

Notice to users:

Please print this User's Guide on

**A5 paper.**

The font sizes used in this document  
will look just right at the reduced  
size.

# GWALL

Cantilever and Gravity  
Retaining Wall Analysis Program

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Distributed by **Geosolve**

User's Guide

Version 3

for Windows 9x, ME, NT, 2000, XP

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### **Appendix E** Example data and results

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## 1.0 INTRODUCTION

### 1.1 SCOPE OF THE PROGRAM

GWALL analyses a wide range of retaining wall problems including gravity walls and cantilever walls with a base.

#### 1.1.1 Limit state analysis

GWALL carries out two types of analysis within the one program:-

a) **Ultimate limit state analysis.** This is a limit equilibrium analysis for calculating factors of safety against sliding and overturning. The calculation is done using partially factored soil strengths.

b) **Serviceability limit state analysis.** This is a calculation of bending moments and shear forces in the stem and base (including the effect of earth pressures due to compaction) under working conditions. The calculation is done using un-factored soil strengths.

In GWALL Version 2.42 the ULS and SLS analyses were called the Stability and Bending Moment analyses respectively

#### 1.1.2 Wall geometry

A wide variety of wall geometries can be analysed including variable heel and toe width, battered front and back faces and a shear key at any position.

#### 1.1.3 Soil properties

Up to 20 soil strata may be defined. For each stratum the following parameters may be specified:-

- Bulk unit weight
- Friction angle and cohesion
- Earth pressure due to compaction
- Earth pressure coefficients

The program will, if desired, calculate earth pressure coefficients from values of soil friction, wall friction, batter angle and backfill angle given by the user.

#### 1.1.4 Water pressures

Hydrostatic or simple non-hydrostatic water pressure profiles may be defined on both sides of the wall.

### **1.1.5 Applied loads**

Surcharges may be specified to act on or below the ground surface on the active side.

**Vertical, horizontal and moment loads** may be applied to the top of the wall. Horizontal and vertical components of anchor load may be applied to the face of the wall.

The actual application of the surcharges and loads is controlled by the load case definitions

### **Load cases**

The ULS and SLS analyses are carried out for each of a series of load cases defined by the user. Each load case represents a different loading condition in which different partial factors are applied to the surcharges and loads. For a simple problem you need only specify a single load case and unit partial factors on all loads.

### **1.1.6 Units**

Data may be entered in any consistent set of units e.g. (kN, m) or (lb feet). All printout from the program is automatically annotated in the appropriate units.

## **1.2 GWALL VERSION COMPATIBILITY**

GWALL Version 3.01 is the first Windows version of GWALL. GWALL Version 3 has been designed to provide a high degree of compatibility with its predecessor Version 2.42 at many levels:-

### **File readability**

GWALL Version 2 data files can be read and processed by Version 3.

### **Parameter definitions**

The definition and usage of nearly all engineering parameters is preserved in Version 3. The main exception is the Wall friction (adhesion) coefficient. Old GWALL data files can be read by GWALL Version 3 and a suitable value of Wall friction / adhesion coefficient will be assigned automatically.

## **Method of calculation**

The methods of calculation are identical with the following exceptions:

- Surcharges of limited extent are modelled using a more accurate algorithm.
- The partial factor of safety on passive pressures is only applicable to the stability (ULS) calculation.

To summarise, you should be able to read and process your Version 2 data files and obtain virtually identical output using GWALL Version 3.

## **1.3 NEW FEATURES**

There are some major new features in GWALL Version 3.01 for windows which were not available in GWALL Version 2.42

### **1.3.1 Load cases**

Load cases consist of different combinations of loads and surcharges. They are used to represent the different load combinations which may occur under

- temporary and permanent conditions,
- static and dynamic loading,
- unusual or extreme conditions etc...

See Section 11.0 for details.

### **1.3.2 Limit state analysis**

The Stability and Bending Moment analyses of GWALL Version 2.42 are now described as **ULS** and **SLS** analyses. Partial factors can be applied to the soil strength parameters for the ULS analysis.

### **1.3.3 Wall friction / adhesion coefficient**

This parameter supersedes the separate parameters of Wall friction and Wall adhesion defined in GWALL Version 2.42.

### **1.3.4 Surcharge length**

All surcharges have an additional parameter which defines the length of the surcharge parallel to the wall.

### **1.3.5 Array sizes**

The maximum numbers of data items are now as follows:

Maximum number of strata on either side of wall	=	20
Maximum number of soil types	=	20
Maximum number of surcharge loads	=	10
Maximum number of load cases	=	20

### **1.3.6 Formatting**

The title block has been reorganised to accommodate the increased length of Filenames and Run Identifiers. The formatting of all other data and results is preserved virtually unchanged from GWALL Version 2.

## 2.0 GETTING STARTED

Before attempting to install or execute the program you should read the README.RTF file on the master disk. This file contains important information about the program and how to install it.

### 2.1 SYSTEM REQUIREMENTS

#### 2.1.1 Memory requirements

GWALL requires approximately 10 Mb of RAM.

#### 2.1.2 Disk Space Requirements

Disk space requirements for GWALL Version 3 are as follows:

	<b>File type</b>	<b>Disk space</b>
Program files		4 Mb
Each data file		9 kb
Output files	.OUT file	4 kb per load case
	.BIN file	15 kb per load case
Report files	.RTF file	20 kb
		+1 kb per load case (text only)
		+100 kb per load case (b/w graph)
		+2 Mb per load case (colour graph)

You are responsible for removing old or unwanted files which will otherwise occupy valuable disk space.

#### 2.1.3 Screen and colour resolution

GWALL requires a screen resolution of 800x600, 1024x768 or greater.

The GWALL Graphical User Interface (GUI) which allows you to edit the data interactively will not work properly unless you enable the "True color" or "High color" palette. You can change the current Windows setting by selecting:

**Control Panel | Display | Settings | Color palette**

#### 2.1.4 Printed output

Printed output from the program is in lines up to 78 characters long. A choice of fonts and point sizes is available. Pagination of the output is designed for printing on A4 paper. Printer options are selected at print time using a standard windows printer dialog box.

## Font selection

The default font is Courier New 9pt. Alternatives are available under the **Format | Font selection** menu

## 2.2 PROGRAM INSTALLATION

Please read the README.RTF file on the master diskette before installing.

To install the program run SETUP.EXE on Disk 1 of 2 (via the Windows **Start** button). Full instructions on installation and de-installation can be found at [www.geosolve.co.uk/faq.htm](http://www.geosolve.co.uk/faq.htm)

## 2.3 STARTING THE PROGRAM

If the installation routine has created a Geosolve program group you can click Start and select

### **Programs | Geosolve | GWALL 3.01**

If the installation routine has created a GWALL icon on the Windows Desktop you can double click on that. Otherwise use Windows explorer to view the GWALL folder and double click on the GWALL.EXE application.


## 2.4 BEGINNERS GUIDE

Please read the release notes for GWALL Version 3. The following sequence of steps will familiarise you with the basic operations of GWALL:-

1. Using Windows explorer create a folder called MyData (or other suitable name)
2. Copy the demonstration data files DEMO???.DAT from the GWALL folder to your data folder.
3. Run GWALL and after the opening screen press **Ctrl+O** or select **File | Open** from the main menu.
4. Use the Open file dialog box to select MyData as your current data folder
5. Select file DEMO3.DAT.
6. Note the graphical display in the bottom right corner which shows the wall, strata profile and surcharges at Load Case No.1.
7. To view the data at other load cases press the **load case selection** arrows next to the green box at the top right of the screen.
8. Use the "plus" and "minus" buttons in the corner of the graphic

- box to increase and decrease the size of the box.
9. Select Load Case No.2
  10. From the data edit tabs select the **Surcharge** tab.
  11. Toggle the "**surcharge position**" from "**At GL**" to "**Below GL**"  
Edit the elevation of Surcharge No.1 to a value of 5.50 - observe the change in elevation on the data plot. You can also change the elevation and width of the surcharge by clicking and dragging on the red lines.
  12. From the data edit tabs select the **Wall** tab.
  13. Edit the **elevation of toe of wall** from 0.50 to 1.00m.

### **Edit the data using the Graphical User Interface (GUI)**

14. Move the mouse cursor to a point on one of the strata. Find a point where the mouse cursor changes to a double-ended vertical arrow,  then click and drag to move the position of that stratum data point.

Observe the tabulated data display change to show the modified strata profile. You will have noticed that you are only able to drag profile data points within the limits of the strata above and below the stratum being edited.

### **More about the graphical display**

15. Observe the **hints** (yellow) which appear when the cursor is over a data item.
16. Type **Alt+C** to see the strata profile with colour shading.
17. Right click anywhere on the data plot to see the pop-up menu options.

### **Undo and Redo**

18. Type **Ctrl+Z** or click the Undo button to undo the edits one step at a time.
19. Type **Ctrl+R** to Redo the edits

### **Save, Analyse and View results**

20. Select **File | Save As** and save the data as DEMO3A.DAT (so as not to overwrite the original data in DEMO3.DAT) and note the **Data last modified** time change to the current date and time.  
Only one data set can be stored in each file. Data which are not stored will be lost when closing the program.
21. Press **Alt+A** to enter analysis mode.

22. While the analysis is in progress, click and drag the scroll bar in the **progress summary** box in order to view the complete summary. Note that the analysis pauses while the scroll bar is clicked.
  23. Allow the analysis to finish normally and then view the output for successive load cases by pressing **Alt+Right**. Observe the tabulated results and the graphics change as you move through the load cases. Type **Alt+W** to toggle between bending moment and soil pressure display in the graphical output.
  24. Press the **Report** button to create and print a report or  
Alternatively  
Use the **copy** and **paste** facilities to copy data and results to a separate (Word) document:-  
Display the Summary results - select the tabulated text by typing **Ctrl+A** - copy it to the windows clipboard using **Ctrl+C** - paste it into the Word document. Now click on the summary graphics - copy the graphics to the windows clipboard using **Ctrl+C** - paste the graphics into the Word document.
- Before going on to explore further you might like to read the General rules for data entry (Section 3.9).**

## 3.0 GUIDE TO PROGRAM OPERATIONS

### 3.1 THE GWALL DESKTOP

A screen shot of the GWALL Desktop in Data Input mode is shown in Figure 1. GWALL always runs 'maximized'. The program can be minimized but not 'normalized'. The main menu contains the following items

**File Import Edit View Format Analysis Help**

Beneath the main menu the Titles of the current data set are displayed. A yellow box in the top right corner displays the current data file name and its folder. Beneath the yellow box is the date/time stamp of the current data set i.e. the time the data was last saved to disk or edited.

A green box in the top right corner shows the number of the currently displayed load case (both during Data Input and View Results modes).

The arrow buttons next to the green box are used to move backward and forward through the sequence of load cases. Alternatively, click on the green selection button/indicator to see a list of load cases and select one for viewing.


The four Mode buttons are located under the main menu and Titles in the top left corner of the screen. The Graphics display (data or results) can be made larger or smaller using the [+] and [-] buttons in the lower right corner of the screen.


#### 3.1.1 The Graphical User Interface (GUI)

The GWALL Graphical User Interface allows you to input and edit data and manipulate the results interactively using the mouse. The GUI is discussed in the remainder of this section and also in Sections 2.1.3, 2.4, 3.12, 5.3.1, 7.2, 8.5, 9.3, and 15.6.

#### Hot spots and interactive data editing

The display is data aware. As the mouse moves over the picture a yellow hint box appears with a description of the type of data being pointed. When the mouse is over an item which can be edited

interactively, the mouse cursor changes to a hand,  or double

headed arrow, . When you click, you will see the current edit menu change to show the data item which was selected and a box

appears in the control panel at the bottom of the graphics display. It shows the name of the item and its x or y coordinate (or both) which can be dragged. The coordinate values in the box are updated as you drag the data item. The edit menus (top left of screen) are only updated when the mouse button is released. Press **Ctrl+Z** to undo an edit.

The following items can be edited by clicking and dragging:

- Strata elevations
- Ground water level
- Surcharge positions
- Wall geometry
- Load positions

### 3.1.2 Data graphics - description

#### Axes

The vertical axis has the positive direction pointing upwards. Horizontal distances are measured as positive "uphill". The toe of the wall is at x coordinate zero.

The x-axis is automatically marked at appropriate intervals.

#### Soil strata

Soil strata are shown in solid black lines. By default soil descriptions are shown in full. Choose **View | Plot options | Soil descriptions** to toggle display of the soil descriptions on and off.

#### Strata shading

By default the soil strata are not colour shaded. Choose **View | Plot options | Colour shading** or click the stripy coloured button to toggle colour shading of soil strata.


#### Surcharges

The positions of surcharge loads are shown by vertical red arrows. The lengths of the vertical arrows are an approximate indication of magnitude for small surcharges. The arrow length is roughly equal to an equivalent height of soil.

#### Ground water

Ground water level is shown as a blue dashed line with a blue triangle. The piezometric elevation at the base of the wall is shown as a blue standpipe.

## Select part of the GWALL section for detailed viewing

When the mouse cursor shows as  you may click and drag to select a part of the graphical display for detailed viewing. A dashed rectangle indicates the selected area.

It may be necessary to view a detail in this way in order to perform precise interactive editing or to confirm the effect of previous edits on the geometry.

Double click anywhere on the graphical display to restore display of the whole section.

## Resize the graphical display

The graphics display (data or results) can be resized for convenience of viewing:-

choose **View | Zoom +** or  
 type **Alt+Up arrow** or  
 click the **+button** to increase the size of the display

choose **View | Zoom -** or  
 type **Alt+Down arrow** or  
 click the **-button** to decrease the size of the display

Alternatively use the Maximize button in the bottom right corner of the plot to increase to maximum size or the Normalize button to return to the previous non-maximized size.

### 3.1.3 Results graphics – description

The graphical display shows either:-

- **Bending moment and shear force profiles for the Stem and the Base.**  
 Shear force and bending moment are plotted on one diagram with shear forces shown in dashed lines or,
- **Earth pressures for Stability (ULS) and Wall Force (SLS) calculations.**  
 The two sets of earth pressures are shown on adjacent diagrams.

Type **Alt+W** to toggle the display between the two sets of graphs. Use the Load Case Selection Button to display results for a particular load case. There is no Summary graphics.

## 3.2 THE MAIN MENU

### 3.2.1 'File' menu

Menu item	Shortcut	Description
New Data Set		Start a new data set
Open	Ctrl+O	Open an existing file
Save	Ctrl+S	Save the current data file.
Save As		Save the current data file under a new name
-----		
PrintSetup		Select printing options
Print		
Data listing		Print current input data
Current selection - tabulated results		Print numerical output for current load case
Current selection - graphical results		Print graphical output for current load case
Report		
Review options		Review selections for printing
Print report		Print selected results of the current analysis
-----		
1.	1	List of recently opened data files
2.	2	- see Quick file open
etc. . .		
-----		
Exit	Alt+X	Terminate GWALL execution
-----		

### 3.2.2 'Edit' menu

Menu item	Shortcut	Description
New	Ctrl+N	Insert new data item
Delete	Ctrl+X	Delete data item
Copy	Ctrl+C	Copy data item to GWALL clipboard or Copy text/graphics to Windows clipboard
Paste	Ctrl+V	Paste data item from GWALL clipboard
Undo	Ctrl+Z	Undo data edits
Redo	Ctrl+R	Redo data edits
-----		

### 3.2.3 'View' menu

<b>Menu item</b>	<b>Shortcut</b>	<b>Description</b>
Select load case	Alt+L	Select a load case for viewing
Previous load case	Alt+Left	Select previous load case for viewing
Next load case	Alt+Right	Select next load case for viewing
-----		
Graphics	Alt+G	Move focus to the graphical display
Zoom Plus	Alt+Up	Increase size of graphical display
Zoom Minus	Alt+Down	Decrease size of graphical display
Half screen	Alt+V+H	Toggle the GWALL window between full and half screen
	Alt+Z	Reduce the GWALL window width in steps
Select detail		Click and drag to select part of the GWALL section for detailed viewing
Deselect detail	Double Click	Revert to showing the whole GWALL section
Plot Options		
Colour shading	Alt+C	Toggle display of colour shading of strata
Soil descriptions		Toggle display of soil descriptions on data plot
-----		
Data	Alt+D	Select Data input mode
Previous Data Block	Shift+Ctrl+Tab	Display previous data block for editing
Next Data Block	Ctrl+Tab	Display next data block for editing
-----		
Summary results	Alt+S	View Summary output
Selected results	Alt+R	View brief results for all load cases
Messages / Details		View messages generated during analysis
Data Listing	Alt+N	View complete data listing
-----		
View Report	Alt+T	Create and View Reports
-----		

### 3.2.4 'Format' menu

Choose **Format | Font** from the main menu or type **Alt+O** to select a new font, style or size. The new font will be applied to all subsequent analyses and their results. The new font will also be remembered the next time the program is executed. Old output files will be displayed and printed in the font prevailing at the time they were created.

To revert to the default font (Courier New, 9pt) choose **Format | Default font** from the main menu.

It is assumed that output will be printed on A4 paper and the results are paginated accordingly.

### 3.2.5 'Analysis' menu

**Analyse (Alt+A)** starts analysis of the current data. Clicking this option is equivalent to clicking the Analysis mode button.

**Interrupt analysis (Alt+I)** allows you to interrupt an analysis while it is in progress - see Section 3.3.2.

### 3.2.6 'Help' menu

There are 5 items, **Context sensitive help**, **Help Contents**, **Help Index**, **Visit Geosolve website**, **E-mail to Geosolve**, **Report a bug**. See Section 3.4 for details.

## 3.3 MODE BUTTONS

### 3.3.1 'Data input' mode button

Click the **Data** input mode button or select **View | Data** from the main menu or press **Alt+D** to enter Data input mode.

In Data input mode a set of 9 data edit tabs is visible. Click one of the tabs to display the associated data block e.g. Titles, Strata, Soil types etc...

Beneath the box displaying the data there is the **Data errors and warnings** box. If not all the data or errors/warnings can be displayed at once, scroll bars appear at the sides of the boxes. You can also move the splitter bar between the data and the error/warnings listings to view more or less of one box or the other.

