MDC

1 Introduction

1.1 MDC Retaining Walls

Analysis of Gravity and reinforced concrete retaining walls either resting upon direct foundations or borne on piles, and optionally restrained by tiebacks (anchors). The program performs geotechnical calculations using th theories of **Coulomb, Rankine & Mononobe and Okabe** (Coulomb in seismic conditions) and also performs verification according to ruling standards among which global stability even in seismic conditions. Structural computation sizes reinforcements both to Ultimate Limit State and to Allowable Tension, and verifies reaction at different heights of the stem.
Beyond the strictly technical functions, the program provides facilities for: **Saving and recalling** 6 project files, **operational language** 17 selection, selection of **measurement units** 17, **Graphic default** 17 set up, **Graphic print preview** 5, **Text Print Preview** 6 and Edit, and **Resource files** 4 for common geotechnical constants.
For other Geostru Geothechnical Software products follow link below or consult GeoStru Software.

1.1.1 Geostru Software

For a complete description and Technical datasheets of all Geostru Software and please consult the **GeoStru** web site at www.geostru.com.

1.2 Computation model

Verification of the wall is done in the following sequence:

Phase I
Terrain pressures and any surcharge on the stem are calculated. The stem is then divided into a fixed number of segments that will hereafter be the verification segments. For this phase, the thrust surface is taken to be the face of the stem. If Coulomb 's method is selected the thrust is considered at an angle corresponding to the terrain wall angle of friction declared in the geotechnic properties. If Rankine's method was selected the thrust is considered to be horizontal. In phase I, the program determines stresses only on the stem and performs structural verification using the materials specified by the user and the selected criterion (Admissible Tension, or Limit State).

Phase II
In this phase pressures calculations are repeated taking as thrust surface the vertical line that passes through the uphill edge of the foundation heel. This time, with Coulomb’s method, it is the angle of soil resistance that is used. Then all pressures (Overturning and stabilizing moments) are determined in respect to the datum point that is the lower

corner of the foundation toe. Thereafter the program performs Ultimate limit state, Overturning, Sliding, and Limit load verifications.

Phase III
In this phase the stresses on the footing shelves, segmented to a fixed number, are determined. Then structural verification on the footing is performed.
If the footing is not anchored on piles, this completes the calculation.

Phase IV
This phase is only relevant where pile further support the footing. Stresses transmitted by the wall to the piles are consist in the moments obtained in phase II. The user may chose to have transmitted to the piles the net resulting moment (difference between overturning and stabilizing) or only the overturning one. Clearly this latter choice is only reasonable where the overturning moment far exceeds the stabilizing. If more than one line of piles is declared, the program performs verification calculation on the line that is most stressed (normally by compression).

1.3 Measurment Units

The program is designed to allow the choice of either technical international measurement units. Transfer from one set of units to the other is permitted at any time. However the user might bear in mind that the conversion factors may involve decimal approximations so that, in normal practice, it would be advisable to select one set and hold it constant.
The set used may be selected in the **Preferences menu**.

Standards for materials
Naming conventions for concrete resistance are adapted to whether **S.I.** (international) or **M.K.S.** (technical) measurement system is chosen. In either case the user is requested to declare the typical cubic resistance in the following conventions.

M.K.S.	$R_{ck}250$	$R_{ck}300$	$R_{ck}350$
S.I.	C-20	C-27	C-30

1.4 Program Installation

Package contents
The package should contain a CD–ROM, the program’s usage license and optionally, the hardware key. Manuals and help file can also be downloaded individually from our web site.

Minimum configuration

Windows 95/98/2000/XP/Vista or NT operating system.

A VGA screen with 16 Mb memory and 6 Mb free disc space.

For Optimum configuration, the following are recommended:
64 Mb memory and 100 Mb free disc space.
Colour Palette: 65536 colours.
Screen Resolution: 1024 × 768 pixels recommended, however not inferior to 800 x 600.
Small font size.

Installation
Start computer and insert CD–ROM in drive (or if downloaded, the files will be present in the download library).
No automatic loading occurs. Use Windows Explorer to view contents of the CD (or download library).
Files with Zip extension should first be 'unzipped'.
Installation requires the presence in your operating system of MS Installer program.
This is included in Windows 2000, ME, XP operating systems. For W95/98/NT, it must be added as a one-time requirement.
For Windows 95/98 2click on instmsia.exe. For WindowsNT 2click on instmsiw.exe. (check carefully)
This installs the MS Installer program in your operating system.
(If you do not know whether MS Installer is present in your system, 2click the msi file as indicated below. If the installer is present, installation will start. Otherwise Windows will open the 'Open with' window indicating that it does not recognise this extension. If this happens, Cancel and add the MS Installer as stated above).
To actually install the program(s), click on each file with extension msi.
The file name is an acronym of the program name (slope.msi etc. Note that your computer may be set up so as not to show extension acronyms, in which case the file will show as slope alone.)
Follow instructions displayed during program installation.
If you have previously installed the same program, see below under Version Update.
Installation loads the program (exe), the help file (chm), and example/auxiliary files. The manual, in zip, form must be loaded and expanded separately.
In the Start, Programs menu a 'Geostru' item is placed which expands to the programs installed.

Hardware lock
If you have purchased a hardware key you will need to install an additional item on the CD (or download library).
Click on HDD32.exe to do this.

Software lock
The use of this system requires the exchange of information (Email or Fax etc.) between yourself and **GeoStru Software S.a.S.**. You will send Geostru the control number in the Registration from the Help menu window when the program is run. GeoStru will respond by sending you a registration number to enter in this opening window. This opens the full functionality of the program. Until this is done the program operates in demonstration mode.

Disintallation
This may be achieved in control panel (Start, Settings, Control panel).
Select Application Installation and chose remove against the program name.

Version Update
When a version update is obtained, click on the msi extension as above but as a first step, select remove. This removes the previous version. Then proceed as above (2click msi file) to install the new one. With version update the previous registration number will remain valid.
With some version updates, intentionally, this removal option is not presented and on installing the new version the previous version remains. In the concrete case it will be clear why this is. In such cases a new registration number will be required.
Later when the older version is no longer required, it may be removed from the control panel. See Disinstallation above.

1.5 Resource Files

Many **GeoStru programs** are distributed with .txt files which contain tables of data to be used in the program, most typically to populate drop down selection lists. Among the ones most widely used is the list of lithologic types and properties.
These files are distributed as a help to data entry and as it is envisaged that users may have some more specific examples, they are available to the user for addition and amendment. Typically the files are found within the program folder. (Ex: \Programs\Geostru\Slope). Before undertaking any amendment it is advisable to save the original file so that if any error occurs in the change, the situation may be restored. Needless to say when applying changes to the files the original format and conventions should be retained. These are not always evident when the file is opened in Notepad or even Word Pad and therefore the following is suggested.
The method entails doing the actual editing in a Word table.
Open the file by clicking on it. Notepad starts and displays the file content. Select all the file (SHFT+ CTRL+END). Copy the data. Open a new Word document (or other equivalent text processor) Paste the file data into the document. Select all the data in the document.
Convert to table after:

1. Identify the separator character (either tab or semicolon (;))

2. Set this as the operative separator;

3. Check ‘adapt to content’.

When editing a Word document the graphics for space, tab, paragraph, page separator and many others are hidden. It is useful in this case, and in the authors opinion always, to show them.
The menu: Tools, Options, Display, check All does this.
When the table is created amendments or additions can be applied with ease.
When all amendments have been applied and checked, reconvert the table to text (using the same separator). Copy the text and paste back into the Notepad file text, replacing the original, and save. The amended file is now operative.

