Department of Civil, Architectural and Environmental Engineering
The University of Texas at Austin

Spring Semester, 2009
Unique No. 15305

CE 375

EARTH SLOPES AND RETAINING STRUCTURES

	Class Lectures:
Days:	Monday, Wednesday, Friday
Time:	11:00 a.m. - 11:50 a.m.
Building:	Ernest Cockrell, Jr.
Room:	ECJ 5.410
	Instructor:
	Dr. Jorge G. Zornberg
Office:	ECJ 9.227G
Phone:	(512) 232 - 3595
E-mail:	zornberg@mail.utexas.edu
Office Hours:	Mon, Wed 2:00 p.m. - 3:00 p.m.

Course Textbooks

Required: *Course Notes - CE 375: Earth Slopes and Retaining Structures* - Available in the Textbook Department of the University Co-op (2246 Guadalupe St.). This packet contains all of the supporting materials for the course lectures. *Please bring these course notes to class each day.*

Suggested: Coduto, Donald P. (1999). *Geotechnical Engineering: Principles and Practices.* Prentice Hall, Upper Saddle River, New Jersey. (ISBN 0-13-576380-0).

Several basic textbooks on geotechnical engineering cover the subjects we will discuss in this class. Consequently, I have selected the same textbook used in CE 357. However, since the textbook does NOT cover all the material as presented in class, you will need to take good, complete notes in the lecture. Lectures will be supplemented with handouts, but your notes will be very important. In addition, I suggest the following books, which should be available in the library:

Cedergren, Harry R. (1989). *Seepage, Drainage, and Flow Nets.* Third edition. John Wiley and Sons, New York.

Cernica, John N. (1995). *Geotechnical Engineering: Soil Mechanics.* John Wiley and Sons, New York.

Das, Braja M. (2002). *Principles of Geotechnical Engineering.* Fifth edition, Brooks/Cole, Pacific Grove, California.

Holtz, Robert D., and Kovacs, William D. (1981). *An Introduction to Geotechnical Engineering.* Prentice Hall, Englewood Cliffs, New Jersey.

Lambe, T.W., and Whitman, R. (1969) *Soil Mechanics.* Wiley and Sons, New York.

McCarthy, David F. (2002). *Essentials of Soil Mechanics and Foundations: Basic Geotechnics*. Sixth edition, Prentice Hall, Upper Saddle River, New Jersey.

Sowers, George F. (1979). *Introductory Soil Mechanics and Foundations: Geotechnical Engineering*. Fourth edition. Macmillan Pub., New York.

Course Prerequisite

- Civil Engineering 357 - *Geotechnical Engineering*

Course Scope and Objectives

This course concentrates on geotechnical engineering problems associated with the behavior of earth masses. Unlike foundation engineering, where we evaluate how much load can be placed on a soil, our interest here will center on problems where the soil itself must be supported. That is, our discussions will focus on the evaluation of stability in a soil mass, and on the design of structural supports or other remedial measures to stabilize a soil mass. Specifically, the four major areas of discussion to be covered in this course are:

(1) *Soil compaction:* laboratory compaction tests, properties of compacted soils, compaction specifications, field compaction procedures, control of compaction in the field, and in-place densification of natural deposits.

(2) *Seepage and drainage:* principles of water flow through soils, water pressures and stresses in soil, flow net solutions, filter criteria, and drainage for stabilization.

(3) *Slope stability:* principles of soil shear strength, fundamentals of limit equilibrium analyses, infinite slope analyses, $\phi = 0$ analyses, chart solutions, ordinary method of slices, and remediation and design of slopes.

(4) *Earth pressures and retaining structures:* at-rest earth pressures, Rankine active and passive pressures, Coulomb and wedge theories, overview of retaining structures, modes of instability, and design of retaining structures.

A sloping ground surface generates shear stresses in the underlying soil mass, with steeper slopes imparting larger shear stresses. A ground slope will be stable if the internal shear stresses are less than the associated shear strength of the soil. However, we all know that a landslide will occur if you try to form a slope that is too steep. Such a slope is unstable because the shear stresses exceed the shear strength of the soil; the soil mass then undergoes excessive deformations and we say that the slope has failed. We can thus see how the shear strength of a given soil deposit determines how steeply one can shape the ground surface without inducing a failure. One way to increase the stability of a soil slope is to construct an artificial support, often some type of earth retaining wall, which contributes to the overall stability of the soil mass. Accordingly, important objectives of this course is to **apply the theory of earth pressures** and use the calculated lateral pressures to **design earth retaining structures**.

