Java applets in geotechnical engineering

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***Abstract**: Computer assisted learning has been shown to provide a useful facility for enhancing learning. Recently, Java applets have provided a convenient and effective means by which learning objects can be developed and disseminated. This paper describes 8 new Java applets which have been developed specifically to assist students understand the fundamentals of soil mechanics in the civil engineering sub-discipline of geotechnical engineering. Their benefits and limitations are also examined.*

Computer assisted learning

Since the late 1980s, computer assisted learning (CAL) has provided important and useful additional learning resources to those traditional methods of instruction such as lectures, tutorials, text books, practical sessions and videos. As identified by Jaksa et al. (2000), CAL offers many advantages over traditional forms of learning, which include: (1) the ability to run simulations of laboratory experiments and design scenarios that allow the student to observe the effect on some behaviour by modifying various parameter(s); (2) the subject matter can be delivered in an engaging, effective and challenging manner; (3) students are able to learn at their own pace, rather than adhering to a schedule established by the course timetable; (4) student progress and areas of difficulty can be automatically monitored; and (5) scarce teacher, technician and equipment resources can be diverted to other areas, such as research.

However, while CAL has a number of benefits, it also suffers from several limitations. With respect to geotechnical engineering, a sub-discipline of civil engineering which deals with the engineering behaviour of soils and rock, these limitations include: (1) students never handle soil or rock, nor operate real test apparatus, hence, they are unable to benefit from these important tactile experiences; (2) students may not appreciate experimental errors nor the often significant time needed to carry out some geotechnical tests; (3) if the CAL resources are poorly designed, the student may be more concerned with navigating or 'playing' the software than with learning; (4) hardware limitations may cause the software to crash or the web-navigator to be unbearably slow, hence, detracting from the learning experience. As a consequence, CAL should not be seen as a replacement for traditional instructional methods. Rather, CAL offers an additional powerful and engaging instructional tool which enhances the students' learning experience and learning outcomes.

With regards to geotechnical engineering, among the early developments of CAL were the significant UK *GeotechniCAL* suite of programs (Davison, 1996), Geotechnical Courseware (Budhu, 2006), *CATIGE* (Jaksa et al., 1996), and the TU Delft Software and Resources (Verruijt, 2006). Jaksa et al. (2000) provided a relatively extensive overview of the geo-engineering CAL resources available at that time and the interested reader is referred to this paper for details on each of the above. Since then, however, very few new CAL resources have been developed and many of the ones listed above have failed to keep pace with changes in PC operating systems. This is a serious issue for CAL, as new operating systems and technology often render obsolete the significant efforts devoted to developing such CAL resources.

However, as a more positive development in recent years, several geo-engineering software companies provide student versions of their programs at no cost (e.g. Centre for Geotechnical Research, 2009; Geo-slope Int., 2009; Oasys, 2009; SoilVision Systems, 2009). Each of these software packages contains several powerful geotechnical analysis and design programs, which have been scaled down for student use. Despite this, and while they have been developed primarily to facilitate analysis and design and not necessarily to assist students in learning, the programs are nonetheless extremely valuable tools for use in geotechnical engineering education.

More recently, because of the limitations imposed by platform-dependent CAL, as discussed above, online, Java applets have become increasingly prevalent in web-based learning environments as authentic learning objects (Crisp, 2007). One of the benefits of such applets is that they run within the user's internet browser and can either be downloaded or executed from a web page.

The present paper describes 8 recently developed Java applets in geotechnical engineering and discusses their relative merits and limitations with respect to enhancing student learning.

Java applets

As noted by Crisp (2002), Java applets are small, web-based applications written using the Java™ language and they are consistent with the active constructivist approach where students are engaged in activities that encourage and facilitate learning. Nair et al. (1996) identified a number of advantages of Java-based applets, including they: (i) can be made widely available and can be run from a local computer; (ii) are platform-independent; (iii) provide browsers with a high degree of dynamism; and (iv) enable sophisticated animation. Java applets can be embedded in course web sites or used as simulation tools in classroom environments, and provide interactivity to engage students in active learning (Crisp, 2002). A great number of examples of Java applets, developed across the broad range of higher education disciplines, are provided by Crisp (2007).

Very recently, Java applets have been developed to facilitate geotechnical engineering simulations. For example, TAGA Engineering Software Ltd. (2009) provides a relatively simple Java applet for the solution of an infinite slope.