Textures: Textures are also resource files distributed automatically with relevant

programs but which may also be downloaded and installed in isolation. Textures are held in a folder: "**Retini**" within the Geostru folder. Within the parent folder are four folders for Cohesive, Cohesionless, Rocks, and Others. Within each of these folder are stored a number of BMP files with the textures to display. The files are named with numbers i.e. 12.bmp, 43.bmp etc. These are the actual images used to 'paint' the object. The textual description of the file is held in a text file named "bmp.txt". However for international versions this one text file is replaced by three: bmp_it.txt, bmp_es.txt, and bmp.en.txt for Italian, Spanish and English texts.
It is only necessary that the text files contain the names of the soils in the folder but for simplicity all soils are present in each file. Editing of bmp.txt could be done as described above.

1.6 Graphic Print Preview

When this command is invoked it opens the **Print preview** dialog window displaying a print preview of the drawing in the worksheet set up to print at a scale such that it will fit on the predefined page size.
In the preview window are present a number of menu functions which affect the print result without affecting the original in the worksheet. One of these invokes printing of the image to the predefined printer.

The commands are:

Move: Pressing this button causes the mouse pointer to change to a hand and can be used to 'take' (click) the drawing and move it (drag) elsewhere on the paper as seen in the preview.

Scale + e Scale - : Alters the scale of the drawing up or down in steps of 100:1. The scale adopted is displayed in the plan scale frame. See also Plan Scale factor .

Plan Scale: Displays the scale at which the plan diagram will be printed. May be altered as desired. Press enter to actuate the new scale.

Fit to page: Adjusts the scale of the image such as to fit on the defined page size exactly. The scale adopted is displayed in the plan scale frame. (Selection of paper size and orientation occurs in the **Set Up printer** in the **File menu**).

No. of Copies: Default is 1.

Print: Prints the preview image on the predefined printer (see **Set Up printer** in the **File menu**).

Exit

1.7 RTF Editor

The program includes an internal text editor which enables text, such as reports, to be produced edited and saved using RTF format.
RTF (Rich Text Format) is a document format that is compatible with all major text processing programs. This format may be read by these text processors (Word, Word Perfect etc.) and thereafter edited and saved in the text processor native format.
The editor may be invoked by requesting **Print Report** or from the toolbar. When invoked the editor is opened and the program' s data report is presented. Thereafter the user may modify and/or enhance its aspect or contents at will, and/or save or print it.
Basic text processing functions such as editing, tables, margins, tabs, and formatting are available.
When the editor is closed, control returns to the original program.

2 Menu

2.1 File Menu

The **File menu** contains those functions that enable the insertion, recall, printing and closure of project files and their management.

New
Creates file(s) for a new project.(Function is also available from the Standard toolbar)

Open
Opens file(s) for a previously created project. (Function is also available from the Standard toolbar).

Save
Save file(s) for the currently open project, replacing any previous version. (Function is also available from the Standard toolbar)

Save As
Save file(s) for the currently open project under the name and in the folder, to be entered in a subsequent dialogue window. This creates a new file with that name. If the file already exists the user is asked to confirm that it should be overwritten.

New Project Step by step
Step by step guide to project set up. Among choices offered are the normative standard to be applied, which measurement units to be used, Type of wall (gravity, cantilever, pile anchored etc), pile types, wall height. with these parameters a default wall is generated, for user approval or amendment.

Import 'Slope' walls
Enables Stratigraphy and walls previously defined in the Geostru program 'Slope' to be imported.

Print Set-up
Presents standard Windows printer select & set up dialogue window.

Print Preview
Presents preview of worksheet printed page(s) with dialog window for the control of the printed image (scale, position etc.).

Recent Projects
Recalls the names of the last three open files.

Exit
Program exit.

2.2 Edit Menu

The **Edit menu** presents those functions relative to editing data for the currently open project.

Copy
Copies to the clipboard the selected area of the active window. (Function is also available from the Standard toolbar). This function is particularly useful to copy bitmaps of images in the various phases of computation to a preferred editor (Word, Works etc.)

Paste
Copies to the current active window, the contents of the clipboard. This command permits any raster image (e.g. slope sections read with a scanner) to be copied to the current work sheet and then be used to define a new profile and/or layer by operating with the mouse.

Delete
Remove any bitmap inserted on the worksheet.

Copy
may profitably be used to copy results including graphics from the worksheet for pasting on the numeric report or as required.

2.3 View Menu

Redraw
Redraws the drawing correcting any defects due to editing process. (Normally caused by editing of the contents)

Zoom All
A zoom factor is applied, such that the whole contents of the worksheet are displayed.

Zoom Window

Lets you draw a selection rectangle or "window" to view part of your display in the drawing window. Use the left button to select one corner of the view you want. Now the cursor becomes a stretching rectangle. Select a second corner for the view. The screen is redrawn to show the part of your drawing that fits within the rectangle.

Dynamic Zoom
Provides an interactive zoom effect using the mouse to control it.
Once the left mouse key is pressed the pointer alters into an enlargement lens. Dragging the pointer upwards increases the size of the image, while downwards drag reduces it. The zoom factor may be read in the toolbar display.

Previous Zoom
Returns to the zoom factor current before the last operation.

Move
Moves the image by dragging with the mouse. Dynamic interactive preview is given.

Axis View
View (highlight) datum point and X & Y axis vectors.

Distance
Enables the measurement of distance between two points. Left click on first point and drag pointer to next point, during which time a small text box shows the actual distance.

Stratigraphy legend
This is a switch that activates/deactivates the display of the legends of Stratigraphy.

Discretizzazione
Attiva la visualizzazione della discretizzazione del muro usata dal programma nell'eseguire i calcoli; i tratti evidenziati con tratteggio rappresentano le sezioni di verifica.

Note: **Zoom does not alter the absolute dimensions of the drawing and does not impact on its scale when printing.**

2.4 Data Menu

Data menu contains items to invoke the windows in which program parameters required for the calculation may be entered such as wall type, geometric declarations, material properties, and terrain descriptions.

Main Parameters 9

Geometry data and loads 10

Terrain profile 10

2.4.1 Main Parameters

This command opens a window in which the main parameters of the project can be given.

Works description
This field is intended for a synthetic description of the project.

Wall Type
In this pane it is possible to specify the type of wall by selecting from the drop down list and check boxes.

Global safety margin coefficients
Safety factor coefficients for slide, overturn and limit load can be specified here and can if required be saved as predefined in other projects.

Thrust
This pane is used to determine a number of factors and methods in the calculation of soil thrust either at rest (i.e. for fixed head supports) or active.
For Active thrust it is possible to opt either for **Rankine's method** - valid for horizontal backfill with no soil/wall friction (d=0), or **Mononobe & Okabe' s method** - valid for seismic condition - based on Coulomb's non seismic condition theory. For passive thrust on downhill terrain the actually applied percentage thrust can be specified. The program only calculates passive thrust on terrain downhill of the wall footing and not on the soil covering it (See Fill pane).
In the evaluation of increase in thrust due to seismic action, the user is requested to specify the point of application of such increment on the stem either at 1/3,or 2/3 of H, considering seismic thrust diagram as a triangle or as a constant on stem height at 1/2 H.

