GeotechniCAL - Computer Assisted Learning in Geotechnical Engineering

L.R. Davison
B.Eng, M.Eng, Ph.D., C.Eng., M.I.C.E.
Senior Lecturer, Faculty of the Built Environment, University of the West of England, UK

Summary GeotechniCAL is a set of computer and paper-based resources for teachers of geotechnical subjects. These resources are designed to: be used within the framework of a university-taught course; supplement rather than replace other teaching methods; permit maximum flexibility in the way they are used; encourage independent learning; support different learning styles; ease the problems of large classes. They have been developed by a consortium of teachers at 23 universities in the UK supported by a grant of £612 000 from the Teaching and Learning Technology Programme. TLTP is jointly funded by the four UK higher education funding bodies, HEFCE, HEFCW, SHEFC and DENI. As a condition of TLTP funding, the resources produced are freely available to universities in the UK. All 76 TLTP projects are under pressure from the funding bodies to generate income from other sources, to fund maintenance. To this end, negotiations covering publishing and sales outside the UK are in progress at the time of writing (March 1996). News of these negotiations, together with details of the project and access to evaluation are available via the World Wide Web at **http://CL24.uwe.ac.uk/geocal/geocal.htm**

1. HARDWARE REQUIREMENTS

All GeotechniCAL software runs on IBM compatible PCs under the Microsoft® Windows® 3.1 operating system. It has been designed for 800 x 600 pixel screens with 256 colours, but most of the software can be used with a 640 x 480 pixel 16 colour screen. A 486 processor running at 33MHz with 4Mb RAM should be regarded as the minimum specification. Machines with less than 8Mb RAM will have difficulty multi-tasking (e.g. using a wordprocessor such as Write® to take notes, along side GeotechniCAL software, while keeping the on-line reference open). The soil-structure interaction software makes intensive use of the processor and benefits from higher clock speeds.

2. ON-LINE REFERENCE MANUAL

In addition to the normal Windows® on-line help, a hypertext geotechnical reference manual can be accessed from all parts of the GeotechniCAL software. The reference manual uses a tree structure to divide topics into sections, fitting the limitations of a computer screen. This structure, together with a keyword search facility, makes it easy to find information; but unlike a book, it cannot sustain a logical argument. While recognising the financial difficulties faced by many students, it is important that they are encouraged not to regard the reference manual as a replacement for text books.

3. STRANDS

The project is divided into five components, known as strands, each designed to address a different aspect of geotechnical teaching and learning:

- GeoTutor
- Soil-Structure Interaction
- ConFound
- Site Investigation
- LabSim

4. GEOTUTOR

The GeoTutor (Figure 1) enables students to explore some of the important concepts in geotechnical engineering by manipulating simple models and observing the effect. Twenty five models have been produced to date, dealing with strength, compression, permeability, walls, foundations and slopes. Others will follow.

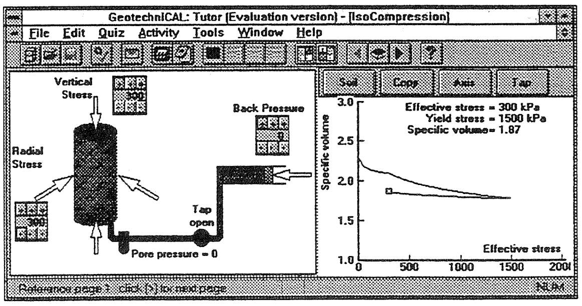

Figure 1. Example of a GeoTutor screen.

