A soil exploration exercise in Bachelor's level education in soil mechanics

Exercice d'exploration de site au niveau de bachelor de mécanique des sols

Jan Laue, Ralf Herzog & Sarah M. Springman
ETH Zurich, Switzerland   jan.laue@igt.baug.ethz.ch

ABSTRACT

Geotechnical education at Bachelor level usually commences with a simplified theoretical introduction into soil mechanics, which may be supported later during the course by hands-on laboratory experiments to cover classification of soils and provide the evidence for the elementary mechanical behaviour of soils. The application of such a curriculum to practice is challenging because the students are not confronted with practical reality where limited information is available to develop a model of the ground. An exercise on site investigation has been developed and incorporated into the ETH Zurich soil mechanics course to help to bridge this gap based on an initial development for undergraduate education in soil mechanics at the University of Sheffield.

This exercise, focusing on the three aspects of practical site investigation, creation of a soil model and decision making for best soil condition for a foundation will be introduced and described here. It has been compulsory for the Bachelor students in their first geotechnical course during the first three years after its development. After gaining more experience with the exercise, and under the pressure of growing numbers of students, it has been changed from being compulsory for all students to one of the challenges, from which the students have to select and pass 4 out of 6. Regular evaluation by the students shows that the students appreciate this practical experience and are surprised how little information is often available for practical design tasks.

RÉSUMÉ

L'enseignement géotechnique au niveau du bachelor commence habituellement par une introduction théorique simplifiée à la méchanique des sols qui peut être appuyée plus tard dans le cours par des essais pratiques en laboratoire pour traiter la classification des sols et fournir le témoignage du comportement méchanique élémentaire des sols. L'application de ce programme à la pratique est un défi car les étudiants ne sont pas confrontés à la réalité pratique où on ne dispose que d'une information limitée pour développer un modèle du sous-sol. Un exercice de reconnaissance de site basé sur un concept initial pour un cours de premier cycle de l'Université de Sheffield a été développé et incorporé au cours de mécanique des sols de l'ETH de Zurich pour aider à combler ce fossé.

On présente dans cet article cet exercice qui se concentre sur trois aspects: l'étude de site pratique, la création d'un modèle de sous-sol et la prise de décision quant aux meilleures conditions de sol pour une fondation. Il a d'abord été obligatoire pour les étudiants de bachelor durant les trois premières années après son développement. Après avoir acquis plus d'expérience avec l'exercice et aussi sous la pression d'un nombre croissant d'étudiants, il est passé du statut obligatoire pour tous les étudiants à celui d'un des challenges parmi lesquels les étudiants doivent choisir et en réussir 4 sur 6. Une évaluation régulière par les étudiants montre que ceux-ci apprécient cette expérience pratique et sont surpris du peu d'information souvent disponible pour les travaux pratiques de conception.

Keywords : site investigation; teaching; Bachelors education

1 MOTIVATION

Practical site investigation for small and medium sized projects is often limited to penetration tests. A simple ground model is then developed based on restricted information, supported by any additional information available e.g. from geological maps. In some cases, the soil model is verified further using penetration tests with a grooved or slotted sampler (as e.g. described in DIN 4021, 1990), allowing classification of the soil in a very limited fashion.

The introduction of geotechnical engineering to civil engineering students at ETH Zurich takes place in the second term of the second year in the Bachelor studies (Caprez et al., 2008, Sharma et al., 2001, Springman et al., 2003). It contains a simplified theoretical introduction into soil mechanics, which is supported by hands-on laboratory experiments. Some of the experiments deal with classification of soils and others establish the evidence for the elementary mechanical behaviour. Thus the students are faced with an ideal situation, which is rare in practical reality, where most of a ground model is based on very simplified site investigations. To confront the student with this reality, a site investigation exercise has been developed and incorporated into the ETH Zurich soil mechanics course.

The exercise is inspired by and based on an initial development for undergraduate education in soil mechanics at the University of Sheffield (Pyrah et al. 1991, Hird, 2004). An artificial soil model is prepared in the laboratory at small scale and the students expose the layers in the soil model using a driven grooved sampler, measuring the number of beats as well as collecting limited amounts of soil. The amount of drilling is limited as in reality by a limited budget. Beneath conducting the site investigation under limited financial exercise, the task for a group of students is to derive a ground model for a simple foundation design project.

The site investigation exercise has been used in the course for 4 years. After 3 years of being compulsory, around 50% of the students have chosen this exercise as one of the challenges they have to pass. The course and thus the exercise has been evaluated regularly. Based on this evaluation the exercise could be developed further.

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2 THE EXERCISE.

