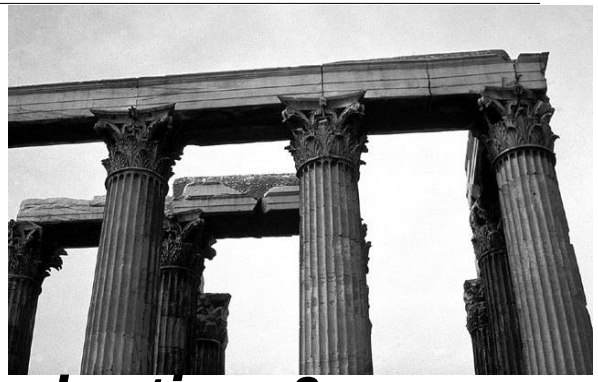
ELEMENTS OF ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN
ARCH 614
DR. ANNE NICHOLS
SPRING 2013

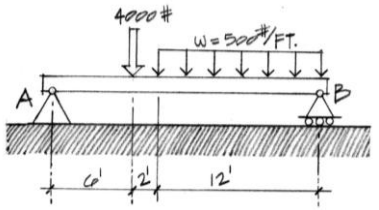
lecture
SIX

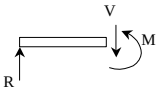


beam introduction & internal forces

Beams

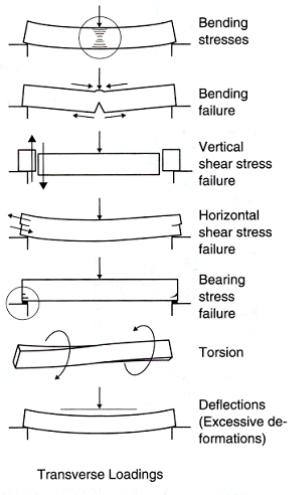
- span horizontally
  - floors
  - bridges
  - roofs
- loaded transversely by gravity loads
- may have internal axial force
- will have internal shear force
- will have internal moment (bending)





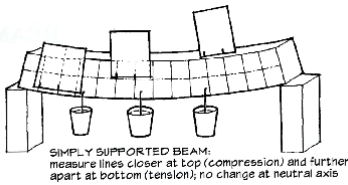
Beams

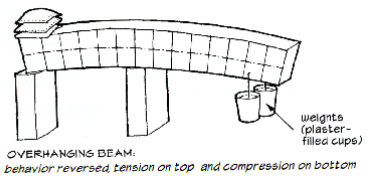
- transverse loading
- sees:
  - bending
  - shear
  - deflection
  - torsion
  - bearing
- behavior depends on cross section shape



Beams

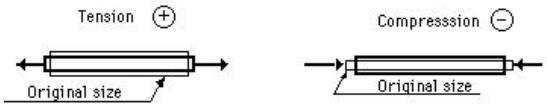
- bending
  - bowing of beam with loads
  - one edge surface stretches
  - other edge surface squishes

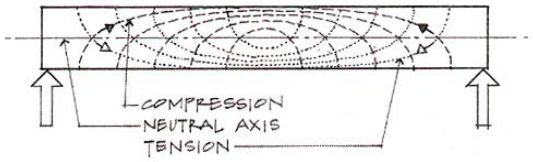




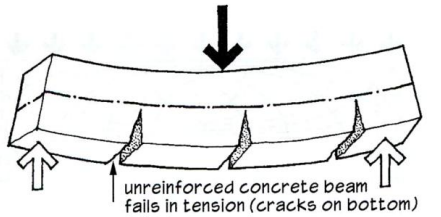
Beam Stresses

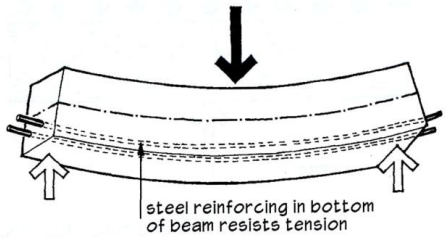
- *stress = relative force over an area*
  - *tensile*
  - *compressive*
  - *bending*
    - *tension and compression + ...*





