ELEMENTS OF ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 614

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SPRING 2013

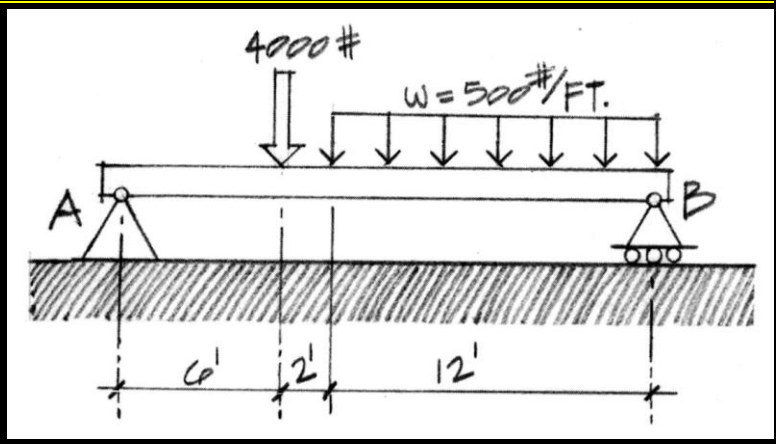
lecture SIX

http:// nisee.berkeley.edu/godden

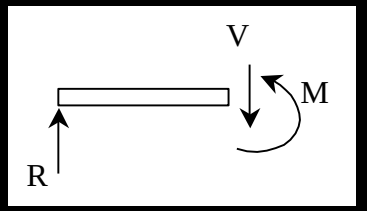
beam introduction & internal forces

Beams

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

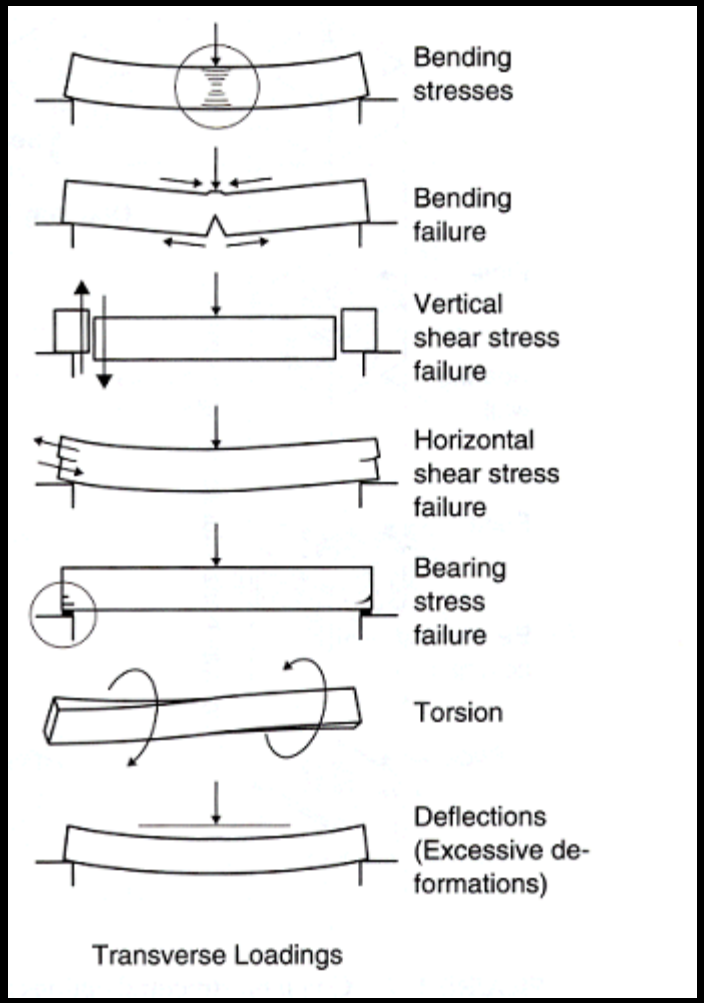


- *loaded transversely by gravity loads*
- *may have internal axial force*
- *will have internal shear force*
- *will have internal moment (bending)*



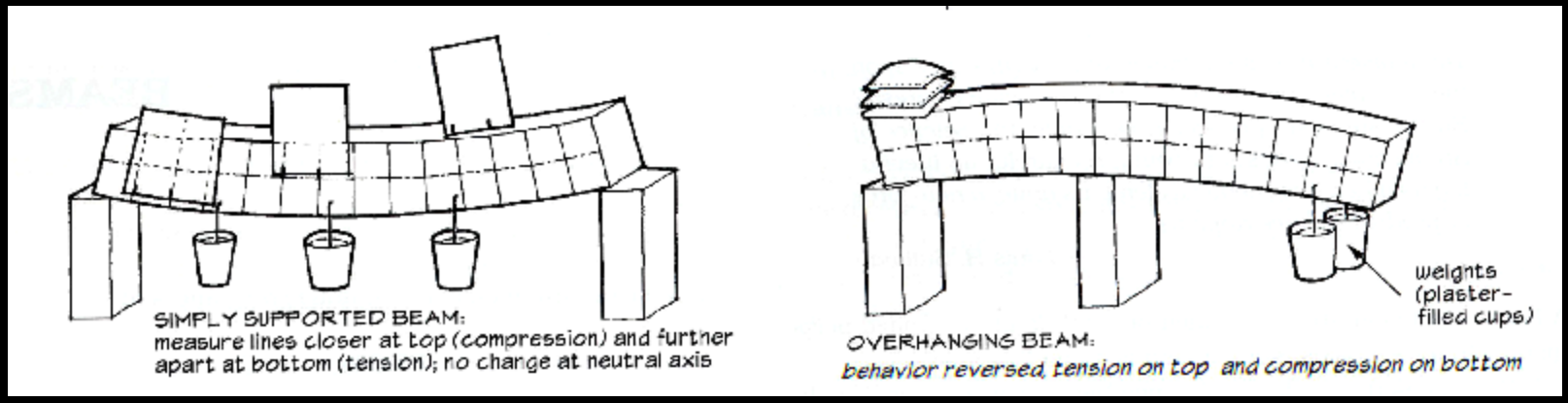
Beams

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



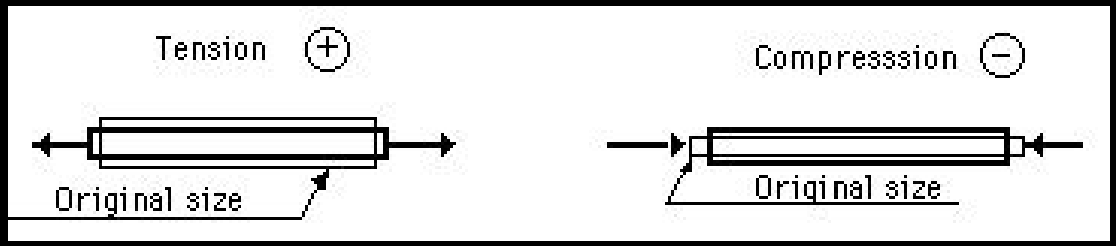
Beams

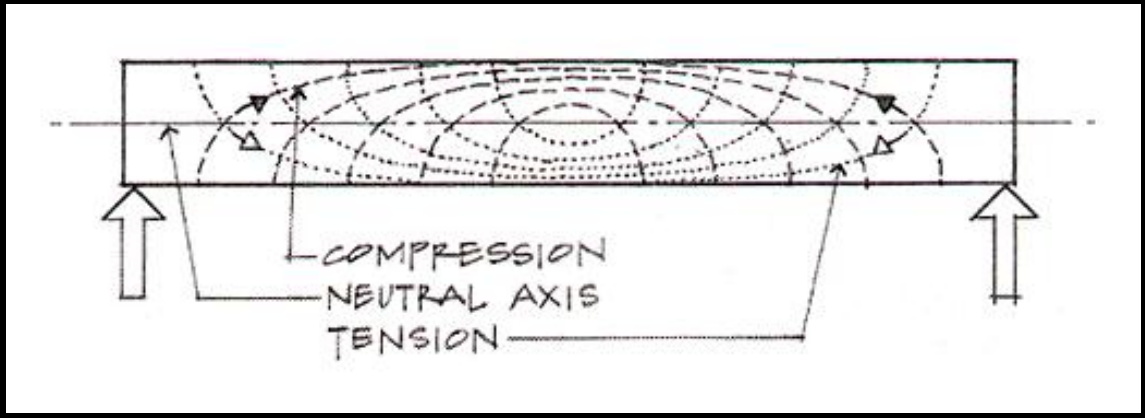
- *bending*
  - *bowing of beam with loads*
  - *one edge surface stretches*
  - *other edge surface squishes*



