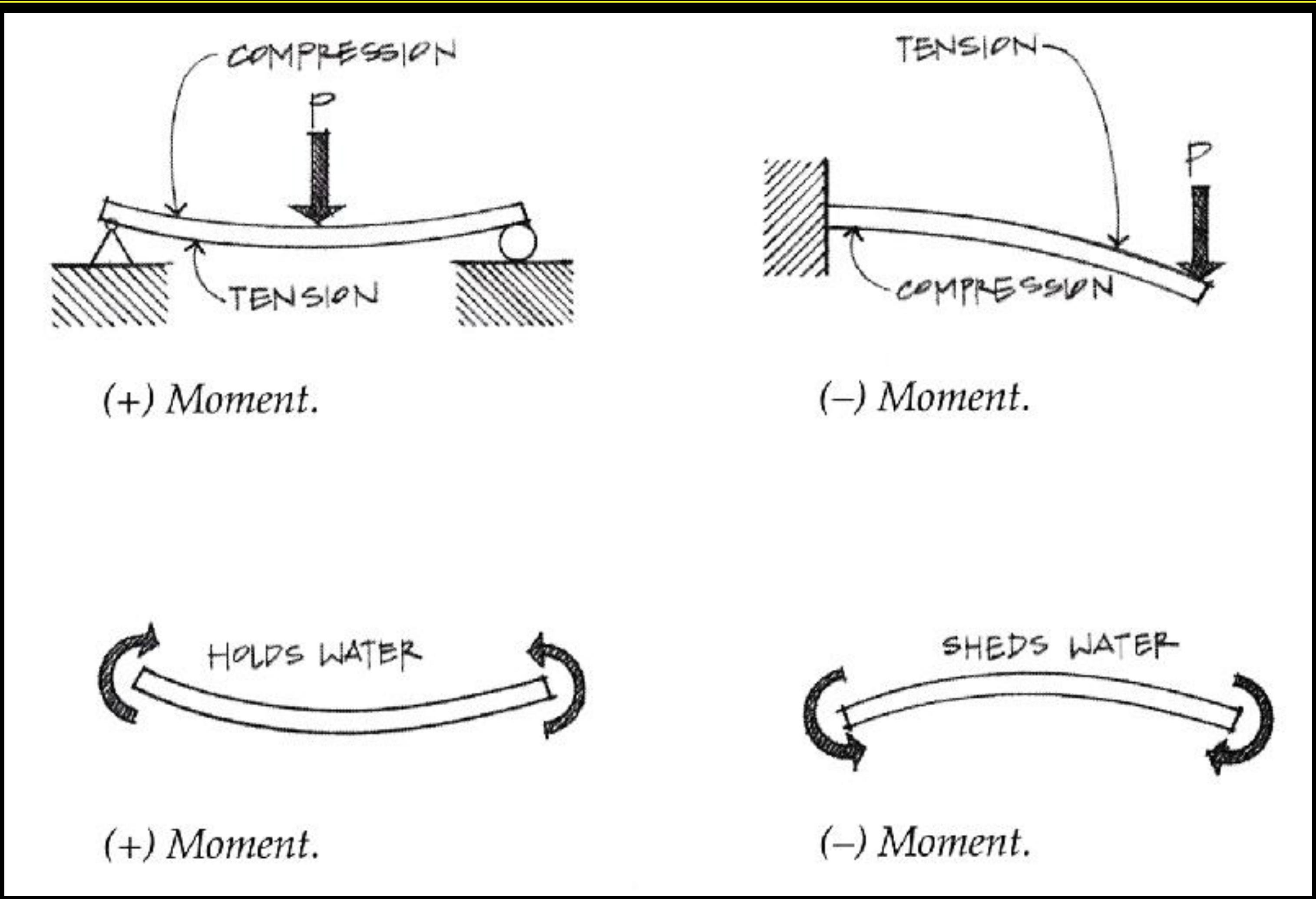


Sign Convention

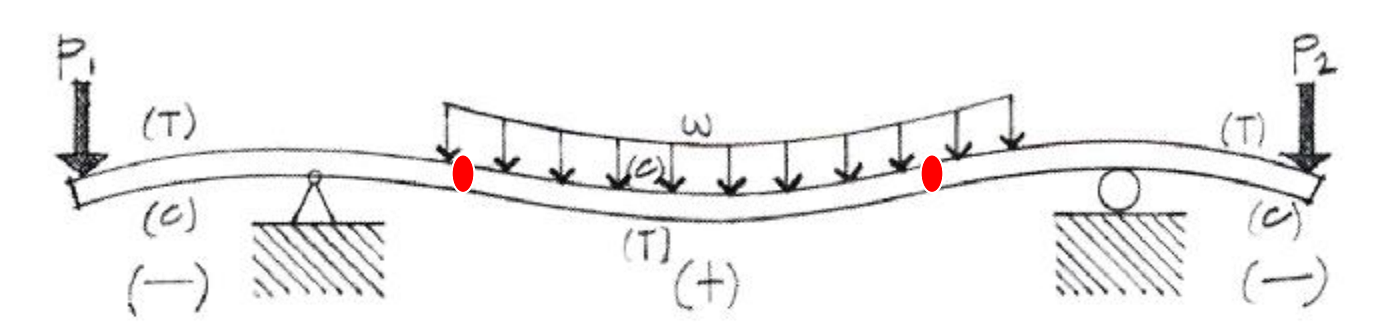
- *bending moment, M:*
  - *cut section to LEFT*
  - *if $\sum M_{cut}$ is clockwise, M acts ccw and is POSITIVE – flexes into a “smiley” beam has to resist bending apart by M*



Bending Moment Sign Convention