CATIGE Java applets

Eight of the *CATIGE* (Computer Aided Teaching in Geotechnical Engineering) suite of 15 PC-based programs have recently been re-programmed as Java applets. These include: Consolidation Processes, Direct Shear Test in Sand, Mohr's Circle, Permeability Test, Proctor Compaction, Sheet Pile Retaining Wall Analysis, Triaxial Test and Vertical Effective Stress Calculation. The design philosophy of the *CATIGE* suite is given in detail by Jaksa (2000). For the purposes of analysis, the majority of the *CATIGE* programs make use of 6 hypothetical soils, whose geotechnical properties include those associated with gravel, sand and clays. The applets also provide the facility to enter user-specified geotechnical properties.

In order to facilitate improved learning outcomes, the applets are made available free-of-charge from the first author's home page (www.ecms.adelaide.edu.au/civeng/staff/mjaksa01). Each of the applets is discussed briefly below.

Consolidation processes

This applet provides an introduction to the processes that occur during one-dimensional consolidation. The applet allows the user to choose one of the 6 standard soils described above, or user-specified soil properties, one- or two-way drainage, the thickness of the consolidating layer, the stress increment, and the time interval between results. The applet subsequently displays the consolidating layer, as well as plotting in real-time, graphs of excess porewater pressure vs. depth of the layer, and the change in layer thickness vs. time, as shown in Figure 1.

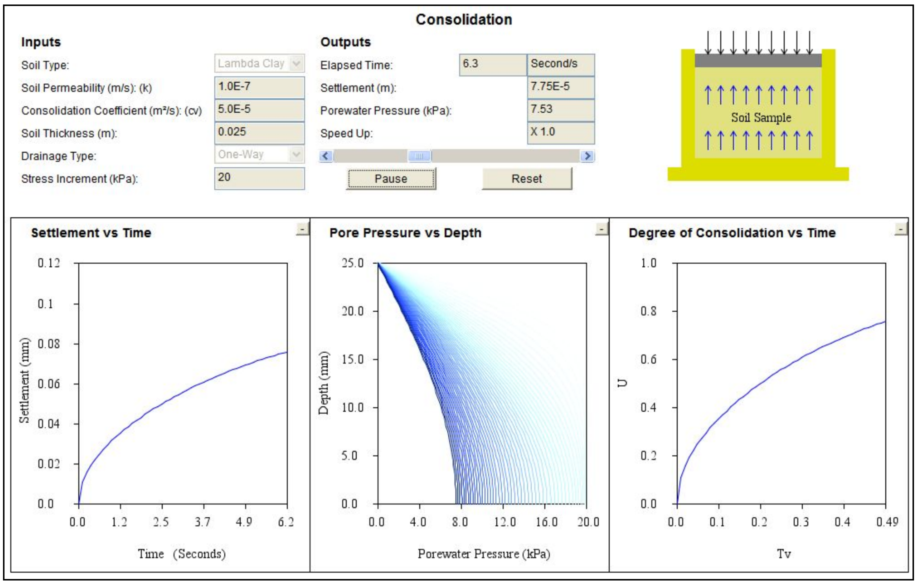

Figure 1: Consolidation processes Java applet

Direct shear test in sand

This applet provides 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, the applet then animates the test apparatus and plots the results on shear stress vs. displacement and a normal stress vs. peak shear stress graphs. The user is then able to perform additional tests with different hanger loads, after which, the user may estimate the internal angle of friction, ϕ, as shown in Figure 2.

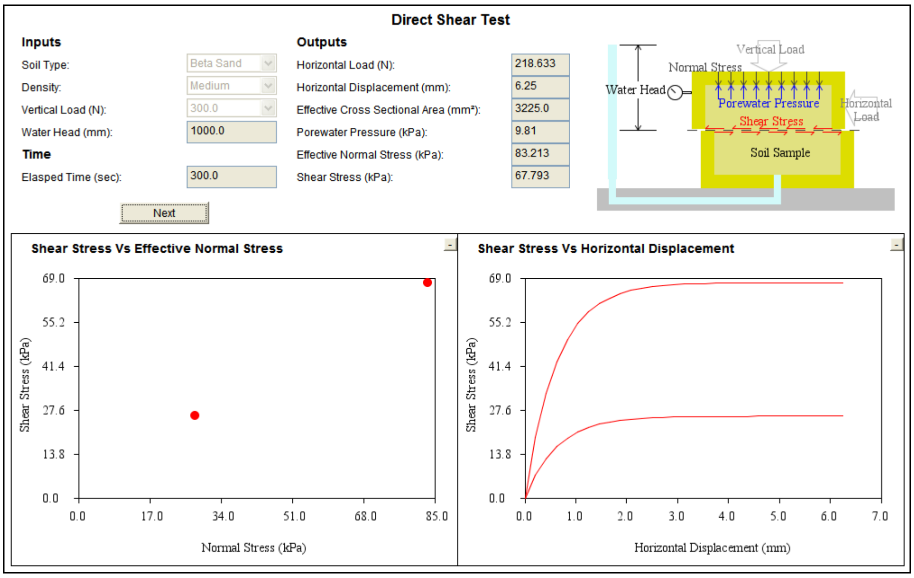

Figure 2: Direct shear test Java applet

Mohr's circle

This applet demonstrates two-dimensional stress transformation by means of the Mohr circle. An element of soil is displayed with user defined values of horizontal, vertical and shear stresses, and as the user rotates the element, the applet plots a vector representation of the normal and shear stresses, and plots the Mohr circle, as shown in Figure 3.