The soil model to be investigated is placed in a cubical wooden box with the dimensions of 70cm x 70cm x 70cm (Fig. 1). A model is considered to be at a scale of 1:100 to plan, carry out, and analyse the ground investigation for this exercise. Only one cross-section will be investigated by each group of students to enable similar boundary conditions. A 3 dimensional soil model is prepared in order to guarantee different results. Figure 2 shows the soil model prepared for the first application in 2005 incorporating several clays of different colours, sand layers and some structural elements, as well as contaminated zones. These features have been removed from the soil model in the subsequent years as it made the investigation too complicated and diverted the students from the main task. The top of the model is covered by cat gras to achieve a degree of reality. The bottom layer consisted of a load bearing moraine.

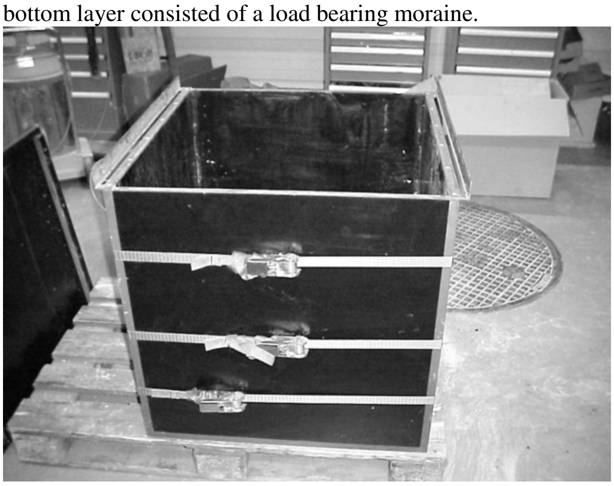

Figure 1. Wooden Box containing the soil sample. A guiding bar is attached left and right with the North – South (Fig. 2) coordinates of the model.

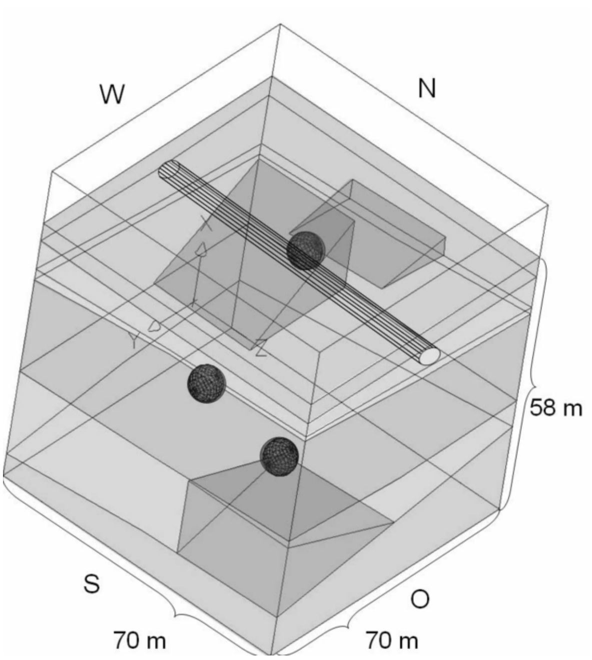

Figure 2. Three Dimensional sketch of the soil model used in the first year of use of the exercise. (Springman, 2005).

The investigation is conducted with a slotted sampler (Fig. 3) driven into the soil using a rubber hammer (Fig. 4) via a guiding tube (Fig. 5) to fix the location. The sampler is equipped with marked heights to allow the depth to be recorded and to note the relationship between numbers of blows for a unit of penetration. A maximum intrusion of 30 cm can be reached before the sampler has to be removed to inspect the material collected (Fig. 6). The sampler can be reinserted into the same hole to extract samples from greater depth. The soil must be collected (Fig. 7) and classified according to EN 14688-1. Based on these results, the soil strata for each vertical profile can be derived. The hole is filled with a bamboo cane to minimise disturbance for subsequent investigations after finishing the extraction at one site,

Figure 3. Slotted sampler with marked heights on the shaft.

Figure 4. Students driving the sampler into the model.

Each group receives a virtual amount of money (3500 CHF) that is equivalent to the "clients" budget for the site investigation along one cross-section. The money is charged at a given rate per cm of penetration; 25 CHF for each cm of the first 30 cm and 30 CHF/cm for investigations at greater depths.

