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The use of field visits in graduate geotechnical teaching

R. Jimenez
Technical University of Madrid, ETSI Caminos, Canales y Puertos, Spain

W. Martin-Rosales
University of Granada, Facultad de Geología, Spain

ABSTRACT: Field trips are a good tool for effective geotechnical engineering teaching and learning at graduate level. This paper presents our recent experience with the planning of an “Applied Geology” MSc field trip to two tunnelling construction sites that involved TBM and NATM methods. In particular, this article presents some (personal) recommendations for the planning of field trips, it discusses the learning outcomes (including knowledge and subject-based, as well as other key and cognitive skills), and it argues that such well-planned field trips are useful because (i) they provide the students with hands-on experience about the unique technologies, the scale, and the inherent difficulties involved in this type of geotechnical project; (ii) they serve as a basis for discussion after student’s presentations; (iii) they serve as a basis for a related design-based term-project using real parameters of geotechnical materials found at the site; and (iv) the new assessment methods that can be implemented after the field trip help to increase the motivation of students and encourage the students’ interaction and teamwork.

1 INTRODUCTION

The teaching of soil mechanics and other civil engineering subjects has traditionally been (and still is) mainly conducted in the classroom. However, despite recent technological and audio-visual developments that allow more effective classroom teaching, there are still limitations to effectively illustrate the scale and complexity associated to real geotechnical projects.

For that reason, it is common that geological or geotechnical curricula include field work and site visits into their requirements. For instance, in the traditional Civil Engineering Curriculum of ETSI Caminos Madrid, students of the ‘Applied Geology’ course (in the 3rd year) would have a three-day field trip in which they visit several sites of engineering-geological interest; similarly, in later years, students would have a week-long field trip that is mainly focused on construction sites of large infrastructure projects related to the students’ selected specialty (transportation, water resources, etc.). Similar arrangements can be found in the curricula of other programs elsewhere in Europe, the U.K. and the U.S.A. In fact, the first author has ‘learnt’ many of the ideas presented herein as a PhD student in UC Berkeley and in field trips with the Soils Mechanics and Engineering Geology MSc programs of Imperial College London.

In this paper, we share our recent experience with the organization of a graduate-level field trip for the 3 ECTS “Underground construction” module of the MSc program of “Applied Geology in Civil Engineering and Water Resources” offered by the University of Granada. The first author serves as Invited Lecturer for this module—he also teaches a similar course at the Technical University of Madrid (UPM); whereas the second author is the Course Director. In particular, we discuss a full-day field trip performed with MSc students to visit a tunnel construction project that involved TBM and conventional methods (NATM).

It is reasonable to assume that, as it happens in any other teaching activity (see e.g., Griffiths, 2003), successful teaching and learning by means of field trips “does not happen by chance”. As we will show, and in agreement with Beaty (2003), field trips should be planned so that they become efficient tools in the context of the new educational paradigm of the European Higher Education Area (EHEA; see http://www.ehea.info/) and, in particular, in relation to the two main educational changes brought forward by the EHEA (i.e., to increase the interactivity between student and instructor and also to stimulate collaborative work in student groups; Michavila (2009)).

Additional positive outcomes result from such well-planned field trips, such as the possibility to have a hands-on experience with the unique technologies, scales and challenges related to a specific geotechnical project; to serve as a basis for discussion after student’s presentations; and to serve as a basis for a related term-project that involves real parameters from geotechnical materials found at the site.
2 FIELD TRIP PLANNING FOR SUCCESSFUL TEACHING AND LEARNING

2.1 Introduction

The Underground Construction module covers several aspects related to tunnel design, such as engineering geology of underground excavations (see e.g., Goodman, 1993); construction methods (e.g., TBM vs. NATM); and methods for tunnel design (see e.g., Hoek and Brown, 1980; Panet, 1995).