Foundation
Soil resistance values for slide resistance verification are taken parameters in stratigraphy data unless these are otherwise specified here.

Seism 20

2.4.2 Wall Geometry and Loads

This option opens a tab window in which definition of wall geometry, loads on the wall or on the backfill can be entered.
This option opens a tab window in which definition of wall geometry, loads on the wall or on the backfill can be entered.

Wall Geometry
Wall geometry is entered by wall element. Thus a pane each is devoted to wall stem, wall footing, footing key, and flying shelf. It is also possible to define the uphill side of the wall as a number of steps, whose individual geometry is then declared.
Within the same window, there where no supporting piles are present, a pane enables the presence of a lean mix base below the footing to be specified, that is taken into consideration for slide limit state verification.

Loads on backfill
A strip load on the backfill may be modeled, declaring its extent by entering its initial and final abscissa. Load scale may be used to define the desired scale. Reference point is the X vertex of the wall head.(see **Loads** in **menù Projects**)

Point loads (on the wall)
Vertical and horizontal forces and moments may be applied to the model at any point of the wall.
These may be declared in tabular form entering ordinal number, X and Y coordinates referred to the lower corner of the downhill footing, and the load extent.
Horizontal forces are entered as positive numbers when acting right to left, the vertical when acting top downwards, and moments when acting anticlockwise.(see **Loads** in **menù Projects**)

2.4.3 Terrain profile

This screen enable the terrain profile on either side of the wall to be defined in one (downhill) or two (uphill) segments of which the first is the one abutting upon the wall and may be inclined to rise or fall as required. It is further possible to model an embankment on the uphill side, that rises above the stem head, whose height and weight per unit volume is declared here.

2.4.4 Stratigraphy

No.: Layer ordinal number.

N.B.: Layers must be entered in sequence from the uppermost down.

Soil DB: The user can take advantage of a database of more common soils that is included in the program. To expand the scope of this database refer to Resource files from the Introduction.

Height i [cm]: Height of upper level of layer. This will coincide with the lower level height of the previous layer (if any).

Height f [cm]: Height of lower level of layer. This will coincide with the upper level height of the next layer (if any).

Incl. [°]: Inclination of layer in respect of the horizontal.

Water Table: Check to indicate that layer is in contact with the water table so as to consider the thrust effect of water and the analysis of effective pressures. In such a case, please enter the total weight per unit volume.

K: Layer permeability.

Gamma: Soil weight per unit volume.

Fi [°]: Soil shear resistance angle; where water table is present enter the effective parameter.

c : Soil cohesion; where water table is present enter the effective parameter.

delta [°]: Soil-wall angle of friction.

Elastic Modulus: Elastic modulus of the layer. This is required to evaluate settlement where piles are involved.

Colour: Use colour palette to select colour that will denote this layer.

Description: Identifying description of the layer.

Fill: For fills on either side of the wall, it is required that: Soil weight per unit volume, Shear resistance angle, and Height be given in order to evaluate the stresses on the wall stem and foundation. The data is entered on a tab card at the right side of the screen.

N.B. In the global checks (load limits, overturning and sliding), the thrust is referred to a plane passing through the extrados of the founding upstream. Along this plane, the friction that develops in the presence of the shelf of founding is soil-soil friction and not soil-wall. Where, however, the foundation upstream is not present or is negligible, it is reasonable to assume that throughout the plan is to develop soil-wall friction, so the thrust evaluated with the theory of Coulomb is inclined the angle friction δ of the soil-wall. In such cases it is possible to use the angle of soil-wall for global checks selecting this option down in the environment of definition of the stratigraphy.

2.4.5 Piles

When a wall resting on piles is specified (Main Parameters) the Pile command is made available in the Data Menu, within which the pile configuration can be specified.

Pile properties
Type and geometry as well as the coefficient of horizontal reaction, whether this is constant or varies with depth, and Poisson coefficient for the layer in which the pile tip is embeded for the calculation of settlement.

Foundation placement
To be able to locate the piles in the model the xxis distance from external edge is requested. In case of double pile row these are placed symmetrically, in case triple, threse are place in quincuncial format. Finally the distance of the longitudinal interaxis distance is requested.

Pile inclination
To each pile can be assigned a positive (anticlockwise) inclination.

Safety coefficients
For the calculation of bearing capacity, it is possible to declare a reduction of the tip and lateral limit loads by giving specific coefficients or else reduce to total limit load by giving a total reduction coefficient. See Technical notes regarding Bearing capacity calculation.

Analysis options
For pile calculations, it is possible to choose either overturning moment or total moment of the action transmitted to the wall structure.

2.4.6 Tiebacks

A tieback is considered by the program as a force of the same magnitude as the drag, applied to the wall. This force is taken into consideration in the calculation of global stability whenever any potential slide surface crosses the line of the tieback.

N°
Ordinal tieback no.

DH [cm]
Distance of tieback from wall stem head.

Li [cm]
Length of drag rod/cable of tieback.

La [cm]
Length of anchor part of tieback.

Df [cm]
Perforation diameter.

Db [cm]
Bulb diameter.

Inter. [cm]
Longitudinal spacing.

Incl. [°]
Angle to horizontal.

Soil-Tieback friction [°]
Soil/Tieback angle of friction

Adhesion
Tieback/Soil adhesion.

No. of Strands
No. of strands in tieback cable.

Tieback drag
User choice for drag value for tieback that, when entered, overrules that calculated (and shown here) by the program.

Colour
Select colour that should denote the tieback.

Suggested path to applying tiebacks to wall:

1. Calculate wall without tiebacks.

2. Enter tieback geometry: as data is entered the program automatically calculates the tieback's drag. The user can override the calculated value by entering the preferred one.

3. Repeat wall calculation and check the foundation stress diagram. It is desirable that this diagram result roughly rectangular or at least with the major side on the uphill side. Further slide safety and overturning safety should verify.

4. If the foundation stress diagram does not satisfy the above requirements, the drag should be reduced or increased as required.

5. If limit load verification fails, piles should be introduced.

6. The tieback rod(cable) length should be such as to place the anchor bulb outside the rupture zone identified by the program after tieback insertion.

2.4.7 Materials and Armatures

This window enables wall and pile materials and armatures to be determined and of their verification parameters.

Reinforced concrete verification parameters

Standard to apply
For the non Italian user, this will reduce to selection of Eurocodes that will involve that verification will be performed based on ultimate limit state, subject to declaration of partial safety factors (below) for cement and steel.
Verification by the Admissible pressures method is in practice bound with selection of Italian national standards.

Concrete, partial safety factor
Partial safety factor to determine calculation resistance for concrete. Eurocodes value = 1.5.

Steel bar, partial safety factor
Partial safety factor to determine calculation resistance for reinforcement steel. Eurocodes value = 1.15.

I parametri di cui sopra sono assunti in automatico dal programma in funzione della normativa scelta dall'utente.

Ratio between stretched and compressed reinforcement
The ratio between stretched and compressed reinforcement in each section is held to the value requested by the user.

Distribution steel
Distribution steel quantity is calculated as the user selected percentage of the stretched reinforcement of the most reinforced section.

Lap splice bars
There where the reinforcement bars anchored in the footing, do not extend for the full height of the stem, additional bars extend to the full height these are spliced to the original ones. The user is requested to specify the anchorage length of the original bars extending above the footing.