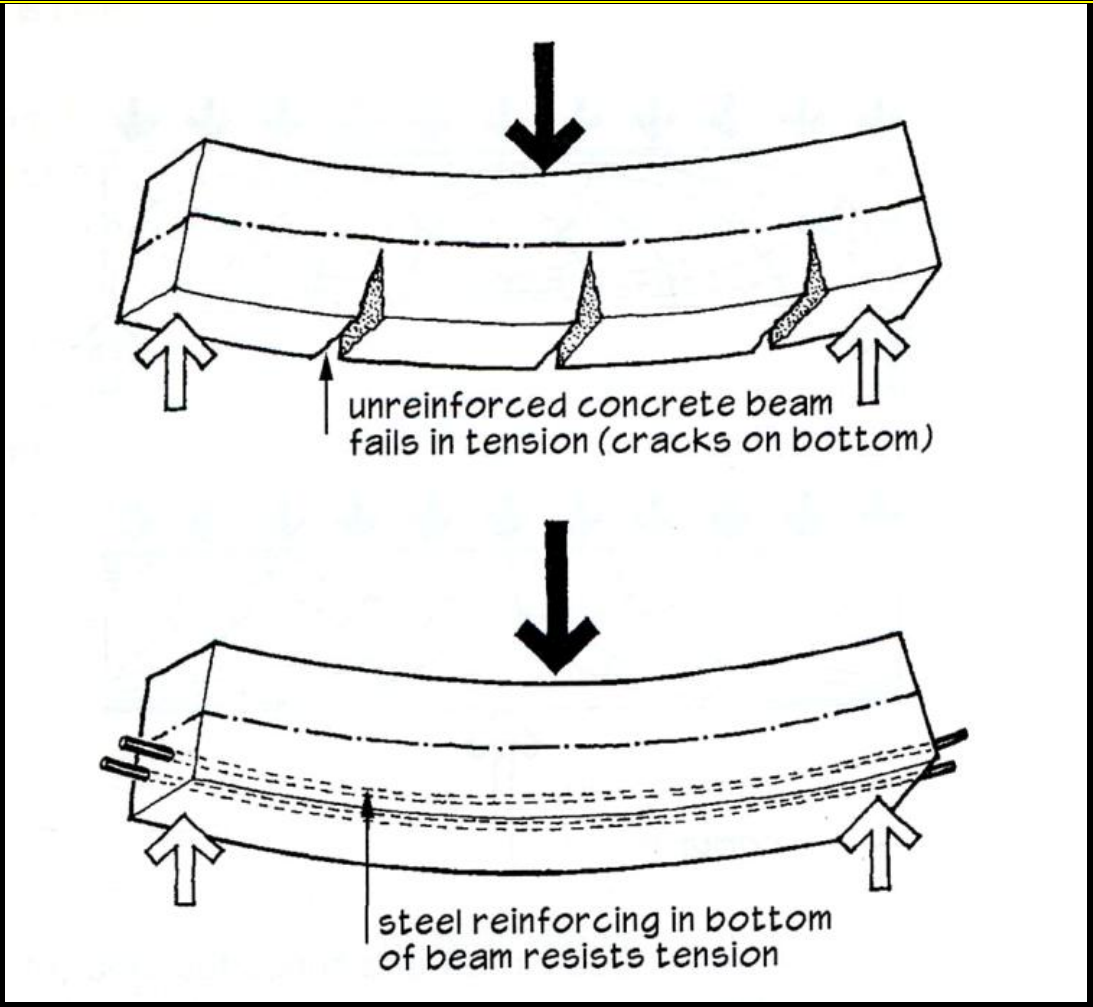
Beam Stresses

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



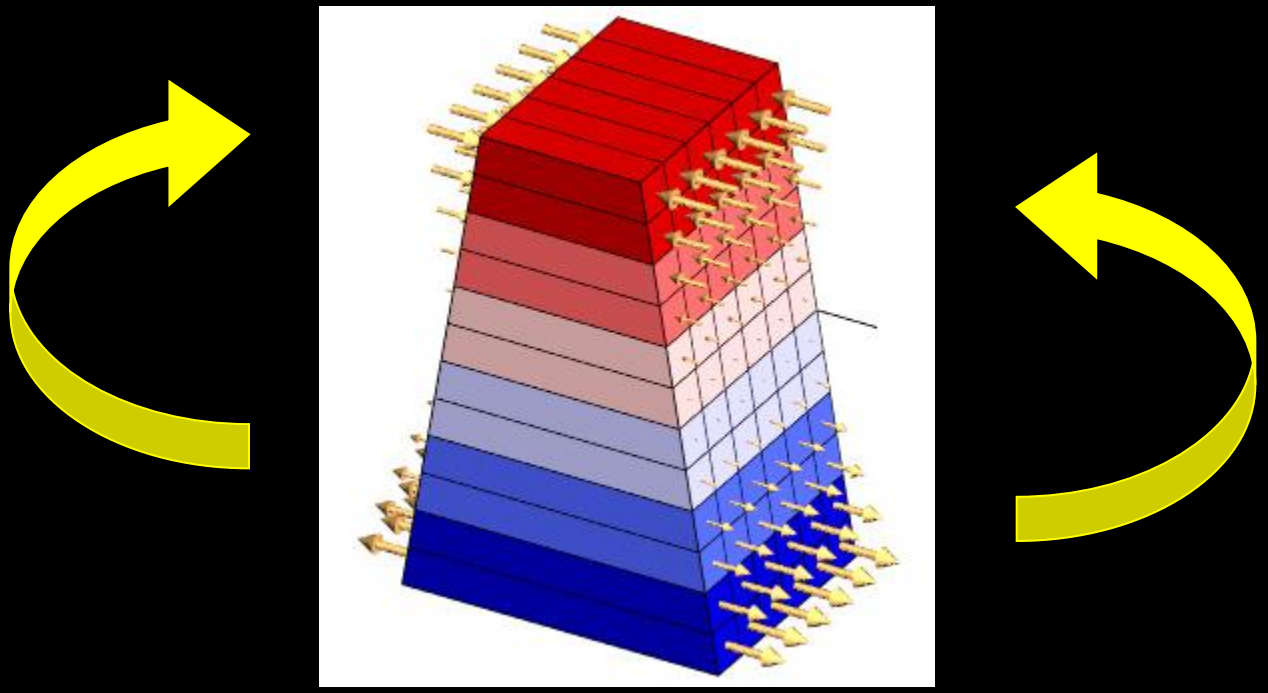


Beam Stresses



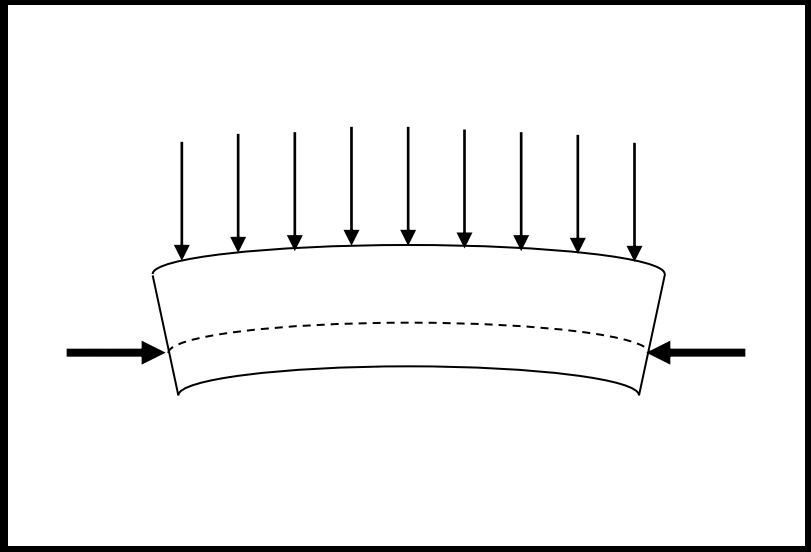
Beam Stresses

- *tension and compression*
  - *causes moments*



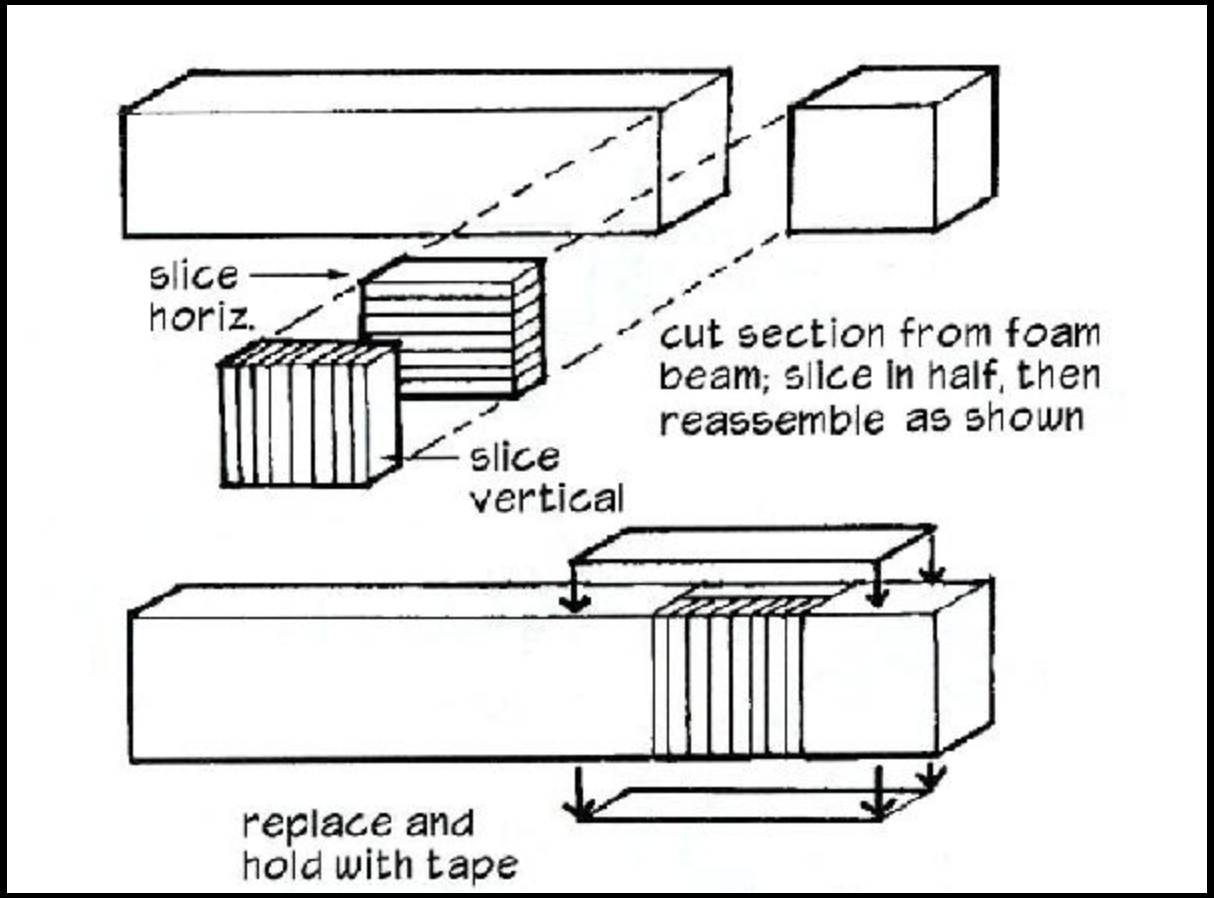
Beam Stresses

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



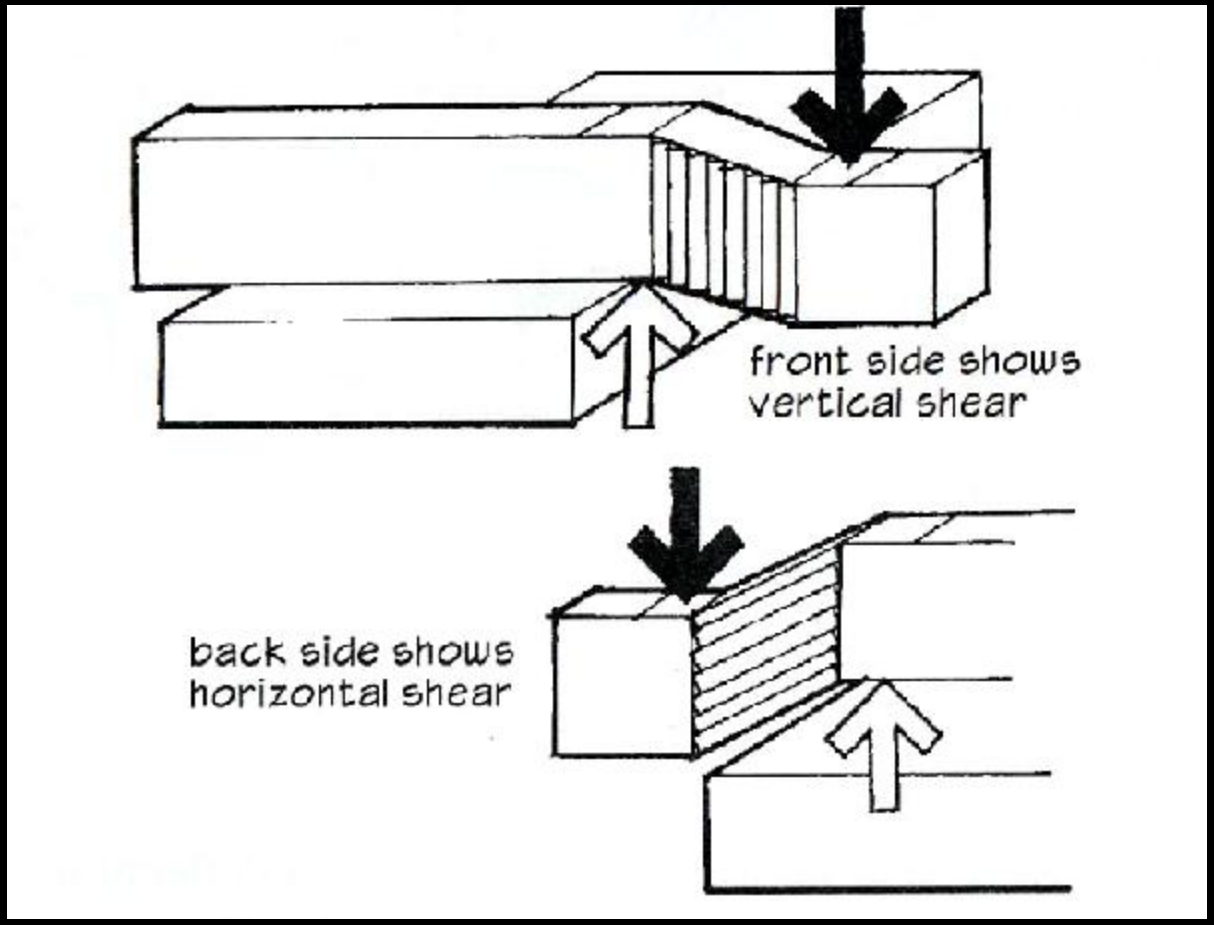
Beam Stresses

