Structural Organization

- classifications
  - geometry
    - line-forming
    - surface-forming
  - stiffness
    - rigid
    - flexible
  - one-way or two-way
    - spatial organization and load transfer
  - materials

Structural Components

- bearing walls
- columns
- beams
- flat plates
- trusses
- arches
- shells
- cables

Bearing Walls
Bearing Walls

• behavior as “deep beams”

Columns & Walls

Beams & Plates

(a)

(b)

shorter

longer

shorter

longer

(a)

(b)
Trusses and Shells

- (c) Pitched Pratt truss
- (d) Pitched Howe truss

Arches and Cables

- (c) Uniform loads (horizontally) — parabolic.
- (d) Uniform loads (along the cable length) — catenary.

Building Framing

- Components or Assemblages

- One-level system
- Two-level system
- Three-level system

- Load-bearing walls
- Columns

- (a) Common types of horizontal spanning systems (one, two, and three level systems) used in relation to different types of load-bearing wall and columnar vertical support systems.

- Roofloads
  - Horizontal spanning system
  - Lateral support system

- Truss reactions cause compressive forces to develop in columns.
- Column reactions become forces on foundations (which distribute the forces into the earth).
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
Systems by Materials

- Wood
- Steel
- Concrete
- Masonry
- Composite

Timber Construction

- all-wood framing systems
  - studs, beams, floor diaphragms, shearwalls
  - glulam arches & frames
  - post & beams
  - trusses
- composite construction
  - masonry shear walls
  - concrete
  - steel

Timber Construction

- studs, beams
- floor diaphragms & shear walls

Timber Construction

- glulam arches & frames
  - manufactured or custom shapes
  - glue laminated
  - bigger members
**Timber Construction**

- post & beam
- trusses

**Steel**

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

**Steel Construction**

- standard rolled shapes
- open web joists
- plate girders
- decking

http://nisee.berkeley.edu/godden
**Steel Construction**
- welding
- bolts

**Concrete**
- columns
- beams
- slabs
- domes
- footings

**Concrete Construction**
- cast-in-place
- tilt-up
- prestressing
- post-tensioning

**Steel Construction**
- fire proofing
  - cementicious spray
  - encasement in gypsum
  - intumescent – expands with heat
  - sprinkler system
Concrete Floor Systems

- types & spanning direction

Masonry

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

Grids and Patterns

- often adopted early in design
  - give order
  - cellular, ex.
- vertical and horizontal
- square and rectangular
  - single-cell
  - aggregated bays
**Grids and Patterns**

**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
Two-Way Systems

- Flat-plate system
- Flat-slab system
- Two-way beams and slab system

Roof Shapes

- Coincide
- Within

Tubes & Cores

- Stiffness

Span Lengths

- Crucial in selection of system
- Maximum spans on charts aren’t absolute limits, but usual maximums
- Increase L, increase depth^2 required (ex. cantilever)
- Deflections depend on L
Approximate Depths

Loading Type and Structure Type

- light uniform loads
  - surface forming elements
  - those that pick up first load dictate spacing of other elements
- heavy concentrated loads
  - member design unique
- distributed vs. concentrated structural strategies
  - large beam vs. many smaller ones

Design Issues

- lateral stability – all directions

- configuration
Design Issues

• vertical load resistance

  - Walls
  - Columns

Design Issues

• lateral load resistance

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

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

Design Issues

• lateral load resistance

  - Rigid frame structures require no additional bracing or shear walls, as shown in this elevation and plan.

  - The locations of braced frames or shear walls must be considered in relation to the elevation and plan of the building.

Design Issues

• multi-story
  - cores, tubes, braced frames

  - Shear walls are commonly used with columns and slab systems. In this elevation and plan, the shear walls are shown incorporated into a pair of rectangular cores.

  - Shear walls can be used with other stability mechanisms, such as columns and slabs.
Design Issues

• multi-story
  – avoid discontinuities
    • vertically
    • horizontally

Foundation Influence

• type may dictate fit
  – piles vs. mats vs. spread
  – capacity of soil to sustain loads
    • high capacity – smaller area of bearing needing and can spread out
    • low capacity – multiple contacts and big distribution areas

Grid Dependency on Floor Height

• wide grid = deep beams
  – increased building height
  – heavier
  – foundation design
• codes and zoning may limit
• utilize depth for mechanical

Large Spaces

• ex. auditoriums, gyms, ballrooms
• choices
  – separate two systems completely and connect along edges
  – embed in finer grid
  – staggered truss
Meeting of Grids

• common to use more than one grid
• intersection important structurally
• can use different structural materials
  – need to understand their properties
    • mechanical
    • thermal

Meeting of Grids

• horizontal choices

Other Conditions

• circulation
• building service systems
  – one-way systems have space for parallel runs
  – trusses allow for transverse penetration
  – pass beneath or interstitial floors
    • for complex or extensive services or flexibility
Other Conditions

• poking holes for member services
  – horizontal
    • need to consider area removed, where removed, and importance to shear or bending
  – vertical
    • requires framing at edges
    • can cluster openings to eliminate a bay
  – double systems

Fire Safety & Structures

• fire safety requirements can impact structural selection
• construction types
  – light
    • residential
    • wood-frame or unprotected metal
  – medium
    • masonry
  – heavy
    • protected steel or reinforced concrete

Fire Safety & Structures

• degree of occupancy hazards
• building heights
• maximum floor areas between fire wall divisions
  – can impact load bearing wall location

Fire Safety & Structures

• resistance ratings by failure type
  – transmission failure
    • fire or gasses move
  – structural failure
    • high temperatures reduce strength
    – failure when subjected to water spray
      • necessary strength
  • ratings do not pertain to usefulness of structure after a fire