

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

ARCH 614

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SPRING 2014

lecture
SIX

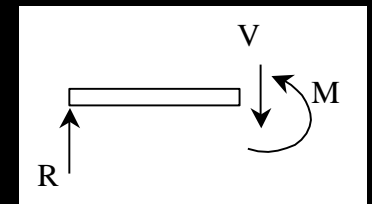
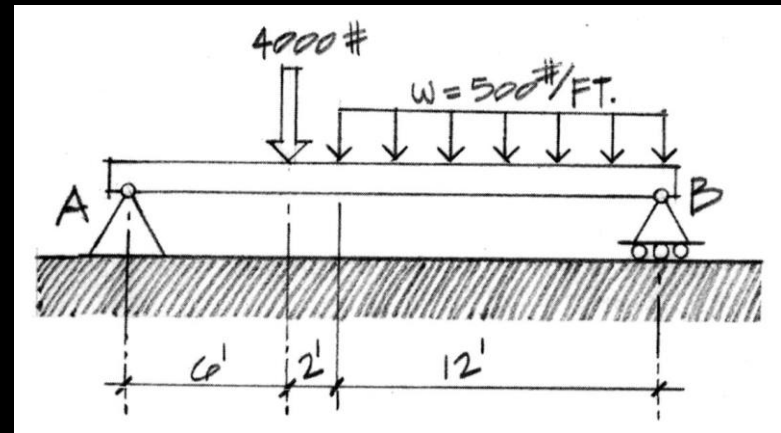


<http://nisee.berkeley.edu/godden>

**beam introduction &
internal forces**

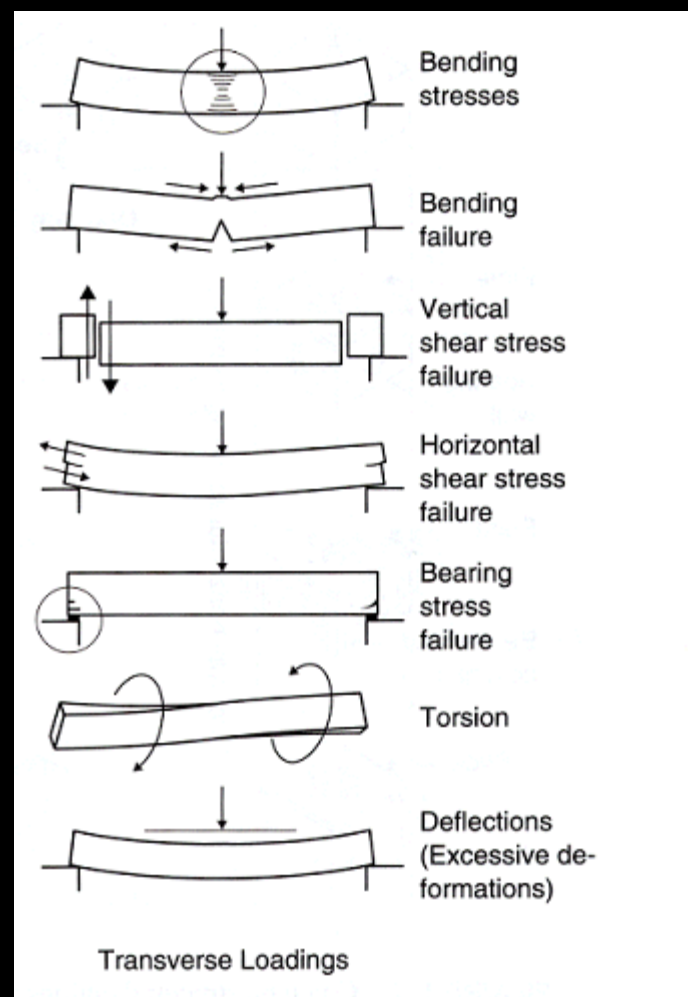
Beams

- *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)*



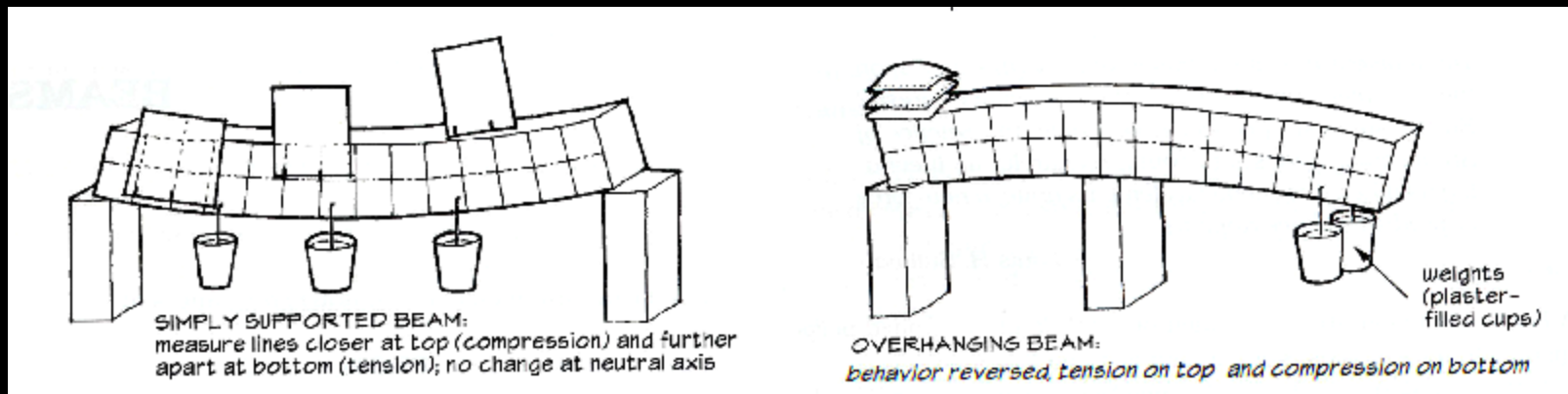
Beams

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



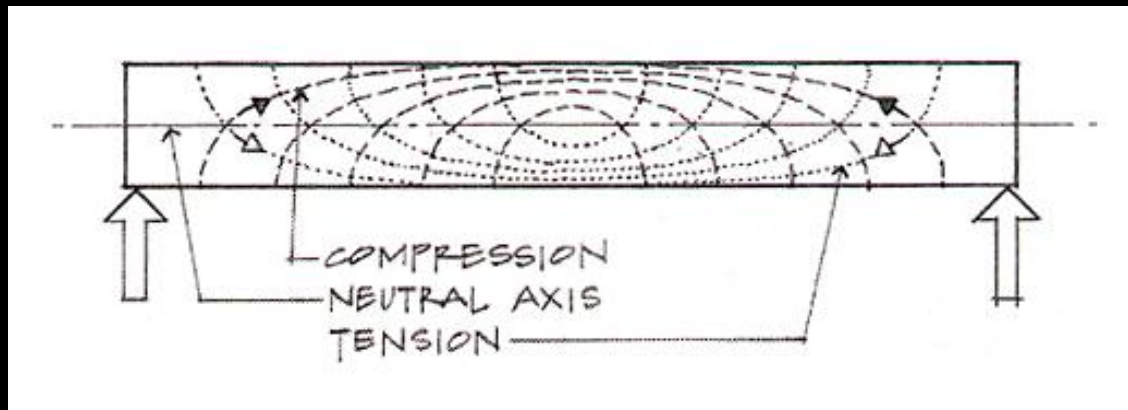
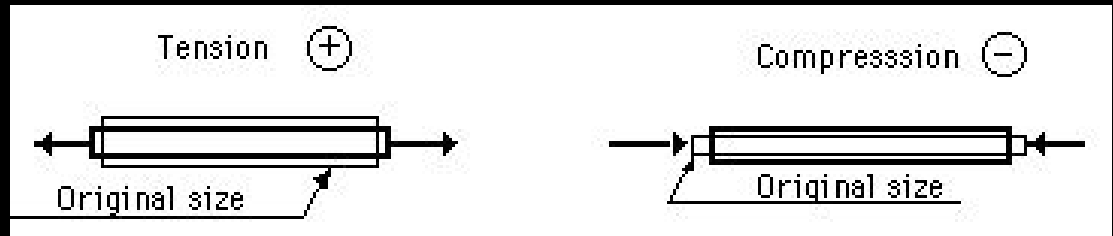
Beams