Wall Material

Material properties
For concrete typical cubic resistance value and specific weight are required.
For reinforcement steel the required values are typical yield strength (F_{yk}) permissible tension (for permissible tension verification), the elastic modulus the homogeneity ratio and the cover value.
Naming conventions for concrete resistance are dependent on the choice of measurement units **S.I.** (International) or **M.K.S**. (technical). In either case the typical cubic resistance according to the following convention.

M.K.S.	R_{ck}250	R_{ck}300	R_{ck}350
S.I.	C-20	C-27	C-30

Stem bars - Footing bars - Barre dente
For each of these elements it is possible to specify differentiated bar diameter, and minimum and maximum number of bars.
Based upon these parameters the program attempts verification at various vertical levels, starting with the minimum and proceeding up to the maximum number of bars, and if these verifications fail, the diameter is increased until verification succeeds

Pile Material

Material properties
For concrete typical cubic resistance value and specific weight are required.
For reinforcement steel the required values are typical yield strength (F_{yk}) permissible tension (for permissible tension verification), the elastic modulus, the homogeneity ratio, and the cover value.

Longitudinal bars - Tie bars - Tubular armature
For reinforcement steel the required values are typical yield strength (F_{yk}) permissible tension (for permissible tension verification), the elastic modulus, the homogeneity ratio, and the cover value.
If the pile is also reinforced with tie bars and or longitudinal bars, diameter and number/separation are requested.
For tubular armature internal and external diameter are requested, however selecting from a drop down list of types these data are inserted automatically.

2.5 Compute Menu

Computation
Performs geotechnical calculation on the wall and displays summary results.

When invoked the command presents the Combination (see **Loads** nel **menù Projects**) screen where the user defined loads (backfill and wall loads) are shown along with those calculated by the program (i.e. weight, thrust, seism, water thrust etc.)
At this point the user may wish to define a number of combinations of actions and coefficients to verify the structural resistance of the wall, of the terrain specifying reductions in property values.
The program itself generates two combinations (see **Loads**). One for wall structural capacity and the other for geotechnical dimensions.
The program performs a complete calculation for each combination (i.e. Computation model 1) and returns a summary of the more notable verification results (overturning, sliding an bearing capacity). When one of the combinations fails verification in one or more respects this is highlighted.
Combinations may be removed with the mouse or using the tool bar buttons:

- **Cancel combination**
  Select target combination and press right mouse key then click **Cancel** combination to remove it.

- **Verify combination**
  Select target combination and press right mouse key then click **Verify**.

- **New combination**
  Click right mouse on the text '**Load Combinations**' in the entry pane (not the pane Heading) and click on **New**.

Layer View
Displays wall and soil layers.

Discretization
Displays wall segmentation.

Soil Pressures
Displays diagram of soil pressures on wall.

Water table pressures
Displays diagram of water pressures.

Foundation pressures
Displays progress of pressures on foundation (only if no piles are used).

Moments diagram
Displays diagram of moments on stem and footings.

Static-dynamic wedge
Displays magnitude of thrust wedge.

Armature
Displays armature list. Armature includes all armatures in combinations.

Resultant armature
For the combination selected in the tool bar, the armature involved is displayed.

Armature editor 26
This function opens the armature editor where in amendments to the armature can be made.

Global stability analysis 26
This function invokes the process of global stability analysis.

Materials Estimate
Displays the estimate of quantities of steel and concrete required.

2.6 Export Menu

Enables selection of export format for the calculation results.

Generate RTF Report
Generates the computation report in an Internal editor (**RTF Editor from the Introduction**) window. This provides its own File menu with Print and Save functions.

Export in DXF format
Stores in DXF format the contents of the worksheet window.

Export in Bitmap format
Stores in BMP format the contents of the worksheet window.

Note: **Exported file have the same name as the project with unique suffix and the type (DXF, BMP, RTF).**

2.7 Preferences Menu

Options
Opens the Options window in which the following may be determined:

Worksheet

Colours
Line & background colours.

Graphic
Line thickness.

Outputs

DXF Parameters
DXF file export folder path text size & scale factor.

Text Output
RTF report margins, background colour, & table formatting.

Company data
Enable the recording of four lines of company data as Headings in reports.

Save
Enable selection of and interval for automatic project file saving.

International System (S.I.)
Switch to select International System (S.I.) (See Measurement Units 2).

M.K.S. System
Switch to select M.K.S. System (S.I.) (See Measurement Units 2).

Language Selection
Opens a window to enable an alternative language to be set. After an alteration, closing the window initiates the program closing sequence. On restart the new language is

operative.

2.8 Help Menu

Help
Opens Help window.

Registration
Opens Registration window. Within this window the Registration number obtained from Geostru can be recorded.

About
Shows window with program version and revision numbers.

2.8.1 Registration

The program is distributed both on CD, or as a download, in a demonstration mode
In **Demo mode**, some functions, among which, print, export and save are suppressed, and assignment of point coordinates is randomly altered while the other functions remain active, thus demonstrating its capabilities.
When the user purchases the program the registration number necessary for full functionality may be obtained by sending **GeoStru Software S.a.S.** the Control Number to be found in the registration window.
GeoStru Software S.a.S. will respond with the correct registration number.
This may then be entered (one time operation) into the registration window field. The whole exchange may occur by Email quoting the license number. The registration number is specific to the computer and if the program is to be loaded on another PC, a new registration number should be requested, giving the control number, which appears on that machine.
An alternative to this process is to obtain a hardware lock (dongle) which when inserted in the parallel or USB port opens all the functions of the program. This must however be present whenever the program should be used.

3 Projects

3.1 Data Input

A suggested approach, until better familiarity with the program is reached, is to generate a default wall design by selecting "**New Project Step by Step**" in the **File Menu**. This design can then be amended to reflect user requirements.
The default sizing of the wall is conditioned by the support height declared and the geotechnical terrain parameters.
Wall Geometry and Loads (from the data menu) functions can be used to alter the

default sizings as required, while the geotechnical parameters can be specified in Stratifigraphy, both to be found in the Data menu.

3.2 Materials and Armatures

This window enables wall and pile materials and armatures to be determined and of their verification parameters.

Reinforced concrete verification parameters

Standard to apply
For the non Italian user, this will reduce to selection of Eurocodes that will involve that verification will be performed based on ultimate limit state, subject to declaration of partial safety factors (below) for cement and steel.
Verification by the Admissible pressures method is in practice bound with selection of Italian national standards.

Concrete, partial safety factor
Partial safety factor to determine calculation resistance for concrete. Eurocodes value = 1.5.

Steel bar, partial safety factor
Partial safety factor to determine calculation resistance for reinforcement steel. Eurocodes value = 1.15.

I parametri di cui sopra sono assunti in automatico dal programma in funzione della normativa scelta dall'utente.

Ratio between stretched and compressed reinforcement
The ratio between stretched and compressed reinforcement in each section is held to the value requested by the user.

Distribution steel
Distribution steel quantity is calculated as the user selected percentage of the stretched reinforcement of the most reinforced section.

Lap splice bars
There where the reinforcement bars anchored in the footing, do not extend for the full height of the stem, additional bars extend to the full height these are spliced to the original ones. The user is requested to specify the anchorage length of the original bars extending above the footing.

Wall Material

Material properties
For concrete typical cubic resistance value and specific weight are required.
For reinforcement steel the required values are typical yield strength (F_{yk}) permissible tension (for permissible tension verification), the elastic modulus the homogeneity ratio and the cover value.

