Geotechnical engineering education in METU and computer aided learning resources

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ABSTRACT: In this paper, the state-of-practice in undergraduate geotechnical engineering (Soil Mechanics and Foundation Engineering) education in the Department of Civil Engineering of the Middle East Technical University (METU CE) is given. The use of computers in undergraduate courses is becoming a more widespread form of teaching in geotechnical engineering education. This paper also presents a list of web resources (e.g. PC Programs, web-based resources, cd-rom resources) currently available in geotechnical engineering education. An approach is proposed for the delivery of these courses by mixing traditional methods such as lectures, laboratory work and text books with interactive on-line learning resources (web based resources and cd-rom resources).

1 INTRODUCTION
Civil Engineering program in the Middle East Technical University (METU CE) is 4-years program leading to B.S. degree (http://www.metu.edu.tr). The curriculum of the Civil Engineering Department is planned to provide a sound professional education for the students (http://www.ce.metu.edu.tr). The undergraduate program in Civil Engineering was evaluated by ABET (Accreditation Board for Engineering and Technology) in 1996 and 2004.

2 THE STATE OF PRACTICE IN UNDERGRADUATE GEOTECHNICAL ENGINEERING EDUCATION IN METU CE
The first geotechnical course (CE 363 Soil Mechanics, 3rd year, 1st semester course in METU CE) in most civil engineering curricula includes a significant laboratory component along with traditional lecture based learning. This has been the model for decades. The course content of the Soil Mechanics course is: Introduction, Basic Properties of Soils, Effective Stress, Seepage, Consolidation Theory, Shear Strength, Lateral Earth Pressure, and Stability of Slopes.

Students are strongly advised to acquire a copy of the proposed text-books. For example, the chapter layout of Budhu (2000) (one of the proposed text books) is as follows: The introduction of each chapter attempts to capture the student’s attention, to present the learning objectives, and to inform the student on what prior knowledge is needed to master the material. At the end of the introduction, a sample practical situation is described. The intention is to give the student a feel for the kind of problem that he/she should be able to solve on completion of the chapter. (Example for soil compaction: When you complete this chapter you should be able to: determine maximum dry unit weight and optimum water content. Sample practical situation: “A highway is proposed to link the city of Noscut to the village of Windsor Forest. The highway route will pass through a terrain that is relatively flat and is expected to be flooded by a 100 year storm event. The highway will be supported on an embankment constructed from soils trucked to the site from two possible pits…”. Definitions of maximum dry unit weight and optimum water content are given. At the end of the chapter, a problem similar to the sample practical situation is solved.

The format for delivering the undergraduate Soil Mechanics course is three hours of lecture per week over the period of one semester, accompanied by a one credit our weekly laboratory session. The average size of the class lecture sections is 40 students. The typical lab section held 7-10 students. Teaching assistants and technical staff attend the laboratory sections.

The undergraduate soil mechanics laboratory is an opportunity for civil engineering students to investigate soil behavior in a controlled experimental setting. All of these may already be covered in a soil mechanics course in the lecture portion, but are still worth noting as a consideration for hands-on learning in the laboratory.

Laboratory work covers the following tests: sieve analysis; Atterberg limits, determination of specific gravity of solids, dry density, hydrometer test, compaction test, unconfined compression test, unconsolidated-undrained triaxial test, direct shear
test, laboratory vane test, consolidation test, and constant head permeability test.

There is a good quality geotechnical laboratory testing manual available (Mirata, 2001), the manual is a simplification of Turkish Standard, British Standard and ASTM. The manual is straight forward with easy to follow steps, nice diagrams that help the students understand the purpose of the laboratory exercise and how to calculate the results. Lab reports are required one week after the lab session.

The second course offered in Geotechnical Engineering is the CE 366 Foundation Engineering course (3rd year, 2nd semester course in METU CE), the Foundation Engineering course content is: Introduction, Stress Distribution in Soils, Site Investigation, Settlement of Structures, Bearing Capacity of Soils, Design of Shallow Foundations, Retaining Structures - Excavations, Pile Foundations.

The format for delivering the undergraduate Foundation Engineering course is two hours of lecture per week over the period of one semester, accompanied by a one credit our weekly design session.

The average size of the class lecture and design sections is 40 students.