### 3.3.2 'Analyse' mode button

Click the **Analyse** mode button to commence the analysis of the current data. Alternatively choose **Analysis | Analyse** from the main menu or type **Alt+A**. It is good practice to save newly edited data before analysing it.

On entering analysis mode the data edit display is hidden and a progress summary box appears together with a progress bar at the bottom of the screen.

At the end of the analysis the program enters **View results** mode.

### Interruption of analysis

During an analysis it may become apparent that the data is unsuitable and that time will be wasted by allowing the analysis to proceed to completion. To interrupt the analysis at any stage choose **Analysis | Interrupt Analysis** from the main menu or type **Alt+I**. After a short pause the program will display the question:-

Interrupt run?

If the response is N (no) the analysis will proceed as if nothing had happened. If the response is Y (yes) the run is interrupted and the program displays whatever results have been calculated so far.

### 3.3.3 'View Results' mode button

Click the **View Results** mode button to view the results of an analysis. The display shows 4 pages which can be viewed by clicking the tab at the top of the page, via the main menu or via a shortcut key.

Page	Shortcut	Description
Data listing	Alt+N	View a complete listing of the current data set.
Selected results	Alt+R	View results for the currently selected load case.
Summary results	Alt+S	View summary results for all load cases
Messages	-	View messages generated during the analysis

If the data file has been edited since the results file was created then a '**Data modified**' warning is issued.

The **Selected results** box displays the results for one load case at a time. Use the Results selection button to display results for a particular load case. Information on these pages may be copied to the windows clipboard for use in other documents.

The display on the right hand side of the screen shows a graphical representation of the tabulated results.

### **View stored output**

To view the results of a previous analysis, read the data file from disk and then follow the procedure above for viewing results.

#### **3.3.4 'Report' mode button**

To create a report for printing or output to disk file, click the Report mode button, choose **View | Report** at the main menu or type **Alt+T**.

Details of the report options are given in Section 3.11

## **3.4 HELP FACILITIES**

### **3.4.1 Context sensitive help**

Press **F1** at any time to obtain help on the currently selected menu or data item. This help includes advice and suggestions on appropriate values for data items.

### **3.4.2 Help Contents**

Select **Help | Help contents** from the main menu to access the Contents page of the GWALL help system.

### **3.4.3 Help Index**

Press **Alt+H** at any time to access the complete Help Index. Then click the **Find** tab of the Help Topics window and type a word or phrase to obtain Help on a topic of your choice. The help index covers most topics related to operation of the program, data input and interpretation of output.

You may browse through the complete index or a selection of the index topics. For example if you enter 'surcharge' you will see a list of all index items containing the text string 'surcharge'. The 'topic' need not be a complete word e.g. 'piezo' will suffice for 'piezometric'.

### **3.4.4 Geosolve website**

The website offers much useful information and downloads of the latest version of the software.

### **Frequently Asked Questions - FAQ file**

The GWALL FAQ file is regularly updated and includes many items which are not in this User's Guide. You can download the FAQ file from [www.geosolve.co.uk/faq.htm](http://www.geosolve.co.uk/faq.htm)

### **E-mail to Geosolve**

Selecting this option will cause your e-mail system (probably Outlook Express) to open up ready to send an e-mail to Geosolve. Please paste in relevant bits of GWALL data listings or output and add a message or question.

### **Report a bug or other problem**

The report form emails your question to the Geosolve help desk.

### **3.4.5 Geosolve help line**

For rapid assistance, or to report any quirks or bugs to Geosolve, please contact:

Daniel Borin	Tel: 0044 20 8674 7251
Geosolve	Fax: 0044 20 8674 9685
E-mail	<a href="mailto:support@geosolve.co.uk">support@geosolve.co.uk</a>
Website	<a href="http://www.geosolve.co.uk">http://www.geosolve.co.uk</a>

### 3.5 POP-UP MENUS AND HOTKEYS (SHORTCUTS)

A **right-click** of the mouse button on any part of the GWALL desktop (Figure 1) will display useful pop-up menus. These pop-up menus provide convenient access to many features available from the main menu or via Hot keys. Here is a summary of all the shortcut keystrokes (Hot Keys) available in GWALL

<b>Key</b>	<b>Action</b>
F1	Context sensitive help
Ctrl+C	Copy Data / Results to clipboard
Ctrl+M	View memory usage
Ctrl+N	New data item
Ctrl+O	Open file
Ctrl+P	Print
Ctrl+R	Redo
Ctrl+S	Save
Ctrl+V	Paste data item
Ctrl+X	Delete
Ctrl+Y	reserved as alternative to Ctrl+R
Ctrl+Z	Undo
Ctrl+Tab	Move focus to Next block (data or results)
Shift+Ctrl+Tab	Move focus to Previous block (data or results)
Alt+A	Analyse
Alt+C	Toggle colour shading
Alt+D	View data
Alt+E	'Edit' menu
Alt+F	'File' menu
Alt+G	View graphics
Alt+H	Help index
Alt+I	Interrupt analysis
Alt+L	Select a load case
Alt+M	View messages
Alt+N	View data listing
Alt+O	Select font
Alt+R	View selected results
Alt+S	View summary results
Alt+T	Enter report mode
Alt+V	'View' menu
Alt+V+H	Toggle half width desktop option
Alt+W	Swap display of Bending moments / Earth pressures
Alt+X	Exit
Alt+Z	Reduce the width of the GWALL desktop (Alt+V+H to restore)
Alt+Left	Previous load case
Alt+Right	Next load case
Alt+Up	Zoom + (enlarge graphical display)
Alt+Down	Zoom - (reduce graphical display)

### 3.6 LOAD CASE SELECTION

The green button in the top right corner of the GWALL desktop shows you the number of the current load case. The current load case may be selected in one of the following ways:-

- Click on the green button or type **Alt+L** and select from the dropdown menu.
- Use the hot key combinations **Alt+Left** or **Alt+Right** to move backward or forward through the list of points / layers.
- Right click anywhere and select one of the options **Alt+L**, **Alt+Left** or **Alt+Right**.

During data input the graphical display in the lower right corner of the screen shows the data for the currently selected load case including surcharges and loads applied to the wall together with their respective partial factors.

While viewing results, you may find that not all load cases are available for selection because not all load cases were analysed. The graphical display in the lower right corner of the screen shows the results for the currently selected load case. At the same time the tabulated results for the current load case are shown in the panel on the left hand side of the screen.

When viewing **detailed results** the graphical display shows either:-

- Bending moment and shear force profiles, or
- Active and passive earth pressures.

Type **Alt+W** to toggle the display between the two sets of graphs.

### 3.7 DATA FILES

A data file contains one data set.

If several data sets containing different versions of a problem are to be stored on disk, they must be stored in files with different names. If you attempt to store a data set under an existing filename, the program will print the warning:-

C:\...\filename.dat exists. Over-write?

#### **Filenames**

A filename consists of any sequence of up to 45 letters or numbers.

You will not normally have to type the file extension (.DAT or .OUT). The program automatically gives data and output files the appropriate file extension. The following characters should not be included in filenames:

[ ] \ . < > ? : ; /

### **Data folders**

When data files are accessed, the program assumes that they are stored in the current folder on the currently logged drive as displayed in the yellow panel at the top of the screen. Use the **Open** and **Save As** dialog boxes to select a new folder.

#### **3.7.1 Opening an existing data file**

Choose **File | Open** from the main menu or type **Ctrl+O**. Use the dialog box to select a data file. While browsing the data files, the title and subtitle of the currently highlighted file are displayed in a box at the top of the screen to assist in selecting the correct file. If the highlighted file is not a GWALL data file a warning is displayed.

You may use the dialog box to access data on other drives and folders. The newly selected folder becomes the current folder and the data are read into memory and become the current data set.

#### **Quick file open**

To re-open a recently accessed data file choose **File** from the main menu and select one of the files listed.

#### **3.7.2 Starting a new data set**

Choose **File | New** from the main menu. You will be prompted to save your current data if it is not already saved. The program creates a skeleton data set consisting of typical wall (with shear key), 1 stratum either side of the wall and a different soil type for the founding material and 1 soil type. You must modify and adapt it to represent your particular wall.

Soil types may be imported from other data files by copying their properties via the GWALL clipboard (Section 6.13.4).

On completion of data entry, the data are stored in memory and are referred to as the current data set. The new data must be stored in a disk file if they are not to be lost at the end of the session.

### **3.7.3 Saving data on disk**

Choose **File | Save** or type **Ctrl+S**. The current data are saved to the current filename. Existing data in that file will be overwritten.

#### **Saving to a new file**

Choose **File | Save As** from the main menu. Use the dialog box to enter a new filename or select an existing file which will get overwritten. Use the dialog box to select a different folder or create a new folder for saving your data. You can access data in any folder on any drive. The folder containing the selected file becomes the current data folder.

### **3.7.4 Where to store your data**

Store your data in folders set aside specially for GWALL data. Never store your data in the GWALL program folder. Data for different projects should be kept in separate folders to facilitate archiving and retrieval of data and results.

## **3.8 DATA STRUCTURE**

### **3.8.1 Data sets**

A data set contains all the data necessary to carry out one analysis. The data in a data set are grouped into 9 data blocks. When a data set is stored on disk it occupies one file.

When a data set is entered for the first time via the keyboard, or read from a disk file, it is stored in memory (RAM) and becomes the current data set.

### **3.8.2 Run Identifiers and data file names**

The Run ID which appears in the title block is always the same as the last data filename which was read or stored on disk. In order to maintain the correspondence between Run ID and Data filename, you should always store newly edited data before carrying out an analysis. This will enable you to trace printed output to a particular data file.

You should choose a convenient mnemonic and numbering system to identify the various data files and the corresponding analyses which are generated during a job.

### **File maintenance**

You are responsible for removing old or unwanted files which will otherwise occupy valuable disk space.

## 3.9 GENERAL RULES FOR DATA ENTRY

### 3.9.1 Selecting a data block

Click the Data input mode button or select **View | Data** from the main menu or press **Alt+D** to enter Data input mode. In Data input mode a set of 9 data edit tabs is visible. Click one of the tabs to display the associated data block e.g. Titles, Strata, Soil types etc...

### 3.9.2 Selecting and editing a cell

Use the mouse or keypad arrows to highlight the item to be edited. Obtain help on the currently selected item by pressing **F1** .

### Numeric and Text data

To edit Numeric data or Text data press **Enter** or click on the item to open the item for editing. To overwrite the existing value simply start typing at the highlighted box. Conclude the data entry by pressing **Tab**, **Up arrow**, **Down arrow** or **Enter**, or by clicking on another cell.

### Options data (e.g. yes/no, drained/undrained)

Where a data item is selected from a series of options you can:-

- Click on the option and select from the dropdown menu, or
- Press the space bar to cycle through the various options, or
- Type the initial letter of the option, Y, N etc... ( this only works where there is a choice of 2 options)

### Insert New data item

To define a new soil type, surcharge etc..., highlight the undefined item or the position in the sequence where the new item is to be inserted and:-

- Press **Ctrl+N**, or
- Choose **Edit | New** from the main menu, or
- Right click and choose **Insert at cursor** from the pop-up menu.

### Delete data item

To delete a soil type, surcharge etc..., highlight the item and:-

- Press **Ctrl+X**, or
- Choose **Edit | Delete** from the main menu, or
- Right click and choose **Delete at cursor** from the pop-up menu.

### 3.9.3 Clipboard operations

Groups of data can be copied and pasted via the GWALL clipboard. The following example illustrates the procedure for soil properties. To copy the properties of Soil Type **i** to Soil Type **j**

1. Click the **Soil types** tab
2. Move the cursor to Soil Type **i**
3. Type **Ctrl+C** or right click within the soil properties menu and select **Copy**. This copies the properties of Soil Type **i** to the GWALL clipboard
4. Move the cursor to Soil Type **j**
5. Type **Ctrl+V** or right click within the soil properties menu and select **Paste**. This pastes the properties of Soil Type **j** from the GWALL clipboard

Soil types can be also copied and pasted from one data file to another via the GWALL clipboard (see Section 6.13.4).

For windows clipboard operations on results listings and graphics see Section 3.12

### 3.9.4 Undo and Redo data edits

Data edits can be undone up to a 100 steps. Type **Ctrl+Z** or choose **Edit | Undo** from the main menu.

Edits which have been undone can be redone provided no other changes have been made in the mean time. Type **Ctrl+R** or choose **Edit | Redo** from the main menu.

### 3.9.5 Moving focus

During data input, focus is either on the main form, the current data block (left side of screen) or the Graphics box (lower right) corner of screen. In general the current data block may obscure part of the Graphics box or vice versa. Click on the visible part of either box to bring it to the front.

## 3.10 VIEWING RESULTS

Refer to Section 3.3.3 for a description of the **View Results** mode button. There are 4 tabs in View Results mode. Select the item you wish to view.

### 3.10.1 Data listing

This is a complete listing of the input data. This item can be viewed even when no analysis has been done and there are no results to view. Type **Alt+N** or choose **View | Data Listing** from the main menu.

### 3.10.2 Detailed results for each load case

Use the (green) selection button to select a particular load case for viewing. The tabulated results are also shown in graphical form in the plot on the right side of the screen.

### 3.10.3 Summary results

Summary results show the critical factors of safety for all load cases. Descriptions of summary output are given in Section 15.4. There is no graphical summary output.

### 3.10.4 Messages / Details

These progress messages generated during the analysis are generally not of interest but may be useful in certain circumstances where a problem has been encountered.

### 3.10.5 Formatting the output

The font size and style of the results listings can be controlled using the Format option in the main menu. Click **Format | Font selection** or type **Alt+O** to bring up the font selection box. Font selection must be done before the analysis. Results cannot be reformatted after the analysis.

The default font is Courier New 9pt.

### 3.11 CREATING AND PRINTING REPORTS

To create a report for printing or output to disk file, click the **Report** mode button, choose **View | Report** at the main menu or type **Alt+T**. The following options control the information included in the report.

To leave Report mode, click **Close**, type **Esc** or close the form. No other GWALL processing is possible while in Report mode.

#### 3.11.1 Load case selection

Use this option to select the load cases for which detailed results will be included in the report.

#### 3.11.2 Graphical output

Graphical output in the report will show the currently selected part of the wall profile. Make an appropriate selection (see Section 3.1.3) before entering **Report mode**

#### Data graphics

Tick **Data graphics** to include a picture of the data.

#### Results graphics

Tick **Graphs for all selected load cases** to include separate graphs of Bending Moments and Earth Pressures for each of the selected load cases.

#### 3.11.3 Create report

Click **Create report** to begin creation of the report using the options selected above. The report will be created in an RTF (Rich Text Format) file in the same folder as that in which the data and results files are stored. An RTF file can be viewed and printed using MS-Word, WordPad and many other non-Windows word processing programs.

#### 3.11.4 View report

Click **View report** to open the report file using your default word processing package (usually MS-Word). You are free to edit the report file and add comments or other information.

To return to GWALL, close MS-Word or click on the GWALL icon on the Windows taskbar.

### 3.11.5 Print report

Click **Print report** to print the report on your default printer. To print to another printer or select non-standard printer options, use **View report** and use the print facilities in MS-Word.

### 3.12 USING THE WINDOWS CLIPBOARD

Data and results listings may be copied to the windows clipboard as follows:-

1. Select all or part of the text box. This may be done by clicking and dragging or by typing **Ctrl+A** to select all text in the box.
2. Copy the selected text to the windows clipboard using the standard keyboard shortcut, **Ctrl+C** or by choosing **Edit | Copy** on the main menu.

Graphical output may be copied to the windows clipboard as follows:-

1. Display the required graphic (data or results).
2. Click in the graphics box.
3. Copy the graphic to the windows clipboard using the standard keyboard shortcut, **Ctrl+C** or by choosing **Edit | Copy** on the main menu.
4. The graphic will be scaled to occupy a fixed area suitable for an A4 page in the destination document.

### 3.13 TERMINATING PROGRAM EXECUTION

Type **Alt+X** or choose **File | Exit GWALL** from the main menu or close the main form. Any unsaved data will be lost.

## 4.0 TITLE BLOCK and FORCE, LENGTH UNITS

I.K.BRUNEL and PARTNERS	Sheet No.
Program: GWALL Version 3.01 Revision A01.B01.R23	
Licensed from GEOSOLVE	Job No. ABC/123
Run No. DEMO1	Made by : DLB
Bletchley Bridge Abutment	Date:01-06-2006
Braking loads surcharge   Checked :	
-----	
	Units: kN, m

### 4.1 TITLES

'Titles' consists of six items of information which are printed in the title block at the top of the input data and at the top of each section of output. They are:-

	<b>Maximum permitted no. of characters</b>
Main title	60
Sub-title	60
Job number	7
Engineer's initials	4
Force units	2
Length units	2
Unit weight of water	-

### 4.2 FORCE AND LENGTH UNITS

The Force units and Length units entered by the user are used by the program to prompt data entry in the correct units and also to annotate the output. The suggested style is:-

**kN, m or kg, cm or lb, ft**

Data can be entered in any consistent set of units. It is up to you to ensure that the values entered for strength, bulk unit weight etc., correspond to the given units.

### 4.3 UNIT WEIGHT OF WATER

The units of unit weight of water must be the same as those used for unit weight of soil (see Section 6.5) e.g.

## 5.0 STRATA PROFILE

### 5.1 COORDINATE SYSTEM

A cross-section of the wall should be drawn on graph paper with equal scales in the horizontal and vertical directions and the retained soil on the left. Horizontal distances are measured as positive "uphill". The toe of the wall is at x coordinate zero. A set of x-y axes should be marked on the section with the x-axis horizontal and the positive y-axis must point upwards. There is no restriction on the use of negative coordinates except that all coordinate values must lie between -10000 and +10000. It is often convenient to use O.D. levels for the y coordinates.

### 5.2 SOIL STRATA

The section should show the wall profile, ground level on either side of the wall, the angle of backfill on the active side and the boundaries between the different soil strata. All strata interfaces except active ground level must be horizontal.

