Computational Modeling in Geotechnical Engineering
CVEN 5788, Summer 2020
lectures posted on canvas.colorado.edu

Instructor:
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Course Description:
Introduces computational modeling for geotechnical and geological engineering applications, such as linear and nonlinear Finite Element Analysis (FEA) of seepage, coupled soil or rock elastoplastic consolidation, elastoplasticity models for soil and rock and their numerical implementation, and possibly advanced computational methods for failure in soil and rock. Uses primarily the ABAQUS FEA software program for analysis of geotechnical and geological engineering applications, but also may use Plaxis and GeoStudio. Introduces separate nonlinear FEA with Matlab code to demonstrate how such models are implemented. Possibly covers user subroutines UMAT/VUMAT for custom constitutive model implementation into ABAQUS.

Course Objective:
To provide an introduction to linear and nonlinear FEA for geotechnical and geological engineering applications.

Pre-requisite (required):
CVEN 3718 (geotechnical engineering 2), or equivalent.
Recommended (not required):
CVEN5708 (graduate level soil mechanics), CVEN 5768 (graduate level rock mechanics), CVEN4511/5511 (introductory finite element analysis), or equivalents.

Course Grading:

Problem Sets/Computing Assignments	50%
Midterm Exam (take-home)	25%
Final Project (individual)	25%

Problem Sets/Computing Assignments:
You can work together on problem sets and computing assignments but must hand in your own solutions. You are encouraged to try the problems yourself before working with other students. This will enhance your learning experience, and help prepare you for the in-class (or take-home) Midterm Exam, and conducting the Final Project individually.
You are allowed <u>one problem set to be handed in one week late</u> with no penalty. Otherwise, no late problem set will be accepted after after 5pm on the day that the problem set is due.

Final Project:
The final project will involve applying FEA (or other numerical method) to solve a geotechnical or geological engineering problem, case study, or research of interest to you. As part of your project, you may implement a geomaterial constitutive into ABAQUS or other code, for instance, and use in your application. <u>You must work individually on the final project</u>.

Required Text Book: S. Helwany, Applied Soil Mechanics with ABAQUS Applications, John Wiley & Sons, Inc., 2007.

Other books on reserve in the Engineering Library:
- J.H. Atkinson, P.L. Bransby, Mechanics of Soils: An Introduction to Critical State Soil Mechanics, McGraw-Hill, 1978 (TA710.A79)
- R.O. Davis, A.P.S. Selvadurai, Plasticity and Geomechanics, Cambridge University Press, 2005 (online)
- E. Derringh, Computational Engineering Geology, Prentice Hall, 1998 (TA705.D47 1998)
- C.S. Desai, H.J. Siriwardane, Constitutive Laws for Engineering Materials: With Emphasis on Geologic Materials, Prentice-Hall, 1984 (TA417.6.D47 1984)
- R.E. Goodman, Introduction to Rock Mechanics, 2nd Ed., John Wiley and Sons, 1989 (TA706.G65 1989)
- T.W. Lambe, R.V. Whitman, Soil Mechanics, SI Version, John Wiley & Sons, 1979 (TA710.L246)

- N. Lu, W. Likos, Unsaturated Soil Mechanics, Wiley, 2004 (TA710.L74 2004)
- R.F. Scott, Principles of Soil Mechanics, Addison Wesley, 1963 (online, TA710.S36)
- K. Terzaghi, Theoretical Soil Mechanics, John Wiley and Sons, 1943 (TA710.T4)
- K. Terzaghi, R.B. Peck, G. Mesri, Soil Mechanics in Engineering Practice, John Wiley & Sons, 1996 (TA710.T39 1996)
- D.M. Wood, Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, 1990 (TA710.W598 1990)

Course Outline (tentative, subject to change):

1. Overview of Computational Modeling in Geotechnical and Geological Engineering (*1 lecture*)
    a. Finite difference versus finite element (spatial and temporal discretization)
    b. Boundary element methods
    c. Discrete element methods (particulate mechanics)
    d. Summary of commercial programs and how they are classified/used (GeoStudio, ITASCA, Plaxis, Abaqus, …)
    e. Review of Abaqus capabilities for Geomechanics
2. Stress analysis (*2 weeks, Chap3*)
    a. FEA for stress analysis: soil/rock weight, point load, line load, surface pressure load
    b. Elasticity constitutive model implementations in Matlab and UMAT/VUMAT in Abaqus
3. Plasticity and Shear Strength of Soil and Rock (*3 weeks, Chap2, 5, 6, 7, 8*)
    a. Usage of soil and rock plasticity in FEA: strength vs deformation, or both
    b. Drucker-Prager Cap Plasticity
    c. Overview of Critical State Soil Mechanics and Cam-Clay Plasticity
    d. Elastoplasticity constitutive model implementations in Matlab and UMAT/VUMAT in Abaqus

*Final Project Proposal 5 minute Presentations (*students present individually their proposals to Dr. Regueiro*)

4. Seepage (*3 weeks, Chap9*)
    a. flow nets and FEA
    b. Determination of phreatic surface in embankment dam seepage
    c. Saturated versus partially-saturated flow analysis
    d. Usage of Matlab code and Abaqus
5. Consolidation (*3 weeks, Chap4*)
    a. Review of consolidation theory
    b. Coupled FEA for consolidation analysis at small and finite strain
    c. Usage of Matlab code and Abaqus
6. Soil/Rock Dynamics (*2 weeks*)
    a. Wave propagation in elastic soil/rock, and FEA
    b. Wave propagation in elastoplastic soil/rock, and FEA
    c. Usage of Matlab code and Abaqus
7. Final Project 10 minute Presentations (*final exam period*)

Honor Code:
Please refer to the following webpage: http://www.colorado.edu/honorcode/

Special considerations:
- If you have a disability and require special accommodations, please provide Dr. Regueiro with a letter from Disability Services outlining your needs. Refer to the webpage http://www.colorado.edu/disabilityservices
- If you have a conflict as a result of religious observances, please notify Dr. Regueiro at least 2 weeks in advance of the exam or assignment due date. http://www.colorado.edu/policies/observance-religious-holidays-and-absences-classes-andor-exams

Access to Bechtel Lab: If you do not already have access to the Bechtel Lab (ECCE 157, 161), see instructions on the door. Also, given distance learning requirements, you can access the Bechtel Lab remotely via a web browser. Dr. Regueiro will email instructions. Also, there are student editions of Abaqus and Geostudio you can download to your personal computer for use for most problem sets in the course, except a couple with Abaqus involving user subroutines, for which logging in remotely to Bechtel lab will be easier.