Static Probing

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1 GeoStru Software

The GeoStru Software company develops technical and professional software for geotechnical engineering, civil engineering, geology, geomechanics, hydrology, soil testing, geophysics.

Thanks to GeoStru Software you can now use the most effective tools for your own profession. The GeoStru software represents a complete, reliable (the computation algorithms are the most technologically advanced in the research field worldwide), regularly updated, easy to use tool with an intuitive user interface.

Attention to customer service and the development of software using modern technologies allowed us to become one of the strongest companies in the field on international markets. The software – currently translated into eight languages – is compatible with international computation rules / normatives and it is one of the most used in over 50 countries worldwide.

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Today working with GeoStru is more than just buying software – it means having beside you a team of professionals willing to share their knowledge and experience for excellent results.

There are many areas where the company has specialized in over the years.

The family of GeoStru products is, in fact, divided into several categories:

- ➢ Structures
- ➢ Geotechnics and geology
- ➢ Geomechanics
- ➢ In situ soil tests
- ➢ Hydrology and Hydraulics
- ➢ Topography
- ➢ Energy
- ➢ Geophysics

➢ Office

For further information about our products please visit our website
http://www.geostru.com

Among the many services offered by GeoStru Software you can use the free service GeoStru Online that includes software applications on the web that will help you solve many different problems.

ISO 9001:2008 certification
CVI Italia s.r.l. awarded GeoStru Software the UNI EN ISO 9001 company certification on 1st June 2009, certificate no. 7007, for software design and sale.

1.1   Autoupdate

The software comes with an integrated auto-update system.

A few seconds after opening the software, by moving the mouse pointer on the indication of version (shown in the bottom right side of the main window: Geostru _._._._), the user can check whether or not it is available an update of the software.
If a message will warn the user about the availability of an updated version, the user can automatically update the software by clicking on the icon of the message.
In the event that there are no updates available, the message shown will be ''No updates available.''

1.2   Copyright

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1.3   Customer technical support service

For any queries regarding a GeoStru product:

- Consult the documentation and other printed material
- Consult the Help OnLine section
- Consult the technical documentation used for software development (Web Site)
- Consult the FAQ area (Web Site)
- Consult the GeoStru support services (Web Site)

It is active the new ticket support service developed by GeoStru Software in order to respond to our users support requests.

This service, reserved to registered users and owners of valid licenses, allows you to get answers to your requests regarding different aspects of your programs directly from our specialists (Web Site).

Web Site: www.geostru.com

1.4   Contact

Skype ID: geostru_support_it-eng-spa

Web: www.geostru.com

E-mail: geostru@geostru.com

See the contact page on the website for more information about our contacts and offices' addresses in Italy and abroad.

2 Utility

2.1 Conversion Tables

✦ Converting slope inclination into degrees and vice versa

Inclination (%)	Angle (°)	Inclination (%)	Angle (°)
1	0.5729	26	14.5742
2	1.1458	27	15.1096
3	1.7184	28	15.6422
4	2.2906	29	16.1722
5	2.8624	30	16.6992
6	3.4336	31	17.2234
7	4.0042	32	17.7447
8	4.5739	33	18.2629
9	5.1428	34	18.7780
10	5.7106	35	19.2900
11	6.2773	36	19.7989
12	6.8428	37	20.3045
13	7.4069	38	20.8068
14	7.9696	39	21.3058
15	8.5308	40	21.8014
16	9.0903	41	22.2936
17	9.6480	42	22.7824
18	10.2040	43	23.2677
19	10.7580	44	23.7495
20	11.3099	45	24.2277
21	11.8598	46	24.7024
22	12.4074	47	25.1735
23	12.9528	48	25.6410
24	13.4957	49	26.1049
25	14.0362	50	26.5651

✤ Forces conversion

From	To	Operation	Factor
N	kg	Divide by	9.8
kN	kg	Multiply by	102
kN	Tone	Divide by	9.8
kg	N	Multiply by	9.8
kg	kN	Divide by	102
Tone	kN	Multiply by	9.8

1 Newton (N) = 1/9.81 Kg = 0.102 Kg ; 1 kN = 1000 N

✤ Pressures conversion

From	To	Operation	Factor
$Tons/m^2$	kg/cm^2	Divide by	10
kg/m^2	kg/cm^2	Divide by	10000
Pa	kg/cm^2	Divide by	98000
kPa	kg/cm^2	Divide by	98
Mpa	kg/cm^2	Multiply by	10.2
kPa	kg/m^2	Multiply by	102
Mpa	kg/m^2	Multiply by	102000

1 Pascal (Pa) = 1 Newton/mq ; 1 kPa = 1000 Pa

2.2   Database of soil physical characteristics

Soil	Minimum value	Maximum value
Loose sand	0.48	1.60
Average compact sand	0.96	8.00
Compact sand	6.40	12.80
Average compact clayey sand	2.40	4.80
Average compact silty sand	2.40	4.80
Compact sand and gravel	10.00	30.00
Calyey soil with qu< 2 Kg/cm²	1.20	2.40

Soil	Minimum value	Maximum value
Calyey soil with 2< qu< 4 Kg/cm²	2.20	4.80
Calyey soil with qu> 2 Kg/cm²	>4.80	