Lectures are mainly delivered using computer-based presentations for the more ‘geological’ and ‘construction-related’ topics, and using blackboard derivations for (some of) the more ‘mathematical’ topics. Despite the use of photographs and diagrams in the presentation slides, however, it was found that students needed a closer grasp to reality, as it is sometimes difficult to illustrate, in the classroom or by independent readings, complex tunnelling operations, or to get a ‘feeling’ for the scale of real projects and for the difficulties associated to underground construction such as variability of geological conditions, lack of space for plant and equipment operations, reduced visibility and ventilation, difficulties associated to water flow into the tunnel, etc.

Although the details of TBM operations can be satisfactorily demonstrated using video simulations, the problem of illustrating project scale and the inherent difficulties associated to tunneling remains. (Although photographs and site videos can be helpful in some cases, light conditions are often challenging in real tunnels!) In addition, it is very difficult to reproduce the ‘atmosphere’ of a tunnel using only photographs and videos. Field trips can be employed as a teaching method to overcome such difficulties. For that reason, we organized a field trip to visit the construction works of two tunnels in the Murcia-Almería High-Speed Train project in South-Eastern Spain. In particular, we visited two tunnels (Sorbas and El Almendral) constructed in different geological formations and with different construction methods.

Sorbas tunnel was mainly excavated through sedimentary units of relatively good quality (conglomerates, sandstones, limestones and marls); although there were also some formations in which non-standard difficulties could be expected, such as gypsum-anhydrites and metamorphic rocks (slates, phyllites and schist) with intense tectonization due to reverse faulting. It has a length of about 7.4 km of which approximately 90% were to be excavated with a 10.08 m (external) diameter TBM; the remaining length—up to the location of the fault zone—was to be constructed using NATM.

El Almendral tunnel has a total length of 1.1 km, of which 786 m are constructed using mine-excavation and the rest using cut-and-cover, and a cross-section of approximately 100 m². It was constructed using ‘conventional’ (NATM) methods, and most of its length was to be excavated in a formation of black schist with varying degrees of fracturing.

Below, we present some additional points related to the planning of the field trip and to the possibilities for further work and for assessment that opened after the trip.

2.2 Before the field trip

Having an ‘introductory’ field trip at the early stages of a course or academic program can be a good way to motivate students and to build relationships (‘ice-breaking’ or team-building) among peers, hence facilitating future collaborative work (Beaty, 2003). This point is probably more relevant in one-year programs such as MSc’s than in multi-year programs such as Bachelor degrees.

However, if acquisition of skills or knowledge is the main objective with this type of ‘specialized’ field trips, they are probably more effective if conducted once that students have received a good deal of exposure to the subject (say, after more than 50% of the contact hours have passed); the reason is that such previous exposure to the subject allows them to better understand what they see for a more productive visit. In addition, it is helpful that the students are given an introductory lecture and some background reading about the project and the site geology. Geological maps (Fig. 1), as well as photographs and diagrams of the project are useful to acquire an ‘overall view’ of the project at this stage; furthermore, providing simple ‘fact-sheets’ of the different geological formations involved, and that include their origin and description, as well as photographs and geotechnical properties. As an example, Figure 2 shows the corresponding ‘fact-sheet’ for the “Black Schist” formation in which a large proportion of El Almendral tunnel as well as the South portion of Sorbas tunnel were excavated. These ‘fact-sheets’ are helpful for a better understanding of the geology during the field trip and for the design projects that can/will be proposed for further work after the trip. For example, a design project could be the investigation of geological hazards and support design of the disassembly cavern constructed in the schist formation (Fig. 2) and that is shown in Figure 4, or the support design of the ‘regular’ tunnel in one of the formations for which there is geotechnical information (see Sect. 2.4).

This introductory lecture should be given before the field trip and, in addition to the technical content, it should (of course) include a safety briefing, and information about equipment and clothing requirements, as well as about ‘logistics’ (food stores and expected times for meals, restroom availability, etc.). In addition, to increase the motivation and the attention of the students during the trip, information about the assessment during and after the field trip should be provided at this stage. We feel that a total of 1–2 hours of student time (including the pre-trip lecture and readings) should be enough for preparation of this type of field trips.

