Grids and Patterns

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

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

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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
Roof Shapes
- coincide
- within

Systems & Spans
- 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 $L$

Span Lengths

$W = \frac{f_{b_{-max}} \cdot W L}{(bd)^{2/6}}$
Moments in Members

<table>
<thead>
<tr>
<th>Structure</th>
<th>Basic Moment-carrying Mechanism</th>
<th>Free-body Diagrams with Respect to Rotational Forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truss</td>
<td>![Truss Diagram]</td>
<td>![Rotational Forces Diagram]</td>
</tr>
<tr>
<td>Cable</td>
<td>![Cable Diagram]</td>
<td>![Rotational Forces Diagram]</td>
</tr>
<tr>
<td>Beam</td>
<td>![Beam Diagram]</td>
<td>![Rotational Forces Diagram]</td>
</tr>
</tbody>
</table>

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

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

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
Case

• grid
• system orientation
  – one-way or two?
• span lengths
• loading type
  – concentrated vs. distributed
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
Design Issues

• degree of fit
  – single (1:1)
  – multiple (2:1, etc.)
  – any number of patterns possible
  – simple patterns generally more “elegant”

• one-on-one fit
  – good for large spans
  – material selection influences short span fit
    • steel & concrete for “looser” fits

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

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

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

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

Slipped Units

• usually one-way systems
• bearing walls allow unlimited slip
• columns allow slip by
  – column to column distance
  – columns can shift

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
Non-Uniform Grids

• irregular column placement
  – concrete & flat slabs adaptable
• regular vertical supports required for most long span systems

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
    • high up, less load transfer
    • low – more load transfer & heavy girders
  – 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

- 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

- 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