CATIGE for Windows - A Computer Aided Teaching Suite for Geotechnical Engineering

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Summary A suite of 11 computer programs has been written to assist with the teaching of elementary geotechnical engineering principles to university students at the undergraduate level. The suite known as *CATIGE for Windows*, was written in Turbo Pascal for Windows® and Visual Basic™ and operates in the Windows™ environment on IBM-compatible PCs. This paper briefly details each of the *CATIGE for Windows* programs and discusses their benefits and limitations in regard to the teaching of geotechnical engineering.

1. INTRODUCTION

Undergraduate civil and environmental engineering students at the University of Adelaide, as in many universities in Australia and throughout the world, are introduced to the study of geotechnical engineering during the second and third years of the course. The course is taught by a series of lectures, tutorials, demonstrations, laboratory and in situ experiments, and geological field trips. However, for some time, the staff in the Department of Civil and Environmental Engineering at the University of Adelaide have been concerned that undergraduate students tend to learn the principles of geotechnical engineering as a series of mathematical models and design rules, and often have difficulty in extending their understanding to solve different problems (Priest et al., 1990).

In order to address this issue, Drs. S. D. Priest, J. N. Kay, and D. J. Walker, in 1990, developed a suite of computer programs known collectively as *CATIGE* (Computer Aided Teaching in Geotechnical Engineering) *for DOS*. The suite consisted of 10 computer programs each written in Turbo Pascal® Version 5.5. The programs operate in the DOS environment on the IBM PC platform. The *CATIGE for DOS* suite is described in detail by Priest et al. (1990), Jaksa (1994) and Jaksa et al. (1994). In late 1993, the authors received a University of Adelaide teaching development grant to upgrade the *CATIGE for DOS* programs, so that the suite would be able to operate in the Windows™ environment. This software is known as *CATIGE for Windows* and is detailed below.

2. DESIGN PHILOSOPHY OF THE *CATIGE FOR WINDOWS* SUITE

It is a common experience in engineering education that traditional methods of teaching have several limitations. Firstly, while lectures and tutorial exercises are a useful and efficient means of teaching, they encourage students to approach new problems using a *cookbook* procedure - the *recipe* being the method(s) adopted in lectures, or in the tutorial exercise. On the other hand, field trips and practical sessions are time intensive, and often the number of sessions is reduced to fit an already crowded timetable. Alternatively, the number of students per group is increased in order to achieve the same objective. In addition, practical sessions are expensive to run - since the equipment is costly to purchase and maintain; sample preparation is time-consuming and labour-intensive; and close supervision is needed during the sessions themselves (Priest et al., 1990). Often, the students' focus is not on understanding the underlying geotechnical principles, but on how to operate a piece of apparatus which they may never be required to use again. While the authors do not advocate the removal, nor the reduction, of practical sessions - quite the contrary - it is believed that computer assisted teaching can supplement the traditional teaching methods, both efficiently and effectively.

In order to create effective teaching tools, the developers decided that the *CATIGE* suites should meet a number of design criteria. These include:

- The software should be easy to use, and should be user friendly - that is, sympathetic to the student's inexperience with regard to geotechnical engineering parameters, as well as operating the computers themselves;

- The programs should have adequate help facilities to encourage the students to use the software in their own time, at their own pace, and in order to minimise supervision by others;
- While the programs have elements of analysis and design associated with them, the primary aim should be to enhance the students' understanding of fundamental geotechnical engineering principles and <u>not</u> to provide experience in computer aided design;
- The software should be *user interactive* - that is, the student should be encouraged to participate in the solution process, rather than simply watching the computer solve a problem, or animate a particular apparatus.

In addition, it was proposed that the upgraded *CATIGE for Windows* suite provide the following improvements to the *CATIGE for DOS* programs:

- *be easier to use* - that is, more user friendly, with clear error messages, and utilising the excellent input/output facilities that are part of the Windows graphical user interface;
- *be more robust* - that is, less susceptible to program terminations as a result of incorrect input, or network incompatibilities;
- provide better help facilities.

Each of the *CATIGE for Windows* programs endeavours to satisfy these constraints.