4.1 Flexible Teaching and Learning

Independent learning is a wonderful idea, but most students want to be guided by their teacher. What they see when they access GeoTutor is controlled by their human tutor. Which activities are available, how they are set out on the screen, and the soil parameters used, are all controlled by the entries in standard Microsoft INI files. These can be changed using a simple text editor.

```
[Topic1]
TopicName = Compression and swelling
TaskName = Isotropic compression
Activity = IsoCompression
Instructions = soilmech\compress.ins
QuizFile = soilmech\compress.qst
ActivityWidth = 100
ActivityDataAtSide=1
NextTask = Topic1_Task2

[Topic1_Task2]
TaskName = .....
Activity = ..
```

4.2 Workbook and Instructions

Students like having printed sheets they can keep, whether or not they read them before filing them away. Worksheets have been produced for the topics covered, and are available as a workbook of Word for Windows files. They can be copied and used as supplied, or edited as required.

Keeping printed material succinct increases the chances of it being read, and revising one text file on the university computer network is much easier than trying to notify all students of a minor change which has been made in the light of feedback. So GeoTutor can display on-screen instructions in a separate window, as shown in Figure 2. The values in the INI file control the way these windows are displayed initially. Students can change the display using the Window menu.

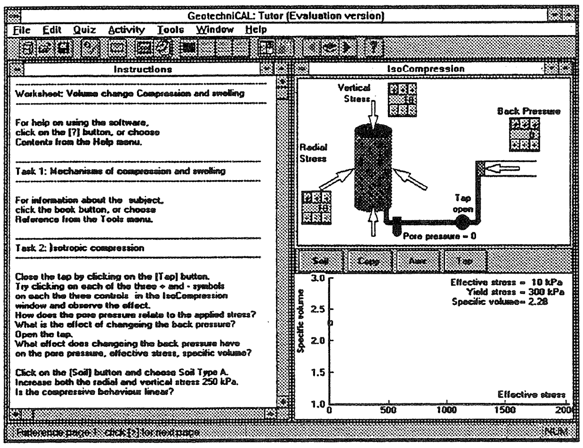

Figure 2. Example of GeoTutor's worksheets.

4.3 GeoTutor Tools

The menu and tool bar provide access to a range of supporting features. These include:

- a link to a word processor for taking notes;
- a simple spreadsheet within GeoTutor for processing results;
- help on how to use the software;
- a geotechnical reference manual (Figure 3);
- a quiz which will record students' scores;
- a mechanism for collecting feedback.

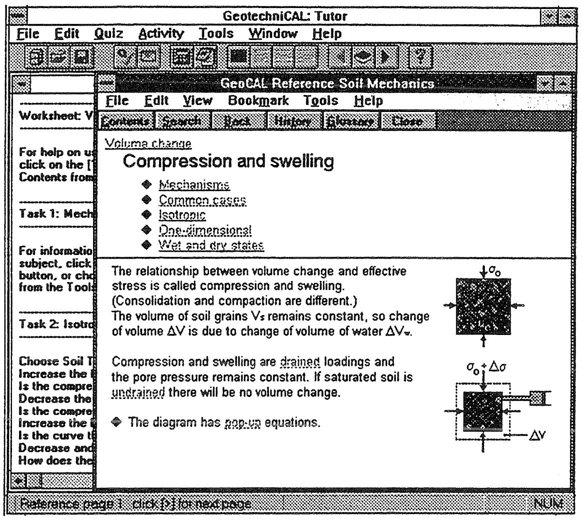

Figure 3. Example of GeoTutor's tools.

4.4 Evaluation

The software has been used extensively by students at UWE in Bristol. Some parts have been evaluated at the Universities of Bristol, Hertfordshire, Nottingham, Nottingham Trent and Sheffield. Teachers at City, Durham, Glasgow, UWE and Warwick have been involved in producing the workbook, reference material and quizzes.

5. SOIL-STRUCTURE INTERACTION

5.1 What is SSI?

SSI stands for Soil-Structure Interaction. In Civil Engineering we often encounter situations where there are structural elements embedded in, or resting on, the ground. Examples include pile and slab foundations, tunnels, retaining walls and reinforced earth structures. In each of these cases the response of the system depends on the stiffnesses of both the soil and the structure as well as the loads which are applied.

