

Soil Mechanics “Virtual” Laboratory – A Multimedia Development

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Abstract

This paper discusses development of a highly interactive multimedia package which includes series of standard soil mechanics laboratory experiments for teaching and learning purposes at undergraduate level of a typical Civil Engineering or Earth Science course. The developed software is in the form of a CD-ROM and consists of three distinct key elements including, a) photo-panoramic guided tour of a typical soil mechanics laboratory (navigable movies), b) technical information, which includes a procedural statement for each experiment, a description of the equipment and apparatus, an example, typical results, references to other literature and additional information to underpin lecture notes, c) questions and log file of results and navigation. The paper also provides an example test (Shear Box Test) explaining step by step procedure of using the package. Finally detailed technical and programming information about how this package was designed and developed have been provided in this paper.

Keywords: *Multimedia, Soil Mechanics, Teaching & Learning, Software, ToolBook.*

1.0 Introduction

The procedures adopted for students to undertake laboratory experiments have remained virtually unchanged for many years. Students are expected to undertake experiments using a "recipe" sheet, which provides them with a step-by-step procedure. This work sheet is often only provided on the day that the experiment is to be carried out, and consequently student's procedural progress is severely hampered by a general lack of confidence.

If experiments are to be valid and worthwhile, students must be provided with a sense of ownership, both before and after experiments have been conducted. In the process of undertaking an experiment, and in the subsequent writing up, students need to be able to revisit

the laboratory and refresh their memory so that they are more capable of relating their results to expected outcomes. Very often students struggle through experiments with very little insight and procedural guidance - a direct consequence of not having essential prior knowledge of the laboratory, its equipment, and function.

The main objective of this investigation/development is to address the above problems by providing students of relevant disciplines with a computer aided virtual (real-time) Soil Mechanics Laboratory which enables them to view the laboratory facilities at their own leisure and pace.

The resulting software, which is in the form of a CD-ROM, provide students with unrestricted access to the facilities, the principal advantage of which is that they may 'visit' the laboratory electronically in a highly interactive and information-rich environment - before, during and after the experimentation period. This package consists of three distinct key elements:

- Photo-panoramic guided tour of a typical Soil Mechanics Laboratory (navigable movie), providing students with navigational access to the laboratory facilities. This incorporates a high degree of interactivity, direction, level and pace.
- Technical information, which includes a procedural statement for each experiment, a description of the equipment and apparatus, an example, typical results, references to other literature and additional information to underpin lecture notes. This element also includes a video clip of each individual experiment demonstrating preparation of the sample/s, assemblage and mode of operation of each experiment (animated), standard procedure, equipment details and good practice.
- Questions and log file of results and navigation. Users can examine their level of understanding from each experiment by answering questions provided under the heading of "what can you remember" at the end of each session. Also properties that can be set are a password log-in utility, a question score method,

score results encryption (tamper proof scoring) and feedback to the tutor (email facility).

2. Application Requirements

Factors influencing the choice of software, hardware and application design is a limited time schedule, very tight budget and remote working practices between the project leader and software designer. The application also required a large amount of media to be produced in the form of video clips, 3D animation, digital still images of laboratory equipment and narration. The whole package has to be published on a single CD-ROM. Based on the above criteria, it was evident that the latest multimedia authoring and animating software would be required.

2.1. Hardware

The computer and peripherals used to develop MSL are a 400MHz Pentium II, 192MB of RAM, 9GB hard drive, 17 inch monitor, 32Mb AGP card with video capture capability, CD read/writer, scanner, printer and zip drive.

2.2. Media Equipment

Recent advances in the home media market have allowed us to produce digital formats in an affordable way. Much of the video footage has been captured in a digital format on Hi 8 videotape. Digital formats have a quality far higher than required by the application at present but it is useful to archive the footage for later advances in technology. The equipment used in MSL is a video camera (digital recorded on Hi 8 tapes), digital camera, camera, video capture/editing equipment (University of Portsmouth Media Centre), video capture/editing software (PC based) and a sturdy tripod.

