ARCHITECTURAL STRUCTURES: FORM, BEHAVIOR, AND DESIGN

ARCH 331

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lecture one

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
• ability of a material to resist breaking
• structural elements that resist excessive
  – deflection
  – deformation

Figure 2.34  An example of torsion on a cantilever beam.
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
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

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

• *member breadth & depth*

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

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

- stabilization

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

Figure 1.9 (a) Walls stabilizing each other at the ends.
Structural Action

• shear & bracing

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

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

- lateral resistance
Structural Action

• twisting
Structural Design

- planning
- preliminary structural configuration
- determination of loads
- 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
Structural Loads

- wind loads
  - dynamic, wind pressures treated as lateral static loads on walls, up or down loads on roofs
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 \((F=m\times g)\)
- 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: mathematical relationships
- need
  - reference frame
  - measure of length, mass, time, direction, velocity, acceleration, work, heat, electricity, light
  - calculations & geometry