3. THE *CATIGE FOR WINDOWS* SUITE

The *CATIGE for Windows* suite consists of 11 computer programs written in Turbo Pascal for Windows® and Visual Basic™. The programs deal with the following geotechnical engineering principles: soil classification; vertical effective stresses; Mohr circle of stress; direct shear testing of sands; triaxial testing of cohesive and cohesionless soils; permeability testing of soils; one-dimensional consolidation processes; laboratory compaction of soils; sheet-pile retaining wall design; 2D seepage analysis; and vertical heave of expansive soils. Central to the *CATIGE* suites is a data file containing the geotechnical parameters of six hypothetical, yet realistic, soils which many of the programs utilise.

It was originally anticipated that the conversion from Turbo Pascal Version 5.5 to Turbo Pascal for Windows Version 1.5, would be relatively straightforward. This was <u>not</u> the case. Unfortunately, Turbo Pascal for Windows Version 1.5 is a much lower level of programming environment than Visual Basic. The first author has had considerable experience programming in Visual Basic™ - an excellent tool for creating Windows software. Facilities that are relatively straight-forward to code using Visual Basic, are far more complex in Turbo Pascal for Windows. In retrospect, it would have been easier, and more efficient, to translate the existing Turbo Pascal Version 5.5 programs into Visual Basic.

The 6 hypothetical soils include: (i) *Alpha Gravel* (GP)- a coarse grained, grey/brown soil containing hard, rounded quartzite pebbles; (ii) *Beta Sand* (SW) - a coarse grained, predominantly red soil containing small black grains of heavy minerals; (iii) *Kappa Sand* (SC/SM) - a soft, cream/white sandy soil containing small shell particles; (iv) *Lambda Clay* (CL) - a heterogeneous, buff-coloured soil with a gritty texture; (v) *Sigma Clay* (OL) - a sticky, grey/black organic soil with a slightly gritty texture; (vi) *Omega Clay* (CH)- a highly plastic, brown, cohesive soil. The geotechnical properties associated with each of these soils are detailed by Priest et al. (1990) and Jaksa (1994).

A brief description of each of the *CATIGE for Windows* programs is given below.

3.1 *CLASS4W* - Soil Classification

This program guides students through the process used to identify and classify soils using the Unified Soil Classification System. *CLASS4W* uses the six hypothetical soils and allows students to choose various laboratory tests and field identification techniques to identify the soils. The results of liquid limit tests and sieve analyses can be plotted to assist the student in classifying the soils. In order to make the process realistic, students are given a budget and each laboratory test is charged against this budget. A typical screen from *CLASS4W* is shown in Figure 1, displaying the results of a liquid limit test and sieve analysis, as well as the Casagrande Plasticity Chart.

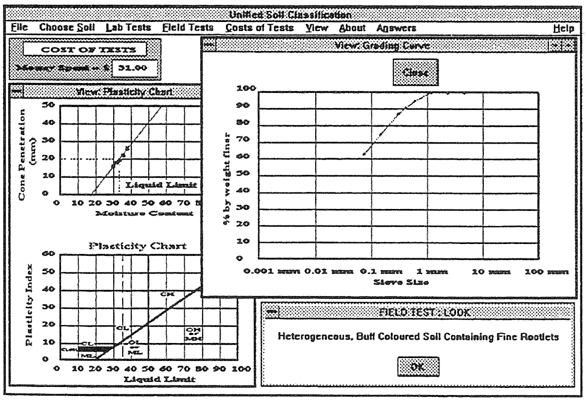

Figure 1. A typical screen from *CLASS4W*.

3.2 *EFFECT4W* - Vertical Effective Stress

The program *EFFECT4W* seeks to reinforce the understanding of vertical effective stresses. A maximum of 4 separate soil layers may be input with different void ratios, bulk unit weights, moisture contents and specific gravities. Each of the 6 hypothetical soils may be used, or others defined by the user. *EFFECT4W* plots the total and effective stresses, and the porewater pressure, as a function of depth, and allows the user to view the effect of varying the depth of the water table on these pressure distributions. A typical screen from *EFFECT4W* is shown in Figure 2.