Increasingly engineers in industry are using computer-based techniques such as the finite element method when Soil-Structure Interaction effects are important. These techniques will be used along side older, more traditional approaches which just assess stability or predict ground movements based on very simplified calculation models or experience.

5.2 Why Teach SSI?

Why use this software in teaching? We think that some of the benefits are:

- Students can observe the basic modes of ground deformation and stress changes associated with the construction and loading of foundations, retaining walls etc.
- Students can alter parameters such as soil

stiffness and dimensions of the structure and observe the effects of these changes on structural forces (e.g. bending moments) and ground movements. In other words, the students are learning about the principles of Soil-Structure Interaction.

- Students can learn how to examine results of numerical analysis packages in a critical fashion. Engineers in industry increasingly need these skills.
- Students can undertake design exercises, using the software to evaluate the success of their design choices.

5.3 A New Topic for Geotechnical Teachers

The SSI program can be used in conjunction with some parts of existing geotechnical syllabi (for example settlements of foundations). To do just this, however, misses the full potential of the software. If our students are to become engineers who are capable of using modern methods of analysis, they require adequate preparation during their university studies. In our view, this requires the presentation of a new and distinct topic to our students. Because perhaps only a minority of geotechnical teachers have direct experience of these techniques, we are intending to produce a comprehensive set of materials (lecture notes, worksheets) to support our colleagues in teaching this new topic.

5.4 Program Capabilities

At present the program assumes that the soil is a linear elastic isotropic material. This will be extended later to incorporate either (probably) time dependent Biot consolidation or (possibly) strain dependent elastic modulus. The software presents a number of SSI "problems" (Walls, Embankments, Foundations, Tunnels) and within each of these there are a number of "topics" (e.g. Embedded Wall and Wall with a Berm under the Walls problem, cf Figure 4). Within each topic students can vary the parameters (e.g. soil stiffness and structural dimensions) and examine the effects of these changes.

The following data can be displayed for each case:

- diagram of the problem showing what can be varied;
- the finite element and deformed mesh;
- displacement vectors for the nodal points;
- contours of displacement and stress components;
- plots of horizontal and vertical displacements on horizontal and vertical lines within the mesh;
- plots of bending moments in structural components;
- plots of stress changes at the soil-structure interface (i.e. contact stresses);
- stress changes at points in the mesh.

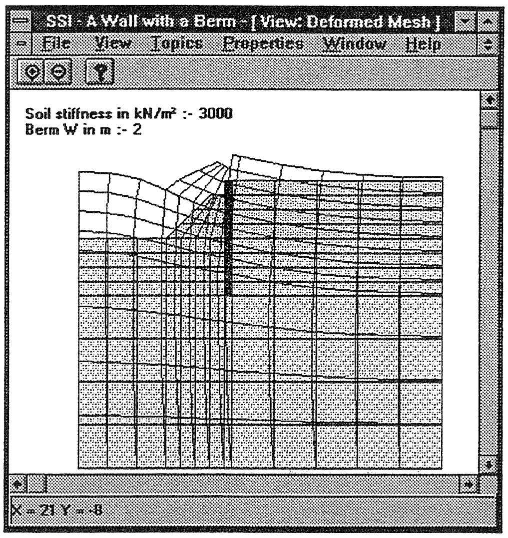

Figure 4. An example screen from SSI.

Perhaps more importantly, it is possible to display the results of two or more analyses simultaneously to enable comparisons (and deductions about the influences of parameter changes) to be made.

The program incorporates quizzes to allow students or lectures to check progress, and a tutorial in the basic operation of the software.

5.5 Finite Elements (Without Tears)

Although the underlying method used by the program is based on finite elements, the detail of the process of constructing the mesh is completely hidden from students. This is deliberate, as we believe that the basic skill of interpreting the results does not depend on detailed knowledge of finite element theory or how to create a mesh. The software will have the capability for setting up meshes for new problems, but we anticipate that these facilities will be used by lecturers, or students doing project work, rather than in normal class use.