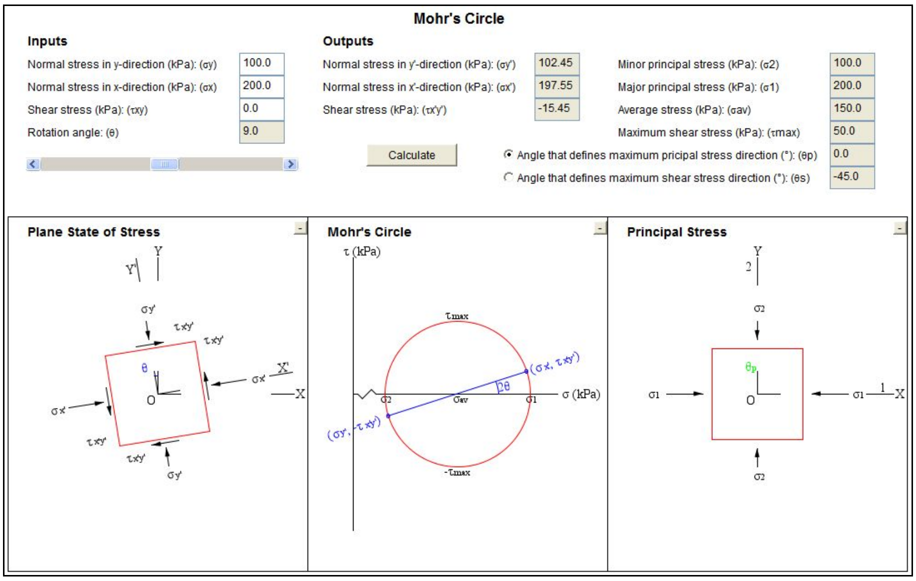

Figure 3: Mohr's circle Java applet

Permeability test

This applet provides the user with an introduction to the measurement of the permeability of soils by means of the falling head test. After specifying one of *CATIGE*'s 6 standard soils, an air pressure and a simulation time interval, the applet provides an animated representation of the test, and the head of the water in the standpipe is plotted against the simulation time. The user is able to start and stop a timer, thereby enabling values to be recorded throughout the test. After completing the test the user is able to evaluate the coefficient of permeability of the soil.

Proctor compaction

This applet demonstrates the Proctor, as well as the modified Proctor, compaction tests. The user may choose one of *CATIGE*'s six hypothetical soils and the type of Proctor test. The process is demonstrated by using an animated graphics screen and, if desired, sound. The applet guides the user through the compaction test procedure and plots the results on a standard compaction graph. The user is able to add or remove moisture and repeat the test, enabling several compaction points to be determined. Having done this, the user is then asked to estimate the optimum moisture content and the maximum dry unit weight of the soil, as shown in Figure 4.