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

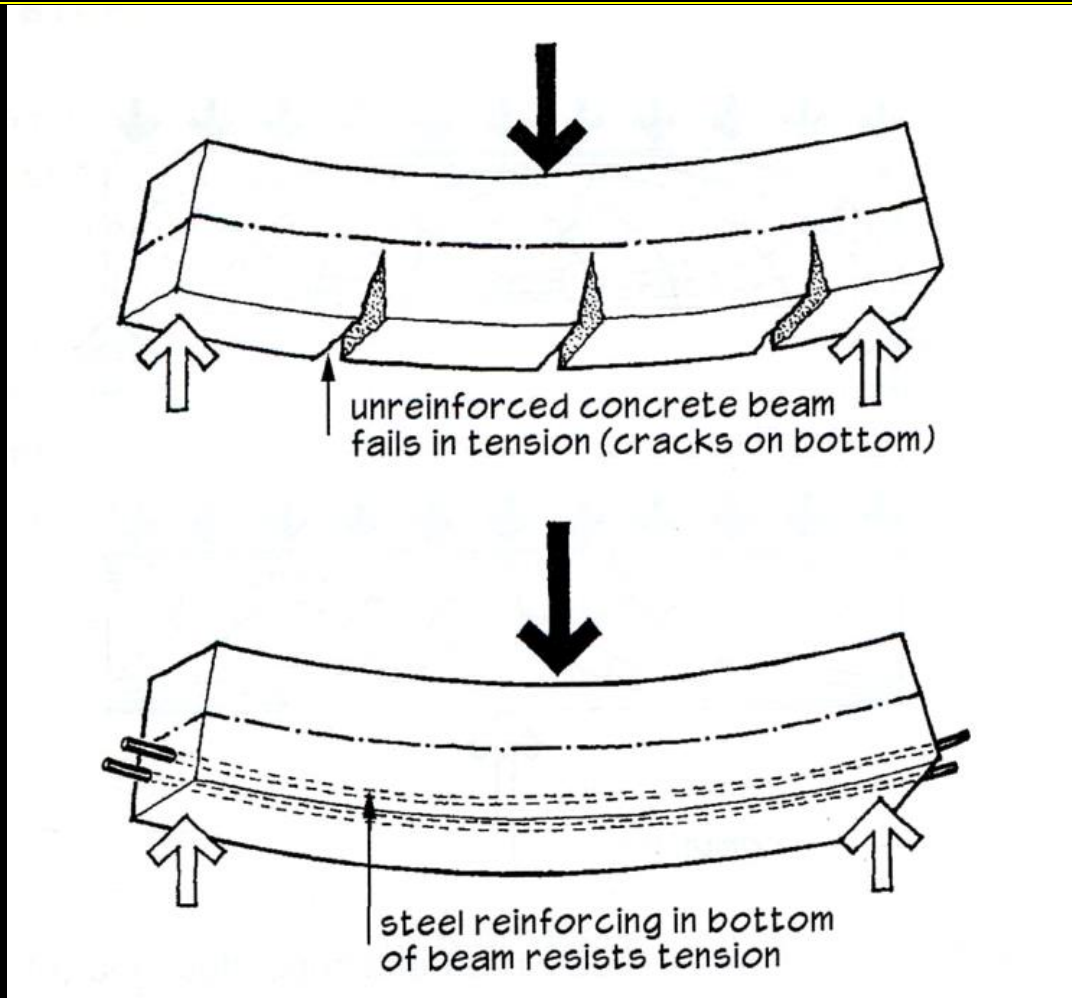


Beam Stresses

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

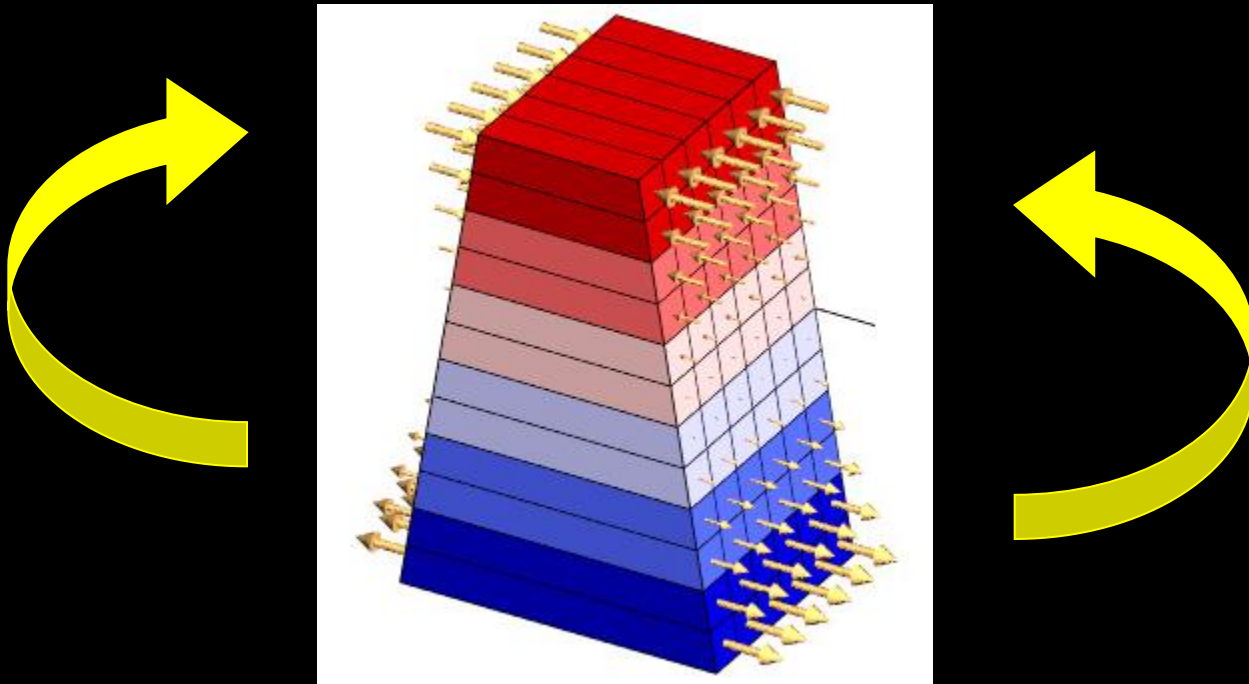


Beam Stresses



Beam Stresses

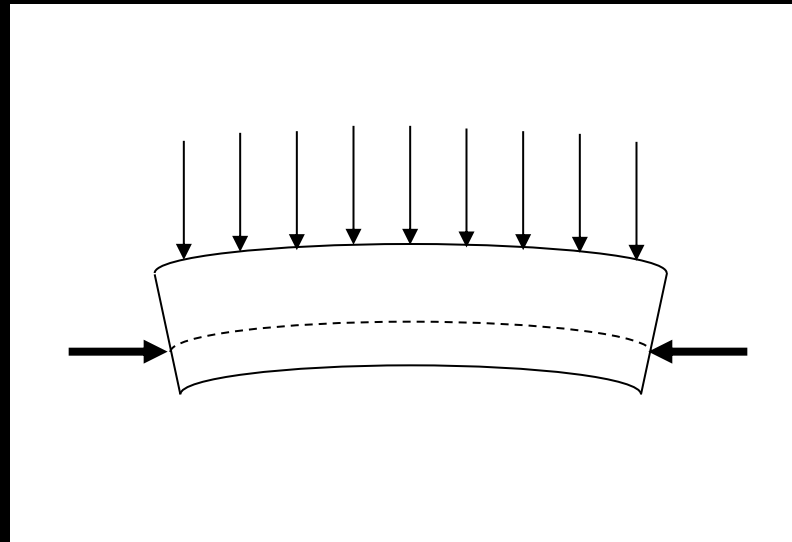
- *tension and compression*
 - *causes moments*



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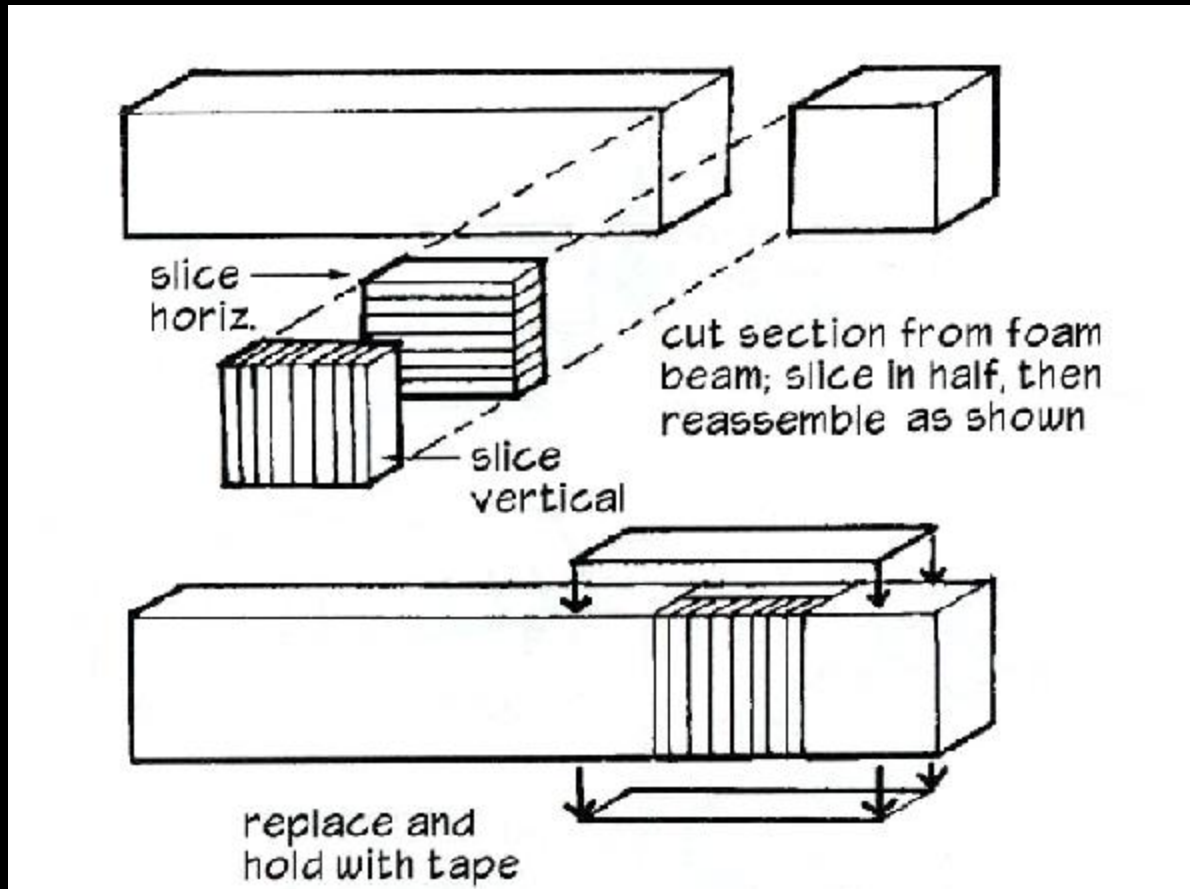
Beam Stresses