Approximate values of Winkler's constant K in Kg/cm³

Soil	Minimum value	Maximum value
Dry gravel	1800	2000
Wet gravel	1900	2100
Compact dry sand	1700	2000
Compact wet sand	1900	2100
Loose dry sand	1500	1800
Loose wet sand	1600	1900
Sandy clay	1800	2200
Hard clay	2000	2100
Semisolid clay	1900	1950
Soft clay	1800	1850
Peat	1000	1100

Approximate values of the volume weight in Kg/cm³

Soil	Minimum value	Maximum value
Compact gravel	35	35
Loose gravel	34	35
Compact sand	35	45
Loose sand	25	35
Sandy marl	22	29
Fat marl	16	22
Fat clay	0	30
Sandy clay	16	28
Silt	20	27

Approximate values of the friction angle j, in degrees, for soils

Soil	Value
Sandy clay	0.20
Soft clay	0.10
Plastic clay	0.25
Semisolid clay	0.50
Solid clay	1
Tenacious clay	2÷10

Soil	Value
Compact silt	0.10

Approximate values of cohesion in Kg/cm²

Soil	Maximum value of E	Minimum value of E
Very soft clay	153	20.4
Soft clay	255	51
Medium clay	510	153
Hard clay	1020	510
Sandy clay	2550	255
Loess	612	153
Silty sand	204	51
Loose sand	255	102
Compact sand	816	510
Clayey schist	51000	1530
Silt	204	20.4
Loose sand and gravel	1530	510
Compact sand and gravel	2040	1020

Approximate values of the elastic module, in Kg/cm², for soils

Soil	Maximum value of n	Minimum value of n
Saturated clay	0.5	0.4
Not saturated clay	0.3	0.1
Sandy clay	0.3	0.2
Silt	0.35	0.3
Sand	1.0	-0.1
Gravelly sand commonly used	0.4	0.3
Loess	0.3	0.1
Ice	0.36	
Concrete	0.15	

Approximate values of the Poisson's ratio for soils

Rock	Minimum value	Maximum value
Pumice	500	1100
Volcanic tuff	1100	1750
Tufaceous limestone	1120	2000
Coarse sand dry	1400	1500

Rock	Minimum value	Maximum value
Fine dry sand	1400	1600
Wet fine sand	1900	2000
Sandstone	1800	2700
Dry clay	2000	2250
Soft limestone	2000	2400
Travertine	2200	2500
Dolomite	2300	2850
Compact limestone	2400	2700
Trachyte	2400	2800
Porphyry	2450	2700
Gneiss	2500	2700
Serpentine	2500	2750
Granite	2550	2900
Marble	2700	2750
Syenite	2700	3000
Diorite	2750	3000
Basalt	2750	3100

Approximate values of specific weight for some rocks in Kg/m³

Rock	Minimum value	Maximum value
Granite	45	60
Dolerite	55	60
Basalt	50	55
Sandstone	35	50
Calyey schist	15	30
Limestone	35	50
Quartzite	50	60
Marble	35	50

Approximate values of the friction angle j, in degrees, for rocks

Rock	E		n	
	Maximum value	Minimum value	Maximum value	Minimum value
Basalt	1071000	178500	0.32	0.27
Granite	856800	142800	0.30	0.26
Crystalline schist	856800	71400	0.22	0.18
Limestone	1071000	214200	0.45	0.24
Porous limestone	856800	35700	0.45	0.35
Sandstone	428400	35700	0.45	0.20
Calyey schist	214200	35700	0.45	0.25
Concrete	Variable		0.15	

Approximate values of the elastic module and Poisson's ratio for rocks

2.3   Shortcut commands

The bar shown below can be used for a variety of functionalities:

1) With the shortcut letters of the menu followed by Enter you have quick access to commands.
    Ex: N + Enter to create a new file.

2) You can ask a question followed by ? + Enter. In this a case advanced research will be made in Help .
    Ex.: Seism+?+Enter for information on seismic analysis.

3) Opening a program in a quick way.
    Ex.: Slope+Enter to open GeoStru Slope software.

4) Quick access to GeoStru contacts.
    Ex.: Contact+?+Enter to access the contact list.

5) Quick acces to web features:
    Ex.: www.geostru.com+Enter or geostru@geostru.com. + Enter

This bar can be used as shortcut to some commands.
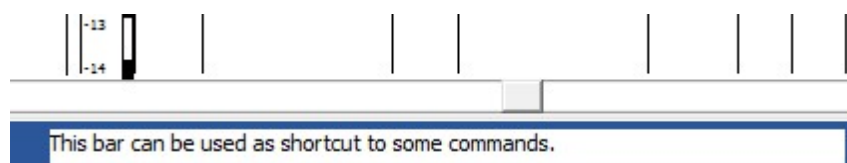
3   Static Probing

Static Probing provides a tool for the recording, management, processing and archiving of readings obtained from static soil penetration tests, in a reactive continuous graphic environment, supported by a database of correlative methods and parameters for the determination of soil types, aimed at the generation of a comprehensive mapping of the subsurface. The graphic display and process support enables the soil to be catalogued, parameterized and compared with adjacent soil tests to gain an insight of the stratigraphy encountered.

The soil penetration test provides fairly precise information regarding the depth of boundary levels in the substrata, depth of water table, breach surfaces on slopes as well as the general consistency of the soil.
The use of the data should be treated with caution and critical discrimination augmented by local geotechnical knowledge.