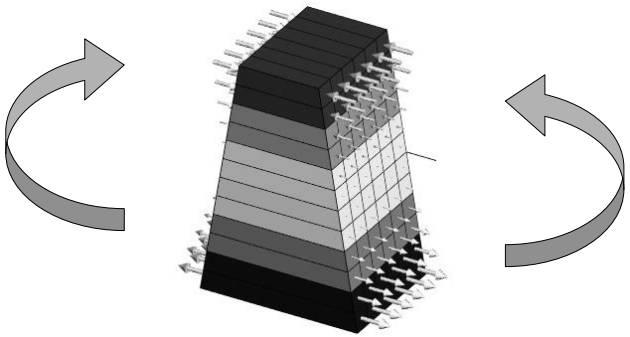
Beam Stresses





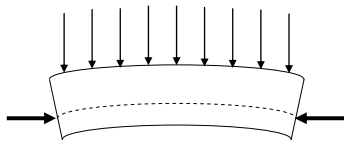
Beam Stresses

- *tension and compression*
  - *causes moments*



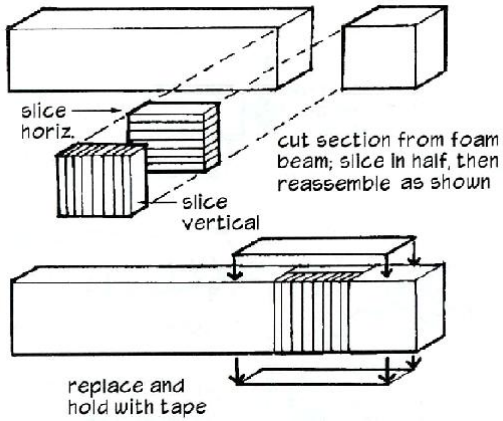
Beam Stresses

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



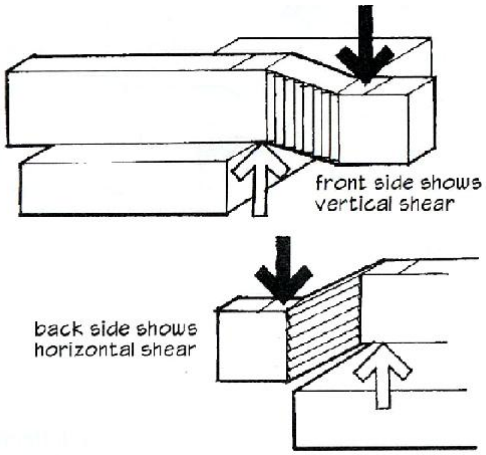
Beam Stresses

- *shear – horizontal & vertical*



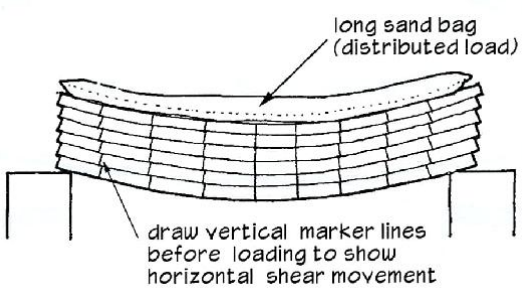
Beam Stresses

- *shear – horizontal & vertical*



Beam Stresses

- *shear – horizontal*



Beam Deflections

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

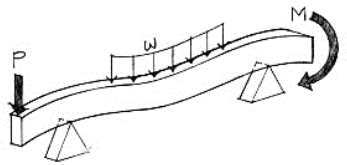
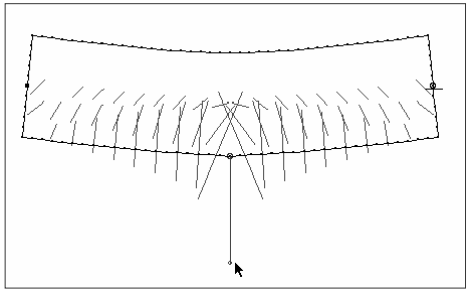
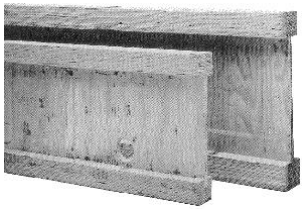


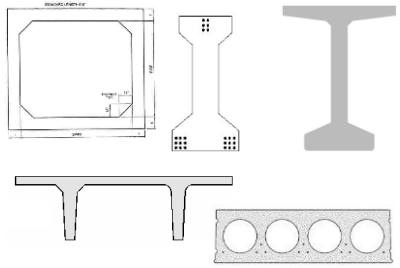
Figure 5.4 Bending (flexural) loads on a beam.

