CE 375 EARTH SLOPES AND RETAINING STRUCTURES
(Unique No.: 15635)

Spring 2012

Instructor:	Dr. Chadi El Mohtar
Office:	ECJ 9.227B
Office Hours:	- Monday 9:00 AM – 10:30 AM; Room ECJ 9.227B - Wednesday 9:00 AM – 10:30 AM; Room ECJ 9.227B - By appointment: ElMohtar@mail.utexas.edu
Class Hours:	MWF 11:00 AM – 12:00 PM, ECJ 7.208
Prerequisites:	CE 357 (Geotechnical Engineering).
Text:	B.M. Das: Principles of Geotechnical Engineering – Seventh Edition. Thomson Engineering, 2010; ISBN-10: 0495411329
Other Materials:	You will need drawing instruments (compass, protractor, straightedge, etc.) to plot data and other information for homework assignments, laboratory reports and exams. You should always bring these and a calculator to exams unless you are told otherwise.

OBJECTIVES OF COURSE

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, ϕ=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, an important objective 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

A tentative lecture schedule is attached. Reading assignments from your text are indicated on the lecture schedule. You are expected to read the appropriate assignment before the lecture. A list of texts containing introductory geotechnical engineering is provided at the end of this syllabus. If you are having difficulties in this course, you may want to consult some of these texts.

Prepared notes will occasionally be handed out in class to supplement, or in some cases to substitute for, reading material from the book. Be sure to save the notes because you may be examined over some of the material in the handouts.

GRADING

Your grade for this course will be determined on the basis of 800 points as follows:

1. Two midterm examinations (ME), each one about 50 minutes duration, given in class (150 points each)

2. Final examination (FE) (300 points)

3. Homework (HW) (150 points)

4. Class quizzes and participation (50points)

Final grades will be assigned according to the following scale (+ and- will be used to separate students within each letter grade):

A > 90, 80 < B < 90, 70 < C < 80, 60 < D < 70, F < 60

The instructor reserves the right to adjust the final grade cutoffs at the end of the semester; such adjustment would be by assigning lower cutoffs if found necessary (example A>88 instead of 90). Therefore, if you were to get a B, for example, on the grading scale presented above, you would get at least a B on the adjusted scale.

The final exam will be held from 2 PM to 5 PM on May 11th, 2012.

In accordance with University regulations, students who miss examinations will receive grades of zero. Exceptions to this rule will be made only on a carefully considered individual basis, and only if the student contacts the instructor before the exam.

HOMEWORK

Homework problems will be assigned almost every week of the semester. 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 a legible, neat, professional-looking assignment 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.

Important note: Copying solutions is dishonest and will result in at least failing course grade whether such occurs on homework, laboratory reports, quizzes, or exams. All work must be original.

The University of Texas at Austin
Department of Civil Engineering

CE 375
Earth Slopes and Retaining Structures

EXAMPLE COVER MEMORANDUM FOR ASSIGNMENTS

MEMORANDUM

To: Prof. Jorge G. Zornberg

From: C. E. Student A.B.C.

Date: January 19, 2005

Subject: Design of Braced Excavation
Plaza of the Americas, Galveston, Texas

Attached are our design recommendations for the braced excavation at your site in Galveston. Our design earth-pressure diagram, shown on page 5, indicates a uniform horizontal pressure of 1600 psf. If three rows of struts (10 ft vertical spacing) are placed on every soldier pile (5 ft horizontal spacing), each strut should be designed to carry 80 kips of axial compression. The factor of safety against bottom heave is estimated to be 1.2.

The soldier piles should be driven into the firm soil below the clay layer. Care should be taken to avoid excessive settlements in the sands during driving of these piles. In addition, an earth berm should not be relied upon to support the excavation in the clay. Other considerations and problems that should be addressed include:

(1) Timely placement of struts and lagging as the excavation progresses will be critical to minimizing ground movements.
(2) In the first 20 ft of the excavation, it may be difficult to prevent sloughing of sand into the excavation before the lagging can be placed. It will be necessary to have the lagging closely follow the excavation work in this zone to prevent excessive settlements behind the wall.
(3) The upper sands will have to be dewatered to prevent flooding of the excavation, which will result in a time-dependent consolidation of the deeper clays.

Movements adjacent to the excavation will be mostly due to movements within the clay layer. As indicated on page 8, a vertical settlement of 0.4 ft and a horizontal movement of 0.4 ft should be expected in this area. The expected settlement profile shown on page 9 indicates that settlements are likely to be observed at distances up to 60 ft from the side of the excavation. Settlements in excess of 0.4 ft may occur due to the loss of the upper sandy soils into the excavation during construction, and consolidation of the clay due to dewatering.

