Teaching Geotechnical Engineering using Professional Practice

Sanjeev Kumar, Ph.D., P.E.
Associate Professor
Department of Civil and Environmental Engineering
Southern Illinois University Carbondale
Carbondale, IL 62901 - 6603

Abstract *- It is a famous quote that "Every structure is supported on soils or rock, those that aren't, either fly, float, or fall over". Soils are natural deposits on which humans have no control. Soils at no two sites are likely to be the same. Even, at a particular point at a site, different types of soils exist at different depths. Several theories and formulas have been developed since the birth of soil mechanics and Geotechnical Engineering in 1925. Most of these formulas have been developed from experimental data on soils that have some particular characteristics, which may or may not be applicable to soils with even slightly different characteristics. Due to this reason, Prof. Karl Terzaghi, who has been recognized as the father of soil mechanics, in 1936 stated that the accuracy of computed results in geotechnical engineering using theories and relationships never exceeds that of a "crude estimate". Therefore, principal function of teaching theories in geotechnical engineering in a classroom is to train students as to what and how to observe in the field. Keeping this in mind, necessity of incorporation of professional practice into the geotechnical engineering curriculum has been recognized by both the academicians and professional practitioners. Recently, the author developed a full, three credit course on "Geotechnical Engineering in Professional Practice" for undergraduate seniors and graduate students. The course has successfully been taught two times at SIUC. This paper presents the details of the course, course outline, and the procedures used to teach this course.*

INTRODUCTION

The ABET's Engineering Criteria 2000 places significant emphasis on preparing graduates so that they can successfully enter and continue practice of engineering and it is the responsibility of the institution to satisfy these criteria. Therefore, participation of the industry and/or professionals in engineering education has become an integral part of engineering curriculum. Professional practice can be defined as the act of working first hand with situations for customers by using a combination of highly specialized knowledge and skills that are obtained through study, training, and experience (Aldridge, 1994). Professional practice requires that graduates from a four year engineering curriculum are capable of setting up and solving problems which do not have answers given at the back of books.

For several years geotechnical engineering was based on past experiences through succession of experiments without any real scientific character (Skempton 1985). Although, structures were supported on soils since the beginning of mankind, soil mechanics and geotechnical engineering are still considered as the most recent branches of civil engineering. A new era in the development of soil mechanics started with the publication of a book in German titled Erdbaumechanic (Soil Mechanics) by Dr. Karl Terzaghi in 1925 (Puri and Prakash, 2004). Karl Terzaghi is considered as the father of soil mechanics. After publication of this first book on soil mechanics by Karl Terzaghi, the publications of "Theoretical Soil Mechanics" by Terzaghi (1943), "Fundamentals of Soil Mechanics" by Taylor (1948), and Soil mechanics in Engineering Practice" by Terzaghi and Peck (1948) placed the subject of geotechnical engineering on a firm footing (Puri and Prakash, 2004).

GEOTECHNICAL ENGINEERING VERSUS OTHER DISCIPLINES

Couttolenc (2000) stated that geotechnical engineering is not a list of procedures but list of challenges. The geotechnical engineers never have the same project in the same soil. Unlike other construction materials, strength of soils and dimensions of soils and rock layers can not be decided based on the project needs. Instead, projects need to be analyzed and designed based on what is available at a particular site. Chances of having the same subsurface conditions at any two project sites are slim to none. Therefore, the projects which look similar to others pose significantly different challenges for geotechnical engineers. Solving every geotechnical engineering problem requires significant amount of judgment, in addition to strong understanding of basic principles of soils mechanics and foundation design.

Most of the schools in the United States and abroad teach basic principles of soil mechanics and foundation design in one or two courses. Students only learn basic principles, formulas, and theories in these courses without much exposure to applications. One of the reasons for limited exposure of students on applications aspects is that most of the faculty members teaching geotechnical engineering do not have sufficient training on real-world projects. Kumar (2001) stated that because of the variability in soil and groundwater conditions at every site, every project offers challenge for the design. Therefore, every project site serves the purpose of a laboratory for the geotechnical engineers in practice.

At his first job as a geotechnical engineer the author learned that “for every dollar earned by geotechnical engineering firms, their engineers have to write more worlds in the form of project reports and recommendations than any other discipline of civil engineering”. This signifies the importance of project report writing skills which are essential to be a successful geotechnical engineer. In addition, entry level geotechnical engineers are engaged in preparing field boring logs, storing soil and rock samples, transporting soil and rock samples, and monitoring soil compaction. Training to successfully perform these tasks is generally not included in traditional soil mechanics and foundation design courses.