6. CONFOUND

ConFound is a knowledge-based system (KBS) being developed for preliminary (conceptual) design of foundations. It is specifically designed for use as a CAL tool and can be used in two modes:

- In **browsing mode** the system presents the options and offers general hints to aid decision making. Students will also have access to context sensitive help on each option but no decision support is given.
- In **decision-making mode** the KBS will also offer a critical assessment of the decision after it has been made.

By offering the student alternatives and highlighting any factors that must be considered it is thought to give the student a better understanding of the processes behind foundation design. Whilst it is backed up by extensive reference material in the form of Help files, a certain degree of understanding of geotechnics and foundation engineering is expected. The system is therefore seen as a supplement to a lecture course, not a replacement. Its primary use is intended to be in conjunction with design projects. ConFound provides the student the opportunity to investigate possibilities, whilst getting instant feedback on their decisions, something not possible with large class sizes or through other forms of self study.

6.1 Components of ConFound

ConFound consists of 3 components:

- database of project specific information;
- knowledge base of foundation types;
- help files.

6.1.1 Project Specific Information

Project specific information can be entered into the system by the student under 3 categories:

- Information about the structure (e.g. loading, tolerance to movement);
- Information about the site (e.g. past uses, topography) (cf. Figure 5);
- Information about the ground (e.g. soil/rock conditions, test results).

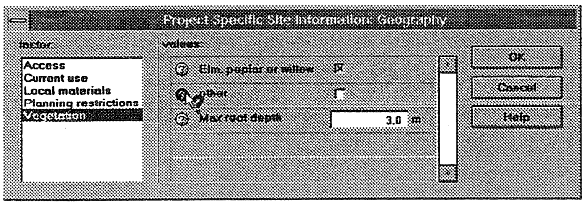

Figure 5. Dialog box used to enter information about the site.

6.1.2 Foundation Type Knowledge Base

The foundation type knowledge base held in the system contains all the information about the various foundation types available to the student. A default set will be provided by the software developer but tutors will have access to add to, modify or delete from the knowledge base. Anything that might influence the suitability of a given foundation type is stored within the knowledge base. This knowledge comprises a rule, a series of comments (and link to a help file) and a value quantifying the suitability. Each foundation type can have any number of rules associated with it.

Therefore, depending on the information stored in the project specific database each foundation type will return a value signifying its suitability and a series of comments. The system can then use this information to evaluate the student's decisions.

6.1.3 Reference Material (Help Files)

At any stage the user can find more detailed information about any point raised by the KBS by jumping to the corresponding page in the help files.

A distinction should be made between the help files providing assistance in the operation of ConFound (an on-line manual) and the help files created to contain reference material for foundation design. These reference help files, whilst essential to ConFound's operation, have been created independently.

Browsing mode
The user can browse through the hierarchy on the left of the screen (Figure 6); a description of each foundation type appears on the right along with a list of comments giving details of when that foundation type might be applicable. At any time the user can select one of these 'Applicable When' comments to read a page in the help files giving a fuller explanation. Due to the structure of the help files, the student can easily put any piece of information into its context by clicking backward or forward at the point of entry into the help file. It is also possible to access the whole GeotechniCAL reference manual.

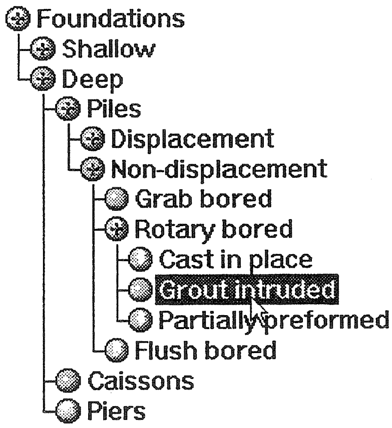

Figure 6. Example of foundation types hierarchy held within ConFound

Decision-making mode
In decision-making mode, ConFound takes an active role in the decision process and starts acting as an intelligent system offering feedback to the user's decisions. It is therefore necessary that the system has all the relevant information available about the particular project at hand.

