CEE6460: Theoretical Geomechanics

Course Description: This course provides an introduction to the basic analytical and numerical methods and constitutive laws used for the analysis of boundary value problems in geomechanics. The material presented in the first part of the course is common to the general study of solid mechanics and groundwater hydraulics, and will be of general interest to students who are not only majoring in geotechnical engineering. Constitutive models specifically related to soil behavior are introduced in the second part of the course: linear elastic, nonlinear elastic, linear elastic-perfectly plastic and nonlinear elastoplastic models based on the Critical State Soil Mechanics Theory. The geotechnical finite element program PLAXIS v8 will be also used for constitutive model validation and static analysis of earth structures.

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Office Hours: Tuesdays 2:00 - 4:00pm

Course Textbook: No textbooks are assigned for this class. Copies of the required/recommended references for each section of the course will be distributed during the term. The following two texts cover most of the fundamental material presented in this course:

Malvern, L.E. (1969) Introduction to the Mechanics of a Continuous Medium, Prentice Hall Inc.

Bear, J. (1979) Hydraulics of Groundwater, McGraw-Hill.

Course Organization:

Lectures	Mondays & Wednesdays 11:05-12:35pm, Room Mason 312
	Lectures "Introduction to FEM 1-4" in computer lab TBA
Homework	12 problem sets, including 4 computer-based assignments
Grading	Homework (35%), Midterm (15%), Final Exam (50%)

Course Outline

Week	Topic
1	**1. Introduction to Numerical Modeling in Geomechanics**
1-2	**2. Background: Review of Tensor and Matrix Algebra** Properties and operations of vectors and tensors, tensor calculus including Gauss theorem, review of matrix algebra
2-6	**3. Elements of Continuum Mechanics** Definition of stress at a point, Mohr circle representation Principle stresses, stress invariants and stress decomposition Equilibrium equations and conservation of momentum Measures of deformations and strains, strain compatibility Stress-strain relations, rheological classes of materials Boundary value problem representation Linear elasticity: formulation of field equations, fundamental solutions of static problems, methods of solution (analytical techniques, stress functions & superposition)
6-8	**4. Yielding and Failure in Soil** Yield criteria for perfectly plastic and frictional materials Upper and lower bound theorems in plastic analysis Numerical solutions for limit analysis Hardening rules and normality Plane-strain bearing capacity and slope stability problems
8-11	**5. Steady Flow in Porous Media** Continuity equation and conservation of mass Linear flow regime: Darcy's law and permeability tensor Application in confined and unconfined flow Analytical solution techniques, construction and interpretation of flow nets, finite difference and finite element methods
11-12	**6. Transient flow in porous media** Free surface movement and unconfined flow Formulation of uncoupled diffusion equation for 1D consolidation (Terzaghi theory), solution of simple problems Poro-elastic formulations for soils, Biot equations for coupled consolidation in 2D & 3D Introduction to large strain problems
13-14	**7. Plasticity theory** Elasto-plastic modeling of material behavior Analysis of elasto-plastic boundary value problems
15-16	**8. Effective Stress Constitutive Models** Constitutive models of soil behavior using incremental plasticity Critical State soil mechanics and Cam Clay

School of Civil & Environmental Engineering
Dr. Dominic Assimaki

CEE6460: References

General
Scott, R.F. (1963) Principles of Soil Mechanics, Addison-Wesley
Taylor, D.W. (1948) Fundamentals of Soil Mechanics, Wiley and Sons
Terzaghi, K. (1943) Theoretical Soil Mechanics, Wiley and Sons

Fundamentals of Mechanics:
Biot, M.A. (1965) Mechanics of Incremental Deformations, Wiley and Sons
Fung, Y.C. (1965) Foundations of Solid Mechanics, Prentice-Hall Inc.
Malvern, L.E. (1969) Introduction to the Mechanics of a Continuous Medium, Prentice Hall Inc.

Numerical Methods:
Bathe, K.-J. (1982) Finite Element Procedures in Engineering Analysis, Prentice-Hall
Pande, G.N., Beer, G. and Williams, J.R. (1990) Numerical Methods in Rock Mechanics, Wiley and Sons
Zienkiewicz, O.C. (1977) The Finite Element Method, McGraw-Hill

Elasticity and Elastic Solutions:
Obert, L. and Duvall, W.J. (1967) Rock Mechanics and the Design of Structures in Rock, Wiley and Sons
Poulos, H.G. and Davis, E.H. (1974) Elastic Solutions for Soil and Rock Mechanics, Wiley and Sons
Sokolnikoff, I.S. (1956) Mathematical Theory of Elasticity, McGraw-Hill
Timoshenko, S.P. and Goodier, J.N. (1970) Theory of Elasticity, McGraw-Hill

Groundwater Flow:
Bear, J. (1979) Hydraulics of Groundwater, McGraw-Hill
Cedergren, H.R. (1977) Seepage, Drainage and Flow Nets, Wiley and Sons
Verruijt, A. (1970) Theory of Groundwater Flow, Gordon & Breach, NY

Plasticity:
Atkinson, J.B. (1981) Foundations and Slopes, McGraw-Hill
Hill, R. (1950) The Mathematical Theory of Plasticity, Oxford: Clarendon Press
Prager, W. and Hodge, P.G. (1951) Theory of Perfectly Plastic Solids, Dover, NY

Rheology and Constitutive Laws:
Ashby, M.P. and Jones, D.R.H. (1986) Engineering Materials I, Pergamon Press
Desai, C.S. and Siriwardene, H.J. (1984) Constitutive Laws for Engineering Materials, Prentice Hall Inc.

Soil and Rock Behavior:
Atkinson, J.H. and Bransby, P.L. (1978) An Introduction to Critical State Soil Mechanics, McGraw-Hill
Jaeger, J.C. and Cook, N.G.W. (1970) Fundamentals of Rock Mechanics, Chapman and Hall
Schofield, A.N. and Wroth, C.P. (1968) Critical State Soil Mechanics, McGraw-Hill
Wood, D.M. (1991) Soil Behavior and Critical State Soil Mechanics, Cambridge University Press

Applications in Foundation Engineering:
Desai, C.S. and Christian, J.T. (1977) Numerical Methods in Geotechnical Engineering, McGraw-Hill
Scott, R.F. (1981) Foundation Analysis, Prentice-Hall