HANDS-ON GEOTECHNICAL ENGINEERING AT THE UNDERGRADUATE LEVEL

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INTRODUCTION

Defining the characteristics of a subsurface profile is a challenge that is unique to geotechnical engineering. It is important, therefore, that aspiring geotechnical engineers have knowledge of site exploration strategies and sampling techniques before entering professional practice. In most undergraduate geotechnical programs, students are taught these topics using textbooks and/or videotapes. This practice is often frowned upon by industry professionals since the students are unable to get a true feel for the work and thought involved in a typical site investigation.

A primary goal of the geotechnical engineering program at Cal Poly, San Luis Obispo is to integrate field and laboratory experiences into the undergraduate curriculum using a hands-on approach. The faculty of the geotechnical engineering program believe that students must have a complete understanding of geotechnical exploration practices if they are to appreciate the judgment required in geotechnical analysis and foundation design. Described in this paper is the geotechnical engineering program at Cal Poly. Emphasized are experiences that the program has had incorporating field and laboratory testing procedures into the undergraduate curriculum. A brief discussion focuses on technical and financial support from industry that has helped to enhance the program.

BACKGROUND

California Polytechnic State University, San Luis Obispo

California Polytechnic State University (Cal Poly), San Luis Obispo is one of the twenty-three (23) campuses of the California State University, the nation's largest four-year university system. Cal Poly's primary mission is undergraduate education, and it specializes in preparing its 15,000 students for careers in applied professional and technical fields.

Cal Poly's College of Engineering has been consistently identified as one of the nation's top state-funded engineering programs. Its "learn by doing" motto, while cliché to some, is taken very seriously by the students, faculty, and staff. Undergraduates are required to take numerous laboratory classes as well as a two-quarter, capstone senior research/design project. The hands-on experience gained in these activities stimulates self-discovery and creativity while preparing students for the rigors of professional practice.

Civil and Environmental Engineering Department

The Civil and Environmental Engineering (CEEN) Department is housed within the College of Engineering. The department provides approximately 750 undergraduates with a theoretically sound, practice-oriented education. Taught by 18 tenured and tenure-track faculty and several local professionals, the program consists of 210 quarter units with courses in each of the five traditional civil engineering sub-disciplines: environmental, geotechnical, structural, transportation, and water resources engineering. Laboratory-based instruction accounts for 21 units of the required curriculum.

Geotechnical Engineering Program

The geotechnical engineering program administered by the CEEN Department has been recognized as one of the top undergraduate programs in California. Cal Poly students have received over 10% of all International Association of Foundation Drilling (ADSC) scholarships awarded since 1990. In addition, Cal Poly students have received the California Geotechnical Engineers Association (CGEA) annual Outstanding Graduating Senior Award four of the past eight years (1990, 1991, 1992, and 1995).

Undergraduate CEEN students are required to take one course and one laboratory in basic geotechnical analysis. A student interested in geotechnical engineering may then choose from eight geotechnical engineering electives offered by the department (Table 1). Shallow and deep foundation design, slope stability analysis, geotechnical earthquake engineering, and earth pressure theory are among the topics covered in the elective courses.

Table 1: Geotechnical engineering courses offered at Cal Poly.

Course Number	Title	Quarter Units	Associated Laboratory
CE 381	Introduction to Geotechnical Engineering	4	N
CE 382	Geotechnical Engineering Laboratory	1	Y
CE 481	Analysis and Design of Shallow Foundations	4	Y
CE 482	Conventional Subsurface Exploration	4	Y
CE 581	Advanced Geotechnical Engineering	4	Y
CE 582	Advanced Geotechnical Testing	4	Y
CE 583	Geotechnical Earthquake Engineering	4	N
CE 584	Lateral Support Systems	4	N
CE 585	Slope Stability Analysis	4	N
CE 586	Analysis and Design of Deep Foundations	4	N

High undergraduate student enrollments are typical in the geotechnical courses. Figure 1 illustrates the enrollment trend for these courses over a ten year period. The figure shows that an average of approximately 300 undergraduate students enroll in geotechnical analysis and design courses each year.

Figure 1: Enrollment in geotechnical engineering courses at Cal Poly.

The geotechnical engineering program is directed by two full-time faculty and one part-time lecturer who practices geotechnical engineering in the San Luis Obispo area. Each of the geotechnical courses are well supported by members of the professional community who serve as guest lecturers and participate in the development and evaluation of student design projects.

EXAMPLES OF THE HANDS-ON APPROACH

Laboratory Instruction

The engineering curriculum at Cal Poly is laboratory intensive. As shown in Table 1, five of the ten geotechnical engineering courses have a laboratory component. The geotechnical laboratories are commonly held in the field, in one of two well-equipped teaching labs, or in one of two modern computer-aided design studios. During a typical ten-week quarter, a laboratory course will have six to eight organized lab sessions, each lasting anywhere from two to three hours. The lab sessions, designed with help from industry, simulate situations that students will eventually see in professional practice. Required laboratory reports or term projects are modeled after project reports provided by outside geotechnical engineering consultants.