The strata and the boundaries between them are numbered from ground level downwards as shown in Figure 2. Thus the number of each soil stratum is the same as the number of its upper boundary so that boundary No.1 corresponds to ground level. The strata are numbered separately on either side of the wall. There is no lower boundary to the section and the program assumes that the lowermost stratum extends downwards indefinitely.

Each stratum should be allocated a "soil type". Different soil types may be allocated to the ground on either side of the wall. The same soil type can be assigned to more than one stratum.

The adhesion and friction between the base of the wall and the foundation soil are defined under **Wall properties** and are not directly related to the properties of any "soil type". However, where a shear key is specified, the base friction and cohesion should not exceed the friction and cohesion of the soil type in front of the shear key.

Soil Strata are allocated properties via Soil Types in the Soil Properties section.

## 5.3 DATA ENTRY

### Defining a new soil profile

From the main menu select **File | New** to start a new data set. The default data set consists of a simple wall profile which you should modify to achieve the section you wish to model.

### Maximum number of strata

A maximum of 20 soil strata can be defined either side of the wall. At least one stratum must be defined on either side of the wall. The lowermost stratum is assumed to extend downwards indefinitely.

Special edit key strokes are:



- |        |                             |
|--------|-----------------------------|
| Enter  | to edit selected coordinate |
| Ctrl+N | to add a stratum            |
| Ctrl+X | to delete a stratum         |

### 5.3.1 Edit y coordinates of soil strata

In the table of coordinates move the cursor to the y coordinate to be edited and enter the new value. The new elevation must lie between the values of the strata immediately above and below. If you want to change the strata sequence, delete a stratum and insert a new stratum at the required elevation.

### Edit y coordinates using the GUI

Move the cursor over one of the strata interfaces. The cursor changes

from  to . Click and drag. The stratum coordinate can be moved vertically only. You cannot drag a stratum above or below its immediate neighbours. The selected stratum coordinate will be highlighted in the table of strata coordinates. To edit the fine detail of the strata, select part of the wall section for detailed viewing before editing (see Section 3.1.2).

### Special treatment of Active Ground Level

Two parameters define the position of Active GL. Both parameters can be edited graphically:

- Elevation of GL adjacent to the wall  
Move the cursor over the active GL *near to the wall*. Notice the message “Stratum 1” in the box at lower left corner of the graphics  
Click and drag to change the elevation.
- Backfill angle  
Move the cursor over the active GL towards the *outer edge of the section*. Notice the message “Backfill angle” in the box at lower left

corner of the graphics. Click and drag to change the backfill angle. The backfill angle is listed under Wall properties.

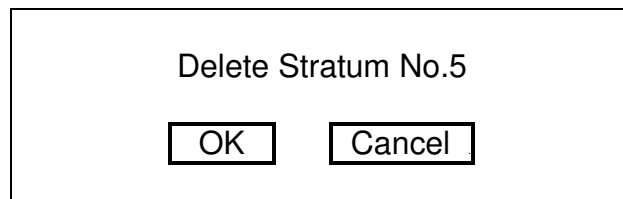
### 5.3.2 Insert a new stratum

A new stratum can be inserted anywhere in the existing profile. The position of the new stratum in the existing sequence of strata is determined by its y coordinate. Move the cursor to the Active side or Passive side according to which side you wish to insert the new stratum and press **Ctrl+N** or click on the word 'new'. Type the new y coordinate in the pop-up box. Remember that the new y coordinate defines the *upper* boundary of the new stratum.

After entering the y coordinate the program will request a soil type for the new stratum.

### 5.3.3 Delete a stratum

To delete the n<sup>th</sup> stratum, place the cursor in the table of coordinates at the n<sup>th</sup> stratum and type **Ctrl+X**



After each deletion the strata below the deleted stratum (if any) are renumbered automatically. The soil type of the remaining strata are also renumbered accordingly.

## 6.0 SOIL PROPERTIES

### Ultimate limit state and Serviceability limit state parameters

See Section 12.1 for a description of the ULS and SLS analyses.

GWALL carries out ULS and SLS analyses in parallel.. Each analysis requires its own values of soil strength and (by implication) earth pressure coefficients. The following table indicates which parameters have separate values for the ULS and SLS cases.

Soil parameter	Usage
Soil description Bulk Unit Weight Cohesionless or Cohesive soil type Drained or Undrained soil type Datum elevation for Cohesion	The same value is used for ULS and SLS analyses.
Compaction pressure	This parameter is only used in the SLS analysis.
Soil Friction Angle, $\phi$ Cohesion (drained or undrained) Rate of increase of cohesion with depth	A single value for each parameter is entered in the data. The given values are used un-factored in the SLS analysis but are partially factored for the ULS analysis.
Wall friction (adhesion) coefficient - active and passive side	Separate values are entered in the data appropriate to the ULS and SLS cases.
Set earth pressure coefficients automatically	This Flag is usually set to 'Yes' for the ULS case and 'No' for the SLS case.
Earth pressure coefficients, $K_a$ , $K_{ac}$ , $K_p$ , $K_{pc}$	If the Flag (above) is 'Yes' then $K_a$ , $K_{ac}$ , $K_p$ , $K_{pc}$ are calculated automatically from the friction angle and wall geometry, using partially factored strengths in the ULS case.  If the Flag is 'No' then $K_a$ , $K_{ac}$ , $K_p$ , $K_{pc}$ are entered manually.

## 6.1 STRATUM DESCRIPTION

The stratum description is a text of up to 20 characters.

## 6.2 COHESIONLESS OR COHESIVE SOIL TYPE

All soil types are defined as Cohesionless or Cohesive. The following restrictions apply:

Category	Restrictions	Typical soils
Cohesionless soil	Always "drained". Cohesion value is zero.	Sand, gravel, Cohesionless silt
Drained Cohesive soil	No restrictions	Medium/long term Behaviour of clays
Undrained Cohesive soil	$\phi = 0$	Short/medium term Behaviour of clays

## 6.3 DRAINED OR UNDRAINED SOIL TYPE

Cohesive soils are defined as behaving in either a Drained or Undrained manner. Drained and Undrained analyses are applicable as follows:-

	Applicability
Drained analysis	Medium / long term Behaviour
Undrained analysis	Short / medium term Behaviour

### 6.3.1 Drained soil

The analysis of Drained cohesive soil is carried out in effective stress terms i.e. pore pressures are assumed to have time to reach equilibrium.

### 6.3.2 Undrained soil

The analysis of Undrained cohesive soil is carried out in total stress terms (there is insufficient time for pore pressures to reach equilibrium). Limiting active pressures in Undrained soil take account of the "minimum equivalent fluid density" criterion and the "maximum

water filled tension crack depth" criterion (see Sections 12.2 and 12.3). Soil pressures in Undrained strata are reported in Total stress terms.

### 6.3.3 Critical conditions for Drained and Undrained analysis.

Soft and very soft clays tend to be weakest under undrained (short term) loading and gain strength with time. Stiff and very stiff clays tend to be strong under undrained (short term) loading and lose strength as suctions dissipate with time. It is important to check behaviour under all relevant conditions. The following table gives some indication of the likely critical conditions for soft and stiff clays.

	<b>Undrained analysis (Short term)</b>	<b>Drained analysis (Long term)</b>
Soft / very soft clay	Critical	---
Stiff / very stiff clay	---	Critical

See Section 6.6 for discussion of values of Drained and Undrained cohesion.

## 6.4 BULK UNIT WEIGHT

For each stratum two values of bulk unit weight must be specified:-

Above ground water level	Dry or partially saturated bulk unit weight
Below ground water level	Saturated bulk unit weight

The program automatically uses the appropriate values in the analysis according to the position of the water table. **Submerged** unit weights must **not** be specified. Water pressures on submerged ground are taken account of automatically in the analysis.

The units of bulk unit weight must be consistent with those used for cohesion and surcharge loads:-

Cohesion	Corresponding units of bulk unit weight
Units	
kN/m <sup>2</sup>	kN/m <sup>3</sup>
kg/cm <sup>2</sup>	kg/cm <sup>3</sup>
lb/ft <sup>2</sup>	lb/ft <sup>3</sup>

## 6.5 SHEAR STRENGTH PARAMETERS

Soil strength is defined by the usual  $c, \phi$  parameters. The values entered in the data should be 'Moderately Conservative' values as defined in CIRIA Report C580 (Glossary) and in BS8002 as Representative values. For a description of the design approach and the use of partial factors see Section 12.1.

## 6.6 COHESION

Cohesion is used with the earth pressure coefficients in calculating active and passive pressures on the stem, base and shear key (if present).

For an effective stress analysis (long term stability) the drained cohesion should be specified. For a total stress analysis (short term stability) the undrained cohesion should be specified.

### 6.6.1 Drained cohesion

For drained cohesive soils the drained cohesion,  $c'$  must be specified. The drained cohesion may be derived from drained triaxial tests or (more usually) undrained triaxial tests with pore pressure measurement. The latter are susceptible to error if the rate of testing is not sufficiently slow (Bishop and Henkel, 1962). High values of drained cohesion should be regarded with suspicion.

### 6.6.2 Undrained cohesion

For undrained cohesive soils the undrained cohesion,  $c_u$  must be specified. Undrained cohesion values may be obtained from undrained triaxial tests or estimated from correlations with SPT values. For over-consolidated clay the following correlation may be used:-

$$C_U \text{ (kN/m}^2\text{)} \cong 4.5 \times N \quad 6.1$$

where  $N$  is the SPT value. The following table gives an approximate indication of cohesion values in terms of the usual borehole log descriptions:-

	Consistency		
	Soft	Medium	stiff
Undrained shear Strength, $\text{kN/m}^2$	20-40	40 – 75	75 - 150

Table 6.1 Approximate values of Undrained Cohesion

### 6.6.3 Cohesion varying with depth - $dc/dy$

For undrained cohesive soil the cohesion may be specified to vary linearly with depth according to the equation:-

$$c = c_o + (y_o - y).dc/dy \quad 6.2$$

where  $c_o$  is the cohesion at a datum elevation  $y_o$  and  $dc/dy$  is the rate of increase of cohesion with depth (see Figure 8).  $dc/dy$  may take any value, positive or negative. A positive value represents cohesion increasing with depth. For constant cohesion within the stratum enter zero. If a non-zero value is entered for  $dc/dy$  the program requests a value for the datum elevation  $y_o$  in Equation 6.2 .

### 6.7 FRICTION ANGLE

The friction angle is used:

- in calculating the passive resistance of the soil in front of the Shear Key.
- in conjunction with the Wall Friction (Adhesion) Coefficient to calculate the Wall Friction Angle
- in the calculation of earth pressure coefficients when Automatic setting of earth pressure coefficients is selected

For undrained cohesive soils the friction angle is automatically set to zero.

### 6.8 WALL FRICTION (ADHESION) COEFFICIENT, $\psi$

The value of  $\psi$  is used in conjunction with the soil friction and cohesion to calculate the friction and adhesion between soil and wall.

For drained soils  $\psi$  is defined as

$$\psi = \tan \delta / \tan \phi \quad 6.3a$$

For undrained soils  $\psi$  is defined as

$$\psi = C_w / C_u \quad 6.3b$$

Separate values,  $\psi_a$  and  $\psi_p$  are defined for the active and passive sides of the wall and for the ULS and SLS calculations i.e. for the virtual back of the wall (see Figure 5) and the actual back of the wall (see Figure 6).  $\psi$ ,  $\delta$  and  $C_w$  are defined as positive when the friction force acts as shown in Figures 5 and 6.

For drained soils, wall friction is calculated according to the equations:

$$\begin{aligned} q &= p' \cdot \tan(\delta) + C_w & 6.4a \\ &= \psi ( p' \cdot \tan(\phi) + C' ) \end{aligned}$$

For undrained soils, wall friction is calculated according to the equations:

$$\begin{aligned} q &= C_w & 6.4b \\ &= \psi \cdot C_u \end{aligned}$$

### **ULS case – virtual back of the wall**

Where this plane is a soil-to-soil contact the value of  $\psi$  will be close to unity. Where there is no heel to the wall and the back face is vertical (or nearly so),  $\psi$  represents the interaction between wall and soil and its value will be less than unity and may be as low as 0.4 .

**Note:** This parameter,  $\psi$  supersedes the separate parameters of Wall friction and Wall adhesion defined in GWALL Version 2.42. Old GWALL data files can be read by GWALL Version 3 and a suitable value of  $\psi$  will be substituted. In the unlikely event that the old GWALL data contains conflicting values of  $\tan \delta / \tan \phi$  and  $C_w / C'$  then the program will set  $\psi$  equal to  $\tan \delta / \tan \phi$  .

### **6.9 ACTIVE PRESSURE DUE TO COMPACTION**

The active pressure due to compaction is used as a lower limit on the active (effective) pressure in the calculation of bending moments and shear forces (SLS analysis - see Section 6.12.1), but not in the stability calculation (ULS analysis).

The way in which this parameter is used is described in detail in Chapter 6 of Clayton, Milititsky and Woods (1993) and Section 6.4 of CIRIA Report CP/58 (1998).

### **6.10 AUTOMATIC SETTING OF EARTH PRESSURE COEFFICIENTS**

Values of  $K_a$ ,  $K_{ac}$ ,  $K_p$  and  $K_{pc}$  may be entered manually or you can set the program to calculate them automatically based on the values of Soil friction, Wall friction (adhesion), Wall batter and Backfill angle.

The values calculated in this way include the effects of partial factors on soil strength as defined in the Analysis Options. The values  $K_a$ ,  $K_{ac}$ ,  $K_p$  and  $K_{pc}$  are derived using the formulae in Eurocode 7 and are, of course, limiting values of earth pressure derived from consideration of active and passive wedges. The Automatic Setting option is therefore

normally applicable only to the ULS parameters. A warning message is issued if the Automatic Setting option is selected for the SLS parameters.

### **Help facility for Earth Pressure Coefficients**

If you do not use the Automatic Setting option then you can still use the Help facility which will calculate values of  $K_a$ ,  $K_{ac}$ ,  $K_p$  and  $K_{pc}$  from the soil parameters and backfill angle. Just Press <F1> while editing the earth pressure coefficients.

### **Formulae for calculating earth pressure coefficients**

#### **Eurocode 7, Part 1, Annex G**

This is the default formula. You should normally use this method.

#### **Coulomb formula**

This is an alternative formula. It has two disadvantages

- It is inaccurate at high angles of wall friction and slope angle.
- It only gives values of  $K_a$  and  $K_p$ , **not**  $K_{ac}$  and  $K_{pc}$ .

**Note:** The calculated values in all cases (whether for automatic setting or via the Help facility) are the components of earth pressure normal to the wall (or virtual wall) and can therefore be entered directly into the data.

## **6.11 EARTH PRESSURE COEFFICIENTS FOR STABILITY ANALYSIS - ULTIMATE LIMIT STATE**

### **Definition of factor of safety**

The stability analysis considers the balance between forces acting on **vertical** planes through the heel and toe of the wall as shown in Figure 5.

### **The virtual back of the wall**

The virtual back of the wall is defined as a vertical plane through the heel of the wall as shown in Figure 5.

### **The virtual front of the wall**

The virtual front of the wall is defined as a vertical plane through the toe of the wall as shown in Figure 5.

### **Walls with backward batter and no heel**

For walls (without a heel) which are battered back in to the soil, the concept of a "virtual back" to the wall is not strictly applicable. However the following rules for calculating earth pressure coefficients will lead to reasonably conservative results.

### 6.11.1 Active earth pressure coefficients, $K_a$ and $K_{ac}$ (ULS)

$K_a$  and  $K_{ac}$  are functions of:-

$\phi$	angle of soil friction
$\psi_a$	wall friction coefficient (see Section 6.8)
$\beta$	slope angle of the backfill

and are calculated as described in Section 6.10. For cohesionless soils  $K_{ac}$  is zero. For undrained cohesive soils  $K_a$  is unity.

#### Drained soil

For drained soil the program calculates limiting active (effective) pressures according to the equation:-

$$p_a' = p_v' \cdot K_a - K_{ac} \cdot c' \quad 6.5a$$

where  $p_v'$  is the vertical effective stress,  $c'$  is the drained cohesion. The limiting total pressure is:-

$$p_a = p_a' + u \quad 6.5b$$

where  $u$  is the water pressure. When the value of  $p_a'$  (in cohesive soil) calculated from Equation 6.5a is negative, the program takes  $p_a'$  as zero and the minimum wall pressure is taken as equal to  $u$  in accordance with the recommendations of BSPH (1997).

#### Undrained soil

For undrained soil the program calculates limiting active total pressures according to the equation:-

$$p_a = p_v \cdot K_a - K_{ac} \cdot c_u \quad 6.6$$

where  $p_v$  is the total vertical stress and  $c_u$  is the undrained cohesion. Limiting active pressures in undrained soil take account of the "minimum equivalent fluid density" criterion and the "maximum water filled tension crack depth" criterion (see Sections 12.2 and 12.3).

### 6.11.2 Passive earth pressure coefficients, $K_p$ and $K_{pc}$ (ULS)

The designer must consider carefully how much, if any, passive resistance should be allowed taking into account the substantial movement required to mobilise full passive resistance and the possibility of excavation for services at the toe of a wall. For this reason passive pressures in ULS analyses may be reduced by a factor specified by the user (Section 12.4).

$K_p$  and  $K_{pc}$  are functions of:-

$\phi$	angle of soil friction
$\psi_p$	wall friction coefficient (see Section 6.8)

and are calculated as described in Section 6.10. For cohesionless soils  $K_{pc}$  is zero. For undrained cohesive soils  $K_p$  is unity.

### **Drained soil**

For drained soil the program calculates limiting passive (effective) pressures according to the equation:-

$$p_p' = (p_v' \cdot K_p + K_{pc} \cdot c') / F_p \quad 6.7a$$

where  $p_v'$  is the vertical effective stress,  $c'$  is the drained cohesion and  $F_p$  is the partial factor of safety on passive resistance (Section 12.4).

The limiting total pressure is:-

$$p_p = p_p' + u \quad 6.7b$$

where  $u$  is the water pressure.

### **Undrained soil**

For undrained soil the program calculates limiting passive total pressures according to the equation:-

$$p_p = p_v \cdot K_p + K_{pc} \cdot c_u / F_p \quad 6.8$$

where  $p_v$  is the total vertical stress and  $c_u$  is the undrained cohesion.