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



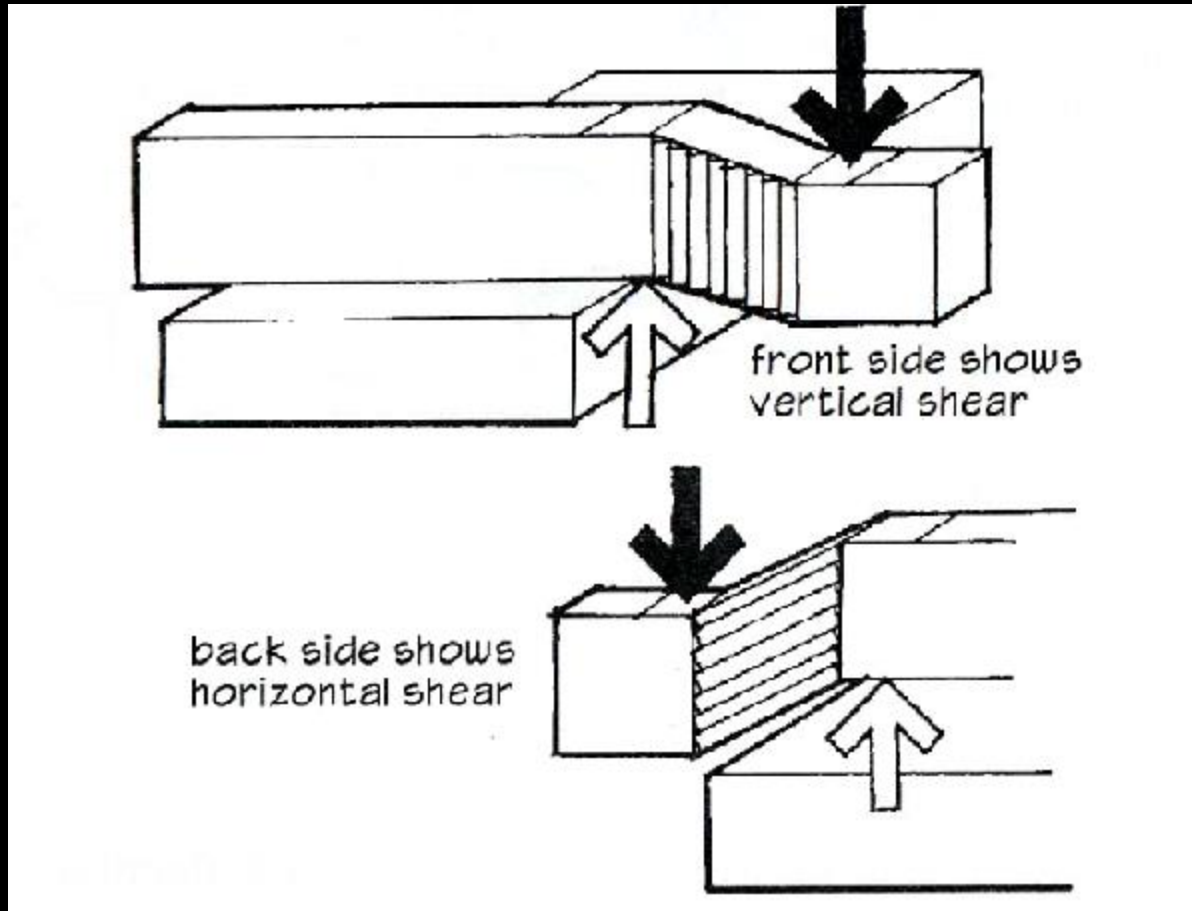
Beam Stresses

- *shear – horizontal & vertical*



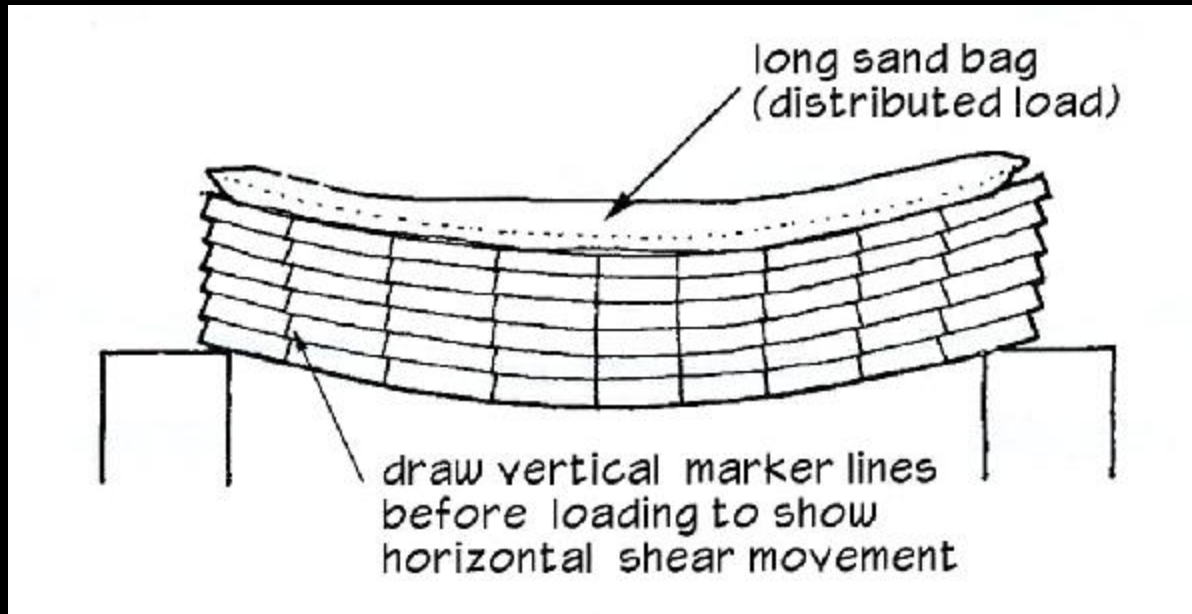
Beam Stresses

- *shear – horizontal & vertical*



Beam Stresses

- *shear – horizontal*



Beam Deflections

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

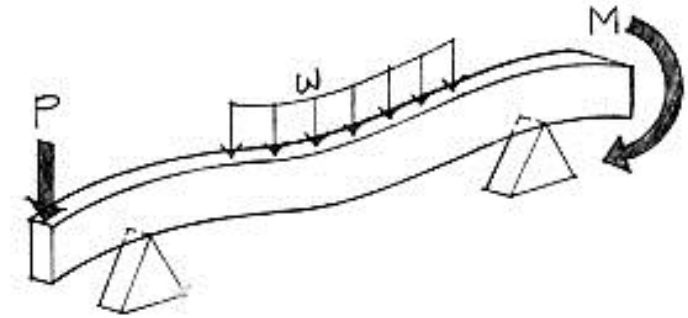
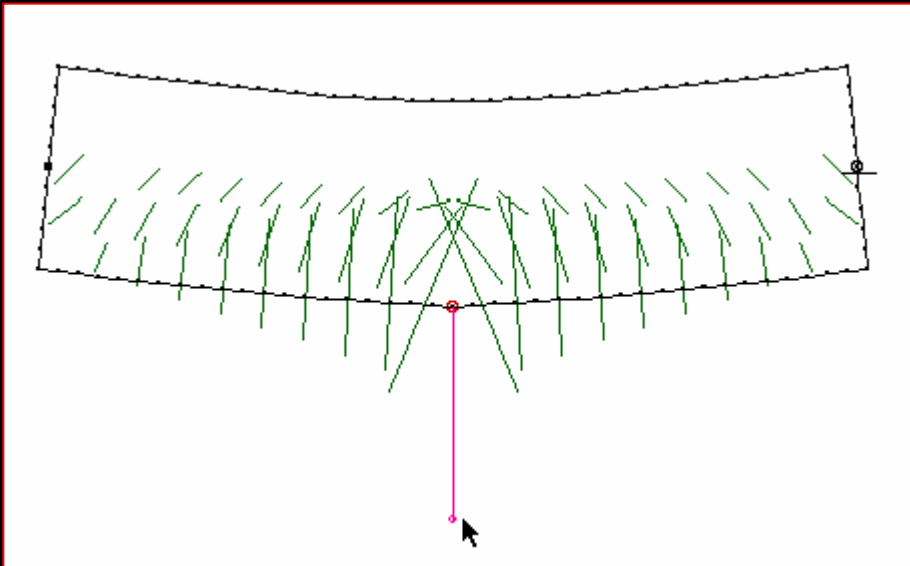
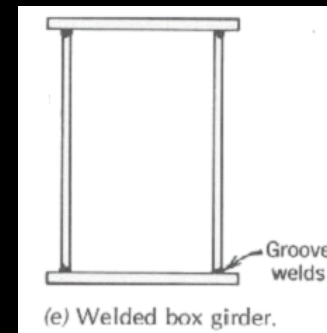
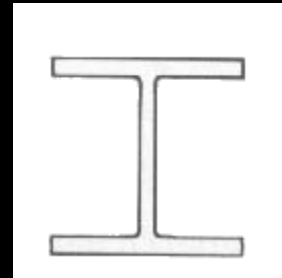
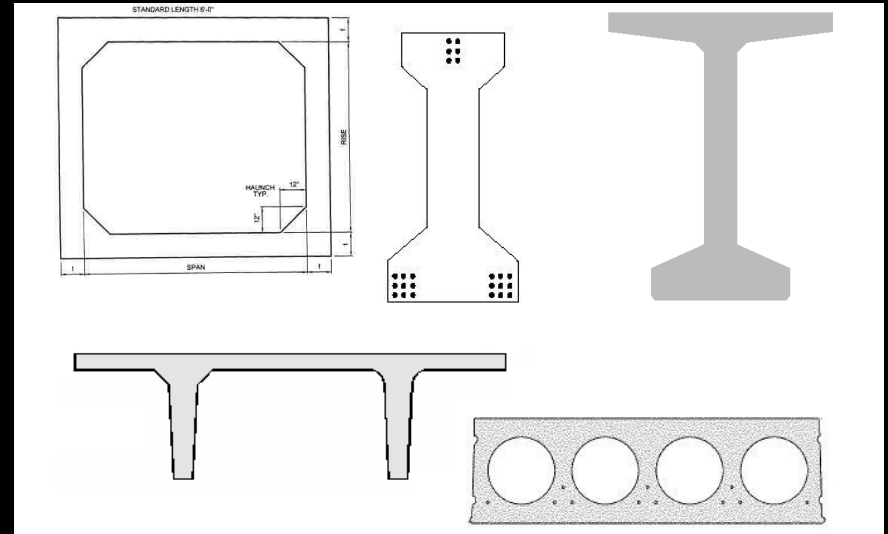
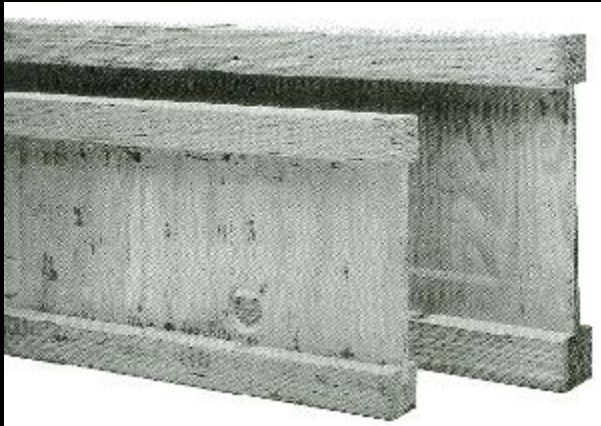


Figure 5.4 Bending (flexural) loads on a beam.