7. SITE INVESTIGATION

The site investigation package comprises a game supported by a series of tutorial modules. It enables students to encounter, through near life simulation, the challenges of Site Investigation. It is hoped that it will allow "learners" at whatever level to grasp the range and nature of site investigations for themselves and reduce some of the common failings in site investigation.

7.1 Tutorial Modules

The tutorial modules are designed to enable students to learn about the basic constituents of a site investigation, to see the range of information available and its usage. In the games section, students explore in a less prescriptive way some of the consequences of decisions taken about costs, assembling information and exploratory techniques. They cover:

- Brief
- Desk Study
- Ground Investigation
- Reporting

These modules are designed to be used at one of three levels selected by the tutor to achieve the specified learning outcomes appropriate to a particular course of study. They can be linked together to form a bespoke work programme. Tutors may also develop their own versions of the modules. Students are posed questions which may simply require multiple choice, or have to identify features on a screen or visualise data from presented information. In some instances worksheets are also provided for optional use by the tutor.

7.2 SI Games Package

This part of the package is essentially free-standing and there is only limited linkage with the tutoring modules. It is generally recommended that students familiarise themselves with some of the principle elements of site investigation prior to playing the game but this may be done through the tutor's own instruction rather than use of the modules.

The approach is less directed than the tutoring package, requiring students to develop a desk study and site investigation based on a client brief. Each action has a financial consequence measured against a "tendered" cost for the investigation. The student may gather desk study data and then drill boreholes across the site, obtain logs and laboratory test results. Tutors can monitor progress by looking at the "Log File" of each student, by evaluating expenditure or by reading a simple interpreted report.

Three case study areas are provided:
Case 1: Rectangular site with some modest topographical variation. Ground conditions are Made Ground over Terrace Gravels and London Clay. A modest range of exploratory holes and laboratory test results exist. Suitable for light commercial developments, access roads, landfill, domestic housing, multi storey structures, basements, etc.

Case 2: A redevelopment site in a historic town. An irregular shaped site with complex archaeological problems combined with access difficulties. Geological sequence requiring both soft ground and coring techniques. Suitable for Desk study exercises combined with industrial and commercial developments or also dock redevelopment, or segment of road/bypass, etc.

Case 3: A linear site of modestly complex geology, in the Lower Lias series with some topographical variation and perglacial modification. Both soft ground and coring exploratory holes available together with trial pits.

The package can be used in a number of ways:

- Provide a structured progression from a Brief, through a Desk Study, and Ground Investigation to Reporting using three or four afternoon sessions on various sections of the Game.
- Use the tutor modules in Brief, Desk Study, Ground Investigation and Reporting to give students an overview of Site Investigation in one or two tutorials.
- In conjunction with the tutor's own lecture material, an afternoon tutorial or laboratory using the Game to investigate one of the three "virtually" real sites.
- Student-centred learning using targeted tutoring modules on Aerial Photographs, Types of Drilling Equipment or Walk over Surveys.
- Using it as a live and interactive reference augmenting existing lecture based work on contracts or engineering geology from tutor modules such as Documents and Geological Maps.
- Augmenting existing laboratory work on soil description and other common laboratory tests using the modules Soil Description and Laboratory Tests as an easy reference source.
- Use cost data in Laboratory Tests, and Ground Investigation group modules to assist with design projects.

8. LABSIM

LabSim is computer simulation of the triaxial test (Figure 7). The principal objective and mode of use of LabSim is to provide students with the opportunity to carry out triaxial tests on-screen, when time, physical and personnel resources are insufficient to allow individual experimentation in the laboratory. The emphasis is on understanding soil behaviour and, only secondarily, training in test procedures.