Interpretation of bar chart

Choosing the type of lithological interpretation (recommended or not depending on the type of penetrometer used) we get an automatic stratigraphy with the step of the instrument and automatic interpolation of the layers. The program also creates the Depth/Lithological evaluations graphic (for various authors), to display directly the stratigraphy along the investigated vertical.

Soil section mapping, tailored to other Geostru software, can be generated for lines connecting test borings.
Penetrometric probes enable fairly accurate evaluations of the depth of lithologic boundaries in the substrata, depth of water table, breach surfaces on slopes as well as the general consistency of the terrain.

3.1 Equipment

This window may be used to select an instrument in the list of the ones in the database, review its characteristics, add those of a new one or remove an existing one. The window may be reached from the *Home > General data* menu.

Three categories of instruments, Mechanical Cone, Electric Cone, and Piezoelectric cone, may be specified, under the headings: CPT, CPTE, CPTU.
Under each category the individual equipment items recorded are listed.
Click on one equipment from the list to select it for use or for editing.

To add a new instrument, right click the root ("*Equipment*" at the top of the list*)*. This enables the "*New*" function that opens a blank window in which the new characteristics may be entered.

To delete an instrument, right click the name. This enables the "*Delete*" function.

As regards the Electric cone generally this instrument allows to obtain continuous data with a very close step (even 2 cm), compared to the

Mechanical cone (20 cm). For the Piezocone data insertion in addition to those of LP and LT are the measured neutral pressure and the dissipation time. This measurement is generally done by measuring the overpressure obtained in the thrust phase and the neutral pressure (dissipation over time) measured at rod thrust lightening (penetration arrest). The program allows to enter U1 - U2 - U3 ie neutral overpressure measured respectively with a porous filter positioned in the cone, around the cone or around the sleeve, depending on the type of piezocone used. This overpressure (that is the sum of the hydrostatic pressure existing before penetration and pore pressures produced by compression) can be positive or negative and generally varies from -1 to max. + 10-20 kg/cm^2 and is produced by compression or expansion of the soil as a result of the penetration. For the calculation in addition to the general instrumental data must be entered for a correction of input values:

Area of the cone tip is the outside tip area.

Internal area of the cone tip (area of the narrowing in the vicinity of the porous septum - internal cone-sleeve). Generally the ratio of the areas varies from (0.70 - 1.00).

Step of the penetrometer is the interval within it performs the reading, generally for normal penetrometers is 20 cm, but can be can be 2 cm for electric cone or piezocone.

The program processes the data of tip and side resistance fs with appropriate corrections due to the normalization (with the lithostatic stress and the pore pressure).

Robertson defines the characteristic value of the Ic (soil behavior type index) and Fine content FC % (ie the percentage of clay content <2 microns).

3.2   Correlations to apply

The program contains a data base of methodologies and data to correlate the observed soil properties to the more significant geotechnical parameters that characterize soils.
For each parameter type a number of different authors may be selected (see *Geotechnical correlations*). By default the program uses a set of

correlations but with expert, or local knowledge, or for explorative aims these can be altered.
To see or alter the selected set open the "*Correlations to apply*" window (*Home > General Data* menu).
The window has a tab for cohesive soils, one for cohesionless soils and one for Vs and within each parameter's evaluation can occur according to different authors.

3.3 General data

Allows the user to assign the general data for the header (Customer, Site, Location, Operator and Manager for the test, Order code and certificates to attach).

⚠ By inserting the location in the format: xxxx street, city, state, country, will be detected automatically the work area. Alternatively, the user can assign the coordinates in decimal degrees in the WGS84 system.
The localization system requires an internet connection.

3.4 Statistical analysis

Enables statistical processing of numerical data in Static Probing using in the calculation of layer's representative values a value less than or greater than the arithmetic average of the layer, and the possible values are:

- Average: Arithmetic average of the tip resistance values on the layer (Default).

- Minimum: Minimum value of the tip resistance values on the layer.

- Maximum value: Maximum value of the tip resistance values on the layer.

- Minimum average: Arithmetic average of values below the average, of the tip resistance values on the layer.

- Average + deviation: Average incremented by average deviation.

- Average – deviation: Average decreased by average deviation.

- Normal distribution R.N.C. - see <u>Characteristic parameters</u>

- Normal distribution R.C. - see <u>Characteristic parameters</u>

3.5   Draw section

Geological sections can be created simply by connecting multiple tests using the mouse. Choose the "*Draw section*" command (*Home > Tests management* menu) and select at least three tests for creating the section. Right click and choose "*Generate section*" command.
The section created can be read directly from Slope software which can be run directly from Static Probing software, or, in case Slope is not available, an additional module for the creation of the sections can be ordered separately.

3.6   Insert new test

The program is based on the graphic entry of the penetration soil tests. To enter them:

1) Select the "*Tests management*" icon
2) Go on the work area
3) Click on the right button of the mouse and then choose
the test type to input and enter the "*General data*"

- *Equipment* - Select the equipment used from the drop down list. (If not present on the list it will be necessary to record its parameters in the <u>*Equipment window*</u> reachable from the General data menu). The choice of instrument controls the format of the data entry grids.

- *Test Id* - Enter an identifying code for the test.

- *X, Y, Z* - X and Y representing the location coordinates are automatically entered but may be altered as required. Z indicates the elevation.

- *Test depth* - Final depth (m) reached by the test.