2.3 During the field trip

It is highly advisable that the Technical Staff (Engineers, Geologists, etc.) involved in the tunnel design
or construction (or both) join the group during the trip. This is because they are more familiar with the details of the design and, therefore, are better prepared to answer detailed questions; in addition, as discussed below, having a larger number of 'supervisors' tends to produce—if allowed by safety—the division of the group into smaller sub-groups, in which the students may feel more confidence to interact and to ask questions or to make comments.

After a reminder of safety requirements, the field trip can start with an introduction of the technical staff, followed by a brief presentation of the overall project and of its more important aspects. Poster-type panels can be helpful for that (see Fig. 3), but other 'technologies' such as computer-based presentations or paper handouts can also be employed. Depending

Figure 1. Example of geological maps for the tunnels (not to scale).

Figure 2. Example of 'fact-sheet' for the Black Schist formation in which the tunnels are excavated.

Figure 3. Illustration of initial introduction of the project conducted by the Technical Staff.
on the amount of material, a total of 30–45 minutes is probably enough for this task.

Then, the actual visit to the site can commence. The planning of the actual visit and number of stops will, of course, depend on the characteristics of the site and on the travel time. In this case, for instance, the travel time of slightly more than 2 h was relatively long for a single-day field trip, since there are also safety limitations with the number of working hours for the driver. In our case, this reduced the possibilities for ‘hands-on’ experience (e.g., mapping of faces or outcrops or field testing), although that could be a very interesting exercise, if time allows, in this type of field trips.

As an example of our visit, Fig. 4 illustrates the visit to one particular location in Sorbas tunnel in which the TBM machine was being disassembled inside a cavern specifically constructed for such task, and once the TBM portion of the tunnel had been completed.

At each location, a brief introductory discussion should be delivered to the students, explaining what they are about to see and emphasizing its more important or interesting aspects. Due to background noise etc., and before proceeding to the next location, it is always a good idea to verify that everybody in the group understood the explanations. Students should be encouraged to take photographs and carefully recorded notes. A good incentive for that is to emphasize that field notebooks are “documents of record” that indicate a student’s professional skills and, on that basis, to include their notebooks into the materials for assessment after the trip. If allowed by safety, they could be encouraged to ‘explore’ the site in small groups (that should be accompanied by an Instructor or by the tunnel’s Technical Staff). As indicated above, this facilitates communication (if, for instance, the background noise is loud), and it also encourages student interaction and participation, as ‘shy’ students can feel more confident to make questions in a more relaxed and informal atmosphere.

2.4 After the field trip

The information and knowledge acquired during the field trip can be employed as a basis for at least two additional learning activities. The first is the preparation of ‘short’ group presentations by the students; the second is the preparation of a design project based on ‘real data’ obtained from the field trip information and, in particular, from the geotechnical characterization of the geological formations involved (Figs. 1 and 2).

To prepare their short presentations, students are divided into several groups, so that each group covers one different aspect of the visit. For instance, in our case, one group could cover El Almendral tunnel; another group the TBM portion of Sorbas; another group the cavern for disassembly of the TBM; etc. However, to help students maintain their attention levels during the field trip, it is probably a good idea that topics are not assigned to groups until the trip (or the day, for a multi-day field trip) has been completed. The presentations are better scheduled shortly after the field trip (if time allows, they can even be conducted on the same day), as the objective is that students still have a ‘fresh memory’ of what they saw (or of what they did not quite understand).

The presentation equipment does not need to be very advanced, and a simple large-piece of paper with color markers can be employed in multi-day field trips; for a single-day trip, in which the presentations can be conducted in the classroom the next day, more advanced technology, such as computer-based presentations, should be preferred, so that students can share the photographs that they took during the trip. However, even in that case, the productions of hand-diagrams should be encouraged, since the efforts to formalize ideas into simple and clear diagrams is a good learning exercise.

