

Dr. Azadeh Riahi, an NSERC Postdoctoral Fellow at Rocscience Inc., taught the course, *Introduction to Geotechnical Engineering I* (CME 321) in the Civil Engineering Department at the University of Toronto during the Fall 2009 semester. She discusses the challenges of engaging her third-year class of 153 students in the subject of geotechnical engineering, using numerical modeling and the software tool, *Settle^{3D}*. RocNews was interested in how the course went and what the students thought of it in the end.

In your opinion, what is the educational value of numerical modeling?

Dr. Azadeh Riahi (AR):

I wanted to include components in the course that would engage students' enthusiasm for 13 weeks. My intention was to leave them with a lasting, positive experience of geotechnical engineering. To do so, I knew I had to expose them to the difficulties and subtleties of the discipline, but without overwhelming them with information.

Based on my experience with numerical analysis, I have come to believe that it is an exciting field that offers the tools and avenues for tackling geotechnical challenges.

In addition to their application in industry, numerical modeling and software tools must be regarded as valuable educational aids. Computational methods connect traditional civil engineering subjects to current and future technologies. They also provide an effective platform

within which different scientific and design approaches can interact. I believe that although the fundamental principles of a subject need to be taught through the simplest technique – chalk and blackboard – numerical analysis tools, in the form of software, are very effective in helping students see these principles in action.



Can you elaborate on your decision to include the Finite Difference Method in the course?

AR: One-dimensional consolidation theory is a classical subject in introductory geotechnical courses and is part of the course syllabus. Other numerical techniques such as the finite element method are too complex for the students. So, the natural choice seemed to be the application of the finite difference method in the analysis of consolidation problems.

The finite difference method (FDM) is simple, yet widely applicable. Through the solution

of the one-dimensional (1D) consolidation problem, the basic elements of FDM can be covered in a one-hour lecture.

You may be skeptical that undergraduates can grasp the concepts of the finite difference method in only one lecture; numerical method courses are

challenging, even for graduate students. Clearly, this would not be possible if the goal was to comprehensively cover the method. However, if the emphasis is on how relevant numerical methods are to geotechnical problems, then it can be done.

The numerical section integrated into CME 321 was intended to help students understand the initial and boundary conditions associated with consolidation, and to appreciate what is involved in practical geotechnical problems.

For example, the engineering approach to problems that involve non-uniform stress distributions or multilayered soil profiles could be discussed within

this context. I also wanted them to gain first-hand experience with geotechnical challenges such as the reliability (or lack thereof) of soil property values, effect of hydraulic conductivity on how soils consolidate, and the scale and time frame of real geotechnical problems.

So how was this implemented into the course?

AR: The numerical module introduced FDM, discussed challenges in real engineering problems (such as non-uniform stress distributions and multilayered soil profiles), and utilized the commercial software, *Settle^{3D}*, in the course project.

After discussing settlement analysis and covering the numerical solution of the 1D consolidation equation with the finite difference method, I introduced students to *Settle^{3D}*, a settlement and consolidation analysis program. Although I work at Rocscience Inc. (the company that developed *Settle^{3D}*), my decision to use their software was mostly based on how intuitive and user-friendly the program was. It would allow students to build models and solve problems without getting bogged down by the details of how to use the software.

The following aspects also made *Settle^{3D}* an attractive tool to use for CME 321:

- ◆ In contrast to advanced programs based on three-dimensional consolidation theory, *Settle^{3D}* assumes consolidation occurs in the vertical direction only and solves the 1D consolidation problem using FDM. Therefore the program perfectly matched the course material presented to students.
- ◆ *Settle^{3D}* provides the Boussinesq, Westergaard, and 2:1 stress distribution solutions. It also calculates the three-dimensional stress distribution using a boundary integral approach. These options are classical methods used in soil mechanics and geotechnical design.
- ◆ The program has built-in embankment loading and wick drain functionalities for modeling the acceleration of consolidation settlements. This made it easy for students to appreciate the material covered under the engineering design component of the course.
- ◆ Options provided in the application are well described in a theory manual.

The course project involved analysis of an earth dam which was constructed in multiple

stages on a 30-meter soft clay deposit in Turkey. Through this



case study, students were exposed to construction processes, typical dimensions and profiles of dams, construction time frames, data collection and monitoring, as well as material properties and stratigraphy of soil deposits. The students also investigated the effectiveness of wick drains.

What were some of the outcomes of the Numerical Module?

AR: I came into teaching the *Introduction to Geotechnical Engineering* course believing that numerical techniques could contribute to dispelling students' misconceptions about geotechnical engineering. After all, in many ways designing for geomaterials poses much greater challenges than doing so for man-made materials such as concrete and steel. I think that the objectives were achieved.

Apart from the usual complaints of little time and heavy work loads, students were satisfied with the experience of working with *Settle^{3D}*. They were most impressed with the rich diversity of geotechnical engineering problems and the opportunities the field offered.

EDUCATION BULLETIN

ROCSCIENCE INC * ISSUE 4 * WINTER 2010

Most of the students said that they had gained a better understanding of how soil mechanics principles are used in engineering design.

Throughout the course, I repeatedly explained to my students the limitations of graphical methods. Interestingly, it was only when I solved a finite difference example on the blackboard that students grasped exactly how limited graphical approaches were.

I can confidently conclude that the numerical module, especially the project, was successful in meeting the primary objectives. It provided an effective medium for discussing the engineering design components and emphasizing the theoretical aspects of the course. It was also successful in increasing undergraduate students' interest in geotechnical engineering.

I believe that universities have the responsibility to pay greater attention to the application of numerical techniques in geotechnical engineering. This will help close the current gap between geotechnical practice and the potential of numerical modeling tools; these applications are not unreliable black boxes.

- Dr. Azadeh Riahi
Rocscience Inc., Postdoctoral Fellow

At the end of the course, it was very interesting to review the students' course comments and their thoughts on using the software for their projects.

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“ I thoroughly enjoyed using Settle^{3D}. Learning the basics of the program was relatively simple.

Settle^{3D} is a very effective module for the geotechnical community. It can be used to check the design's feasibility by inspecting its consequences on the soil it is applied to. It could also be used for economic analyses, testing different designs to find the optimal solution. Different types of soils can be tested, using different types of loading, in order to understand the compaction and seepage properties of those soils.

In the end, I found the program to be very user-friendly. ”

- Heather Trommels
3rd year Civil Engineering
University of Toronto, Canada

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“ I found that Settle^{3D}'s intuitive interface combined with the default split screen view allowed for easy manipulation of input parameters. The control over the calculations that are possible is very convenient since it allows a user to select an appropriate tradeoff between desired accuracy and computation time by choosing the number of discrete calculation layers.

A suggestion for improving the program would be the ability to input data from several sample points and have the program interpolate soil characteristics between the samples. This could result in more accurate calculations, probably at a cost of increased complexity and greater calculation time.

Overall, the value of the learning experience gained by using Rocscience's Settle^{3D} is high as it demonstrates real world applications of theory studied in the classroom. ”

- Nick Yugo
3rd year Lassonde Mineral Engineering
University of Toronto, Canada