- *Groundwater* - If any water tables are encountered, initial and final depths may be entered.

- *Test color* - Color to be assigned to the test identifying marker on the worksheet.

4) Right click on the test and choose *Data entry*

5) In "*Data entry*" a series of quick menus are available, among which:

-Right click on the unit weight column for automatic computation of the weight
-Right click on the graphic for a series of functions like input of layers, export, etc.
-To delete a layer select the entire row in the Layer table and press "Delete" key on the keyboard

6) Once the input is finished, go on the test and choose "*Process*"
7) In "*Process*", to choose parameters, go on the grid in upper right corner and press the right button of the mouse.

*The difference between *Process* and *Reprocess* command is the following:

The *Process* command calculates the geotechnical parameters and keeps eventual alterations to them, while the *Reprocess* command recalculates the parameters without keeping eventual alterations made by the user.

3.6.1   Data entry

The readings to be inserted in the program are formed by the tip resistance measured by the probe in the first part of driving in the ground, and from the total value including the tip resistance and lateral resistance (total thrust of the tip and the friction sleeve).

The specific resistance Qc and Ql are derived through appropriate constants and on the basis of specific values of the base tip area and the lateral friction area of the sleeve. More precisely, the terms used are:

- *Tip reading* = first reading of the used equipment
- *Side reading* = second reading of the used equipment (total reading)
- *A* = base area of the probe's cone (ex. 10 cm^2)
- *Am* = area of the friction sleeve (ex. 150 cm^2)
- *K* = transformation constant used to obtain readings in the expected output value
- *Qc (RP)* = (Tip reading x K) / A   Tip resistance
- *Ql (RL)* = (Tip reading − Lateral reading) x K) / Am   Lateral resistance

The input data of the test is a pair of values for each reading interval consisting of LP (Tip reading) and LT (Full reading tip + sleeve). The strengths are then derived for difference, also the lateral resistance is counted 20 cm below the elevation of the first tip reading. The input data may be entered in Kg/cm², in T/m, in MPa, in kN/m², in kPa as chosen by the user and can be inserted automatically with a simple copy/paste operation (ex. from Excel).

The output data are therefore RP (tip resistance) and RL (Lateral resistance or fs specific lateral friction that considers the surface of the friction sleeve).

The program automatically calculates, during the input, the values of fs (Fs (specific lateral friction) Lateral Resistance), the ratio RP/RL (Begemann Report 1965), the ratio RL/RP (Schmertmann Report, 1978 (FR)%) .

Choosing the type of lithological interpretation the program automatically offers the stratigraphy with the instrument step and automatic interpolation of the layers.

For each layer the program calculates the average Qc, the average fs, the average natural unit weight, the geotechnical behavior (cohesive, cohessionless or cohesive-cohessionless), and applies a texture.

Cohesive - Cohesionless

Check the appropriate checkbox if you know the type of soil or check both if unsure (the software will perform calculations for both cases).

Stratigraphy on equipment step

Sets the detailed stratigraphy of the user. The command allows to create a stratigraphy with thicknesses equal to the equipment step. After processing it is possible to obtain for each layer defined by the user, a set of values for the geotechnical parameters calculated at intervals equal to the equipment step. These values can be used by the user to evaluate the distribution law of values in order to calculate the characteristic geotechnical parameter.

The command *"Lithologic evaluation graphic"* offers the possibility to view a Depht-Litologic evaluation graphic according to the author selected.

The command "*Instant lithology*" identifies the lithology (cohesive/cohesionless) as the user enters the depth of the layer.

"Dynamic layer search" is a command used to synchronize the stratigraphy on the chart with the grid of the layers below: ie when the user goes with the mouse over a layer of the graphic, this layer is highlighted in the stratigraphy below.

Graphic

When a new test is inserted, data is displayed on a graphical model that shows the identification data of the test, the bar graphic depicting the number of blows at each step, the trend of the tip dynamic resistance, the groundwater table and the lithostratigraphy.

The basic model proposed interacts in the same time with the number of blows entered at each step and the grid in the bottom part of the window, where the management of the stratigraphy is made. Each data entered in the number of blows column is updated on the graphic model, as well as any change performed on the stratigraphy grid is modified on the graphic in the lithostratigraphic column.

The graphical model proposed is manageable from a shortcut menu that is activated with the right mouse button. The options of colors, lines and scale are repeated also in the Preferences menu, item Options.

Observations

Copy-Paste functions allow the user to copy or paste the sequence of data (N° blows) from an Excel spreadsheet to the software Static Probing: they are activated with a right click on the data input columns.

How to insert a layer from the keyboard

Type in the table below the chart (bottom right side in the input window) the depth of the layers.

How to insert a layer with the mouse

Right click on the chart, select the "Insert layer" command, click and enter the corresponding elevation of the layer.

Delete a layer

Select an entire row from the stratigraphy table and press "Delete" key from the keyboard.

3.7 Process test data

3.7.1 Process

In the main window of the software, right click on the test to be processed and choose "Process" command. This procedure enables automatic processing of penetration data and offers the relevant lithological parameters (see Geotechnical correlations) for each layer, based on the options made in "Correlations to apply". The correlations used are indicated by red highlight in the left pane. The values are derived also according to the choices made in the Statistical analysis drop down list.