If you need additional information, or have further questions, please do not hesitate to contact me.

CLASS QUIZZES AND PARTICIPATION

Class quizzes will be given randomly throughout the semester. The quizzes will consist of one of the homework problems submitted in the same week (or part of it). The main purpose of these 5-minute quizzes is to ensure your understanding of the covered material and your ability to demonstrate this individually. Students missing the class without prior notice to the instructor (your notice must be received before the class starts for it to be considered for a valid excuse) would get a zero on the quiz.

Class participation would be accounted for through attendance (checked occasionally and through class quizzes), asking questions in class and participating in class room discussions. Additionally, participating in the midcourse evaluation survey (an anonymous survey to evaluate class progress and make any adjustments if needed) would count towards your class participation grade.

EXAMINATIONS

We will have two midterm exams, of approximately 50 minutes duration each, during the semester, and a comprehensive final exam.

The University of Texas has several rules about examinations that we will follow. For example:

(1) "Students are expected to (a) remain in the examination room until the test is completed; (b) refrain from talking; and (c) leave all notes and books where they are not accessible during the examination unless otherwise directed by the instructor."[i]

(2) There should be a final examination given at the officially scheduled time, which, for this section, is from 2 PM to 5 PM on May 11th. **Do not schedule trips, weddings, etc. at that time.**

Mandatory guidelines (failure to follow them will result in a lower grade):

1) Do not crowd your work.
2) Sketch and label with given data as appropriate.
3) State the quantities to be found.
4) State any assumption you make.
5) Work vertically, do not string equations horizontally. Do not work around figures.
6) Show all major steps in your calculations or reasoning, so it is clear how you proceeded.
7) Underline the answer and be sure to give proper units.

On occasion, students are ill on the day of an examination and are unable to attend. However, no makeup exams will be given for the exams during the semester. Makeup exams take a great deal of time to prepare and, much more importantly, it is virtually impossible to prepare a makeup exam that is equivalent to the regular exam. Regardless of how carefully one attempts to prepare a makeup exam either the student taking the exam or the other students in the class are given an unfair advantage. Instead of a makeup exam, if you miss an hour exam during the semester you will be graded on the basis of the exams which you have taken as follows: A grade for the exam

[i]From The University of Texas at Austin 2002-2003 General Information catalog

that you missed will be estimated based on how you did on the other exams (includes the final exam) relative to the rest of the class. For example, if you scored twelfth among thirty students on the exams that you took, you will be given a grade for the exam that you missed that would place you twelfth among the students who took the exam that you missed. If you miss an exam for reasons other than illness, serious, disabling injury or other valid excuse, you will be assigned a grade of zero. If you miss an exam due to illness, you may be asked to present evidence that you were, in fact, ill. If you must miss an exam, you must inform the instructor in advance of the time that the exam is given that you will miss the exam.

University class work should be given precedence over other activities, so do not plan trips or other such activities and then say you can't attend an exam.

If you have questions about the grading on exams, please see your instructor immediately. Grades on exams will only be reconsidered if brought to the attention of the instructor within one week after the date the exam is returned to the class. This is necessary because it is very difficult to remember exactly how partial credit was assigned to ensure that all grading is done on the same basis. You should be able to determine if there is a problem within the first day or two and act accordingly. No exceptions will be made to the above policy because you missed class and did not pick up your exam the day it was returned.

ATTENDANCE

Students are expected to attend all class periods. Those who fail to attend class regularly are inviting scholastic difficulty and, with the approval of the Dean of the College of Engineering, may be dropped from the course with a grade of F for repeated (5 or more) unexcused absences.

Homework assignments and other material will only be collected and distributed in class.

COURSE/INSTRUCTOR EVALUATION

A formal course/instructor evaluation will be conducted in class near the end of the semester. This would be your chance to bring up any concerns about the course and the way the class is conducted and highlight the positive aspects and what worked for you.

DROP POLICY

From the 1st through the 12th class day, an undergraduate student can drop a course via the web and receive a refund, if eligible. From the 13th through the university's academic drop deadline, a student may Q drop a course with approval from the Dean, and departmental advisor. After the academic drop deadline has passed, a student may drop a course only with Dean's approval, and only for urgent, substantiated, non-academic reasons.

Poor performance in the course is not an acceptable reason for dropping. Students are strongly urged to make any changes in their course schedules during the first week of classes so that other students who need to add the course(s) can be accommodated.

