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

Office Hours

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

Arches

- behavior
  - stabilization
  - resist thrust
- compression only

Milenium Bridge in Newcastle, UK
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

http://nisee.berkeley.edu/godden
Kimball Museum, Kahn 1972

- outer shell edges

Domes

- arch of revolution
- compression
- some tension

Kimball Museum, Kahn 1972

- skylights at peak

Domes

- stresses and displacements
Annunciation Greek Orthodox Church

- Wright, 1956

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

http://www.bluffton.edu
Zarzuela Hippodrome, Torroja 1935

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**

  - Shear walls may be arranged in a two-form to resist lateral forces from all directions.

  - When combined with other stabilizing mechanisms, shear walls may be arranged so as to resist forces in only one direction of a building.

**Design Issues**

- **lateral load resistance**

**Design Issues**

- **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 (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

Final Exam Material (continued):

- systems
  - levels
  - design considerations

- design specifics
  - steel (ASD & LRFD)
  - concrete
  - wood
  - masonry