TEACHING GEOTECHNICAL ENGINEERING

Traditionally, courses have been taught in a straight-forward way, starting with lot of definitions, basic concepts, and methods for solving well defined problems, which in most cases are simplified and idealized (Sallfors and Sallfors, 2002). In most of the basic geotechnical engineering courses, the instructors provide just the necessary information to solve an idealized problem which includes a step-by-step procedure to efficiently solve the problem.

Wesley (2000) discussed three issues or “weaknesses” in conventional geotechnical engineering education (1) there is too much emphasis on methods and not enough on concepts and principles, (2) Course layouts are unsatisfactory; too much time is spent in the early stages on rather dull, uninteresting material, such as definitions, phase relationships, clay mineralogy, Atterberg limits, and particle size, and (3) Components of the basic conceptual and theoretical framework of the subject are no longer satisfactory, and need rethinking. Students are having to learn and relearn significant aspects of material learnt in formal courses when they reach the work place. They encounter soils whose behavior does not conform to what they have been taught, or which is presented in standard textbooks. However, this author does not agree with all the “weaknesses” which Wesley (2000) has discussed. In a conventional geotechnical engineering curriculum, it is important to expose students to the basic definitions, phase relationships, clay mineralogy etc. This author believes that on one hand these topics are necessary to teach the students’ basic principles and formulas needed to make judgments. On the other hand, this way of teaching is not sufficient to develop a sense of critical thinking and confidence in the students’ to design real-world projects. Therefore, an additional course(s) which can relate the basic topics to real-world projects is needed.

Couttolenc (2000) reported a quote from another paper by Graham (1993) that “if someone asks me how to get from my office here in the university to a consultant’s office in downtown, I can do two things: I can tell him to get University Crescennt, turn right on Bishop Grandin Boulevard, then north of St. Mary’s Street, etc. That is I can teach him the path to follow. Alternatively, I can show him on a map where the consultant’s office is located relative to the university and let him find his own way”. Currently, most of the courses in geotechnical engineering, particularly at undergraduate level, are taught to show the path to the students. A simple mistake in following the path can lead to wrong answers and/or wrong decisions. Teaching students on how to find their way based on what is available and what is needed will inculcate in them the habit of critical thinking and determining various solutions to a problem in hand.

As discussed previously, teaching of some basic geotechnical engineering courses using a standard lecturing method of instruction may be needed to teach students basic principles, formulas, and theories, unless the whole curriculum is based on problem based learning (PBL) model. However, in conventional civil engineering curricula, the author strongly believes that there is an immediate need of at least one course in each area of specialization which teaches professional practice issues to students, in addition to a capstone design course, so that they are better prepared to start entry-level positions in the area of specialization of their interest. The author, based on his 11 years of extensive professional practice experience in various fields of civil engineering, developed a unique, 3 credit hour course titled “Geotechnical Engineering in Professional Practice”. This course is a part of regular civil engineering curriculum at Southern Illinois University Carbondale. The course is based on problem based learning model where students are challenged to "think and learn," by solving real-world problems while working in groups and learning from each other, rather then lecturing by the course instructor. The course outline including purpose and objectives of the course, list of topics usually covered in the course, and the format of the course are discussed in the following section.

COURSE OUTLINE

Purpose and Objective of the Course

The purpose of this course is to provide understanding of the concepts of geotechnical engineering in professional practice to the undergraduate (senior) and graduate students planning to pursue their career in geotechnical engineering or any other field of civil engineering. The course objectives are given below:

- Apply the principles of geotechnical engineering effectively in a "real-world setting".
- Plan, manage, and successfully execute geotechnical projects.
- Interpret and use the recommendations developed by geotechnical engineers.
- Incorporate Total Quality Management in the geotechnical projects.
- Apply professional liability, risk management, and loss prevention principles to geotechnical projects.
- Train students to work effectively and efficiently as a member of an interdisciplinary team, satisfy the needs of *internal* and *external* clients.

List of Topics Covered in the Course

- Review of principles of soil mechanics and design of foundation, discussion on field and laboratory tests commonly used in practice, methods available for field investigations, selection of an appropriate method for a particular project, development of subsurface profiles based on the field data.

- Key elements of geotechnical engineering proposals and reports, Total Quality Management (TQM), project management, marketing for geotechnical projects, understanding competition, time and manpower required for regular geotechnical projects for budget estimation and scheduling purposes, red-flag words etc.

