INNOVATION IN TEACHING OF GEOTECHNICAL EXPLORATION AND LABORATORY TESTING

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ABSTRACT

Geotechnical engineering is a unique branch of civil engineering as it comprises of concepts and principles of many other branches as well. Soil mechanics is not just an engineering application or a theoretical science, it is also an art that comes through experience. Eventually, engineers have to apply their knowledge, what they learn in the classrooms as students, in the field. Everything cannot be taught in class rooms through conventional teaching. Complete understanding of geotechnical engineering is not possible without field and laboratory testing. Laboratory testing and geotechnical exploration provide an opportunity to understand the depths of geotechnical engineering within a confined and well controlled environment and to eventually correlate the test results with the soil behaviour. Students need laboratory and field testing to link their theoretical concepts and soil behaviour in actual field work which will enable them to integrate the results into the design process.

In India, geotechnical exploration and laboratory testing is still taught by the old traditional methods and laboratory manuals are old. Most of books lack the testing part and only a few separate manuals are available in the market but those are insufficient and do not include professional issues. Most of the laboratory manuals seem to be reprint of different codes and standards used in various countries and does not contain various other relevant things related to those tests. Presently available laboratory manuals do not includes anything to develop problem solving approach and critical thinking in students to handle the problem in a reasonable logical manner.

To enhance a student's learning and produce a proficient geotechnical engineer for 21st century, the current practice of teaching geotechnical exploration and laboratory testing needs to be improved. It should be flexible enough to change with the demand in the field of industry and research. Students cannot be thrown into industrial world with just a few formulas and methodology for conducting the tests and performing

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calculations. Instead, they should be made clear with the need of performing the tests. Students should be familiar with the practical significance of tests they perform in the field and how they are useful to tackle the actual field situations. It is very common that new professionals are not familiar with current specialized practices and problems faced in the field. Most of institutions in India are new and do not have a well-developed laboratory set up.

With the lapse of time, geotechnical engineers are now facing more challenges in the field. Variability in soil characteristic and ground features make every project a new challenge for site engineers. Various factors affecting the teaching of geotechnical exploration and laboratory testing are discussed in paper and based on studies of curriculum of geotechnical exploration and laboratory testing, some suggestions have been made to improve the proficiency of new graduate and the teachers as well. A methodology have been presented for teachers to teach and conduct laboratory testing. It will definitely help students to develop better understanding of testing, data interpretation, relevance of testing and field exploration.

Keywords: geotech, teaching, laboratory testing, innovation, exploration

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ABSTRACT: Geotechnical engineering is not only an engineering application or theoretical science, but also an art that comes through experience. Geotechnical engineering cannot be taught within class rooms through conventional method of teaching. Complete understanding of geotechnical engineering is not possible without geotechnical exploration and laboratory testing. Laboratory testing and geotechnical exploration provide an opportunity to understand the geotechnical engineering within a confined and well controlled environment and to correlate the test results with the soil behaviour and its characteristics and to eventually integrate the results into the design process. In India, geotechnical exploration and laboratory testing is still taught by the old traditional methods and laboratory manuals. Most of books lack the testing part and only a few separate manuals are available in the market. However, such manuals are insufficient and they do not include various relevant issues and they also lack information about physical significance of tests and applicability in the field. To enhance student's learning and produce a proficient geotechnical engineer for 21st century, the current practice of teaching geotechnical exploration and laboratory testing needs to be improved. It should be flexible enough to change with the demand in the industry and current research practice. Various factors affecting the teaching of geotechnical exploration and laboratory testing are discussed in this paper and based on studies of curriculum of geotechnical exploration and laboratory testing, some suggestions are given to make teaching methodology innovative and improve the proficiency of new graduates and the teachers as well. A methodology has been presented for teachers to teach and conduct laboratory testing..

INTRODUCTION

Geotechnical engineering is a unique branch of civil engineering, since it comprises the concepts and principles of many other branches of science and engineering as well [1]. Soil mechanics is not just an engineering application or a theoretical science; it is also an art that comes through practical experience. Complete understanding of geotechnical engineering is not possible without field and laboratory testing.