Naming conventions for concrete resistance are dependent on the choice of measurement units **S.I.** (International) or **M.K.S**. (technical). In either case the typical cubic resistance according to the following convention.

M.K.S.	$R_{ck}250$	$R_{ck}300$	$R_{ck}350$
S.I.	C-20	C-27	C-30

Stem bars - Footing bars - Barre dente
For each of these elements it is possible to specify differentiated bar diameter, and minimum and maximum number of bars.
Based upon these parameters the program attempts verification at various vertical levels, starting with the minimum and proceeding up to the maximum number of bars, and if these verifications fail, the diameter is increased until verification succeeds

Pile Material

Material properties
For concrete typical cubic resistance value and specific weight are required.
For reinforcement steel the required values are typical yield strength (F_{yk}) permissible tension (for permissible tension verification), the elastic modulus, the homogeneity ratio, and the cover value.

Longitudinal bars - Tie bars - Tubular armature
For reinforcement steel the required values are typical yield strength (F_{yk}) permissible tension (for permissible tension verification), the elastic modulus, the homogeneity ratio, and the cover value.
If the pile is also reinforced with tie bars and or longitudinal bars, diameter and number/ separation are requested.
For tubular armature internal and external diameter are requested, however selecting from a drop down list of types these data are inserted automatically.

3.3 Seism

Calculation of seismic movement effects is dependent on a number of parameters, that in turn are dictated or recommended by various legislative norms. This program, with Italy as country of origin includes norms native to that country as well as the Europe wide **Eurocodes 8**.
This latter is the more relevant for users outside Italy and will be treated here. If it is desired to consult the Italian standards, the user is referred to the Italian language help file, accessible directly by executing the file: **Muri_IT.chm** in the home folder for the program.
The following parameters can/should be entered or considered by the user.

Soil Category

Type A soils	Stone like formations or very rigid homogeneous soils	S=1
Type B soils	deposits of highly condensed sands or gravels or highly consistent clays	S=1.25
Type C soils	deposits of moderately condensed sands or gravels or medium consistent clays	S=1.25
Type D soils	deposits of granular, loose or slightly dense soils, or else cohesive soils of slight to medium consistency	S=1.35

Project seismic acceleration

- No seism Zone
- Zone 1 = 0.35g
- Zone 2 = 0.25g
- Zone 3 = 0.15g
- Zone 4 = 0.05g

Factor r
The recommendation for reinforced concrete walls factor r is a value of 1. Only for gravity walls or such as are deformable can this set to 2.
The factor is used in the determination of horizontal seismic coefficient.

Horizontal seismic coefficient K_h
See Theoretical notes. Used in evaluating project force in seismic condition.

Vertical seismic coefficient K_v
See Theoretical notes. Used in evaluating project force in seismic condition with sign + or – depending on a more unfavourable effect.

3.4 Tiebacks

A tieback is considered by the program as a force of the same magnitude as the drag, applied to the wall. This force is taken into consideration in the calculation of global stability whenever any potential slide surface crosses the line of the tieback.

N°
Ordinal tieback no.

DH [cm]
Distance of tieback from wall stem head.

Li [cm]
Length of drag rod/cable of tieback.

La [cm]
Length of anchor part of tieback.

Df [cm]
Perforation diameter.

Db [cm]
Bulb diameter.

Inter. [cm]
Longitudinal spacing.

Incl. [°]
Angle to horizontal.

Soil-Tieback friction [°]
Soil/Tieback angle of friction

Adhesion
Tieback/Soil adhesion.

No. of Strands
No. of strands in tieback cable.

Tieback drag
User choice for drag value for tieback that, when entered, overrules that calculated (and shown here) by the program.

Colour
Select colour that should denote the tieback.

Suggested path to applying tiebacks to wall:

1. Calculate wall without tiebacks.

2. Enter tieback geometry: as data is entered the program automatically calculates the tieback's drag. The user can override the calculated value by entering the preferred one.

3. Repeat wall calculation and check the foundation stress diagram. It is desirable that this diagram result roughly rectangular or at least with the major side on the uphill side. Further slide safety and overturning safety should verify.

4. If the foundation stress diagram does not satisfy the above requirements, the drag should be reduced or increased as required.

5. If limit load verification fails, piles should be introduced.

6. The tieback rod(cable) length should be such as to place the anchor bulb outside the rupture zone identified by the program after tieback insertion.

3.5 Loads

Loads may be modeled on the project as:

1. Loads distributed on backfill;

2. Loads on the wall structure.

Loads may be specified either by acting on the respective tool bar icon or by invoking "Wall Geometry and loads" from the Data Menu.

Distributed loads
The extent of the load is defined by the start and end abscissa values; the load value can be constant or variable. The depth indicates its placement in relation to the stem head. Even multiple loads can be defined and their action combined during the calculation according to specified permutation factors.
The effect of loads on the active thrust is only considered if this is located within the failure wedge.

Point loads
Such loads can be modeled according to the following conventions below:

- Horizontal forces (F_x) defined as a positive value when directed right to left;
- Vertical forces (F_y) defined as a positive value when directed top downwards;
- Moments (M_z) positive when anticlockwise.

Multiple point loads can also be defined and their action combined during the calculation according to specified permutation factors.

Load permutations
The user can define that loads be considered in calculation, in one or more combinations each with specific coefficients.
Computation 15 from the menu with the same name brings up a “Combination” dialog window from within which, new combinations can be defined and calculation performed for each of them.
By default, the program suggests (For Eurocodes) two load combinations:
- The first (A1 + M1) aimed at determining the structural capacity of the wall, uses actions amplified by specific coefficients (A1), shown below, and the given geotechnical parameters (M1);
- The second (A2 + M2), aimed at geotechnical sizing of the structure, uses actions as defined (A2) and reduces the defined geotechnical values by specific coefficients (M2).

Resistance parameter	Specific coefficient γ_m	
	M1	**M2**
Shear resistance angle tangent: $\tan\varphi'_k$	1,00	1,25
Effective cohesion c'_k	1,00	1,25
Undrained cohesion c_{uk}	1,00	1,40
Unit volume weight γ	1,00	1,00

Action	Specific coefficient	
	A1	**A2**
Constant unfavourable	1,40	1,00
Constant favourable	1,00	1,00
Variable unfavourable	1,50	1,30
Variable favourable	0,00	0,00

These defaults may be varied by the user by selecting the relevant one and altering the specific coefficients.

New combinations
New combinations may be added (check the new combination button or right click on the 'Combinations' column header).

This displays the all calculated loads (structure weight, soil weight, thrust, seism) and those defined by the user (Distributed and point loads) as well as resistance parameters (Shear resistance angle, cohesion etc.) all with specific factors set at one which the user can change to reflect requirements.

Delete combination
Combinations can be deleted either by right click on the combination name in the list or by selecting and pressing the delete button.

Rename combination

The name of combinations are assigned when inserted and can be altered at any time by selecting it on the list and typing the new name in the list box (top right).

Verify combination
The user may run a verification of all combinations by pressing the computation button. The program shows with a yellow triangle those that totally or partially failed to verify (Overturn, slide and limit weight verification). By clicking on the combination name on the list the results of that combination are shown in the relevant boxes.

3.6 Compute progression

Calculation progresses through a number of steps.

