ARCH 631. Topic 6 Reading Notes

- Funicular shapes are dependent on the magnitude and location of the external forces (related to the shape of a hanging rope)
- A rope carrying a distributed load (weight or uniform) forms a catenary shape
- Magnitude of forces developed in arch or cable are dependent on the height or depth with respect to span and location/size of the loads
- Cables are in tension; reactions exceed number of equilibrium equations, "joints" at changes in cable geometry must be in equilibrium; section equilibrium must be maintained
- The lowest point of a cable under uniformly distributed load and supports at the same elevation will have no vertical component because the slope is horizontal; the low points for a cable with supports at different elevations can be estimated
- The total cable length for one under distributed load is in the form of a parabola depending on the span and sag
- Cable roof structures are susceptible to flutter and uplift due to wind loading; if the wind matches the natural frequency of vibration, resonance will occur with amplification of the motion; can add dead load, provide anchoring guy cables, use a cross cable or double cable system
- Suspension cable structures categorized as single-curvature, double-cables in a plane, double-curvature structures with crossed cables
- Cable-stayed structures use vertical or sloping compression mast with straight cables to horizontal spanning members
- Design issues for suspension cable structures:
  - good for long spans when adequate depth (simple type)
  - sensitive to wind induced vibration (simple type)
  - support elements required (simple type)
    - foundation or horizontal compression strut can absorb horizontal thrust
  - sag influences horizontal thrust
  - double-cables systems resist flutter by pretensioning of the cables and struts
- Design issues for cable-stay structures:
  - magnitude of tie-back cable forces sensitive to the distance between the cable and mast in a parallel cable and mast system; prone to collapse under large lateral loads
  - number of cables depends on the size and stiffness of the spanning element
  - common to assume the cables carry all the load in determining tension forces
  - shallow angles are to be avoided
  - masts can get tall and buckling needs to be considered
- Masonry arches resist compression stress only (cracks form in tension); shapes are not necessarily funicular
- Preferred loading is distributed (including self weight); large concentrated loads cause bending and failure unless designed for
- Non-masonry rigid arches can resist bending

- Reactions for an arch with uniformly distributed loading are same as uniformly loaded cable: $H = wL^2/8h_{max}$, $V = wL/2$ with max (resultant) at support (springing)
- Design issues for arches:
  - funicular shaping reduces undesirable bending moments (uniform load – parabolic shape); shape can still carry other loadings but with bending; prestressing is an example
  - foundation or tie-rods must absorb the horizontal thrust; tie-rods as tension members are efficient
  - elevated arches on a vertical system will require buttressing because of the horizontal thrust
  - prevent lateral movement or buckling by lateral bracing, with fixed (moment resisting) supports or increase stiffness (buckling)
- The three-hinged arch (or frame) has conditions of zero moment at the pin connections and pin supports; systems are statically determinate; may not be funicularly shaped
- Three-hinge arch can be shaped such that the size of family of funicular shapes falls within the depth of the cross section; even better if family of shapes falls within the kern for no tension stress
- Two-hinges arch and fixed-end arch are statically indeterminate; sensitive to support settlements, thermal expansions; and are stiffer than a three-hinged arch;
- End conditions important to behavior; without hinges, the structure can't flex freely and unwanted bending moments can be generated