Integrating an Outdoor Soils Lab into Traditional Geotechnical Education

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Abstract – Traditional geotechnical education programs do not lend themselves to field activities, but normally rely on laboratory experiences to reinforce theoretical concepts and physical properties introduced in the classroom. In assessing the traditional geotechnical program at The Citadel, it was determined that field or outdoor laboratory activities be incorporated in order to address several EC 2000 criteria (3.c and 3.k) in how the students should be able to design a foundation system to meet desired needs and their ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. In response to this assessment, geotechnical fieldwork, in the form of an Outdoor Soils Laboratory (OSL), was incorporated into a traditional classroom/laboratory geotechnical program. This involved integrating three aspects of instruction (the classroom, the laboratory, and the field activities) in an effort to develop a more complete learning experience for the students. The design/construction process of field investigation, laboratory analysis, design, and construction operations was used to provide contextual learning opportunities. The integration of these aspects, along with specific student activities, will be presented.

Keywords: geotechnical, engineering, outdoors, soils, laboratory, constructivist

INTRODUCTION

This paper describes a unique outdoor soils laboratory that provides students with an opportunity to experience field testing using state-of-the-art equipment and to interact with geotechnical experts and technicians. It illustrates how, on a limited budget, students can be provided with a learning opportunity that goes beyond the classroom and laboratory. This paper also addresses actions taken to improve students' understanding of the design/construction process by introducing significant geotechnical field experiences. This paper should be of particular interest to faculty in Civil Engineering.

The Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (EAC/ABET) [1] identifies the basic criteria for all engineering programs. Within these requirements, Criterion 3, Program Outcomes and Assessment, prescribes eleven specific criteria for graduates of engineering programs to be able to demonstrate. Of these eleven criteria, two attracted particular interest when performing an internal annual assessment of the geotechnical engineering courses at The Citadel. Criteria 3.c expects the graduate to demonstrate their "ability to design a system, component, or process to meet desired needs." In a similar vein, Criteria 3.k asks that the graduate demonstrate "an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice." In addressing these criteria, it was identified that field experiences may play a significant role in the early career of a civil engineer and, possibly, throughout their career. For students who lacked field experience, the knowledge gap between the design and construction of a structure needed to be addressed through exposure to field operations.

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This assessment took place within what is viewed as the traditional geotechnical coursework and learning environment. At The Citadel, in the first semester of a student's senior year, geotechnical concepts and principles are presented in an introductory geotechnical engineering course. The next semester, students have their geotechnical laboratory course as a co-requisite to their second geotechnical, or foundations, course. The student is introduced to the course material in the classroom and what follows is the applicable or related laboratory investigation. This "two-step" process serves to reinforce a student's understanding of soil properties and their ability to design and or analyze foundations. But, the question remains, "Does it adequately address ABET Criterion 3.c and 3.k?"

The answer to this question revealed itself in a three-part solution of integrating the classroom, the laboratory, and structured field experience to provide a deeper and more valuable learning experience. The purpose of this integrated solution was to address the need to get students to think like and to begin performing like geotechnical engineers. This challenge resulted in a constructivist learning approach that attempted to emulate the design process as practiced by our constituents from industry and addressed ABET Criterion 3.c and 3.k. by providing applicable field experiences. This paper discusses that approach.

BACKGROUND

Where do civil engineering undergraduates at The Citadel have the opportunity to see, understand, or learn about what could most likely be a significant part of their early career – field operations? Site investigation, site reconnaissance, activities related to soil exploration, and typical field records are generally found in accepted geotechnical textbooks [2-4]. Engineering journals either directly or indirectly ascribe to the subject. Presentations by interns from a summer hire program and presentations by junior design engineers often make references to geotechnical field activities. Field trips to construction sites and presentations by junior engineers describe their daily activities and the engineering connection between geotechnical data determined by primary field investigation and the secondary engineering design process. During the 2002-2003 annual course assessment, these issues were addressed and it was determined that ways to incorporate more field activities into the geotechnical engineering coursework was required.

Also, the student's learning experiences and frame of reference as they enter their first geotechnical lecture involved building materials that contrast drastically from soil and rock materials. Many of the theories they have studied and applied for the mechanical behavior of engineering materials were ideal allowing them to predict physical responses under engineering loads. Soil, as a material, was a radical departure from their past experience and in some cases resulted in a rather confusing series of first lectures. Table 1, describes some differences between common engineering material properties and those of soil and rock [2].