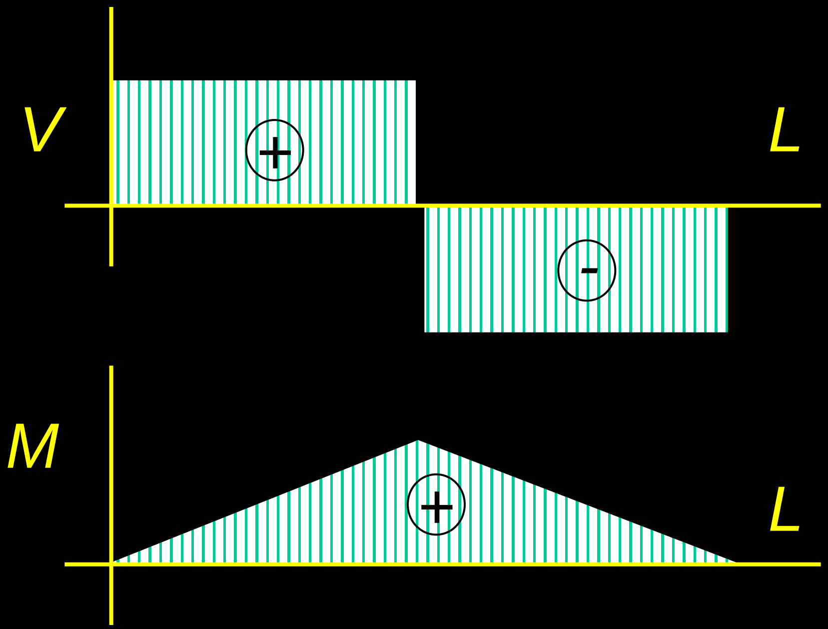
Deflected Shape

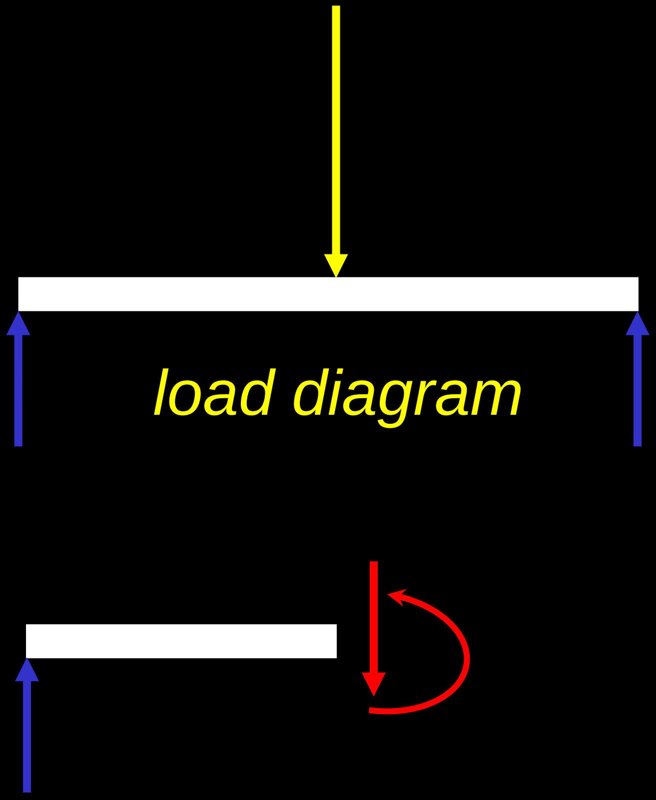


- *positive bending moment*
  - *tension in bottom, compression in top*
- *negative bending moment*
  - *tension in top, compression in bottom*
- *zero bending moment*
  - *inflection point*

