Elements of Architectural Structures: Form, Behavior, and Design

Arch & Shell Systems
- curved, thin surface or 2D structures
- see very little bending stresses
- design for
  - axial stresses
  - shear stresses
- efficient because of uniformly distributed loads

Arches
- behavior
  - stabilization
  - resist thrust
- compression only

Office Hours

link to posted schedule
http://faculty.arch.tamu.edu/anichols/schedule/
Shell Types

- **shape classifications**
  - developable:
    - revolution (vault)
  - synclastic
    - doubly curved
    - same direction
  - anticlastic:
    - doubly curved
    - opposite curvature
  - free form

Vaults

- “wide” arch

Vaulted Shells

- can resist tension
- shape adds “depth”

Kimball Museum, Kahn 1972
**Kimball Museum, Kahn 1972**

- outer shell edges

![Outer shell edges diagram](image1.png)

**Kimball Museum, Kahn 1972**

- skylights at peak

![Skylights at peak](image2.png)

**Domes**

- arch of revolution
- compression
- some tension

![Domes diagram](image3.png)

**Domes**

- stresses and displacements

![Domes stresses and displacements](image4.png)
Annunciation Greek Orthodox Church

- Wright, 1956

Anticlastic Shells

- saddle or “ruled” shapes
- surface generated with straight lines
- tension follows “cable drape”
- compression follows “arch”

Zarzuela Hippodrome, Torroja 1935
Zarzuela Hippodrome, Torroja 1935

- tie-down prevents cantilever from sloping forward
- uplift of tie-down helps support floor and canopy
- shell collects roof load and transfers it to column

Folded Plates

- increased stiffness with folding

State Farm Center, Harrison & Abramovitz 1963

- State Farm Center (Assembly Hall), University of Illinois
- Harrison & Abramovitz 1963
- Edge-supported dome spanning 400 feet wound with 614 miles of one-fifth inch steel wire

Systems

- total of components
- behavior of whole
- classifications
  - one-way
  - two-way
  - tubes
  - braced
  - unbraced
One-Way Systems
• horizontal vs. vertical

Two-Way Systems
• spanning system less obvious
• horizontal
  – plates
  – slabs
  – space frames
• vertical
  – columns
  – walls

System Selection
• evaluation of alternatives
Structural Design Criteria

- components stay together
- structure acts as whole to be stable
  - resist sliding
  - resist overturning
  - resist twisting and distortion
- internal stability
  - interconnectedness
- strength & stiffness

Structural Design Sequences

- first-order design
  - structural type and organization
  - design intent
  - contextual or programmatic
- second-order
  - structural strategies
  - material choice
  - structural systems
- third-order
  - member shaping & sizing

Design Issues

- lateral stability – all directions

Design Issues

- configuration
Design Issues

• vertical load resistance

walls  columns

Design Issues

• lateral load resistance

Design Issues

• lateral load resistance

• multi-story
  – cores, tubes, braced frames
**Design Issues**

- multi-story
  - avoid discontinuities
    - vertically
    - horizontally

**Final Exam Material**

- my list:
  - equilibrium - $\Sigma F$ & $\Sigma M$
    - supports, trusses, cables, beams, pinned frames, rigid frames
  - materials
    - strain & stress (E), temperature, constraints
  - beams
    - distributed loads, tributary width, V&M, stresses, design, section properties (I & S), pitch, deflection

**Final Exam Material**

- my list (continued):
  - columns
    - stresses, design, section properties (I & r)
  - frames
    - $P$, $V$ & $M$, $P-\Delta$, effective length with joint stiffness, connection design, tension member design
  - foundations
    - types
    - sizing & structural design
    - overturning and sliding
  - systems
    - levels
    - design considerations
  - design specifics
    - steel (ASD & LRFD)
    - concrete
    - wood
    - masonry