Step 1
The wall stem is divided into a number of sections. For each section the thrust coefficients (Ka, Ko, Ks) are evaluated as also the proportions of each coefficient absorbed by the vertical and horizontal thrust components so that for each section these components are evaluated and the incidence point determined.
Thereafter for each section the weight of the wall, its centre of gravity coordinates, and its inertial force are determined.
Then when all forces acting on the stem are determined, the program calculates the tensions on each section (Fx = Shear; Fy = normal tension; M = Moment) and then the calculates of the armatures.

Step 2
In this step the sequences in step 1 are repeated but in respect the total wall height (i.e. stem and footing) and thrust calculation is related to a vertical line that passes through the uphill edge of the foundation heel.
The analysis in this step yields global forces, and those at every section that will be used for verification of overturning, sliding, and limit load.
For cantilever walls, in this step footing thrust and the contribution to the passive thrust generated downhill are calculated. In the report will be found the total forces taken into account in global verification.

Step 3
In the last step having ascertained soil pressures, normal shear and moment forces on the joints of the toe and heel base sections to the stem are calculated. Thereafter armatures for these sections are calculated.
Wall anchored on piles.

Where pile further support the footing
In Step 2 , overturning and resulting moments are calculated (Mstab- Mrib) in respect of the lower corner of the toe base. These are transmitted to the piles, according to previous user choice and the components absorbed by each pile, differentiated between compression and extension, are calculated.
The forces acting on the most affected pile are used to calculate stem head displacement, settlement and soil horizontal limit pressure corresponding to the wavelength.
The program calculates peak lateral and total limit load of foundation soil and proceeds

to verification of the sections of the pile subject to greatest tension and returns normal force, moment and armature of the section.
In Step 3 in the verification of the up and downhill footing bases, the reactions of piles on these are applied and thereafter the process is as described.

3.7 Armature Editor

Within Armature Editor the user can modify and verify wall armatures.

Bar selection
Amendment of the single bar requires that it be selected and this is achieved by utilising the Select command icon in the side pane and clicking on the target bar within the wall diagram. On selection, the ends of the bar are highlighted by small coloured spots at every vertex. The characteristics of the bar (number, diameter, length and inclination) are shown on the **Armature Editor** pane and may be altered there.
If a bar is selected from the explosion bar diagram beside the wall, as opposed to within it, it can only be moved.

Freeze and unfreeze a bar
As a safety measure it is possible to 'freeze' a bar, that is to prevent any alteration to it. This function is available from a floating menu recalled by right clicking the mouse. On the same menu an unfreeze all releases all bars to editing.

Bar alterations
Each bar can be cut, shaped, by introducing one or more vertices, or removed. Commands for these operations are within the floating menu invoked by right clicking within the worksheet area and must be confirmed by the Apply command. Once removed a bar cannot be reinserted and in such cases the undo edits command should be used.

Armature Verification
After having altered the armature the alterations should be verified. Selecting the **Armature** list command (or pane tab), opens the Armature specification list showing value before editing. Pressing the Bar compute values button updates the list with the alterations.
At this point the Verify button performs verification of the armature and unless a message appears this can be taken as satisfactory. The amended armature is included in the Calculation Report.
Please note that on the wall stem, the diameter of reinforcement bars on the same side, up or down hill, must be the same.

3.8 Global Stability

This performs Global Stability verification with the classical DEM and Limit Equilibrium methods. Verification can be performed both with circular and free form slip surfaces. For circular surfaces, the program generated a default centres grid however the user can alter it and move it as required.

3.9 Customize

Graphic profile of projects can be customized either in the Preferences menu or in the **Options** tab of the Data card placed on the right of the worksheet.
Both font type an size and colours of the various components can be determined.

3.10 Gravity Wall

For Gravity walls, the program reports the results of thrust calculation and verifies slide, overturning, and limit load. Moreover it performs verification of cohesion of stem to footing joint. The latter is performed to check that the section under consideration does not generate traction but only compression tension. Such verification is presented in the report.

3.11 Fixed Head Wall

For for fixed head wall calculation, it is advisable to select thrust at rest (Ko) and to apply a low value for passive thrust contribution (min. 1%). The program reports soil pressure, that will have a nearly constant value.
Such walls are considered fixed in downwards and downhill directions.
For this type of wall, stem head movement is inhibited, so that the program only performs verification of limit load of foundation on its base, and omits slide and overturning verification.

4 Seismic coefficients

The values of the horizontal and vertical seismic coefficients can be manually assigned by the user.
They can also be calculated automatically by the software on the base of the maximum acceleration at site.

For the application of Eurocode 8 (geotechnical planning), the horizontal seismic coefficient is defined as follows:

$$K_h = \frac{a_{gR} \cdot \gamma_I \cdot S}{g}$$

$$K_v = \pm 0.5 \cdot K_h$$

where:

agR: reference peak acceleration on hard outcropping ground,
γI: importance factor,
S: soil factor, depending on the kind of ground (from A to E).

is the "design ground acceleration on type A ground".

5 Theoretical Notes

5.1 Standards

The Standards that can be chosen for geotechnic and structural calculation are **European Union Eurocodes** and also specific **Italian National legislation** norms as listed below, that may be of relative interest to the non Italian user.

Eurocode 2
Projects involving concrete structures. Part 1-1: General Rules.

Eurocode 7
Geotechnic Projects. Part 1: General Rules.

Eurocode 8
Project guidelines for structural resistance to seismic events. Part 5: Foundations, Retaining structures, and geotechnical aspects.

Italian National legislation:
(quoted from relevant legislation)

NTC 2008
Ministero delle Infrastrutture e Trasporti Norme Tecniche per le Costruzioni marzo 2005.
Ordinanza della Presidenza del Consiglio dei Ministri n. 3274 del 20 marzo 2003 e successive modifiche ed integrazioni:

- Primi elementi in materia di criteri generali per la classificazione sismica del territorio nazionale e di normative tecniche per le costruzioni in zona sismica.
- Allegato 2 – Norme tecniche per il progetto, la valutazione e l'adeguamento sismico degli edifici.
- Allegato 4 – Norme tecniche per il progetto sismico di opere di fondazione e di sostegno dei terreni.

D.M. 11 Marzo 1988
" Norme tecniche riguardanti le indagini sui terreni e sulle rocce, la stabilità dei pendii naturali e delle scarpate, i criteri generali e le prescrizioni per la progettazione e il collaudo delle opere di sostegno delle terre e delle opere di fondazione".

D.M. 9 Gennaio 1996
"Norme tecniche per il calcolo, l'esecuzione ed il collaudo delle strutture in cemento armato, normale e precompresso e per le strutture metalliche".

D.M. 16 Gennaio 1996
"Norme tecniche per le costruzioni in zone sismiche".

