Using ICT in Geo-Engineering education: the case of UPC at Barcelona, Spain

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ABSTRACT: The paper describes the experience of using information and communication technologies (ICT's) in the teaching of Geo-Engineering Sciences in the degrees of "Civil Engineering" and "Geological Engineering" of the Tech. University of Catalonia ("Universitat Politècnica de Catalunya" - UPC), at Barcelona, Spain. The paper also describes briefly the framework of the Engineering degrees in Spain and how they will be probably adapted to the "Bologna guidelines" that affect all European University diplomas. Those guidelines will be used to change the traditional teaching process. Some ideas for future developments in the context of teaching Geo-Engineering are suggested as well.

1 INTRODUCTION

1.1 *Geo-Engineering*

Many of the Faculties and Schools of Engineering in Europe were created according to the branches of different professional activities without any apparent connection between them. However, mining, civil and geological engineering share a common background that suggests joining efforts in future developments. The need for coordination between corresponding professional societies has been highlighted in recent years. As an example, in November 2000, the Conference "GeoEng 2000" was organized in Melbourne, hosted by the International Society of Soil Mechanics and Geotechnical Engineering, the International Society of Rock Mechanics and the International Association of Engineering Geology. Other related Associations sponsored the meeting as well. In that Conference, Norbert R. Morgenstern (2000), in a special lecture entitled "Common Ground", presented the main trends defining the "geotechnical family". It should be recognized that we are still far from being a "single family", but this Conference on Geo-Engineering Education and Training is obviously a step on that direction.

1.2 *Engineering Degrees in Spain*

In Spain the "Bologna framework" is still under discussion regarding the details of the implementation on engineering degrees. In fact we still maintain the traditional Spanish Engineering degrees that include a 3-years "Technical Diploma" and a 5-years High Engineering Diploma.

In Spain both degrees are taught at the University, but most often in different Engineering Schools. Students select the School when they enter the University, usually according to their qualifications in the higher Secondary school. They are not cyclic degrees, but students finishing the "short degree" may enter in the "high degree" after following some additional subjects. Technical degrees are more practically oriented whereas the "high" degrees are more general and more scientifically based. Each degree has the corresponding professional competence defined by law and assigned directly to the University diploma.

In 2006 some Master courses following the format of the Bologna reform started already. In the near future most probably there will be a unique degree on, say Civil Engineering, involving 4 years of studies, and a further Master degree after 2 additional years of courses and a Master thesis.

1.3 *Geo-Engineering at UPC*

The School of Civil Engineering of the Tech. University of Catalonia ("UPC") in Barcelona, offers 3 degrees: a 5-year diploma on Civil Engineering since 1973, a 3-year diploma on Technical Civil Engineering since 1986 and a 5-year diploma on Geological Engineering since 1990. The School was the first in Spain offering several diplomas within the same organization, thus sharing faculty members and experiences. The diploma on Geological Engineering is in fact a join degree with the Faculty of Geology of the University of Barcelona, and that implies a close coordination between both institutions and a common perspective on Geo-Engineering education. All degrees include core subjects on Applied Geology, Soil Mechanics and Foundation Engineering. In addition to that, other subjects are offered as optional or compulsory, depending on the curriculum followed by the student: Tunnelling, Slope Stability, Seismology, Numerical Methods in Geomechanics, etc.

Due to the high number of students requiring more time than the official duration of the studies to get their degrees, the University launched 10 years ago a plan to improve the efficiency of the system. The first course of each degree is selective, whereas the students that do not earn a minimum of 15 credits are not allowed to continue in the same degree. Students not completing the full first course within the first two natural years are also not allowed to continue in the same degree. Despite that, those students who continue in the system still need more than 7 years on average to obtain the "5-years diploma". The reasons are very complex and are not due to the education system only, i.e., some students start working on engineering companies before finishing the degree.