Beam Deflections

- “moment of inertia”

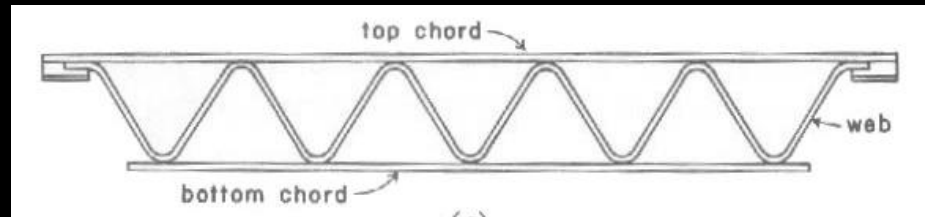


Beam Styles

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

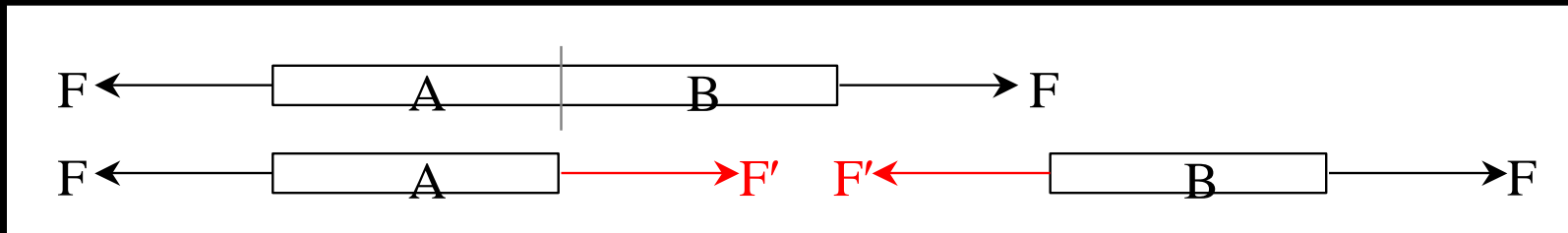


<http://nisee.berkeley.edu/godden>

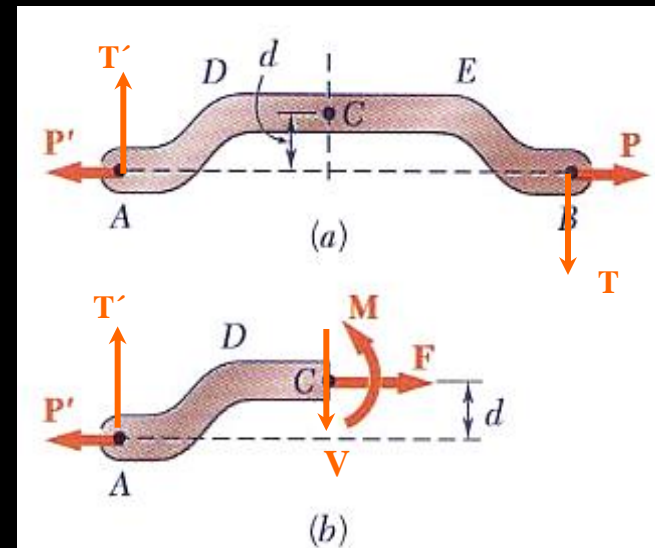


Internal Forces

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

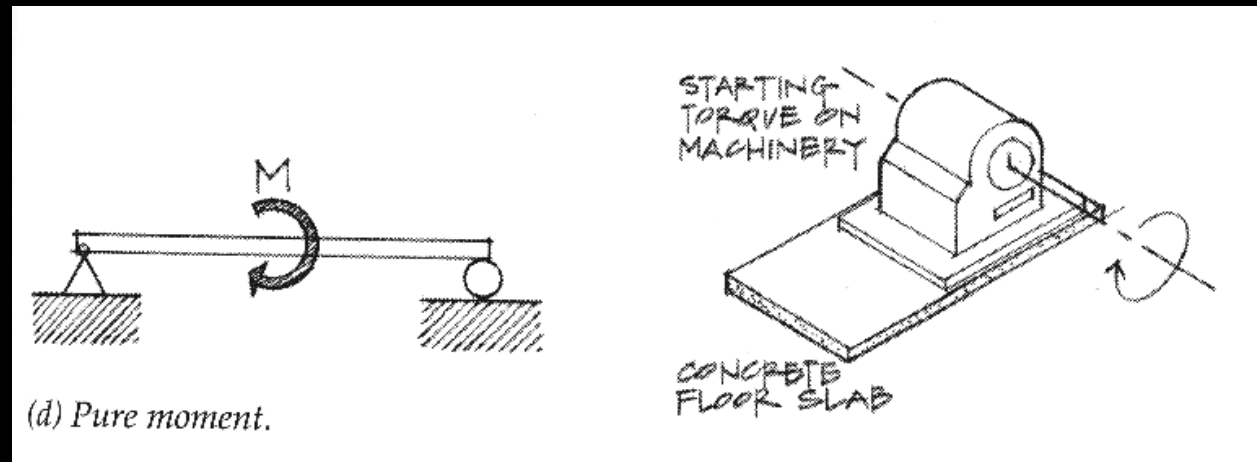
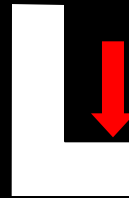