- Professional liability, risk management and loss prevention issues on geotechnical engineering projects, types of contracts, understanding contracts and avoiding excessive and/or inappropriate professional liability.

- For a given real-word project: collection of available information from geological maps, soil conservation reports; identification of geotechnical aspects of the project; planning a soil investigation study including type and magnitude of investigation that will be used on the project; development of scope of work, proposal, and budget.

- Using the actual field testing data from tests such as standard penetration testing and test pits, development of lab testing program as per the budget assigned, defining site soil model and soil property values for analyses.

- Perform geotechnical analyses to evaluate the aspects of soil behavior pertinent to the project and develop recommendations.

- Preparation of a complete report summarizing the available information, the interpretation of the data, the results of the analyses, conclusions, recommendations, and presentation of the findings to the client.

- Review of the full original reports developed by consulting firms and comparing work with the actual reports, detailed discussion on the reports developed by the teams and consulting firms.

Course Format

The class is divided into groups of 3 to 4 students. At any one time, each group works on the same project. The type of projects selected are real-world projects either recently completed by a practicing firm or are being simultaneously executed by students and a practicing firm. The projects are carefully selected so that the level of complexity on projects is similar to the projects which entry-level engineers are expected to work during first few years of their career. The selected projects also cover a wide range of geotechnical issues. In a semester, each group of students works on 4 projects. Projects are selected such that at least one project includes field work, e.g., staking the borings, taking split-spoon and Shelby tube samples, preparing field boring logs, and storage and transportation of samples. On the project which includes field work, students are asked to assign the laboratory testing, perform the laboratory testing, interpret the data from laboratory tests, and estimate soil/rock parameters required for performing the analysis and design.

After completion of each project, teams are reorganized and a new project is assigned. After completion of each project, the students review the full original report of the project prepared by the consulting engineering. Comparison of reports prepared by the students and the consulting firms gives them the opportunity to evaluate their own work in light with the work performed by professional engineers. Similarities between the work completed by students and consulting engineers develop confidence in the students to execute a real-world project independently.

The course does not include formal lecturing by the instructor based on a set schedule of topics. Students who take this course are expected to have already taken basic courses on soil mechanics and foundation design. First few weeks, class discussions include how to develop scope of work, cost estimate, and proposal. Students are then informed that a client is planning to build a project on a particular site. Each group then comes up with a scope of work required to be performed, a cost estimate to perform that work, and a formal proposal. The proposal is evaluated by the instructor and detailed comments are provided to the students. Proposals of all groups are discussed in detail in the class. After completion of the first proposal, the class discussions include how to develop project reports. The technical discussions are based on the questions asked by the students, instead of lectures by the instructor. Before any technical discussion, students are asked to find the material related to the topic of discussions and read it.

STUDENTS FEEDBACK

The author has already taught this course twice and he is scheduled to teach this course again in Spring 2005. Students are showing more and more interest in the course. The feedback from employers of the students who took this course is very positive. Students who have taken this course feel more confident in starting their first entry-level position. Although, several students have commented on their positive experiences in obtaining their dream positions and their employers' satisfaction with their performance, Figure 1 shows a portion of an unsolicited, handwritten letter from one of SIUC's alumni, clearly stating the benefits the student received from this course.