2.3. End User Requirements

The application has been designed to run on Windows 95/98/NT4.0 using a 200MHz Pentium, 32MB of RAM, 1GB hard drive, 14 inch monitor, 12 X CD

2.4. Software

The following software has been used to develop MSL:

- ToolBook II instructor Version 6.1a by Asymetrix, 3D Studio MAX R3.1
- Corel Draw 7
- Digital Video Producer (DVP V4) by Asymetrix.

- ForeHelp V 2.96
- Adobe Acrobat V3.01

3. Application Design

3.1. Introduction

The design of the application has been kept simple. Navigation is kept very open utilizing traditional forward/back buttons and via the two panoramic views of the soil laboratory. An open navigation allows full access to all parts of the application. This allows past and future topics to be explored at will. A simple visually pleasing background image and layout provides initial visual impact but does not dominate the overall look and feel. Each page has an identical look and feel, keeping topic lists and button groups in identical locations. This is important to achieve user familiarity.

3.2. Pages

Pages contain the background image, a topic list with buttons (Figure 1) , all other navigation buttons and buttons to open the laboratory viewers.

A single page is used for each test. All information, equipment, video clips, references and questions are available by selecting items from the topic list on the page. To aid in the navigation shortcut keystrokes and button tabbing order is available. Users can use familiar keystrokes to launch items on the screen without using a mouse.

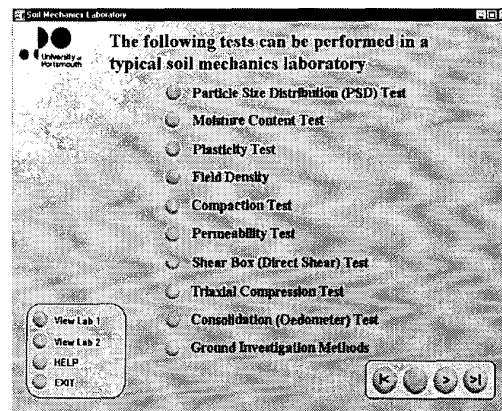


Figure 1, Title of the tests included in the package

3.3 ToolBook Viewers (Windows)

ToolBook viewers are used extensively throughout the application. Viewers are windows, which overlay the page. The advantage of this is that the user is able to open many viewers at once and manage these on the desktop using functions to close, minimize, maximize and window dragging. Viewers are used to display a field of scrollable text, graphics to display items or parts of equipment and a selection of questions.

3.4. An Example Test

On entering a laboratory test page, the user is able to select topic items that provide descriptive information (Figure 2), perform tasks, and display audio-visual material or answer questions. Although the list of topics is set out in a liner fashion, it is possible to access any component on the page at any time. The topic titles below represent the Shear Box Test topic list and describe what is launched when a button in the list is clicked.

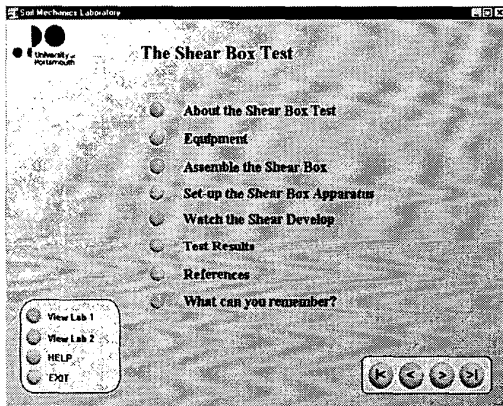


Figure 2, Typical information included in each test

3.4.1. About the Shear Box Test. On clicking the button, a window displays a description of the test with images of apparatus, formulae to calculate test results and example graphs (stress strain curve and shear stress/compressive stress).

A content list at the top of the page is provided which links to the corresponding location within the body of the text. To navigate easily back to the content list (top of the page), links are placed intermittently throughout the text. Images and graphs are displayed as "popup" windows by clicking links within the text.