Constructing V & M Diagrams

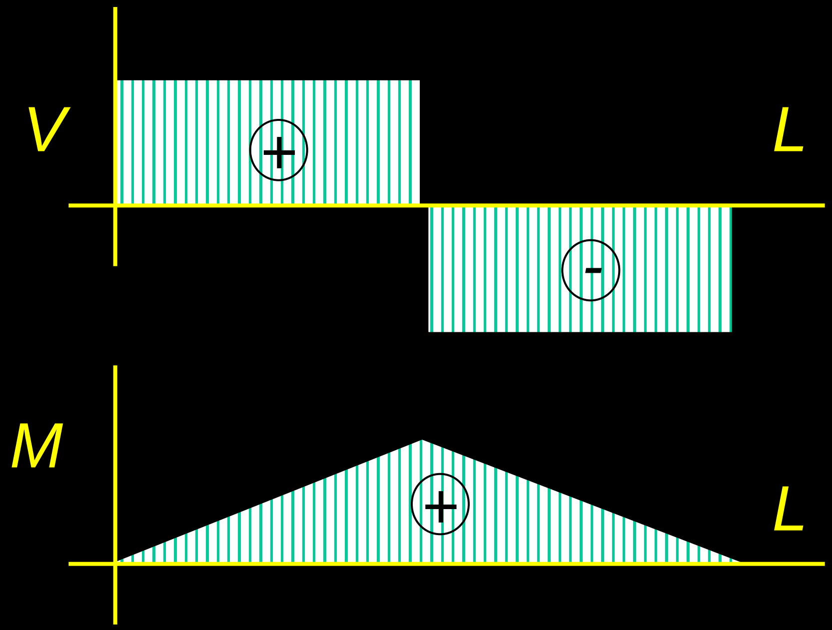
- along the beam length, plot V, plot M

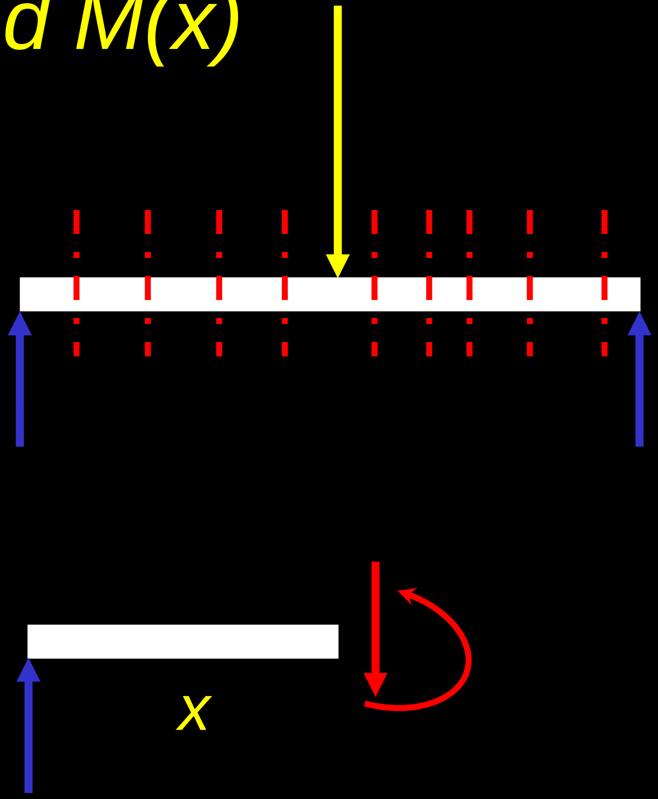




Mathematical Method

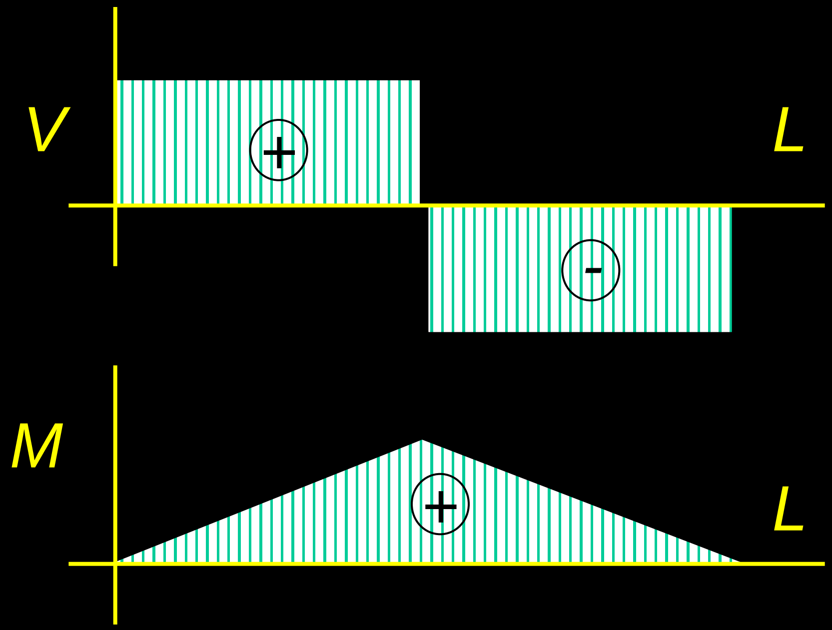
- cut sections with x as width
- write functions of V(x) and M(x)

