Balancing Classical Solutions with Computer Technology in the Undergraduate Geotechnical Curriculum

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Abstract
One of the desired outcomes of civil engineering technology education is to prepare students for the practice of civil engineering after they graduate. This requires developing student knowledge and competence in the use of standard design practices, tools, techniques, and computer hardware and software appropriate to their technical discipline.[1] To accomplish this, technical courses must balance the coverage of engineering theory with engineering applications typically encountered in practice. Computer technology commonly used in civil engineering practice must be included to achieve this. To meet the needs of employers, students need familiarity with current computer software, as well as an understanding of theories and analysis methods used by the software. Educators must carefully balance the coverage of theory and classical solutions with computer applications to provide students the background they need for their profession.

Introduction

Many educators rely on their own experiences as students and the material presented in textbooks to select topics covered in their courses. However, computer technology has resulted in many changes to civil engineering practice since many educators were students themselves. Many current textbooks still present classical solutions for many engineering problems. While some classical methods are historically important, their practical use in current engineering practice is limited and their value in the undergraduate curriculum is less important today than in the past. Some methods, however, are still appropriately taught in the undergraduate curriculum. Methods that reinforce basic concepts, solution procedures and behavior still provide students valuable learning experiences. To prepare graduates for industry, educators must balance teaching classical methods that emphasize the solution process and behavior with computer methods graduates will use in industry.

Due to changes in the professional practice of civil engineering, updates to what is taught within the civil engineering curriculum are needed.[2,3] This is in part due to the abilities of computers to conduct computations much more efficiently than in the past.[3] Graduates from structural engineering programs with considerable computer usage[4] have an employment advantage over their peers since they tend to be more productive in industrial positions immediately after graduation. In most civil engineering programs, computer software use is introduced into the curriculum directly through discipline specific courses. The literature presents numerous examples of computer usage and software implementation in discipline specific courses.[5,6,7] This can be difficult when hardware or software problems arise or when student questions on software usage result in loss of valuable class and instructor time thereby limiting coverage of technical content.[8] Civil engineering programs using an integrated course format[9,10] show how separate computer programming courses can be coordinated with technical courses to develop computer student competencies. Another approach is to use separate software specific "short courses", in conjunction with required technical courses.[9] In this specific case,[9] students signed up for a one- or two-credit special topics course on using a specific software package while enrolled in a technical course in which the software was used. Although students received credit for the software course, it was not counted toward meeting their degree requirements. It was a formal course, however, so it appeared on their transcripts and was seen as an advantage when looking for employment. Students liked the self-paced format, bi-weekly meetings with the instructor and assignments and exercises using the software.[9]

Although other options are available,[8,9,10] most civil engineering educators will need to incorporate computer usage into their discipline specific courses. To successfully accomplish this, faculty must consider which classical solutions most benefit student learning and how they should be utilized. This paper considers some classical methods geotechnical educators should consider as benefiting student learning when combined with computer methods commonly used in industry. Geotechnical cross-sections sketched by hand, elastic stress distribution using charts and equations, elastic settlement calculations, seepage analysis using flow nets, and slope stability charts and hand solutions all emphasize the engineering solution process and encourage student understanding of soil behavior. Yet the approach to such problems in practice commonly involves computer software usage at some level. Practicing engineers must understand the assumptions and limitations of the computer software and must properly interpret the results of these programs. In many cases the classical approach is still worth presenting, but the solution process and behavior should be emphasized rather than calculation details. Computer usage allows assignments involving parametric studies where students can further explore the behavior and limitations of the various analyses. Even with learning computer technology commonly used in practice, today's engineering students still need to understand the solution process, as well as engineering behavior. Classical analysis methods combined with computer technology provide a way to develop this knowledge.

Geotechnical Analysis and Design in Practice

Good old fashioned hand calculations and chart solutions are still used on many projects as a quick way to get a feel for engineering performance and behavior, or to check the results of more detailed computer solutions. On small projects with low budgets, hand calculations and chart solutions may actually be the standard of practice. In most cases, however, geotechnical engineers typically use a combination of computer software and spreadsheets, along with more classical approaches to accomplish their work. The engineering challenges, however, are in understanding the important design considerations on a project, relative to the geotechnical site conditions, and the determination, selection or estimation of appropriate properties for use in the analyses. Without a good understanding of the behavior of the ground, and selection of values appropriate for the soil conditions present, the results of even the most sophisticated computer analysis will be suspect. Where computers provide precision in their calculations, geotechnical engineering is a field often based on approximations and estimations. Students of this subject must learn to appreciate the uncertainty involved in the calculations and the assumptions and limitations of the various analysis and design procedures. Where uncertainty in technical values is present, computer analyses provide an easy way to consider the effect of this uncertainty and bracket the range of results expected.