Correlations applied depend on whether the layer is considered cohesive or cohesionless. In layers where this distinction could not be determined, both types of correlations are applied. The user has the possibility to control this treatment by altering the value of the specific columns in the stratigraphy grid in "Data Entry" window.
The correlations used for this test are 'attached' to the test and will be reused for every later use of this command on this test. Thus any subsequent change in "Correlations to apply" list will not affect the result of this command on this test.

If after processing is completed, it is desired to either view the result of another correlation author/method or apply that correlation to selected layers please proceed as follows:

1. Click the new correlation type from the list in the left hand pane, and note the results in the computation results pane above the report pane.
   The new result is merely shown in the computation pane.
2. At this point it is possible to apply this new result to the test and update the report preview. Applying it will thereafter permanently

modify the set of correlations. To apply the new result and method, select the layer in the computation result pane and execute the floating menu command (right mouse click) "Send correlation to print page".

Thereafter it is this amended correlation set that is associated with the test and will be reused every time "Process" command is called.
Note the significant difference in operation of "Reprocess" which performs process as if it was a first time use.

3.7.2   Reprocess

⚠ *"Reprocess" command resets the set of correlations for the test to the current choices in the list of "Correlations to apply" thus replacing any previous ones.*

To perform the command,right click on the test of interest and choose "*Reprocess*".
The correlations used are those selected in "*Correlations to apply*" of the "*General data*" menu and are highlighted in red in the list on the left.

3.7.3   Soil classification from correlations

In the soil determination phase the software loads automatically the data of the current test. If a stratigraphy was defined in the current test, the software automatically determines: Depth, Description, Qc, fs, Type (cohesive, cohesionless or cohesive-cohesionless), Author, Vs and Cu.

The automatic loaded data can be altered independently of the data from the current test.

Geotechnical parameters
The geotechnical parameters necessary for the soil classification are calculated in this window..
They can also be assigned by the user and the program determines the soil category.

In the Soil Category Range table the minimum and maximum values of the geotechnical parameters that determine the soil category can be set.

3.7.4   Soil classification from seismic tests

## Static seismic piezocone penetration test (SCPTU)

Using the seismic piezocone we have available a very quick and inexpensive way to determine: detailed stratigraphy, geotechnical parameters and velocity of shear waves.

The seismic piezocone allows you to determine in the same time the parameters of a static penetration test (qc, fs, U) and also the shear wave velocity (Vs). It consists of triaxial geophones, orthogonal between them according to the directions X, Y and Z.

The use of two accelerometers positioned orthogonally between them allows to acquire a significant seismic wave signal regardless of the orientation of the probe (during drilling is not possible to maintain an orientation).

The energizing system must generate predominantly shear waves in large amplitude with few compression components .
The analysis of the signal is made by charting individual signals recorded by the triaxial geophones.
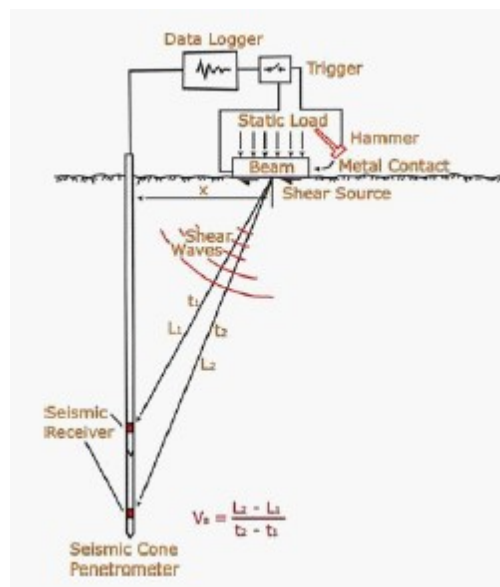
For the calculation of the arrival times it can be used the cross-over method of superposition of two polarized signals.
From the values of the arrival times were calculated the Vs relative to the source-geophone segment and then the Vs in the lithologycal level.

For the classification of the ground reference is made to the parameter Vs30 corresponding to the velocity of shear waves in the first 30 meters.

$$V_{s30} = \frac{30}{\sum_{(i=1,N)} \frac{h_i}{V_i}}$$

Where hi and Vi indicate the thickness and the velocity of shear waves for N layers present in 30 meters.

3.7.5   Bearing capacity and settlements

Shallow foundations

This function enables the computation of limit and allowable bearing capacity of shallow foundations according to the following authors:

- Terzaghi & Peck
- Meyerhof
- Schmertmann
- Herminier

Deep foundations (Driven piles)

This function calculates the bearing capacity of deep foundations (Driven piles) in tons, using Meyerhof's method, that uses the similarities in behaviour of the penetrometer probe drive with that of driven piles.

3.8   Raster images

Raster images can be imported to overlay the worksheet, in order that the drawing may be set in relation to some previously established mapping or imaging. To this end three commands are available:

Import raster image

Opens a file open window to enable the path and identity of the file (*.jpg or *.bmp) to be imported. Calibration and positioning may be defined as well.

Calibrate raster image

Normally the import of an image applies the stated scale to map the image to the worksheet that is displaying a down zoomed real scale and no further action is required. This function can be applied if the result of

applying the nominal scale to the image, seems to diverge from real observed dimensions for whatever reason. In this case enter the observed dimension and the rendered dimension in the image (Use Dimensions command to. retrieve) and its position on worksheet to again adjust the image.

Delete raster image
Removes the image background from the worksheet.

