

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