Department of Civil and Environmental Engineering

Mississippi State University

CE 8443 - Soil Behavior

Spring 2015

Monday/Wednesday/Friday, 12:00 -12:50, Walker Hall, Room 304

Disclaimer: to be used to evaluate general content, are not binding, and may/may not include updates for the upcoming semester.

Instructor:

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Office hours: MW, 1:30-3:30 *or* by appointment

Required Textbook and Other Resources:

There will be no required textbook for this class. In place of a text, you will be given a collection of classic technical papers dealing with the shear strength of soils. These papers and other useful handouts will be made available in class. The course website will contain much of the information that is distributed in class, as copyright permissions allow.

Supporting Texts: The following texts provide useful supplemental information for this course. If desired, copies of these books can be obtained through Mitchell Memorial Library *andlor* via the Interlibrary Loan system.

- *Soil Strength and Slope Stability (2005), J. M. Duncan and S. G. Wright, John Wiley & Sons, 297 pps.*
- *Soil Mechanics* (1969). T. William Lambe and Robert V. Whitman. John Wiley and Sons, Inc. 553 pps.
- *Unsaturated Soil Mechanics in Engineering Practice*, (2012), D. G. Fredlund, H. Rahardjo, M. D. Fredlund, John Wiley & Sons, Inc., ISBN: 978-1-118-13359-0, 944 pages.
- *Unsaturated Soil Mechanics, Ning Lu and William Likos, John Wiley & Sons, Inc., 2004.*
- *Research Conference on Shear Testing* of *Cohesive Soils* (1961). ASCE, University of Colorado, Boulder, CO, 1164 pps.
- *Laboratory Shear Testing* of *Soils* (1964). ASTM STP 361, American Society for Testing and Materials, 505 ps.
- *Laboratory Shear Strength* of *Soils* (1981). ASTM SPT 740., R. N. Yound and F.
- C. Townsend, Eds., 717 pps.
- *Advanced Triaxial Testing* of *Soil and Rock* (1988). ASTM STP 977, Robert T. Donague, Ronald C. Chaney, and Marshal L. Silver, Eds., American Society for Testing and Materials, Philadelphia, 896 pps.

Objectives:

The course is designed to provide students the theory and experience-based knowledge necessary to specify appropriate types of strength tests for use in analyses of soil stability, bearing capacity and earth pressure problems; to interpret results of laboratory and in situ strength tests on soils; and to determine appropriate values of shear strength parameters using laboratory tests and correlations with in situ and index tests.

On completion of the course, successful students will be able to:

1. Write clear memos that record and transmit information effectively.
2. Specify suitable types of tests and test conditions for measurement of the shear strength of soils.
3. Evaluate the quality of laboratory and in situ strength tests.
4. Interpret the results of laboratory and in situ strength tests.
5. Use the results of laboratory and in situ tests to evaluate soil shear strength parameters.

More specific, detailed course objectives are listed at the end of this syllabus.

Instructional Approach:

A practical approach will be taken in this class, with much of the material presented by use of example problems worked in class. Students are expected to participate in class in the solution of example problems. The required reading supplements the lecture presentations. The reading and homework assignments are essential parts of the course.

Grades and Grading:

The work in the course will be weighted as follows:

First Exam	15%
Second Exam	15%
Final Exam	30%
Homework	40%

<u>Homework policy:</u> In this class, homework should be submitted in the form of a memo outlining the scope, solution procedure, and results. If you are not skilled in memo writing, see the handout on memos presented on the course website.

All homework assignments that require hand calculations should be submitted on engineering paper, with proper referencing of design equations used. Always include all of your calculations and analyses. Neatness and a professional style of presentation counts! Homework assignments will be due at the beginning of the class period on the due date specified. *Late homework will not be accepted without prior instructor approval.*

<u>Exams:</u> During the semester, there will be two mid-term tests and a final exam. All tests will be closed book and closed notes. The final exam will be cumulative.

Academic Honesty:

The Mississippi State University Academic Honesty Policy sets strict guidelines with respect to Academic Honesty. Anything submitted under your name alone must be solely your work, and any form of academic dishonesty will not be tolerated. Some assignments may require that you work with other students. In such cases, you must indicate clearly who you worked with, and give full credit for their contribution to what you submit.

Lecture Outline:

I. Introduction and course organization

II. Basic stress and strength concepts and measurement devices

- A) Principal stresses, Mohr diagrams, pole of Mohr's circle
- B) Mohr-Coulomb failure criteria
- C) Triaxial tests
- D) Direct shear tests
- E) Pore pressure parameters
- F) Vector curves
- G) Stress paths

III. Shear strength of sands, gravels, and rockfills

- A) Drained triaxial results of sands
- B) Drained direct shear test results of sands
- C) Sources of shear resistance
- D) Factors affecting strength and stress-strain behavior
- E) Volume change behavior
- F) Undrained behavior of sands
- G) Steady state and critical state theories

IV. Shear Strength of Saturated Clay

- A) Drained strength behavior
- B) Hvorslev's shear strength concept
- C) Shear strength of stiff fissured clays and shales
- D) Undrained strength of clay
    - 1) Interpretation of UU tests
    - 2) Interpretation of ICU tests
    - 3) Interpretation of ACU tests
    - 4) SHANSEP