3.9   Output

Graphic report
Print of diagrams related to a test (the print preview includes graphic options that can help you modify existing settings).

Print preferences
Allows the user to choose what results to include in the print report.

Readings
Print only the input data of the tests entered.

Processing by author
Print the processing result for each test as a function of an author selected from the correlations available.

Process with all authors
Print the processing result for each test considering all available correlations.

Export DXF
Export the current window in *.DXF format.

3.10   Theoretical notes

3.10.1 Geotechnical correlations

Hundreds of geotechnical correlations for Cohessionless and Cohesive soils.

3.10.1.1 Cohesionless soils

3.10.1.1.1 Angle of friction

Durgunouglu-Mitchell (1973-1975)
- For non cemented N.C. & S.C. sand.

Meyerhof (1951)
- For N.C. & S.C. sand.

Caquot
- For non cemented N.C. & S.C. sand and for depths > 2 m in saturated soils or > 1 m in non saturated soils.

Koppejan
- For non cemented N.C. & S.C. sand. and for depths > 2 m in saturated soils or > 1 m in non saturated soils.

De Beer (1965-1967)
- For non cemented N.C. & S.C. sand. and for depths > 2 m in saturated soils or > 1 m in non saturated soils.

Robertson & Campanella (1983)
- For non cemented quartzy sand.

Schmertmann (1977-1982)
- Diverse soils (This correlation generally gives an overestimate).

3.10.1.1.2 Relative density

Baldi ed all (1978-1983) - Schmertmann (1976)
- For NC uncemented sand.

Schmertmann

Harman (1976)

Lancellotta (1983)

Jamiolkowski (1985)

Larsson (1995)
- For homogeneous ungraded sand.

3.10.1.1.3 Young's modulus

Schmertmann (1970-1978) (Ey 25 –50)

25% & 50% shear value – first phase of load/deformation curve

Parkin ed al. (1980)
- For NC and SC sands

Robertson & Campanella (1983)
- For quartzy NC sand.

ISOPT-1 (1988)
- For OCR sand.

3.10.1.1.4 Oedometric modulus

Robertson & Campanella from *Schmertmann*

Lunne-Christoffersen (1983) - Robertson and Powell (1997)
- For NC sands

Kulhawy-Mayne (1990)

Mitchell & Gardner (1975)

Buisman - Sanglerat

ENEL - CRIS ed al. (1983)

Chapman & Donald (1981)

3.10.1.1.5 Unit weight

Unit weight

- For loose sand and dense sand.

Saturated unit weight
- For loose sand and dense sand.

3.10.1.1.6 Shear deformation modulus

Ohsaki & Iwasaki
- Valid for fine plastic sand or clean sand.

Robertson & Campanella (1983) Imai & Tonouchi (1982)
- Valid mainly for sand and for lithostatic tension from 0,5
  - 4,0 kg/cm^2.

3.10.1.1.7 Liquefaction potential

Applies to soils below phreatic level submitted to seismic acceleration.
This function verifies liquefaction for cohesionless soils (*Robertson & Wride 1997* – CNR – GNDT) Safety factor related to various seismic zones I II III IV cat.

N.B. Liquefaction is absent for Fs >= 1,25, possible for Fs = 1,0 – 1,25 and very probable for Fs< 1.

3.10.1.1.8 Consolidation coefficient Cv

Consolidation coefficient Cv (*Piacentini-Righi, 1988*).

3.10.1.1.9 Permeability

Permeability coefficient K (*Piacentini-Righi, 1988*).

3.10.1.2 Cohesive soils

3.10.1.2.1 Undrained cohesion

Lunne & Eide

Sunda (experimental report)

Lunne T.-Kleven A. (1981)

Kjekstad (1978) - *Lunne, Robertson and Powell (1977)*

Terzaghi – minimum value

Begemann

De Beer - Applicable to light cohesion

Baligh et al. (1976-1980)
In this evaluation the value of Nk must be entered (generally variable from 11 to 25).

Marsland (1974) - *Marsland and Powell (1979)*

Rolf Larsson SGI (1995)

3.10.1.2.2 Compression index C and consolidation coefficient Cv

Schmertmann (1978)

Piacentini-Righi Inacos (1978)
Compression factor load branch C

Piacentini-Righi Inacos (1978)
Average compression factor load branch Crm

Piacentini-Righi (1988)
Consolidation coefficient Cv

3.10.1.2.3 Oedometric modulus

Mitchell - Gardnerr (1975)
- For silt and clay.

General confined consolidation modulus method.

Buisman
- Correlation valid for silt and average plasticity clay.

Buisman and Sanglerat
- Valid for compacted clays

3.10.1.2.4 Undrained deformation modulus

Cancelli et al. (1980)

Ladd et al. (1977)
Insert value of n where 30 < n < 1500

3.10.1.2.5 Unit weight

Saturated soils, cohesive soils

3.10.1.2.6 OCR

Stress-History

P.W. Mayne (1991)
For clay and over consolidated clay.

Piacentini-Righi Inacos (1978)

Larsson 1991 (S.G.I.)

Jamiolkowski (1979) (cohesive)

Schmertman (1978) (cohesive)

3.10.1.2.7 Permeability

Permeability coefficient K *(Piacentini-Righi, 1988).*

3.10.2 Shear modulus G

The theory of elasticity correlates the shear modulus (G) with the soil density (r) and the velocity of the waves (Vs):

$$G = \rho \times Vs2$$

So the shear modulus is in relation with the velocity of the shear waves.

