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MODERN SYLLABUS FOR INTRODUCTION TO GEOTECHNICAL ENGINEERING

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SUMMARY: The field of geotechnical engineering has evolved remarkably over the last 50 years yet in many universities the content of the course usually called introduction to geotechnical engineering may have lagged behind the progress made in research and practice. Topics such as engineering geology, hydrogeology, unsaturated soils, geosynthetics, MSE walls, and more are not typically mentioned in an introduction class. Other more basic and older topics are often bypassed while they represent much of the core of the field; this is the case of engineering geology and site investigation. Of course it is not possible to cover all topics in one single course which may have between 30 and 40 hours of instruction but it is also very important to get students excited about the discipline during that first course. The authors are proposing a syllabus and an approach aimed at getting the students to learn to be interested and even to be excited about the topic through the use of case histories, applications, and the professor's experience while remaining fundamental through the use of mechanics, global by outlining the breadth of the field, and innovative by stressing the importance of progress through research. The authors think it is important to consider a multidisciplinary approach so that the students don't miss out on some aspects of the problem they face.

KEYWORDS: Modern Syllabus, Introduction to Geotechnical Engineering, Multidisciplinary Approach, Engineering Geology, Saturated and Unsaturated Soils.

1 INTRODUCTION

Civil engineering is a very diverse discipline of engineering which includes many different sub disciplines. These disciplines can be thought of as the dry side such as geotechnical, structural, construction, transportation, materials, and the wet side such as water resources, environmental, ocean. This creates a significant amount of competition for courses in the undergraduate curriculum. As such many programs only have one required course in geotechnical engineering even though geotechnical engineering is involved in all aspects of civil engineering development be it offshore, onshore or on the coast.

Because of the large amount of information associated with even the basic knowledge in geotechnical engineering, it is very difficult to choose a series of lecture topics to fit into only one course. The goals set in this article for a first course in geotechnical engineering are as follows:

1. Propose a syllabus to cover the most important and fundamental concepts thereby providing a solid base for the student to build on.
2. Show the student the importance of taking into account the geological aspects influencing design, construction and maintenance of engineering structure.
3. Set the frame work in unsaturated soil

mechanics with saturated soil mechanics as a special case.

4. Show the breadth of the field of geotechnical engineering.
5. Stress the limits of knowledge acquired in only one course.
6. Encourage graduate studies and continuing education.
7. Convey the impressive nature of the geotechnical engineering work.
8. Make the learning environment fun and exciting.

One of difficulties in selecting a single syllabus for many different universities worldwide is that the time allocation for such a course can vary dramatically from one country to another. As an example, in the United States the course on Introduction to Geotechnical Engineering may consists of 14 weeks with two 50 minute lectures and a 3 hour laboratory per week for a total of 65 hours. In Russia, the Introduction to Geotechnical Engineering course in a civil engineering department typically has much more hours dedicated to the topic as the lectures are 90 minutes long and not just 50 minutes. There are also a number of laboratories which are similar in length to the United States. All in all, the time devoted to the topic in Russia is about double the time devoted in the US. Some web sites listed in the references can be very helpful when teaching such a course.

2 BRIEF HISTORY OF GEOTECHNICAL ENGINEERING

While it is commonly agreed that geotechnical engineering started with the work of Karl Terzaghi at the beginning of the 20th century, history is rich in instances where soils and soils-related engineering played an important role in the evolution of humankind. In prehistoric times (before 3000 BC), soil was used as a building material and as foundation for engineering structures (Fig. 1). Underground structures started to develop in ancient India and Egypt. In ancient times (3000–300 BC), roads, canals, and bridges were very important to warriors. In Roman and Greek times (300 BC–300 AD), structures started to become larger and foundations could no longer be ignored.