Common Engineering Material Properties	**Soil and Rock Material Properties**	**Comment**
Homogeneous	Heterogeneous	Material or engineering properties may vary greatly within a soil mass.
Linear stress-strain relationship	Nonlinear stress-strain relationship	In general and as a material, soil does not obey linear stress-strain laws.
Conservative	Nonconservative	A soil's engineering behavior is determined by previous events or conditions.
Isotropic	Nonisotropic	A soil's material or engineering properties are not the same in all directions.

Table 1. Comparison of common engineering material and soil and rock material properties.

In describing the characteristics of a geotechnical engineer, Holtz and Kovacs state [2]:

> Successful geotechnical engineering depends on good judgment and practical experience of the designer, constructor, or consultant. Put another way, the successful geotechnical engineer must develop a "feel" for soil and rock behavior before a safe and economic foundation design can be made or an engineering structure can be safely built.

Another major challenge in geotechnical engineering education is to get the student to think like a geotechnical engineer. Geotechnical engineering is quite different from other civil engineering disciplines because it is highly empirical and more of an "art" because of the unique nature of soil and rock materials and their significant differences from other construction materials [2]. These are some of the issues taken into consideration when assessing the geotechnical engineering coursework at The Citadel. They reflect some of the input received from constituents, but also come from the instructor's identification of the perceived need to develop deeper learning on the part of civil engineering students, especially in regards to their knowledge and ability to apply geotechnical concepts as part of a realistic design process.

WHAT IS AN OUTDOOR SOILS LABORATORY?

At The Citadel, an outdoor soils laboratory (OSL) is a parcel of land set aside for the education of undergraduate civil engineering students. On this site, students are provided the opportunity to engage in learning about field investigation activities, geotechnical and construction equipment, and the role of the geotechnical engineer in the design process. The Citadel Facilities operation made it available to The Department of Civil and Environmental Engineering for the purpose of conducting geotechnical experiments and demonstrations. The OSL is parcel of land, 150' by 165', on a low bluff overlooking the Ashley River, and free from obstructions including underground utilities, electrical power lines, and building foundations. The layout of the parcel allows access for large vehicles and room for safe operation. As shown in Figure 1, it is located in the corner of The Citadel campus in an area that is unlikely to disturb campus activities. It is large enough to offer potential to expand its use to include load testing of pile foundations and the construction of full and reduced size earth structures. The OSL provides civil engineering undergraduates the opportunity to see, understand, or learn about what could most likely be a significant part of their early career – field operations.

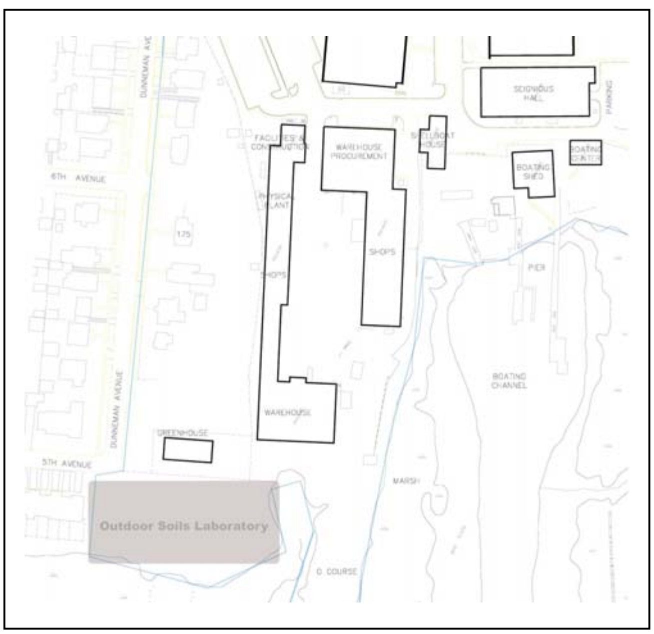

Figure 1. Location of OSL on The Citadel campus.