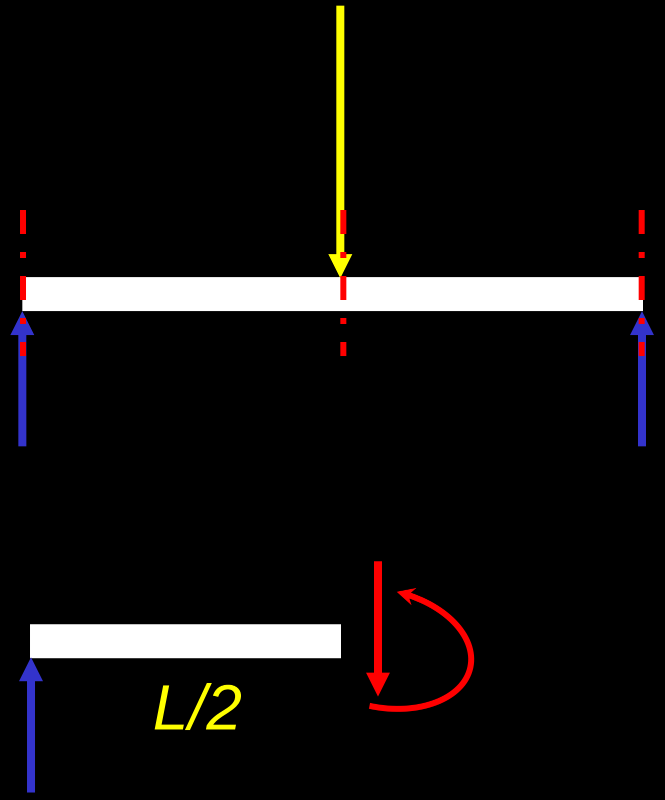




Method 1: Equilibrium

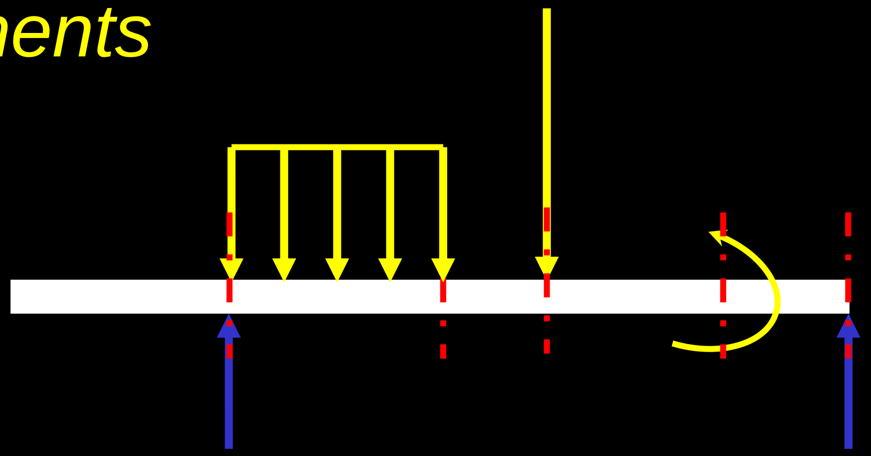
- *cut sections at important places*
- *plot V & M*





