ARCHITECTURAL STRUCTURES:
FORM, BEHAVIOR, AND DESIGN
ARCH 331
DR. ANNE NICHOLS
FALL 2013

lecture
one

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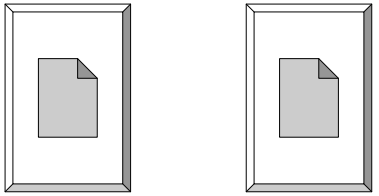
# structural behavior and design



## Syllabus & Student Understandings





## Course Description

- *statics*
  - *physics of forces and reactions on bodies and systems*
  - *equilibrium (bodies at rest)*
- *structures*
  - *something made up of interdependent parts in a definite pattern of organization*
- *design*
  - *assessing and meeting structural requirements of parts and the whole*



## Course Description

- *mechanics of materials*
  - *external loads and effect on deformable bodies*
  - *use it to answer question if structure meets requirements of*
    - *stability and equilibrium*
    - *strength and stiffness*
  - *other principle building requirements*
    - *economy, functionality and aesthetics*

## Structure Requirements

- *stability & equilibrium*
  - *STATICS*

*Figure 1.16* Equilibrium and Stability?—*sculpture by Richard Byer. Photo by author.*



## Structure Requirements (cont)

- *strength & stiffness*
  - *concerned with stability of components*

*Figure 1.15 Stability and the strength of a structure—the collapse of a portion of the UW Husky stadium during construction (1987) due to a lack of adequate bracing to ensure stability. Photo by author.*



## Structural System Selection

- *kind & size of loads*
- *building function*
- *soil & topology of site*
- *systems integration*
- *fire rating*
- *construction ($$, schedule)*
- *architectural form*



## Knowledge Required

- *external forces*
- *internal forces*
- *material properties*
- *member cross sections*

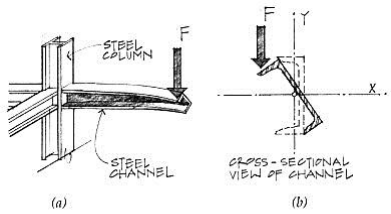
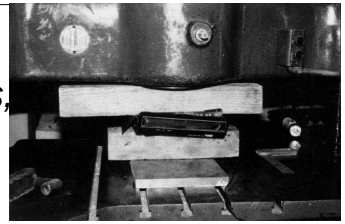



*Figure 2.34 An example of torsion on a cantilever beam.*

- *ability of a material to resist breaking*
- *structural elements that resist excessive*
  - *deflection*
  - *deformation*

## Problem Solving



1. *STATICS:*

   *equilibrium of external forces, internal forces, stresses*

2. *GEOMETRY:*

   *cross section properties, deformations and conditions of geometric fit, strains*

3. *MATERIAL PROPERTIES:*

   *stress-strain relationship for each material obtained from testing*



## Relation to Architecture

*"The geometry and arrangement of the load-bearing members, the use of materials, and the crafting of joints all represent opportunities for buildings to express themselves. The best buildings are not designed by architects who after resolving the formal and spatial issues, simply ask the structural engineer to make sure it doesn't fall down."* -Onouye & Kane
Statics and Strength of Materials for Architecture and Building Construction



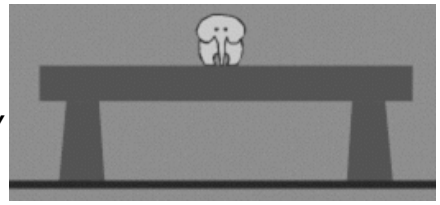
## Architectural Space and Form

- *evolution traced to developments in structural engineering and material technology*
  - *stone & masonry*
  - *timber*
  - *concrete*
  - *cast iron, steel*
  - *tensile fabrics, pneumatic structures.....*



