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Geotechnical Failures: an Excellent Tool to Teach Geotechnical Engineering

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ABSTRACT

It is well understood that geotechnical engineering is a branch of civil engineering that requires most engineering judgment. However, the question remains, how to effectively convey this to the students who are used to learn from typical lectures, using textbook approach, i.e., explanation of basic concepts by the course instructor, solution of a lot of example problems with assumed parameters having straight forward steps and definite answers, solution of additional similar problems by students as a part homework assignments, and traditional exams. Case histories of geotechnical failures could play an invaluable role in training the geotechnical engineers for 21st century. Southern Illinois University at Carbondale (SIUC) offers a unique 3 credit hour course on geotechnical engineering in professional practice which is entirely based on practical aspects of geotechnical engineering. The course contents include learning from geotechnical engineering case histories. This paper presents information about the course and how case histories are used to train geotechnical engineers at SIUC.

INTRODUCTION

Civil Engineering is a profession which has contributed enormously to human development and has always faced challenges of the future, i.e., continuously improving the quality of life, advancing civilization, and providing health and safety to the public. Even though advancements in technology and design methods, knowledge and skills of engineers, understanding of behavior of civil engineering materials and structural components have provided civil engineers with unprecedented tools to design and construct safe structures, failures do happen. However, when a failure happens even after designing and constructing a structure using the best tools available, strictly from an engineering point of view, it provides an excellent opportunity to advance the state of knowledge, practice, and art. Therefore, it is extremely important that we learn from the failures and modify our design tools to prevent them from happening again.

Geotechnical engineering is a branch of civil engineering which was born out of necessity to understand failures in earth materials. Many of theoretical concepts and geotechnical models which are in use today were developed to match the features of geotechnical failures. These concepts and models are being updated regularly based on the new information learned from case histories. According to Dr. Karl Terzaghi, who is considered as the father of soil mechanics "A well documented case history should be given as much weight as ten ingenious theories" (Brandl, 2000). According to Couttolenc (2000) "today, the success of designing, projecting, constructing, and maintaining the different works depends not only of the techniques and procedures, but also of the common sense, the economic resources, the social circumstances and the great and valuable information given by the good results and failures of different works done in the past."

The Engineering Criteria 2000 (ABET 1998), the accreditation criteria established by the Accreditation Board for Engineering and Technology (ABET), is focused on what students learn not what is taught to students. It has already been recognized that students learn and retain more when the concepts being discussed are related to real world situations. Therefore, case histories should be considered an integral part of civil engineering education in general and geotechnical education in particular. Discussion on a case history using a problem-base learning (PBL) approach provides students an opportunity to learn themselves by connecting a series of inter-related problems. Kumar and Hsiao (2007) presented Table 1 showing the difference between problem-based learning approach and traditional approach of teaching.

Table 1. Difference between PBL based instruction and traditional lecture based instruction (Kumar and Hsiao, 2007)

Traditional Lecture Approach	PBL Approach
Teacher direct student's thinking and evaluate students. Student is a passive learner	Teacher coaches students as and when needed and direct their learning, engages students in the process of critical thinking, and assess students
Students listen and solve problems using given parameters as directed	Students work in teams, engage in discussions, think critically, develop list of parameters needed to solve the problem in hand, obtain parameters, and resolve the problems
Learning occurs in an enclosed lecture hall	Discussions occurs in an enclosed room but the real learning occurs outside the classroom, in the real-world

A number of universities now set up engineering courses where team leadership skills, writing, oral presentations and resolution of problems are part of obtaining an engineering degree (Bollinger, 2002). According to NAE (2005), curricular approaches that engage students in team exercises, in team design courses, and in courses that connect engineering design and solutions to real-world problems so that the social relevance of engineering is apparent, appears to be successful in retaining engineering.

The author joined academia after working in professional practice for over 11 years. Based on his extensive professional experience he introduced a new course titled "Geotechnical Engineering in Professional Practice" to prepare students to practice geotechnical engineering. He uses case histories of geotechnical engineering failures to enhance students' learning of design and analysis concepts of geotechnical engineering. More specific information about the course and how case histories are used in classroom discussions is presented in this paper.

GEOTECHNICAL ENGINEERING EDUCATION

Every civil engineering programs has one or more courses on soils mechanics, foundation design, geotechnical engineering, etc. All geotechnical engineering educators discuss settlement, consolidation, shear strength of soil, weight-volume relationships in their courses in one form or the other. Consolidation settlement can be taught starting from the famous spring-cylinder analogy, squeezing of pore fluid, and reduction in pore volume. However, just imagine the interest of students in learning about the formulas for calculation of consolidation settlement after this discussion versus their interest in learning about the same formulas if the discussion starts with a short presentation on sinking of Kansai International Airport of Japan due to over 30 feet of settlement or leaning tower of Pisa in Italy.