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*

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

Method 2

- *relationships*

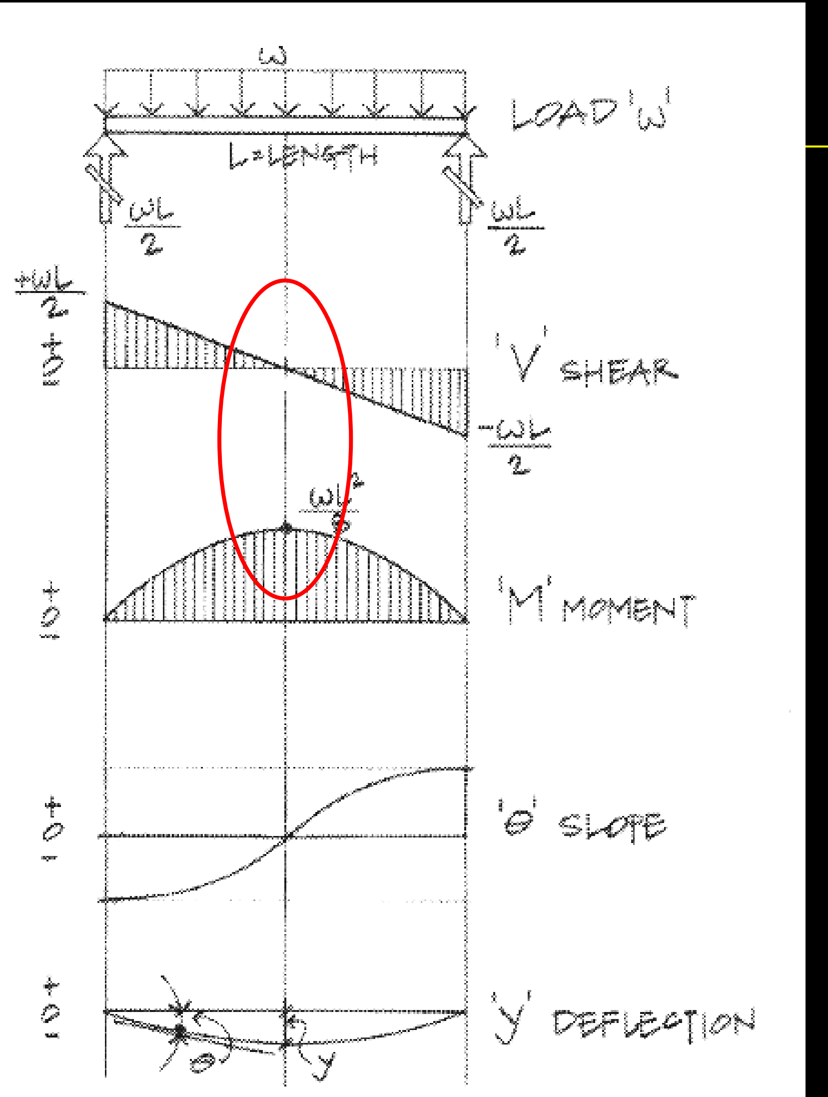
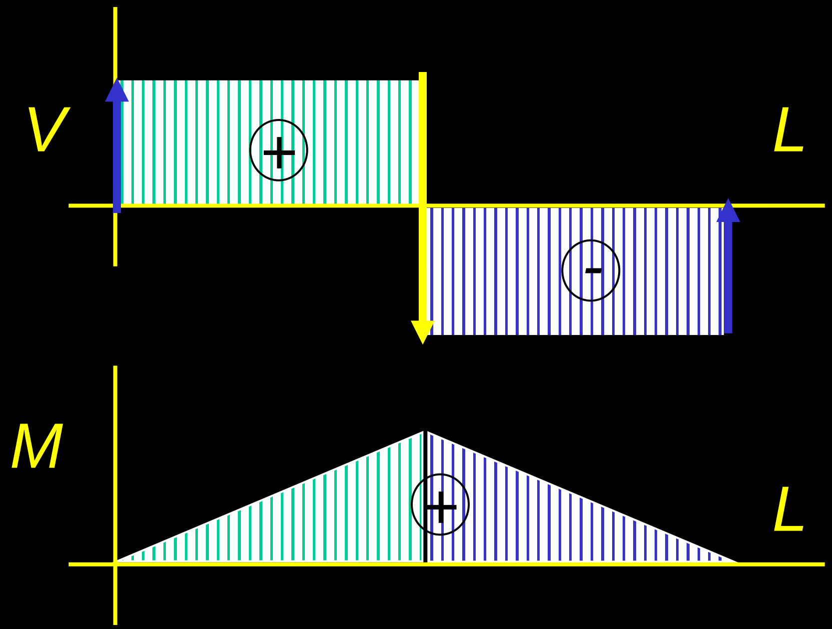
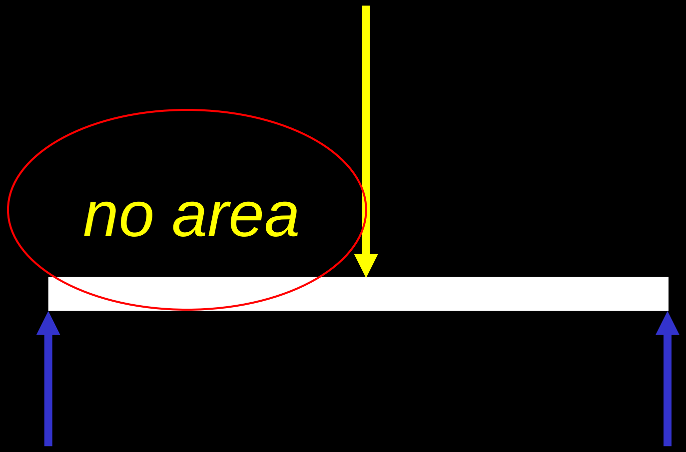


Figure 7.11 Relationship of load, shear, moment, slope, and deflection diagrams.