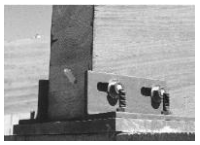


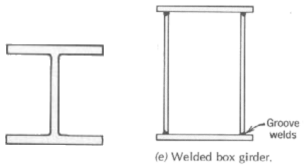
Beam Deflections

- *"moment of inertia"*





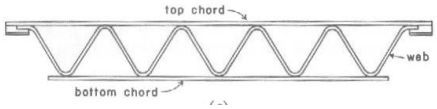




Beam Styles

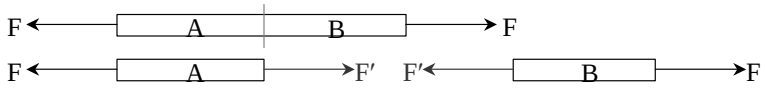
- *vierendeel*

- *open web joists*
- *manufactured*

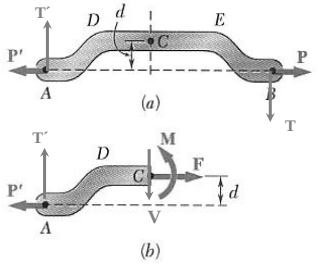


Internal Forces

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

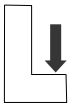


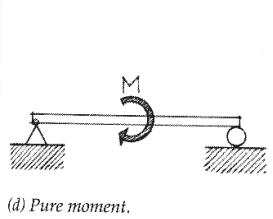
- *in general*
  - *axial force*
  - *shear force, V*
  - *bending moment, M*

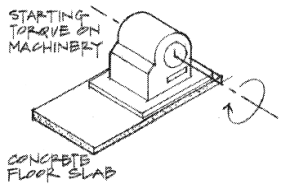


Beam Loading

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

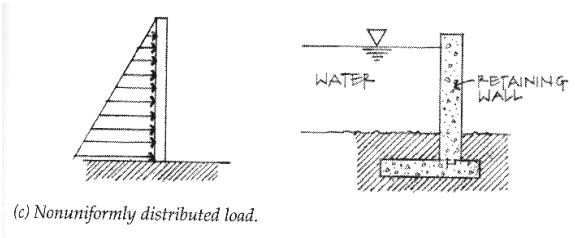






Beam Loading

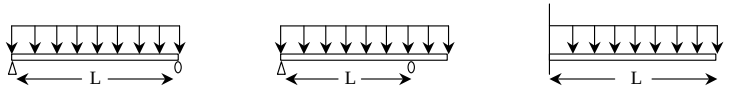
- *uniformly distributed load (line load)*
- *non-uniformly distributed load*
  - *hydrostatic pressure = γh*
  - *wind loads*



(c) Nonuniformly distributed load.

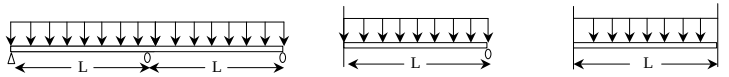
Beam Supports

- *statically determinate*



simply supported (most common) | overhang | cantilever

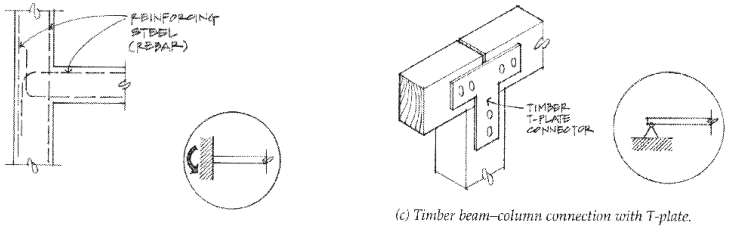
- *statically indeterminate*



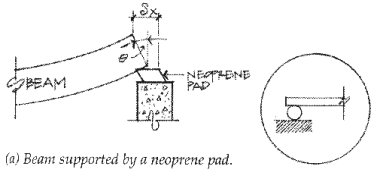
continuous (most common case when $L_1=L_2$) | Propped | Restrained

Beam Supports

- *in the real world, modeled type*



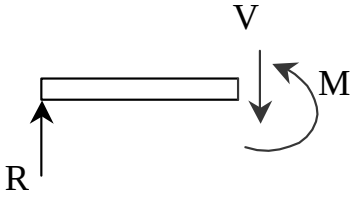
(c) Timber beam–column connection with T-plate.



