Course Name:
Advanced Numerical Methods in Geomechanics

Course Number:
20409

Credit:
3

Course Content (outline):

1. **Advanced Topic In FEM**
   - 1.1 Lagrangian and Serendipity Elements
   - 1.2 Rayleigh-Ritz Method as Theoretical Basis for FEM
   - 1.3 Solution Convergence in FEM Modeling
   - 1.4 Selection of The Order of Numerical Integration
   - 1.5 Non-Conforming Elements and Patch Test
   - 1.6 Zero-Energy Modes
2. **Nonlinear Analysis In Solid Mechanics**
   - 2.1 Iterative and Incremental Approaches in Nonlinear Analysis
   - 2.2 Material Nonlinearity
   - 2.3 Application of Nonlinear Elastic Models
   - 2.4 Application of Elasto-Plastic Models
   - 2.5 Application of Time-Dependent Models
   - 2.6 Geometric Nonlinearity
   - 2.7 Definitions of Stress and Strain in Large Deformations
   - 2.8 Total Lagrangian Formulation
   - 2.9 Updated Lagrangian Formulation
3. **Dynamic Analysis**
   - 3.1 Static, Quasi-static, and Dynamic Problems
   - 3.2 FEM Form of Equation of Motion
   - 3.3 Direct Integration Methods
   - 3.4 Mode Superposition
   - 3.5 Mass and Damping Matrices
   - 3.6 Mesh Configuration and Boundary Conditions
   - 3.7 Application of Load in Dynamic Analysis

4. **Numerical Simulation of Discontinuities**

    4.1 Weak and Strong Discontinuities

    4.2 Smeared and Discrete Approaches in Modeling Cracks

    4.3 Existing Cracks and Propagating Cracks

    4.4 Crack Modes (Tensile, Shear, Mixed)

    4.5 Application of Interface Elements in Discrete Crack Modeling

    4.6 Simulation of Fluid Flow inside Cracks

5. **Coupled Problems**

    5.1 Difference between Coupled and Uncoupled Problems

    5.2 Examples of Coupled Problems and Their Governing Equations

    5.3 Formulation of a Hydro-Mechanical Problem

    5.4 Formulation of a Thermo-Hydro-Mechanical Problem

    5.5 Two-Phase Flow in a Deforming Porous Medium

6. **Other Numerical Methods**

    6.1 Boundary Element Method

    6.2 Discrete Element Method

    6.3 Extended Finite Element Method

    6.4 Spectral Elements Method

    6.5 Mesh-Free Methods

References:

- Cook, Malkus and Plesha, "Concepts and Applications of Finite Element Analysis", (1989), John Wiley
- Bathe, K.J., "Finite Element Procedures in Engineering Analysis", (1996), Prentice Hall
- Zienkiewicz & Taylor, "The Finite Element Method", vol. 2, 4th Edition, (1989), McGraw Hill
- Smith, I.M., & Griffith, D.C., "Programming the Finite Element Method", 2nd Edition (1992), John Wiley & Sons
- Zienkiewicz, O.C., Chan, A.C.H, Pastor, M., Schrefler, B.A., Shiomi, T., "Computational Geo-mechanics, with special reference to earthquake engineering", John Wiley, (1999)
- Chen, W.F. and Mizuno, E., "Nonlinear Analysis is Soil Mechanics (1990), Elsevier
- Owen, D.R.J., and Hinton, E., "Finite Elements in Plasticity, Theory and Practice", Pineridge Press, (1980)

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