There are few restrictions on the utilization of the OSL site. Structures erected or piles driven in the OSL are considered temporary and may be removed if the area needs to be developed or utilized for other purposes. This type of arrangement is necessary when considering the developmental nature of The Citadel, but because of its location in reference to the overall campus, relocation is unlikely. However, there are several necessary considerations. Piles must be driven and other tests conducted in an area away from potential vehicular traffic, thereby minimizing the potential for accidents, while allowing space for demonstrations to be conducted in a way that provides access and visibility for students. Also, activities are coordinated with the Facilities and Engineering department and the Campus Safety Officer.

How Does The OSL Promote Learning?

The objective is to provide activities that promote deep learning by prompting a student to begin to think like a geotechnical engineer. Getting to that point is not easy and very likely requires some sort of stimulus to challenge a student's existing mindset. Felder and Brent [5] in discussing the models and challenges of intellectual development of science and engineering students make the following statement:"

> A prerequisite to helping students attain the intellectual maturity they will need to function effectively as professionals is to understand the stages of their progression for ignorant certainty to intelligent confusion – what their attributes are at each stage and what kind of stimulation might facilitate their movement to higher stages.

What are the stimuli to facilitate a student's movement to a higher stage of intellectual development and where do they come from? The issue of identifying appropriate stimuli to facilitate a student's movement to higher stages of cognitive development was taken into account when planning to introduce the OSL experiences. Not only were students being introduced to an engineering discipline involving a material that did not respond as expected, they were being asked to think like geotechnical engineers. The stimulus selected to facilitate that transition into higher, new ways of thinking was the OSL with its demonstrations of common geotechnical practices and field procedures.

Also, the OSL fits well with the constructivist approach employed by the instructor. Constructivist methods place the student at the center and in relative control of the learning process, thereby allowing the learning process to follow the path dictated by the student's activities. It is believed that the best instructional methods are based on student discovery and active interaction with the environment and among students [6]. The OSL provides an ideal resource for creating authentic experiences and provides realistic learning situations.

In geotechnical engineering, much effort is spent in connecting the lecture with the traditional laboratory experience. A sampling of accepted geotechnical textbooks with sections on site investigation [2-4][7][8] identified representative examples, pictures, and diagrams of traditional laboratory investigations. These textbooks contained pictures and diagram to show procedures that included soil borings, standard penetration tests, and boring logs. A student with little or no field experience would finish reading the site investigation section with a general understanding that specific engineering data, including a soil boring log, should be provided to the structural engineer. But the question remained, "How does the geotechnical engineer go about using the appropriate pieces of equipment to obtain the necessary data and how does this relate to the design process?" Answering this question prompted the development of the OSL and bringing students onto the site for their OSL experiences.

Initial OSL Experiences

The first OSL experiences took place during the 2003-2004 school year and involved two primary field activities, separated by classroom activities, laboratory investigations, and data analysis. Modeled after the engineering and construction process, the field investigation took place either at the end of the fall semester or in the first few weeks of spring semester. The data analysis and laboratory investigations were performed during February and March. And the installation of a driven pile occurred in mid-April. [9]

During the first OSL experience, two local engineering and testing companies moved onto the site and set up four demonstration stations. Station 1 involved a mud rotary soil boring operation involving a boring rig, split-spoon sample soil boring with Standard Penetration Tests (SPT) at five-foot intervals. In addition, undisturbed Shelby Tube soils samples were taken at 10-foot intervals. At this station, students observed and asked questions about drilling operations and sampling procedures and received disturbed soil samples from the SPT and the Shelby Tubes containing undisturbed soil samples. To complete this station, the testing firm provided a copy of the field report showing the soil profile and related data. Another engineering and testing company provided the equipment and people to conduct Stations 2, 3, and 4, a truck-mounted Seismic Cone Penetration Test (SCPT) investigation, along with a "Troxler" nuclear density testing device and a "Speedy" moisture, respectively.

After the students proceeded through the four stations, their learning was assessed using a verbal oral examination before being released from the area. Generally, the students did quite well in answering fundamental, probing questions related to the processes, tools, and techniques used by the companies to perform field investigations.