(a) Beam supported by a neoprene pad.

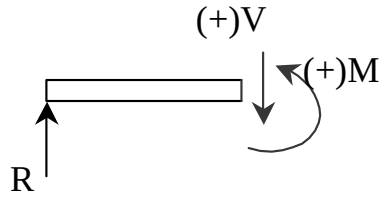
Internal Forces in Beams

- *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*



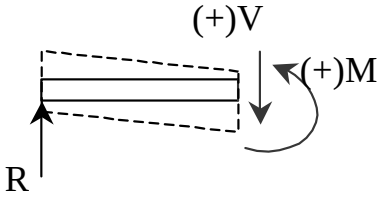
V & M Diagrams

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

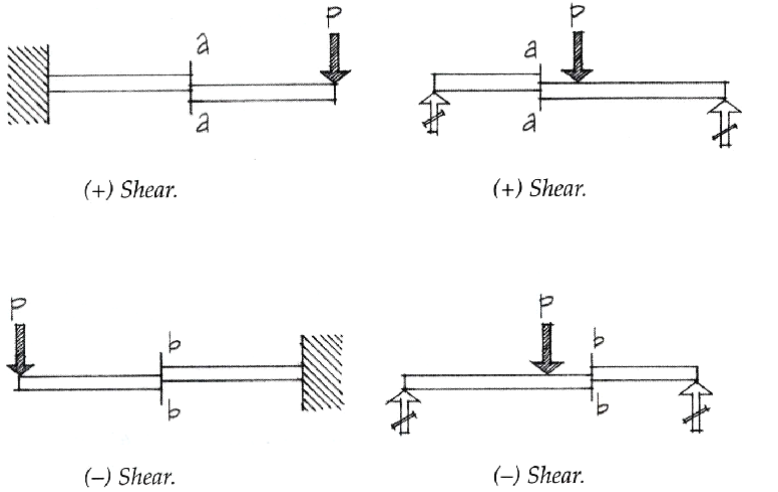


Sign Convention

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

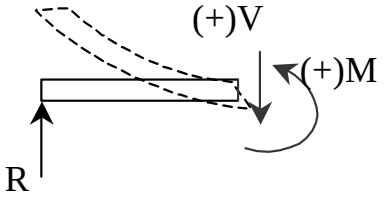


Shear Sign Convention

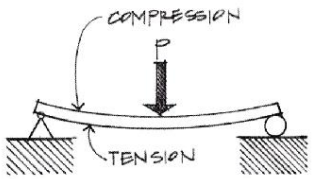


Sign Convention

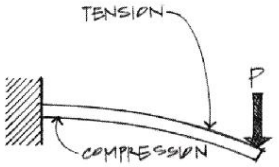
- *bending moment, M:*
  - *cut section to LEFT*
  - *if $\sum M_{cut}$ is clockwise, M acts ccw and is POSITIVE – flexes into a "smiley" beam has to resist bending apart by M*



Bending Moment Sign Convention

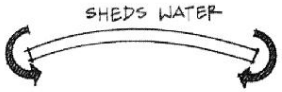


(+) Moment.



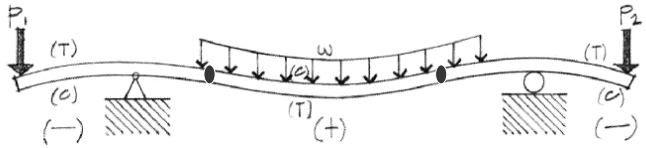
(–) Moment.

(+) Moment.



(–) Moment.