- *shear – horizontal & vertical*



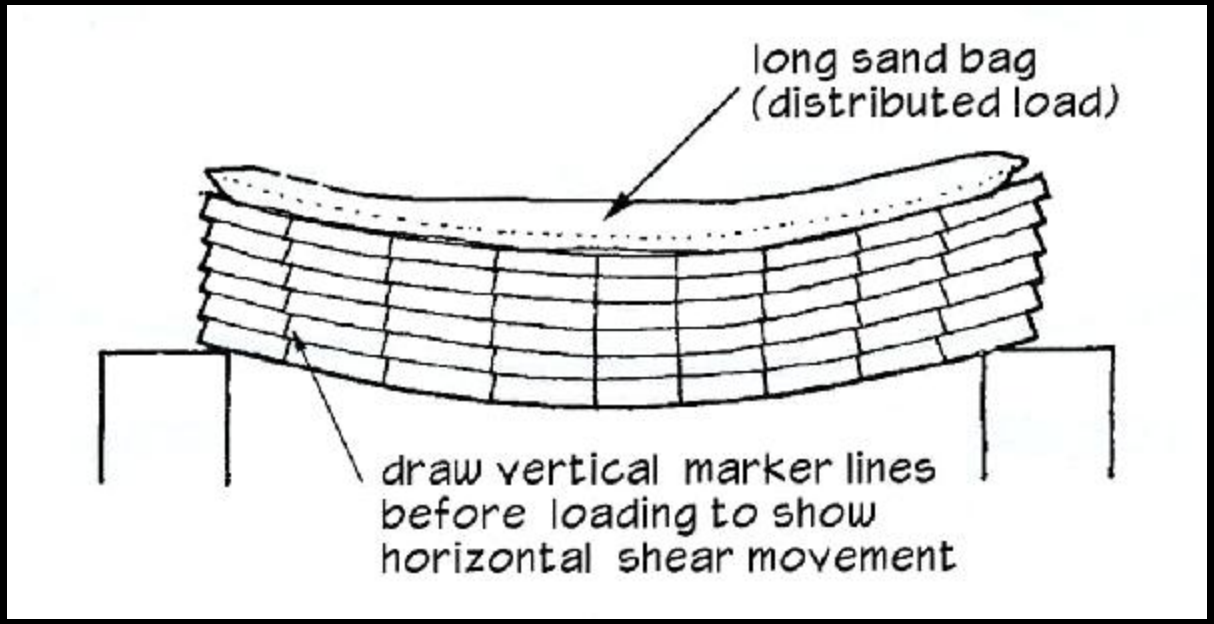
Beam Stresses

- *shear – horizontal & vertical*



Beam Stresses

- *shear – horizontal*



Beam Deflections

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

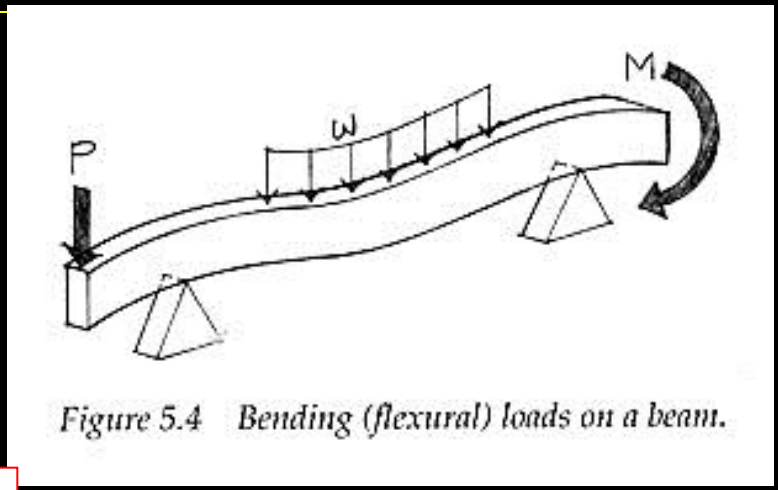
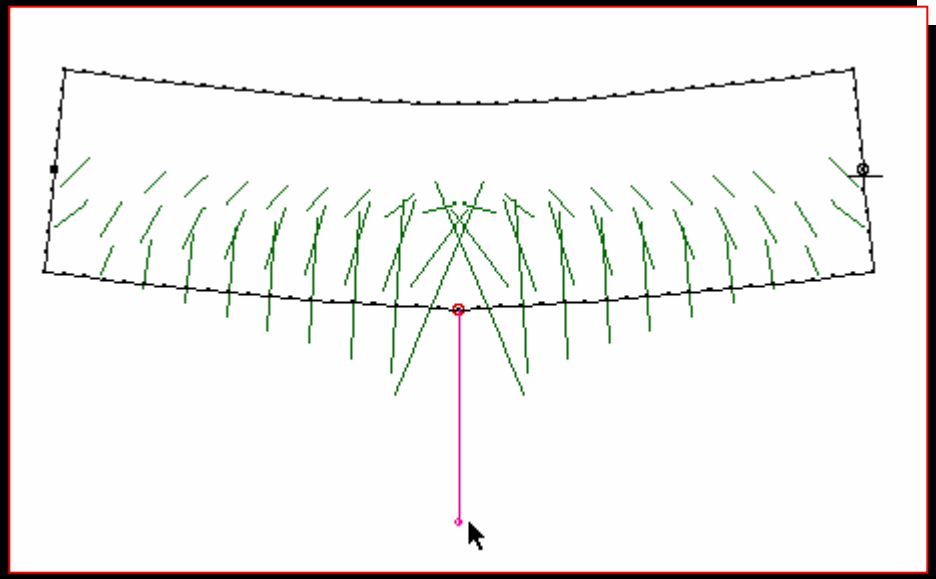
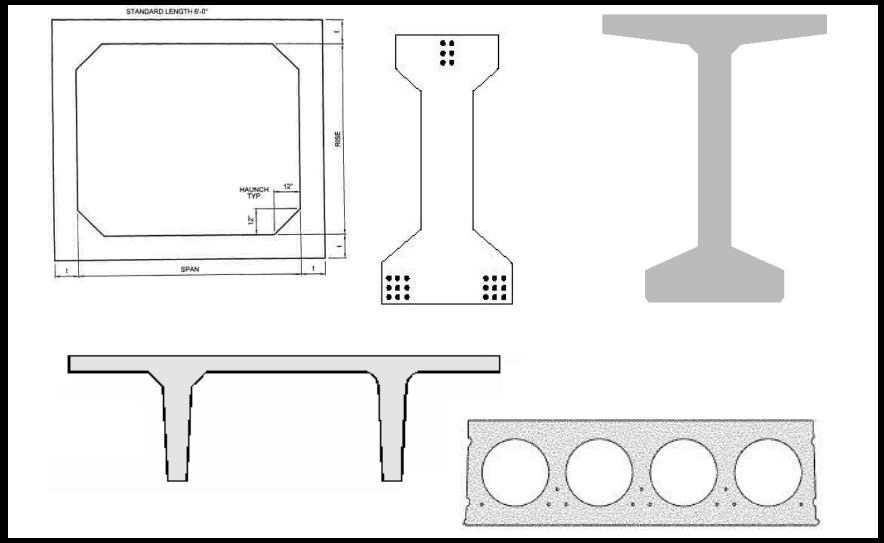


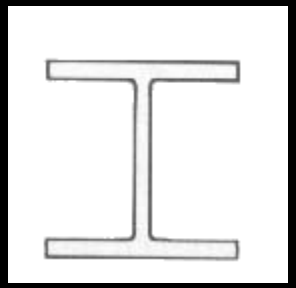
Figure 5.4 Bending (flexural) loads on a beam.