Nearly all undergraduate civil engineering and postgraduate geotechnical curriculum include a course on geotechnical exploration and laboratory testing. Laboratory testing and field exploration is the most important part of graduate study in technology and science classes. Laboratory testing and field exploration provides an opportunity to graduates to understand the geotechnical engineering and examine the soil behaviour within a confined and well controlled environment and to eventually correlate the test results with the soil performance and characteristics in the field. Students have to work in a group for geotechnical exploration and laboratory testing so that it provides an opportunity to teacher to develop team spirit in the students [2]. It also laboratory testing offers an opportunity to encourage the young students to make career in the field of research and industry [3]. In this whole process, students get a chance to actively participate in understanding the practical problems; develop problem solving approach and

critical thinking to handle various geotechnical problems in a reasonable manner. It also enables the students to integrate the results in the design process.

There are various problems that exist in the teaching of geotechnical exploration and laboratory testing such as unavailability of updated laboratory manuals, unavailability of skilled teacher, outdated laboratories, costly geotechnical engineering FEM software, costly testing apparatus and old traditional method of teaching [4-5].

In India, geotechnical exploration and laboratory testing is still taught by the old traditional methods and with old laboratory manuals. Most of the institutions in India are new and do not have well developed laboratory. Most of books lack the testing part and only a few separate manuals are available in the market and library but those are insufficient and do not include anything to develop problem solving approach and critical thinking in the students to handle the real field problem in a reasonable manner.

With the passage of time, geotechnical engineers are now facing more and more challenges in the field. Variability in soil characteristics and ground features make every project a new challenge for engineers [6]. Many western educational institutes have constituted advisory or review committee to assess the existing art of practice and study material and based on suggestion various measures were incorporated in syllabus and teaching methodology of subject. Now it is high time for us to think about Indian practice of teaching.

Students cannot be thrown into industrial world and research institutes with just a few memorised formulas and methodology for conducting the tests and performing calculations. Instead, they should be made clear with the need of performing the tests, calculation and preparation of report. Students should be familiar with the practical significance of tests that they perform in the field and laboratory and able to predict the performance of soil based on exploration and testing. It is very common that new professionals are not familiar with current specialized practices and it creates a lot of problems to them in the field. To enhance the student's learning and produce a proficient geotechnical engineer for 21st century, the current practice of teaching geotechnical exploration and laboratory testing needs to be improved with the demand in the field of industry and research.

Various factors affecting the teaching of geotechnical exploration and laboratory testing are discussed in paper. Based on studies of curriculum of geotechnical exploration and laboratory testing, some suggestions have been made to improve the proficiency of new graduates and the teachers as well. A methodology is presented for teachers to teach and conduct laboratory testing. It will definitely help students to develop a better understanding of testing, data interpretation, relevance of testing and field exploration.

OBJECTIVE OF LABORATORY STUDY

Goals and objectives of laboratory and exploration study depend on the requirements of county and industries [3]. Various objectives can be achieved through innovative reaching of laboratory and field exploration i.e., observation and measuring capacity, developing an alternative approach to see the problem and tackle it, interpretation of data and generalization of formula, imagination and creativity development, developing scientific approaches, development of team spirit and professional ethics, development of scientific attitude, interpretation of study data, development of technical skills and augmenting the art of handling and using the equipment and many more [7-8]. Nevertheless the primary objective is to optimize the student learning without compromising with department and institute objective and it should be achieved within limited time frame.

STATE OF ART OF TEACHING

Teachers have to communicate their knowledge to students effectively. Improper communication may reduce the effectiveness of teaching despite the teacher being proficient in his domain and having strong concepts about the subject. So teachers have to use a proper technique or method to communicate their knowledge. Any method or combination of

methods that transfers knowledge effectively from a teacher to students can be considered as an innovative teaching. Innovative methods of teaching help in achieving the goals of education easily.