### **6.11.3 Earthquake conditions**

There are no facilities as yet within GWALL for calculating earth pressure coefficients for earthquake conditions.

## 6.12 EARTH PRESSURE COEFFICIENTS FOR BENDING AND SHEAR - SERVICEABILITY LIMIT STATE

Bending moments and shear forces in the stem and base of the wall are calculated from the earth pressures acting on the front and back faces of the stem as shown in Figure 6. Earth pressure coefficients for the SLS analysis are designated with an asterisk e.g.  $K_a^*$ , to distinguish them from the ULS values.

### 6.12.1 Active earth pressure coefficients, $K_a$ and $K_{ac}$ (SLS)

Earth pressure coefficients for the SLS should reflect the state of the soil under working conditions. Due to the stiffness of the stem of cantilever walls, earth pressures in the lower half of the wall are likely to approach the  $K_o$  condition. In the upper half of a (flexible) wall, earth pressures usually approach the theoretical active condition in which  $K_a^*$  and  $K_{ac}^*$  are functions of:-

$\phi$	angle of soil friction
$\psi_a$	wall friction coefficient
$\alpha_a$	batter angle of the wall (see Figure 3)
$\beta$	slope angle of the backfill

and are calculated as described in Section 6.10. For cohesionless soils  $K_{ac}$  is zero. For undrained cohesive soils  $K_a$  is unity.

#### Drained soil

For drained soil the program calculates the active (effective) pressure **normal** to the wall according to the equation:-

$$p_a^{*'} = p_v' \cdot K_a^* - K_{ac}^* \cdot c' \quad 6.9a$$

where  $p_v'$  is the vertical effective stress,  $c'$  is the drained cohesion. The total pressure is:-

$$p_a^* = p_a^{*'} + u \quad 6.9b$$

where  $u$  is the water pressure. When the value of  $p_a^{*'}$  (in cohesive soil) calculated from Equation 6.9a is negative, the program takes  $p_a^{*'}$  as zero and the wall pressure is taken as equal to  $u$  in accordance with the recommendations of BSPH (1997).

### Undrained soil

For undrained soil the program calculates active total pressures **normal** to the wall according to the equation:-

$$p_a^* = p_v \cdot K_a^* - K_{ac}^* \cdot c_u \quad 6.10$$

where  $p_v$  is the total vertical stress and  $c_u$  is the undrained cohesion. Limiting active pressures in undrained soil take account of the "minimum equivalent fluid density" criterion and the "maximum water filled tension crack depth" criterion (see Sections 12.2 and 12.3).

### Active pressure due to compaction

In the SLS calculation the **Active pressure due to compaction** is used as a lower limit on the active (effective) pressure in the calculation of bending moments and shear forces (see Section 6.9).

#### 6.12.2 Passive earth pressure coefficients, $K_p$ and $K_{pc}$ (SLS)

Due to the stiffness of the stem of cantilever walls, passive earth pressures are likely to approach the  $K_o$  condition. This condition can best be modelled by setting  $K_p^*$  equal to  $K_o$  and  $K_{pc}^*$  to zero.

### Drained soil

For drained soil the program calculates passive (effective) pressures **normal** to the wall according to the equation:-

$$p_p^{*'} = p_v' \cdot K_p^* + K_{pc}^* \cdot c' \quad 6.11a$$

where  $p_v'$  is the vertical effective stress,  $c'$  is the drained cohesion. The limiting total pressure is:-

$$p_p^* = p_p^{*'} + u \quad 6.11b$$

where  $u$  is the water pressure.

### Undrained soil

For undrained soil the program calculates passive total pressures **normal** to the wall according to the equation:-

$$p_p^* = p_v \cdot K_p^* + K_{pc}^* \cdot c_u \quad 6.12$$

where  $p_v$  is the total vertical stress and  $c_u$  is the undrained cohesion.

## 6.13 DATA ENTRY

A maximum of 20 soil types may be defined.

### 6.13.1 Edit a soil type

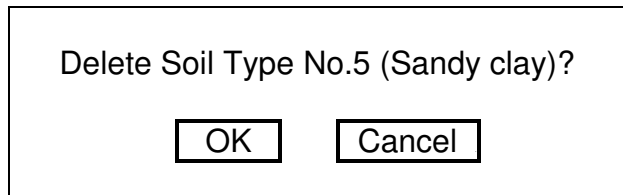
Click the **Soil properties** tab to access the table of soil types. Move the cursor to the soil type to be edited and click or press <Enter>.

### 6.13.2 Define a new soil type

Place the cursor in the table of soil types at an undefined type and type **Ctrl+N**. Enter the properties as requested. Press <Esc> to abandon input of a new soil type.

### 6.13.3 Delete a soil type

To delete the **n<sup>th</sup> soil type**, place the cursor in the table of soil types at the **n<sup>th</sup> soil type** and type **Ctrl+X**



### 6.13.4 Copy soil properties

Soil properties can be copied from one soil type to another. GWALL has its own clipboard for copying and pasting Soil properties.

Click the "Soil properties" tab. In the table of properties move the cursor to the soil type to be copied. Type **Ctrl+C**. The soil type is copied to the GWALL clipboard (you cannot view the clipboard). Move the cursor to the destination soil type. Type **Ctrl+V**.

This facility can also be used to copy soil properties from other GWALL data files via the following steps.

1. Save your current data file
2. Open the 'source' data file.
3. Select and copy the required soil type
4. Return to your original data file.
5. Paste the soil properties in the destination soil type.

The above steps can be repeated to copy several soil types.

## 7.0 GROUND WATER CONDITIONS

### 7.1 GROUND WATER LEVELS

The program requires the elevation of the water table on either side of the wall. Submerged ground is modelled by simply defining a water table above ground level. By default the program assumes hydrostatic pressure distributions on either side of the wall. This assumption may be reasonable where the wall is founded on an impermeable stratum.

### 7.2 NON-HYDROSTATIC WATER PRESSURE DISTRIBUTIONS

Where non-hydrostatic conditions are to be modelled the user may define the piezometric elevations,  $h_a$  and  $h_p$  at the base of the wall at the heel and toe (see Figure 4). In this case the program assumes a linear distribution of pore pressure between the specified ground water level (or ground level, whichever is lower) and the base of the wall on each side.

The pore pressure at the base of the heel is given by:-

$$u_{\text{heel}} = \gamma_w(h_a - y_b) \quad 7.1$$

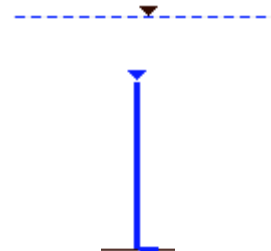
The pore pressure at the base of the toe is given by:-

$$u_{\text{toe}} = \gamma_w(h_p - y_b) \quad 7.2$$

Data is entered in the following table:


Ground water levels		
	Active side	Passive side
Water table elevation	5.00	1.20
Piezometric elevation at base of wall	4.00	1.50

The graphical display shows ground water level as a blue dashed line with a blue triangle.



The piezometric elevation at the base of the wall is shown as a blue standpipe.

The Water table elevation can be edited graphically. Place the cursor over the dashed blue line and observe that it changes to a double-ended

vertical arrow, , then click and drag to change the elevation. If the piezometric elevation at the base of the wall is *equal* to the water table

elevation (hydrostatic conditions) then both values are changed at the same time by clicking and dragging. If, however the piezometric elevation at the base of the wall has a different value from the water table elevation then it is left unchanged and its value can only be changed by entering a new value in the table of data – not graphically.

### **7.3 WATER PRESSURES UNDER BASE OF WALL**

The program assumes a linear distribution between the water pressures,  $u_{\text{heel}}$  and  $u_{\text{toe}}$ , at the heel and toe of the wall as defined above.

### **7.4 BULK UNIT WEIGHT OF WATER**

Bulk unit weight of water is entered with the Titles (see Section 4) and its units must be the same as those used for bulk unit weight of soil (see Section 6.1)

## 8.0 WALL PROPERTIES

### 8.1 SLOPING GROUND BEHIND THE WALL

Although not strictly a property of the wall, the inclination of the ground level,  $\beta$  (beta) is included in this data block for convenience. The inclination is entered in degrees and is defined as positive when the ground rises away from the wall (see Figure 3).

#### Backfill angle behind wall

The backfill angle can be edited interactively by clicking and dragging a point on the *active ground level* close to the *left boundary* of the graphical display.

It is the responsibility of the user to ensure that the values of  $K_a$  and  $K_{ac}$  correspond to the slope angle. If you specify the "Set Earth Pressure coefficients Automatically" option then the values of  $K_a$  and  $K_{ac}$  will take account of the backfill angle.

### 8.2 BULK UNIT WEIGHT OF WALL MATERIAL

The bulk unit weight of the wall,  $\gamma_c$  must be given in the same units as used for the bulk unit weight of water (see Section 4).

### 8.3 WALL GEOMETRY

The following list of parameters defines the geometry of the wall as shown in Figure 3:-

$y_b$	Elevation of base of wall (excluding shear key)
$y_t$	Elevation of top of wall
$D_b$	Thickness of base of wall
$B_h$	Width of heel of wall
$B_t$	Width of toe of wall
$B_b$	Width of base of stem
$B_a$	Width of stem at top of wall
$\alpha_a$	Batter angle of back face of wall (+ve forward sloping)
$\alpha_p$	Batter angle of front face of wall (+ve forward sloping)
$D_k$	Depth of shear key
$B_k$	Width of shear key
$x_k$	Distance from toe to front of shear key

**Elevation of top of wall**

This is the elevation,  $y_t$ , of the top of the stem of the wall measured in the same frame of reference as the base elevation. It can be edited interactively by clicking and dragging a point along the top of the stem of the wall.

**Batter angle of back of wall,  $\alpha$  (degs, +ve forward sloping)**

This is the angle  $\alpha_a$  of the back of the wall to the vertical. It is positive when the wall slopes forwards (towards the passive side). It can be edited interactively by clicking and dragging a point on the *upper half* of the back of the wall.

**Distance from toe to front of shear key**

This is the distance,  $x_k$ , from the front of the shear key to the front face of the base of the wall. It can be edited interactively by clicking and dragging a point on the front of the shear key of the wall.

The shear key is optional. If Depth of Shear Key is not defined (zero) then this parameter is greyed out.

**Width of shear key**

This is the width,  $B_k$ , of the shear key. It can be edited interactively by clicking and dragging a point on the *rear side* of the shear key.

The shear key is optional. If Depth of Shear Key is not defined (zero) then the width of the shear key is greyed out and also cannot be entered.

**Depth of shear key**

This is the depth,  $D_k$ , of the shear key. It can be edited interactively by clicking and dragging a point on the *underside* of the shear key.

The shear key is optional. If Depth of Shear Key is not defined (zero) then the width of the shear key is greyed out and also cannot be entered.

**Width of toe of wall**

This is the width,  $B_t$ , of the toe of the wall. It can be edited interactively by clicking and dragging a point on the *front* of the toe of the wall.

**Width of heel of wall**

This is the width,  $B_h$ , of the heel of the wall. It can be edited interactively by clicking and dragging a point on the *back* of the heel of the wall.

**Thickness of base of wall**

This is the depth,  $D_b$ , of the base of the wall. It can be edited interactively by clicking and dragging a point on the *upper face* of the base of the wall.

**8.4 FRICTION AND ADHESION ON THE BASE OF THE WALL**

The friction angle,  $\phi_b$ , and adhesion,  $c_b$ , between the base of the wall and the foundation soil are required in addition to the soil properties defined in Section 6.

These values are used to calculate the available shear between the base of the wall and the soil in contact with it. A warning message is issued if this interaction value is greater than the cohesion of soil type in contact with the base of the wall.

## 8.5 DATA ENTRY and EDITING

All geometrical properties of the wall can be edited numerically or graphically. The following table shows where to place the cursor in order to edit each part of the wall geometry. You should observe the prompt in the bottom left corner of the graphics window which shows the item currently in focus for interactive editing.

X = 2.77	Y = 0.50
Base of wall	

Item to be edited		Cursor position
Elevation of base of wall	$y_b$	Under side of base
Elevation of top of wall	$y_t$	Top of stem
Thickness of base of wall	$D_b$	Top of base
Width of heel of wall	$B_h$	Rear face of base
Width of toe of wall	$B_t$	Front face of base
Position of stem on base	$B_t + B_t$	Front face of stem (lower half)
Width of base of stem	$B_b$	Rear face of stem (lower half)
Width of stem at top of wall	$B_a$	Front face of stem (upper half)
Batter angle of back face of wall	$\alpha_a$	Rear face of stem (upper half)
Depth of shear key	$D_k$	Under side of shear key
Width of shear key	$B_k$	Rear face of shear key
Distance from toe to front of shear key	$x_k$	Front face of shear key
Inclination of ground level	$\beta$	Ground level - active side (near outer edge of section)

## 9.0 LOADS APPLIED TO THE WALL

### 9.1 LOADS APPLIED TO THE TOP OF THE WALL

Horizontal, vertical and moment loads can be applied to the top of the wall. All loads are defined per unit length of wall. The position of the vertical load is defined by its distance,  $x_v$ , from the front of the wall. The sign convention for applied loads is shown in Figure 4.

### 9.2 ANCHOR LOAD APPLIED TO THE FRONT FACE OF THE WALL

An anchor load,  $A$ , can be applied to the front face of the wall. The position of the anchor load is defined by its elevation,  $y_A$ , and its inclination,  $\theta$ , to the horizontal. The anchor load is defined as positive when it acts in the direction shown in Figure 4.

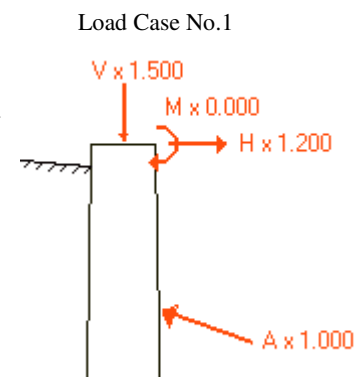
### 9.3 PARTIAL FACTORS APPLIED TO LOADS

The loads are modified by the partial factors defined in the load case section of the data (see Section 11.0). Each load case has its own set of partial factors. In this way you can model different loading conditions and combinations of loads.

You specify individual partial factors to be applied to each of the components of load applied to the top and the face of the wall (horizontal, vertical and moment load). Each load is multiplied by the specified partial factor. A zero value means in effect that the load is not applied.

The graphical display shows the values of partial factors for the currently displayed load case. In the example on the right the moment load has a zero load factor and therefore has no effect in this load case.

The location of the Vertical force and the Anchor force can be edited using the GUI (see Section 3.1.1)



## 10.0 SURCHARGE LOADS APPLIED TO THE GROUND

Surcharges can be applied at or below ground level on the active side of the wall. Surcharges are defined in units of pressure (e.g. kN/m<sup>2</sup> , lb/ft<sup>2</sup>) and may take any value positive or negative. A positive surcharge acts downwards; a negative surcharge acts upwards.

Surcharges do not take effect unless they are actually applied in one of the load cases (see Section 11.0). Load factors may be applied to the surcharges when they are included in a particular load case. Different combinations of surcharges (and forces on the wall) may be applied in different load cases.

### 10.1 SURCHARGE DEFINITION

All surcharges are defined as acting over a rectangular loaded area. "Surcharge Length Parallel to the Wall" is the length of the surcharge perpendicular to the plane of the analysis.

The following parameters define a surcharge (see Figure 4):

$y_q$	Elevation at which the surcharge is applied (buried surcharges only)
$x_q$	Distance of (near edge of) surcharge from wall
$B_q$	Width of surcharge perpendicular to wall
$L_q$	Length parallel to the wall
$Q$	Magnitude of surcharge

A surcharge is defined as being either:

- **At ground level**                      or
- **Below ground level.**

For a surcharge defined as being **At ground level** you do not define the actual elevation, this is derived by the program from the strata information and takes into account any sloping backfill. If the ground is changed, the surcharge moves with it

For a surcharge defined as being **Below ground level** you define the actual elevation.

Because the analysis is essentially two dimensional, the program calculates the effect of a surcharge at a point on the wall closest to the mid-length of the surcharge.

Surcharge loads are taken into account in the program by adding their effect to the vertical stress,  $p_v'$  which is used in Equations 6.5 to 6.12. The calculation is based on elastic Boussinesq distributions with doubling of the calculated values to allow for the rigidity of the wall as suggested by Terzaghi (1954).

### **Surcharges on sloping ground**

The distance of the surcharge from the wall is measured from the point on the wall where ground level intersects the wall.

## **10.2 SURCHARGE APPLICATION and PARTIAL FACTORS**

Surcharges are included in the analysis according to the load case data (see Section 11.0). Each load case defines a list of surcharges to be included and a Load Factor by which the magnitudes of the surcharges are to be multiplied for that load case. All the selected surcharges are multiplied by the specified Factor.

This facility enables the user to apply different combinations of surcharges to model various loading conditions

### **Graphical display of surcharge loads**

The positions of surcharge loads are shown by (red) arrows. Only those surcharges which have been selected for a particular load case are shown in the graphical display for that load case. The lengths of the arrows are an approximate indication of magnitude. The graphical display shows the value of the partial factor by which the surcharges are factored for the currently displayed load case.

## 11.0 LOAD CASES

Load cases consist of different combinations of loads and surcharges. They are used to represent the different load combinations which may occur under :

- temporary and permanent conditions,
- static and dynamic loading,
- unusual or extreme conditions etc...

You define load factors to be applied to each surcharge and wall load in each load case. This enables you to model the various combinations of dead and live loads required by codes of practice.

GWALL carries out the ULS and SLS analyses for each load case in turn. For a simple problem you need only specify a single load case and unit partial factors on all loads and surcharges. The results for each load case are displayed on separate pages and a Summary page lists Factors of Safety as well as Maximum and Minimum Bending Moments for each stage.

