**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**

- total of components
- behavior of whole
- classifications
  - one-way
  - two-way
  - tubes
  - braced
  - unbraced

**Systems & Spans**
Systems & Spans

Span Lengths
- crucial in selection of system
- maximum spans on charts aren't absolute limits, but usual maximums
- increase L, increase $d^2$ required (ex. cantilever)
- deflections depend on L

Moments in Members

Spans
- long-span structures
  - over 60’ or 20 m
  - depths are large compared to span
  - usually shaped
    - trusses, arches, cables, nets, pneumatics & shells
    - common for roofs
    - camber
    - flat systems not as efficient
    - deflections can govern size
Spans

- intermediate- and low-span systems
  - 15’ – 40’ or 5 – 15 m
  - more common
  - good for planar surfaces
  - lots of options
  - cost usually dictates

Moving Supports

- location of supports can redistributed the moments
  - reduced section size
- using cantilevers & continuous beams
  - rule of thumb for simple supported beam
    - move L/5 in both ends
    - move L/3 one end

Support Density

- concentrated structure
  - fewer columns
  - few large beams
- distributed structure
  - many columns
  - more smaller beams
- efficiency vs. character of interior space
- loads

Foundation Influence

- type may dictate density
  - 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
**One-Way Systems**

- horizontal vs. vertical

**Two-Way Systems**

- spanning system less obvious
- horizontal
  - plates
  - slabs
  - space frames
- vertical
  - columns
  - walls

**Square Bays**

- two-way systems rely on square-ness
  - peripheral wall system or columns
  - columns extending 2 ways common
  - for low & intermediate span ranges
- one-way systems *can* be used
  - don’t have 4 walls
  - columns extending 1 way only
Rectangular Bays
• 1:1 to 1:1.5
• direction of joists & beams not obvious
  – run comparison for material amounts
• generally:
  – with no collectors, span the short way
    • lightweight joists or trusses
  – with collectors, try the short way
    • same tributary load over shorter span

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

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Grid Dependency on Floor Height
• wide grid = deep beams
  – increased building height
  – heavier
  – foundation design
• codes and zoning may limit
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Non-Uniform Grids

- irregular column placement
  - concrete & flat slabs adaptable
- long spans
  - complex
  - increased story heights

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

Corners

- terminate system & change
- transition, rotation, or two-way system
- depends on vertical elements
- prefer constant member sizes AND spacings with steel & wood
- can use cast-in-place concrete
Meeting of Grids

- vertical choices

![Grid diagrams](image)

Large Spaces

- ex. auditoriums, gyms, ballrooms
- choices
  - embed in finer grid
    - high up, less load transfer
    - low – more load transfer & heavy girders or deep truss
  - staggered truss

Case

- grid
- system orientation
  - one-way or two?
- span lengths
- support strategy
  - concentrated vs. distributed

Case

- Engineering Design & Research Center

![Case study image](image)
Case

- grid

Case

- system?

Case

- span lengths
  - 30-40 m (100 - 130 ft)
  - 15-20 m (50 – 65 ft)

Case

- pre-stressing & loading type
Design Issues

- **critical programmatic dimensions**
  - minimum clear spans for functional areas
    - determines selection of beam, or roof/ floor systems
  - vertical support elements
    - match clear span or greater

Spatial Implications

- **one-directional or linear space**
  - load bearing walls
  - beams & columns
    - column shape & orientation
  - long spans
- **two-way, relatively neutral space**
  - flat plate
  - beams & slabs
  - space frames
**Roof Shapes**

- coincide
- within

**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

[http://www.nfpa.org](http://www.nfpa.org)
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