3.4.2. Equipment. A digital still image of the apparatus is presented in a window (Figure 3). As the user moves the mouse over a zone an explanation of that component is displayed in a text field located below the image. Some zones when entered display a zoom cursor indicating that a larger more detailed image is available for viewing. Components in the image are zoned using invisible polygons. ToolBook provides a polygon tool that allows components to be zoned with precision by dragging around the outline. The polygon is then assigned a name and a script is written using a "mouse over" event. The polygon is made transparent and then grouped together with the image (pictureObject). This ensures that all the polygons keep their positions in relation to the image.

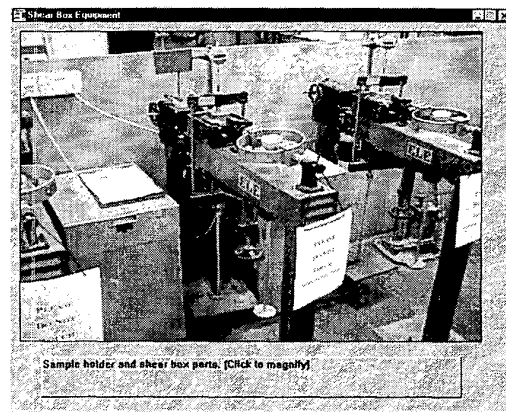


Figure 3, Shear Box Apparatus (zoned images)

3.4.3. Assemble the Shear Box. The traditional method of demonstrating the shear box sample holder assembly is during a soil mechanics practical lesson. However, it would be useful to demonstrate this before the student enters the laboratory to have some familiarity with the components and how they fit together. We have achieved this by using a narrated animation (Figure 4). On entering the exercise page, the student is presented with a list of components to assemble, a numbered image indicating the assembly sequence and the first frame of the animation. The student clicks an item in the list, which starts an audio narration describing the procedure. Following the audio, an animated sequence is displayed. The words of the narration are also presented in a text field. The combination of reading from the screen and listening to a narration helps the student retain the information. It also caters for hearing disabilities or machines which do not have audio enabled. The student can assemble the apparatus by activating each component in succession or randomly.

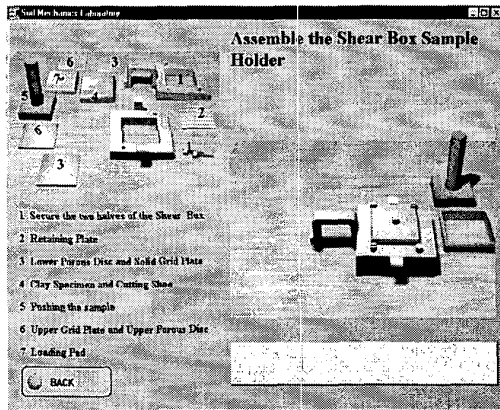


Figure 4, Shear Box assembly (animation)

3.4.4. Set-up the Shear Box apparatus. During a soil practical lesson the student will normally watch a skilled technician perform the test and then is expect to perform a similar task under supervision. To provide a similar demonstration, a narrated video clip is used. The student is able to play, rewind, forward wind and stop the clip using the video player provided in the viewer.

3.4.5. Watch the Shear Develop. This topic demonstrates the processes within the shear box as the normal load and shear forces are applied. During the laboratory practical lesson these processes are not clear as the box is enclosed. Animation is the best method to demonstrate this (Figure 5). Objects making up the box are rendered with varying degrees of transparency so that components are visible through one another. Objects are annotated to make identity even clearer. As the clip progresses, one half of the box is moved over the other and a shear plane develops. At the same time a graph of shear stress against stain is drawn.

3.4.6. Test Results. Example test sheet(s) and test results are provided here. In the shear box test, graphs of stress strain curve and shear stress/compressive stress are displayed. During the practical demonstration, the student is given a laboratory test sheet to fill in which adds more confusion to an already hectic environment. To alleviate this, the student can see how the laboratory test sheet is completed and see a set of calculated test results before entering the practical lesson (Figure 6).