Classical Approach and Solutions vs. Computer Applications

Consideration will now be given to several topics within the geotechnical field where civil engineering educators can supplement classical approaches or solutions with the use of computer technology and software commonly used in industry. In each case, the role of the classical approach or solution is to develop and improve student understanding of concepts and behavior. Computer technology and software is used to supplement the classical approach and is not meant to be a substitute for the classical solution methods.

Geotechnical Cross Sections. A decline in the quantity and quality of geotechnical cross-sections has been noted[11] and is attributed to the lack of experience recent graduates have in graphical communication and an increased reliance on computers for drafting, analysis and design. Hand-drawn geotechnical cross-sections may seem "old-fashioned," but their value in site characterization remains.[11] Hammel[11] states that sketching to scale the geotechnical site conditions with pencil and eraser allows time for critical thinking about the geotechnical conditions relative to proposed site development.

To develop skills in cross-section development and understanding of site geology, a laboratory class period in introductory geotechnical engineering courses can be devoted to researching site geology, site exploration methods, and cross-section development. Students often want to develop their cross-sections on the computer, especially those with considerable CAD experience. When this is allowed, students often interpret the assignment as an exercise to practice their CAD skills and focus too much on developing a perfect drawing, rather than an exercise to learn to appreciate the variability, uncertainty, and significance of the geologic conditions at the site. Requiring cross-sections to be sketched by hand requires students to think about the variability of the geologic deposits at a site, as well as the characteristics of the soils present, relative to the proposed development. The sketching assignment should require students to reflect on the geotechnical conditions at the site and write detailed engineering report quality paragraphs describing the conditions. If desired, a computer generated cross-section can be prepared once a hand-sketched cross-section is developed.

Elastic Stress Distribution. Text books all present elastic stress distribution theories and a variety of tools using those theories to estimate changes in stress beneath different load configurations. Equations and charts are available to predict these changes in stress. While historically these equations and charts were the standards used in engineering practice, software, based on the same theories, is available today for use in industry. Today's civil engineering students should learn the theories and their related assumptions and limitations. They should also develop an understanding that for a given problem, selecting the appropriate chart is as important as learning how to use the chart. Many charts can be confusing to students and attempting to present too many chart solutions for a variety of load conditions can lead to students focusing too much on the charts and their usage rather than developing an understanding of stress distribution behavior. Conversely, exposing students to only one chart solution may lead them to believe that the chosen chart can be applied to all problems. Students must understand that many charts are available and each chart has certain conditions for which it is applicable.

Stress distribution equation and chart use in an introductory course should not be eliminated and should allow students to apply the theories to real problems. Charts selected for presentation and use should be relatively simple to use and have a high potential for use in practice. A good set of examples will help students use the charts properly. Assignments using charts and equations can be supplemented by using either stress distribution software or spread sheets to confirm equation and chart results. Software[12] or spread sheet assignments can also be used to perform parametric studies on the effect of different variables on the change in stress. Assignments involving parametric studies should require students to discuss the effect of changing the different variables. Without required reflection on the results, students tend to overlook the engineering behavior illustrated by varying the parameters.

Settlement Calculations. The Schmertmann method[13] is one method available for estimating elastic settlements of shallow spread footings on cohesionless soil. Based on empirical relationships between subsurface investigation data and soil properties, the variation in vertical strains can be approximated. For soil deposits with uniform properties, the calculations can easily be done by hand. When the soil properties vary over the depth immediately below the footing, considering the soil in layers and adding the strain effects seems straightforward, but the procedure can be intimidating for students. A detailed example in class followed by a similar practice homework problem often illustrates the difficulty students have in applying this method. Spreadsheet solutions[14] are available, or can be developed to solve such problems. One possible student assignment is to develop a spreadsheet solution for a specified range of applicability. These are especially useful in subsequent courses in foundation design, where the effect of slight changes in variables can be considered as part of the design process. For consolidation settlements, students should learn and practice using equations. Other software[15] can also be used to estimate consolidation settlements under embankment loads.