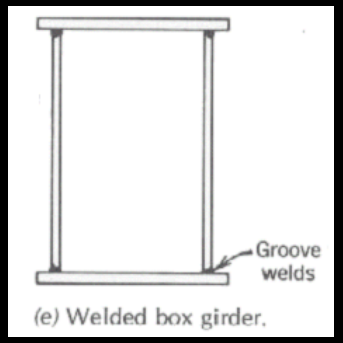


Beam Deflections

- *"moment of inertia"*







Beam Styles

- *vierendeel*

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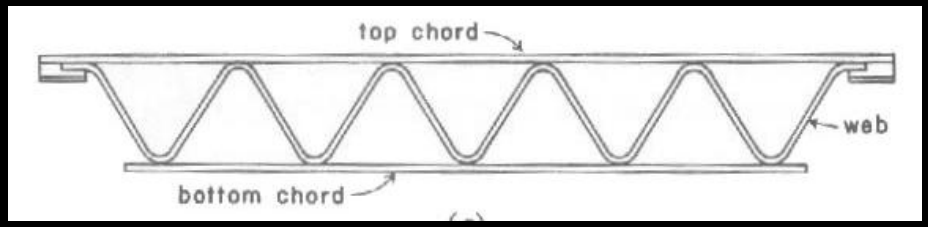
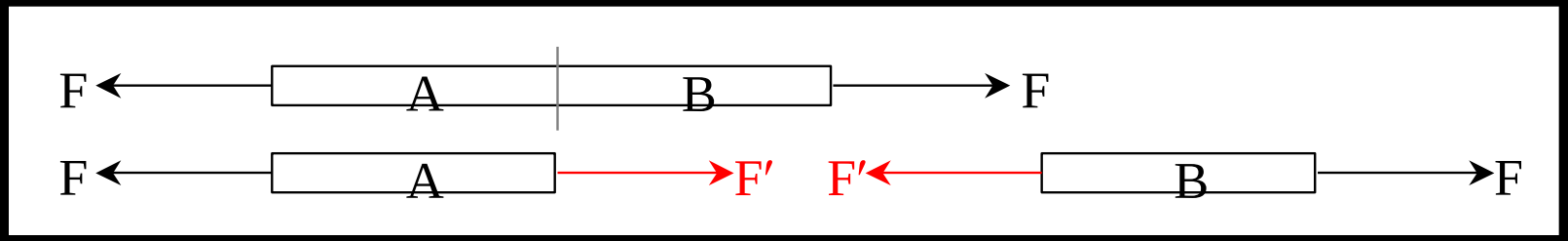
- *open web joists*
- *manufactured*

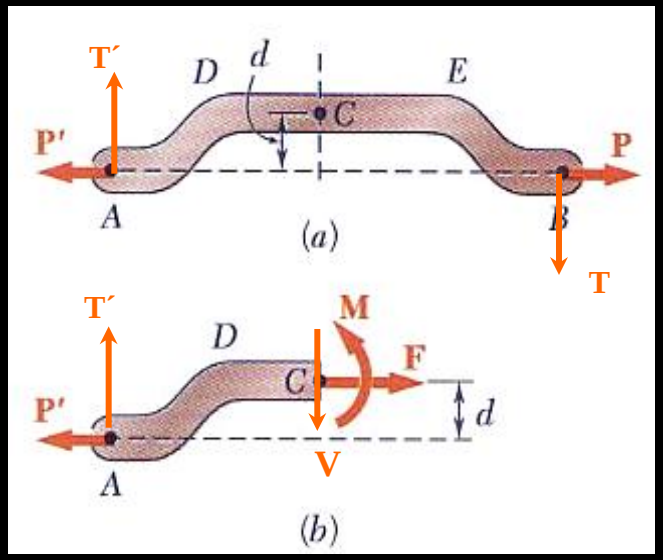


Internal Forces

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

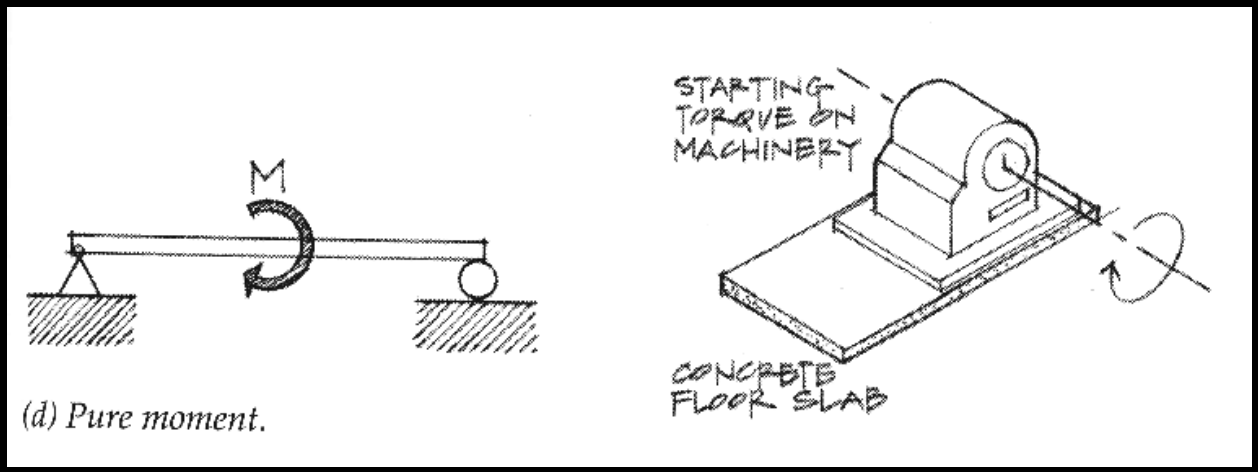


- *in general*
  - *– axial force*
  - *– shear force, V*
  - *– bending moment, M*



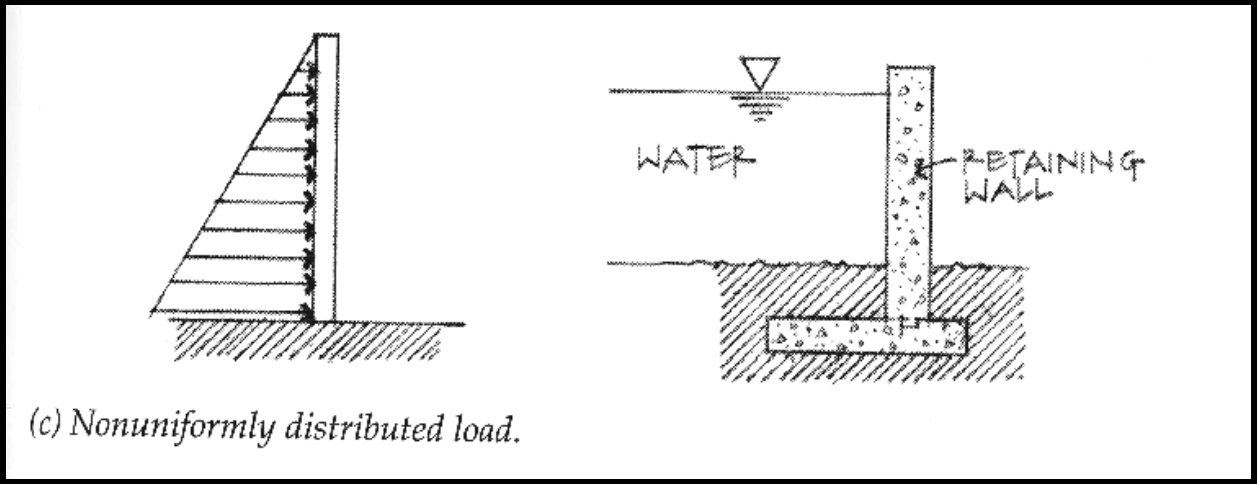
Beam Loading

- *concentrated force*
- *concentrated moment*
  - *spandrel beams*



Beam Loading

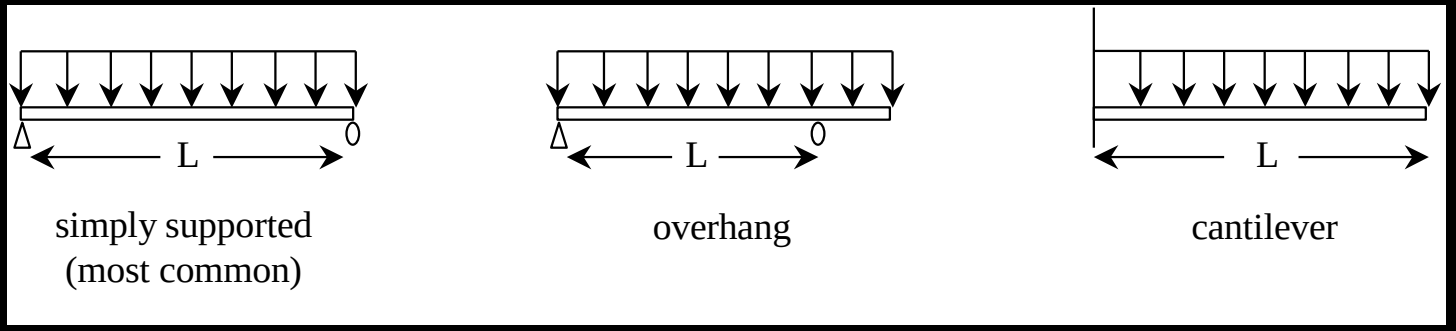
- *uniformly distributed load (line load)*
- *non-uniformly distributed load*
  - *hydrostatic pressure = γh*
  - *wind loads*



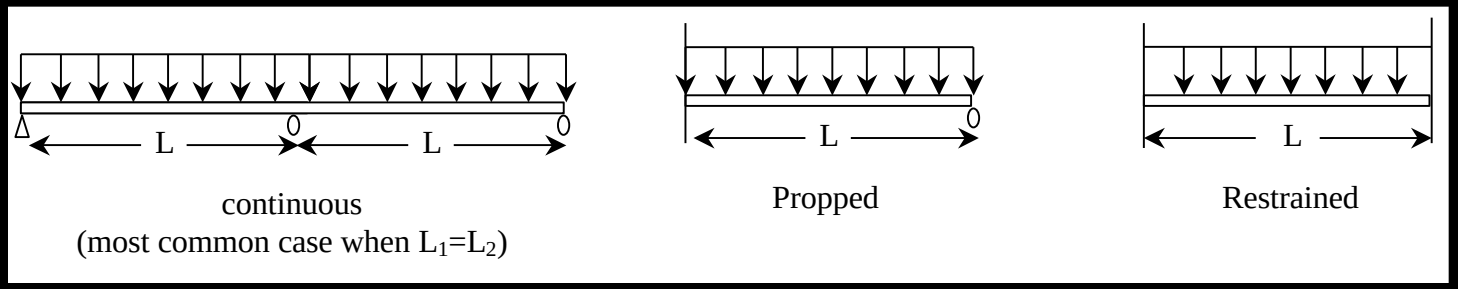
(c) Nonuniformly distributed load.