Field Testing

Since 1986 the geotechnical engineering program has owned a trailer-mounted cone penetrometer testing system. The system was originally supplied with two cones, a flat-plate dilatometer, and an electronic data acquisition system. Recently, the data acquisition system was upgraded using funds provided by a National Science Foundation Division of Undergraduate Education grant (DUE #9751318). The new state-of-the-art system has both piezo-cone and seismic cone capability.

Traditionally, the cone penetrometer and flat-plate dilatometer testing systems have been used in the Advanced Geotechnical Testing course (CE 582). Students in this course spend much of their time in the field performing cone penetrometer and dilatometer tests under the direct supervision of faculty. Four or five person laboratory groups are used so that each student receives hands-on experience with the equipment. Data and soil samples retrieved during field exploration are examined as part of detailed design projects. The design projects teach the students how to plan and complete subsurface investigations, interpret field test data, and design simple foundation systems.

Student evaluations indicate that this course is very well received. Last year, the instructor of the course received an overall rating of 3.9/4.0 during student evaluations. Some example student comments taken from these same evaluations are included below.

"I learned a lot in this class."

"Nice to learn about field methods that we are not exposed to in the classroom."

"Great course, should be offered in the future."

"I finally understand CE 381 and CE 481, thanks."

Based on the above comments and individual conversations with the students, the hands-on, start-to-finish approach appears to be the most attractive element of the geotechnical testing course.

Recently, Foremost/Mobile of Indianapolis, Indiana agreed to provide Cal Poly with a completely refurbished Mobile B-53 Explorer drill rig at a substantially reduced cost (Figure 2). Funds required to purchase the rig and tooling were obtained from the National Science Foundation's Division of Undergraduate Education, numerous Cal Poly geotechnical engineering alumni, the ADSC West Coast Chapter, the CEEN Department, the College of Engineering, and Cal Poly. The rig was mounted on a truck donated by Anderson Drilling of San Diego, California, a prominent member of the ADSC West Coast Chapter. Tooling for the rig was provided by Foremost/Mobile through Drilling and Trenching Supply, also a member of ADSC.

Figure 2: Cal Poly's truck-mounted drill rig.

The drill rig will significantly enhance the education of Cal Poly's civil and environmental engineering undergraduates by providing them with a means for acquiring hands-on training in conventional subsurface exploration and field testing. The drill rig, in combination with the cone penetrometer, will provide Cal Poly students with unparalleled and unprecedented exposure to all aspects of real-world geotechnical investigation, analysis, design, and construction.

During the current academic year, the drill rig is being used on a trial basis by a group of five senior project students. The students are in the process of establishing a 1 acre field experiment site on the Cal Poly campus. By the end of this year, the site will have been fully characterized using the drill rig and cone penetrometer. The experiment site will eventually serve as a field laboratory. Students in undergraduate courses will be able to use the experiment site for design projects and other course assignments.

Next year, it is planned to introduce the drill rig to the entire civil and environmental engineering student body. Site exploration and sampling methods will be demonstrated during two laboratory sessions of CE 382, a junior-level course. Subsequent lab testing in the course will be completed using soil specimens obtained during the initial field exercises. The objectives of the initial field exercises will be to introduce the geotechnical testing equipment, to illustrate site exploration practices, and to stimulate interest in the geotechnical engineering field.

The drill rig will also be used in several other courses. The drill rig will allow students in the shallow and deep foundations courses (CE 481 and CE 586) to complete start-to-finish spread footing, driven pile, and drilled shaft designs. The drill rig will be used exclusively in a new course entitled Conventional Geotechnical Field Testing (CE 482) where several field exercises will help to compare and contrast different drilling and sampling techniques. In the Advanced Geotechnical Testing course (CE 582), which to date has focused solely on cone penetrometer (CPT) and flat-plate dilatometer (DMT) testing, students will be able to perform side-by-side CPT and SPT (standard penetration) testing. Finally, in the Geotechnical Earthquake Engineering course (CE 583), students will have the opportunity to perform SPT tests to provide the data necessary for state-of-the-art liquefaction analyses.