Students are strongly advised to acquire a copy of the proposed text-books.

Design exercises are about the following subjects: Site Investigation, Settlement, Bearing Capacity, Shallow Foundations, Retaining Walls, and Pile Foundations.

The spread-sheet and word processing programs are used to aid calculations and presentations in these courses.

Site visits are made in Foundation Engineering course (e.g. site investigation, deep foundations, retaining wall).

In these courses, in addition to understanding the fundamentals of soil mechanics, students need to develop the analytical and creative thinking skills to solve the problems typical of foundation engineering.


In these courses, in addition to midterm examinations and other work, students are required to take a final examination. At least one midterm examination is given during each semester.

Like in many universities, our university considers that Soil Mechanics and Foundation Engineering courses are sufficient for an undergraduate degree in Civil Engineering.

3 COMPUTER AIDED LEARNING RESOURCES IN SOIL MECHANICS AND FOUNDATION ENGINEERING

Internet based teaching tools may be used for delivering soil mechanics and foundation engineering courses. Computer enhanced classrooms/visual presentation may help the students to better understand the subjects.

Resources Currently Available: PC Programs, Cd-rom resources, Web-based resources

3.1 PC programs

CATIGE (Computer Aided Teaching in Geotechnical Engineering) for windows, (http://www.civeng.adelaide.edu.au/CATIGE) is a suite of fifteen windows based programs written for undergraduate students to assist in teaching and learning of fundamental soil mechanics and foundation engineering principles (Figure 1).

Figure 1. An example page of CATIGE (Computer Aided Teaching in Geotechnical Engineering) for windows.
SLOPE/W (Student version) (http://www.geoslope.com) uses limit equilibrium theory to compute the factor of safety of earth and rock slopes. The student edition is a limited version of the complete full-featured software and can only be used for educational and learning purposes.

3.2 Cd-rom resources

The CD-Rom (Budhu 2000) contains the fundamentals of soil mechanics and foundation engineering with soil mechanics virtual laboratory. Users learn to understand the index properties of soils, soil strength, soil deformations, etc.

According to Budhu (2000) with the advent of personal computers, learning has become more visual. Some studies have reported that visual images have improved learning by as much as 400%. The textbook (Budhu 2000) is accompanied by a CD ROM that contains text, interactive animation, images, a glossary, notation, quizzes, notepads, and interactive problem solving (Figure 2).

![Figure 2. Dry unit weight- water content curves (Budhu 2000)](image)

Michael Kalinski of the University of Kentucky has written a lab manual (2006) introducing students to the most common soil mechanics tests, and has included laboratory exercises and data sheets for each test. Each test described in this manual has an associated ASTM standard number. Brief video demonstrations are also available in CD for each of the experiments described in this manual (Figure 3).

![Figure 3. Trimming excess soil from the top of the mold using the cutting bar, after compacting soil in the mold (Kalinski 2006).](image)

3. 3 Web-based resources

Software has been and continues to be developed to permit students to simulate the testing process in a virtual environment Budhu (2000). Virtual tests can be a valuable learning tool. In particular, virtual tests can provide students with some experience before performing an actual test. In addition, the use of virtual tests can be a substitute when laboratory equipment, expertise, or time to perform an actual test is unavailable. Some examples include Budhu (2000) and Sharma and Hardcastle (2000). Animated simulations that cover the various basic laboratory experiments in geotechnical engineering are provided. Some of these animations demonstrate typical laboratory tests (e.g. particle size distribution using sieve analysis, Proctor compaction test, oedometer test, direct shear test etc.) while others simulate geotechnical processes (e.g. groundwater flow, deposition of soil particles, etc.) or provide analytical tools (e.g. Mohr circle). Although actual hands-on experiences in the laboratory are essential for teaching basic soil mechanics, the use of virtual labs can be used as a supporting material.

An internet site, which lists an extensive source of links to geotechnical engineering software, is provided by the Geotechnical and Geoenvironmental Software Directory (http://www.ggsd.com) which also provides a list of educational links.