Reference [5] discussed three ways to teach laboratory testing; namely, controlled exercises, experimental investigation and project based teaching. Controlled exercises are generally designed and depend upon individual faculty member. It offers preliminary experience of material handling and procedures of test, apparatus and chemicals used in testing. It also provides flexibility to the teachers to make own manuals and modify them with change in time and technology, but possess an important drawback that students can lose their interest in fully controlled environment. It comprises of lecture by lab assistant or faculty in charge describing method to conduct the exploration and testing. Then the students have to determine the properties of soil in laboratory distinctly as well as conduct isolated element tests on separately allotted samples. Geotechnical exploration is conducted in a group and each group consist of 4-5 members depending upon the availability of apparatus. Based on test results a report is prepared for each test. This is considered to be the best method as it offers hands-on experience to every individual. However, many drawbacks are also associated with this type of practice such as lack of information regarding interpretation of soil characteristics or behaviour based on test results and how these results are used in design process. Despite of conducting the experiments, most of the students are unable to choose an appropriate test for obtaining the desirable properties and they don't know the physical significance of the tests they were performed in laboratory in field. This method encourages the students to concentrate on the methodology of test.

Experimental investigation consists of a wide range of teaching methods that encourage the students to take individual initiative to perform the exercise. Investigation can be classified as structured and unstructured. In structured investigations teacher hold control on materials or methods while giving an opportunity to students for queries. Unstructured investigations provide full freedom to students to choose the material and the method to conduct test and teacher holds control on deciding the objective of test. Unstructured investigations help the students to develop planning skills, motivation and creative thinking same time it creates problem for teacher and laboratory staff. Unstructured investigations are useful in the condition where students have attained the sufficient knowledge and basic concept in the theory class. It also needs more time and resources compared to other methods. Unstructured investigations are suitable in the institutes like IITs and NITs where the laboratories are well equipped with instruments, software and other facilities.

Project based laboratory study is not good for undergraduate student as it requires good skills and prior knowledge to most of things. It can be used for students pursuing higher education.

An approach "Z to A" approach was developed for laboratory studies. In this approach a teacher first explicate the application of a specific concept of soil mechanics and foundation engineering and upshots of application of the concept. The teacher explains the students the reasons behind applying the concept for the particular problem [9]. Using the currently available tools and technology a teacher can develop new ideas in teaching. Incorporating "Z to A" approach and a virtual laboratory can attract many students.
All approaches have some advantages and disadvantages. Teachers cannot rely on any one particular method. Method of teaching depends on objectives, programme and policy of individual institutes, facilities available at institute and individual teacher as well.

California State Polytechnic University conducted a review on existing syllabus. To strengthen and overcome the shortcomings of existing syllabus, incorporation of a design project in laboratory class was suggested [10]. Many other universities have

assimilated field visit along with sampling and site investigation at the field itself and project in the geotechnical exploration and laboratory testing to make it more innovative and offer more exposure to students [11-13].

FACTOR AFFECTING TEACHING OF GEOTECHNICAL EXPLORATION AND LABORATORY TESTING

Definition of a problem in geotechnical engineering changes with change in time. It means that the soil behaviour and characteristics change with change in the environment and local site conditions. It is not always possible to achieve 100% results due to various reasons. In case of laboratory and field exploration study, various problems arise because of untrained teaching staff, old methods of teaching, outdated syllabus, unavailability of apparatus and technical support and most importantly lack of interest of students. Most of these reasons are interrelated and can be solved by an innovative teaching methodology.

Reference [5,14-15] were presented various problems involved in the laboratory classes, some of them are; lack of concrete information whether goals are achieved or not, giving more importance to theoretical classes, encouraging students to concentrate on the methodology of experiment rather than understanding the theory and its physical significance. The factors affecting the laboratory teaching include development in technology in testing apparatus, condition of laboratory and available facilities, teacher's quality, manuals and standards and code to perform testing. Factors affecting teaching of geotechnical exploration and laboratory testing are discussed briefly.

Government and Universities

Apart from teachers, teaching material and teaching method, the government and the university also affects the teaching quality of soil exploration and laboratory testing. The practise of performing geotechnical exploration and laboratory testing is not uniform in academia and it usually differs from university to university and even from one teacher to other teacher within a university.