A load case is defined by the following parameters

- The selected surcharges
- Partial factor on surcharges
- Partial factors on loads applied to the wall (see Section 9.3)
- Load case description

### Load case description

This is a text of up to 20 characters describing the load case

### Selecting a load case for Viewing

To select a load case for viewing – either during data input or while viewing results - press the **load case selection** arrows next to the green box at the top right of the screen and select a load case from the drop down menu.

### Selected surcharges

Only the selected surcharges actual apply in a particular load case. You can enter the selected surcharges in the usual Windows notation using the comma or space as a separator for individual selections and a dash to denote a range e.g. 1 - 5,8 denotes surcharge numbers 1,2,3,4,5 and 8.

## 12.0 ANALYSIS OPTIONS

‘Analysis options’ is a set of parameters, which control various aspects of the method of calculation. It includes partial factors which are related to the design philosophy. They are accessed by clicking on the **FoS options** tab to see the following menu:

<b>Analysis options</b>		
	Ultimate limit state	Serviceability limit state
Minimum equivalent fluid density(kN/m <sup>3</sup> )	5.00	=
Max. depth of water filled tension crack	2.00	=
Partial FoS on Drained Cohesion and Phi'	1.200	1.000
Partial FoS on Undrained Cohesion	1.500	1.000
Partial FoS on passive	2.000	n/a
Include base shear in base B.M.?	n/a	Yes

### 12.1 Design Approach

GWALL is designed to be used in accordance with Design Approach A as described in CIRIA Report C580 (Section 5.9). Partial safety factors to be used in conjunction with these parameters are as recommended in Section 6.1 of C580.

	-----Effective stress -----		Total stress
	Partial factor on C'	Partial factor on $\phi'$	Partial factor on $C_u$
Ultimate limit State	1.2	1.2	1.5
Serviceability limit State	1.0	1.0	1.0

Partial factors are applied to their respective parameters *before* the analysis starts. All factor of safety calculations are performed on partially factored values.

## 12.2 Minimum Equivalent Fluid Density

When the theoretical active earth pressure in undrained cohesive soil is small or negative, the program will impose a minimum earth pressure calculated from the minimum equivalent fluid density.

This option allows designs to be carried out in accordance with codes of practice e.g. BSPH (1997) which require retaining walls to be designed for a minimum equivalent fluid density of 5kN/m<sup>3</sup>.

The specified minimum equivalent fluid density is applied by the program to all undrained strata. If a zero value is given no minimum pressure will be assumed.

The printed results are annotated to show which values of active limit pressure have been determined by the minimum equivalent fluid density rule.

## 12.3 Maximum Depth of Water-filled Tension Crack

In some design codes it is assumed that where the theoretical active pressure in undrained cohesive soil is less than zero, that the wall will be subjected to full water pressure. In practice this may be a rather severe assumption where the theoretical depth of tension crack is very great.

The program allows a flexible approach in permitting you to specify the maximum depth,  $Z_t$ , below (current) ground level to which full water pressure will be taken. The actual depth to which tension cracks develop in practice is rarely greater than 3m or 4m.

A large value of  $Z_t$  will ensure that full water pressure is taken to the full depth of any theoretical tension crack (but this may be excessively conservative). A zero value of  $Z_t$  will result in zero water pressure in tension cracks, which may be excessively optimistic.

If you want to model water pressures in tension cracks in undrained soil you must specify a suitable non-zero value for "Maximum depth of water filled tension crack".

The water pressure in a tension crack is calculated with respect to a water table which is the higher of:-

- a) the specified ground water level, or
- b) the top of the undrained stratum.

This rule is based on the reasonable assumption that the water table defined in a drained stratum overlying an undrained stratum is the highest water level which will occur. It is up to the user to specify an appropriate water level in any such overlying drained strata.

The specified maximum depth of water filled tension crack is applied by the program to all undrained strata.

#### **12.4 Partial Factor of Safety on Passive (ULS only)**

The resistance to sliding has three components:-

- Sliding resistance on the base of the wall,  $S$
- Shear key resistance,  $P_k$
- Passive resistance at the toe of the wall,  $P_p$

The passive resistance,  $P_p$  includes a partial factor of safety,  $F_p$  as discussed in Section 6.11.2.  $F_p$  is intended to allow for the large displacements usually required to mobilise full passive resistance in front of the wall. A value of 2 is often used. Passive earth pressures are divided by the given value of  $F_p$ , as shown in Equations 6.7a and 6.8 before being used in the rest of the calculations. This parameter is only applicable to ULS calculations.

#### **12.5 Include base shear in base bending moments?**

Shear forces on the underside of the base, reduce the calculated bending moments in the base of the wall. Due to uncertainty about the distribution of these shear forces, some codes of practice ignore the effect of the shear forces altogether.

This option allows you to ignore the effect of the shear forces leading to slight increase in the calculated bending moments.

### 13.0 INTERPRETATION OF RESULTS

See Section 3.10 for details of how to view the results on the screen and Section 3.11 for instructions on creating reports.

Reports include output for all load cases for which output was requested. The output for each load case begins on a new page with the title block and the load case description. The results of the stability analysis are output first followed by the bending moment and shear forces.

#### Subdivision of the wall into elements

The program creates a node at every elevation at which data has been defined e.g. strata, surcharge and water table elevations. The larger element lengths are automatically subdivided by the program so that no element is too long. Results are printed for all node levels (see pages E-6 and E-8).

### 13.1 OVERALL STABILITY (Ultimate limit state)

Detailed results are given separately for each load case.

#### 13.1.1 Force components

The program lists the components of horizontal and vertical forces and their moments about the toe of the wall (see page E-4). All forces are positive or negative according to the direction in which they act. The sign convention is:-

Vertical forces :	Downwards - positive
Horizontal forces :	From active to passive - positive
Moments :	Overturning - positive

#### 13.1.2 Sliding stability

The resistance to sliding has three components:-

- |  |        |
|--|--------|
| a) sliding resistance on the base of the wall, | S      |
| b) passive resistance at the toe of the wall,  | $P_p'$ |
| c) shear key resistance (see page E-5)         | $P_k$  |

All surcharges and applied loads are taken into account whether they tend to increase or decrease stability. The factor of safety against sliding is calculated in two ways:-

**The factor of safety on base shear** (including shear key resistance),  $F_b$ , is defined as:-

$$F_b = \frac{S + P_k}{P_a' + U_a - P_p' - U_p + H - A_h}$$

**The overall factor of safety on base shear plus passive resistance**,  $F_s$ , is defined as:-

$$F_s = \frac{S + P_k + P_p'}{P_a' + U_a - U_p + H - A_h}$$

The passive resistance  $P_p'$  includes the partial factor of safety on passive resistance,  $F_p$  (Section 11.1 and Equations 6.7a, 6.8). A typical set of results is shown at the bottom of page E-4.

### 13.1.3 Overturning stability

Overturning stability is assessed in two ways:-

- a) Position of the line of action of the resultant (effective) force on the base of the wall. This should be within the middle third of the base of the wall for a safe design. A warning message is printed if the line of action is outside the middle third.
- b) Factor of safety against overturning  
This is a rather vague concept due to the difficulty in identifying all the forces as being either disturbing or restoring forces. In GWALL the following convention has been adopted:-

#### Disturbing forces

- Horizontal active soil force
- Nett horizontal water force
- Forces and moments applied to the top of the wall which tend to cause overturning

#### Restoring forces

- Horizontal passive soil force
- Wall weight
- Weight of fill on heel and toe of wall
- Surcharges on ground behind the wall
- Wall friction
- Anchor force
- Shear key resistance
- Forces and moments applied to the top of the wall which tend to resist overturning

The factor of safety against overturning is defined as the ratio of the moment of all the restoring forces to that of the disturbing forces.

#### **13.1.4 Shear key resistance**

Two modes of shear key failure are considered (see Figure 7) in order to establish the available shear key resistance.

##### **Shear key failure - Mode 1**

Sliding on a horizontal plane through the base of the shear key, plus passive failure at the toe (see Figure 7a).

##### **Shear key failure - Mode 2**

Sliding on an inclined plane through the toe of the shear key, plus sliding on part of the base of the wall. Several angles of the inclined plane are considered, from a maximum of 45 degrees to the horizontal down to a plane which just passes through the toe of the wall (see Figure 7b).

A trapezoidal distribution of vertical pressure on the base of the wall is assumed so that the sliding resistance of each part of the mechanism is correctly calculated.

The actual shear key resistance is the least of the values calculated for the various mechanisms. The active pressure on the back of the shear key is deducted to give the nett shear key resistance i.e. the nett benefit due to the shear key compared to a wall without a shear key.

Details of the shear key calculation are set out as on page E-5.

### 13.1.5 Earth pressures

The earth pressures used in the stability analysis are the active and passive pressures on vertical planes through the heel and toe of the wall. A typical table of earth pressures is shown on page E-6. The items are described below:

<b>Heading</b>	<b>Interpretation</b>
Elevation	Elevation at which results are given. Where there is a step change any of the pressures, one y coordinate refers to two lines of results.
Soil type	The soil type at this elevation
Water	In drained strata the water pressure is given. In undrained strata the message " <b>TOTAL&gt;</b> " is printed to indicate that soil pressures at this elevation are given as total stresses.
Vertical	Vertical stress (effective stress in drained soil) (total stress in undrained soil)
Active	Active pressure (effective stress in drained soil) (total stress in undrained soil) 'm' indicates Minimum Equivalent Fluid Pressure. 'w' indicates water pressure in tension crack
Passive	Passive pressure (effective stress in drained soil) (total stress in undrained soil)

## 13.2 BENDING MOMENTS and SHEAR FORCES

### (Serviceability limit state)

The Bending moment results are presented in three tables:

- Forces in the stem of wall
- Forces along base of wall
- Earth pressures on the wall

#### 13.2.1 Forces in the stem of the wall (page E-8)

Bending moments are calculated about the centre line of the stem. Shear forces are calculated perpendicular to the centre line of the stem. Where the front and back faces of the stem are not parallel, the centre line is taken to be mid-way horizontally between the two faces.

#### 13.2.2 Forces in the base of the wall (page E-8)

Forces on the base of the wall comprise the soil weight and surcharges on the heel and toe, the forces transmitted from the stem and the soil reaction on the base.

#### 13.2.3 Earth pressures (page E-6)

The earth pressures used in the calculation of bending moments and shear forces are the active and passive pressures normal to the active and passive faces of the stem. The items in this table are described in Section 13.1.5.

## 13.3 GRAPHICAL OUTPUT

Graphical output for each load case consists of 4 small diagrams as shown in Appendix E, page E-9.

The top 2 diagrams show the bending moment and shear force distributions in the stem and the base for the SLS case.

Shear force and bending moment are plotted on one diagram with shear force shown in dashed lines. In the plot of forces in the base of the wall, the forces are plotted against distance (x) from the toe of the wall (plotted vertically!).

The lower 2 diagrams show the earth pressures for the ULS case (left) and SLS case (right). Within each diagram active pressures (left) and passive pressures (right) are plotted versus elevation. Total stresses (water +soil pressure) are shown in solid lines while effective stresses are shown in dashed lines.

### 13.4 SUMMARY OUTPUT

Summary output consists of a table showing, for each load case, the

- Factors of Safety
- Max. and min. bending moments in the stem and base
- Max. and min. shear forces in the stem and base

There is no graphical summary output.

### 13.5 DESIGN CRITERIA

In assessing the results for the purposes of design you should follow relevant codes of practice. Three of the points to be considered are:

- Factors of safety
- Bearing pressure
- Bending moments and shear forces

#### **Factor of safety - Design criteria**

Factor of Safety calculations must be used in conjunction with the design factors recommended for the relevant design conditions e.g. permanent or temporary works; level of risk etc.

#### **Bearing pressure - Design criteria**

The program gives no indication about the acceptability of the calculated bearing pressure beneath the toe of the wall. The user must assess safe bearing pressures from his knowledge of the foundation soil and ensure that they are not exceeded.

#### **Bending moments - Design criteria**

In selecting a design bending moment profile it should be remembered that the actual bending moments occurring in the field will be sensitive to the construction technique and in particular the compaction of fill. The design should include a clear specification of compaction procedures.

## **13.6 ERROR MESSAGES**

### **13.6.1 Data errors**

\*\*\* Data error - Negative vertical effective stresses

This condition arises due to excessively high water pressures. The water pressure at all elevations must be less than the total vertical pressure i.e. the weight of all soil layers plus any surcharges.

### **13.6.2 Data warnings**

\*\*\* Warning - The base adhesion is greater than the cohesion of soil type N in front of the shear key.

\*\*\* Warning - The base friction angle is greater than the friction angle of soil type N in front of the shear key.

The shear key resistance is calculated from the cohesion and friction values of the soil type in front of the shear key. The base friction and cohesion would usually be expected not to exceed the bulk strength of the foundation soil.

## REFERENCES

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## NOTATION

$\alpha_a$	Batter angle of back face of wall
$\alpha_p$	Batter angle of front face of wall
$\beta$	Backfill angle
$\gamma_w$	Unit weight of water
$\gamma_c$	Unit weight of wall material
$\delta_a$	Angle of wall friction on vertical plane at heel of wall
$\delta_p$	Angle of wall friction on vertical plane at toe of wall
$\delta_a^*$	Angle of wall friction on back face of stem
$\delta_p^*$	Angle of wall friction on front face of stem
$\phi'$	Angle of soil friction
$\phi_b$	Angle of friction between wall and foundation soil
$\theta$	Inclination of anchor force
$\psi$	Wall friction/adhesion coefficient
A	Anchor force applied to front face of wall
$A_h$	Horizontal component of Anchor force
$A_v$	Vertical component of Anchor force
$B_h$	Width of heel
$B_t$	Width of toe
$B_b$	Width of stem at top of base
$B_a$	Width of stem at top of wall
$B_k$	Width of shear key
$B_q$	Width of surcharge
$c_u$	Undrained shear strength of cohesive soil
$c'$	Drained shear strength of cohesive soil
$c_w$	Adhesion between wall and soil
$c_b$	Adhesion between base of wall and foundation soil
$D_b$	Thickness of base
$D_k$	Depth of shear key
$F_p$	Partial factor of safety on passive resistance
$F_b$	Calculated factor of safety on base shear (+ shear key) resistance
$F_s$	Calculated overall factor of safety on base shear and passive resistance
$h_a$	Piezometric elevation at base of wall on active side
$h_p$	Piezometric elevation at base of wall on passive side
H	Horizontal load on top of wall
$K_a, K_{ac}$	Active earth pressure coefficients for stability
$K_p, K_{pc}$	Passive earth pressure coefficients for stability
$K_a^*, K_{ac}^*$	Active earth pressure coefficients for bending moments
$K_p^*, K_{pc}^*$	Passive earth pressure coefficients for bending moments
$L_q$	Length of surcharge parallel to wall
M	Moment load on top of wall

## NOTATION (continued)

### Stresses

$p_v$	Vertical total stress
$p_v'$	Vertical effective stress
$p_a'$	Horizontal component of effective soil pressure on vertical plane at heel of wall
$p_a^{*}$	Effective soil pressure normal to stem of wall on the active side
$p_p'$	Horizontal component of effective soil pressure on vertical plane at toe of wall
$p_p^{*}$	Effective soil pressure normal to stem of wall on the passive side
$q_a$	Wall friction on vertical plane at heel of wall
$q_p$	Wall friction on vertical plane at toe of wall
$q_a^{*}$	Wall friction on back face of stem (active side)
$q_p^{*}$	Wall friction on front face of stem (passive side)
$Q$	Surcharge at or below ground level on active side
$u$	Water pressure
$u_{\text{heel}}$	Water pressure at heel of wall
$u_{\text{toe}}$	Water pressure at toe of wall

### Forces

$P_a'$	Effective soil force on vertical plane at heel of wall
$P_p'$	Effective soil force on vertical plane at toe of wall
$P_a^{*}$	Effective soil force on back face of wall
$P_p^{*}$	Effective soil force on front face of wall
$P_k$	Shear key resistance
$Q_a$	Shear force on vertical plane at heel of wall
$Q_p$	Shear force on vertical plane at toe of wall
$Q_a^{*}$	Shear force on back face of wall
$Q_p^{*}$	Shear force on front face of wall
$R'$	Effective reaction on base of wall
$S$	Available shear resistance on base of wall
$U_a$	Water force on vertical plane at heel of wall
$U_p$	Water force on vertical plane at toe of wall
$U_a^{*}$	Water force on back face of wall
$U_p^{*}$	Water force on front face of wall
$V$	Vertical load on top of wall
$x_v$	Distance of $V$ from front face of wall
$x_k$	Distance of shear key from toe of wall
$x_q$	Distance of near edge of surcharge from wall
$x_r$	Distance of line of action of $R$ from toe of wall
$y_A$	Elevation of anchor force
$y_t$	Elevation of top of wall
$y_b$	Elevation of base of wall
$y_q$	Elevation of surcharge

