ARCH 631. Topic 14 Reading Notes

- Process of designing a structure is *implicitly* linked to process of designing the building
- During early stages the designer often adopts a pattern or develops reasons for a pattern; advantages of some structural patterns are considered
- Loading type, span, and patterns of supports inform the selection and design of overall system
- Patterns for grids include
    - single-cells
    - aggregated bays
        - serial
        - square
        - rectangular
        - surface/irregular columns
- One-way systems (horizontal and often hierarchical):
    - two levels can span farther than one, typically
        - 2^{nd} level considered “collectors”
    - three levels is usual max
    - long spans dictate columns
    - short spans or narrowly spaced collectors, bearing walls or pilasters system possible
    - 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
- 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
- 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 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
- Low spans of 15-30 have lots of economical choices; from 50-60ft flat two-way concrete systems are not as viable as one-way systems; from 80-100ft one-way systems are used
- Surface forming structures made up of closely spaced similar elements or mass-produced components are useful for light, uniformly distributed loads; optimizing the smallest elements (like steel decking) usually determines the joist spacing
- Surface forming structures are usually not appropriate with large concentrated loads, and are usually supported with one-way elements that are custom built (like plate girders)
- Concentrated structure is characterized by designing a few very large members to carry the load
- Distributed structure is characterized by designing a greater number of relatively smaller elements
- 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
- 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 that 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
- Square bays:
  - good for two-way systems and need a grid of square vertical support are necessary
  - does not mean that two-way systems always preferable
  - if directionality of vertical system can go both ways, two-way action is best
  - if long span, then one-way system better (but not encountered often)
- Rectangular bays:
  - most likely to be a one-way system
  - aspect ratios greater than 1:1.5 will be one-way acting
  - 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"

- 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)
- Slipped units:
  - typically one-way
  - columns can be shifted along the bearing line easily
- Manipulation of support locations can lead to improved structural efficiency (reducing bending moments) (if pattern is fixed, manipulation isn't possible); adding overhangs is the method for beams and trusses
- 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 $wl^2/8$)
- Irregular vertical support system makes effective or economical use of systems very difficult; site cast concrete is usual; large spans aren't possible with irregular supports
- 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
- Large spaces: (putting big grain into smaller grain)
  - separate systems completely
  - 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
- 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
  - interpenetration (looks like overlap)
- Strategies for vertical grid intersections:
  - vertical support points common to both systems
  - separate vertical supports (bypassing – rare)
- Intermixing structural materials within primary systems can be difficult with alignment, etc.
- 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; splices 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