Theory can be taught without the help of university facilities but effective training in soil exploration and laboratory testing is not possible without the help of universities and government. Procurement of laboratory and field testing apparatus is done only with the financial support of the government and the university. Since last one decade, government has approved many institutes to run undergraduate course in civil engineering and post-graduation in geotechnical engineering without proper and laboratory and field testing apparatus and other eminent facilities. In 2012, India had more than 4000 engineering institutes and 70% of these colleges run civil engineering course with geotechnical engineering being an important course in their curriculum [14]. It is very challenging for small universities and colleges to acquire geotechnical exploration and laboratory testing apparatus as they very costly and sometimes not available in India itself. It is the responsibility of government and technical universities to approve courses of civil engineering and geotechnical engineering in an institute only if it has the capacity to procure the appropriate, reliable and updated apparatus for laboratory works.

Virtual labs and visual presentation

Although the significance of hands-on laboratory work cannot be denied, [16] cited several advantages of computer simulations compared to conventional laboratory activities. There is a substantial amount research work done on computer visualization and virtual laboratory [17-23]. It is now possible to develop courseware on geotechnical exploration and laboratory testing that can simulate the costly and sophisticated geotechnical apparatus.

A number of software have been developed in Geotechnical Engineering which can simulate the various tests in laboratory and field testing process along with varieties of geotechnical problems. Needless to say, such softwares are also user friendly and easy to understand. This virtual environment provides an excellent substitute to actual tests when apparatus is very costly and an expert faculty is not available in the institution. A number of videos are available on internet which

provide all the necessary information about the apparatus, procedure and their applicability. Before performing the tests in laboratory and field this type of material helps the students and teachers to know about test.

Reference [17] presented some elements of virtual soil mechanics laboratory along with information about developed graphical interchange format animation and java based geotechnical laboratory tests. The demerit of commercial software is that the students have to spend more time to understand the complicated programs and theory behind their development. One cannot use these softwares as a black box without understanding them completely. However, the major benefit is that these softwares are very popular in industry as well as in research practice. These software provide more freedom to the students to perform parametric study.

Geotechnical exploration and laboratory testing manuals and standards

The manual of one country may not be suitable for another country because of difference in standards, technology and professional practices. During the revision of manual, many factors should be considered such as apparatus available in institute, local soil condition, professional practice and country standard. Most of the books lack the testing part and only a few separate manuals are available in library. Most of them are old and out dated besides being more or less the same all over India. These manuals lack clarity and relevant information about testing and professional issues.

Currently available laboratory manuals do not have the content that enhances problem solving approach and critical thinking in students. Most of the laboratory manuals seem to be reprint of different codes and standards used in various countries and do not contain various other relevant things related to those tests. There is a large gap between contents of these manuals and actual condition of apparatus in laboratory, as most of the old apparatus is replaced with new automatic apparatus and the field engineers are using the advanced instruments as well.

Illustration and procedure in such manuals is provided for old apparatus. Our geotechnical exploration and laboratory testing manuals have to be updated by incorporating new illustration and method for presently available apparatus. Prof. Krishna Reddy at UIC developed laboratory manual named “Engineering Properties of Soil Based on Laboratory Testing” with all required illustration [24]. Few relevant information but standard manuals for geotechnical exploration are still not available. The selection and content of manual depends on the objectives of the program. The standards and codes for testing do not contain illustration of testing apparatus, examples for calculation, discussion, and shortcoming of procedure to perform the tests. So students face lots of problems in use of manuals and standards.

Teacher

Teachers’ expertise in using technology and ability to transfer his knowledge to student is indeed one of the main concerns in innovative teaching. Now day technology is very developed and [16] has described that how technology is useful to teachers to develop critical thinking skills and problem-solving mind set in students. Teachers often use default and traditional teaching styles with unidirectional knowledge transfer, as some of them lack the skills and particularly the confidence to use new creative method of teaching and learning. So teacher training is an important factor in innovative and effective teaching, which makes the difference very high. Teachers can be send regularly for training purpose in good institutes, research centres and industry to make them efficient in present scenario.