Industry Participation

The geotechnical faculty at Cal Poly serve two sets of clients: the students -- who seek instruction in the theory and practice of civil analysis, design, and construction -- and the professional community -- who seek students with the ability and willingness to "hit the ground running" upon graduation. Continued, direct interaction between these two sets of clients is vital. At Cal Poly, face-to-face communication is fostered by inviting the professional community to participate in the instruction of the students. Approximately 10% of the lectures in each geotechnical course are delivered by highly respected practitioners. Most of these seminars are case-study type presentations that emphasize the application of analysis and design procedures that have been introduced in earlier traditional lecture-type presentations. On occasion, practitioners are invited to prepare a realistic design exercise for the students to complete as a homework problem. Normally, these exercises are a limited-scope version of a recent project from the visitor's own practice. In one instance, the students enrolled in the Slope Stability course (CE 585) were required to respond to a request for geotechnical services that focused on the development of practical remediation alternatives for a local active landslide.

The problem statement was delivered to the students on a Saturday morning by three representatives (one Principal and two Project Engineers) from the participating firm (who assumed the role of the client). The problem statement included (1) geologic and topographic maps of the site, (2) a budget, (3) a fee schedule that fixed the hourly rate of each class of personnel (Office Assistant, Lab Technician, Staff Engineer, Geologist, Project Manager, etc.) as well as the unit cost of all conventional field and laboratory procedures, (4) the required scope of work, and (5) the required deliverables. The students were subdivided into five-person "consulting firms" and driven to the site of the landslide (some 20 miles from the campus). After receiving a short 15-20 minute on-site briefing, the students were given two hours to inspect the site and the adjacent residential neighborhood (see Figure 3). The course instructor, the three visiting practitioners, and the site's owner all remained on hand to respond to student queries.

The competing student-firms were given three days to develop and submit a preliminary report that defined the field investigation (exploratory boring locations and depths), laboratory testing, and field instrumentation programs to be undertaken, should the firm be awarded the contract. Each student-firm was then supplied with the array of geotechnical data (boring logs, lab data, inclinometer profiles) that would be obtained through the field/lab investigation programs specified in the firm's preliminary report.

Figure 3: Visit to the site of a landslide during the slope stability course.

The field and laboratory test data distributed to the students was derived from a model of the site that had been developed as part of an actual contract with the site's owner. With this data in hand, the student-firms were given one additional week to develop and submit a final proposal for remediating the landslide that included (1) a best-estimate of the subsurface stratigraphy, (2) estimates of the safety factor for both the existing and remediated slopes, and (3) a qualitative discussion of the probable environmental impacts of the remediation project. Needless to say, this project was an extremely well-received and worthwhile experience.

INDUSTRIAL SUPPORT FOR THE PROGRAM

The number of scholarships and job offers received by Cal Poly graduates interested in geotechnical engineering indicates that industry supports the hands-on approach. Many practitioners recruit almost exclusively at Cal Poly because of the practice-oriented education that its graduates have received. Interest by the professional community in the Cal Poly geotechnical engineering program has led to tremendous cooperation and support. As discussed, representatives from industry often serve as guest lecturers and participate in the development and evaluation of student design projects. Support is not only technical, however. Recently, representatives from industry have also provided the program with a limited amount of financial support. The drill rig acquisition is an excellent example.

The drill rig was obtained because of the initiative of the West Coast Chapter of the International Association of Foundation Drilling (ADSC). Two years ago the geotechnical engineering faculty asked the West Coast Chapter for assistance in finding a field exploration rig for the geotechnical engineering program. The West Coast Chapter agreed to help and eventually provided the program with a lead on a refurbished drill rig, a truck to mount the drill rig on, and several thousand dollars in funding.

Funding provided by the ADSC West Coast Chapter was combined with contributions from the CEEN Department, the College of Engineering, and Cal Poly and used as matching funds for a National Science Foundation Instrumentation and Laboratory Improvement grant. Sufficient matching funds were not collected, and a fundraising campaign was therefore initiated.

Over an eight month period, Cal Poly alumni working the field of geotechnical engineering and consulting firms practicing in the geosciences were asked to contribute cash to the drill rig project. Potential donors were first contacted by phone. Then, letters were sent detailing the geotechnical engineering program, the drill rig, and proposed curriculum improvements. The response to this solicitation was overwhelming. During an eight month period, nearly \$8,000 in funding was raised which allowed the project to proceed toward completion.

SUMMARY

A hands-on approach is being used to teach geotechnical engineering to undergraduate students at California Polytechnic State University, San Luis Obispo. Summarized in this paper is the hands-on curriculum developed by the faculty of the geotechnical engineering program. It is emphasized that the objective of the curriculum is not to train the students to be drill rig operators or laboratory technicians. Rather, the objective is to teach students to realize the judgment and creativity required in geotechnical engineering. Practice-oriented field and laboratory exercises combined with open-ended design projects are successfully being used to help foster this judgment and creativity. The success has been validated by positive student evaluations and by the number of geotechnical engineering firms recruiting Cal Poly undergraduates instead of M.S. level graduates from other respected schools.

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