STAS 3300-10107/0-90

5.2 Active earth pressure

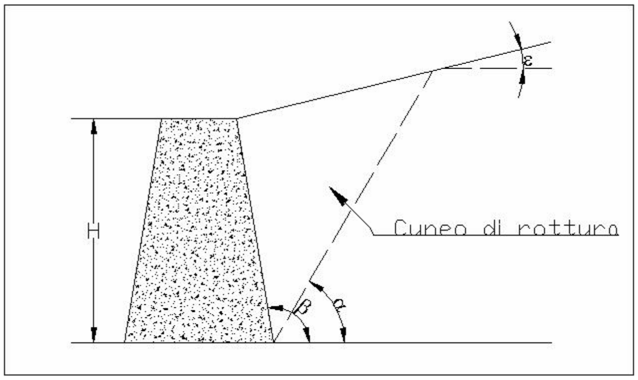
Active thrust calculation using Coulumb's method is based on global limit equilibrium theory of a system whose components are the wall and the wedge of homogeneous terrain behind the work assuming rough surface.
Where terrain is dry and homogeneous the pressure diagram is expressed linearly by the following

$$P_t = K_a \times \gamma_t \times z$$

Thrust S_t is applied at 1/3 H with the value

$$S_t = \frac{1}{2}\gamma H^2 K_a$$

Having :



$$K_a = \frac{\sin^2(\beta-\phi)}{\sin^2\beta \times \sin^2(\beta+\delta) \times \left[1+\sqrt{\frac{\sin(\delta+\phi)\times\sin(\phi-\varepsilon)}{\sin(\beta+\delta)\times\sin(\beta-\varepsilon)}}\right]^2}$$

Limit value of K_A:

$$\delta < (\beta - \phi - \varepsilon) \quad \text{according to Muller-Breslau}$$

γ_t = Terrain unit volume weight
β = Inside wall surface inclination to horizontal plane of footing;
ϕ = Terrain shear resistance angle;
δ = Angle of friction terrain to wall.
ε = Field level inclination to horizontal - Positive if anticlockwise;
H = Wall height.

Active thrust calculation according to Rankine

If $\varepsilon = \delta = 0$ e $\beta = 90°$ (wall with smooth surface and backfill with horizontal surface) thrust S_t is simplified to:

$$S_t = \frac{\gamma \cdot H^2 (1 - \sin\phi)}{2(1 + \sin\phi)} = \frac{\gamma \cdot H^2}{2} tg\left(45 - \frac{\phi}{2}\right)$$

(tg=tan)

that coincides with Rankine's equation that gives active thrust where backfill is horizontal.
Effectively Rankine used the same hypothesis as Coulumb except that he ignored wall-terrain friction and cohesion. Rankine's expression for Ka in general form is as follows:

$$K_a = \cos\varepsilon \frac{\cos\varepsilon - \sqrt{\cos^2\varepsilon - \cos^2\phi}}{\cos\varepsilon + \sqrt{\cos^2\varepsilon - \cos^2\phi}}$$

Active thrust calculation according to Mononobe & Okabe

Mononobe & Okabe's evaluation of active thrust concerns thrust in seismic states with pseudo static method. This is based on global limit equilibrium theory of a system whose components are the wall and the wedge of homogeneous terrain behind the work in an artificial configuration in which both field level inclination and the angle b - inclination of internal wall surface to horizontal -are increased by an amount q such that:

$$tg\ \theta = k_h/(1 \pm k_v)$$

where $\mathbf{k_h}$ is the horizontal seismic coefficient and $\mathbf{k_v}$ the vertical.
Where no specific studies exist coefficients k_h & k_v should be calculated as:

$$k_h = S{\cdot}a_g/r \qquad k_v = 0{,}5\ k_h$$

where $S{\cdot}a_g$ is the maximum seismic acceleration in the various categories in the

stratigraphic profile.
Factor r can take the value 2 where the work is one of some flexibility (e. g. gravity walls). In all other cases (Stiff concrete walls, On piles, Fixed head)) it should be set to 1.

Effect due to cohesion
Cohesion introduces negative constant pressures as:

$$P_c = -2 \cdot c \cdot \sqrt{K_a}$$

As it is not possible to calculate a priori the thrust reduction caused by cohesion a critical height Z_C has been calculated as:

$$Z_c = \frac{2 \times c}{\gamma} \times \frac{1}{\sqrt{K_a}} - \frac{Q \times \frac{\sin\beta}{\sin(\beta + \varepsilon)}}{\gamma}$$

where:

Q = Loads acting on the backfill.

If Z_c<0 the effect may be applied directly as a decrease whose value is:

$$S_C = P_C \cdot H$$

applied at H/2.

Uniform load on backfill
A load Q, uniformly distributed on the backfill generates constant pressures as:

$$P_q = K_A \times Q \times \mathrm{sen}\beta / \mathrm{sen}(\beta + \varepsilon)$$

Integrating, a thrust S_q:

$$S_q = K_a \cdot Q \cdot H \frac{\sin\beta}{\sin(\beta + \varepsilon)}$$

Applies at H/2, indicating as K_a the Muller-Breslau active thrust coefficient.

Active thrust in seismic state
In seimic state the calculation force exercised by the backfill on the wall is given by:

$$E_d = \frac{1}{2}\gamma(1 \pm k_v)K \cdot H^2 + E_{ws} + E_{wd}$$

where:

H = wall height
k_v = vertical seimic coefficient
γ = terrain unit volume weight
K = total thrust coefficient (static + dynamic)
E_{ws} = hydrostatic water thrust
E_{wd} = hydrodynamic thrust

For impermeable terrains, hydrodynamic thrust E_{wd} = 0, but a correction on evaluation of the angle q in Mononobe & Okabe's formula is made as follows:

$$tg\vartheta = \frac{\gamma_{sat}}{\gamma_{sat} - \gamma_w} \cdot \frac{k_h}{1 \pm k_v}$$

In highly permeable terrain in seismic states, the same correction is applied but hydrodynamic thrust assumes the following value:

$$E_{wd} = \frac{7}{12} k_h \gamma_w H'^2$$

where H' is the height of the groundwater tables(Gwt) from the base of the wall.

Hydrostatic thrust
Gwt whose surfac is at height H_w from the base of the wall generates hydrostatic pressures normal to its surface that at depth z are expressed as:

$$P_w(z) = \gamma_w \times z$$

Resulting as:

$$S_w = 1/2 \times \gamma_w \times H^2$$

Thrust of submeged terrain can be obtained substituting γ_t by $\gamma'_t(\gamma'_t = \gamma_{saturo} - \gamma_w)$, effective weight of submerged material.

Passive resistance
In homogeneous terrain a linear diagram of pressures results:

$$P_t = K_p \times \gamma_t \times z$$

integrating with passive thrust:

$$S_p = \frac{1}{2} \cdot \gamma \cdot H^2 \cdot K_p$$

having:

$$K_p = \frac{\sin^2(\phi+\beta)}{\sin^2\beta \times \sin(\beta-\delta) \times \left[1 - \sqrt{\frac{\sin(\delta+\phi) \times \sin(\phi+\varepsilon)}{\sin(\beta-\delta) \times \sin(\beta-\varepsilon)}}\right]^2}$$

(Muller-Breslau) with d limit values at:

$$\delta < \beta - \phi - \varepsilon$$

The expression for K_p according to Rankine assumes the following form:

$$K_p = \frac{\cos\varepsilon + \sqrt{\cos^2\varepsilon - \cos^2\phi}}{\cos\varepsilon - \sqrt{\cos^2\varepsilon - \cos^2\phi}}$$

5.3 Soil limit load

Brich - Hansen (EC 7 – EC 8)

In order that a foundation may safely sustain the projected load in regard to general rupture for all combinations of load relative to the ultimate limit state, the following must be satisfied:

$$V_d \leq R_d$$

where:

V_d is the project load at ultimate limit state normal to the footing, including the weight of the foundation itself;

R_d is the projected foundation ultimate limit load for normal loads, also taking into account eccentric and inclined loads. When estimating Rd for fine grained soils short and long term situations should be considered.