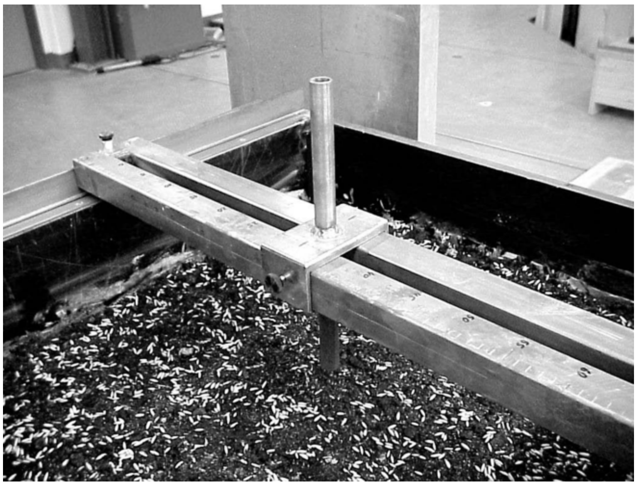

Figure 5. Frame with coordinates and guiding tube.

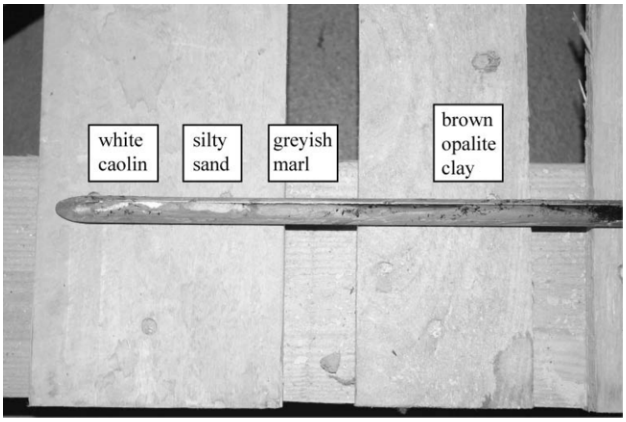

Figure 6. Slotted rod with sample. Three different types of clay and a sand (white caolin, silty sand, greyish marl and brown Opalite) can clearly be differentiated.

Figure 7. Students emptying the slotted rod and storing the samples in bags for further evaluation.

3 TASKS, DOCUMENTATION AND ASSESMENT

The goal of the exercise is to provide a solution for the design of a foundation. The construction proposed was a light industrial building with heavy point loads in some location and including a cellar. The type of construction varied for the subsequent years.

The students are asked to plan the investigation campaign before conducting the exercise, by considering the location of the exploratory borings as well as their depth. They should be prepared to change their boring plan after seeing the results from the first borehole. Due to organisational issues and to promote organisational skills, teamwork and communication they have only 30 minutes to carry out the site investigation. A copy of the plan of boreholes must be handed in at the start of the exercise, based on an orientation plan handed out to all of the groups about a week before the exercise. This should provoke some preparation and ensure that the students have read the instructions!

The results of the exercise should be presented and handed in as follows: each borehole should be individually documented. Based on the borings available, a 2 dimensional model of the subsoil (Fig. 8) should be created, in which the foundation for the planed construction can be sketched (not included in Fig. 8). The drawings should be accompanied by a report describing the soil layers and justifying the location and the foundation-type for the given structure.

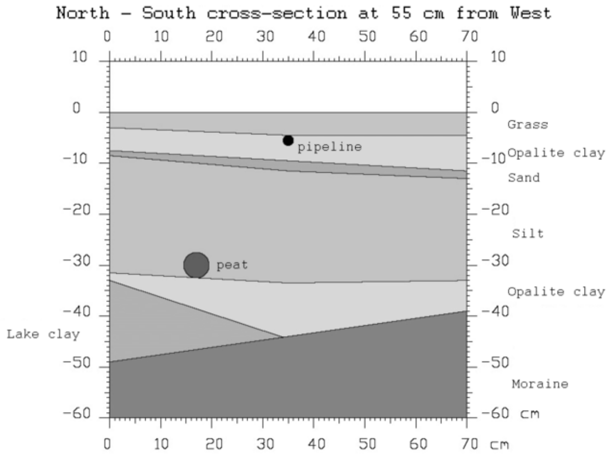

Figure 8. Sample solution for a cross section of the model used in the first year.

The evaluation of the soil model submitted is based on a point system in order to be able to create a competitive atmosphere. A maximum of 1000 points is available, from which points may be deducted as shown in Table 1.

Table 1. Subtractions for various mistakes.