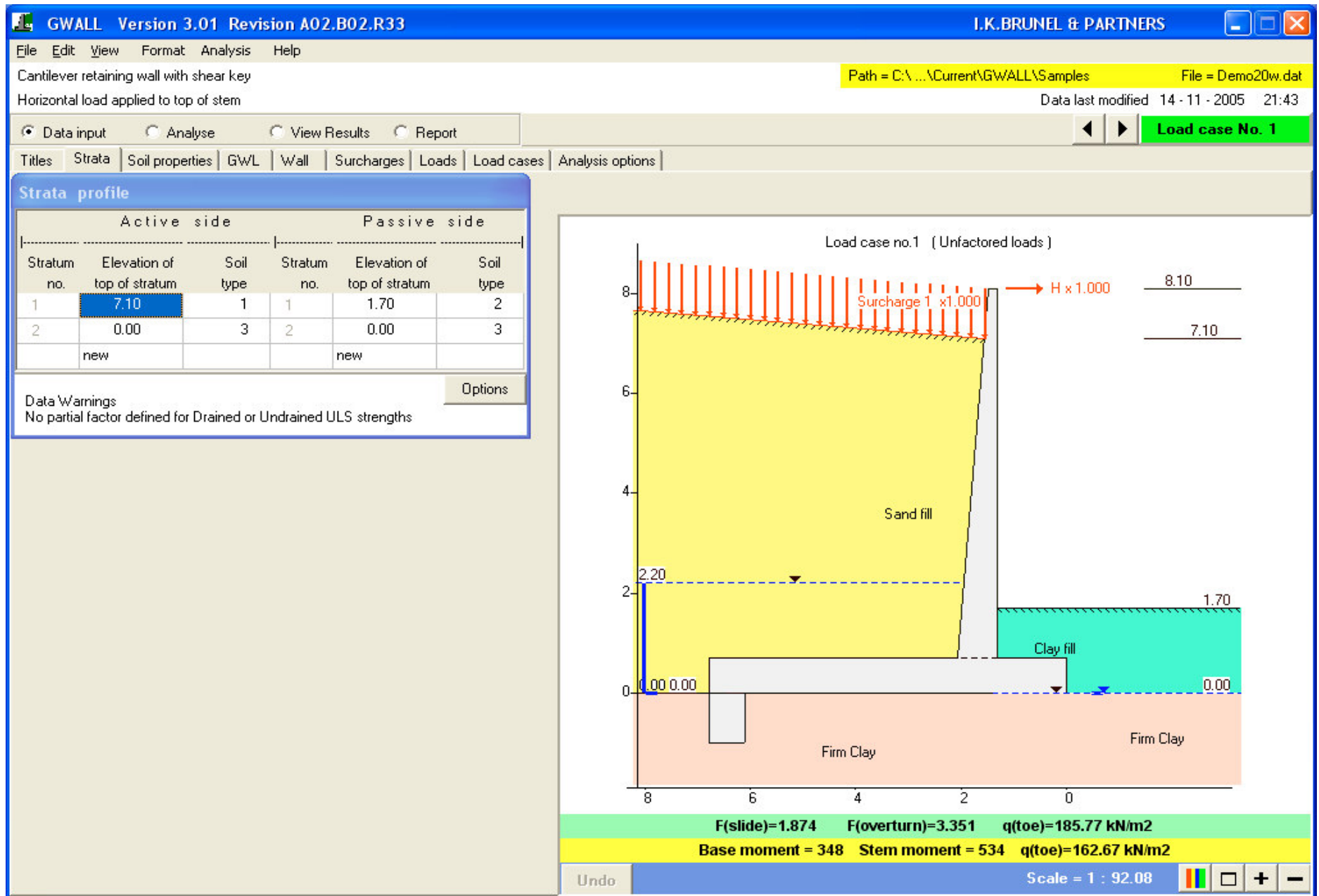


Figure 1 GWALL Desktop

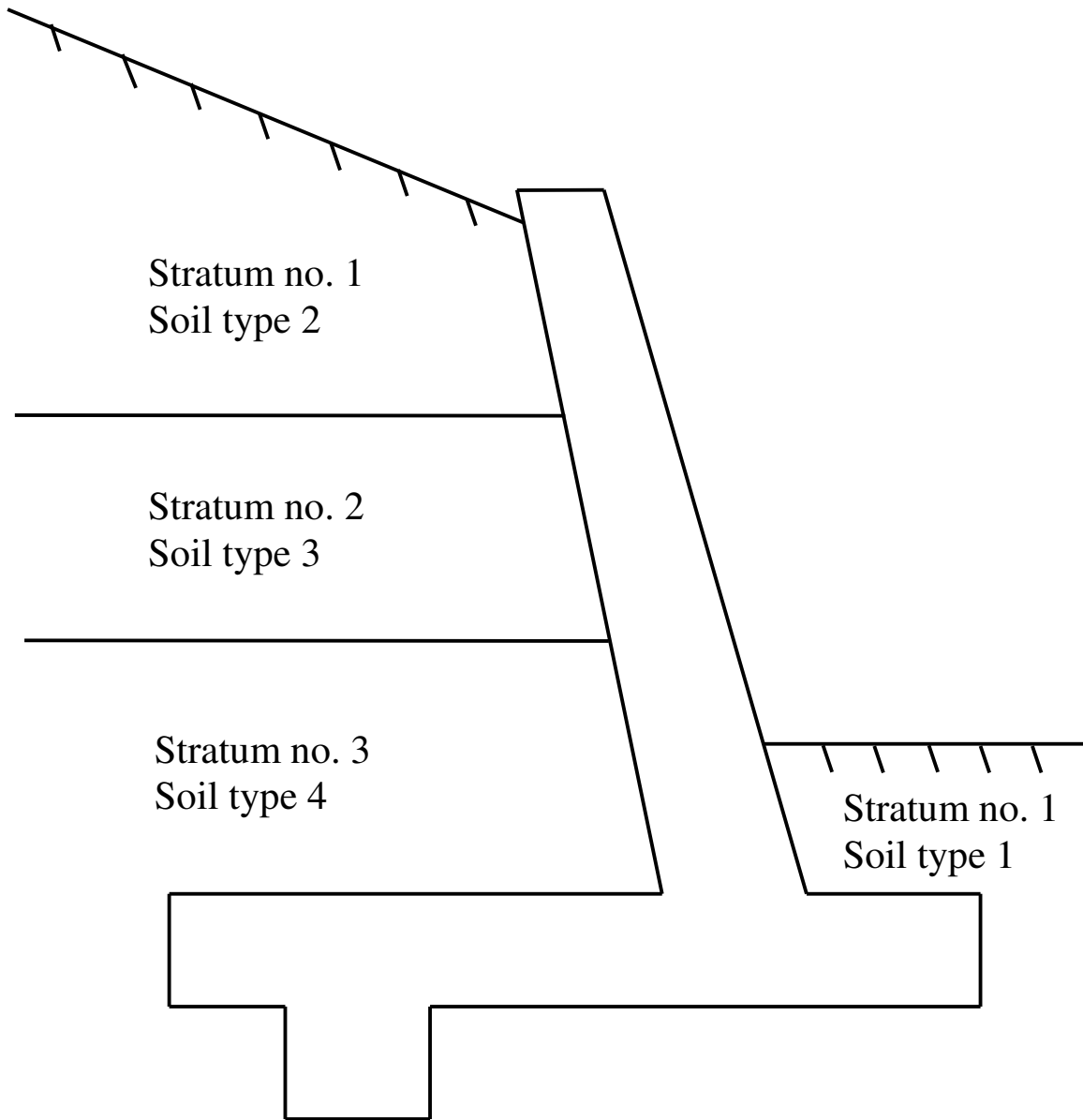


Figure 2 Numbering of strata and soil types

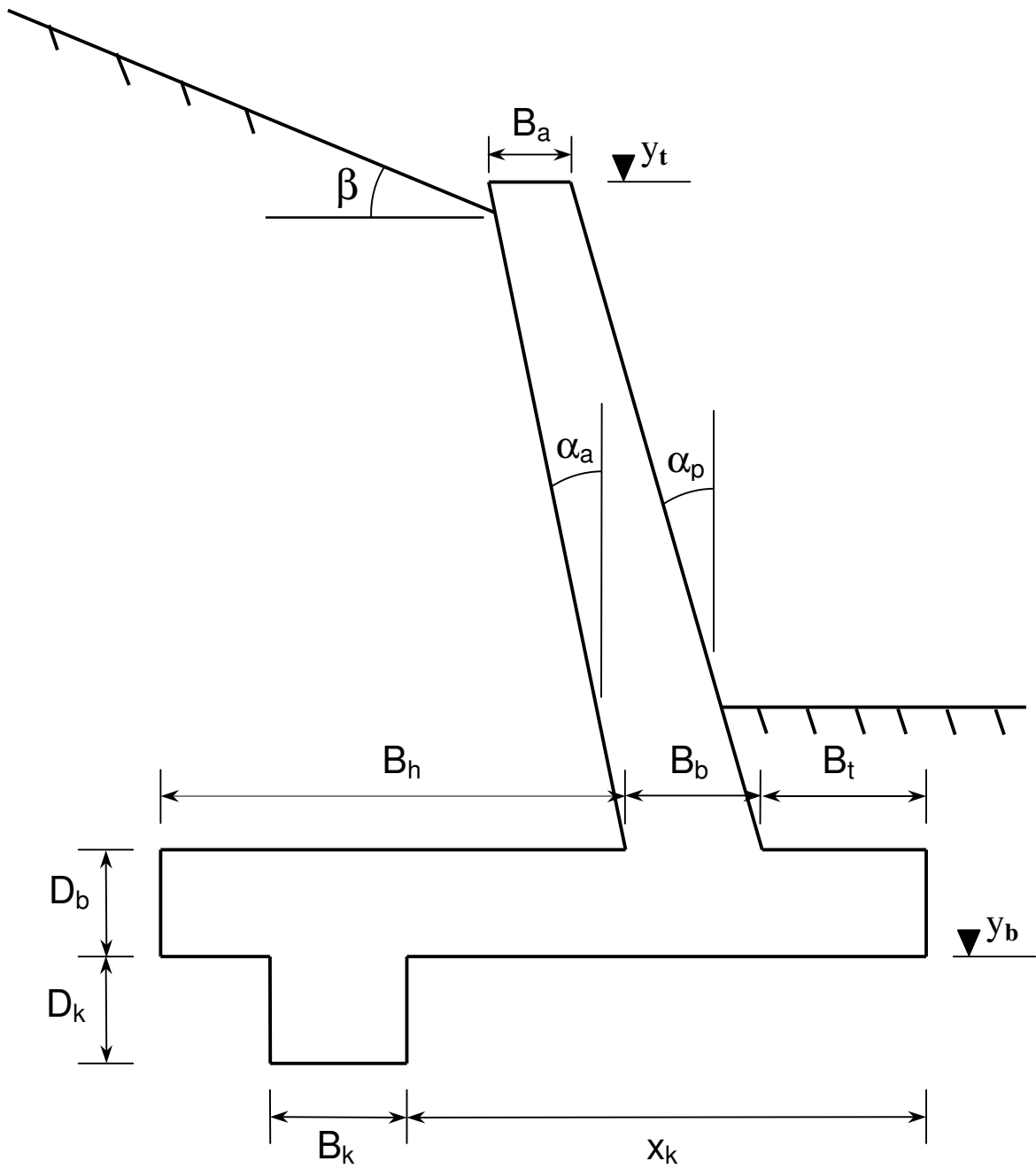


Figure 3 Wall geometry

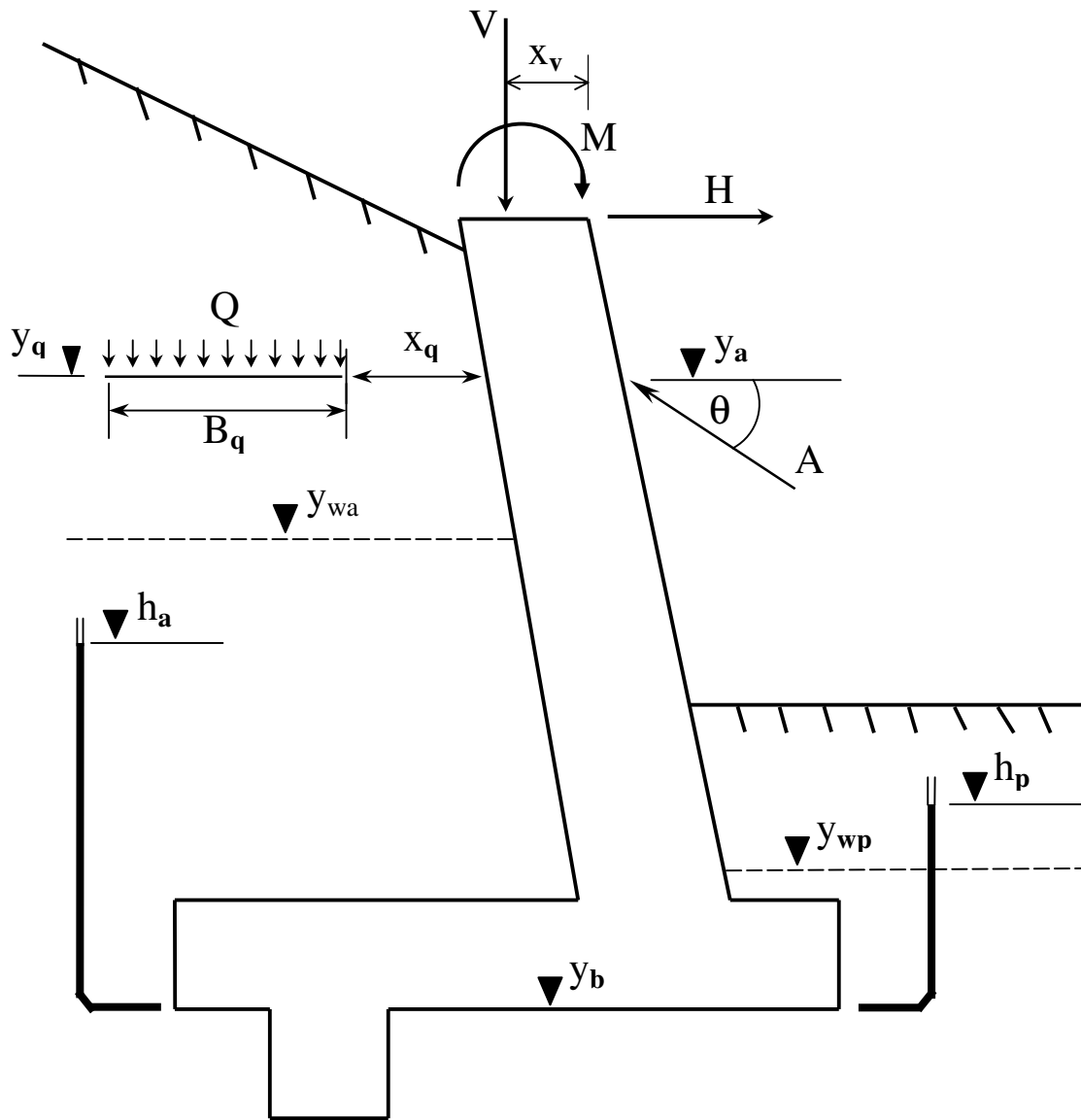


Figure 4 Applied loads, surcharges and water pressures

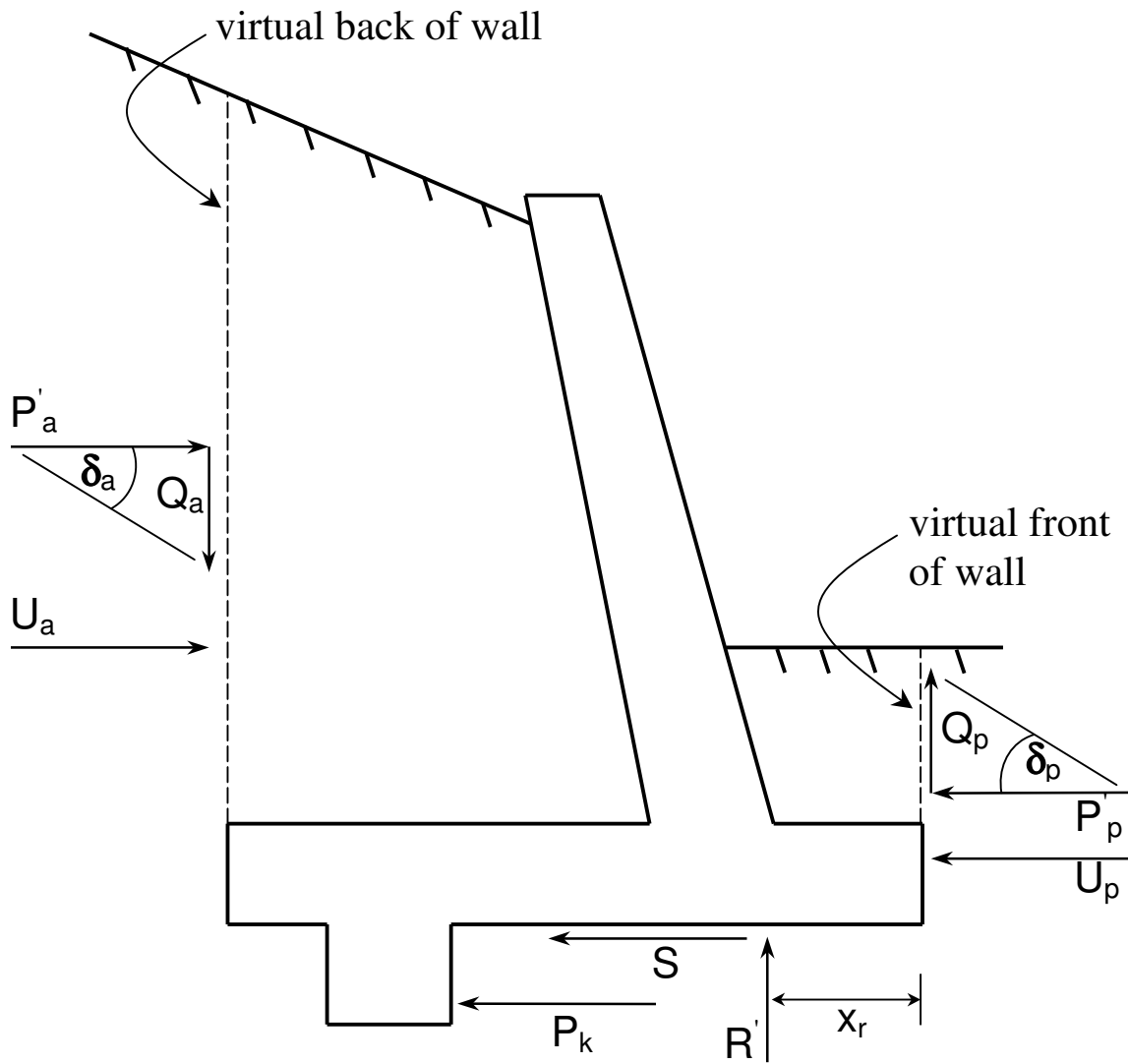


Figure 5 Soil forces for stability analysis  
( Ultimate limit state )