To cope with that situation, the University promoted, among other actions, the use of "Information and Communication Technologies" in the core subjects. The authors where involved in that process, particularly in the subject of Soil Mechanics, which is common to all the degrees, although the scheme is similar to other subjects in the area.

2 ICT IN GEO-ENGINEERING SUBJECTS

2.1 *Virtual campus*

The UPC has a virtual campus including the classical features of this type of platforms: access to documents, downloading, links to internet sites, e-mail and "chat room". A Virtual Campus is used as a tool to link students with professors. All the material required is included in that campus that can be accessed by students registered in the course. The material includes: *i)* PowerPoint files of all the classes, *ii)* proposed problems, *iii)* solutions to the proposed problems, available after two weeks, *iv)* material for 3 selected case histories, *v)* virtual Soil Mechanics Lab, *vi)* material for the laboratory work and finally *vii)* additional optional material.

The presentations used in the lectures (PowerPoint files) are available from the beginning of the course, so students can print the corresponding handouts and follow the class with them. An important effort was devoted to the improvement of the material available for students, because there is not a single book that could be considered appropriate for most of the subjects. Regarding Soil mechanics, a subject with 4 hours per week of teaching during two terms, the amount of material prepared by the authors is quite important. The topics covered include:

- Introduction. Soil and rock. Soil classification.
- Water in soil. Saturated and unsaturated flow.
- Elasticity and Plasticity. General concepts.
- Laboratory in Soil mechanics.
- Deformation and Strength of saturated soils. Cam-clay.
- Deformation and Strength of unsaturated soils.
- Global Failure: Limit Analysis and Limit Equilibrium.
- Hydro-mechanical coupling. Consolidation theory.

For each chapter there is a list of exercises that are proposed and solved in class in an interactive manner with the students. Apart from that, there are several "Case Histories" described and some of them are also presented during the course corresponding to some particular chapters. Particularly well described are:

- The Rissa landslide, a landslide on quick clays in Norway.
- The Failure of Teton Dam in USA.
- The leaning Tower of Pisa in Italy.

These cases include digital videos describing the problem at a technical level and technical documentation as well.

Finally, an executable program consisting on a virtual laboratory is also available for students.

2.2 *Virtual Lab*

All students of Soil Mechanics have to follow at least 3 laboratory classes as well. The core laboratory work includes: *i)* soil description and classification, *ii)* flow and permeability and *iii)* introduction to mechanical tests including oedometer and triaxial. The students can follow other optional subjects involving laboratory testing of Soils and Rocks. The relevance of the Laboratory work is well transmitted to students. This is in fact a key point in the teaching of Geo-Engineering because, in Spain, Civil Engineering Schools have a long tradition of mathematical teaching and students are less sensitive to learning concepts from experiments. The same applies to field trips, which are organized very often in the Geology Faculties but are less common in the Engineering Schools. The importance of Laboratory and Field trips in the teaching process has been highlighted by many authors (Burland, 1987), but now the new Information Technologies allow providing