Dr. Nagaratnam Sivakugan from James Cook University, Australia has a web site (http://eng.jcu.edu.au/research/compgeo/geores.html) which contains PowerPoint slideshows on: Introduction to Geotechnical Engineering (12 minutes), Phase Relations (7 minutes), Soil Classification (8 minutes), Clay Mineralogy (15 minutes), Compaction (10 minutes) (Figure 4), Permeability (17 minutes), Consolidation (17 minutes), Shear Strength (17 minutes), Lateral Earth Pressures (18 minutes). And some lecture notes on: Phase Relations, Soil Classification, Effective stresses & Capillary, Permeability and Seepage.

Figure 4. Field compaction (Sivakugan 2004)

Prof. Ross W. Boulanger has a web site (http://cee.engr.ucdavis.edu/faculty/boulanger/geo_photos_album/GeoPhoto.html) which contains photographs on the following subjects: Compaction (Figure 5), Earthquake hazards, Embankment dams, Erosion & piping, Excavations, Experimental facilities, Foundations - Deep, Foundations - Shallow, Ground improvement, Landslides, Offshore structures, Retaining structures, Site characterization, Underground structures.

Figure 5. Field compaction (Boulanger 1995)

Educational Geo Engineering web sites are given in (http://www.geoengineer.org/learnbyhy.html) gives links to the web sites related with the following topics: Soil Mechanics, Shallow and Deep Foundations, Geotechnical Earthquake, Dam Engineering, Highway Engineering, Slope Stability, Retaining Walls and Deep Excavations, Site Characterization, Laboratory Testing.

University of Illinois at Chicago, CEMM315 Soil Mechanics Laboratory web site (http://www.uic.edu/classes/cemm/cemmlab/) by Prof. Krishna Reddy gives the detailed description of the following soil mechanics laboratory tests: Water Content, Organic Content, Unit Weight, Specific Gravity, Relative Density, Grain Size Analysis, Atterberg Limits, Visual Classification, Moisture-Density Relationship (Compaction) (Figure 6), Hydraulic Conductivity (Permeability), Consolidation, Shear Strength (Direct Shear), Shear Strength (Unconfined Compression), Shear Strength (Triaxial Shear).

Figure 6. Laboratory soil compaction test (Reddy, 2007)

In Prof. Robert Holtz web site (http://www.ce.washington.edu~geotech/courses/cee366/holtz/cive366win00.html) the details of the following laboratory tests are given: Sieve Analysis, Atterberg Limits, Compaction, Permeability, Consolidation, Direct-Shear, Triaxial test, Undrained Shear.

In Prof. Bengt B. Broms’ web site on Foundation Engineering (http://www.geoforum.com/knowledge/texts/broms/viewpage.asp?ID=1) the text book knowledge is
given on the following topics: Aspects of foundation engineering, Soil mechanics (Figures 7, 8), Geotechnical field investigations, Bearing capacity of foundations, Foundation settlements, Factors to consider in foundation design, Spread footing design, Special footings and beams on elastic foundations, Mat foundations, Lateral earth pressure, Soil retaining structures, Pile foundations - Single piles, Single piles - Dynamic analysis, Pile foundations - Pile Groups.

![Figure 7. Proctor compaction test (Broms web site)](image1)

![Figure 8. Compaction curves (Broms web site)](image2)

In University of the West of England web site (http://fbe.uwe.ac.uk/public/geocal/SoilMech/basic/soilbas.htm) Soil Mechanics lecture notes are available on the following subjects: Analysis of stress and strain, Strength, Stiffness, Material behavior.


![Figure 9. Effects of compaction moisture content and energy (Benson 2005)](image3)

![Figure 10. Compaction curve and effect on permeability (Benson 2005)](image4)

In the “Engineering Ethics” web site (http://ethics.tamu.edu/), ethics case studies for undergraduate civil engineering courses are given (some of them are related with geotechnical engineering, e.g. trench boxes and the construction site).
4 CONCLUSIONS

The state-of-practice in undergraduate geotechnical engineering education is given. Today’s students are using computers and internet and obtain some of their information from them. It is likely that, in the future, computer aided learning will play a more prominent role in teaching and learning practices than at present. This is due to the continued falling costs of computer hardware, the increasing presence of the internet. In addition, it seems certain that many more online courses, simulations and virtual laboratories will be offered over the internet. Geotechnical engineering courses may be delivered better by mixing traditional methods such as lectures, laboratory work and textbooks with computer aided learning resources.

REFERENCES

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