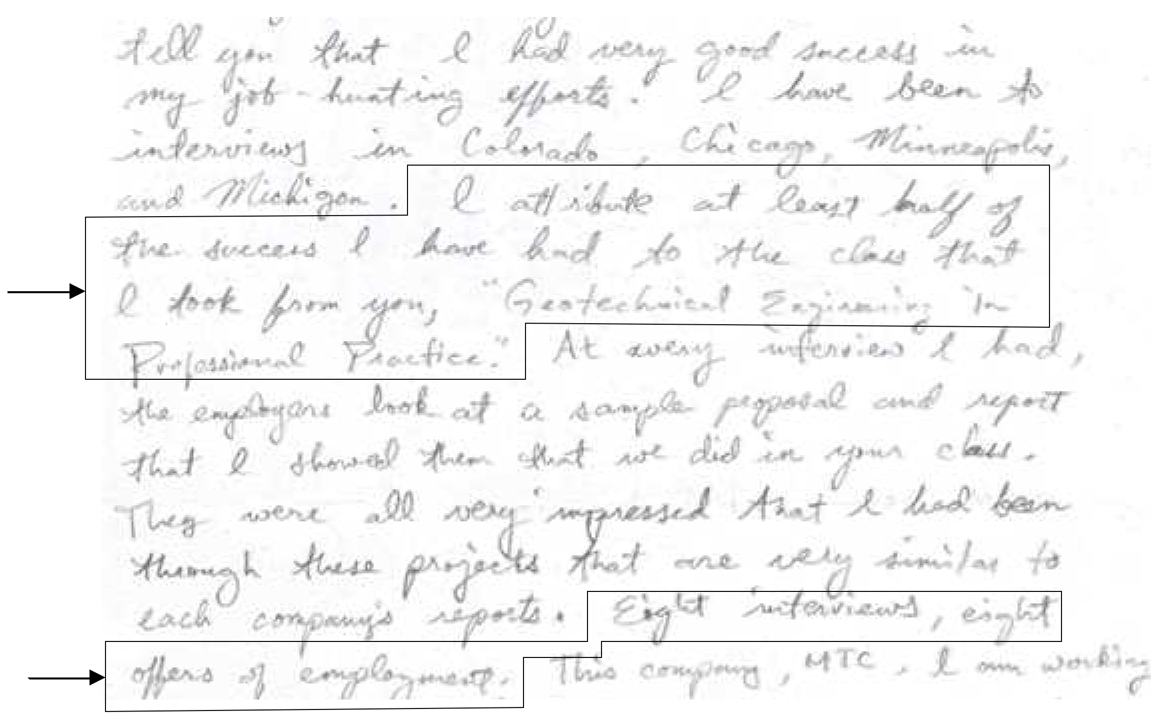
tell you that I had very good success in
my job-hunting efforts. I have been to
interviews in Colorado, Chicago, Minneapolis,
and Michigan. I attribute at least half of
the success I have had to the class that
I took from you, "Geotechnical Engineering In
Professional Practice." At every interview I had,
the employers look at a sample proposal and report
that I showed them that we did in your class.
They were all very impressed that I had been
through these projects that are very similar to
each company's reports. Eight interviews, eight
offers of employment. This company, MTC, I am working

Figure 1 Excerpts from an unsolicited letter from one of the SIUC alumni

CONCLUDING REMARKS

Based on the author's professional practice experience of over 11 years and over 6 years of experience as academician, he strongly believes that there is an immediate need of at least one course in each area of specialization which teaches professional practice issues to students, in addition to a capstone design course. Due to a unique nature of geotechnical engineering practice, the need of such a course in conventional geotechnical engineering curriculum can not be over emphasized. A portion of an unsolicited letter clearly shows the benefits of such a course.

REFERENCES

Aldridge, D.M. (1994), "Professional Practice: A Topic for Engineering Research and Instruction" Journal of Engineering Education, ASEE, Vol. 83, No.3.

Couttolenc, O. (2000). "The Practical Experience of Professors on the Geotechnical Teaching Process", ASCE GEODENVER 2000, Educational Issues in Geotechnical Engineering, Geotechnical Special Publication No. 109, 409-412.

Kumar, S. (2001). "Relationship between Professional Practice and Academia in Geotechnical Engineering", International Conference on Engineering Education, Oslo, Norway, August 06-10.

Puri, V.K. and Prakash, S. (2002). "Past and Future of Geotechnical Engineering Education", Indian Geotechnical Conference, Allahabad, December 18-20

Sallfors, L.L. and Sallfors, G.B. (2000). "Focus on Real Life Problems Facilitating Learning and Understanding", ASCE GEODENVER 2000, Educational Issues in Geotechnical Engineering, Geotechnical Special Publication No. 109, 425-431.

Skempton, A.W. (1985). "A History of Soil properties, 1717-1927", Proceedings, Xi International Conference on Soil Mechanics and Foundation Engineering, San Francisco, Golden Jubilee Volume, 95-121

Taylor, D.W. (1948). "Fundamentals of Soil Mechanics", John Wiley, New York.

Terzaghi, K. (1943). "Theoretical Soil Mechanics", John Wiley, New York.

Terzaghi, K. (1925). "Erdbaumechanik auf Bodenphysikalisher Grundlage", Deuticke, Vienna.

Terzaghi, K. and Peck, R.B. (1948). "Soil Mechanics in Engineering Practice", John Wiley, New York.

Wesley, L.D. (2000). "Challenges of Geotechnical Engineering Education" ASCE GEODENVER 2000, Educational Issues in Geotechnical Engineering, Geotechnical Special Publication No. 109, 241-248.