## Architectural Space and Form

- *structure is a device for channeling loads that result from the use and/or presence of the building to the ground*
  - *span a roof*
  - *hold up a floor*
  - *cross a river*
  - *suspend a canopy*



www.pbs.org/wgbh/buildingbig/

## Stone + Masonry

- columns
- walls
- lintels
- beams
- arches
- footings



## Wood

- columns
- beams
- trusses



## Steel

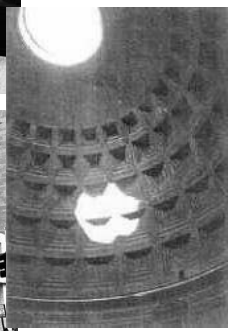
- cast iron – wrought iron - steel
- cables
- columns
- beams
- trusses
- frames


http:// nisee.berkeley.edu/godden



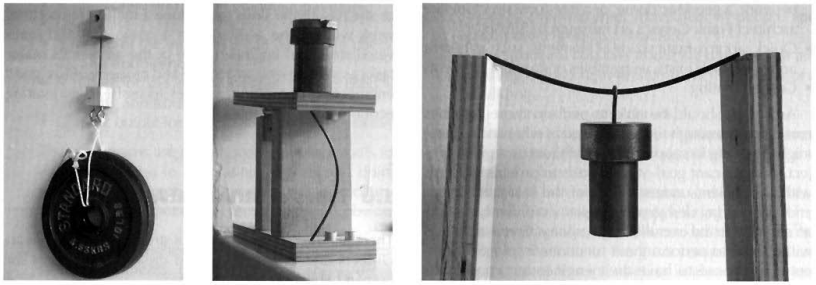
## Concrete

- columns
- beams
- slabs
- domes
- footings



## Structural Action

- *axial tension*
- *axial compression*
- *bending*



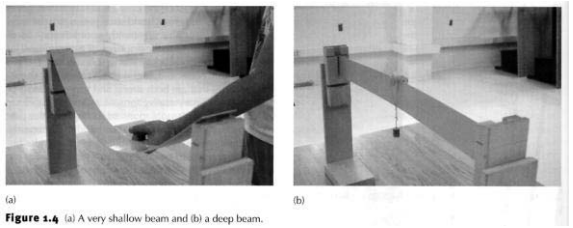
(a) (b) (c)

**Figure 1.2** (a) Axial tension, (b) axial compression, and (c) bending.



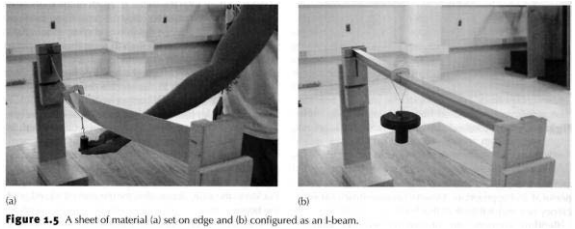
## Structural Action

- *member breadth & depth*



(a) (b)

**Figure 1.4** (a) A very shallow beam and (b) a deep beam.



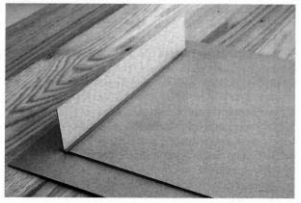
(a) (b)

**Figure 1.5** A sheet of material (a) set on edge and (b) configured as an I-beam.

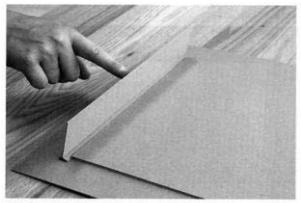


## Structural Action

- *stabilization*

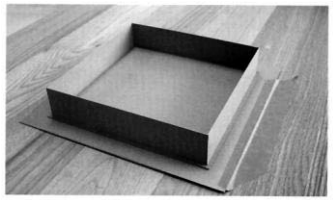


(a)

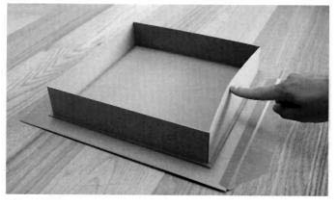


(b)

**Figure 1.8** (a) A thin wall (b) subjected to lateral force.



(a)



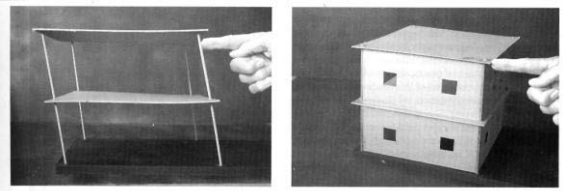
(b)