Method 2: Semigraphical

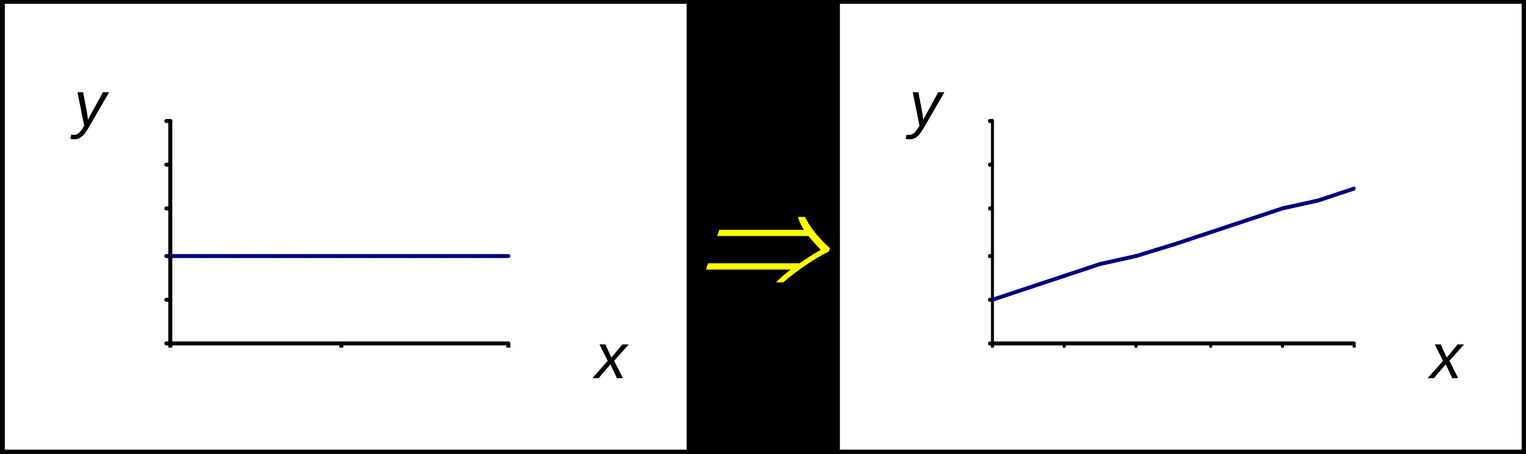
- M_{max} occurs where $V = 0$ (calculus)





Curve Relationships

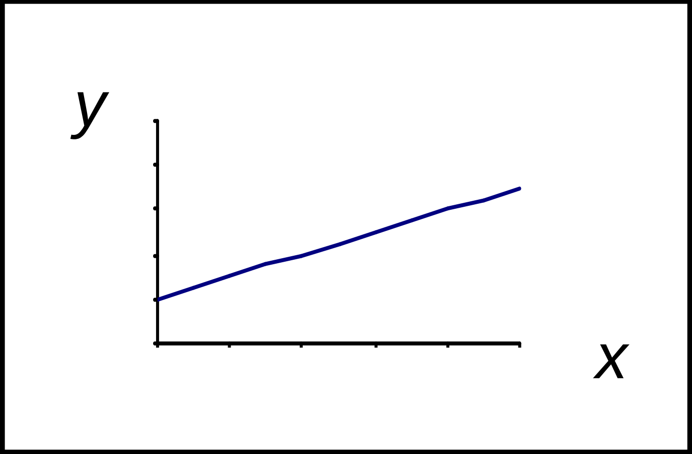
- integration of functions
- line with 0 slope, integrates to sloped



