ARCH 631. Topic 3 Reading Notes

- Serviceability is the defined by the text to include the requirement of strength – ability to carry loads safely) **and** the requirement to not have excessive deformations
  note: the term "serviceability" in engineering refers to the requirement *to limit excessive deformation* *only - see the definition from Note Set 3.2 below*
- Deformations are a function of stiffness, which is a shape and material dependent quantity, and include vibrations and accelerations under dynamic loads
- Efficiency is commonly defined by the use of the least amount of material for the design requirements and is also used to discuss the optimal shape of the structure to resist the loads applied
- Constructability can refer to the manpower used for the construction, equipment, and time but most often refers to the complexity which increases all those needs – repetition of elements is favorable
- Cost of structure depends on material and construction
- Common steps in structural design process:
  define geometry, hierarchies and spanning directions
  determine load quantities based on type
  model the structure and boundary conditions
  quantify the loads for each member
  analyze the reactions and the internal forces
  evaluate with respect to limit stress or limiting internal force/moment and deformation limits
- Loads are primarily categorized as static (slowly applied) and dynamic (suddenly)
- Static loads are subdivided into live (moving, periodic, or occupants) and dead loads (permanent due to gravity)
- Snow loads are a function of snow weight, drifting, snow duration, exposure and roof height
- Wind can be modeled as a static load from pressure or suction; design velocities which are a function of height are used to determine the pressure using the Bernoulli equation for fluid flow; the shape of the building also influences the pressure
- Wind has dynamic effect because of alternating forces called buffeting; with flexible members wind can cause flutter; causes swaying and can cause resonance
- Earthquakes are typically due to slippage between plates at fault zones and cause shockwaves through the earth's surface; inertial forces result from mass resistance to motion
- Building response is a function of mass and rigidity as well as the natural period of vibration
- Inertial force is defined as building mass multiplied by the ground acceleration, and is shear developed at the base of the structure that must be resisted
- Structural response can be complex because of the relative stiffness and vibratory-motion characteristic and the magnitude of the ground acceleration
- Natural period of vibration is the time for one complete sway cycle of a building (T)
- Frequency (f) is number of cycles that occur per unit time
- Flexible structures can have long periods while stiff structures have short periods of vibration

- Damping mechanisms absorb energy and the oscillations die out with time
- Resonance is the amplitude of the vibration when the frequency of the ground movement is nearly the same as the natural frequency of the vibration of the structure (explained with a spring model analogy)
- Predicting multistory structure vibration is complicated, but designers model the behavior using complex system of masses (floors), springs (stiffness) and damping mechanisms (energy absorbers)
- Static models for seismic forces are overly simplistic, but a common form shows up in building codes as $V = ZICW/R_W$ with V as the total static shear at the base, W is the total dead load of the building, C is a coefficient depending on the period of vibration, Z is a geographic factor, I is an importance factor; R_W is a function of building framing type
- C is a function of a coefficient that depends on the period of the site (S) and the building period (T) as $C = 1.25S/T^{2/3}$
- T is estimated through $T=C_t(h_n)^{3/4}$ with h_n as the building height and C_t as a coefficient which depends on the type of system and number of stories
- V must be distributed across the story levels
- V is larger for a stiff bracing system
- Dynamic analysis of base shear (rather than static) is commonly performed using computing
- Blast loads are localized and the load decreases rapidly from the center of explosion; method to limit damage is to block off access to potential bombers ("increase the standoff distance")
- Progressive collapse is due to failure and collapse of key structural elements that cause more or total collapse rapidly
- Load combinations take into account that all load types do not act on the structure simultaneously
- (Typical recommendation: *NOTE: not current with code)* Live load reduction is allowed on floors only (no roofs); areas of 150 ft^2 or more with live load of 100 lb/ft^2 or less can reduce loads by 0.08% $/ft^2$ of are supported by the member (with the exclusion of garages or public assembly space); limited to R **and** 60% where $R = 23(1+D/L)$; storage loads exceeding 100 lb/ft^2 can't be reduced, but the design loads on columns may be reduced by 20%.
- Many allowable stress design codes allow the load to be reduced when there is wind load or earthquake loads.
- Multiple combinations of loads MUST be considered and the structure design to carry that combination which is results in the highest design load values or stresses
- Effective modeling of the structures depends on correctly identifying the nature of the joints between members to obtain the actions (involves judgment)
- Joints must be analyzed for force or moment transmission to the supporting member
- Connections to the ground must provide for equilibrium to be satisfied
- Concentrated loads are modeled as point loads, while distributed loads need to be modeled from area loads to distributed (line) loads to even point loads; contributory areas are the areas of loading that an element supports
- Value of distributed load for a uniform width contributory area is w = area load x strip width

- Self weight must be considered in the dead load, but often isn't know so an assumed or average weight can be included for preliminary design
- Examples illustrate that the loading strip widths are determined from the location of halfway to the next supporting element one side to halfway to the next supporting element on the other side (if there is one) and that openings have no load
- With closely spaced joists or decking, the supporting elements see a uniformly distributed load from the reactions of the joist or decking ends
- Trusses are usually not modeled with distributed load; they are modeled with loads only at the joints (or panel points); example shows the method of finding the contributory area for each panel point (half way both sides in each direction) and multiplying by the area load to get a concentrated force value; exterior panel points don't have adjacent supporting elements (panel point) on one side
- Wind load is distributed load and can act horizontally; vertical members collect the load
- Building codes can influence the materials, size and shape of a building; example of combustibility type limiting height and square footage in Chart 1 of Note Set 3.1 from BOCA(Building Officials and Code Administrators) code
- Chart 2 of Note Set 3.1 shows fire rating for structural element types from BOCA code
- Author lists items from building code that could affect the overall design of a building; permitted are, permitted height; required stairs and exits; required light; required ventilation; required plumbing; heating and A/C equipment; elevators; electrical equipment; fire protection; use
- Zoning ordinances define building use types by location and usually cover lot and yard sizes; building height and setback; space between buildings; parking; floor area to building size ratio; ratio of open space to maximum height
- When building code and zoning ordinances overlap, the stricter of the requirements governs
- Other agencies may have regulations, like for safety
- Exit requirements influence form and are dependent on building use, occupancy, distance to travel to an exit; paths to an exit; safety of exit
- Minimum design loads for buildings and other structures must be designed with to be safely supported in load combinations or factored load combinations depending on the design methodology
- Serviceability requires the system and members to be designed to have adequate stiffness to limit deflections, lateral drift, vibration or any other deformations affecting the intended use or performance negatively
- Structural integrity is required such that if local damage occurs, the system will remain whole and stable; load transfer must be provided for; redundancy, continuity and ductility aid this
- Occupancy types are defined for purpose of applying flood, wind, snow, earthquake and ice provisions; the lower the category, the lower the hazard to human life in event of failure
- Load types are D, D_i, E, F, F_a, H, L, L_r, R, S, T, W, W_i
- There are 7 basic combinations listed for factored load design, with 2 for combinations including flood load, and 3 combinations including atmospheric ice loads

- There are 8 basic combinations listed for allowable stress design (nominal – meaning no load factors), with 2 for combinations including flood load, and 3 combinations including atmospheric ice loads
- If the code, standard or authorities require it, strength and stability must be designed for considering the effects of extraordinary (low probability) events such as fire, explosions, and vehicular impact