The author has found a significant difference in the interest of students to learn the material when students are shown a big picture, a real case history, and then the discussion is narrowed down to a single component of the problem. Geotechnical projects typically bring multiple challenges and interaction between many components than dealing with one component. Therefore, the course "Geotechnical Engineering in Professional Practice" was developed to train students on how to conduct the design of a geotechnical project not just one idealized component of the project. Brief information about the course is presented in the following section.

GEOTECHNICAL ENGINEERING IN PROFESSIONAL PRACTICE

Singh (2000) states that "the typical interaction between instructor and students is that the information passes from the notes of the instructor to the notes of students via the board." In order to avoid having students as merely passive listeners, the author developed a course titled "geotechnical engineering in professional practice" which is taught using the PBL approach. The purpose of this course is to provide understanding of the concepts of geotechnical engineering in professional practice to undergraduate and graduate students planning to pursue their career in geotechnical engineering or any other field of civil engineering. The class is divided into groups of 3 to 4 students. At any one time, each group works on the same project. The projects selected are real-world projects which are going to be built in the near future or were recently built. Technical complexity of the projects selected is similar to the projects on which engineers are likely to work within first 2 to 3 years of their professional career. Students write detailed proposals and project reports similar to those written by practicing engineers. In addition to the real-world projects, students also work on carefully selected individual assignments to enhance their technical skills.

During first few weeks of the course, the instructor coaches the students about intricate details of proposal and report writing, available resources, and technical standards and specifications. During remainder of the semester, the instructor serves as a resource bank. Students decide what information is needed and the instructor coach them how and where to get the information. Whenever needed, the class sessions include technical discussions on developing design data. After completion of each project, teams are reorganized by the instructor and new project is assigned.

USE OF CASE HISTORIES TO ENHANCE LEARNING

Several case histories are used to enhance students' understanding of concepts of geotechnical engineering and how these concepts are applied to a real-world setting. The course instructor provides basic information about the site conditions, subsurface conditions, project layout, characteristics of the structure, etc. and then provides the information about what happened at the site, e.g., excessive settlements, slope failure, lateral movement of structures, etc. The students are then asked to think about all possible causes of problem and share with others in an open discussion. The instructor lists the students' opinion on the board. Each possible cause suggested by the students is discussed in detail and either ruled out as the possible cause or shortlisted for further discussion. Eventually, the cause of the failure is narrowed down to the real cause observed and reported by the authors of the case history. Finally, possible solutions to fix the problem observed are discussed and narrowed down to the one used by the authors of the case history. A particular attention is paid to the constructability of the proposed fixes. This discussion gives students a wide perspective of problems associated with geotechnical engineering conditions and how to design a geotechnical engineering project. An example of how a case history is used by the author in teaching geotechnical engineering is discussed below.

Figure 1 shows subsurface conditions observed at a site. At a site adjacent to this site, the subsurface conditions were very similar (almost the same) to those shown in the generalized soil profile. Moreover, two structures built on that site were similar to those shown on the generalized soil profile, i.e., a multistory office building and an attached parking garage. After about five years of completion of construction, the parking garage starting showing lateral movements towards the downhill side. Both the office building and parking garage were supported on shallow foundations. Some fill placed under the parking garage before construction foundations.