The shear modulus has higher values for low levels of stress and decreases with increasing shear stress.
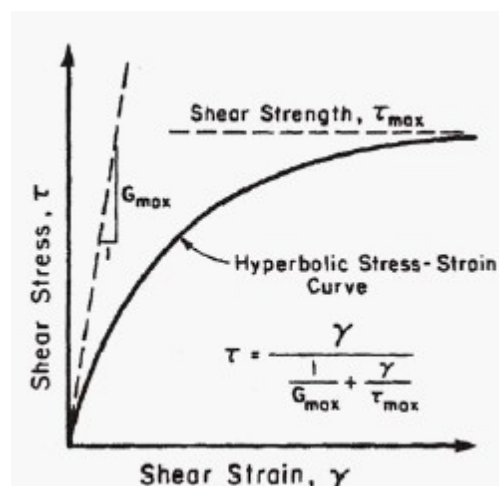
Estimation of shear modulus at low strains (G0) with empirical correlations.

Rix & Stokoe (1991)

$$Go = K \times (qc)^a \times (\sigma'v0)$$

For sands: K=1634; a=0.25; b=0.375

Mayne & Rix (1993)

$$Go = K \times (qc)^a \times (e)^b$$

For clays: K=406; a=0.695; b=-1.13, e: void ratio

3.10.3 Subsoil categories

Once the design seismic action is defined, it becomes necessary to determine the effect of the local seismic response through specific analysis.

In the absence of this analysis, in order to define the seismic action we can refer to a simplified approach, that is based on the determination of the reference subsoil categories. (Tab. 3.2.II and 3.2.III).

Table 3.2.II – Subsoil categories

Category	Description
A	Outcrop rocky mass or very rigid soils characterized by Vs,30 superior to 800 m/s, eventually including in the surface an alteration layer, with a maximum thickness of 3 m
B	Soft rocks and deposits of very dense coarse grain soils or very dense fine grain soils with thickness superior to 30 m, characterized by gradual improvement of the mechanical properties with depth and Vs,30 values between 360 m/s and 800 m/s, (or NSPT,30 > 50 in coarse grain soils and cu,30 > 250 kPa in fine grain soils).
C	Deposits of medium dense coarse grain soils or medium dense fine grain soils with thickness superior to 30 m, characterized by gradual improvement of the mechanical properties with depth and Vs,30 values between 180 m/s and 360 m/s, (or 15 < NSPT,30 < 50 in coarse grain soils and 70 < cu,30 < 250 kPa in fine grain soils).

Cat ego ry	Description
D	Deposits of poor consistency coarse grain soils or poor consistency fine grain soils with thickness superior to 30 m, characterized by gradual improvement of the mechanical properties with depth and Vs,30 inferior to 180 m/s (or NSPT,30 < 15 in coarse grain soils and cu,30 < 70 kPa in fine grain soils)
E	Subsoil terrains of C or D type, with thickness not superior to 20 m, laying on the reference substratum (with Vs > 800 m/s)

The classification is based on the values of the equivalent propagation velocity Vs,30 of the shear waves in the first 30 m of depth.

For shallow foundations and retaining walls made of embankments this depth is considered beginning from the footing of the foundation..

The direct measurement of the propagation velocity of the shear waves is highly recommended. In case this determination is not possible, the classification can be done in base of the values of the equivalent number of blows of the dynamic penetrometric test (Standard Penetration Test) NSPT,30 in soils consisting mostly in coarse grain and in base of the equivalent undrained strength cu,30 in soils consisting mostly in fine grain.

For the soils in the S1 and S2 categories in Tab. 3.2.III specific analysis are required to define the seismic actions, especially when the presence of soils susceptible to liquefaction and/or very sensitive clays can produce soil collapse.

Table 3.2.III – Additional subsoil categories

Cate gory	Description
S1	Deposits of soils characterized by values of Vs,30 inferior to 100 m/s (or 10 < cu,30 < 20 kPa), that include a layer of at least 8 m of poor consistency fine grain soils, or include at least 3 m of peat or clays with high organic content.
S2	Deposits of soils susceptible to liquefaction, of sensitive clays or any other subsoil type that can not be classified in the previous types.

The equivalent velocity of the shear waves Vs,30 is defined by:

$$V_{S,30} = \frac{30}{\sum_{i=1,N}\dfrac{h_i}{V_{S,i}}}\, [m/s]$$

The equivalent dynamic penetrometric strength NSPT,30 is defined by:

$$N_{SPT,30} = \frac{\sum_{i=1,M} h_i}{\sum_{i=1,M}\dfrac{h_i}{N_{SPT,i}}}$$

The equivalent undrained strength cu,30 is defined by:

$$C_{u,30} = \frac{\sum_{i=1,K} h_i}{\sum_{i=1,K}\dfrac{h_i}{C_{u,i}}}$$

In the previous expressions we have indicated with:

hi= thickness (in m) of the i layer comprised in the first 30 m of depth;
VS,i= velocity of the shear waves in the i layer;
NSPT,i= number of NSPT blows in the i layer;
cu,i= undrained strength in the i layer;
N= number of layers comprised in the first 30 m of depth;
M= number of layers of coarse grain terrains comprised in the first 30 m of depth;
K= number of layers of fine grain terrains comprised in the first 30 m of depth;

In case of subsoils formed by stratifications of coarse grain terrains and fine grain terrains, with similar thickness in the first 30 m of depth, included in one of the categories from A to E, and when direct measurements of the shear waves velocity are not available, one can proceed as follows:
 - determine NSPT,30 in the coarse grain terrain layers comprised in the first 30 m of depth;
 - determine cu,30 in the fine grain terrain layers comprised in the first 30 m of depth;
 - determine the categories corresponding to the NSPT,30 and cu,30 parameters;

- refer the subsoil to the worse category.