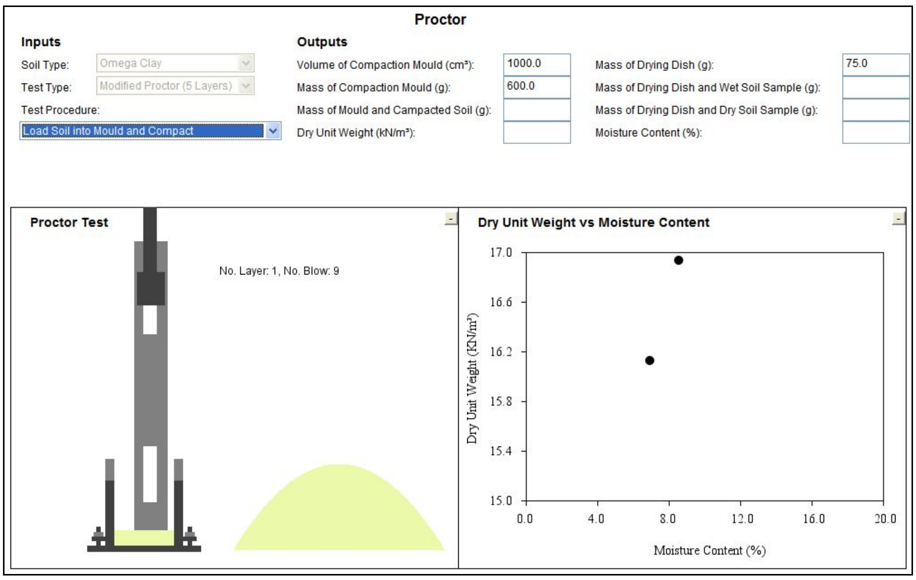

Figure 4: Proctor compaction Java applet

Sheet pile retaining wall analysis

This applet 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. The applet calculates the sliding forces, overturning moments, and the factors of safety against sliding and overturning. If the factors of safety are less than 1, the applet animates the wall and displays its collapse, dependent on which mode of failure occurs.

Triaxial test

This applet simulates the triaxial testing of soils. All six of *CATIGE*'s soils can be tested, as well as user-specified soil, using drained or undrained conditions. The axial stress and cell pressure can be increased or decreased during the test, and the drainage valve can be opened or closed at any time. An axial stress-axial strain graph and an *s*, *s*', *t* stress path can be plotted. Porewater pressures are measured and displayed throughout the test, as shown in Figure 5.

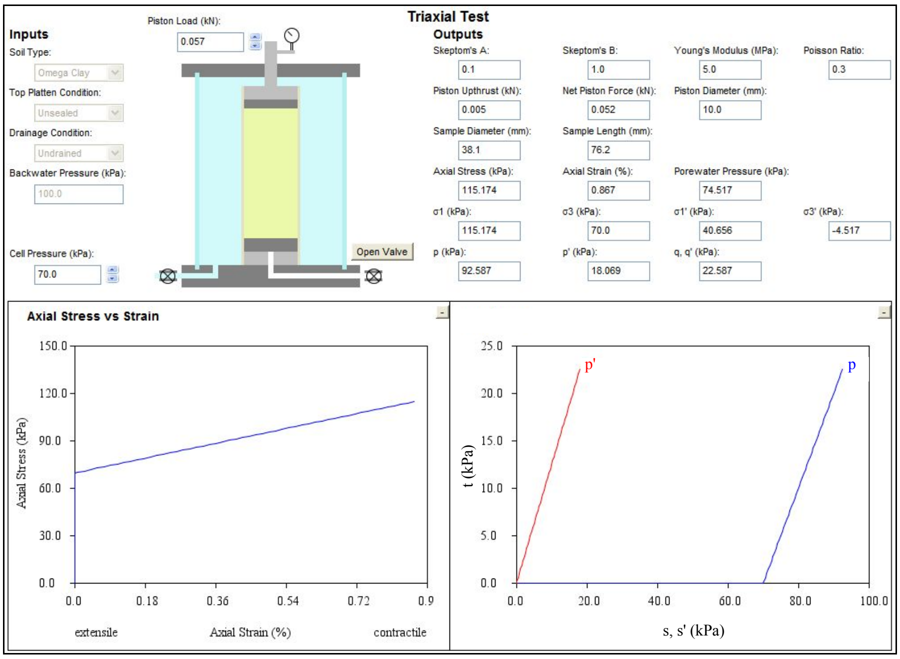

Figure 5: Triaxial test Java applet

Vertical effective stress calculation

This applet seeks to reinforce the understanding of vertical effective stresses. Up to 10 separate soil layers may be input with different void ratios, bulk unit weights, moisture contents, and specific gravities. The 6 hypothetical soils may be used, or others defined by the user. The applet 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.

Learning efficacy and limitations

As the applets have only just been completed and are currently in the process of being incorporated into teaching, formal assessment of their learning efficacy has yet to be undertaken. As a consequence, it is not possible at this time to measure the learning efficacy of the Java applets. However, given that the applets are very closely related to the PC-based *CATIGE* programs, which have been used for many years and have been shown to enhance learning (Priest et al., 1990), it is expected that the applets will also improve learning. However, this remains to be demonstrated.

Whilst Java applets provide a useful and effective means by which to develop and disseminate simulation applications, they nevertheless incorporate inherent limitations. One important disadvantage over other languages is that web-based Java provides limited ability to read from or write to files stored on the client's machine (Nair et al., 1996). In many cases, this has restricted a number of the features of the *CATIGE* applets when compared to their Windows-based counterparts.

The applets are available free-of-charge from the first author's home page (www.ecms.adelaide.edu.au/civeng/staff/mjaksa01). Users are encouraged to provide feedback to the first author in order to improve the applets in future releases.

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