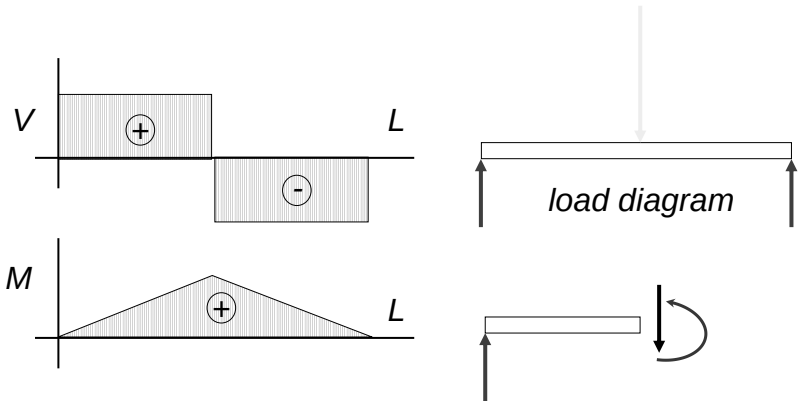
Deflected Shape



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

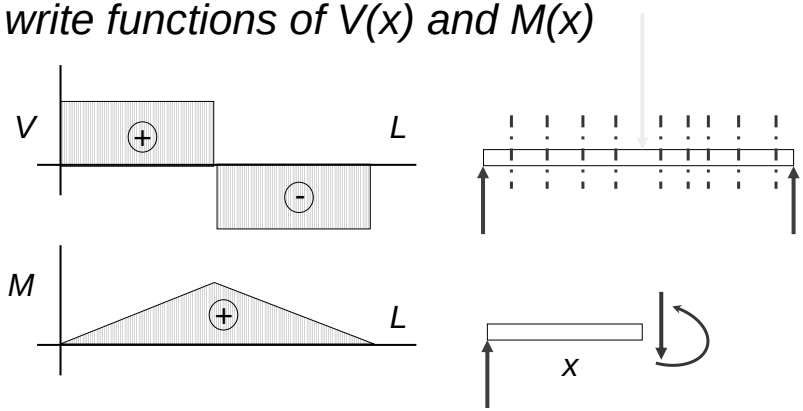
Constructing V & M Diagrams

- *along the beam length, plot V, plot M*



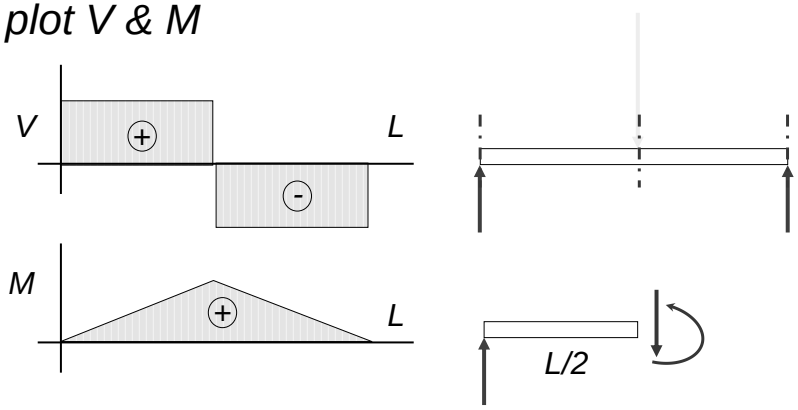
Mathematical Method

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



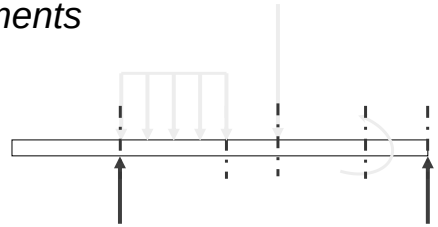
Equilibrium Method

- *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 Meth

- *relationships*

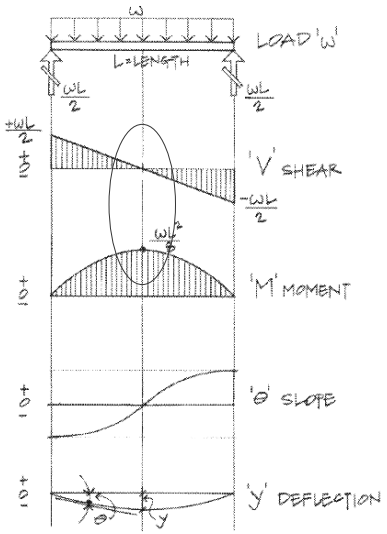


Figure 7.11 Relationship of load, shear, moment, slope, and deflection diagrams.