Beam Supports

- *statically determinate*

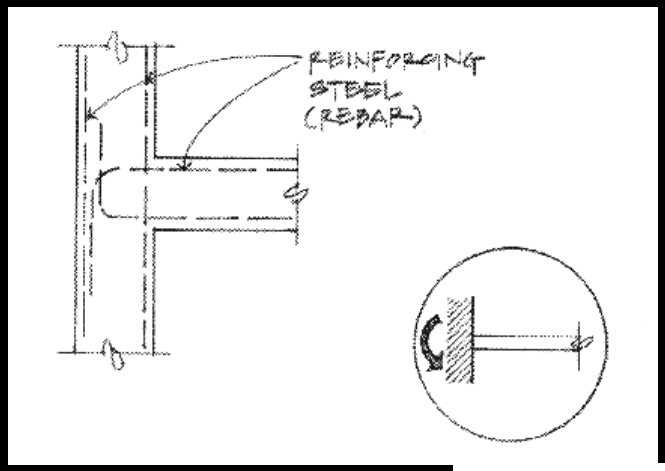


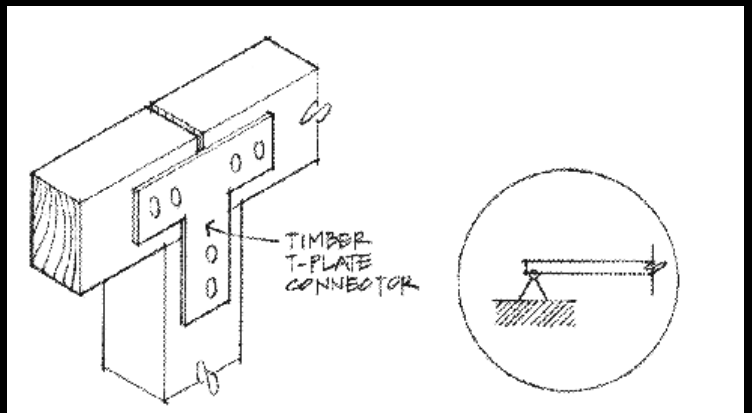
- *statically indeterminate*



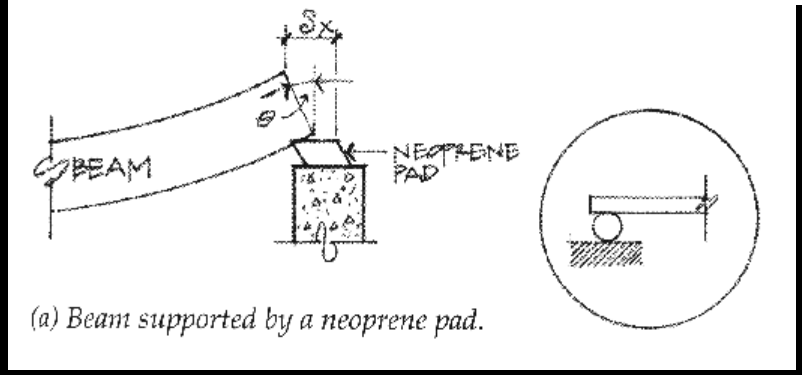
Beam Supports

- *in the real world, modeled type*





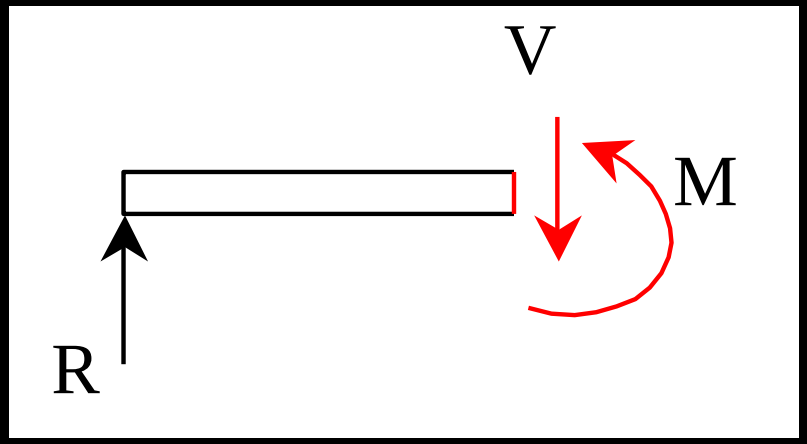
(c) Timber beam–column connection with T-plate.



(a) Beam supported by a neoprene pad.

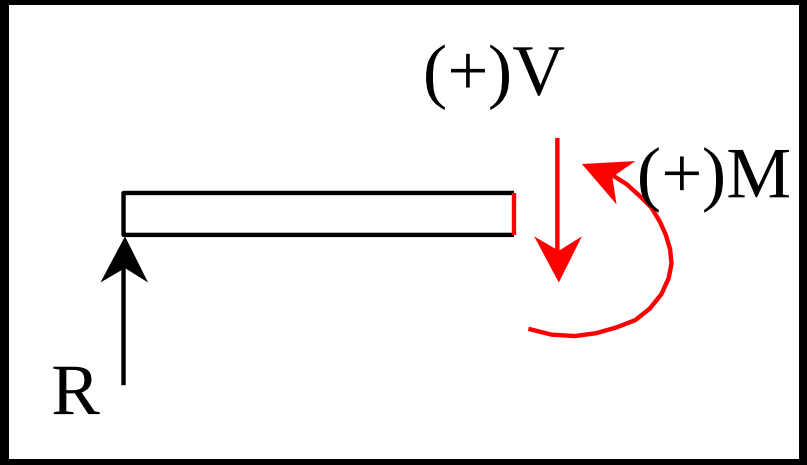
Internal Forces in Beams

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



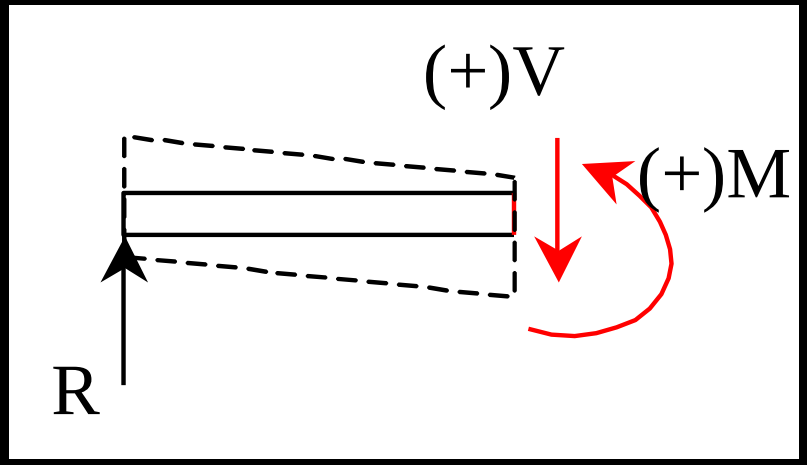
V & M Diagrams

- *tool to locate V_{max} and M_{max}*
- *<u>necessary</u> for designing*
- *M_{max} occurs when V = 0*

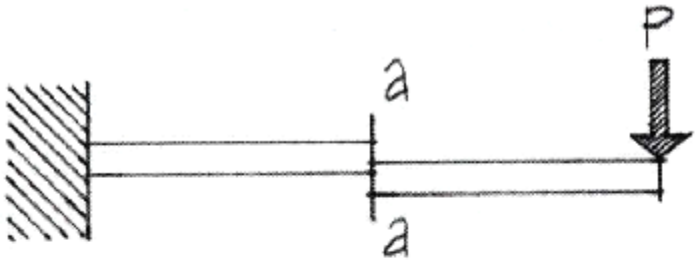


Sign Convention

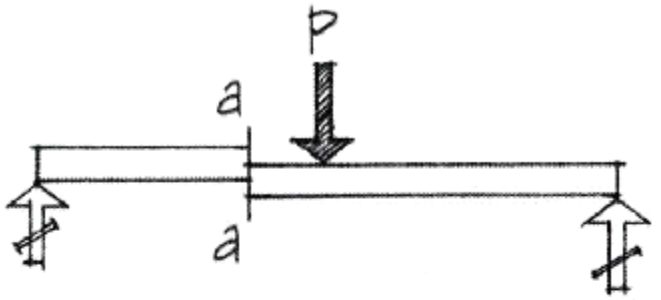
- *shear force, V:*
  - *cut section to LEFT*
  - *if ΣF_y is positive by statics, V acts down and is POSITIVE*
  - *beam has to resist shearing apart by V*



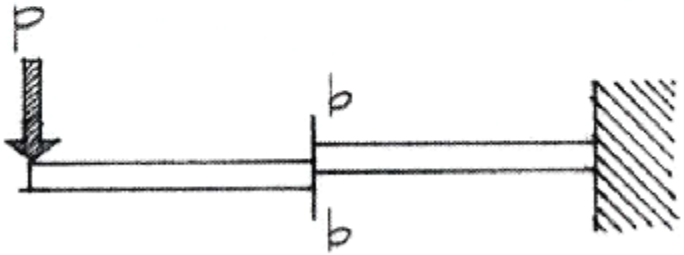
Shear Sign Convention



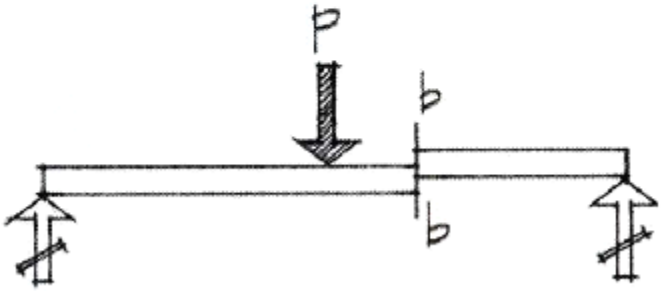
(+) Shear.



(+) Shear.



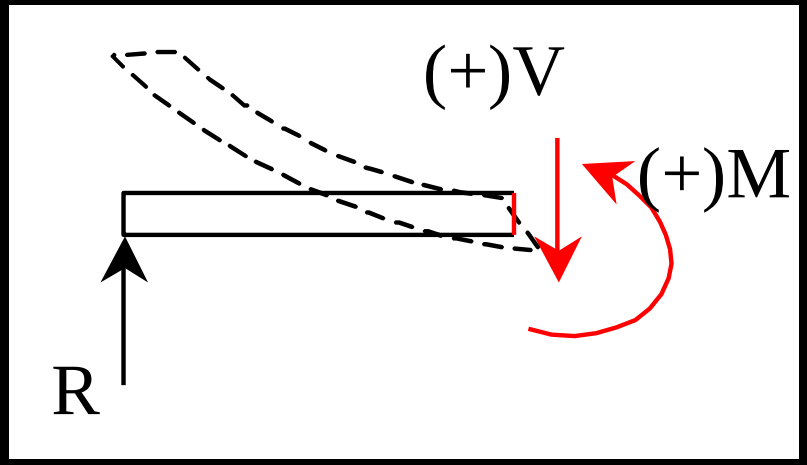
(–) Shear.