3.4.7. References. A carefully selected list of references is displayed in a scrollable window, which refers to the texts used to produce the test example and references suitable for further reading. Reference will aid in the preparation of the practical laboratory report or for revision purposes.

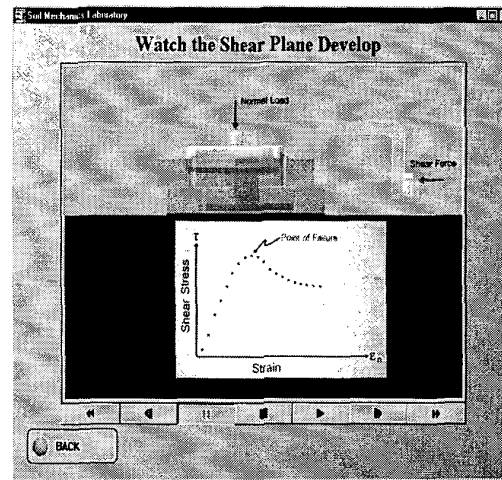


Figure 5, Shear Plane Developing and Stress Strain Relationship (animation)

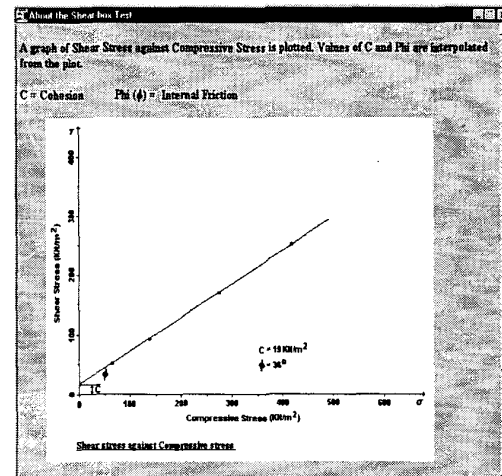


Figure 6, A typical Test Results

3.4.8. What Can You Remember. In this section the student is questioned about test procedures and test results. No score from these questions is generated but the answers are logged. The question styles used are multiple choice, true or false and “fill in the gap”.

When the application is started, the student must define a path to the log file and enters his/her name, which identifies the student to the tutor. The log file records the answers to questions. Analysis of the log file by the tutor will demonstrate a student’s understanding of the topic.

4. Where Hollywood and Soil Mechanics Meet

4.1. 360° Panoramic Views of the Laboratory

Producing the laboratory panoramic views has been problematic technically and photographically. The views are used as an integral part of the navigation to laboratory items in MSL and presented in a ToolBook viewer. The lens of the camera tended to distort the image.

The following method has been used to create the panoramic. The footage is taken with a digital video camera which is fixed to a leveled tripod and rotated 360° in a constant manor while the camera is recording. The resulting clip is then captured as individual frames with sufficient overlap. Each image is enlarged and then stitched together to produce a single 360° panoramic image. ToolBook is only able to support images up to 2000 pixels wide. This then restricted the final panoramic to 200 pixels high. A ToolBook viewer is then used to display a portion of the panoramic. A scroll bar in the viewer (window) allows the full width of the panoramic to be viewed. Laboratory items are defined by invisible polygons on the panoramic image. These are "hot" and display a line of text describing the laboratory apparatus, which may also be used to navigate to pages in MSL.