**Figure 1.9** (a, b) Walls stabilizing each other at the ends.



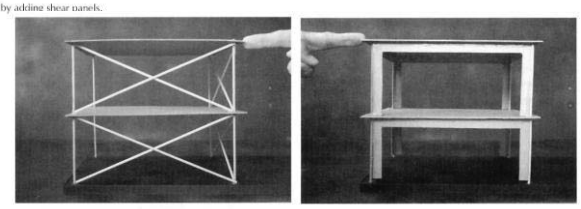
## Structural Action

- *shear & bracing*



(a) (b)

**Figure 1.29** (a, b) Structural frame stabilized by adding shear panels.



(a) (b)

**Figure 1.30** Bracing with (a) triangulation and (b) a rigid frame.

## Structural Action

- *lateral resistance*

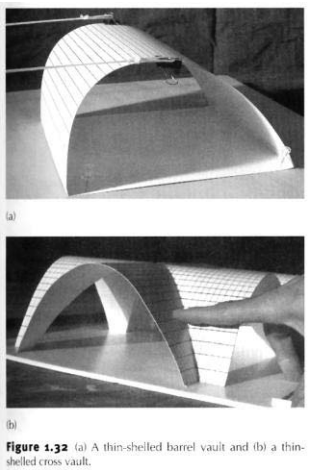


**Figure 1.32** (a) A thin-shelled barrel vault and (b) a thin-shelled cross vault.

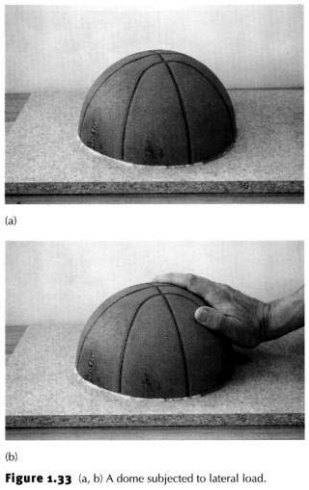


**Figure 1.33** (a, b) A dome subjected to lateral load.



## Structural Action

- *twisting*

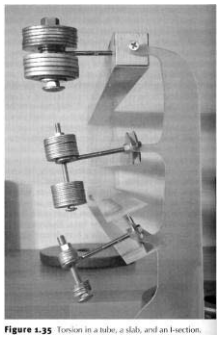
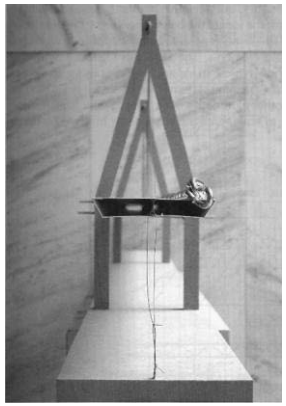
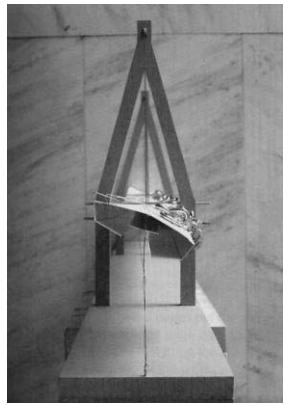


**Figure 1.35** Torsion in a tube, a slab, and an I-section.







## Structural Design

- *planning*
- *preliminary structural configuration*
- *<u>determination of loads</u>*
- *preliminary member selection*
- *analysis*
- *evaluation*
- *design revision*
- *final design*




## Structural Loads

- *STATIC and DYNAMIC*
- *dead load*
  - *static, fixed, includes building weight, fixed equipment*
- *live load*
  - *transient and moving loads (including occupants), snowfall*

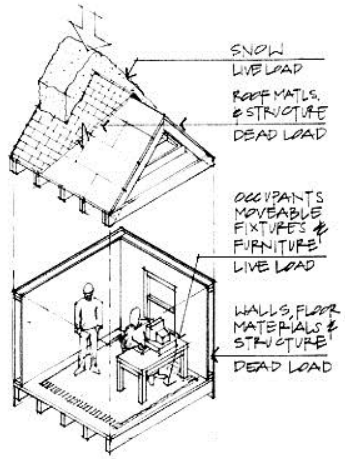



*Figure 1.12 Typical building loads.*

## Structural Loads

- *wind loads*
  - *dynamic, wind pressures treated as lateral static loads on walls, up or down loads on roofs*