3.3 *MOHR4W* - Mohr Circle of Stress

This program aims to demonstrate two-dimensional stress transformation by means of the Mohr circle. An element of soil is displayed with user defined values of horizontal and vertical stresses, and as the user rotates the plane of interest, *MOHR4W* plots a vector representation of the normal and shear stresses, and plots the subsequent Mohr circle of stress.

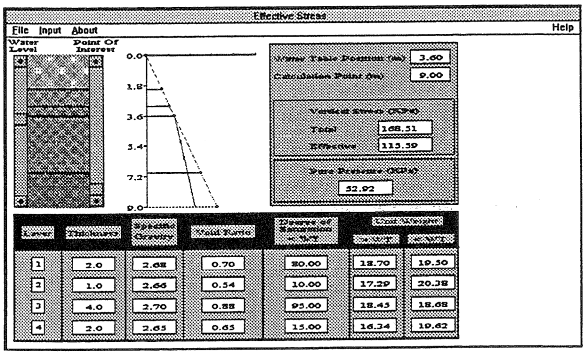

Figure 2. A typical screen from *EFFECT4W*.

3.4 *DSAND4W* - Direct Shear Test in Sand

The program *DSAND4W* is a graphical representation of the direct shear test performed on specimens of sand. The user may select either dry sand or a saturated sand with water pressure, tested in a loose, medium, or dense state. After specifying the hanger load, *DSAND4W* then animates the test apparatus and plots the result on a shear stress vs. displacement, and a normal stress vs. peak shear stress graph. The user is then able to perform additional tests with different hanger loads, after which, the student is asked to estimate the internal angle of friction, ϕ. An example of a screen from *DSAND4W* is shown in Figure 3.

3.5 *TRIAX4W* - Triaxial Test

The program *TRIAX4W* provides the student with an introduction to the triaxial test. The user: selects one of the 6 hypothetical soils; a sealed or unsealed upper platen; whether the test is drained or undrained;

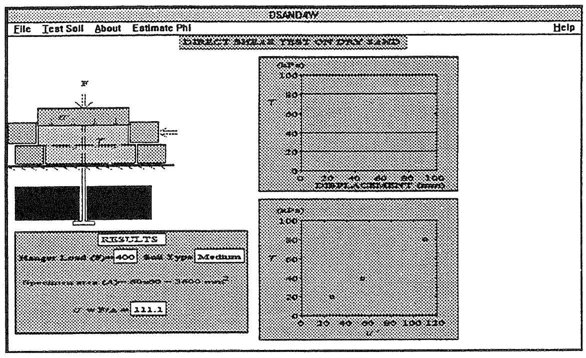

Figure 3. A typical screen from *DSAND4W*.

and inputs a back pressure. *TRIAX4W* displays the triaxial cell and plots the axial strain vs. axial stress, as well as the stress path in p', q stress space. The axial force and cell pressure may be increased or decreased. In addition, the drainage conditions may be varied throughout the test.

3.6 *FALLINGW* - Falling Head Test

The program *FALLINGW* provides the user with an introduction to the measurement of the permeability of a soil using the falling head test. After specifying one of the standard soils and an air pressure, *FALLINGW* provides an animated representation of the test, and a plot of water level vs. elapsed time. The student is able to start and stop a timer, thereby enabling values to be recorded throughout the test. After completing the test the user is asked to evaluate the coefficient of permeability of the soil.

3.7 *CONSOL4W* - Consolidation Processes

The aim of *CONSOL4W* is to provide an introduction to the processes that occur during one-dimensional consolidation. *CONSOL4W* allows the user to choose: one of the standard soils; one- or two-way drainage; the thickness of the consolidating layer; the stress increment; and the time interval between results. *CONSOL4W* displays the consolidating layer, as well as graphs of excess porewater pressure vs. depth of the layer, and the change in layer thickness vs. time. A typical screen from *CONSOL4W* is shown in Figure 4.