- *in general*
 - *axial force*
 - *shear force, V*
 - *bending moment, M*



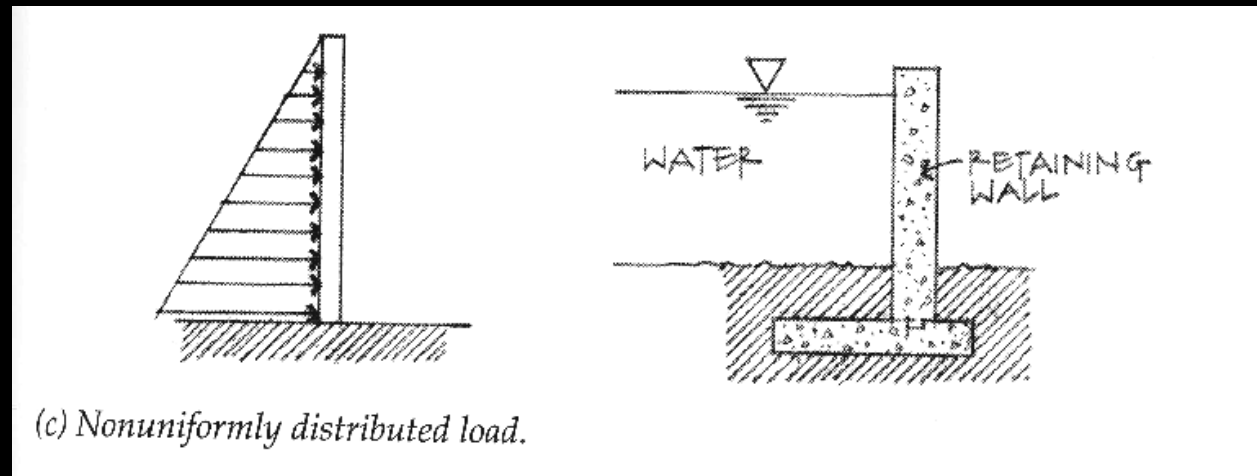
Beam Loading

- concentrated force
- concentrated moment
 - spandrel beams



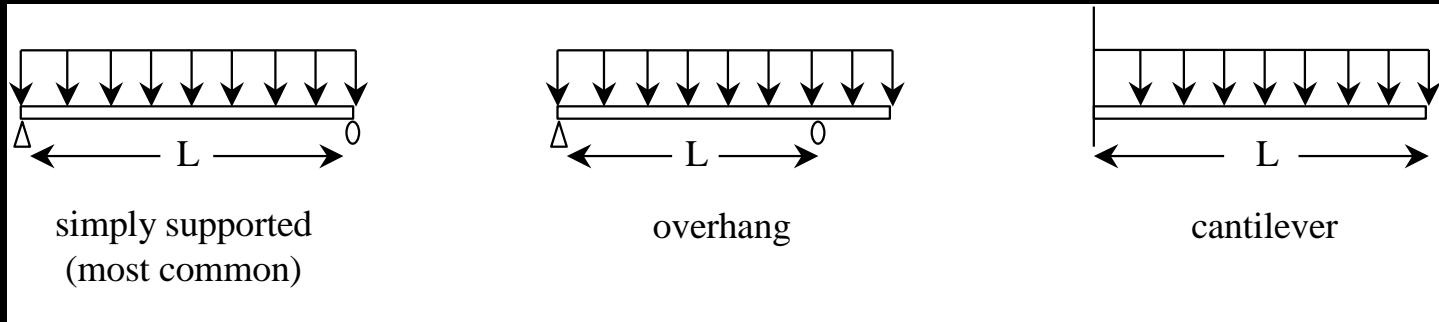
Beam Loading

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

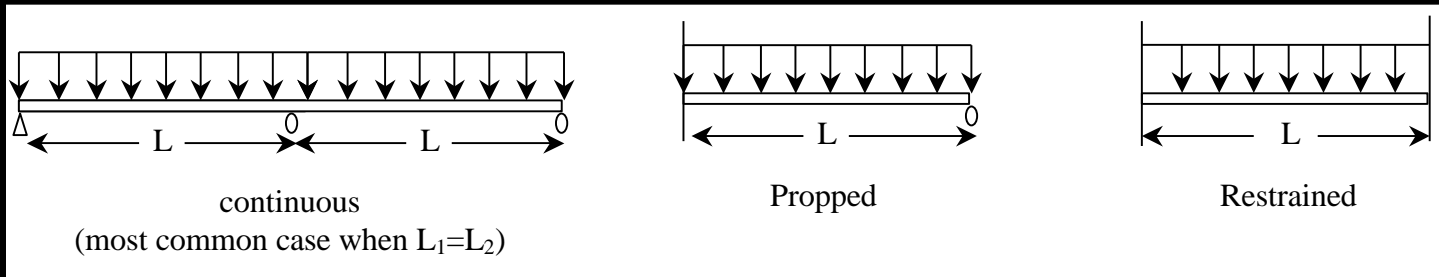


Beam Supports

- *statically determinate*

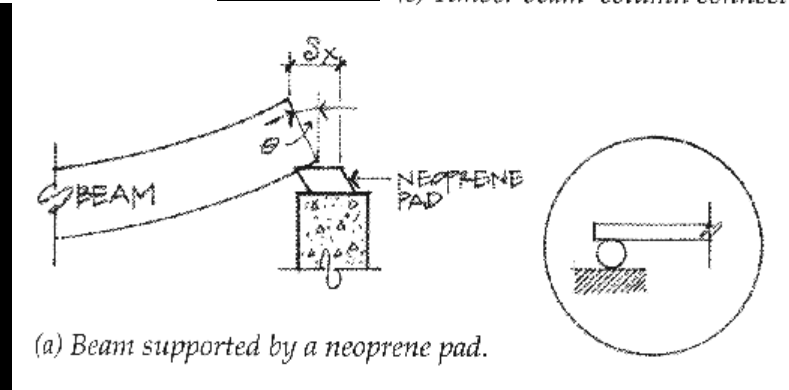
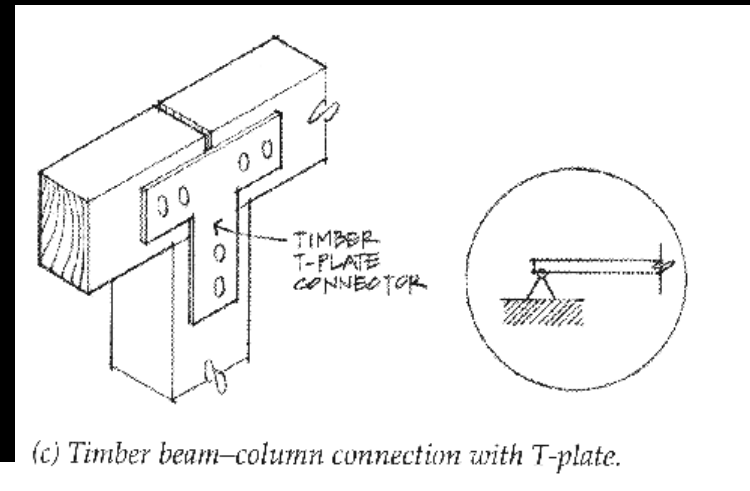
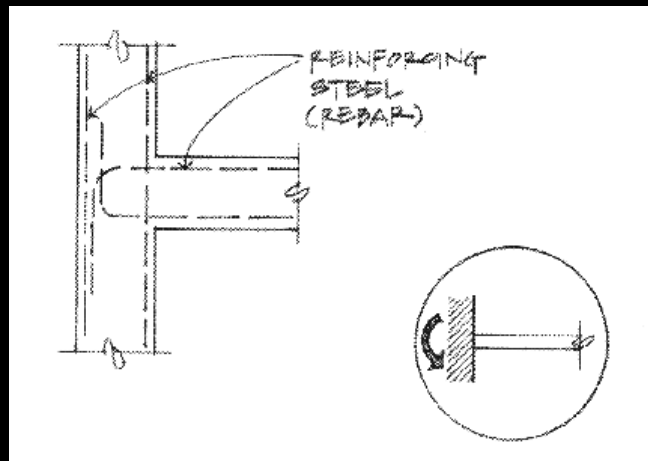


- *statically indeterminate*



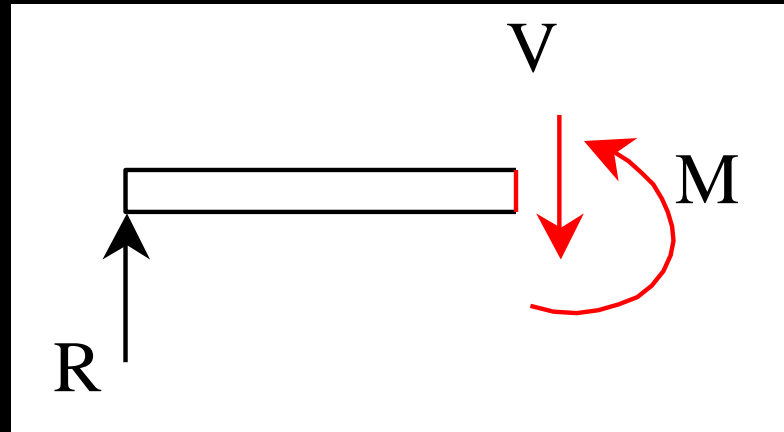
Beam Supports

- *in the real world, modeled type*



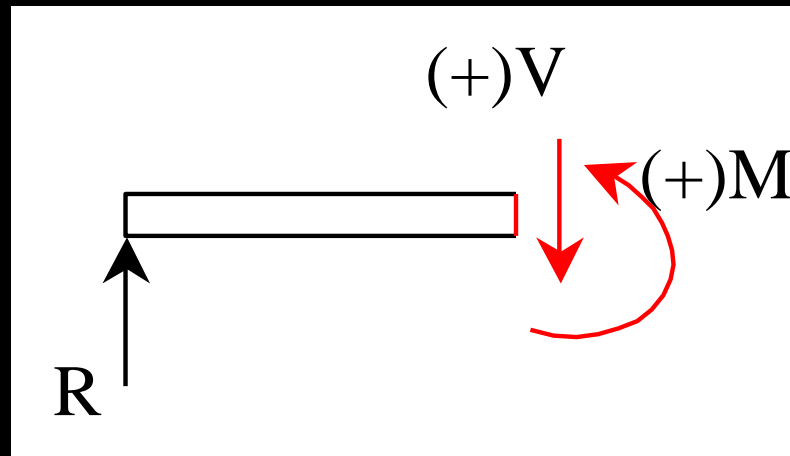
Internal Forces in Beams

- *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*



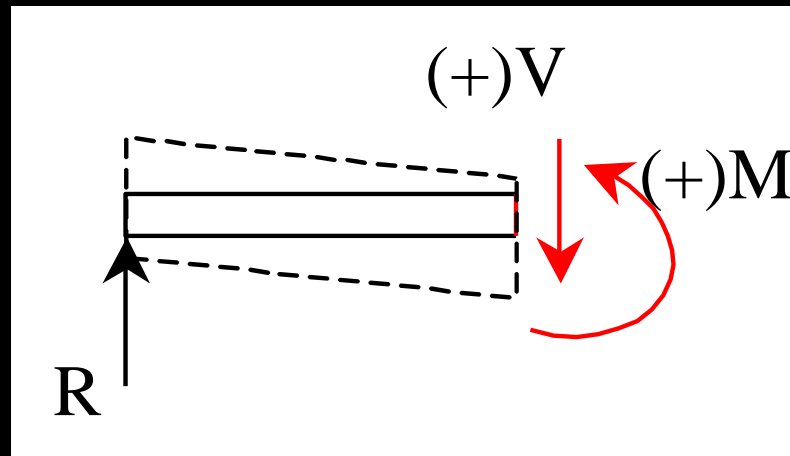
V & M Diagrams

- *tool to locate V_{max} and M_{max}*
- *necessary* *for designing*
- *M_{max} occurs when $V = 0$*

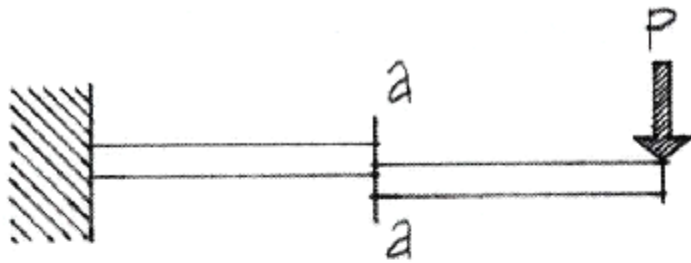


Sign Convention

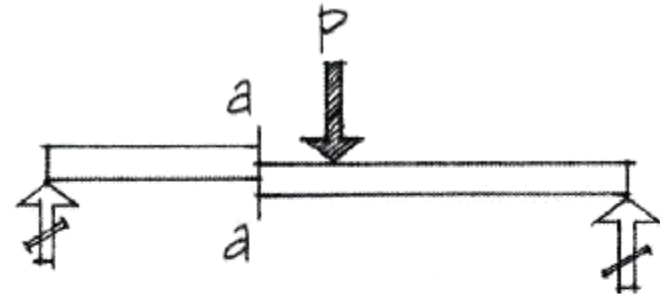
- *shear force, V :*
 - *cut section to LEFT*
 - *if $\sum F_y$ is positive by statics, V acts down and is POSITIVE*
 - *beam has to resist shearing apart by V*



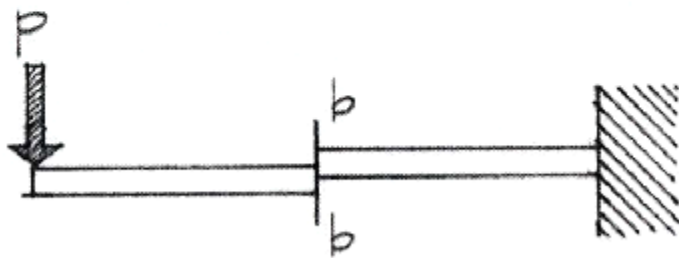
Shear Sign Convention



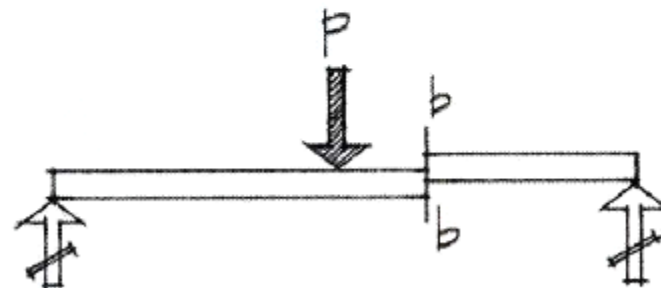
(+) Shear.



(+) Shear.



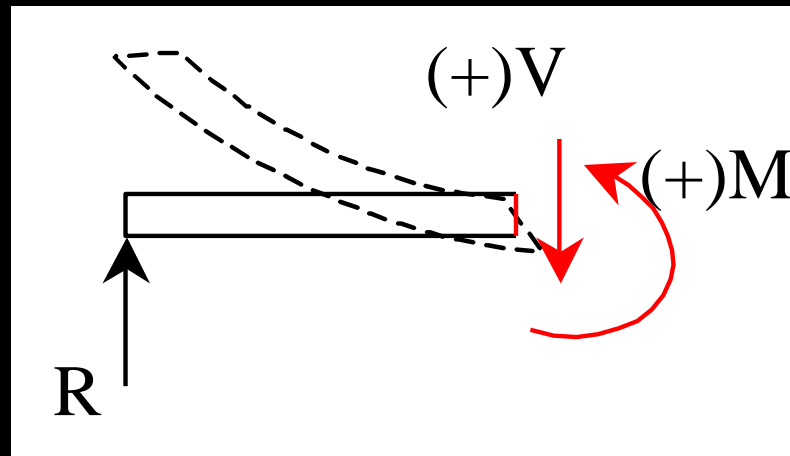
(-) Shear.



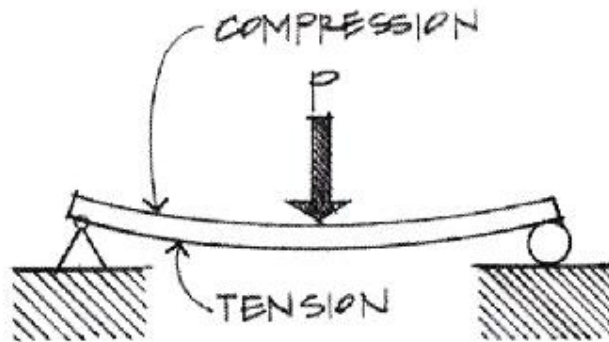
(-) Shear.