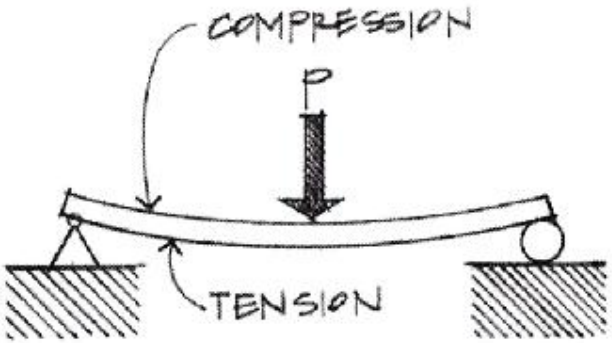
(–) Shear.

Sign Convention

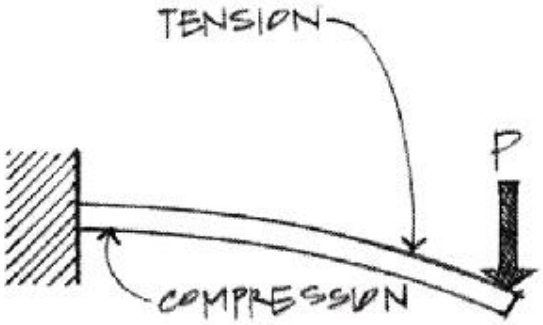
- *bending moment, M:*
  - *cut section to LEFT*
  - *if $\sum M_{cut}$ is clockwise, M acts ccw and is POSITIVE – flexes into a "smiley" beam has to resist bending apart by M*



Bending Moment Sign Convention

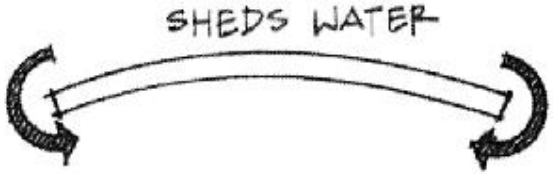


(+) Moment.



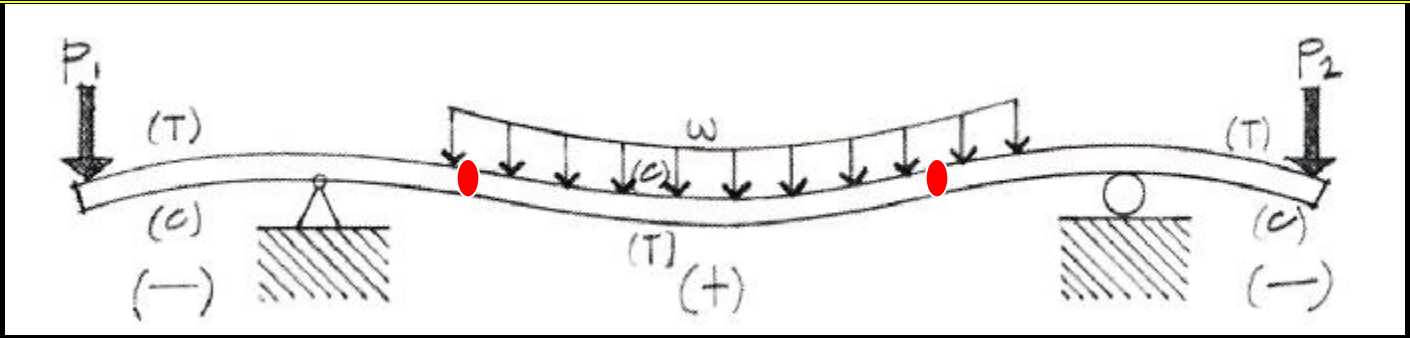
(–) Moment.

(+) Moment.



(–) Moment.

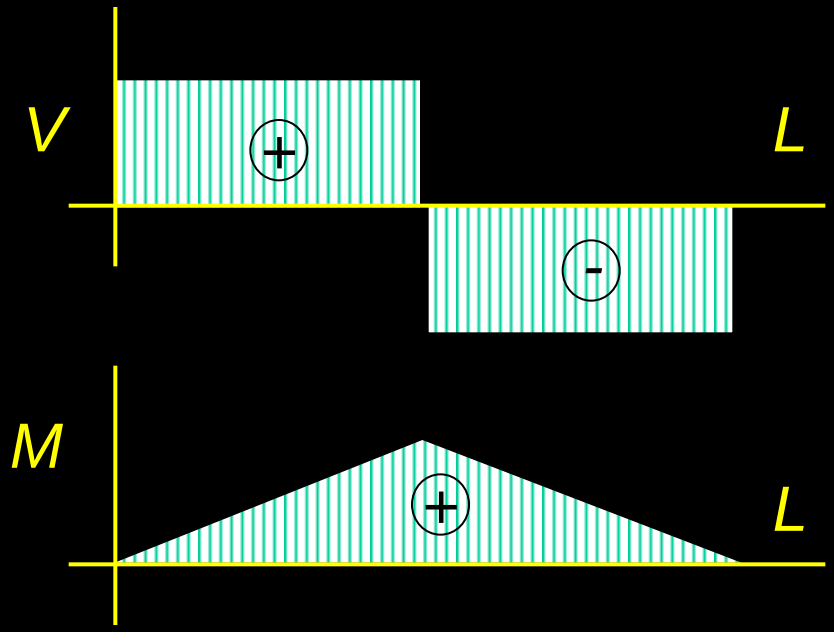
Deflected Shape

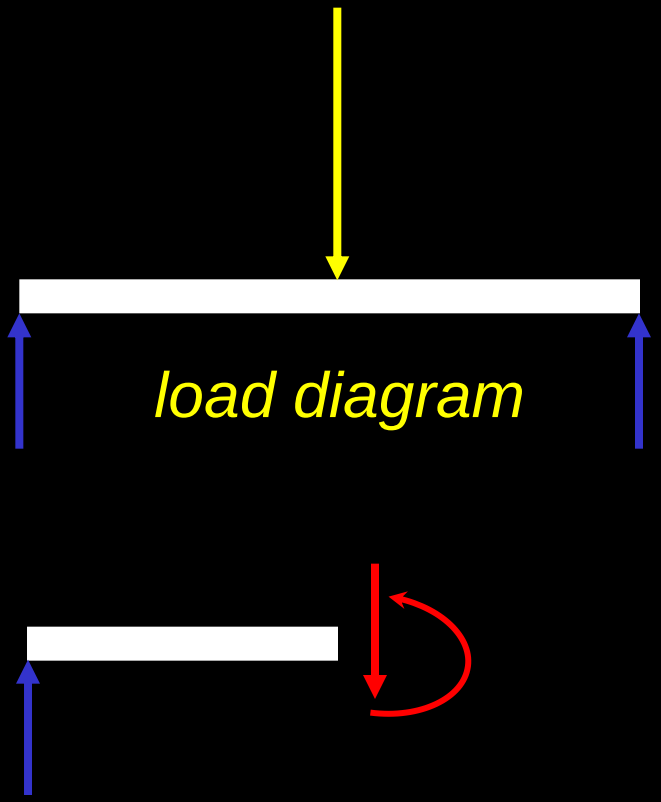


- *positive bending moment*
  - *tension in bottom, compression in top*
- *negative bending moment*
  - *tension in top, compression in bottom*
- *zero bending moment*
  - *<u>inflection point</u>*

Constructing V & M Diagrams

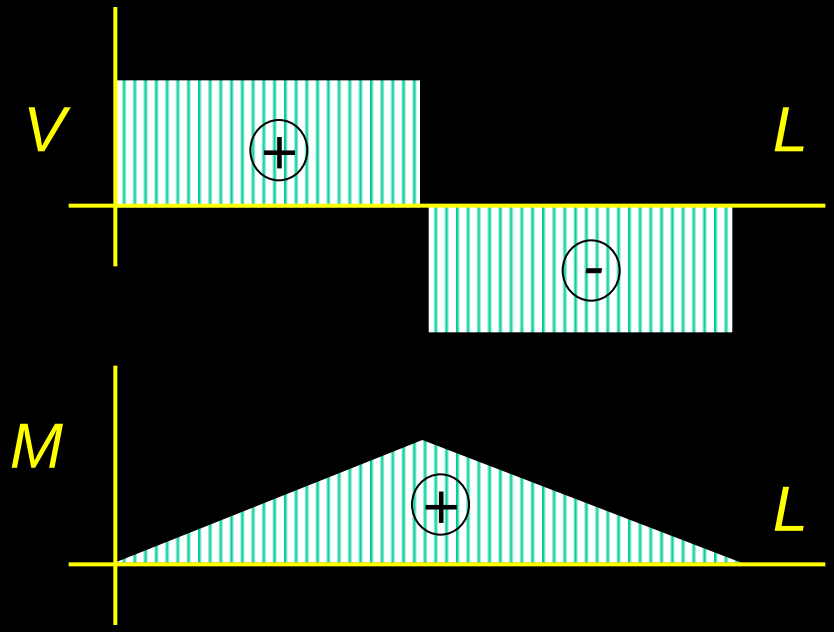
- along the beam length, plot V, plot M

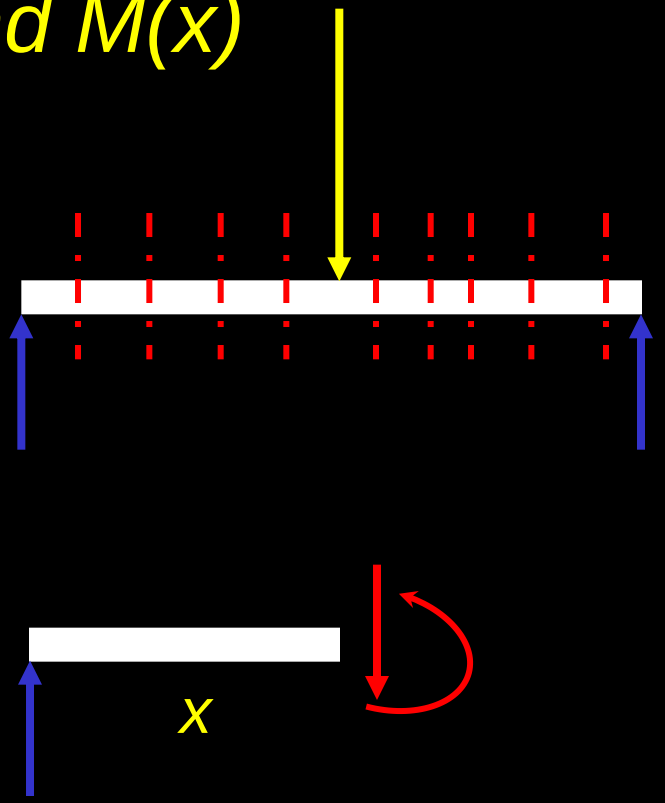




Mathematical Method

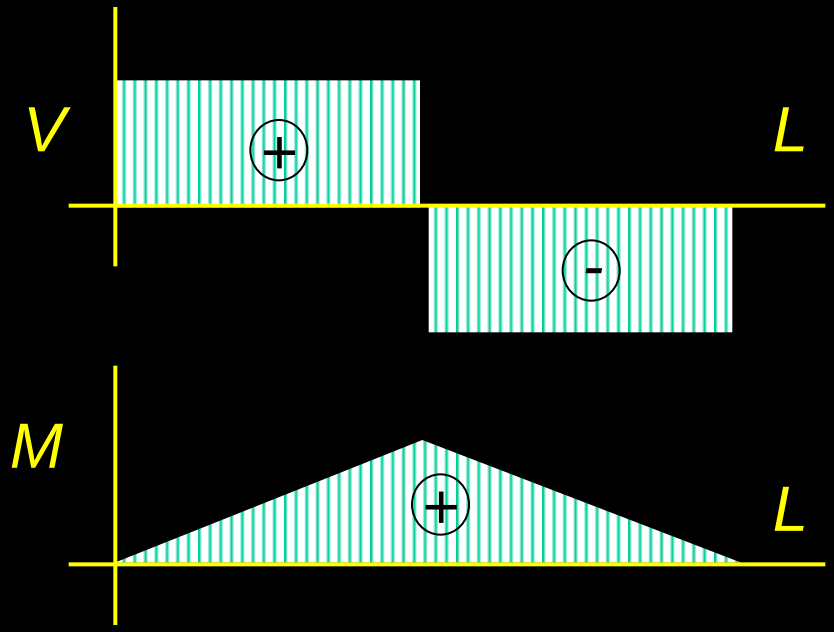
- *cut sections with x as width*
- *write functions of V(x) and M(x)*