4.2. Creating the video

Developing video clips for the Soil Laboratory has proved problematic in that vast amounts of video footage was generated, bad lighting conditions in the laboratory and final clip file sizes were very large (85Mb for 5.5 minute clip). These have been solved by modern video equipment, good video production and editing techniques as well as the use of current compression software (codecs). Soil testing can be a long process involving detailed and complicated applications of equipment. This can generate up to 40 minutes of video footage per a test. This footage is then edited to a clip of around 2 to 5 minutes! A method devised to achieve this is to film the complete test precisely and very quickly (main shot). Important parts of the test are then filmed again in close-up. In the first edit, the close-up portions are then inserted at the appropriate places within the main shot and the bulk of the unwanted footage is removed. The first edit is saved uncompressed. The second edit (final approved edit) removes further unwanted footage. It is at this point where the effects or accompanying animation are added. Fade transition effects are used to break up a lengthy parts of repetitive content. The second edit is compressed at this point using a codec (compression software) and a new file

name. An uncompressed version is also kept for archive purposes. Initially, the first video clips produced for MSL used the Cinipak codec. It was originally chosen because it is installed as part of the multimedia components within Windows 95, 98 and NT. This allows clips to be played using the players installed on these operating systems. However, Cinipak loses a significant amount of picture quality, creates artifacts within the video clip and the files are slightly larger than more recent codecs. Later clips use the Indeo 5.11 codec [<http://www.ligos.com>]. Indeo 5 produces significantly better picture quality, fewer artifacts and smaller file sizes. This codes is not shipped with Windows 95 and needs to be installed. To solve this problem, the Indeo 5 setup is provided on the MSL CD-ROM.

The specification for video is a clip length of 2 to 5 minutes long; compressed using Cinipak or Indeo 5.11 codecs and displayed at 320(w) x 240(h) pixels size in 24 bit color at 15 frames per second.

4.3. Creating the Animation

The animation is created in 3D Studio Max R3.0 (AutoDesk Inc.). In the Shear box example, components of the sample holder are created using standard primitives (cube, sphere, cone etc.) or Splines (line, rectangle, circle etc) which then have modifiers applied to them such as lathe, extrude or mesh edit. Realism is achieved by applying a texture to the surface of the object such as the "scinted-bronze" effect used for the porous plate. This texture is created using digital photographs of sandpaper (bump map) and copper metal mixed with ambient and diffuse color (diffuse map). To set the scene, a target spotlight and several omni lights are added to illuminate objects and apply shadows.

Objects are animated in the track view where time lines and positions in space are displayed (function curve). Fine control of each object in space is performed by changing the shape of the function curves. The function curves display an objects height, left and right movement and back and forth movement. Keys are moved, added or deleted to modify the curve.

Finally, the animation is rendered and compressed to an audiovisual file (.avi). In the render properties window the file location, frame sequences, compression codec (Indeo 5) and image size are set.

The specification for animation is a clip length of 0.5 to 2 minutes long, compressed using Cinipak or Indeo 5.11 codec in an .avi format, displayed in a range of sizes up to 640(w) x 480(h) pixels in 24 bit color at 12 frames per second.

4.4. Narration for Video and Animation

Once the video and animations are finished (final edit) the narration script is then written. The narration is limited to the length of the clip. Some forethought is required while editing the clip to keep enough footage to contain the narration. As very little time is available, the narration script needs to be precise. Audio is recorded using the sound recorder available in Windows 98 and a standard head mounted microphone. The audio file is saved in 16 bit mono at 22KHz as a .wav file. The clip is synchronized with the narration by recording the audio while watching the clip. The narration is then added to the clip using the video editing software. 8 bit recording is too low a quality and is not recommended unless file size is an important consideration.

5. Making the Application Work – Programming in ToolBook

5.1. ToolBook Command Based Language (OpenScript)

ToolBook has a command based scripting language called OpenScript. This enables lower-end development to produce more specialized and sophisticated applications. OpenScript can be learnt quickly without the need of specialized programming ability. A script can be written to control events or actions of objects or to control the presentation of an application.

An object hierarchy exists in ToolBook. Scripts can be placed at object level or higher up at page level and so on. Most events in this application are controlled from the page level or book level. The scripts at page level control nearly all the functions on the page. As every page is virtually the same, a copy of the page copies all objects, scripts and background image. Reproducing pages in this way allows for quick application development and reuse of common scripts. Minor modifications of the script are easy when using a naming convention for objects and variables.