Sign Convention

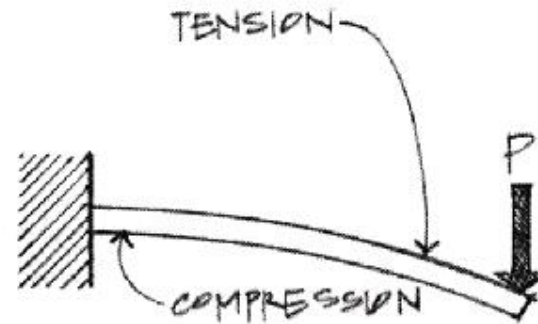
- *bending moment, M :*
 - *cut section to LEFT*
 - *if $\sum M_{cut}$ is clockwise, M acts ccw and is **POSITIVE** – flexes into a “smiley” beam
*has to resist bending apart by M**



Bending Moment Sign Convention



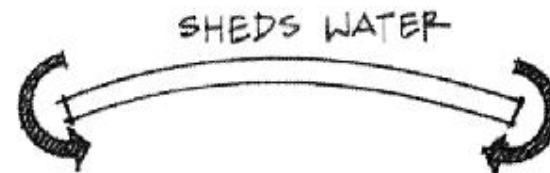
(+) Moment.



(-) Moment.

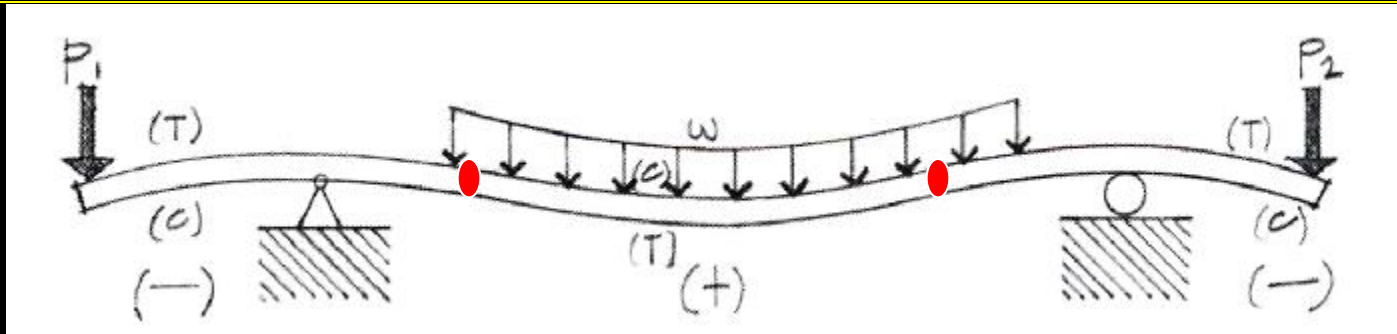


(+) Moment.



(-) Moment.

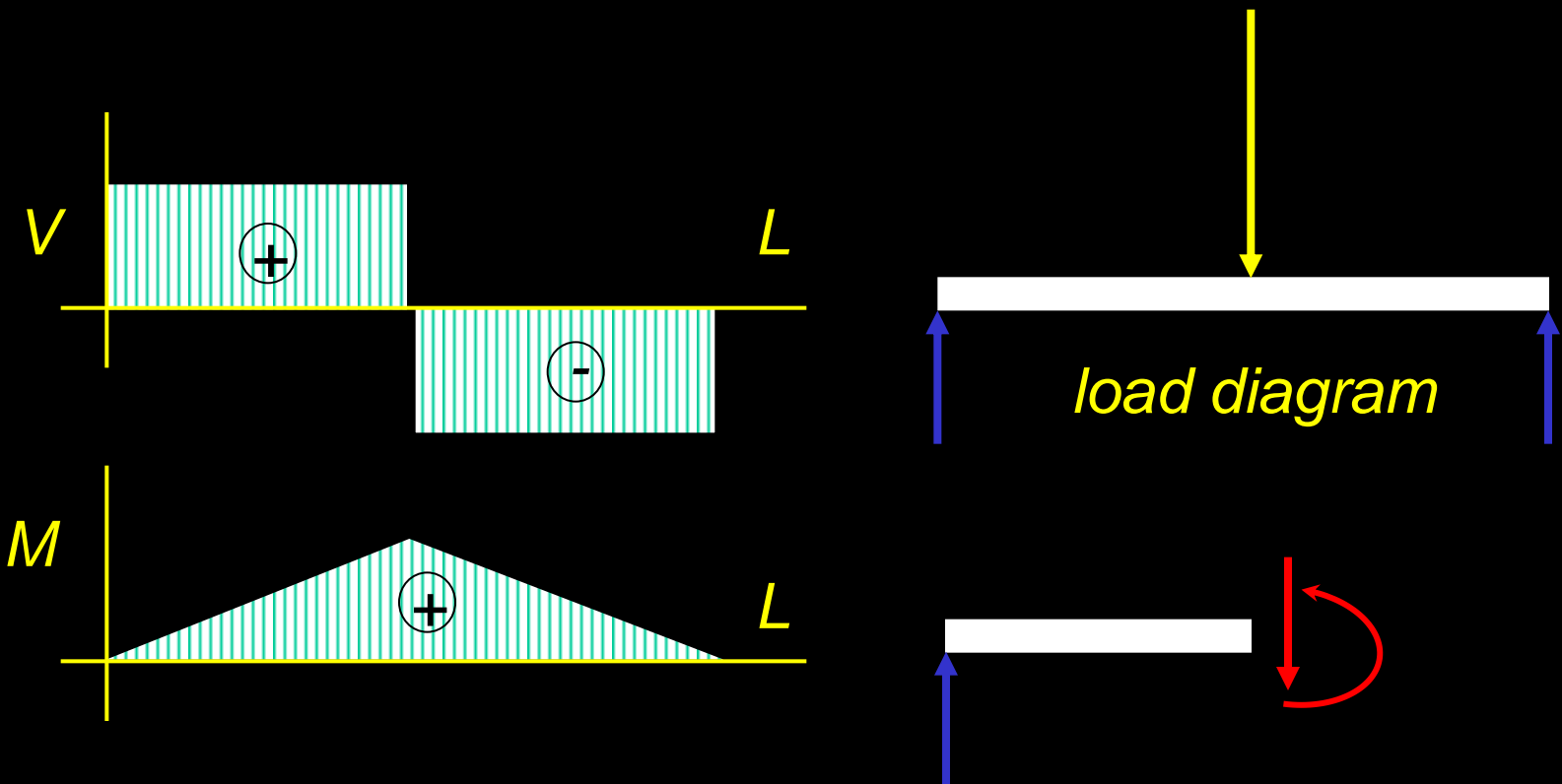
Deflected Shape



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

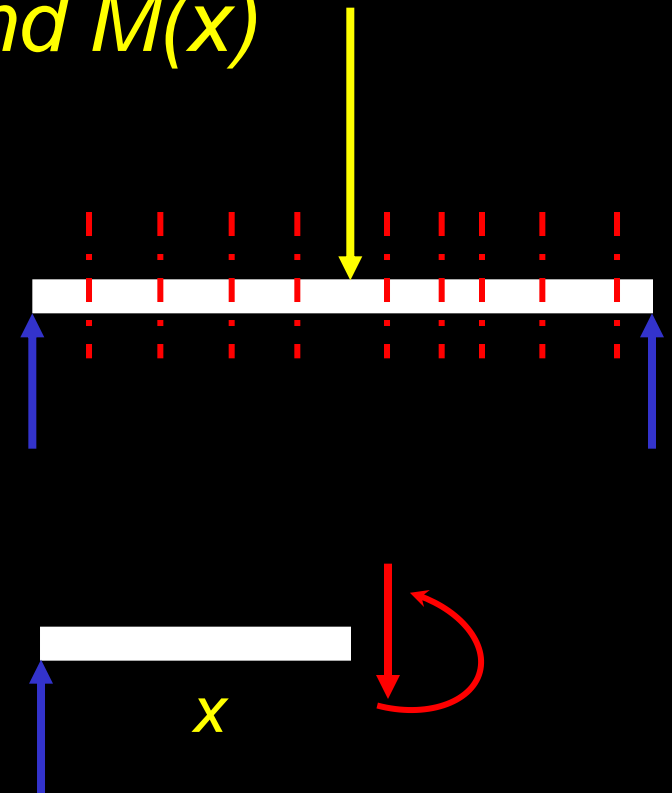
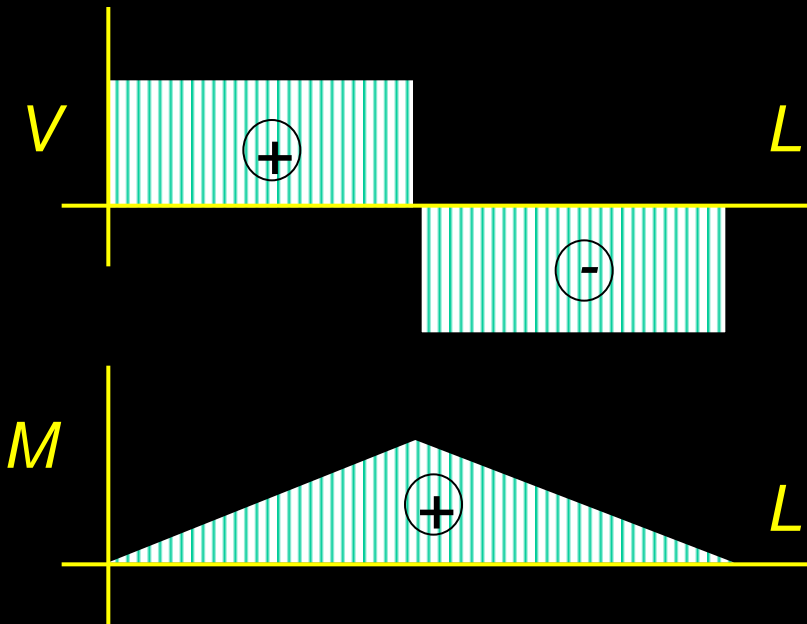
Constructing V & M Diagrams

