elements of architectural structures:
form, behavior, and design
arch 614
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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

• tension and compression
  – causes moments

Beam Stresses

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

- shear – horizontal & vertical

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**Beam Stresses**

- shear – horizontal & vertical

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**Beam Stresses**

- shear – horizontal

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**Beam Deflections**

- depends on
  - load
  - section
  - material

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Figure 5.4  Bending (flexural) leads via a beam.
Beam Deflections

- “moment of inertia”

Internal Beam Forces

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 = \( \gamma h \)
  - wind loads

**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

**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

R

M
**V & M Diagrams**
- tool to locate $V_{\text{max}}$ and $M_{\text{max}}$
- necessary for designing
- $M_{\text{max}}$ 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**

- bending moment, $M$:
  - cut section to LEFT
  - if $\sum M_{\text{cut}}$ 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.
  - Compression
  - Tension

- **(−)** Moment.
  - Tension
  - Compression

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

![Diagram of internal beam forces](image)

**Basic Procedure**

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

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**Equilibrium Method**

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

**Equilibrium Method**

- relationships

![Diagram of equilibrium method](image)

**Basic Procedure**

1. Find reaction forces & moments
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)

$$\text{load}$$

$$\text{height} = V_A$$

$$w \ (\text{force/length})$$

$$x \cdot w = V_A \Rightarrow x = \frac{V_A}{w}$$

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

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**Tools – Multiframe**

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