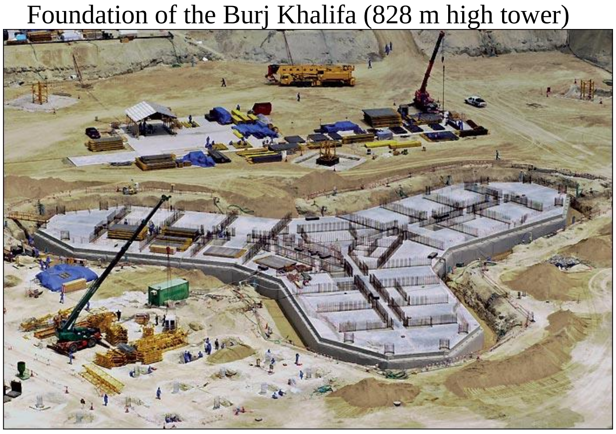
Figure 1. The Pyramids in Cairo, Egypt

The Middle Ages (AD 300–1400) were mainly a period of war, in which structures became even heavier, including castles and cathedrals with very thick walls. Severe settlements and instabilities were experienced. The Tower of Pisa was started in 1174 and completed in 1370. The Renaissance (AD 1400–1650) was a period of enormous development in the arts, and several great artists proved to be great engineers as well. This was the case of Leonardo da Vinci and more particularly Michelangelo.

Modern times (AD 1650–1900) saw significant engineering development, with a shift from military engineering to civil engineering. In 1776, Charles Coulomb developed his earth pressure theory, followed in 1855 by Henry Darcy and his seepage law. In 1857, William Rankine proposed his own earth pressure theory, closely followed by Carl Culman and his graphical earth pressure solution. In 1882, Otto Mohr presented his stress theory and the famous Mohr circle, and in 1885 Joseph Boussinesq provided the solution to an important elasticity problem for soils. From 1900 to 2000 was the true period of development of modern geotechnical engineering, with the publication of Karl Terzaghi's book Erdbaumechanik (in 1925), which was soon translated into English and in Russian; new editions were co-authored with Ralph Peck beginning in 1948. The progress over the past 50 years has been stunning, with advances in the understanding of fundamental soil behavior and associated soil models (e.g., unsaturated soils), numerical simulations made possible by the computer revolution, the development of large machines (e.g., drill rigs for bored piles), and a number of ingenious ideas (e.g., reinforced earth walls). Such history should be communicated to the students leading to the comment that today geotechnical engineering is a remarkable part of human life with gigantic projects (Fig. 2).

Extension of the Tokyo airport

Foundation of the Burj Khalifa (828 m high tower)



Tunnel between United Kingdom and France

Figure 2. Major geotechnical projects (Briaud, 2013, http://www.oobject.com/category/construction-of-the-burj-dubai/, http://www.ispreview.co.uk/index.php/2014/01/vodafone-uk-ee-bring-mobile-broadband-channel-tunnel.html)

The end of 20th century and the beginning of the 21st century saw the development of a more global approach emphasizing innovations rooted in multidisciplinary approaches such as geo-environmental engineering and geo-microbial engineering.

3 WHAT IS BEING TAUGHT TODAY

The emphasis in many courses on introduction to geotechnical engineering today is on:

1. Laboratory tests such as classification, shear strength, consolidation, permeability.
2. Established theories such as consolidation for deformation, flow nets, Mohr circle and strength.
3. Saturated soils and a single effective stress variable.

Some of the deficiencies are the lack of content for

1. Engineering geology
2. Rocks
3. In situ tests including geophysical methods
4. Behavior of unsaturated soils including shrink swell soils, collapsible soils
5. Practical applications (foundations, retaining walls, slopes)
6. Breadth of the field (earthquakes, soil improvement, geosynthetics, geo-environmental, bio-geotechnics, erosion)

Of course, it is easy to point out the topics missing but the question is to know how to include such topics in an already full class program. It boils down to a matter of priority and of the goals to be achieved.

4 PROPOSED MODERN CURRICULUM

The following 27 lectures are proposed as the content for an introduction to geotechnical engineering course. If less than 27 lectures are available, the final 8 lectures can be regrouped to the necessary extent.

