Theory of Structure II

Course Objective:

The threefold objective of the course is to:

1. Familiarize the terminologies and concepts of displacements, stresses, strains, stiffness etc. and their parameters in the context of indeterminate systems,
2. Practice in examples the basic concepts and theorems on static (equilibrium), geometrical (compatibility) and physical (Force, stiffness and displacements) conditions in the context of indeterminate systems,
3. Prepare the candidates for advanced courses in structural mechanics by introducing to the necessary tools like matrix method, force method, displacement method, plastic analysis etc.

1. Introduction (8 hours)
    a. Formulation of problems in theory of structure: functions of the structural systems and the corresponding requirements/conditions to be fulfilled, strength, stiffness and stability of a system
    b. Conditions and equations: static, compatibility, and physical
    c. Satisfaction of conditions
    d. Boundary conditions, partial restraints
    e. Solutions of equations
    f. Structure idealization, local and global coordinate systems and static and deformation conventions of signs
    g. Indeterminacy of structural systems its physical meanings and its types
    h. Degree of static indeterminacy of a system and its determination/calculation: static indeterminacies; use of formula, necessity of visual checking: for plane systems only in the form of truss, frame and arch
    i. Degree of kinematic indeterminacy of a system and its determination/calculation: use of formula, necessity of visual checking: for plane systems only in the form of truss, frame and arch
    j. Definitions and explanations of force and displacement for a structural system as operational parameters in comparison with systemic parameters like dimensions of system and elements and their material properties
    k. Force and displacements as cause and effects; Betti's law and Maxwell's reciprocal theorem, their uses and the limitations
    l. Two theorems from Castigliano and their applications: use of second theorem for determination of displacements in statically determinate and solution of statically indeterminate simple systems like beam and truss
    m. Flexibility and stiffness
    n. Flexibility matrix
    o. Stiffness matrix
    p. Relationship between flexibility and stiffness matrices
    q. Force and displacement methods
2. Force method (12 hours)
    a. Definitions and explanations; specialties of force method and its limitations
    b. Primary systems with replacements of static indeterminacies, choice of unknowns for force quantities and its limitations, primary system with unit forces for static indeterminacies, unit force diagrams
    c. Compatibility conditions and formulation of equations in matrix form, system specific matrix and its dependency upon choice of unknowns

d. Flexibility matrix: generations and calculations
e. Use of graphical method for calculation of coefficients (elements of flexibility matrix); derivation of formula for the standard case of parabola and straight line, its extension to the case when both are straight lines
f. Applications to beams and frames; three moment theorem, effects of temperature variance and settlement of supports in beams and frames, determination of redundant reactions or member forces in a beam (two to three spans) and frames (one storey two bay or two storey one bay), consideration of settlement of support, variance in internal and external temperature for beams (up to two spans) and frames (portal only) involving not more than four unknowns.
g. Applications to trusses; effects of temperature variance and misfits
h. Applications to arches (parabolic and circular): simple cases of two hinged and hinge less arches; cases of yielding of supports and temperature effects, influence line diagrams for two hinged arches
i. Bending moment, shear force and normal thrust diagrams for the abovementioned systems (beams, frames and arches)

3. Displacement method (15 hours)
   a. Definitions and explanations; specialties of Displacement method and its limitations
   b. Primary system: kinematic indeterminacy and unit displacement system, unit displacement diagrams and their applications
   c. Choice of unknowns and its uniqueness in comparison with force method
   d. Equilibrium conditions and formulation of equations in matrix form
   e. Stiffness matrix its formation, properties and application as system specific
   f. Applications to beams and frames, effects of settlement of support and temperature
   g. Applications to trusses, effect of temperature change
   h. Bending moment, shear force and normal thrust diagrams for the systems
   i. Fixed end moment, slope and deflection and their uses in beam systems
   j. Equilibrium conditions of the joints in beams and frames
   k. Slope deflection equations and their applications in beam systems
   l. Stiffness of a member in a rigid joint
   m. Boundary conditions
   n. Distribution of unbalanced moment in a rigid joint
   o. Principle of moment distribution with consideration of cross sectional stiffness, member stiffness (consideration of length) and boundary conditions
   p. Application of moment distribution method to solve beams and frames (simple cases with one bay and two storeys or two bays and one storey)
   q. Consideration of sway conditions(simple cases with one bay and two storeys or two bays and one storey)

4. Influence line (IL) for continuous beams (4 hours)
   a. Definitions and explanations: given section, structural quantity (support reaction, bending moment or shear force etc.) and the given structural system as the three basic elements of definition of IL, IL diagrams as system specific diagrams - independent of operational parameters like loads
   b. Neutral points (focus) in an unloaded beam span of a continuous beam as fixed points with respect to load on left or right of the span, left or right focal point ratios and recurrent formula for their determination, focal point ratios for the extreme spans

c. Use of three moment equations and focal point ratios to determine support moments in a continuous beam
d. Numerical method for drawing IL diagram of support moments using focal point ratios
e. Use of IL of support moments to draw IL for other structural quantities like support reactions, bending moment and shear force in the given section
f. Mueller Breslau principle its physical meaning and its use
g. IL diagrams for reaction, bending moment and shear force in various sections of continuous beams (two to three spans only)
h. Loading of the IL diagrams, determination of reaction, bending moment and shear force at a section of a continuous beam for given loads in the form of a concentrated force, couple and distributed load

5. Introduction to plastic analysis (6 hours)
    a. Definitions and explanations
    b. Plastic analysis of bending members
    c. Plastic bending
    d. Plastic hinge and its length
    e. Load factor and shape factor
    f. Basic theorems on methods of limit analysis
    g. Collapse loads: partial collapse, complete collapse
    h. Collapse with tied loads for simple cases of statically indeterminate beams (not more than three spans) and frames (only portal frames)

Experiments (8 hours)
    a. Determination of redundant reaction components and their comparative studies in the following four experiments:
    b. Continuous beams (propped cantilever, two spanned beams with various end conditions)
    c. Two hinged arch
    d. Symmetrical portal frame
    e. Unsymmetrical portal frame

References

    a. Darkov A et al., 1979, Structural Mechanics, Mir Publishers, Moscow.
    b. Ghali A, Neville A M, 1989, Structural Analysis, A Unified Classical and Matrix Approach, Chapman and Hall.
    c. Joshi H R, 1991, Theory of Structure II - Course Manual, Institute of Engineering, Tribhuvan University, Katmandu.
    d. Norris C H, Wilbur J B, Utku S, 1991, Elementary Structural Analysis, McGraw-Hill International Editions, Civil Engineering Series.
    e. Pandit G S, Gupta S P, 1981, Structural Analysis, A Matrix Approach, Tata McGraw-Hill Publishing Company Limited, New Delhi.
    f. Reddy C S, 1981, Basic Structural Analysis, Tata McGraw-Hill Publishing Company Limited, New Delhi.
    g. Wang C K, 1983, Intermediate Structural Analysis, McGraw-Hill International Editions, Civil Engineering Series.