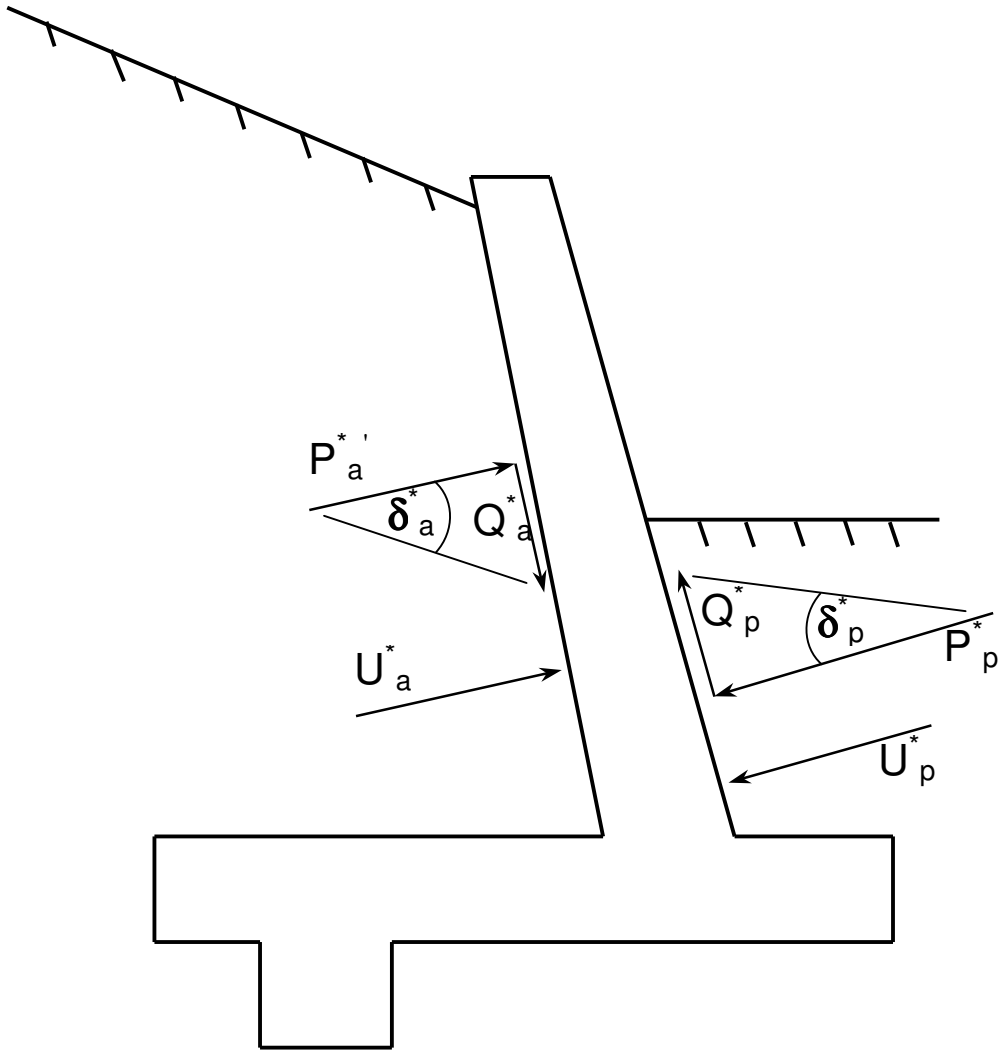


Figure 6 Soil forces for bending and shear calculation  
( Serviceability limit state )

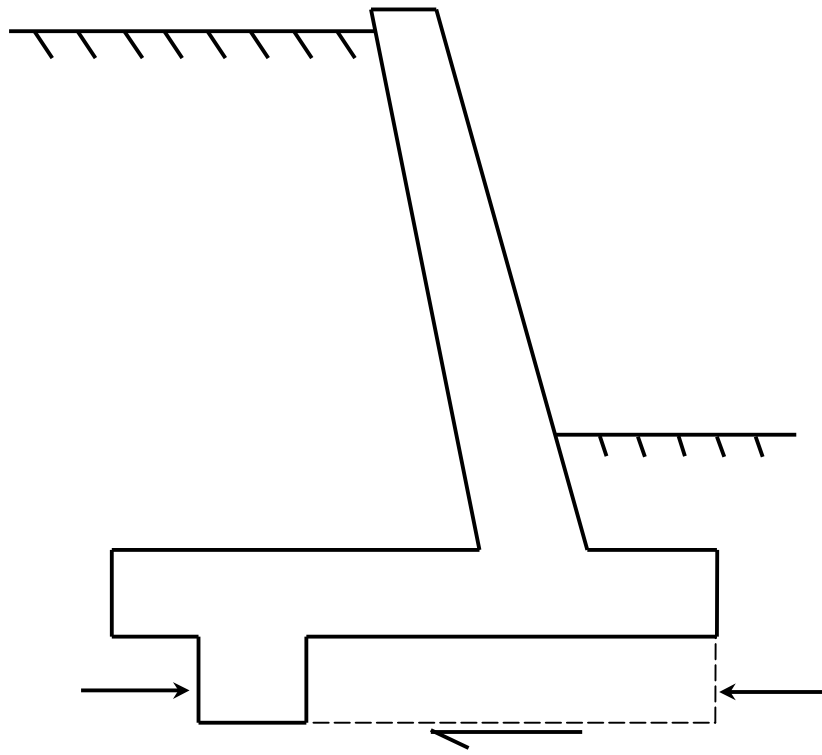


Figure 7a Shear key failure - Mode 1

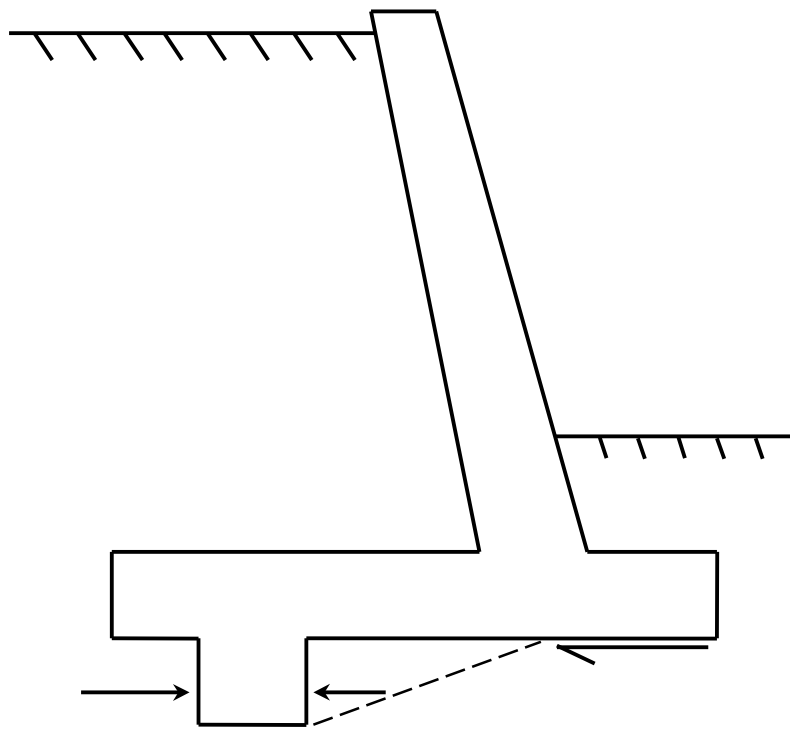


Figure 7b Shear key failure - Mode 2

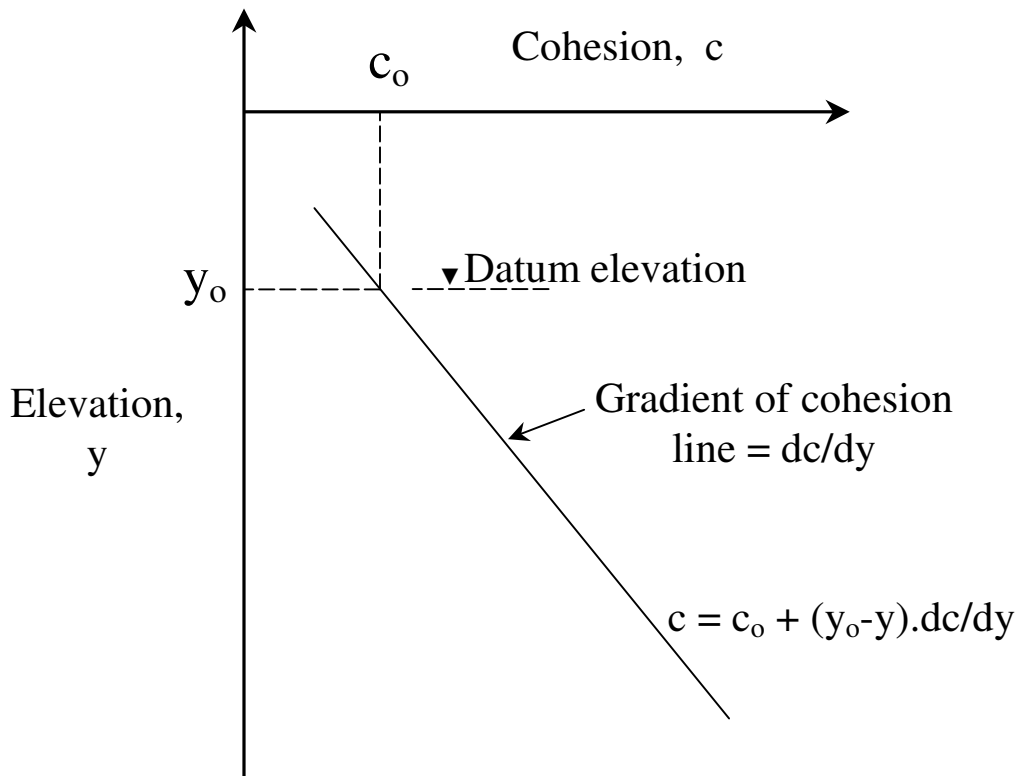


Figure 8. Variation of cohesion with depth

## APPENDIX E

### Example data and results

I.K.Brunel and Partners	Sheet No. 1
Program: GWALL Version 3.01 Revision A02.B02.R33	
Licensed from GEOSOLVE	Job No.
Run ID. Demo30	Made by :
Wall with shear key - For comparison with DOS version	Date:26-11-2006
Soft undrained fill in front of wall	Checked :

Units: kN,m

**INPUT DATA****SOIL PROFILE**

----- Active side -----			----- Passive side -----		
Stratum no.	Elevation of top of stratum	Soil type	Stratum no.	Elevation of top of stratum	Soil type
1	7.10	1	1	2.20	2
2	0.00	3	2	0.00	3

**SOIL PROPERTIES**

No.	Soil type Description	Bulk unit wt.		Strength parameters		Active pressure due to compaction
		above GWL kN/m3	below GWL kN/m3	Phi degs.	Cohesion kN/m2	
1	Sand fill	20.00	21.00	30.00	0.00	15.00
2	Clay fill	19.00	19.00	0.00	40.00	7.00
3	Firm Clay	20.00	20.00	5.20	70.00	10.00

----- Active earth pressure coefficients -----							
----- ULS parameters -----			----- SLS parameters -----				
---- for Stability calcs. ---			---- for Moment calcs. ----				
-- Soil type --		Wall friction coefficient			Wall friction coefficient		
No.	Description	Ka	Kac	coefficient	Ka	Kac	coefficient
1	Sand fill	0.333	1.155	0.00	0.290	0.000	0.00
2	Clay fill	0.9998	2.282	0.33	1.000	2.000	0.00
3	Firm Clay	0.795	2.255	1.00	1.000	2.000	0.00

----- Passive earth pressure coefficients -----							
----- ULS parameters -----			----- SLS parameters -----				
---- for Stability calcs. ---			---- for Moment calcs. ----				
-- Soil type --		Wall friction coefficient			Wall friction coefficient		
No.	Description	Kp	Kpc	coefficient	Kp	Kpc	coefficient
1	Sand fill	3.000	3.464	0.00	5.000	0.000	0.00
2	Clay fill	1.000	2.475	0.67	1.000	2.000	0.00
3	Firm Clay	1.199	2.190	0.00	1.000	2.000	0.00

**GROUND WATER CONDITIONS**

Density of water = 9.81 kN/m3

	Active side	Passive side
Water table elevation	4.30	0.00
Piezometric elevation at base elev.	3.00	0.00

**WALL PROPERTIES**

Backfill angle behind wall =	0.00 degs
Unit weight of wall =	24.50 kN/m3
Elevation of base of wall =	0.000
Elevation of top of wall =	8.100
Width of base of stem =	0.775 m
Width of top of stem =	0.183 m
Batter angle of back of wall =	4.57 degs
Thickness of base of wall =	0.700 m
Width of heel of wall =	4.725 m
Width of toe of wall =	1.300 m
Depth of shear key =	1.000 m
Width of shear key =	0.700 m
Distance from toe to front of shear key =	6.100 m
Friction on base of wall =	0.00 degs
Adhesion on base of wall =	50.00 kN/m2

**SURCHARGE LOADS**

Surcharge no.	Elevation	Distance from wall	Width to wall	Length parallel to wall	Surcharge magnitude kN/m <sup>2</sup>
1	GL	0.00	1000.00	1000.00	20.00

**LOADS APPLIED TO THE WALL**

Horizontal line load on top of wall = 20.00  
 Vertical line load on top of wall = 0.00  
 Distance of line load from front edge of wall = 0.00  
 Moment applied to top of wall = 0.00 kN.m/m run

**LOAD CASES**

Load Case no.	Selected surcharges (Load case description)	Surcharge load factor	Vertical load factor	Horizontal load factor	Moment load factor	Anchor load factor
1	1 (Unfactored loads )	1.00	1.00	1.00	1.00	1.00
2	1 (Factored loads )	1.20	1.00	1.30	1.00	1.00

**FACTOR OF SAFETY AND ANALYSIS OPTIONS**

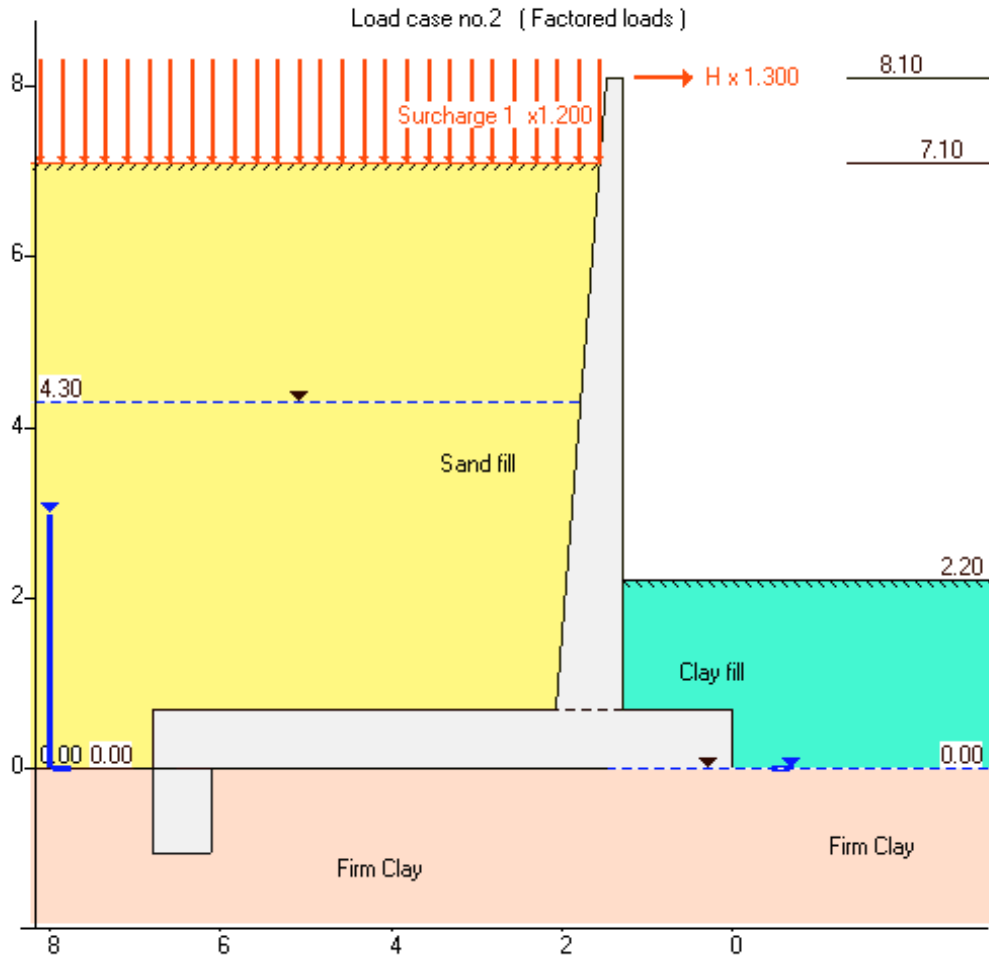
Minimum Equivalent Fluid Density = 4.90 kN/m<sup>3</sup>  
 Maximum depth of water filled tension crack = 0.00  
 Partial FoS on Drained Cohesion and Phi' = 1.00  
 Partial FoS on Undrained Cohesion = 1.00  
 Partial factor of safety on passive (ULS only) = 2.00  
 Include base shear in base bending moments? - Yes

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I.K.Brunel and Partners  
Program: GWALL Version 3.01 Revision A02.B02.R33  
Licensed from GEOSOLVE  
Run ID. Demo30  
Wall with shear key - For comparison with DOS version  
Soft undrained fill in front of wall

| Sheet No. 2  
|  
| Job No.  
| Made by :  
| Date:26-11-2006  
| Checked :

Units: kN,m



I.K.Brunel and Partners	Sheet No. 3
Program: GWALL Version 3.01 Revision A02.B02.R33	
Licensed from GEOSOLVE	Job No.
Run ID. Demo30	Made by :
Wall with shear key - For comparison with DOS version	Date:26-11-2006
Soft undrained fill in front of wall	Checked :

Units: kN,m

**Ultimate Limit State Analysis - STABILITY****Load Case No.2****Load case description: Factored loads**

Surcharge Nos. 1 apply with a Partial factor = 1.20

Partial factor on Horizontal Load = 1.30

Horizontal forces	Force	Moment	Height	Elevation
-----	kN/m run	kN.m/m run	above base	
Active soil	206.83	573.51	2.773	2.773
Active water	63.27	90.69	1.433	1.433
Passive soil	-131.90	-136.66	1.036	1.036
Passive water	0.00	0.00	0.000	0.000
Load on top of wall	26.00	210.60	8.100	8.100
Anchor force	0.00	0.00	4.400	4.400
Nett horizontal load	164.20	738.14	4.495	4.495
Base shear resistance	-340.00	0.00		
Shear key resistance	-227.18	0.00		
Total sliding resistance	-567.18	0.00		

Vertical forces	Force	Moment	Distance of
-----	kN/m run	kN.m/m run	resultant
			from toe
Wall weight	220.61	-643.48	2.917
Fill above heel	655.47	-2823.39	4.307
Fill above toe	37.05	-24.08	0.650
Water above heel	0.00	-0.00	0.000
Water above toe	0.00	-0.00	0.000
Active wall friction	0.00	0.00	6.800
Passive wall friction	-58.61	0.00	0.00
Surcharges	125.68	-525.55	4.182
Load on top of wall	0.00	-0.00	1.301
Anchor force	0.00	-0.00	1.300
Uplift water pressure	-100.06	453.61	4.533
Nett vertical load	880.14	-3562.89	4.048
Moment applied to wall		0.00	
Moment of horiz. loads		738.14	
Soil reaction on base	-880.14	2824.75	3.209

Soil contact pressure at toe 151.2 kN/m<sup>2</sup>  
 Soil contact pressure at X = 6.800 107.7 kN/m<sup>2</sup>  
 Line of action of resultant 3.209 m from toe

	Factor	Disturbing	Restoring
	of safety	force or moment	force or moment
Sliding stability (base shear)	3.454	164.2 kN/m	-567.2 kN/m
Sliding stability (base+passive)	2.361	296.1 kN/m	-699.1 kN/m
Overturning stability	3.126	1328.4 kN.m/m	-4153.2 kN.m/m

- Notes 1. Nett water pressures are used in calculating the disturbing forces and moments for the factors of safety on sliding and overturning.  
 2. All ULS results include a partial factor of 2.00 on passive.