Between the initial and final OSL experience, the students are expected to analyze and confirm the classification of the soil profile using the SPT disturbed soil samples. They also had the opportunity to use the contents of the Selby Tubes in their Geotechnical Engineering Laboratory course. The soil profile data provided by the wash boring, with SPT and undisturbed soil samples were combined with the SCPT data, to the students during their Geotechnical Engineering II or foundations design course, to calculate the ultimate bearing capacity of a single pile. Toward the end of the semester of Spring 2004, an 80-foot HP 10X42 pile was driven and instrumented for dynamic pile-testing procedures. As an incentive, a contest was devised with the student calculating the closest ultimate bearing capacity winning $10 and a case of soft drinks.

The second OSL experience allowed the students to walk around the pile driving rig and ask the operators questions about its operation. Also, they were able to closely observe the geotechnical engineer install strain gages and accelerometers for the pile driving analyzer (PDA). During the pile driving, two students recorded blow counts, while the remainder of the class watched the engineer collect and analyze the data. For Spring 2004, the pile was driven a total of 76 feet, with 30 these feet driven into the Cooper Marl, a thick, uniform calcareous clay [10]. The operation halted for 20 minutes to let the pile gain strength. By restriking the pile with the driving hammer, it was determined that the pile capacity increased from 35 tons to approximately 85 tons. Many of the students expressed surprise and interest at the increase in pile strength and for the value of watching and participating in the OSL.

FEEDBACK AND ASSESSMENT

Student feedback was openly positive for both the initial and final OSL experience. Table 2 summarizes the student feedback.

Overall, the feedback was positive and reflected the student's perspective and level of experience. For many, the OSL was their first exposure to field operations and their first opportunity to associate their classroom design with field or construction activities. Their comments reflected the importance of combining theory and experience to develop knowledge about designing and constructing buildings and structures.

Upon reflection and review, it was determined that during the next cycle of OSL activities the author should conduct a survey of the industry professionals involved to get their input on the importance of the OSL and their suggestions on possible improvements.

Question	Summary of Students' Responses
What could be learned better from the OSL than from lectures and why?	Almost universal positive response for understanding actual field operations (soil sampling, boring, and subsurface investigation) and the construction process
What could be learned better in lectures and why?	Generally, lectures provide an environment for introducing theory and solving calculations
Did your OSL experience help you understand the importance of field investigation?	Eighty-five percent responded with "Yes."
What are the strengths of the OSL as part of CIVL 409 course?	Comments ranged from being informative to allowing the students to see actual demonstrations and touch the "tools of the trade". All, expressed varying degrees of appreciation for participating in the OSL. A few commented on the differences between a typical soils laboratory and the outdoor soils laboratory.
What are the weaknesses of the OSL as part of the CIVL 409 course?	Comments ranged from the ability to hear the speakers over the equipment noise to the desire for having the OSL experience earlier in the semester.
How could the OSL experience be improved?	Comments included converting the verbal quiz to a written format, timing during the week, and increasing the frequency of OSL experiences.

Table 2. Summary of student feedback.

CONCLUSIONS

What can be drawn from this experience? Learning takes place when students are involved and actively participating either physically, mentally, or both. It reinforces the instructor's teaching philosophy that a student's learning follows the path dictated by their activities. Engaging students in this activity provided a degree of learning that the classroom could not provide. For many students, noting this as their first experience involving field investigation and, especially, driving piles, universally described the OSL as positive contribution to their learning. A few students showed enough interest to provide comments identifying ways to improve the OSL experience.

The desired stimulus effect to facilitate higher levels of cognitive development could not be formally assessed. However, if the student survey is viewed as a formative assessment, there is evidence from their vocabulary and statements that some students developed a new understanding of geotechnical engineering and may demonstrate improved clarity in thinking about geotechnical engineering.

The OSL provided an environmental framework within which the instructor can pose authentic problems that require fundamental engineering skills to solve. Also, it provided a mechanism for the instructor to step aside and provide the opportunity for students to engage directly with industry professionals and technicians who are demonstrating their knowledge, skills, and abilities. As a result, it became possible to insert the students into a more realistic situation where many of them may find themselves in the future, thereby stimulating them to progress to higher levels of cognitive thinking.

The three-part solution of integrating the classroom, the laboratory, and structured field experience provided a deeper and more valuable learning experience for the students in an effective and low cost environment. As an integrated solution, the OSL addressed the need to get students to think like and to begin performing like geotechnical engineers. The constructivist learning approach was successful in emulating the design process as practiced by our constituents from industry, while directly addressing ABET Criterion 3.c and 3.k. by providing applicable field experiences.

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