The presentation session should be organized so that all students make at least a portion of the presentation. It should also be employed by the Instructor to emphasize or clarify ideas, as well as to ‘homogenize’ the input received by the students. (Remember that they may have been split into subgroups during the visit and, for that reason, they may have been subjected to different information inputs.) To that end, the students should be encouraged to make comments or questions about the presentations of their fellow students, and they should also be aware that such interaction will be considered for the assessment of the field trip.
Furthermore, the site visit and the information obtained therein can be employed as a basis for a “design-project” in which the students can put in practice what they have learned in the module. The work can include, for instance, a description of the proposed project (that can be the same as or different from the real one), a description and characterization of the geological materials in one specific formation (for instance, the Black Schist formation presented in Fig. 2), and a selection of the tunnel excavation method and design of the support system for the tunnel length located within such formation.

3 LEARNING OUTCOMES

A field trip organized as discussed above combines several approaches to module design for effective teaching. For instance, following the classification proposed by D’Andrea (2003), it is systematic, since it “proceeds from identifiable needs” discussed in Section 2.1 to “predictable outcomes” that should be thought of when the trip is planned. Note, however, that some of the learning outcomes may derive from a problem-based approach (the final term-project) and, perhaps to a lesser extent, from an experiential approach in the form of individual observations (or ‘feelings’) by the student that may have not been generally discussed in class or during the field trip.

As specific learning outcomes, after the field trip and other activities (see Section 2.4) have been completed, able and motivated students should: recall different techniques for tunnel construction (e.g., TBM vs. NATM); explain and describe the functioning of a TBM and the construction sequence in a typical NATM tunnel; use actual geological and geotechnical data, as well as the convergence-confinement method, to compute the support needs of a tunnel; analyse likely difficulties associated to different geologies and construction methods; design a tunnel, proposing a specific excavation/construction method and a specific support; and, assess the validity of different tunnelling approaches and/or support proposals.

The sequence of learning outcomes listed above follows, in order of increased complexity or demand, the taxonomy of outcome levels proposed by Bloom et al. (1956), and it includes “knowledge and understanding” skills in addition to “cognitive” and “subject-specific” skills (following the “domains” of learning outcomes proposed by NCIHE (1997)). Also, there are additional positive learning outcomes related to other “key skills”, such as communication skills (oral and written presentations) and numeracy (quantitative evaluations), among others.

Finally, as additional outcomes of the trip, we found that the new possibilities for assessment based on the field trip had a positive effect on the motivation of our graduate students, as previous research has found that the assessment system is “crucially important in student’s motivation”; (for details, see e.g., Wakeford, 2003; Newstead and Hoskins, 2003), and the field trip was consistently identified by the students as the “most interesting” activity in an assessment conducted by the Instructor at the end of the module. In particular, surveys conducted at the classroom showed that they generally valued its practical aspects, as well as they opportunity that they had to directly observe, as applied in real construction practice, some of the different construction techniques that had been explained in class.

4 CONCLUDING REMARKS

Field trips are a good teaching tool for geotechnical engineering programs and, in many cases, it is very difficult to find good alternatives to them. This paper presents our recent experience with the organization and planning of a full-day field trip for the 3 ECTS “Underground Construction” module of an “Applied Geology” MSc program in Spain. Successful teaching and learning using field trips “does not happen by chance”, and field trips should be planned towards a set of specified (and desired) “learning outcomes”. The learning outcomes will be, of course, to some extent dependent on the availability of construction sites that can be visited and on their actual characteristics, although there is flexibility for the teacher to design the trip—and its ‘pre’ and ‘post’ activities—so that ‘quasi-constant’ teaching outcomes can be achieved.

This article presents some personal thoughts and recommendations for the planning of field trips, it discusses the learning outcomes achieved by our students, and it argues that such well-planned field trips are useful because (i) they provide the students with hands-on experience about the unique technologies, the scale, and the inherent difficulties involved in this type of geotechnical project; (ii) they serve as a basis for discussion after student’s presentations; and (iii) they serve as a basis for a related design-based term-project. Finally, (iv) this type of field trips also helps to incorporate “secondary” learning objectives, such as ‘interactivity’ (between student-instructor but also among peers) and ‘collaborative work’ into the curricula (hence following the new European Higher Education paradigm), and the new assessment possibilities have further been found to increase the motivation of the students.

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