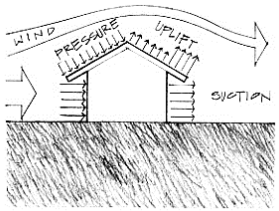
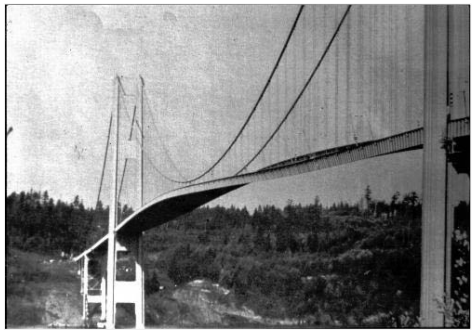



Figure 1.13 Wind loads on a structure.





## Structural Loads

- *earthquake loads*
  - *seismic, movement of ground* ↕ ↔

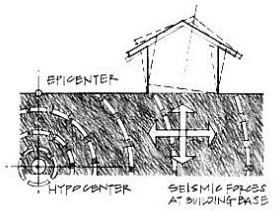
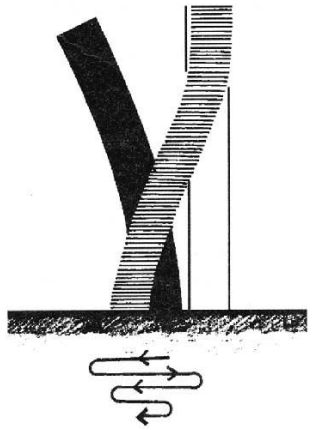


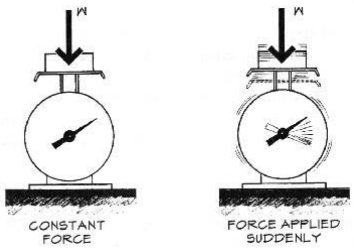

Figure 1.14 Earthquake loads on a structure.

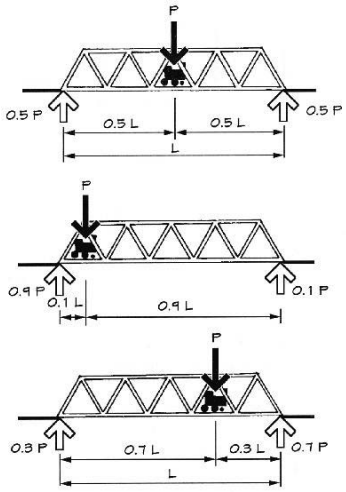




## Structural Loads

- *impact loads*
  - *rapid, energy loads*

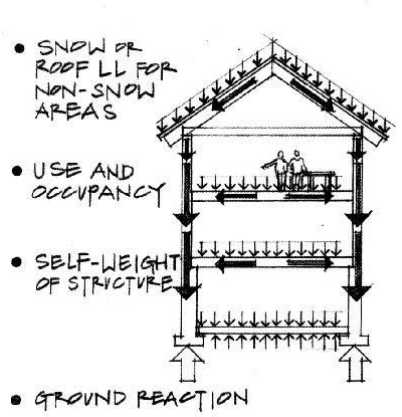





## Structural Loads

- *gravity acts on mass (F=m*g)*
- *force of mass*
  - *acts at a point*
    - *ie. joist on beam*
  - *acts along a "line"*
    - *ie. floor on a beam*
  - *acts over an area*
    - *ie. people, books, snow on roof or floor*



## *Structural Math*

- *quantify environmental loads*
  - *– how big is it?*
- *evaluate geometry and angles*
  - *– where is it?*
  - *– what is the scale?*
  - *– what is the size in a particular direction?*
- *quantify what happens in the structure*
  - *– how big are the internal forces?*
  - *– how big should the beam be?*



## *Structural Math*

- *physics takes observable phenomena and relates the measurement with rules: <u>mathematical relationships</u>*
- *need*
  - *– reference frame*
  - *– measure of length, mass, time, direction, velocity, acceleration, work, heat, electricity, light*
  - *– calculations & geometry*