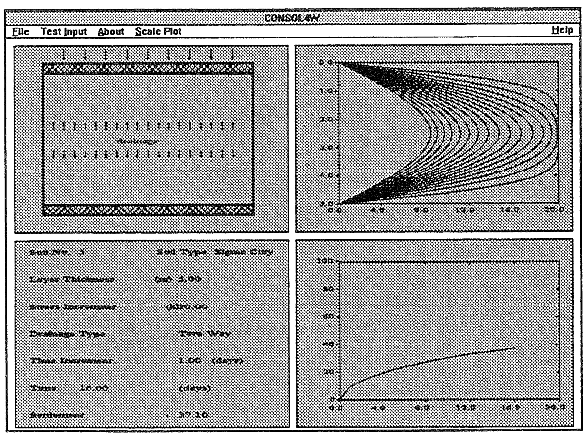

Figure 4. A typical screen from *CONSOL4W*.

3.8 *PROCTORW* - Proctor Compaction Test

The program *PROCTORW* demonstrates the Proctor, as well as the modified Proctor, compaction tests. The user may choose one of the standard soils and the type of Proctor test. The process is demonstrated by using an animated graphics screen. Having compacted the soil and weighed it, the student is asked to determine the moisture content and the dry unit weight of the soil, after which *PROCTORW* plots the result of the compaction test. The student is then able to add moisture and repeat the test, enabling several compaction points to be determined. Having done this, the user is then prompted to determine the optimum moisture content and the maximum dry unit weight of the soil.

3.9 *RETAIN4W* - Sheet Pile Retaining Wall Analysis

The program *RETAIN4W* demonstrates the design and analysis of cantilever sheet pile retaining walls. The analysis is based on the Rankine earth pressure theory, and allows the user to input different soil properties and water tables, on both the active and passive sides of the wall. *RETAIN4W* calculates the sliding forces, overturning moments and the factors of safety against sliding and overturning. If the factors of safety are less than 1, *RETAIN4W* animates the wall and displays its collapse, dependent on the mode of failure which occurred.

3.10 *DAMS4W* - 2D Seepage Analysis

DAMS4W illustrates the two-dimensional flow beneath a dam, sheet-pile, or other user-defined retaining structure. The program allows the user to specify boundary hydraulic heads, soil permeability and the geometry of the retaining structure. By choosing a location within the flow field, *DAMS4W* plots the flow velocity vector. Performing this at several locations within the flow field, enables the student to generate a flow net. The emphasis of this program is not to simply produce a flow net for the student, but to facilitate the task and to involve the user in the generation process. An example of a screen from *DAMS4W* is shown in Figure 5.

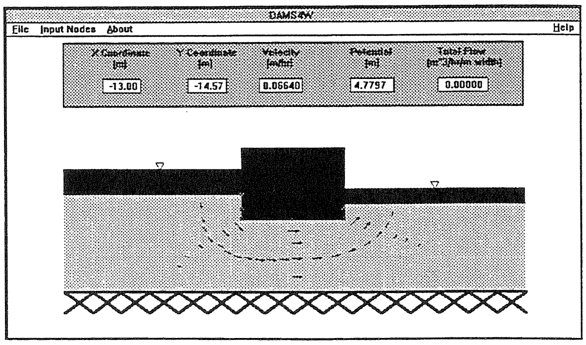

Figure 5. A typical screen from *DAMS4W*.

3.11 *EXPANSIV* - Expansive Soil Heave

EXPANSIV allows the student to input a soil profile - that is, the number of soil layers; the layer thicknesses; and the instability indices for each layer. Using a standard soil suction profile, *EXPANSIV* calculates the amount of surface heave associated with the soil profile, and animates the distortion of a residential dwelling as a function of this heave. In addition, external factors such as: seasonal effects; leaking services; poor stormwater drainage; and tree effects can also be examined by the student. For each of these cases, *EXPANSIV* provides a description of the process that is occurring, the classification of the site, and whether the soil is undergoing centre or edge heave.

4. EVALUATION OF *CATIGE FOR WINDOWS*

The *CATIGE for DOS* suite was developed and first implemented in the geotechnical engineering component of the undergraduate course in 1990. Students are able to use the programs at any time in the Faculty of Engineering's Computer Aided Teaching, PC Suite. In order to evaluate the effectiveness of the *CATIGE for DOS* suite, the students were asked to complete a series of questionnaires after having completed a number of 50 minute tutorial sessions using each of the programs. While full details of the questionnaire and responses were reported by Priest et al. (1990), in general, the students were keen to use the programs, found them to be of a high standard, and easy to use.