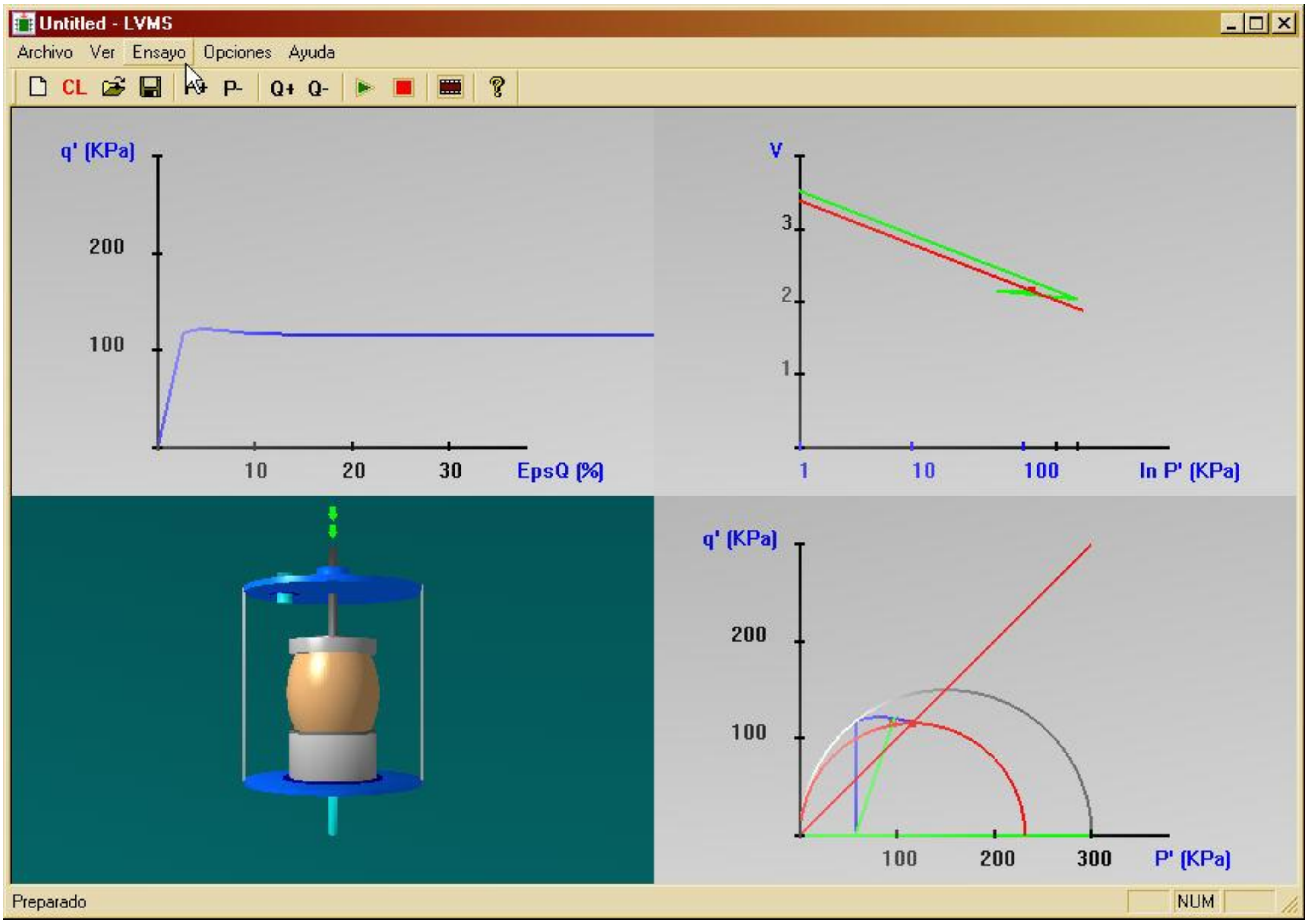

Figure 1. Virtual Lab: CU Triaxial test on overconsolidated clay.

with a simulation of a laboratory or a field environment to each personal computer.

The idea of reproducing a Laboratory experiment in the computer is not new. However, it seems that it has been used in a few cases only (Penumadu et al. 2000). In our case, this simulator of virtual experiments was developed with the aim of helping students to understand Cam-clay model. Introducing an elastoplastic model for soils requires a lot of previous knowledge of Continuum Mechanics and Soil behaviour simultaneously. Constitutive laws, a subject usually taught at PhD level, could be explained at a lower level if students have a simple tool to reproduce soil behaviour. Future developments may include the possibility of programming a different elastoplastic model, a useful feature for advanced students.

The Virtual Lab was written for a Windows environment (95/98/Me/2000/XP) in C++, and using the graphic routines OpenGL. It is possible to simulate oedometer tests and triaxial tests (drained and undrained). Figure 1 shows a typical window of the program, presenting an undrained triaxial test for an overconsolidated sample. The output includes the stress path with the yield surface and its evolution, the volume change plot and the deviatoric stress – deviatoric strain plot. The user can modify the parameters of the Cam-clay model so the response of the "sample" can be reproduced accordingly.

