

## ARCH 631. Topic 8 Reading Notes

- Plates are rigid and planar with small depth to width ratios; commonly constructed with reinforced concrete
- Space frames and grids aren't plates but behave similarly
- Size of load in a grid structure depends on relative stiffness – stiffer elements (like shorter ones) take more load and bending moment (larger curvature)
- Support system critical to plate behavior
- Torsional resistance in grid structures reduces deflection and subsequently, bending moment
- Common to design one way plates as one-unit wide beams and determine moment per unit width ( $m$ ) and units of lb-ft/ft or kN-m/m
- Total bending moment (equal to applied moment) is distributed across the plate width with respect to the curvature – higher curvature/higher moment
- In a column supported plate under uniform distributed load, the maximum moments occur at the midspan of the edges where the curvature is the largest, and smallest moments at the center where the curvature is the flattest (just goes “down with the ride”); center might be the best place to cut a hole with respect to bending stress
- Simply supported plate (continuous edges) under uniform distributed loads has highest moments at the midpoint of the plate
- Fixed edge plate under uniformly distributed load has negative bending moments at the edges (larger), reducing the positive bending moments (smaller)
- The more rectangular a plate, the more it behaves as a one-way system; ratio of short to long of 1 to 1.5
- Plate on beams on columns behaves more like plate on columns when beams aren't stiff and more like continuous (fixed) support when beams are stiff (can reduce plate thickness)
- For a grid structures the bending moment in the beam can be approximately given by the beam spacing times the average moment per unit length at that location;  $M = m(s)$
- For a space frame structures, the resisting couples for the bending moment are provided by the top and bottom bar as well as horizontal spacing;  $M = m(s) = T(d)$
- Design objectives for two-way systems:
  - minimize the bending moments by choice of the support conditions; can add overhangs
  - make bays as dimensionally symmetrical as possible for two-way action
  - fit design to load type – distributed or concentrated
  - verify that the space frame is better suited to the roof (rather than floor)
  - span range economical for system type
- Specific design objectives for reinforced-concrete two-way systems:
  - reinforcement must run both directions and closely spaced where moment is higher
  - common to provide reinforcement spaced over the column strip (higher moments) and the middle strip (lower – goes along for the ride) by assuming the moment is distributed evenly across these strips

- 15-22 ft (5-7m) spans can use thin plate, 5-10 in (13-26mm)
- As spans and loads get bigger, can use grid called waffle slab (with hollows)
- Another alternative is a two-way beam-and-slab system (beams integral with slab)
- Shear forces are highest at columns or other discrete supports; punch-through failure is possible at a perimeter around the column called the “plate area in shear” by the text; design options are to increase the thickness of the plate locally (drop panels), provided steel reinforcement (shear heads), or increase the columns size (locally = column capital); drop panels in waffle slabs are formed with filling the voids at the column
- Flat “plate” don’t have drop panels, “flat slabs” do
- Lateral load capacity is function of floor system stiffness (related to thickness)
- Grids and plates can be shaped to reflect bending moment sizes or along isostatic lines of principal stress (if the reinforced concrete was an elastic material!)
- Space-frames are made up of rigid linear members to form a relatively thin (to span) structure; actually are space-trusses when fully triangulated; useful for distributed load
- Node construction for space-frames is complex, but we can have varying member geometries
- Member force sizes correspond to the bending moment and shears in a plate (depending on support conditions), although are concentrated; finer and deeper grid = smaller member forces
- With few point supports used, member forces in the vicinity of the points are extremely high (like high shear in plates at columns)
- Crude values of member forces can be found from dividing the moment per unit width times the spacing by the depth ( $T$  or  $C = m(s)/d$ )
- Example of space frame with triangulation and corner supports and similar frame without any diagonals illustrates the stiffness and reduction in deflection/moment because of the triangulation
- Suggestions to reduce member sizes because of buckling at supports is to distribute the supports over many contact points
- Construction issues may prevent the members from resisting purely axial load, which means they have to be bigger to resist bending stress as well; repetition doesn’t mean all members are carrying the same loads; difficult problem to size members for efficiency
- Folded plates increase the stiffness of a flat plate by increasing depth; common for roofs and good with uniform distributed loads
- Folded plate elements are long and slender, which means lateral buckling from compression stresses must be considered in design – typically with bracing or stabilization by other plate elements
- Text discusses folded plate behavior in the longitudinal “beam” direction and transversely; shows the beam stresses being all in the thickness of the plates
- At edges, where stabilization isn’t provided or where support doesn’t exist, the lateral playing must be resisted by increasing the stiffness of the free edge; avoid terminating an edge that is in compression
- Steel, timber and concrete can be used to make folded plates, with concrete allowing for posttensioning (increasing span or reducing depth)

- Indeterminate beams have more unknowns than equations from statics; maximum bending moments are a function of loading AND which spans are loaded (partial loading)
- Finding maximum location and size of design values is tedious; design moments and shears are listed for two or more approximately equal spans carrying uniformly distributed loads in which the live load does not exceed the dead load by more than a factor of 3 (more clearly presented in Note Set 8.1)
- Can partially shape a beam for maximum moment with respect to most of the maximum bending moments
- Gerber beam is a compound continuous beam joining different depth sections with pin-type (or shear) connections at or near points of inflection; useful with known (not variable) loads; common with timber because of limited member lengths
- Can control moment sizes by moving supports, adding internal pin connections; but problems with putting internal pins away from points of inflection is the variation in slope at the joint
- For continuous reinforced concrete beams, the tension reinforcement can be bent up from the bottom (positive moment region) to top (negative moment region); can also posttension (prestressing is difficult)
- Live load reduction is allowed for floor slabs, columns, and beams based on an influence area (adjacent panel) larger than 400 square feet but can't be reduced lower than 40% of the unit live load (Note Set 8.1 gives a great chart for reduction multiplier based on influence area)
- Frame analysis by coefficients is a simplified method for analysis of one-way and two-way construction *for gravity load*; there must be at least two spans, spans must be similar in length, the load must be uniformly distributed with the unfactored live load not more than 3 times the unfactored dead load *and the member must have a uniform cross section throughout the span*
- The span length,  $\ell_n$ , is the clear span of the beam or slab
- For two way slab analysis by coefficients applies when there are three or more continuous spans in each direction, slabs with aspect ratio 2 or less, columns nearly in line; uniformly distributed gravity loads with live not more than three times the unfactored dead load
- The Direct Design method (two-way slabs) calculates a total design moment  $M_o$  for a panel with factored loads, then distributes it to the column strip and middle strip for both positive and negative moment
- Interior column strip is the sum of one quarter of the smaller of the bay dimensions each side of the column centerline; exterior column strip is bound by the building edge and extends one quarter of the same smallest dimension; the middle strip is what is left over