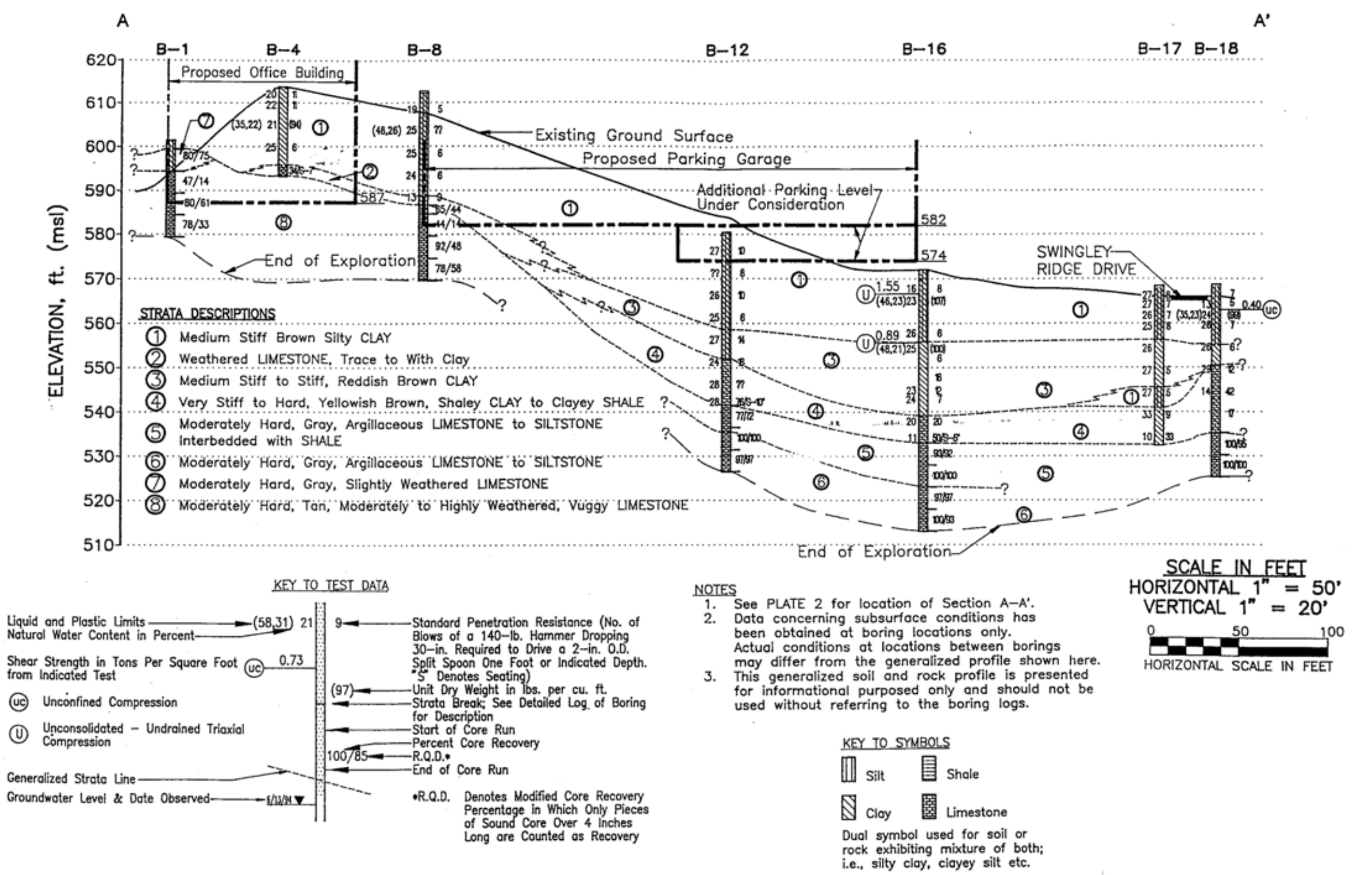

Fig. 1. Generalized soil profile for a project (developed by Geotechnology Inc.)

After discussing the subsurface conditions and project details, when students are asked to provide possible causes of movement, many different opinions emerge. For example students list the possible causes as, shear failure of soils due to footing loads, consolidation settlement of soils under the weight of the fill and parking garage, failure of slope caused by the weight of fill, pressures exerted by the office building on the soils under parking garage. Each of the possible cause proposed by the students is discussed. For example, lateral pressure exerted by the office building on the soils under the parking garage as a possible cause is ruled out because the office building is founded on bedrock and vertical deformation due to shear failure or consolidation settlement as a possible cause is ruled out because the fill is engineered fill and the natural soils are strong enough to cause bearing capacity failure and consolidation settlement. After detailed discussion on each of these causes, it is discussed that the possible cause of failure, as identified by the engineers who worked on the project, is softening of shaley clay to clayey shale layer due to penetration of water when it got exposed due to construction of parking garage. Since the shaley clay to clayey shale layer is on top of slopping bedrock, weight of parking garage and fill caused slippage in this layer resulting in the lateral movement of the parking garage.

This exercise encourages students to think about cause beyond traditional causes of failure commonly observed while learning about the traditional causes of failures discussed as a result of possible causes brought forward by them. This is just one of many examples of use of case histories used by the author to train students for practicing geotechnical engineering. Based on the comments, the author concluded that the discussion on case histories as discussed above has really enhanced their understanding of critical geotechnical design issues.

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CONCLUDING REMARKS

Due to a unique nature of geotechnical engineering practice, the need of courses and topics dealing with professional practice aspects in conventional geotechnical engineering curriculum can not be over emphasized. The author recognizes that addition of a new course dealing with professional practice issues may not be possible in every civil engineering curriculum; however, discussion in the existing geotechnical engineering courses can be modified to include teaching using case histories of geotechnical failures. Based on the comments the author has received from students, discussion on case histories has really enhanced their understanding of critical geotechnical design issues.

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