Interaction between industrial experts and teachers, may increase the efficiency and understanding of teacher and through which both students and teacher could benefited. There are various publications and workshop report are available in the web stating various guidelines, summaries and methods and information of various learning tools for teaches and

instructors to handle the testing equipment and help the students to connect them between theory and field and laboratory work [25-28]. Teachers are most important factor to bring innovation in teaching but teachers alone cannot do this as they need support from institutions and policy-makers as well [29].

Field and laboratory Apparatus

Syllabus and manuals cannot be effective if supportive structures such as testing facility, apparatus are not available in the institute. With the new developments in technology, things are changed in the laboratory study as well. Old manually operated apparatus are now replaced with automatic apparatus. Manually operated equipment and automatic instruments and apparatus have their own advantages and disadvantages. Automatic apparatus can simplify and speed up data acquisition so that students can save a lot of time for calculations and interpretation of results.

Nevertheless, a teacher should be careful in choosing either manually operated apparatus or automatic apparatus suitably as learning and development of problem solving skills and critical thinking is more important than saving time. Geotechnical exploration in the institute premises does not provide any opportunity to experience real time problems that geotechnical engineers face in the field and industry. So, the work of sampling and geotechnical exploration can be planned together in field and industry visit as well.

INNOVATION IN TEACHING OF GEOTECHNICAL EXPLORATION AND LABORATORY TESTING

Innovation can bought in the teaching geotechnical exploration and laboratory testing by means of unconventional method of teaching. Technical universities should provide accreditation to civil engineering or specialization in geotechnical only when institutes are having well equipped laboratory and geotechnical exploration apparatus.

It is the responsibility of universities to provide funding for testing facility. A combination of controlled exercises, experimental investigation and project based teaching can be used together to develop engineers and scientists of 21st century. Points from all methods discussed in state of art of teaching are selected and combined in way to develop technical skill and basic concept in new graduates to conduct the test and analyse the data to predict soil characteristics and behaviour.

Before class

If updated manual is not available, the teacher should have the liberty to collect material from different sources. Instructor has to prepare a manual that consists of illustration of available apparatus in laboratory, theory, practical significance of testing in field and standards code use in present practice.

Manual, hand out and visual material should be provided to student before class so they have an idea of what they are doing and how it should be done. Provide a format of typical professional geotechnical report to students. Use blackboard to provide key and important points which help the student to conduct test very easily. Safety of apparatus as well students is a most important issue, so it should be informed to students as well lab staffs.

Before starting the laboratory testing and field exploration, faculty will have to collect the materials and resources, and select the tools which can enhance the student learning and optimize the allotted time for laboratory and field exploration. Faculties have to collect all other web resources and understand the software which he will be using in laboratory class to make students to understand things in much better manner.

In virtual soil mechanics and geotechnical exploration class

Before going to laboratory or field, the instructor should arrange a theoretical class and virtual soil mechanics lab. It will enable the students to understand the procedure, concepts and physical significance of testing.

If latest testing apparatus is not available in institute then a video demonstration can be used to introduce the student about the recent developments in field

and research. Use blackboard to provide key and important points which help the student to conduct test very easily. Safety of apparatus as well students is a most important issue, so it should be informed to the students as well lab staffs.

In Lab and Field

Laboratory and geotechnical exploration can be conducted in group of students depending on the availability of apparatus. Teacher don't have to assign the laboratory tests to be performed by student to student group. Instead of this, the students should be given different type of soil samples to determine the particular property of soil in the lab and freedom should be given to them to choose the suitable method for that. For example, student have given coarse soil, fine soil and mixed soil to determine the permeability of given soil samples. There are two methods available in the laboratory to determine the permeability of soil samples; one is constant head permeability test and second one is falling head permeability test. Let them think and decide the method to determine permeability of soil samples. It will force them to think deeply about their test. Similar technique can be used for all other possible experiments. After decision of method to conduct testing, a separate log book be given to each student group to record the observations.

Teacher or teaching assistant have to be accessible, active and should maintain a consistent communication during the testing period. Teacher has to monitor the each student group to check their progress and during this process some interaction can be made between teacher and student group. Teacher should raise questions that force the students to think deeply about practical significance and application testing.