Seepage Problems and Flow Nets. Two-dimensional seepage problems in undergraduate geotechnical engineering courses typically have been solved using flow nets. In engineering practice, seepage problems are typically solved using commercially available seepage programs. Educators still need to use flow nets to teach basic principles of seepage through porous media. The value of teaching students how to draw a flow net, however, may not be as important as teaching basic seepage concepts illustrated through flow net calculations. Although sketching a flow net provides engineers time to think about a given seepage problem and develop a better understanding of the conditions present,[16] the little time available for this topic in most courses usually results in frustrated students who draw poor flow nets.

Since the use of flow nets is no longer typical in practice, rather than including flow net drawing techniques in the undergraduate curriculum, instructors can use pre-drawn or textbook flow nets and flow net calculations to teach seepage calculations and behavior. Seepage tank models with dye, or even electrical analogies may be a more effective use of time for helping students develop an understanding about flow paths and head loss associated with seepage problems. Assignments providing experiences using student versions of commercially available seepage software[17] will benefit students and their future employers more than an ability to draw flow nets. Parametric studies can be used to study the effects of different boundary conditions, soil permeablities, or use of sheet pile cutoffs. Using computer results to calculate head, uplift pressure and to consider quick condition development in seepage problems should be included as part of these assignments, just as they would be with flow nets. Any class or laboratory time saved by eliminating flow net drawing techniques might be useful for more thoroughly discussing remediation measures for seepage problems and filter design.

Slope Stability Hand Calculations, Charts and Computers. In many cases introductory geotechnical courses will barely cover slope stability in great detail, if at all. Elective courses may provide ample coverage at the undergraduate level. At other institutions, some coverage of slope stability must be included in introductory courses. Discussion of types of slope movements, infinite slope problems and an introduction to the variety of slope stability analysis methods and their assumptions may be all that can be covered as part of an introductory course. Chart solutions can be easily introduced to provide a broader coverage of the topic, but introduction of computer solutions may also be beneficial.

Although detailed hand calculations can not be conducted in significant quantities, an assignment using hand calculation benefits student understanding of the limit equilibrium approach to slope stability analysis. An assignment where students are given a problem where they can use a chart solution, a computer analysis and hand calculations may provide a worthwhile learning experience for students. Such an assignment can give students an appreciation for the work that went into developing the chart, it gives them an experience of using slope stability software, it can help them understand the limit equilibrium approach of slope stability analysis, and it reinforces the importance of statics in the analysis. To encourage students to reflect on these benefits of the assignment, they should be required to discuss these, along with any differences in the results from the three solution methods. Further student discussion could center around factors that would change the stability of the slope and how the slope could be made more stable. Simple geometry and soil properties should be used, and example problems should be provided. Commercial software[18] and example problems are available in a student version for instructional use.

Conclusions

To meet the needs of employers, civil engineering and civil engineering technology students need familiarity with current geotechnical software, as well as an understanding of theories and analysis methods used by the software. Geotechnical educators must carefully balance the coverage of theory and classical solutions with computer applications to provide students the background they need for their profession. In deciding which classical methods will provide the most valuable learning experiences, educators should focus on methods that reinforce basic concepts, solution procedures and behavior.

The author feels the following is an appropriate mix of classical geotechnical solutions and approaches combined with computer solutions to help prepare graduates for the professional practice of civil engineering:

- Hand-sketched geotechnical cross-sections should be prepared rather than computer generated drawings. This will help students develop an appreciation for the variability of site conditions and the sometimes difficult task of site characterization.
- Carefully selected use of chart solutions for elastic stress distribution, combined with parametric studies and follow-up discussion using either software or student developed

spreadsheets. Presenting too many different chart solutions will probably confuse students.

- Well documented elastic settlement example problems and student calculations by hand, combined with parametric studies and follow-up discussion using either software or spreadsheets.
- Use flow nets to illustrate two-dimensional flow. Examples and assignments of seepage related calculations using flow nets and computer analysis is recommended. Teaching flow net sketching and development in detail is probably not the most efficient use of limited course time. Interpretation and use of seepage program results is important follow-up and should not be neglected.
- Slope stability should still cover some chart usage as well as computer applications. Hand calculations of a simple problem, combined with charts and computer usage may provide adequate exposure in an introductory course.

In all cases, the basic theory, assumptions and limitations of the analysis procedures involved should not be neglected. Students must not be lead to believe that the computer is doing the analysis. The computer is just a tool used by practicing engineers to assist in analyzing complex civil systems and parts of systems. By the time they graduate, if students understand and can apply the theories used in geotechnical engineering practice, and have the ability to use software similar to that used in industry, they should be well prepared to meet the needs of the civil engineering profession.

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