The current version illustrates the *prescriptive* mode of use which is intended to test students knowledge, in this case, of the triaxial CU test procedure and, particularly, their ability to interpret the data generated by the test.

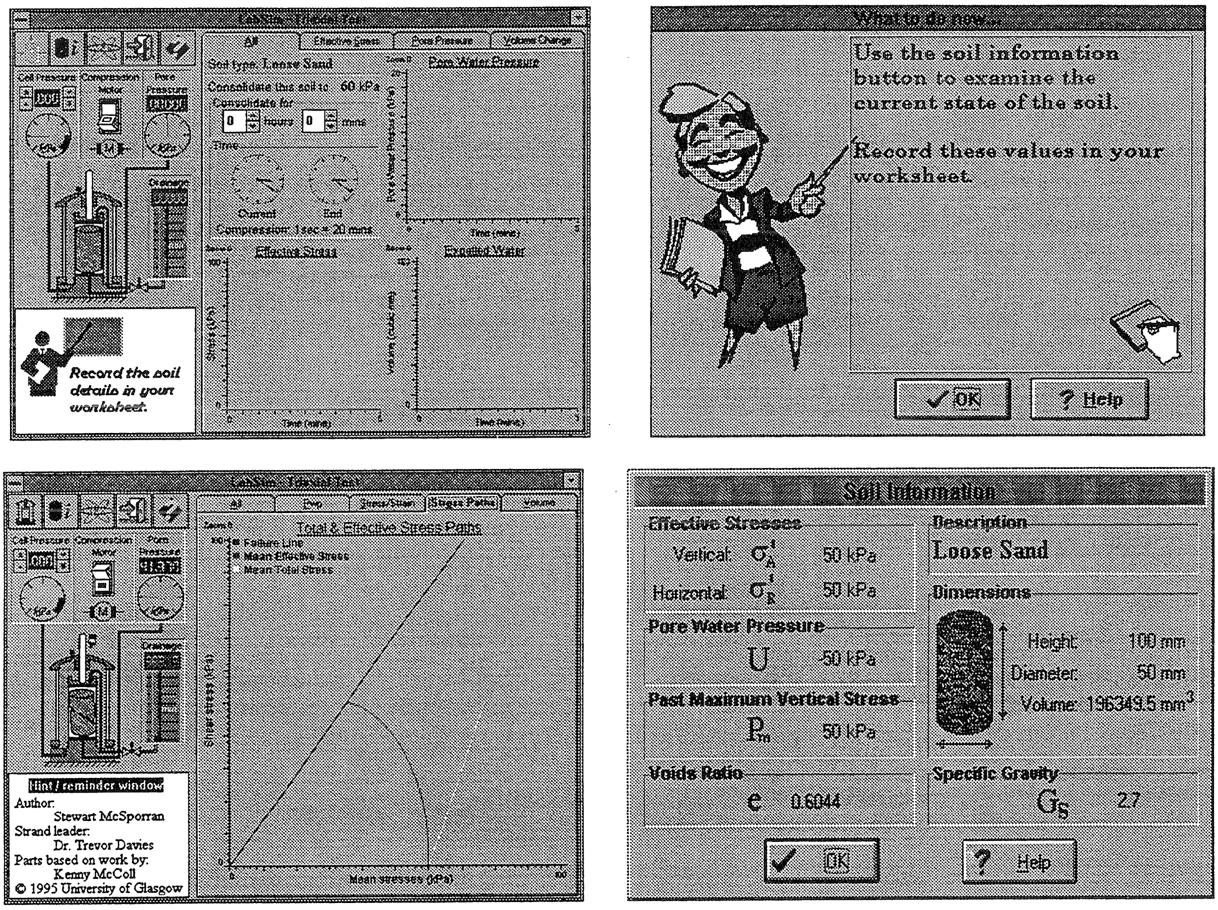

Figure 7. Example windows from LabSim.