We can see that the shear strength of a soil plays a critical role in the evaluation of stability for earth slopes and retaining structures. Remember that the shear strength of soil is greatly affected by water pressures acting within the pore spaces, as expressed in the "effective stress" concept. Experience shows that earth slopes and retaining walls are most likely to fail after periods of heavy rain, indicating the underlying relationship between soil stability and pore water pressures. Accordingly, by the end of this course you should be able to **evaluate the stability of slopes**, which involves assessing the limiting conditions of short-term and long-term stability.

Often, the simplest way to improve the stability of an earth slope or retaining structure is to provide for the free drainage of ground water. Indeed, we are often faced with design problems where the ground water is not stationary, and we do not have hydrostatic pore pressures. When the ground water is moving, evaluating the stability of an earth mass requires an understanding of the resulting pore water pressures at various locations. Hence, in this course you will learn how to **apply hydraulic flow principles** to evaluate the consequences of seepage and drainage on stresses in the soil.

Finally, because the construction of retaining walls, slopes, and other earthworks usually involves the placement and compaction of soil fills, we will also discuss the control of soil compaction in geotechnical construction. Proper placement to achieve a specified minimum density is generally necessary to provide the soil with the strength needed to prevent failures, as well as sufficient stiffness to avoid excessive movements or settlements. Accordingly, you will learn how to **evaluate the engineering properties of compacted soils**.

In addition to our central focus on slopes and retaining structures, we will branch out to cover related questions of similar phenomena as we discuss each of these topics. Finally, while we will develop the technical background to analyze specific problems, the goal of this course will be to **foster a fundamental understanding of applied soil mechanics**. Such knowledge should provide you with the background you will need to address related, but different, problems in geotechnical practice throughout your career.

Schedule

The class will meet for three lectures each week. A tentative schedule and outline of the lecture topics, with planned examination dates, is attached. Because of various national and international committees, meetings and conference, I will have to travel on university-sanctioned business during this semester. I plan to cover these periods by scheduling activities (e.g. presentations, field trips) during the semester. Your help in scheduling these activities is sincerely appreciated.

Attendance

Students are expected to attend all class periods, and I may periodically record attendance. Since the textbook will provide only supplementary information, the lectures are clearly the main source of information to be covered in the homework assignments and exams. Those who regularly miss class are inviting scholastic difficulty and, with the approval of the Dean, may be dropped from the course.

Examinations

There will be two midterm exams, given during the regularly scheduled class time, and a *comprehensive* final examination. Make-up examinations will not be given. Students who miss a midterm exam will receive a grade of zero for that exam. Exceptions to this rule will be made only on a carefully considered basis, and only if the student contacts me *before* the exam. In such cases, your score on the other class exams will count proportionally more in computing your final score.

All exams will be closed-book, closed-notes. However, you are permitted to bring sheets (8.5 x 11 inch) written on one side only, of your *own handwritten* equations to each exam. One sheet will be permitted for the first exam, two sheets for the second exam, and three sheets will be allowed for the final exam. This way, the new sheet you prepare for each exam will be used again for later exams. You may write only equations (no notes, no graphs) on one side of these sheets. Some "formulas" will also be given on the exams. All design charts and similar materials will be provided for during the exam. The organizational effort required to create your equation sheets is an effective means of reviewing the course content before an exam. In addition, you need to bring a straight edge, compass, protractor, and a French curve to the exams.

The final examination will cover all of the material from the semester. According to the university schedule, the final exam will be held from 7:00 p.m. to 10:00 p.m. on Saturday, May 12, 2007.

Homework Assignments

Homework problems will be assigned almost every week of the semester. Extra copies of the assignments, as well as other class handouts, will be placed in the class box outside of ECJ 9.227. Completed assignments are due at the *beginning of class* on the date specified; late assignments will not be accepted for grading.

Homework is intended principally as a means of helping you to learn and understand the course material, rather than as a means of assigning points which directly determine your final grade. The assignments also are aimed at developing your engineering skills. As much as possible, your assignments will reflect real-world engineering practice where one must work with limited data, deal with uncertainty over site conditions, and generate appropriate engineering recommendations. I hope you will find that several of the homework problems are difficult and thought provoking.