Some question can be asked after completion of a test to find out their understanding and clarify their doubts. After completion of an experiment, the logbook should be signed by a lab employee or supervisor to prevent the students from fiddling in test data sheet. Students can be encouraged to write their report in standard format used in industry or research projects but conclusion and discussion should be reasonable for collected data and test.

After lab and field class

Fudging in laboratory and field exploration is very common among the students to show the desired result. Baillie & Elizabeth, 2002 stated that fudging in very common in controlled exercises as compared to project based teaching and investigation. To minimize it, emphasis should be given to discussion and data interpretation section than obtaining a perfect answer. Creative and rational but unconventional thought in application of principles can be rewarded. Grading should be consist for all students.

If required, some suggestion can be made to improve their report and suggestions can be incorporated in next experiment. Comments in the report should be made for specific test and specific part of an experiment rather than for the report as a whole. After assessment, report should be returned to student within time limit.

Oral examination is very common at the end of semester but group assessment and power point presentation can be incorporated into laboratory and field exploration study to find out the individual or group contribution. Feedback can be taken from students to improve the teaching.

Finally, after completion of laboratory testing and grading, teacher should ask himself whether he was able to make them understand the concept and method of different geotechnical testing or not. If something was missed in teaching, remember and incorporate in the next semester. A flow chart representing the summary of sequence of various acts to be adopted for an improved laboratory learning practice has been presented in figure1.

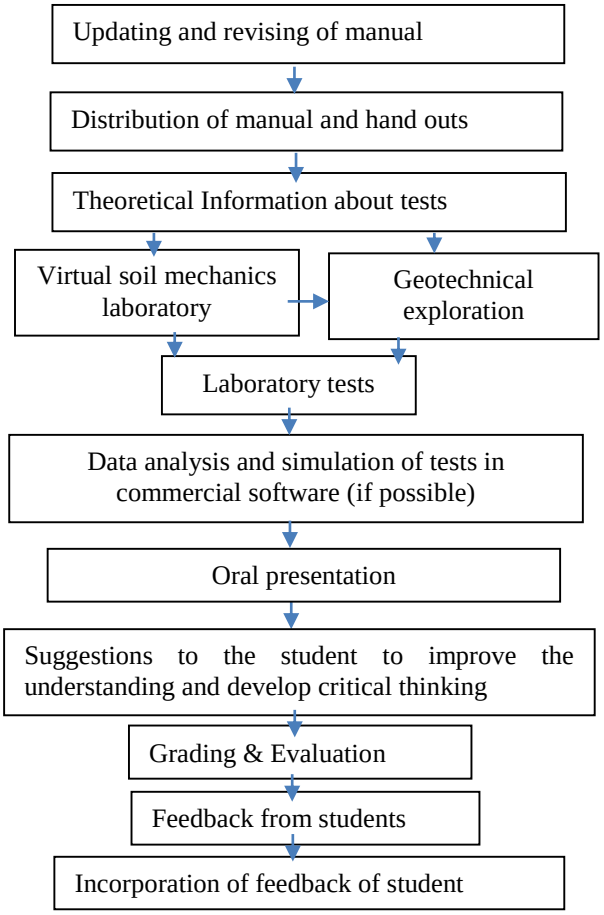

Fig. 1 Flow chart for proposed teaching methodology

CONCLUSION

Geotechnical engineering has to be considered as an art instead of engineering as it depends more on understanding and judgement of engineer, rather than the theoretical knowledge, standard and rules. It is undeniable that the future situations won't be easy for geotechnical engineers and it would surely enforce enormous challenges due to climate change, uncertainty in collected data, natural hazards, globalization, and huge difference in present state of practice and theory. To prepare the graduates for future challenges various reforms are required in curriculum and teaching style with concerns of advancement in the apparatus, data acquisition system and field works; so that technical skill and basic concept can be developed in budding new graduates to test, analyse and predict the soil characteristic and behaviour.

A teaching methodology for Geotechnical exploration and laboratory testing has been presented with consideration of various factors affecting the teaching and students. Incorporating unconventional way such as interactive computer graphics, video and visualization in Geotechnical exploration and laboratory testing can be very supportive to the students to make them agile for future research work and industrial work. Universities should develop well equipped laboratory with good environment for research.

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