5) Rutledge Theory

6) Creep and creep strength loss

7) Anisotropy

V. Shear strength of partially saturated clay

A) Effective stress theories

B) Special triaxial tests

C) Compacted clay

D) Shear strengths for design

VI. Shear strength of silt

VII. Laboratory strength measurement

VIII. In situ shear strength measurement

Detailed Course Objectives:

After completing this course, you will (should?) be able to:

- Calculate the normal and shear stresses on a plane at any orientation given the stresses and stress orientations on two other planes.
- Define the fundamentals of stress and Mohr-Coulomb failure criteria in geomechanics applications.
- Determine the change in pore pressure due to changes in total stress on an element of soil using pore pressure parameters.
- Specify methods of determining pore pressure parameters using laboratory tests.
- Recognize the limitations of using pore pressure parameters in practice.
- Examine the different ways changes in total stress can be decoupled into changes in deviator stress and changes in all around stress.
- Recognize the different ways that the change in deviator stress can be used with the pore pressure parameter A-bar.
- Visualize changes in principal stresses and pore pressure during shear using either vector curves or stress paths.
- Explain how stress paths can be used in geotechnical design.
- Associate different stress paths with their respective laboratory tests.
- Identify the different factors that influence the values of pore pressure parameters.
- Calculate the amount of principal stress rotation for different laboratory soil tests.
- Identify the influence of principal stress rotation and strain boundary conditions on the shear strength of soil.
- List the attractions and detractions of the different types of laboratory tests conducted on soil.
- Identify the factors that control the shear strength of sands, gravels, and rockfills.
- Explain how the volume change tendencies of a cohesionless soil can influence the measured shear strength parameters.
- Explain the association of volume change and pore pressure development in sands and clays.
- Construct steady state lines for sands based on drained and undrained test results.
- List the elements of conducting a slope stability analysis using steady state shear strengths.
- Explain the basic concepts behind critical state soil mechanics.
- Understand the contributions of various factors to the measured friction angle of sand.
- Evaluate the shear strength used for design for cohesionless soils at elevated pressure.
- Calculate "conventional" shear strength parameters for clays using a consolidation curve and Hvorslev shear strength parameters.
- Associate the major landmark contributions to our knowledge of shear strength with the

developer.

- Estimate the undrained shear strength as a function of depth for a saturated clay deposit.
- Interpret the results of UU and CU triaxial tests for determining the in situ shear strength of clay deposits.
- Use the results of ACU triaxial tests to assess the shear strength of compacted clays for rapid drawdown slope stability analysis of earth dams.
- Estimate ACU strengths based on the results of ICU triaxial tests.
- Identify the problems in conventional shear strength assessment that SHANSEP purports to address.
- Outline a sampling and testing program to determine the undrained shear strength of a saturated clay deposit using the SHANSEP procedure.
- Explain how sampling and disturbance can influence the shear strength of soils tested in the laboratory.
- Rely more on scholarly papers, as opposed to textbooks, to learn the advanced concepts in geotechnical engineering.
- Use the Rutledge theory to determine drained and undrained shear strength parameters given the virgin curve and a strength curve.
- Identify the common concepts shared with Rutledge's theory, Hvorslev's theory, and the SHANSEP procedure.
- Calculate the in situ shear strength of a clay deposit using normalized undrained strength ratios.
- Recognize how creep and progressive failure influence field behavior of soil deposits.
- Explain the difference between inherent and stress-induced anisotropy.
- Identify and apply different types of failure criteria to soil tests and recognize the influence of the choice of failure criteria.
- Construct the pertinent plots for presenting triaxial test data.
- Identify soil types where specimen size and inherent anisotropy may influence the measured shear strength.
- Compare the difference in the application of ffective stress theory in saturated and unsaturated soil.
- Specify the proper tests to measure the shear strength of compacted soil for different engineering applications.
- Estimate the change in shear strength parameters and compressibility for compacted clay if the relative compaction is increased.
- Estimate the change in shear strength parameters and compressibility for compacted clay if the compaction water content is increased.
- Explain how drained and undrained shear strengths are used in geotechnical design applications.
- Determine if a drained or undrained analysis is appropriate for a given design situation.
- Recommend the sampling method and testing procedure to measure the shear strength of stiff fissured clays for geotechnical analyses.
- Identify cases where silts can behave like clays or behave like sands.
- Associate the common and less common types of geotechnical laboratory tests with the stress path, consolidation conditions, strain conditions, drainage conditions, and most applicable soil type.
- Specify which type of in situ test is best suited to measure a specific parameter.
- Specify which type of in situ test is best suited for a particular soil type.
- Weigh the advantages and disadvantages of laboratory versus in situ tests for a particular site and/or geotechnical design application.
- Explain how the preconsolidation pressure influences the measured effective stress strength parameters of clay in undrained and drained loading.
- Recognize how strain conditions influence the shear strength of sands, and associate the different strain conditions with the different types of geotechnical shear strength tests.
- Fake the objectives above in a convincing enough fashion to pass the course.