- along the beam length, plot V, plot M



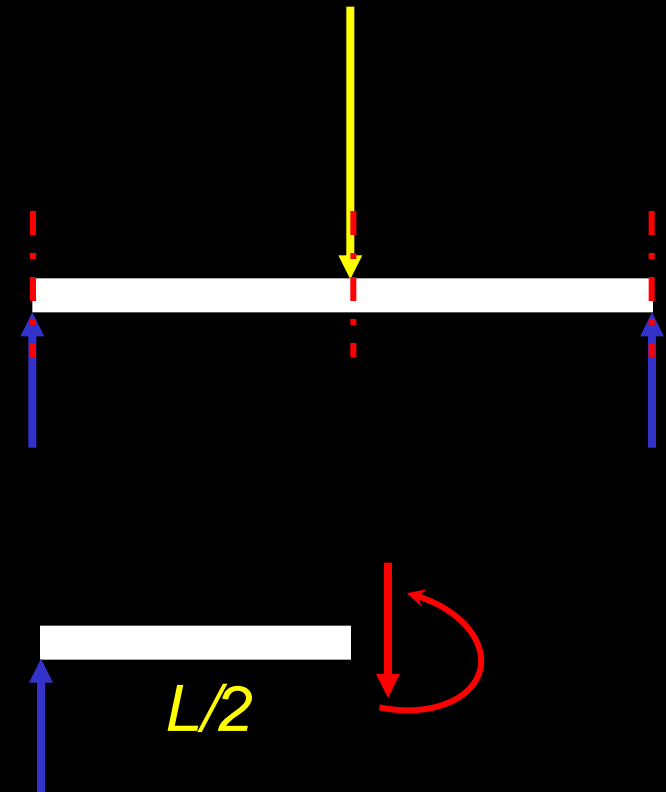
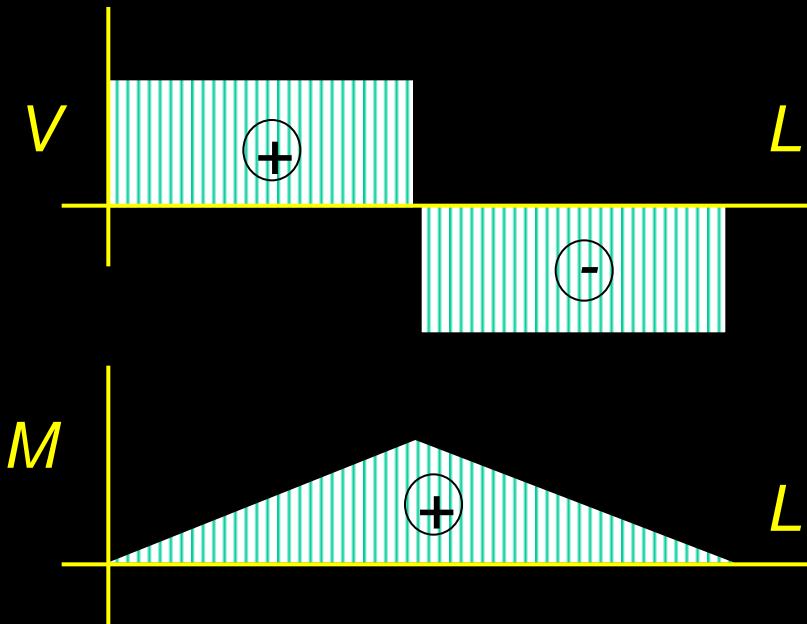
Mathematical Method

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



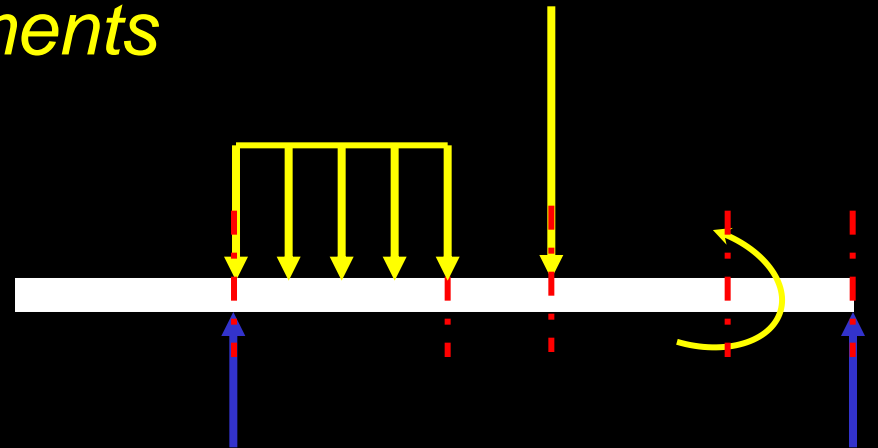
Equilibrium Method

- *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 Methods

- relationships

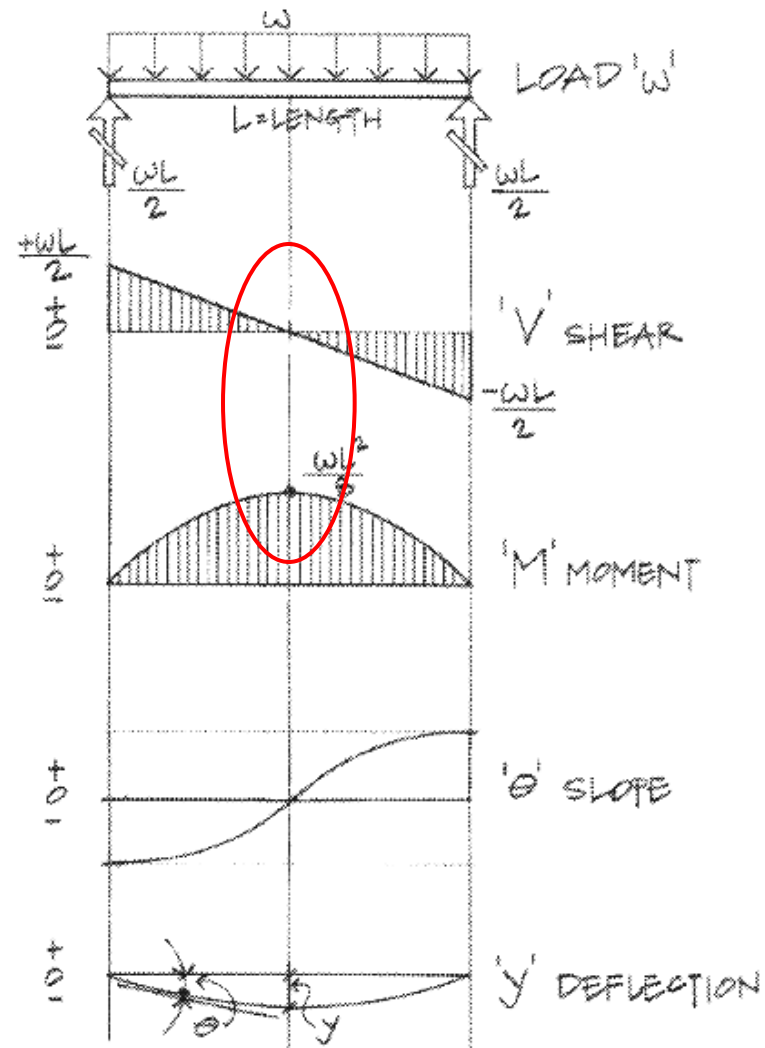


Figure 7.11 Relationship of load, shear, moment, slope, and deflection diagrams.