Limit load in drained conditions is calculated by:

$$\frac{R}{A'} = (2 + \pi) c_u \times s_c \times i_c + q$$

where:

$A' = B' \cdot L'$	Project effective foundation area. There where eccentric loads are involved, use the reduced area at whose center the load is applied.
c_u	Undrained cohesion.

q	Total lithostatic pressure on footing.
s_c	Foundation shape factor.
$s_c = 1 + 0.2\left(\frac{B'}{L'}\right)$	Rectangular shapes.
$s_c = 1.2$	Square or circular shapes.
$i_c = 0.5\left(1 + \sqrt{1 - H/A' \cdot c_u}\right)$	Correction factor for inclination of load H.

Project limit load in drained conditions is calculated as follows:

$$\frac{R}{A'} = c' \times N_c \times s_c \times i_c + q' \times N_q \times s_q \times i_q + 0.5 \times \gamma' \times B' \times N_\gamma \times s_\gamma \times i_\gamma$$

where:

$$N_q = e^{\pi \tan\varphi'} \tan^2\left(45 + \frac{\varphi'}{2}\right)$$

$$N_c = (N_q - 1)\cot\varphi'$$

$$N_\gamma = 2(N_q + 1)\tan\varphi'$$

Form factors

$$s_q = 1 + \left(\frac{B'}{L'}\right)\mathrm{sen}\varphi'$$ Rectangular shape

$$s_q = 1 + \mathrm{sen}\varphi'$$ Square or circular shape

$s_\gamma = 1 - 0.3\left(\frac{B'}{L'}\right)$ Rectangular shape

$s_\gamma = 0.7$ Square or circular shape

$s_c = (s_q \cdot N_q - 1)/(N_q - 1)$ Rectangular, square, or circular shape

Resultant inclination factors due to an horizontal load, H parallel to L'

$$i_q = i_\gamma = 1 - H/(V + A' \cdot c' \cdot \cot\varphi')$$
$$i_c = (i_q \cdot N_q - 1)/(N_q - 1)$$

Resultant inclination factors due to an horizontal load, H parallel to B'

$$i_q = \left[1 - 0.7H/(V + A' \cdot c' \cdot \cot\varphi')\right]^3$$
$$i_\gamma = \left[1 - H/(V + A' \cdot c' \cdot \cot\varphi')\right]^3$$
$$i_c = (i_q \cdot N_q - 1)/(N_q - 1)$$

Beside the factors enumerated above, the following are also taken into account: Complementary of footing depth. of footing inclination and of field level inclination (Hansen).

5.4 Pile limit load

Sign convention

1. Vertical force $F_{y'}$ is positive when directed downwards;
2. Horizontal force F_x is positive when directed towards the right;
3. Couple M is positive when acting to produce movements such as those produced by horizontal force F_x.

Winkler model analysis of pile in operating status

Winkler's model enables variations in mechanical properties of terrain and layers to be

taken into consideration simply.
Where material is homogeneous (K constant) Hetènyi's classification is adopted that defines three different pile behaviour for Winkler depending on relative terrain rigidity (l) soil/pile that is: short or rigid pile, relatively flexible pile, infinitely flexible pile.

Limit vertical load

Limit vertical load is calculated with static formulas that express it in function of pile geometry, of terrain properties and of the interface pile soil.
For the purposes of calculation limit load Q_{lim} is conventionally apportioned in two parts: tip resistance Q_p and lateral resistance Q_s.

Tip resistance

Tip resistance q_p where the terrain displays friction (j) e cohesion (c), is give by:

$$q_p = c \times N_c + \gamma \times D \times N_q$$

where:

γ = Terrain unit volume weight
D = Pile length;
$\mathbf{N_c}$ & $\mathbf{N_q}$ = Bearing capacity factors including form factor (circular).

Factor $\mathbf{N_q}$ is calculated according to Berezantzev.

Stem resistance

Lateral bearing capacity is calculated using method A proposed by Tomlinson (1971) according to the following:

$$f_s = A \times c + q \times K \times tg\ \delta$$

c = Average cohesion value (or shear resistance in undrained conditions).
q = Effective vertical pressure of the terrain.
k = Coefficient of horizontal thrust. This depends on the technique of the pile and on the previous compaction state and is calculated as:

For driven piles	$K = 1 + tg^2\phi$
For drilled piles	$K = 1 - tg^2\phi$

δ = Pile/soil friction coefficient as function of pile surface.

For driven piles	$\delta = 3/4 \times tg\ \phi$
For drilled piles	$\delta = tg\ \phi$

α is a coefficient as below:

Driven pile coefficient

$c < 0.25$	$\alpha = 1.00$
$0.25 < c < 0.5$	$\alpha = 0.85$
$0.5 < c < 0.75$	$\alpha = 0.65$
$0.75 < c < 2.4$	$\alpha = 0.50$
$c > 2.4$	$\alpha = 1.2 / c$

Drilled pile coefficient

$c < 0.25$	$\alpha = 0.9$
$0.25 < c < 0.5$	$\alpha = 0.8$
$0.5 < c < 0.75$	$\alpha = 0.6$
$0.75 < c < 2$	$\alpha = 0.4$
$c > 2$	$\alpha = 0.8 / c$

Further according to Okamoto guidelines where seismic state occurs lateral resistance ie reduced depending on the seismic coefficient k_h as follows:

$$C_{oeffrid} = 1 - k_h$$

Finally:

1. For driven piles both resistance properties (c, j) and the coefficient of the terrain horizontal modulus are reduced by 10%.

2. Where drag action is encountered, tip load is null and lateral load is reduced by 70%.

3. In the vertical safety margin the weight of the pile has been taken into account.

Settlements

Vertical settlements are calculated using the Davis-Poulos method, according to which the pile is considered as rigid (undeformable) embedded in an elastic medium, semi space, or layer of finite thickness.
The hypothesis considers that the interaction between pile and soil is constant for each (n) cylindrical segments in which the pile side surface is subdivided.
The settlement of the i th surface due to the load transmitted by the pile to the soil along the j th surface may be expressed as:

$$W_{i,j} = (\tau_j / E) \times B \times I_{i,j}$$

where:

τ_j = Increment in tension at the mid point of the segment;
E = Elastic modulus of the terrain;
B = Diameter of the pile;
$I_{i,j}$= Influence coefficient.

Total settlement is obtained by the sum of $W_{i,j}$ for all j areas.

5.5 Global Stability

Global stability determines the safety factor of the joint wall, backfill complex, in regard to slide along possible failure surfaces.
The safety factor according to the ordinary strip method may be expressed by:

$$F_s = \frac{\sum c \cdot l + \sum \left[(W + Q + F) \cdot \cos\alpha - K_s (W + Q + F) \cdot \sin\alpha + F_0 \sin\alpha \cdot l \cdot u \right] \cdot tg\phi}{\sum \left[(W + Q + F) \cdot \sin\alpha + K_s (W + Q + F) \cdot {e_s}/{r_0} \right] - \sum \left(F_0 \cdot {e_t}/{r_0} \right)}$$

where:

W = typical slice weight;
Q = distributed load;
F = point load;
$K_s \times W$ = inertial force;
K_s **=** Seismic intensity coefficient;
l = length of typical slice base;
α = slice base angle to horizontal;
c = terrain cohesion;
ϕ = terrain shear resistance angle;
r_o **=** radius of typical slip surface;
u = gwt generated pressure;
F_o= tieback horizontal load generated by tiebacks;
e_t **=** anchorage force eccentricity in respect of centre of rotation;
e_s **=** seismic forces eccentricity in respect of centre of rotation.

6 Contact

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