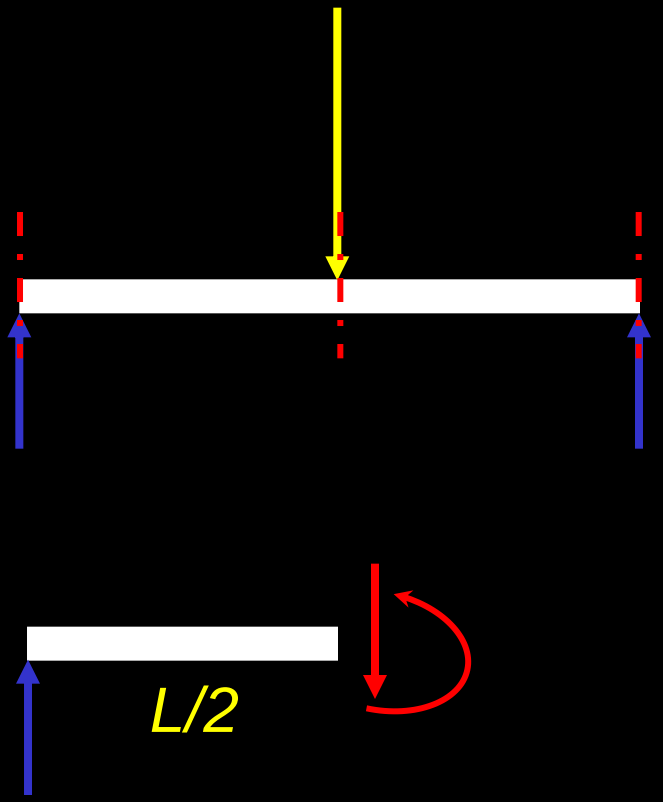




Equilibrium Method

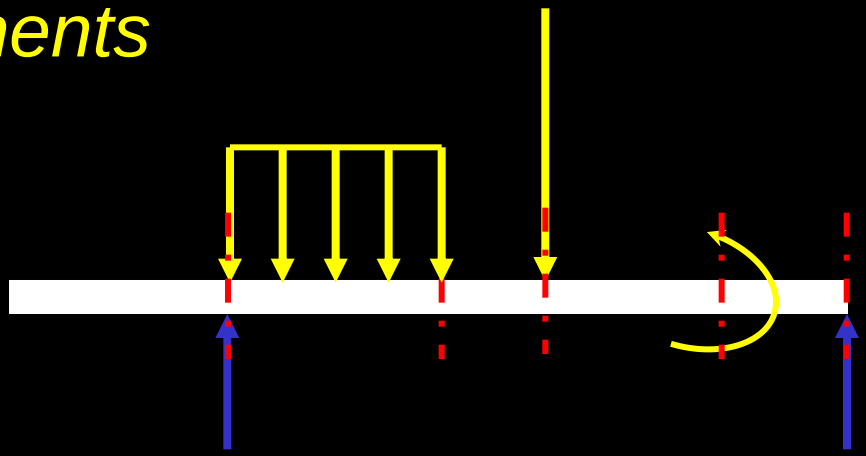
- *cut sections at important places*
- *plot V & M*





Equilibrium Method

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



Equilibrium Meth

- *relationships*

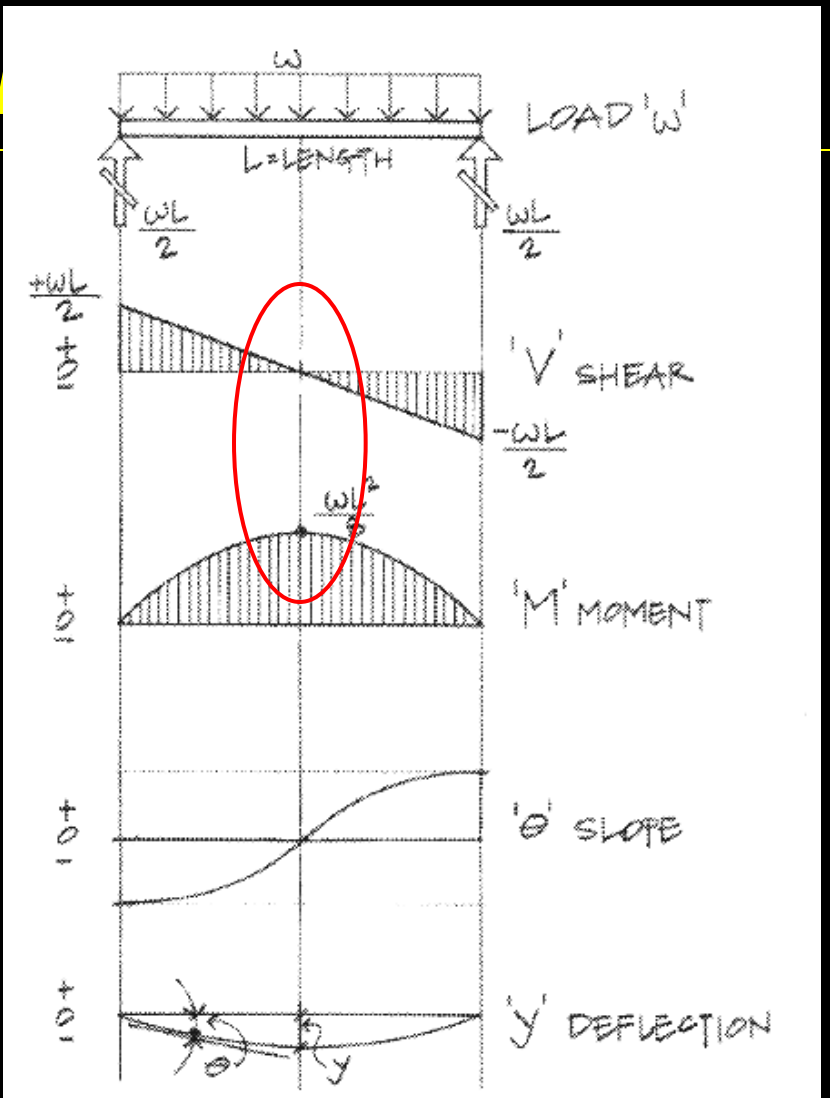


Figure 7.11 Relationship of load, shear, moment, slope, and deflection diagrams.