1. History of geotechnical engineering
2. Engineering geology and rocks

3. Elements of geophysics
4. Sampling and in situ testing
5. Soil particles and mineralogy
6. Weight volume relationships
7. Compaction
8. Classification and tests
9. Stresses and strains in soils
10. Soil constitutive models
11. Flow of fluids through soils (parameters and laws)
12. Flow of fluids through soils (lab and field tests)
13. Flow of fluids through soils (Flow nets and applications)
14. Compressibility of soils (elasticity and the modulus of soils)
15. Compressibility of soils (consolidation tests and settlement magnitude)
16. Compressibility of soils (time rate of consolidation)
17. Shear strength of soils (effective stress case)
18. Shear strength of soils (undrained case)
19. Shear strength of soils (tests and typical values)
20. Shallow foundations
21. Deep foundations
22. Slopes
23. Retaining walls
24. Innovations (reinforced earth, soil improvement)
25. Innovations (geo-environmental, geosynthetics)
26. Innovations (earthquakes, floods)
27. Probability and risk in geotechnical engineering

One might react to any topic on that list by saying how can I possibly teach all this in one 50-minute lecture. It may be much easier to approach that issue by saying what can I tell the students in 50 minutes on this topic that will really give them some most important information and make them want to read further information in the book. Of course there is the alternative of offering elective courses that some students may choose to take. If it is not possible to increase an amount of hours for introduction to geotechnical engineering class, some topic or even courses might be given as facultative classes.

5 THE ROLE OF A “LABORATORY” AS PART OF THE COURSE

This role is critically important and a laboratory experience is a must for such a course. The word laboratory here is taken as any experience where the student learns about soils through, as much as possible, hands on practice. This can be in the form of a laboratory experience like running a triaxial test, or in the form of a field experience like seeing a cone penetrometer truck at work, or in the form of performing design calculations for a simple project like a surcharge method case to speed up the settlement of an embankment, or in the form of performing a simple finite element excavation case, or in the form of a lecture by a visitor from industry relating an impressive geotechnical project such as an embankment dam or a tunnel.

The following 12 topics are suggested to bring diversity for the undergraduate students while impressing upon them the excitement of learning about soil behavior.

1. Major worldwide projects in geotechnical engineering (Foundation of Burj Khalifa, Tunnel between England and France, Aswan Dam, Kansai airport extension).
2. Soil magic (a series of puzzling experiments using soil as the medium; Elton, 2015).
3. Grain size analysis (sieve analysis, hydrometer test), water content, unit weight.
4. Compaction test.
5. Finite element problem and solution.
6. Atterberg limits, field classification.
7. Site investigation experience (cone penetrometer, pressuremeter, and standard penetration test, vane test, sampling through a combination of field demonstrations and movies).
8. Direct shear testing.
9. Triaxial testing.
10. Consolidation test.
11. Earth dam movies, permeability, and flow nets.
12. Disasters (Pisa, Katrina, Fukushima, Teton, Rissa, Fig. 3).

13. Graduate school and research innovations (what problems are faced by geotechnical engineers and challenge the student to come up with answers).

Teton Dam Failure

Transcona Silo Failure

Figure 3. Learning from failures (Briaud, 2013).

Each one of those laboratory experiences should be associated with a write up with problems to be solved. Indeed homework is critical for better understanding concepts at a self-imposed pace. The report should be written as a consulting report with cover letter and invoice to enhance the technical communication of the student. The report should have a significant portion of the grade associated with the presentation quality both visual, professional, and language.

6. HOW TO MAKE IT FUN AND INTERESTING?

The following list is a series of ideas for making class time more interesting, more fun, and more impressive.

1. <u>Start all lectures with the best case history you can think of for the topic at hand</u> (movie, slides, news article, story) and ask why it behaved that way. This will motivate. Here are some examples.
   a. Rissa landslide in Norway for geology and mineralogy.
   b. Miners stuck at depth in Chile for drilling and site investigation.
   c. Transcona silo failure for shear strength.
   d. Teton Dam failure for seepage and erosion.
   e. Hong Kong slope failures for unsaturated soils strength.
   f. Pisa and Mexico City for settlement and remedial ideas.
   g. Niigata Earthquake for liquefaction and effective stress.
2. <u>Use visual demonstrations on the front desk in the classroom (Fig. 4):</u>
   a. Step up on the desk in front of the students, extent a slinky, compress it and release it to demonstrate wave propagation (Fig.5).
   b. Build two piles of dry sand, one with no reinforcement and one with toilet paper reinforcement layers invisible from the outside. Place an increasing number of weights on both piles and show the significant difference. Ask the students to guess why. Give them a knitting needle to poke at both piles; it will pierce through the toilet paper and show no resistance. The student will still wonder.
   c. Use a glove filled with loose sand and connected to a small vacuum pump. Show the difference in strength of the glove hand shake with and without vacuum.
3. <u>Use markers of different colors on the white board and keep each color for a purpose:</u>
   a. Red = important equation to remember
   b. Black = derivations leading to the red equation
   c. Green = commentaries
   d. Blue = Major principles
   e. Or any other combination but set up your own scheme of colors to help the student distinguish between messages.
   f. Choose colors that are highly visible and write large enough on the board without staying in front of what you write.
4. <u>Ask questions and form teams</u>:

   a. Form two teams by splitting your class into two areas of the class (left and right for example).
   b. When you ask a question like when is the undrained shear strength used? Ask each side and write the answer on the board. Keep score during each lecture.
   c. Count to five to limit the amount of time available for the answer.
5. Move around in the classroom:
   a. If you do not need to write something on the board, walk in the alley, this will help connect with all students.
   b. Sometimes teach from the back of the classroom, behind the students. It helps them to think on their own. They are used to see this person in front of them that they think has all the answers.
6. Take pictures of the students in the class:
   a. Ask the students at the beginning of the course to choose a seat and stay in that seat all semester. This is not a restraint as we all usually do this.
   b. Take a picture of the class and put the names of the students on the photo.
   c. Keep that photo in front of you at all times during lectures and call on the students by name.
7. Ask the students to prepare a video on geotechnical engineering as their final project in the class. Play those videos in an after class get together with sodas and popcorn. Organize the evening like the opening of a major movie at a film festival but keep it very light and fun with comments from the crowd.

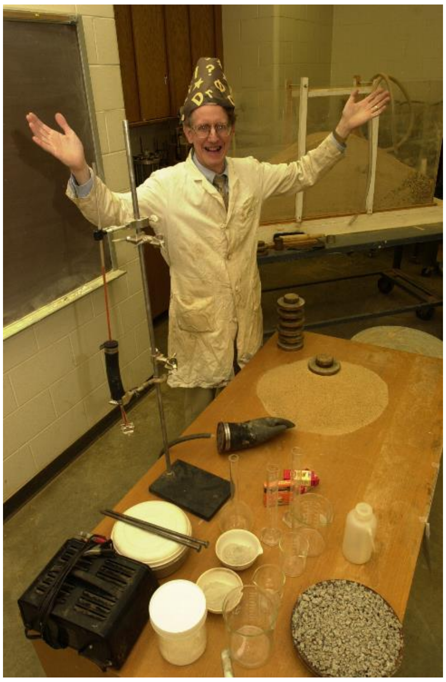


Figure 4. Soil magic (Elton, 2015)

Figure 5. Demonstrating wave propagation using a slinky

7. CONCLUSIONS

There is a drastic need to revolutionize the basic curriculum of the introduction to geotechnical engineering. A modern syllabus for the course “Introduction to Geotechnical Engineering” is proposed along with a series of laboratory experiences in the lab and in the field. Some ideas are shared on possible ways to make the learning process more interesting or even fun. Geotechnical engineering is not yet a mature field of engineering. As such, the way it is taught still varies significantly from one country to another or even within one country let alone between different professors within one university. This paper is by no mean aimed at restricting the creativity of the professor but instead to help foster such creativity. The intended message is that teaching must be a very lively and continuously updated experience that truly reflects the fundamentals and the practice as a whole. It is also a chance to improve the image of our profession worldwide. Geotechnical engineering is extremely important to human kind but the public at large is not very well aware of that fact. Professors have the unique and most important responsibility to help young minds to think and impact their future in the most constructive way while making it fun rather than rehashing old notes. This takes energy, dedication, hard work, but the outcome is well worth the effort. One of the best awards a professor can receive is to have a former student come to them years later and share some words of great appreciations. We must make the effort to change the status quo.

REFERENCES

Briaud J.L. (2013) *Geotechnical Engineering: Unsaturated and Saturated Soils*, John Wiley and Sons, 1000 pages.

Elton D. (2015) *Grounded! Amazing Classroom Demonstrations in Soil Mechanics*, ASCE Press, 204 pages.