Each assignment must be submitted with a cover memorandum. As you will quickly learn after college, most practicing engineers spend more time and effort communicating their ideas, analyses, and results than they do performing technical calculations. A professional engineer's work entails much more than analysis. Hence, all assignments in this class must be submitted with a cover memorandum that briefly discusses your analysis. The cover memo should be typed, addressed to the instructor, and no more than one page long. The text of your memo should:

- Briefly state the purpose of your work (remind the reader of what was requested and what you did).
- Describe the data, material properties, and other information used to solve the problem, including any assumptions you may have used.
- Review important aspects of the problem and your solution.
- Refer to any attached drawings, plots, and other figures and identify the significant information they contain.
- Summarize important results, conclusions, and recommendations.

Attach your calculations, plots, and drawings behind the cover memo. Write your cover memo as if you were submitting your results to a professional client.

Engineering computation paper is recommended for your analytical work (pages torn from a spiral notebook are unacceptable). Data plots and other figures may be drawn with a computer or by hand on graph paper. When needed, neatly draw all sketches and data plots using a straight edge, French curve, compass, etc., and show all relevant labels. When feasible, site plans, schematics, etc. should be drawn to a proportional scale. Failure to submit legible, neat, professional-looking assignments will adversely affect your grade. Above all, present your results clearly and concisely so that someone else, who may be less knowledgeable than you are, can understand and apply your recommendations correctly.

Grading

Your final letter grade will be determined by your performance relative to others in the class. Divisions between grade levels, as well as a likely "class curve", are not pre-determined. In borderline cases your participation and attendance in class will also be considered. Your final score for this course will be computed using the following weights:

Class Assignments	20 %
Midterm Exam # 1	20 %
Midterm Exam # 2	20 %
Final Examination	35 %
Class Participation	5 %
Total	100 %

University Policies and Deadlines

Dropping the course: Students are strongly urged to make any changes in their course schedules during the first week of classes so that other students who wish to add the course can be accommodated. The following policies are in effect for students wanting to drop this course:

- From the 1st through the 12th class day, an undergraduate student can drop a course on ROSE or TEX, and receive a refund.
- From the 13th through the 20th class day, an automatic 'Q' grade is assigned; approval from the Dean and the departmental advisor is required.
- From the 21st class day through the mid-semester deadline, approval is required from the Dean, the course instructor, and the departmental advisor.
- After the mid-semester deadline, drops are not permitted except upon the approval of the student's Dean. "Urgent and substantiated, nonacademic reasons acceptable to the Dean" are required in order to drop a class.

Religious Observances: A student who is absent from a class or examination for the observance of a religious holy day may complete the work missed within a reasonable time after the absence, provided the student has notified the instructor in writing before the absence and not later than the 15th class day.

Students with Disabilities: The University of Texas at Austin provides, upon request, appropriate academic adjustments for qualified students with disabilities. Any student with a documented disability (physical or cognitive) who requires academic accommodations should contact the Services for Students with Disabilities area of the Office of the Dean of Students at 471-6259 as soon as possible to request an official letter outlining authorized accommodations. For more information, contact that Office at 471-6259, TTY at 471-4641, or the College of Engineering Director of Students with Disabilities at 471-4321.

Academic Integrity

Students who violate University rules on scholastic dishonesty are subject to disciplinary penalties, including the possibility of failure in the course and/or dismissal from the University. Since such dishonesty harms the individual, all students, and the integrity of the University, policies on scholastic dishonesty will be strictly enforced. Violations will be reported to the Office of the Dean of Students. For further information, visit the Student Judicial Services web site http://www.utexas.edu/depts/dos/sjs/. Remember, as an engineer, you are held to a high standard of ethical conduct.

All written work submitted for this class *must* be entirely your own. This requirement will be strictly enforced for examinations. In doing class assignments, however, you are encouraged to consult with your fellow classmates regarding the most appropriate solution to a given problem. Still, each student must prepare *his or her own, individual* submission for each assignment. For example, you are permitted to work together in deciding the best approach to a problem, but everyone must work through the entire problem on his or her own. *Identical copies of computations or data plots are not acceptabl*e. Working together on assignments should foster your understanding of the course material; avoid working with other students unless all parties gain from the experience.

Course and Instructor Evaluation

A course and instructor evaluation will be conducted in class at the end of the semester. In addition, I welcome your comments (verbal, written, or e-mail) about the course at any time. Your suggestions for improving the course content or presentation are particularly appreciated, especially if you identify a subject area that may need clarification for the entire class.

