Structural Systems, Planning and Design

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

- shorter
- longer
Trusses and Shells

- Pitched Pratt truss
- Pitched Howe truss

Arches and Cables

- Uniform loads (horizontally) — parabola.
- Uniform loads (along the cable length) — catenary.

Building Framing

- Components or Assemblages

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

  (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.
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 Construction

- composite construction

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

Steel Construction

- fire proofing
  - cementicious spray
  - encasement in gypsum
  - intumescent – expands with heat
  - sprinkler system

Concrete

- columns
- beams
- slabs
- domes
- footings

Concrete Construction

- cast-in-place
- tilt-up
- prestressing
- post-tensioning
Concrete Floor Systems

- types & spanning direction

![Concrete Floor Systems Diagram](image1)

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

- (a) Flat plate system
- (b) Flat plate system
- (c) Two-way framed system
- (d) Two-way framed system
- (e) Two-way ribbed slab system
- (f) Two-way ribbed 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 depth² 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

**Design Issues**

- configuration
Design Issues

• vertical load resistance

walls

• lateral load resistance

columns

Design Issues

• lateral load resistance

Design Issues

• multi-story
  – cores, tubes, braced frames
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

Meeting of Grids

• vertical 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