As the *CATIGE for Windows* suite has only recently been developed, it has yet to be formally implemented and tested by undergraduate students. It is anticipated that the transfer from the DOS to the Windows environment will enable the *CATIGE* suite to be a more effective tool for the teaching and learning of geotechnical engineering principles.

5. BENEFITS AND LIMITATIONS OF COMPUTER AIDED TEACHING

While computer aided teaching methods have significant advantages over the more traditional techniques, there are a number of limitations also. These include:

- Students do not see, nor handle, real soils during the computer sessions;
- There is no opportunity, during the computer session, for the students to familiarise themselves with the operation of the equipment or apparatus under examination. The students do not appreciate the time needed to prepare a soil sample, or to carry out a particular test;

- Students can regard the programs as computer games, rather than serious teaching tools;
- Since the computer, by its very design, is able to provide rapid and accurate results, the students may be misled into believing that geotechnical engineering is a precise science, rather than a combination of science, good judgement and practical experience. Furthermore, the students are given no appreciation of the errors inherent in measuring a particular soil parameter;
- Major difficulties can occur due to software bugs, network incompatibilities, and hardware malfunctions.

It has been shown by others (e.g. Griffith, 1992; Li and Lee, 1992) however, that computer aided teaching can be an efficient and effective means of supplementing the material given by more traditional modes of delivery, such as lectures, tutorials, practical sessions and field trips. The authors do not believe that computer aided methods are, or should be, the only solution to improving teaching in geotechnical engineering.

The benefits of computer aided teaching are:

- The student is able to try an infinite variety of design situations and scenarios, limited only by the flexibility of the software, and to examine their individual and combined effects;
- The concepts can be transmitted in an exciting and challenging way, enhancing the student's interest in the topic;
- Students are able to learn at their own pace, rather than fitting into a schedule set by the course timetable;
- Since no expensive equipment nor apparatus is being used, other than the computer, there is no risk of damaging the equipment. Consequently, maintenance, technical staff and set up costs are reduced. In addition, there is no risk of sustaining physical injury;
- There is no need to obtain and prepare soil samples, learn the intricacies of operating a piece of equipment, or to spend many hours waiting for results of tests;
- Since supervision is reduced, so too are the demands on academic and technical resources.

6. CONCLUSIONS

A computer aided teaching suite in geotechnical engineering, *CATIGE for Windows*, has been presented. It has been found, that students' learning can be enhanced by the use of computer teaching methods, however, their success as a learning facility is directly dependent on the quality of the software and their associated exercises. The authors believe that computers are a valuable part of the overall teaching strategy, but should not replace the traditional teaching methods of lectures, tutorials, practical sessions and field trips.

7. AVAILABILITY OF *CATIGE* SUITES

In order to disseminate the *CATIGE* suites to other teaching institutions, and to the wider community, both the *CATIGE for DOS* suite, and the *CATIGE for Windows* suite are available for purchase for a moderate cost. Any interested persons, requiring further information about the *CATIGE* suites, should contact:

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REFERENCES

Griffith, M. C. (1992). Computer Aided Teaching for Statics. *Proc. of 4th Australasian Assoc. for Engrg. Education Conf.*, Brisbane, pp. 549-552.

Jaksa, M. B. (1994). *Computer Aided Teaching in Geotechnical Engineering (CATIGE) Suite User Manual - DOS Version*, Dept. Civil & Env. Engrg., Uni. of Adelaide, July, 37 p.

Jaksa, M. B., Kaggwa, W. S. and Gamble, S. K. (1994). A Computer Aided Teaching Suite for Geotechnical Engineering. *Proc. of 6th Australasian Assoc. for Engrg. Education Conf.*, Sydney, pp. 457-462.

Li, K. S. and Lee, I. K. (1992). The Role of Computers in the Teaching of Geotechnical Engineering. *Proc. of 4th Australasian Assoc. for Engrg. Education Conf.*, Brisbane, pp. 559-562.

Priest, S. D., Kay, J. N. and Walker, D. J. (1990). *Computer Aided Teaching in Geotechnical Engineering - Report on a Research Project Funded by a University of Adelaide Teaching Development Grant*, July, 37 p.