Users are faced with a schematic of the triaxial cell, complete with cell pressure gauge, pore water pressure gauge, drainage ports, clock etc. Also on display are three plots: of mean effective stress, pore water pressure and volume change: all versus time. By moving the cursor over these plots, the data can be inspected and precise data values recorded. Zooming is possible by clicking the left/right mouse buttons.

The 'Soil information' button provides access to the soil properties. In this mode, this button gives only a brief description of the soil and its current state. The 'current state' changes during testing, of course, and should be examined at each stage of the test. The soil is randomly generated.

To consolidate the soil, set the prescribed cell pressure, open the drainage port, *don't* start the compression drive, and then consolidate the soil for an appropriate time (don't overdo it, unless you are in no hurry!) and observe what happens. When consolidation is 99% complete, you may move on. Record the appropriate data on the worksheet and answer the questions. Once the consolidation phase is over, you can proceed to the loading phase.

The schematic of the triaxial cell during axial loading is similar but the plots are quite different. These are: pore water pressure response, axial stress-strain response, stress paths, and volume change. These plots can be inspected as before using the cursor/zoom facilities, but in addition they can be viewed one at a time, as here, by clicking on the tabs at the top of the screen.

Students load the soil by starting the compression drive and closing the drainage port. They observe the response while the axial load increases to failure. Extract the appropriate data from the graphs and answer the questions.

LabSim is intended to support a range of student levels and learning styles and to be readily customised for use by instructors in various institutions. Instructors will be able to add/delete/modify questions, choose different notations/definitions and soil types etc. LabSim will contain four modes of use: mode 1 will provide the student with an introduction to triaxial testing which can be perused at will; mode 2 is intended to support class room teaching by illustrations of the behaviour of soils of various types when subjected to triaxial testing: mode 4 provides the freedom to perform a range of tests on user-defined soils.

9. ACKNOWLEDGEMENTS AND CONTACT DETAILS

This paper is based on a document prepared by the strand leaders listed below and produced by Neil Porritt at UWE in Bristol for the Meeting of Geotechnical Teachers in Durham in September 1995. Prof. David Muir Wood, of the University of Bristol, and Prof. John Atkinson, of City University, alternately chaired the steering group.

Tutorial: Dr L.R. Davison,
Faculty of the Built Environment, Uni. of the West of England, Coldharbour Lane, Bristol BS16 1QY.
Tel: (0117) 965 6261 ext.3020; Fax: (0117) 976 3895;
Email: lr-davis@uwe.ac.uk

Soil-Structure Interaction Prof. M. Gunn,
School of Architecture and Civil Engineering, Faculty of the Built Environment, South Bank University, London SW8 2JZ.
Tel: (0171) 928 8989 ext. 3135; Fax: (0171) 261 0224;
Email: gunnm@sbu.ac.uk

ConFound Dr D.G. Toll,
University of Durham, School of Engineering, South Road, Durham DH1 3LE.
Tel: (0191) 374 2566; Fax: (0191) 374 2550;
Email: d.g.toll@durham.ac.uk

Site Investigation Mr J. Moran,
School of Architecture and Civil Engineering, Faculty of the Built Environment, South Bank University, London SW8 2JZ.
Tel: (0171) 815 7117; Fax: (0171) 815 7399;
Email: moranja@pisces.sbu.ac.uk

LabSim Dr T. G. Davies,
Department of Civil Engineering, Glasgow University, Glasgow G12 8QQ.
Tel: (0141) 330 4077 / 5205; Fax: (0141) 330 4557;
Email: t.davies@civil.gla.ac.uk
Nick Langdon of Portsmouth and Rick Woods of Surrey are members of the development teams.

10. GEOTECHNICAL ON THE INTERNET

The GeotechniCAL fileserver at UWE is CL24.uwe.ac.uk (IP address 164.11.100.12). Information about the project is available via the World Wide Web from the location **http://CL24.uwe.ac.uk/geocal/geocal.htm**

Details of how to obtain demonstration software for each strand of the project via FTP is provided.