- ex: load to shear, shear to moment

Curve Relationships

- line with slope, integrates to parabola



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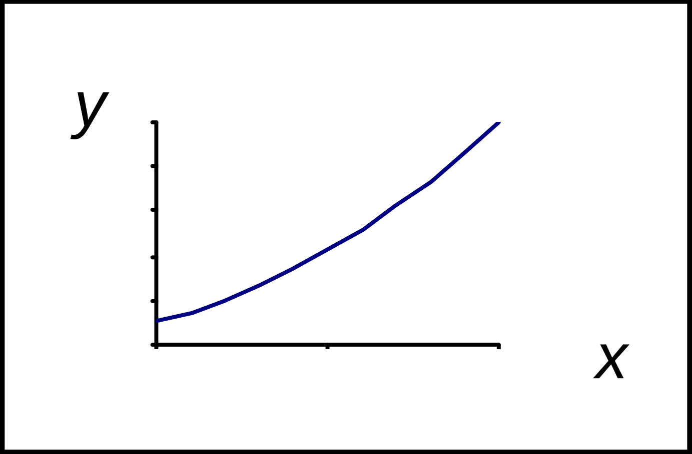
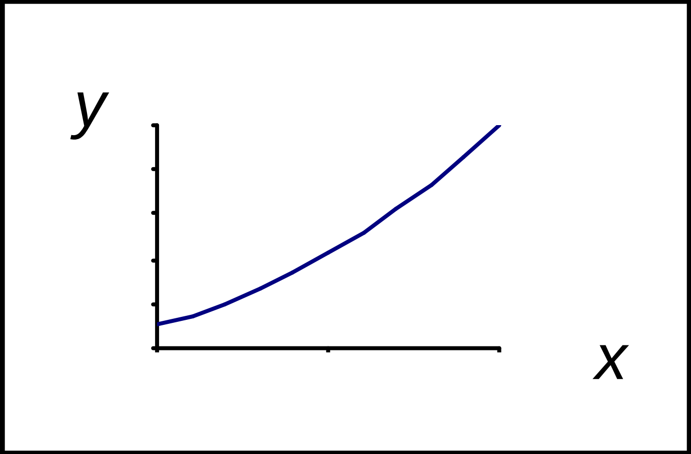


- ex: load to shear, shear to moment

Curve Relationships

- parabola, integrates to 3rd order curve



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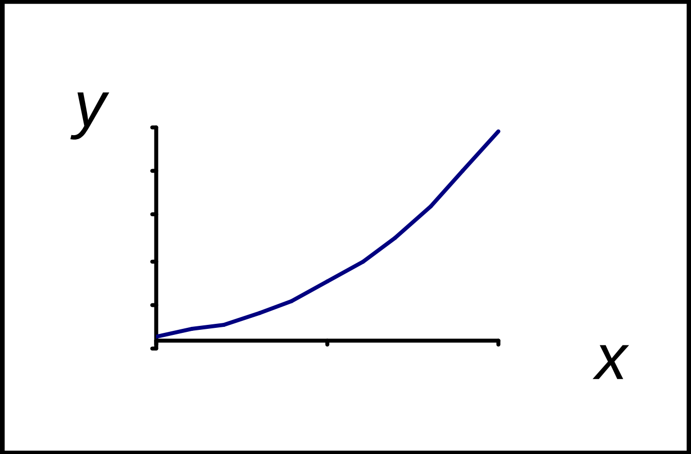