I.K.Brunel and Partners	Sheet No. 4
Program: GWALL Version 3.01 Revision A02.B02.R33	
Licensed from GEOSOLVE	Job No.
Run ID. Demo30	Made by :
Wall with shear key - For comparison with DOS version	Date:26-11-2006
Soft undrained fill in front of wall	Checked :

-----  
Units: kN,m

**Ultimate Limit State Analysis - STABILITY (continued) Load Case No.2**  
**Load case description: Factored loads**

Surcharge Nos. 1 apply with a Partial factor = 1.20  
 Partial factor on Horizontal Load = 1.30

Shear key resistance  
-----

Mode 1 - Sliding at base of key + passive wedge at toe

	kN/m	kN/m
Shear resistance with key	= -540.75	
Shear resistance without key	= -340.00	
Additional shear resistance	=	-200.75
Additional active force	=	34.34
Additional passive resistance	=	-109.69
		-----
Nett additional shear resistance	=	-276.10

Mode 2 - Sliding on inclined plane

Inclination of plane to horizontal degs.	Shear resistance with key kN/m	Shear resistance without key kN/m	Additional shear resistance kN/m	Add. active force kN/m	Nett add. resist. kN/m
9.31	-714.12	-340.00	-374.12	34.34	-339.79
16.45	-631.69	-340.00	-291.69	34.34	-257.36
23.59	-607.38	-340.00	-267.38	34.34	-233.05
30.72	-601.52	-340.00	-261.52	34.34	-227.18
37.86	-605.55	-340.00	-265.55	34.34	-231.22
45.00	-617.71	-340.00	-277.71	34.34	-243.38

Mode 2 : Critical wedge at 30.72 degs. to the horizontal  
-----

	kN/m	kN/m
Shear resistance with key	= -601.52	
Shear resistance without key	= -340.00	
Additional shear resistance	=	-261.52
Additional active force	=	34.34
		-----
Nett additional shear resistance	=	-227.18

Critical mechanism is Mode 2

Nett additional shear resistance due to shear key = -227.18 kN/m

I.K.Brunel and Partners | Sheet No. 5  
 Program: GWALL Version 3.01 Revision A02.B02.R33 |  
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 Run ID: Demo30 | Made by :  
 Wall with shear key - For comparison with DOS version | Date:26-11-2006  
 Soft undrained fill in front of wall | Checked :  
 -----

Units: kN,m

**Ultimate Limit State Analysis - STABILITY Load Case No.2****Earth pressures on vertical planes through heel and toe of wall**

Elevation	---- Active pressures ----				---- Passive pressures ----			
	Soil type	Water kN/m2	Vert. kN/m2	Active kN/m2	Soil type	Water kN/m2	Vert. kN/m2	Passive kN/m2
7.100	1	0.00	24.00	8.00	0	0.00	0.00	0.00
6.550	1	0.00	35.00	11.67	0	0.00	0.00	0.00
6.000	1	0.00	46.00	15.33	0	0.00	0.00	0.00
5.400	1	0.00	58.00	19.33	0	0.00	0.00	0.00
4.900	1	0.00	68.00	22.67	0	0.00	0.00	0.00
4.400	1	0.00	78.00	26.00	0	0.00	0.00	0.00
4.300	1	0.00	80.00	26.67	0	0.00	0.00	0.00
3.950	1	2.40	84.95	28.32	0	0.00	0.00	0.00
3.600	1	4.79	89.91	29.97	0	0.00	0.00	0.00
3.000	1	8.90	98.40	32.80	0	0.00	0.00	0.00
2.600	1	11.64	104.06	34.69	0	0.00	0.00	0.00
2.200	1	14.37	109.73	36.58	0	0.00	0.00	0.00
	1	14.37	109.73	36.58	2	Total>	0.00	49.50
1.825	1	16.94	115.04	38.35	2	Total>	7.13	53.07
1.450	1	19.51	120.34	40.12	2	Total>	14.25	56.63
1.075	1	22.07	125.65	41.88	2	Total>	21.38	60.19
0.700	1	24.64	130.96	43.65	2	Total>	28.50	63.76
0.350	1	27.03	135.92	45.31	2	Total>	35.15	67.08
0.000	1	29.43	140.87	46.96	2	Total>	41.80	70.41
	3	29.43	140.87	0.00	3	0.00	41.80	101.73
-1.000	3	39.24	151.06	0.00	3	9.81	51.99	107.84

**Serviceability Limit State Analysis - BENDING MOMENTS****Earth pressures normal to the stem of the wall**

Elevation	---- Active pressures ----				---- Passive pressures ----			
	Soil type	Water kN/m2	Vert. kN/m2	Active kN/m2	Soil type	Water kN/m2	Vert. kN/m2	Passive kN/m2
8.100	0	0.00	0.00	0.00	0	0.00	0.00	0.00
7.605	0	0.00	0.00	0.00	0	0.00	0.00	0.00
7.110	0	0.00	0.00	0.00	0	0.00	0.00	0.00
7.100	0	0.00	24.00	0.00	0	0.00	0.00	0.00
	1	0.00	24.00	15.06c	0	0.00	0.00	0.00
6.550	1	0.00	35.00	15.13c	0	0.00	0.00	0.00
6.000	1	0.00	46.00	15.20c	0	0.00	0.00	0.00
5.400	1	0.00	58.00	16.82	0	0.00	0.00	0.00
4.850	1	0.00	69.00	20.01	0	0.00	0.00	0.00
4.300	1	0.00	80.00	23.20	0	0.00	0.00	0.00
3.950	1	2.40	84.95	24.64	0	0.00	0.00	0.00
3.600	1	4.79	89.91	26.07	0	0.00	0.00	0.00
3.000	1	8.90	98.40	28.54	0	0.00	0.00	0.00
2.600	1	11.64	104.06	30.18	0	0.00	0.00	0.00
2.200	1	14.37	109.73	31.82	0	0.00	0.00	0.00
	1	14.37	109.73	31.82	2	Total>	0.00	80.00
1.825	1	16.94	115.04	33.36	2	Total>	7.13	87.13
1.450	1	19.51	120.34	34.90	2	Total>	14.25	94.25
1.075	1	22.07	125.65	36.44	2	Total>	21.38	101.38
0.700	1	24.64	130.96	37.98	2	Total>	28.50	108.50

I.K.Brunel and Partners	Sheet No. 6
Program: GWALL Version 3.01 Revision A02.B02.R33	
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Run ID. Demo30	Made by :
Wall with shear key - For comparison with DOS version	Date:26-11-2006
Soft undrained fill in front of wall	Checked :

-----  
Units: kN,m

**Serviceability Limit State Analysis - BENDING MOMENTS** **Load Case No.2**  
**Load case description: Factored loads**

Surcharge Nos. 1 apply with a Partial factor = 1.20  
 Partial factor on Horizontal Load = 1.30

**Forces on Base for Calculating Bending Moments**

Horizontal forces	Force	Moment	Height	Elevation
-----	kN/m run	kN.m/m run	above base	
Shear on heel	0.00	0.00	0.70	0.70
Shear on toe	0.00	0.00	0.70	0.70
Shear at base of stem	87.35	61.15	0.70	0.70
Nett horizontal force	87.35	61.15	0.70	0.70

Components of sliding resistance  
 Base shear -340.00  
 Shear key 0.00  
 Total sliding resistance -340.00

Vertical forces	Force	Moment	Distance of
-----	kN/m run	kN.m/m run	resultant
			from toe
Components of dead load			
Weight on heel	764.94	-3318.33	4.34
Weight on toe	37.04	-24.07	0.65
Stem load	103.06	-173.91	1.69
Weight of base	116.62	-396.51	3.40
Total dead load	1021.66	-3912.82	3.83
Uplift water pressure	-100.06	453.61	4.53
Nett vertical force	921.60	-3459.20	3.75
Moment at base of stem		570.14	
Moment of horiz. forces		61.15	
Soil reaction on base	-921.60	2827.92	3.07

Base contact pressures

-----  
 Soil contact pressure at toe 175.2 kN/m2  
 Soil contact pressure at X = 6.80 95.9 kN/m2  
 Line of action of resultant 3.07 m from toe

\*\*\* SLS results do NOT include a partial factor on passive.

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 Program: GWALL Version 3.01 Revision A02.B02.R33  
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 Run ID. Demo30  
 Wall with shear key - For comparison with DOS version  
 Soft undrained fill in front of wall

| Sheet No. 7  
 |  
 | Job No.  
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 | Date:26-11-2006  
 | Checked :

-----  
 Units: kN,m

**Serviceability Limit State Analysis - BENDING MOMENTS**

**Load Case No.2**

**Forces in stem of wall**

Elevation	Shear force kN/m run	Axial force kN/m run	Bending moment kN.m/m run
8.100	25.98	-1.04	0.00
7.605	26.08	1.42	12.89
7.110	26.19	4.36	25.84
7.100	26.20	4.42	26.10
6.550	34.67	8.59	42.76
6.000	43.21	13.35	64.08
5.400	53.05	19.25	92.79
4.850	63.43	25.32	124.60
4.300	75.59	32.05	162.56
3.950	84.58	36.70	190.40
3.600	94.92	41.64	221.58
3.000	115.79	50.78	284.18
2.600	131.91	57.36	333.32
2.200	149.80	64.32	389.20
1.825	136.88	72.45	442.54
1.450	122.83	81.02	490.77
1.075	107.67	90.03	533.44
0.700	91.39	99.49	570.14

**Forces along base of wall**

Distance from toe m	Shear force kN/m run	Bending moment kN.m/m run
6.800	0.00	0.00
6.100	23.62	5.08
5.500	44.38	22.76
4.900	65.61	53.03
4.200	90.99	104.66
3.500	117.02	174.28
2.800	143.70	262.34
2.438	157.77	315.35
2.075	172.02	373.49
1.688	-935.84	137.24
1.300	162.19	-100.92
0.650	82.64	-24.10
0.000	0.00	-0.00

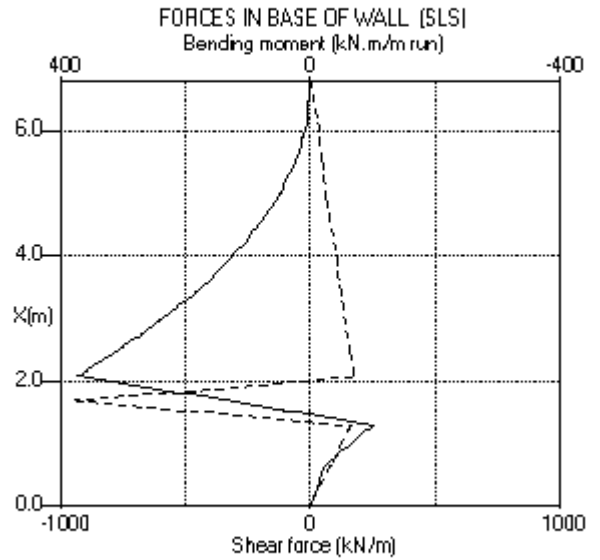
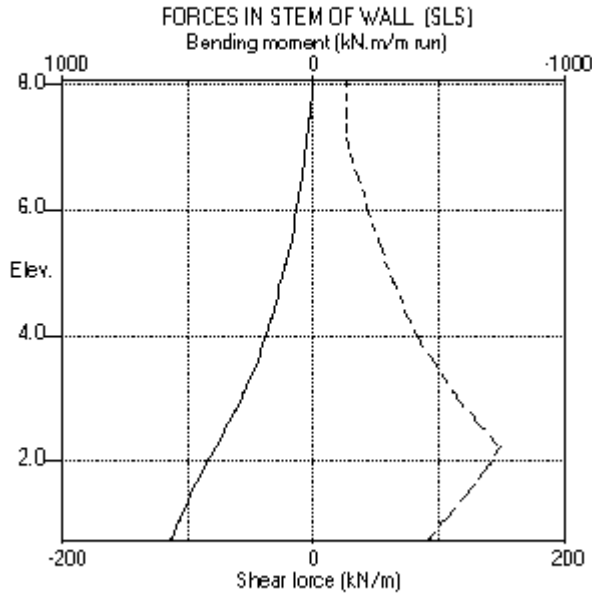
\*\*\* SLS results do NOT include a partial factor on passive.

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Run ID: Demo30  
Wall with shear key - For comparison with DOS version  
Soft undrained fill in front of wall

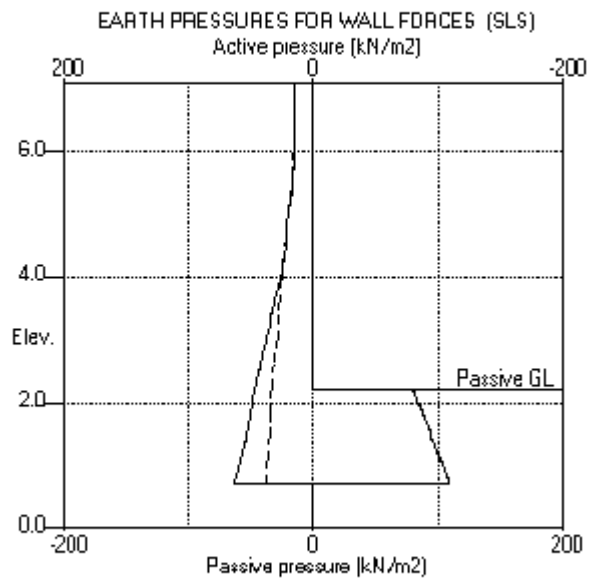
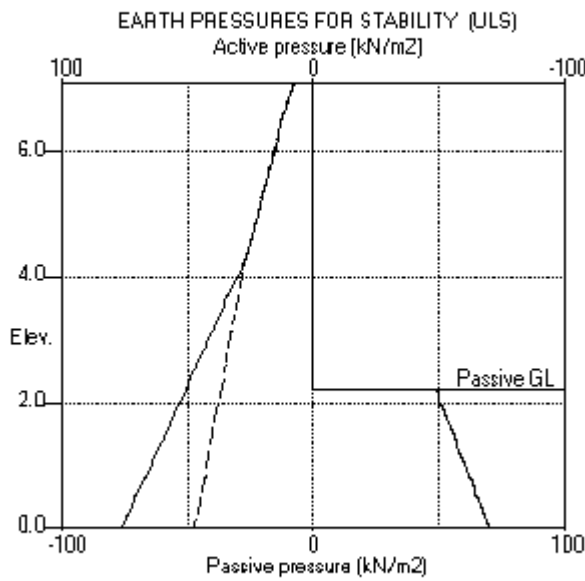
| Sheet No. 8  
|  
| Job No.  
| Made by :  
| Date:26-11-2006  
| Checked :

Units: kN,m

Load case no.2



Load case no.2



I.K.Brunel and Partners	Sheet No. 9
Program: GWALL Version 3.01 Revision A02.B02.R33	
Licensed from GEOSOLVE	Job No.
Run ID. Demo30	Made by :
Wall with shear key - For comparison with DOS version	Date:26-11-2006
Soft undrained fill in front of wall	Checked :

-----  
Units: kN,m**SUMMARY RESULTS**

Load Case No.	Sliding stability (base shear)	Sliding stability (base + passive)	Overturning stability	Contact press. at toe	Distance of resultant from toe
	FoS	Fos	Fos	kN/m2	m
1	3.826	2.498	3.262	139.58	3.28
2	3.454	2.361	3.126	151.20	3.21

- Notes 1. Nett water pressures are used in calculating the disturbing forces and moments for the factors of safety on sliding and overturning.
2. All ULS results include a partial factor of 2.00 on passive.

Load Case No.	----- Stem -----				----- Base -----			
	- Bending moment-		-- Shear force --		- Bending moment-		-- Shear force --	
	maximum	minimum	maximum	minimum	maximum	minimum	maximum	minimum
	kN.m/m	kN.m/m	kN/m	kN/m	kN.m/m	kN.m/m	kN/m	kN/m
1	511.11	0.00	139.70	0.00	326.85	-94.22	156.54	-834.95
2	570.14	0.00	149.80	0.00	373.49	-100.92	172.02	-935.84