Applied Architectural Structures: Structural Analysis and Systems

ARCH 631

Dr. Anne Nichols

Fall 2015

Lecture Fourteen

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

Total of components

Behavior of whole

Classifications

- one-way
- two-way
- tubes
- braced
- unbraced

Structural Components

Timber
- Bolts
- L-shaped beams
- Box beams

Concrete
- Slabs
- Beams
- Panel pistes
- Precast planks
- Precast columns
- Precast cores

Steel
- decking
- Web stiffeners
- Plate girders

Folded plates

Timber
- Plywood
- Panel-in-place

Concrete
- Panel-in-place

Caesar Beegle
**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

\[
f_{b_{\text{max}}} = \frac{WL}{bd^2/6}
\]

**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 beams
    - 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

**Grids and Patterns**

- Grid Dependency on Floor Height
  - wide grid = deep beams
    - increased building height
    - heavier
    - foundation design
  - codes and zoning may limit
  - utilize depth for mechanical
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

![Diagram of meeting grids]

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

![Diagram of large spaces]

Case

- grid
  - system orientation
    - one-way or two?

- span lengths

- support strategy
  - concentrated vs. distributed

![Image of a building grid]

Case

- Engineering Design & Research Center

![Image of Engineering Design & Research Center]
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

- **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

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
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