3.10.4 Characteristic parameters

Characteristic parameters with CVsoils

Static Probing software allows to define two stratigraphies: one established by the user based on the number of blows, the other on instrumental step.

The stratigraphy on instrumental step is very useful as the geotechnical parameters are returned in step, which can be exported from the command *Export to other GeoStru programs*, selecting file xlm for *CVSoil*. These files can be exported for the new GeoStru program, *'CVSoil'*, for the determination of characteristic geotechnical parameters.
In order to perform processing on instrumental step is necessary:

    a) To define in data entry, in addition to stratigraphy user, even the stratigraphy on instrumental step;
    b) To select Elaboration on instrumental step from the shortcut menu of tests.

Characteristic parameters with Static Probing

From the General data menu, qc computation, there is the opportunity to choose how to assess qc in the layer. In addition there is the opportunity to select several options, among them a particular clarification:

Normal distribution R.C.

The value of qc,k is calculated on the basis of a normal or Gaussian distribution, fixed a probability of no exceedance of 5%, according to the following expression:

$$Nspt,_k = Nspt,_{mean} - 1.645 \cdot \left(\sigma_{Nspt} \right) / \sqrt{n}$$

where s_{qc} is the standard deviation of qc.

Normal distribution R.N.C.

The value of qc,k is calculated on the basis of a normal or Gaussian distribution, fixed a probability of no exceedance of 5%, treating mean values of qc normally distributed:

$$Nspt,_k = Nspt,_{mean} - 1.645 \cdot \left(\sigma_{Nspt} \right)$$

where n is the number of samples.

The first distribution gives values near the minimum, whereas the second provides values close to average.

3.10.5 Liquefaction

The method of *Seed & Idriss* (1982) is the most known and used of the simplified methods and requires only the knowledge of few geotechnical parameters: the granulometry, the number of blows in the SPT test, the relative density, the unit weight.

To determine the value of the reducing coefficient *rd* is used the empirical formula proposed by *Iwasaki et al.* (1978):

$$r_d = 1 - 0.015z$$

while for the corrective factor MSF in Table 1 is brought the value of this factor obtained by various researchers, among which *Seed H. B. and Idriss I. M* (1982).

Magnitude	Seed H. B. & Idriss I. M. (1982)
5.5	1.43
6.0	1.32
6.5	1.19
7.0	1.08
7.5	1.00
8.0	0.94
8.5	0.89

Table 1 - Magnitude Scaling Factor

The liquefaction resistance CRR, is calculated as a function of the magnitude, the number of blows, the effective vertical pressure, the relative density.

By selecting the cases of terrains with liquefaction and no liquefaction during the earthquakes, a graphic is obtained.

Initially the correct number of blows at the desired elevation is calculated to take into consideration the lithostatic pressure through the following relation:

$$(N_{1.60}) = C_N \cdot N_m$$

where:

N_m average number of blows in the penetration standard test SPT

C_N corrective factor calculated using the following expression:

$$C_N = \left(\frac{Pa}{\sigma'_{v0}}\right)^{0.5}$$

where:

σ'_{vo} effective vertical pressure;

Pa atmospherical pressure expressed in the same σ'_{vo} units;

n an exponent that depends on the relative density of the soil

It was demonstrated that for an earthquake of a magnitude equal to 7,5 CRR is:

$$CRR \approx \frac{N_{1.60}}{90}$$

Is therefore applied:

$$F_S = \frac{CRR}{CSR}$$

if FS > 1,3 the deposit can not be liquefied

The Authors have specified that this procedure is valid for sand with D50 > 0,25 mm; for sandy silt and silts they suggest to correct afterwards the value of $N_{1,60}$:

$$\left(N_{1.60}\right)_{CS} = N_{1.60} + 7.5$$

3.11   Geoapp

Geoapp: the largest web suite for online calculations

The applications present in Geostru Geoapp were created to support the worker for the solution of multiple professional cases.

Geoapp includes over 40 applications for: Engineering, Geology, Geophysics, Hydrology and Hydraulics.

Most of the applications are free, others require a monthly or annual subscription.

Having a subscription means:

- access to the apps from everywhere and every device;
- saving files in cloud and locally;
- reopening files for further elaborations;
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- access to the newest versions and features;
- support service throught Tickets.

3.11.1 Geoapp Section

General and Engineering, Geotechnics and Geology

Among the applications present, a wide range can be used for Static. For this purpose, the following applications are recommended:

- ➢ NSPT Form
- ➢ Horizontal reaction coefficient of foundation piles
- ➢ Load test on poles
- ➢ Liquefaction (Boulanger 2014)
- ➢ Reinforced earth
- ➢ Soil Classification
- ➢ Bearing capacity
- ➢ Lithostatic tensions

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