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”
Trusses and Shells

- Pitched Pratt truss
- Pitched Howe truss

Arches and Cables

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

Building Framing

**Components or Assemblages**

- One-level system
- Two-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 column vertical support systems.

Building Framing

- Horizontal spanning system
- Decking carries roof loads by bending.
- Decking reactions become forces on beams which carry loads by bending.
- Beam reactions become forces on trusses.
- 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

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**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

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**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

**Timber Construction**
- composite construction

**Steel Construction**
- standard rolled shapes
- open web joists
- plate girders
- decking

[Images of timber construction projects and steel structures are shown to illustrate the points.]
Steel Construction

- welding
- bolts

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](image)

Masonry

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

![Masonry Examples](image)

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 Diagram](image)
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 beam and slab system
- Two-way ribbed system with surrounding beams
- Two-way long-span beam and slab system

Tubes & Cores

- Stiffness
- Overturning moment
- Resisting moment
- Suspended structure, reinforced concrete core
- Tube structure, the exterior columns are closely spaced. Horizontal precast beams are rigidly connected to columns to form an exterior type, vertical parapet, and interior beam and column gravity forces. Interior columns carry only vertical forces.

Roof Shapes

- Coincide
- Within

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

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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

Stabilizing elements may be placed within the interior or at the perimeter of a structure.

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

Stabilizing elements should be arranged in a balanced fashion.

The locations of beam spans or shear walls must be considered in relation to the elevation and plan of the building.
Design Issues

• vertical load resistance

walls

Design Issues

• 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

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