The need for teaching elastoplastic models at a Master level has become evident with the widespread of commercial finite element codes incorporating nonlinear constitutive laws. We have realized that many users of those codes in engineering companies do not have the appropriate background in terms of advanced soil behaviour although they use advanced models in their analyses. This Virtual Lab constitutes a useful tool to make elastoplastic models more accessible to Master students.

3 FUTURE DEVELOPMENTS

3.1 *The "Case History Method"*

Case histories are very useful in the learning process of Geotechnical Engineering. This applies to other disciplines as well. In fact, many Business and Management Schools base their teaching in practical cases, and they introduce new concepts from a description of real situations. The contents of some subjects are not a list of conceptual topics like the one included in section 2.1, but a list of real episodes, some of them well known by the students from the newspapers. We wonder if it is possible to follow the same procedure in Geo-Engineering. It seems difficult to do that at the beginning, but it could be performed at least partially. Note that the so called "Observational Method" is commonly used in many practical problems. When it is difficult to obtain a simple, well documented, real case, it is possible to use "demonstration models" (Bucher, 2000) or simple bright experiments (Elton, 2001).

At UPC we have started that approach by explaining in detail 3 case histories already mentioned: The Rissa landslide, The Teton dam failure and The Pisa tower, but we expect to increase the number with other local well known cases: the Aznalcóllar dam failure, examples of collapse of unsaturated soils and settlements induced by tunnelling.

It should be pointed out that most of the students are fascinated by catastrophic failures, and there are several well documented examples in the History of Soil Mechanics that could be used for this purpose.

The organization of the teaching using this procedure is not straightforward, because in most situations there are several concepts that are required simultaneously to explain the case. It is better if only one concept is related to each case, but a combination of real cases, simple experiments and demonstration models could give a more attractive procedure to present new concepts to students. Obviously the organization of a subject presented in this way needs to focus on those concepts, and the volume of information provided to the students is usually less important than in the classical lecture, where sometimes concepts are hidden behind the information.

3.2 *Project Based Learning*

A further step in the improvement of teaching in Geo-Engineering is to allow students to develop their own skills while solving practical cases. When using the "Project Based Learning" (PBL) approach, students work in small groups and receive the basic data corresponding to a Case History. Then they have to think on how to solve the problem or how to predict the basic variables governing the case. Students learn how to solve problems and also new concepts simultaneously. The process is obviously guided by the professor in such a manner that after the class, students have acquired the concepts, the information regarding an actual case and, in addition to that, they have experienced a methodology on how to solve problems in Soil Mechanics.

This type of teaching and training has proven to be very efficient in many disciplines and there are plans for its implementation in most of the subjects. It is already working in a final year optional subject on "Geotechnical Engineering", but it could be adopted even for more basic subjects as in a core course on Soil Mechanics.

In the University it is also planned that Master's courses will include many subjects within this PBL framework. That will affect PhD studies as well, as they include a first year of regular optional courses that are taken from the Master degrees. This PBL approach becomes now more natural when the problem posed to the student has a research component. A PhD thesis is to some extent a particular "project based learning" developed during several years by a PhD candidate.

4 CONCLUSIONS

The near future changes in the organization of the syllabus due to the Bologna reform, constitute a good opportunity to change procedures and techniques related to teaching and training in Geo-Engineering. At UPC a reform of those procedures already started several years ago with the aim of improving the efficiency of the system in terms of time required by students to obtain their degree. Now there are quantitative indicators that confirm this success. In addition to that, it is expected that the Bologna reform will be another opportunity to improve even more this situation: subjects should be more attractive to students and they should learn basic concepts as well as methodologies. The use of Case Histories, a classical tool in Geo-Engineering, with a "Project Based Learning" approach, seems to be appropriate for that purpose.

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