

ARCH 631. Topic 14 Reading Notes

- Process of designing a structure is *implicitly* linked to process of designing the building
- Stage at which structural considerations enters design process varies with interest and role of structural elements in design philosophy of architect & engineer and structural challenges
- Structural issues on the conceptual design stage more manageable
- Loading type, span, and patterns of supports inform the selection and design of overall system
- Span length is very influential to system selection; approximate span ranges of different system chart presented represents usual possible minimum and maximums
- Key principal of span lengths is that the bending moment increase is squared for every increase in span length (meaning a significant increase in depth required based on stress); deflection becomes a significant issue at long spans as well; shaped structures increase the depth
- Choices for long span structures are shaped – trusses, arches, cables, nets, pneumatics and shells (beams are *not* efficient) and typically used for roofs because of planar need for floors
- More choices for intermediate and low spans (15 to roughly 80 ft) in one-way or two-way systems; economics require cost analysis; lightest or most easy to construct usually chosen
- Trusses versatile for low, intermediate and long spans; open web joists typically closely spaced while long spans trusses placed far apart
- Manipulation of support locations can lead to improved structural efficiency (reducing bending moments) (choice of pattern can contribute to efficiency); adding overhangs is the method for beams and trusses; principle also applies to continuous beams and frames
- 1/5L Rule: move both simple supports in by approximately 1/5 of the span and the positive and negative moments become equal (and reduced from $wl^2/8$)
- 1/3L Rule: move one end support in by approximately 1/3 of the span and the positive and negative moments become equal (and reduced from $wl^2/8$)
- Concentrated structure is characterized by designing a few very large members to carry the load (coarse grid with number and spacing of supports)
- Distributed structure is characterized by designing a greater number of relatively smaller elements (dense grid with number and spacing of supports)
- Choice of concentrated vs. distributed structure is not obvious; load types help determine and economy; for beam systems it is common to assume fewer bigger members and more smaller members; soil and foundation can be influential in decision because of load transfer
- One-way systems (horizontal and often hierarchical):
 - two levels can span farther than one, typically
 - 2nd level considered “collectors”
 - three levels is usual max
 - long spans dictate columns
 - short spans or narrowly spaced collectors, bearing walls or pilasters system possible
 - tend to be used with smaller spans and depths when compared with multilevel systems
 - spacing of level elements commonly standard (like spans of sheet metal decking)

truss nodes dictate where supported elements go
 use of curved beams is *rare* because of the problems and design issues (bi-axial bending, twisting)

- Two-way systems (horizontal)
 - use of plates or slabs
 - nearly square support system usual
 - flat, edge supported, waffle, grid (reinforced concrete)
 - space truss system (usually steel)
 - vertical support can be walls or columns
 - supporting space frames on columns is inefficient, but commonly done
- Patterns for grids include
 - single-cells or aggregated bays
 - orthogonal
 - serial (same unit size)
 - square (usually preferred because of efficiency for two-way systems)
 - rectangular (or elongated); aspect ratios no bigger than 1:1.5 for one-way action
 - not obvious which way to run light elements and collectors (volume and depth calculations need to be done)
 - common to span light members the short direction and the collectors long with “off-the-shelf items”
 - triangulated
 - offsetting parallel gridlines
 - radial & circular
- Grid spacing effects story and building height because of beam depths; prestressing helps reduce concrete member depths; bigger the grid, the heavier the structure; choice needs to be made early
- Irregular vertical support system makes effective or economical use of systems very difficult; site cast concrete is usual; larger spans can be in steel or timber but are complex; long spans might mean story-high beam depths
- Grids commonly change throughout a structure; intersection of grids is a design issue with unique treatment
- Strategies for horizontal grid intersections:
 - random
 - patterns align (coarser to larger)
 - mediating space (separation)
 - third structural system between them (or material)
 - interpenetration (looks like overlap)
- Corners:
 - the pattern may or may not lead to obvious solution at corners
 - grid can turn at corners
 - grid can continue
 - grid can transition
 - corner can “bend” (difficult at large spans)

- Strategies for vertical grid intersections:
 - vertical support points common to both systems
 - shift of grids means a transitional layer to merge load path (transfer beams, deep trusses, etc.)
 - separate vertical supports (bypassing – rare)
- Large spaces: (putting big grain into smaller grain) embed above or below;
 - below implies large transfer members or using long spans which isn't economical
 - above so can carry roof loads only is functionally difficult
- Critical programmatic dimensions are those that define the minimum clear span for a structural system based on function necessities or anything else; vertical elements can't be placed any closer together than this
- Degree of fit is how closely the structural system matches the critical programmatic dimensions (1:1 or other "looser" ratios which are multiples); many options exist; simplest is usually the most elegant; foundation can influence fine vs. rough grain/grid; one-on-one preferable for large spans and timber; "looser" fits for steel and concrete
- Spaces formed by one direction or linear elements have a strong planar quality; shape, spacing and orientation of the columns significantly influence the space characteristics:
 - rectangular columns emphasize linearity
 - circular columns are neutral
 - square columns are bidirectional
- Spaces formed by two way systems are two-directional with neutral spaces
- Shaping members gives spatial expression; single vs. multilayer horizontal spans give sense of scale; non-orthogonality can be "dynamic"
- Roof shape dictates a variety of forms, either volumetrically (within) or surface (coincidental); change in roof profile indicates a change in the framing system at that point
- Accommodating horizontal building services:
 - transverse to one-way system the provides space for parallel runs
 - trusses best
 - holes can be carefully made (especially if very few holes are needed)
 - pass beneath the primary structural system (increases building height)
 - doubled system
- Accommodating vertical building services:
 - minor penetrations are not very difficult
 - major penetrations require edge/local framing
 - eliminate whole bay of two-way system (cluster penetrations)
 - double system
- Fire requirements may influence structural system selection; high hazard occupancies require substantial fire-resistant construction; high structures have a greater degree of inherent fire safety
- Code classifications:
 - light – typically wood frame or unprotected metal framing
 - medium – generally masonry walls as load bearing elements
 - heavy – typically made of reinforced concrete or protected steel framing
- Codes limit the maximum floor area allowed between specially designed fire division walls which separate the building into compartments and restrain the spread of a fire (often load bearing walls)

- Want to prevent local damage from an event such as a blast to lead to a progressive collapse by keeping blast away from the structure with barriers; can place columns close together to reduce loads on them; avoid too many collectors on load transfer elements; provide tension ties and cables
- Planning weaknesses of architects as observed by a structural engineering consultant:
 - building stability and lateral bracing
 - error of relying on the core as only bracing; width of core is effective structural depth of building; slender building can twist (inadequate stiffness)
 - error of lateral bracing only at exterior wall corner bays; worst location because of light loads with no gravity loading to offset overturning uplift
 - structural frame vertical organization
 - error of discontinuities; typically manifested as transfer girders or story-deep trusses
 - tolerance between the structural frame and the architectural finish
 - neglected completely; actual depth of steel column can be up to 2 inches larger than nominal dimension; splicing plates, connections, bolts and base plates sick out!
 - site considerations
 - localities may have special consideration and requirement that the architect should be aware of (like tornadoes); should be aware of constraints of the site or subgrade conditions because of influence on appropriate footing design
 - floor vibrations
 - strength is not always the primary design concern and stiffness may govern; when stiffness isn't considered, the depths are inadequate
- Recommended teaching of these areas is to explore case study and successful design