Final Comments

Geotechnical engineers often deal with significant uncertainty about the behavior of the soils at a given site, and are frequently asked to solve technical problems that lack simple, definitive answers. As a student, I hope you gain an appreciation for the engineering judgment often required in geotechnical engineering projects and do not become frustrated at the apparent lack of simple solutions or straight-forward answers.

Finally, it goes without saying that your class participation is strongly encouraged. Do not hesitate to raise questions, ask for clarification, or suggest your own ideas during class. You are also invited to submit questions and comments on paper or via e-mail. If some particular lecture topic is confusing and unclear, please ask for clarification. You are explicitly encouraged to see me during office hours for help with specific problems.

Topic Outline and Tentative Schedule **CE 375, Spring Semester, 2009**

Day	Date	#	Planned Lecture	Background Reading	Required Reading	
Wed	Jan 21	1	Introduction			Soil Compaction
Fri	Jan 23	2	Earthwork Quantity Computations		4.3, 6.5	
Mon	Jan 26	3	Laboratory Compaction Tests		6.3-6.4	
Wed	Jan 28	4	Properties of Compacted Soils	13.0-13.3; 13.8; 18.2	13.4-13.7	
Fri	Jan 30	5	Properties of Compacted Soils	13.0-13.3; 13.8; 18.2	13.4-13.7	
Mon	Feb 02	6	Compaction Specifications		6.3-6.4	
Wed	Feb 04	7	Field Compaction Procedures		6.1-6.2	
Fri	Feb 06	8	In-Place Ground Improvement	11.7; 12.1-12.2	19.1-19.6	
Mon	Feb 09	9	Water Seepage through Soils	7.0-7.3	7.4-7.5	Seepage and Drainage
Wed	Feb 11	10	Hydraulic Conductivity	7.0-7.3	7.4-7.5	
Fri	Feb 3	11	Seepage Forces	10.7	10.10; 13.4; 8.4	
Mon	Feb 16	12	Seepage Forces	10.7	10.10; 13.4; 8.4	
Wed	Feb 18	13				
Fri	Feb 20	14	Filters		8.5	
Mon	Feb 23	15	Two-dimensional flow		8.1	
Wed	Feb 25	16				
Fri	Feb 27	17				
Mon	Mar 02	18	Flow Net Solutions		8.1	
Wed	Mar 04	19	Flow Net Solutions		8.1	
Fri	Mar 06	20	Finite Difference Analysis of Seepage		8.1	
Mon	Mar 09	21	Principles of Shear Strength		13.1-13.5;13.8	Slope Stability
Wed	Mar 11	22	**Midterm Exam No. 1**			
Fri	Mar 13	23	Principles of Shear Strength		13.1-13.5;13.8	
			- No Class…Spring Break -			
Mon	Mar 23	24				
Wed	Mar 25	25	Intro to Slope Stability		13.5; 14.1	
Fri	Mar 27	26	Infinite Slope Analysis		14.2 – 14.4	
Mon	Mar 30	27	Analyses with Circular Slip Surfaces		14.4	
Wed	Apr 01	28	Slope Stability Charts		14.4	
Fri	Apr 03	29	Ordinary Method of Slices		14.4	
Mon	Apr 06	30	Other Limit Equilibrium Methods		14.4	
Wed	Apr 08	31	Total and Effective Stress Analyses		14.4	
Fri	Apr 10	32	Slope Stabilization		14.5 - 14.6	
Mon	Apr 13	33	Types of Retaining Walls		16.5	Retaining Structures
Wed	Apr 15	34	**Midterm Exam No. 2**			
Fri	Apr 17	35	Types of Retaining Walls		16.5	
Mon	Apr 20	36	Types of Retaining Walls		16.5	
Wed	Apr 22	37	Intro to Earth Pressures, At-Rest Pressures	10.7	16.1; 16.3	
Fri	Apr 24	38	Rankine Active and Passive Pressures		16.1-16.2	
Mon	Apr 27	39	Rankine Active and Passive Pressures		16.1-16.2	
Wed	Apr 29	40	Coulomb analysis		16.3-16.4	
Fri	May 01	41	External Stability of Retaining Structures		16.5	
Mon	May 04	42	External Stability of Retaining Structures		16.5	
Wed	May 06	43	Internal Stability of Retaining Structures		16.5	
Fri	May 08	44	Cut Walls		16.5	
Final Examination: Monday, May 18, 2009, 9:00 a.m. – 12:00 noon						