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

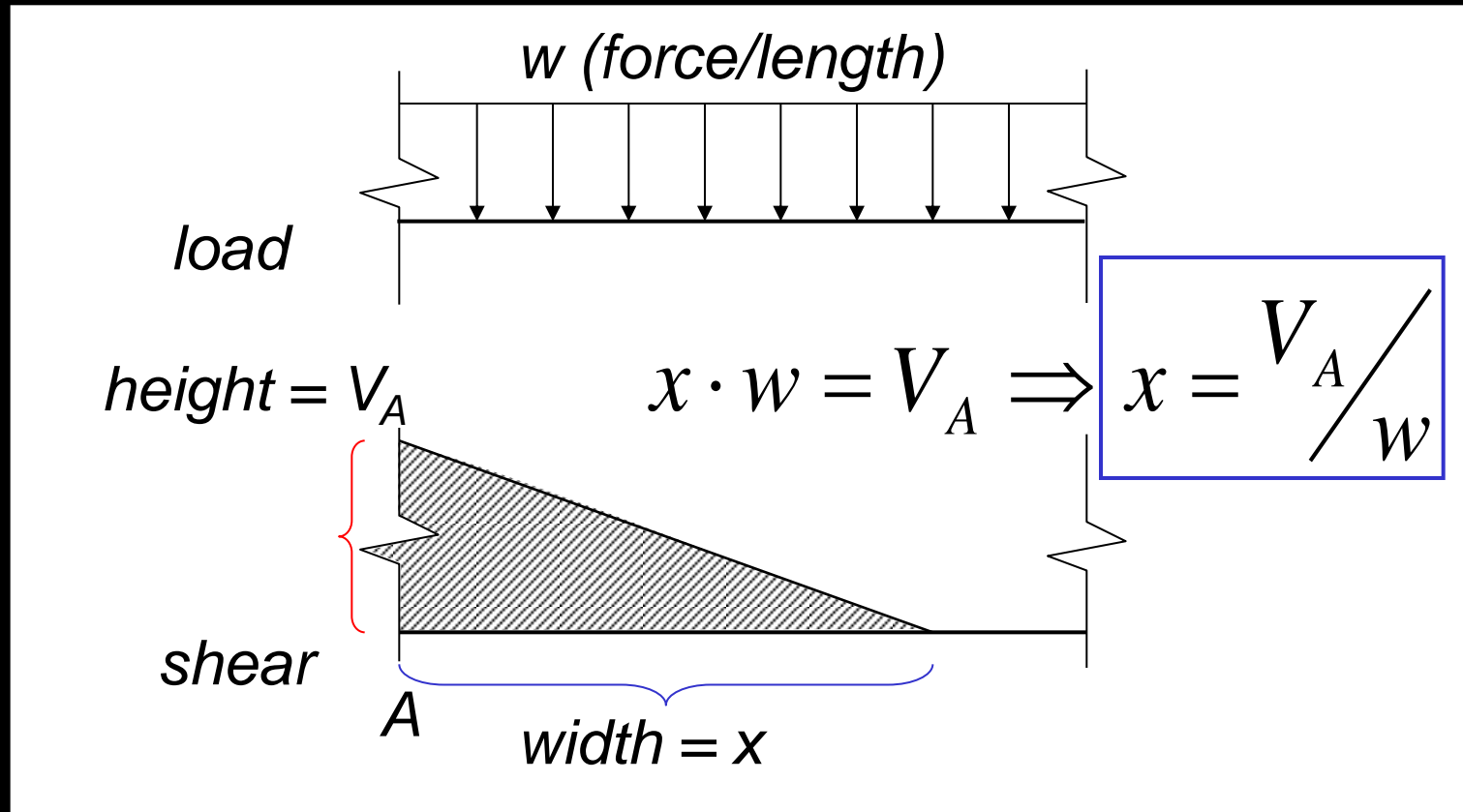
8. Moment has 2 values at moments

9. Sum moments at each section

10. Maximum moment is where shear = 0!

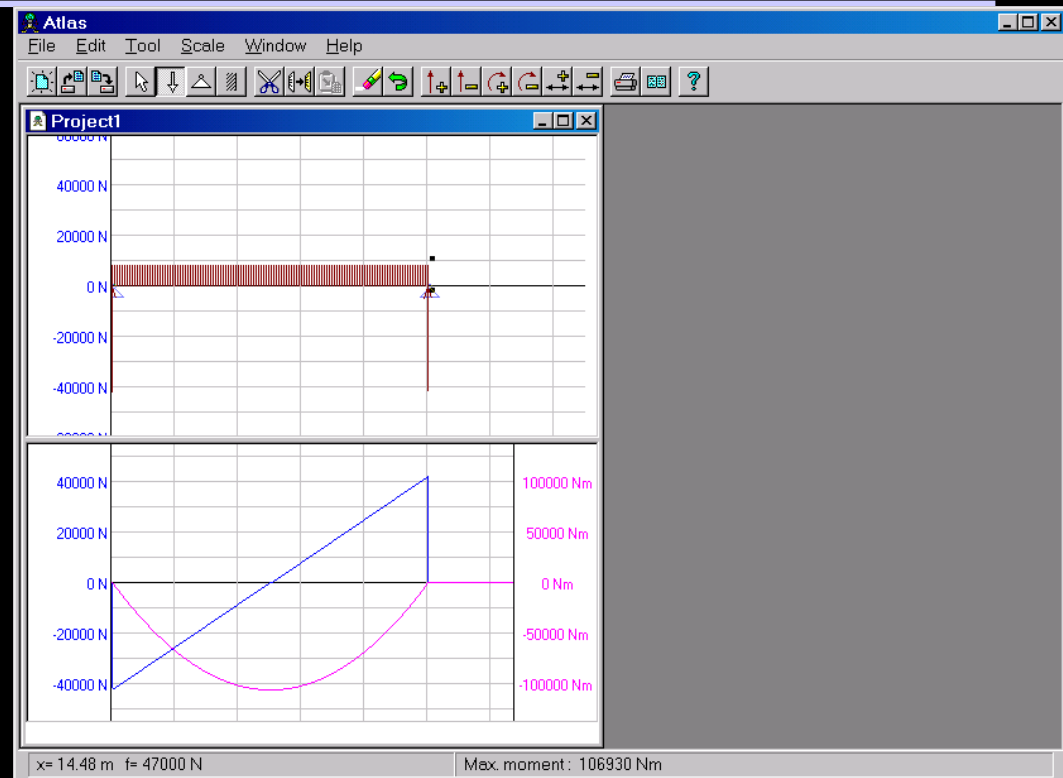
Shear Through Zero

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



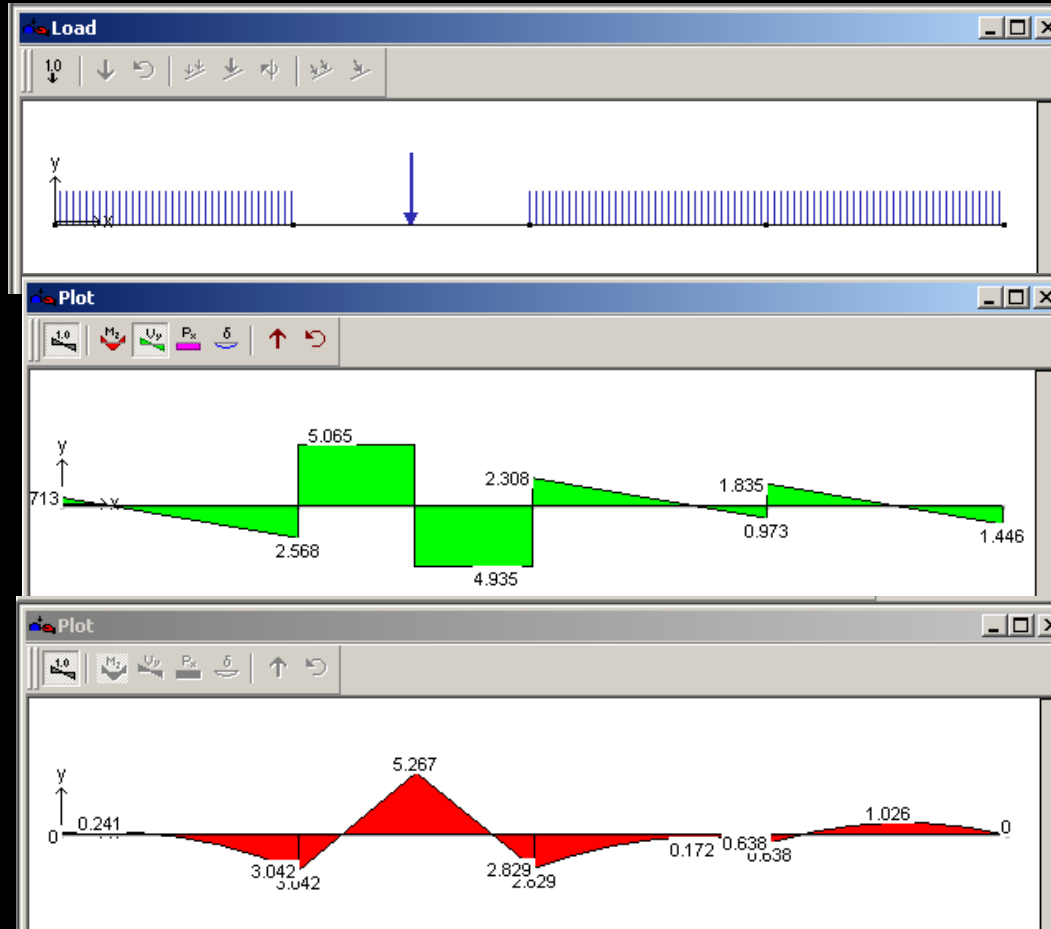
Tools

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



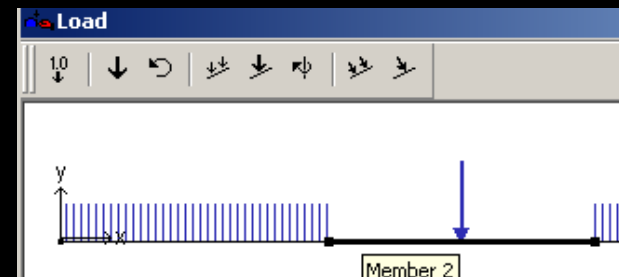
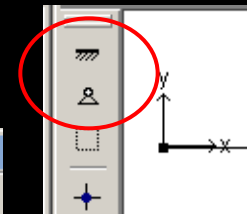
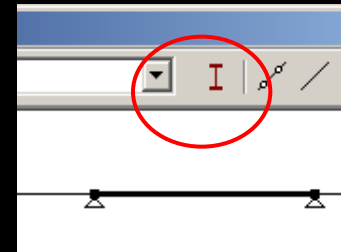
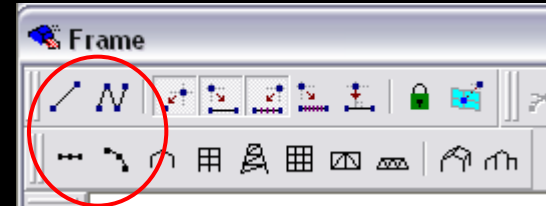
Tools – Multiframe

- *in computer lab*



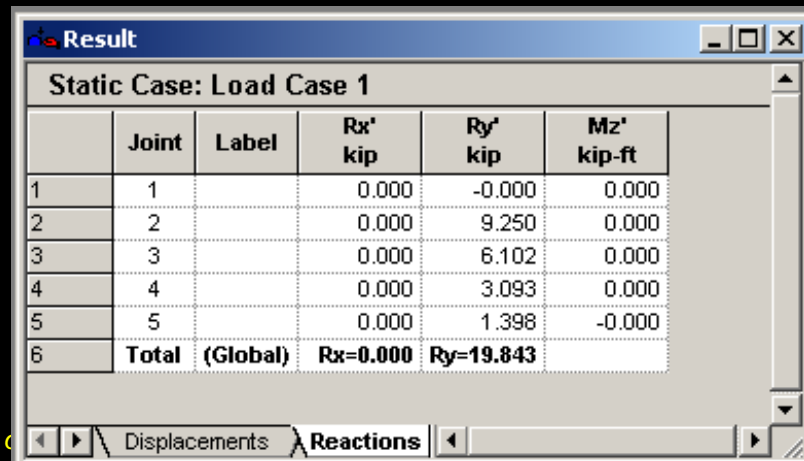
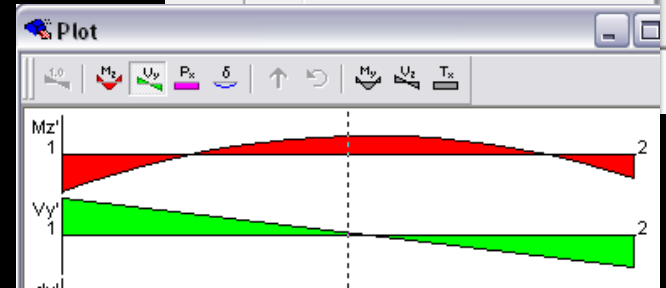
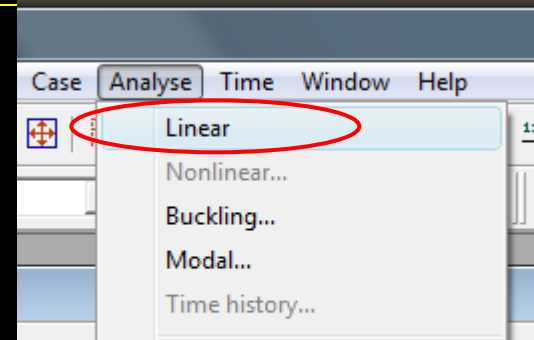
Tools – Multiframe

- *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*



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	