Mistake	Subtracted
Erroneous missing or additional layers	100 points
Incorrect layer thickness or depth of a given layer (calculated as a difference of more than 2cm at model scale)	50 points
Extra centimetres of borehole	50 CHF = 10 points

4 LEARNING ASPECTS

The main objective of the exercise is to confront the students with a "modelled" realistic situation they will be facing in reality in the future. The students will experience the differences in the required outcome (such as a sound soil model) and guidance for the choice of the type of foundation and the often limited input from the site investigations they have in hand to provide this outcome. In the authors opinion, this is a very important experience, especially for those students who do not continue with geotechnical engineering in their master studies and who are the potential clients for geotechnical engineers.

In addition to this experience, the students have the chance to reflect on the lessons learned about classification of the soil and about site investigation. These are rather theoretical to the students when they are presented in an early phase of soil mechanics education.

A third pedagogical aspect is the self organisation in a group. Students taking the first course in soil mechanics sometimes seem quite young with their working style more influenced by their school experience. They work in a less target oriented fashion, especially while working in groups. The students must learn to distribute responsibilities and to organise and to plan work ahead under time pressure. Thus the students are reminded during the task that it is very important to prepare well for the exercise. They are also reminded in written that they must consider, in advance, who will do which job (recording results, hammering the probe, measuring the penetration depth, classification of the bore material…).

5 EVALUATION AND STUDENTS PERCEPTION

Lectures at ETH Zurich are exposed to regular student evaluation. Individual questions are exposed to the students in addition to these standardised questions to offer ideas and impulses for continuous development of the course on soil mechanics. The questions asked with respect to the site investigation exercise, deal with the use of this exercise to gain a better understanding of soil mechanics (Fig. 9) as well as with questions related to the organisation in groups or the contentment of the students with the results obtained. Figure 9 shows one result from the first year's evaluation. Clearly, about 50 % of the students appreciated the exercise while a bit more than a third of the students did not see the sense of it. This distribution remained almost constant over the years of the course until the exercise was offered as an optional replacement for other e-learning exercises or virtual laboratory experiments.

Another interesting aspect was the happiness of the students with the self organisation. After the first year's efforts, only a third of the students would conduct the exercise in a similar fashion. The increase in information and guidance (as cited in chapter 4) allowed the authors to improve this result slightly. The students remarks ranked from remove this exercise to very positive comments, which was confirmed by the fact that more than 50% of the students chose this challenging and more time consuming exercise as 1 out 4 challenges they have to pass in the frame of the course when it was offered as an option last year.

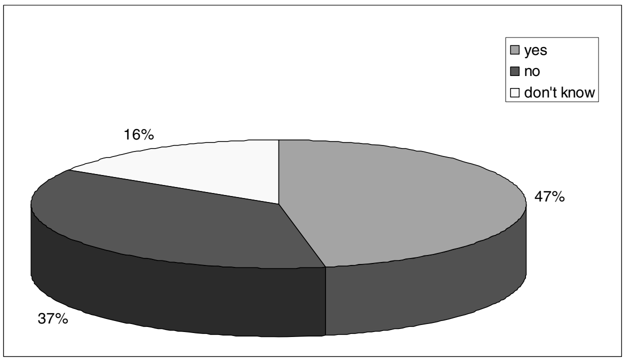

Figure 9. Question of the 2006 evaluation: did the site investigation exercise help in understanding teaching material on site investigations.

The question on "happiness with your obtained results" (Fig. 10) is influenced by ambition to produce a correct answer, when there is no true answer available because limited information is available through site investigation in general. This can lead to frustration, not only for the students, but also for the geotechnical engineer in practice.

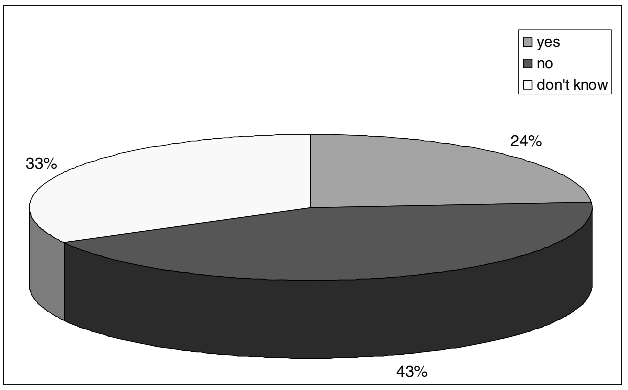

Figure 10. Result of the evaluation 2006 on: were you happy with your group's result in the site investigation exercise.

6 SUMMARY

A soil mechanics exercise has been introduced and incorporated into the basic soil mechanics course at ETH Zurich. The exercise is described in detail to allow for adaption at other universities even though time and supervision has to be provided to conduct this experiment. The evaluation shows that students appreciate this sort of "game type" experiment and that the pedagogical aspects are fulfilled.

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