5.2. An open script example

Printing screens from within ToolBook is troublesome and does not maintain the document formatting. A solution to the problem is to convert the original document into a .pdf file using Adobe Acrobat. The example script below links a dynamic linked library (.dll) and uses a Windows Advanced Programming Interface (API) function.

```
to handle buttonClick
    local STRING pdfFilePath
    linkDLL shell
    WORD ShellExecute( WORD, STRING,
STRING,STRING, STRING, INT )
    end linkDLL
    pdfFilePath = "al_pi.pdf"
    get ShellExecute( sysWindowHandle, "print",
pdfFilePath, NULL, NULL, 5 )
end
```

5.3. Shared Scripts

To reduce the amount of repetitive scripting (same script occurring on each page), the control of keyboard short cuts, cursor changes, exit sequence and button events have been converted to shared scripts. This optimizes the scripts reuse and editing. Editing the script is done in one location but affects all objects using the script throughout the application.

5.4. Managing and Controlling Clips

Another innovative use of ToolBook is to add all media (video, animation, images and narration) to the clip manager. This facility manages large media files which reside outside of the multimedia application. These media files are then loaded as required from the hard drive or CD-ROM (when installed). Scripts are used to control the loading of media files. To develop the equipment assembly sequence, a script is used to start and stop the media file at particular frame sequence and at the same time a narration is played. To control the clip in this way, the clip must be told to hold and/or wait until certain events have finished.

6. Questions and Logging

Every test example has a series of questions. No score from the questions is generated but the answers are logged. To enable a better picture of the student perceptions of the application, a set of optional questions are provided on exit. The properties of these have been set to provide a rating based on the answer response and then recorded in the log file. The log file location is specified when the application is run by the student. The student then provides his/her name, which is recorded in the log. The question types are multiple choice, true or false and "fill in the gap". Question widgets (utilities built into ToolBook) are available from a widget catalogue. These are selected and dragged onto the page. Score and response properties for the question widgets can be set. The log file procedures are set within the lesson

properties. The lesson properties are set to record the navigation route (provides a page name), the time taken to navigate through the application and record responses to questions. The logs from each student are appended to the log file as a tab separated text file. Analysis of the log file by the tutor will identify problems with the application, give an indication of a preferred method of navigation, demonstrate a student's understanding of the topic and show that a student made full access to each topic.

7. Creating the Installation CD and Application Test

For easy and convenient publication, ToolBook II Instructor V6 is shipped with InstallShield. Installations can be created using the Auto Packaging Wizard (written to publish ToolBook applications using InstallShield) or by the more advanced feature contained within the InstallShield application. Additional installers for the Indeo 5.11 codec and Adobe Acrobat Reader are also on the CD-ROM.

A number of tests using the pilot version of MSL were conducted on computers running Windows 95 and 98 using 6 and 24 speed CD drives. The tests showed that on the lowest spec. Pentium 100 MHz, 16Mb of RAM with a 6 speed CD drive efficiently displayed the application. Very little delay was experienced when navigating between pages and very few frames were skipped when playing the video. The audio was of satisfactory quality.

8. Conclusions

Students/staff responses and comments [1], demonstrated that this project is certainly a step in the right direction by providing complementary material to support and improve students' learning experience in the field of Soil Mechanics/Geotechnics. It has also been demonstrated that Multimedia is a viable option to be considered for such purposes.

It was noted that wide availability of software of this nature might influence students' participation in the laboratory sessions with serious consequences. However, it must be stressed that the above situation will depend, to great extent, on how the software is introduced to students and how it is incorporated within the teaching program. From the reactions received to this software, we are encouraged to believe that positive steps have been taken towards the enhancement of students' learning experience in this particular branch of a typical civil engineering course. Utilization of this package, in a formal manner, has already started as it was introduced to a combination of first year BEng Civil Engineering and HND students in the Department of Civil Engineering at the University of

Portsmouth, during the 2nd semester of the academic year 2000/01.

It was also recognized that this experience could expand easily to other practical and experimental based engineering and science courses.

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