STUDENTS WITH DISABILITIES

The University of Texas at Austin provides upon request appropriate academic accommodations for qualified students with disabilities. For more information, contact the Division of Diversity and Community Engagement, Services for Students with Disabilities, 471-6259 (voice) or 232-2937 (video phone) or http://www.utexas.edu/diversity/ddce/ssd .

FINAL COMMENT

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 straightforward 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 email. 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.

SUPPLEMENTAL REFERENCE LIST

Most of the following books are available at either the Engineering Library, or the Geology Library. Please consult them if you have difficulties in the course.

Das, B.M., Fundamentals of Geotechnical Engineering, 2nd Edition, Nelson/Thomson, 2005.

Cernica, J.N., *Geotechnical Engineering*, (1994)

McCarthy, Essentials of Soil Mechanics and Foundations – Basic Geotechnics, Prentice-Hall, 4th Ed. (1993), 5th Ed. (1998), 6th Ed. (2002)

Sowers, G.F., *Introductory Soil Mechanics*, 4th Ed., (1979)

Holtz, R. and Kovacs, W., *An Introduction to Geotechnical Engineering*, Prentice-Hall (1981).

Lambe, T.W. and Whitman, R., *Soil Mechanics*, John-Wiley and Sons (1979)

CE 375 - TENTATIVE OUTLINE AND SCHEDULE – Spring 2012

Period	Date	Topic	HW	Required Reading	
1	W 01/18	Introduction			Soil Compaction
2	F 01/20	Introduction: Weight-Volume Relationships		3.1-3.4	
3	M 01/23	Earthwork Quantity Computations	1		
4	W 01/25	Laboratory Compaction Test		6.1 – 6.5	
5	F 01/27	Properties of Compacted Soils I		6.6	
6	M 01/30	Properties of Compacted Soils II	2	6.6	
7	W 02/01	Compaction Specifications		6.8	
8	F 02/03	Field Compaction Procedures		6.7, 6.9	
9	M 02/06	Water Seepage through Soils		7.1 – 7.2	
10	W 02/8	Hydraulic Conductivity		7.3, 7.4, 7.8 - 7.10	Seepage and Drainage
11	F 02/10	2-D Flow		8.1	
12	M 02/13	Flow Net Solutions I	3	8.3	
13	W 02/15	Flow Net Solutions II		8.4	
14	F 02/17	Filters		8.10	
15	M 02/20	Seepage Forces I	4	8.1 -8.7, 9.1 – 9.6	
16	W 03/22	Seepage Forces II		8.1 -8.7, 9.1 – 9.6	
17	F 02/24	Seepage Forces III		8.1 -8.7, 9.1 – 9.6	
18	M 02/27	Finite Difference Analysis of Seepage	5		
19	W 02/29	Principles of Shear Strength I		12.1 – 12.12	
20	F 03/02	Catching up/MTE Review (time permitting)			Slope Stability
21	**M 03/05**	**Midterm Exam 1**			
22	W 03/07	Principles of Shear Strength II	6	12.1 – 12.12	
23	F 03/09	Principles of Shear Strength III		12.1 – 12.12	
24	M 03/19	Introduction to Slope Stability Analysis	7	15.1-15.3	
25	W 03/21	Analysis with Circular Slip Surfaces		15.6	
26	F 03/23	Slope Stability Charts I		15.9	
27	M 03/26	Slope Stability Chart II	8	15.9	
28	W 03/28	Method of Slices I		15.7 – 15.13	
29	F 03/30	Method of Slices II		15.7 – 15.13	
30	M 04/02	Short/Long Term Stability Analyses	9	15.7	
31	W 04/04	Slope Stabilization			

32	F 04/06	Catching up/MTE Review (time permitting)			Retaining Structures
33	**M 04/09**	**Midterm Exam II**			
34	W 04/11	Types of Retaining Walls I	10	13.14	
35	F 04/13	Types of Retaining Walls II		13.14	
36	M 04/16	Introduction to Earth Pressures	11	13.1 – 13.3	
37	W 04/18	Rankine Active and Passive Pressures I		13.4	
38	F 04/20	Rankine Active and Passive Pressures II		13.5	
39	M 04/23	Coulomb Earth Pressures		13.10 – 13.12	
40	W 04/25	Other Analysis Methods/Final Thoughts			
41	F 04/27	External Stability of Retaining Structures I			
42	M 04/30	External Stability of Retaining Structures II			
43	W 05/02	Internal Stability of Retaining Structures			
44	F 05/04	Q/A session for the Final Exam/Course			
	05/11	**Final Exam (2 PM – 5 PM)**			