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*

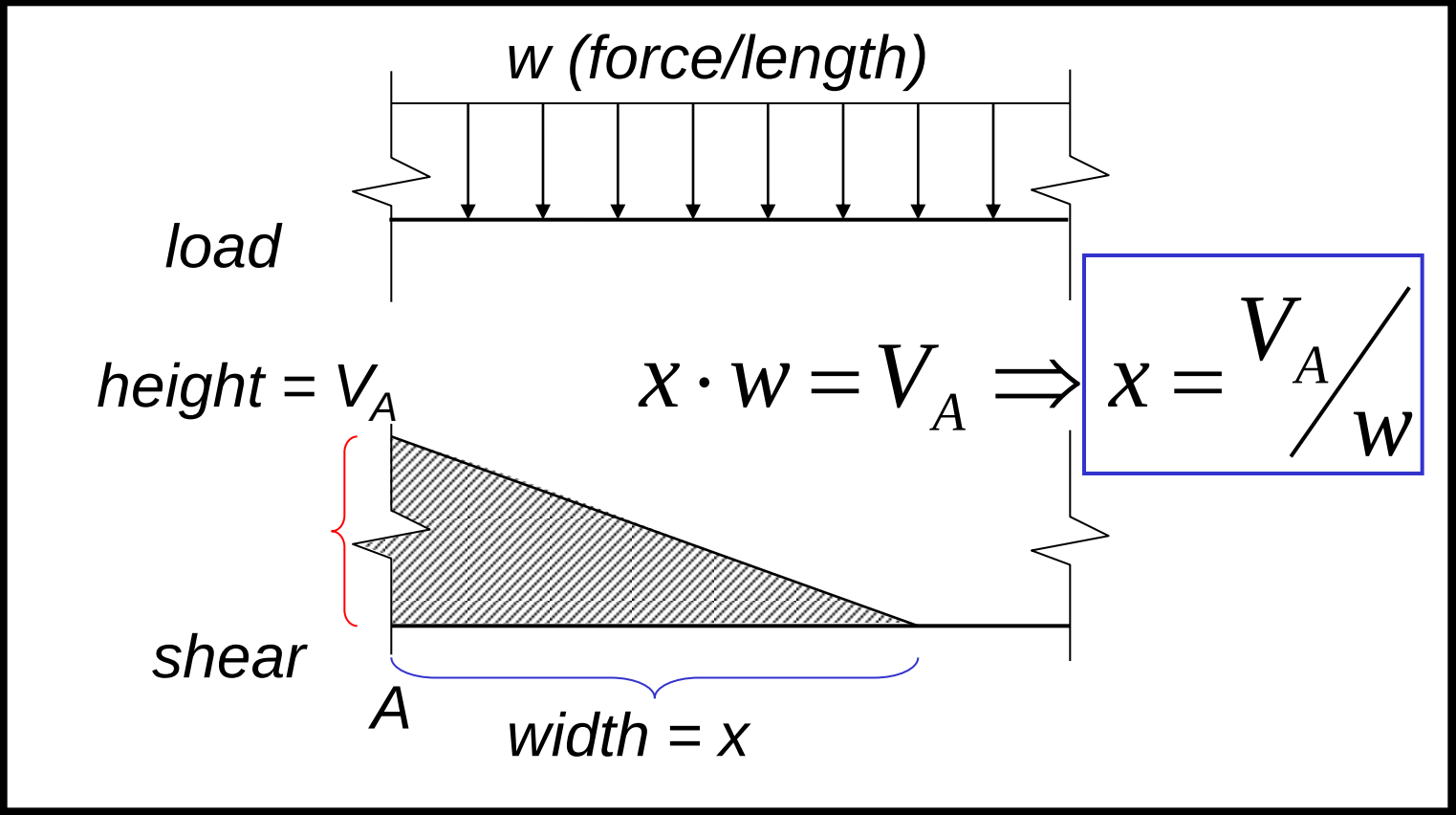
Basic Procedure

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!*

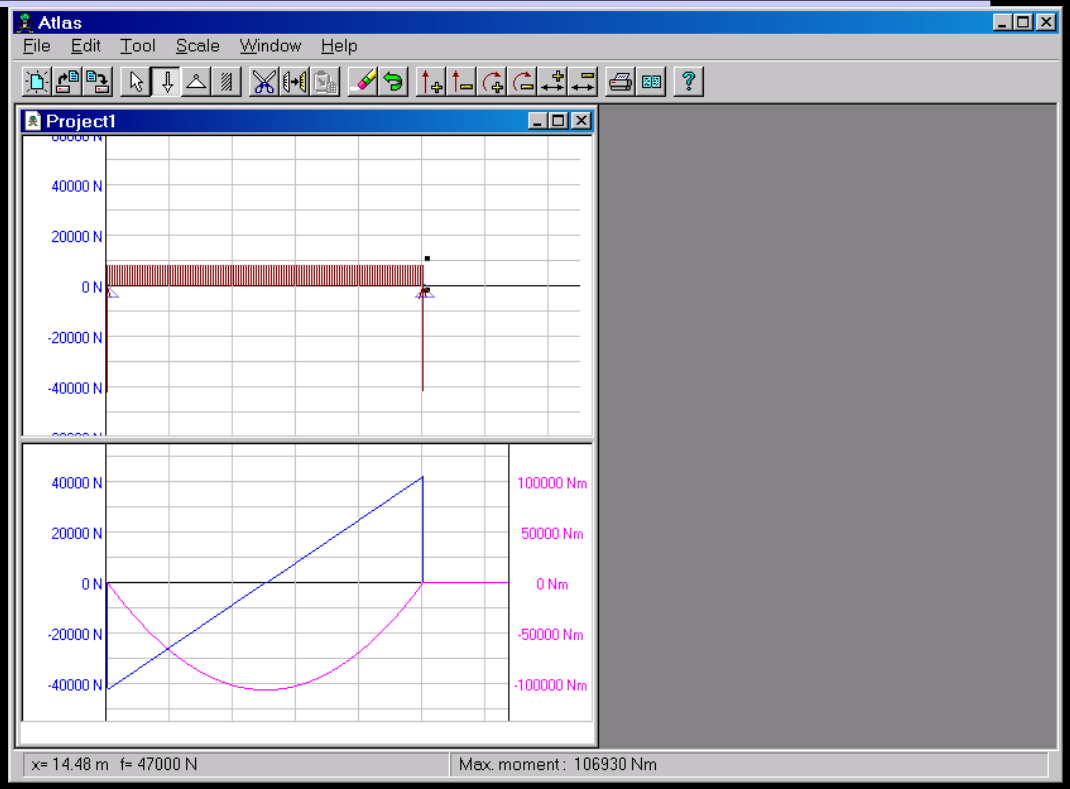
Shear Through Zero

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



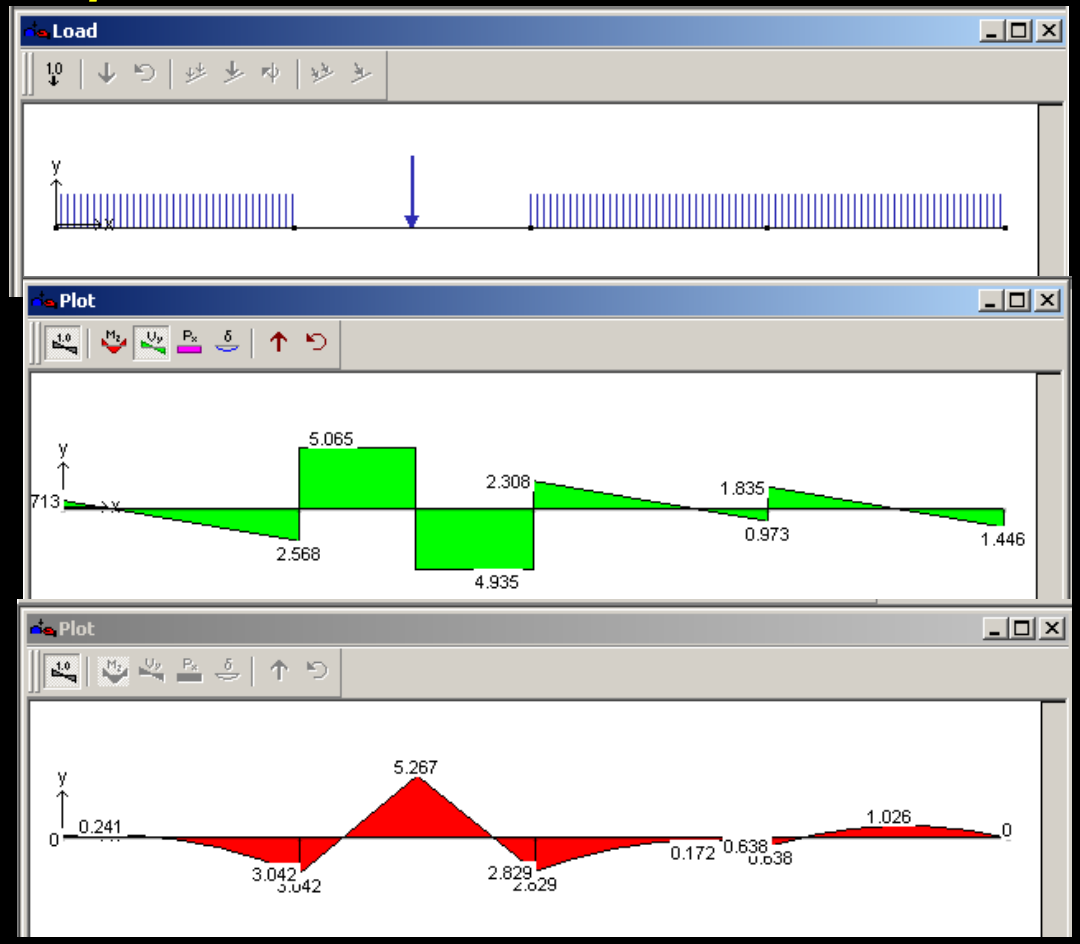
Tools

- *software & spreadsheets help*
- *http://www.rekenwonder.com/atlas.htm*



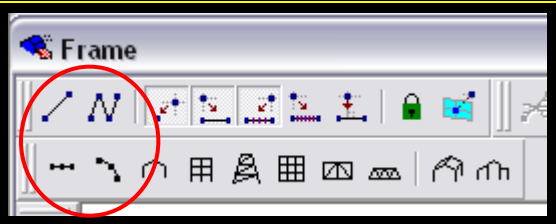
Tools – Multiframe

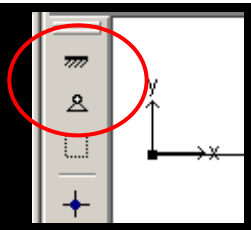
- *in computer lab*

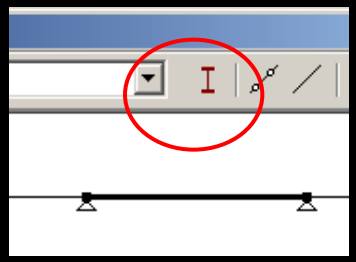


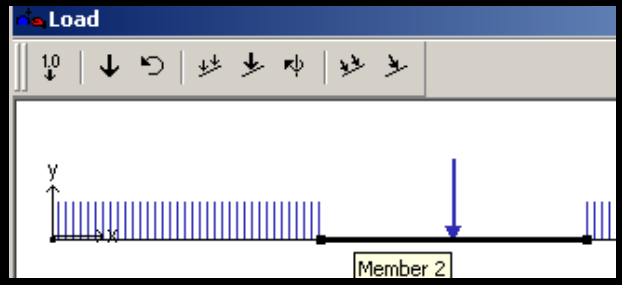
Tools – Multiframe

- *frame window*
  - *define beam members*
  - *select points, assign supports*
  - *select members, assign section*
- *load window*
  - *select point or member, add point or distributed loads*



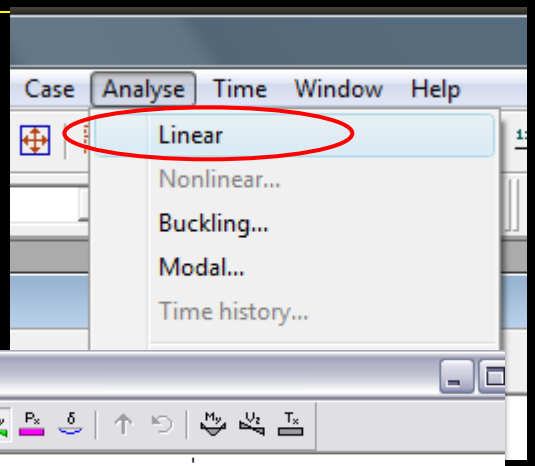


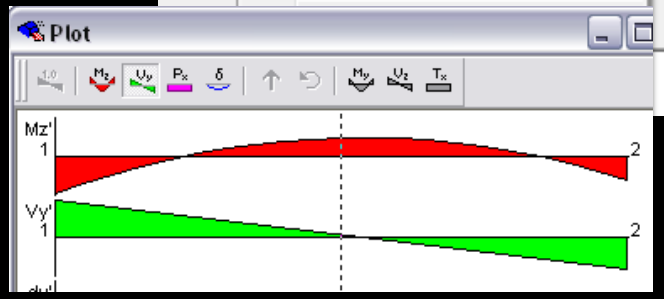




Tools – Multiframe

- to run analysis choose
  - Analyze menu
    - Linear
- plot
  - choose options
  - double click (all)
- results
  - choose options





Result

Static Case: Load Case 1

	Joint	Label	Rx' kip	Ry' kip	Mz' kip-ft
1	1		0.000	-0.000	0.000
2	2		0.000	9.250	0.000
3	3		0.000	6.102	0.000
4	4		0.000	3.093	0.000
5	5		0.000	1.398	-0.000
6	Total	(Global)	Rx=0.000	Ry=19.843	

Displacements | Reactions