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*

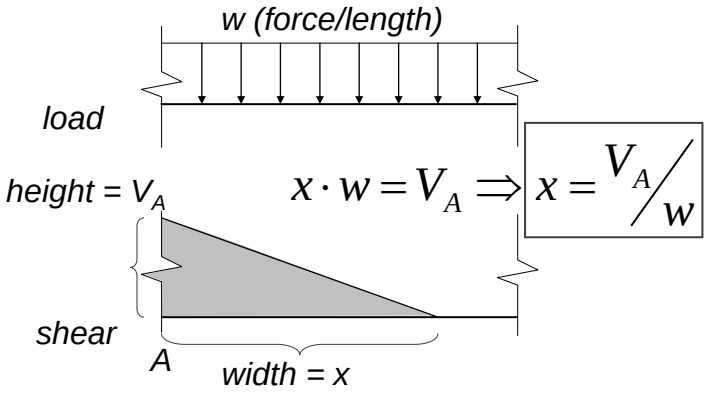
Basic Procedure

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!*

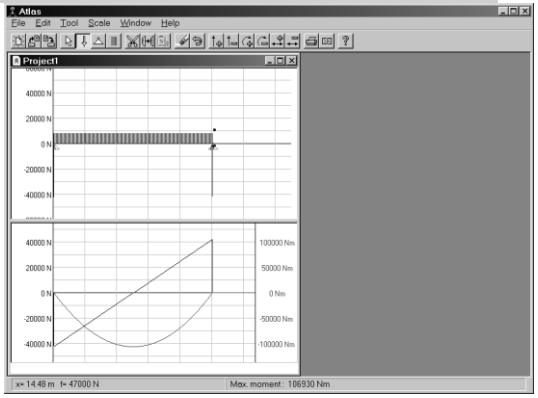
Shear Through Zero

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



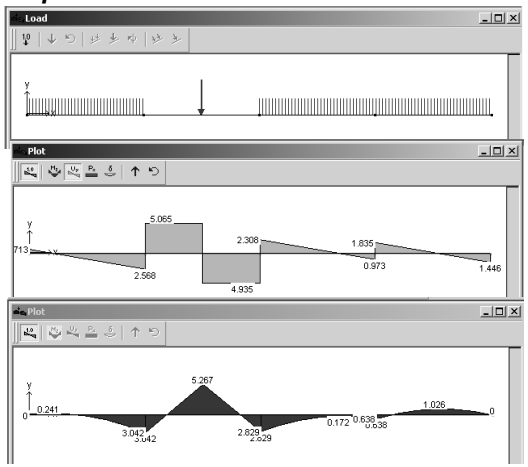
Tools

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



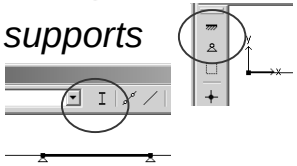
Tools – Multiframe

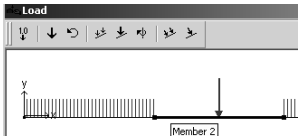
- *in computer lab*



Tools – Multiframe

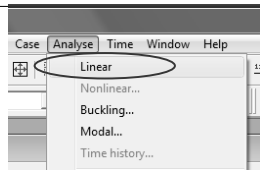
- *frame window*
  - *define beam member*
  - *select points, assign supports*
  - *select members, assign section*
- *load window*
  - *select point or member, add point or distributed loads*

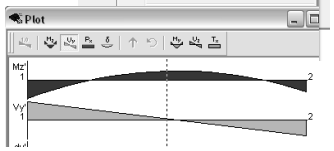


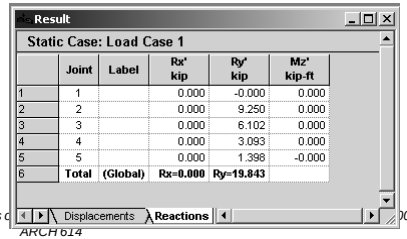


Tools – Multiframe

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







	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	