- ex: load to shear, shear to moment

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*

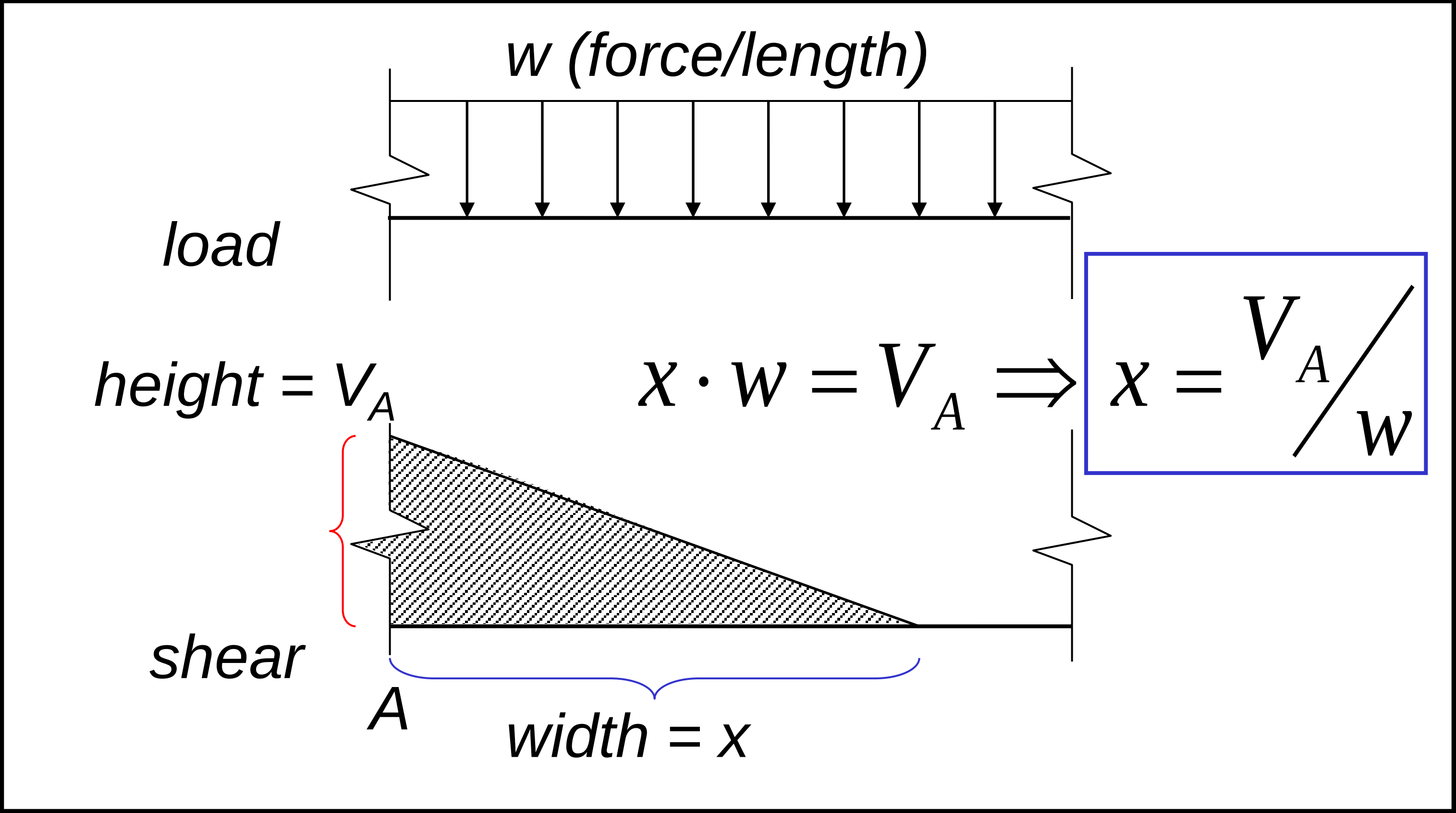
Basic Procedure

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)*

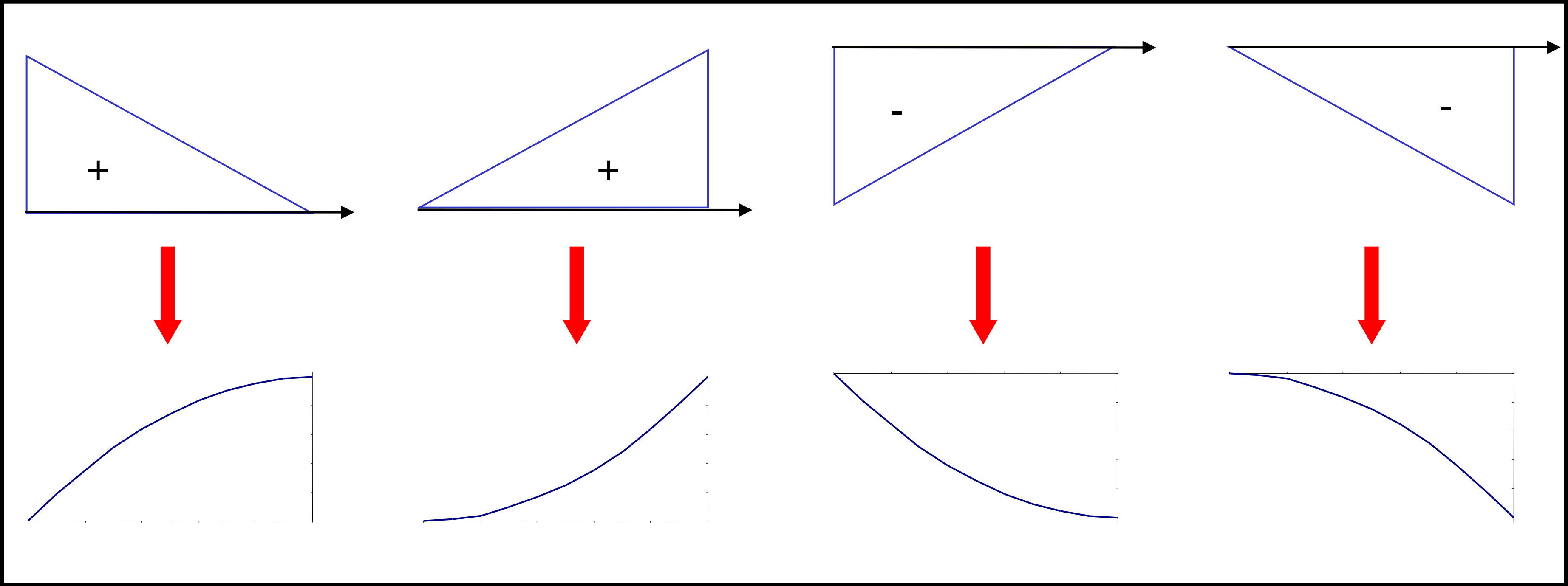
Shear Through Zero

- 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