# NovoCPT User's Manual (Novo Tech Software Ltd.)

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# 1. About

| | |
|---|---|
| Software : | **NovoCPT** |
| First Release : | September 2009 |
| Licensing Model : | License File, On-demand |
| Programming : | Alireza Afkhami (M.A.Sc, M.C.P, P.Eng) |
| Similar Programs : | - |
| Updates : | click to open |
| Disclaimer : | click to read(See 3.) |

NovoCPT is designed and developed for interpretation of Cone Penetration Test data. User can import CPT data files into the program and carry out the engineering analysis in order to estimate more than 35 soil parameters. Please keep your software up-to-date by visiting the program's web page.

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NovoTech software

North Vancouver, BC, Canada

## 2. References

1- Cone Penetration Testing In Geotechnical Practice
T. Lunne, P.K. Robertson and J.J.M. Powell, 1996

2- Calibration of Liquefaction Potential Index for Assessment and Mapping of Liquefaction Hazards
C. Hsein Juang

3- Engineering Design Using the Cone Penetration Test
Paul W. Mayne

4- Guide to Cone Penetration Testing (3rd edition: January 2009)
P.K. Robertson, K.L. Cabal

5- Guide to Cone Penetration Testing (4th edition: July 2010)
P.K. Robertson, K.L. Cabal

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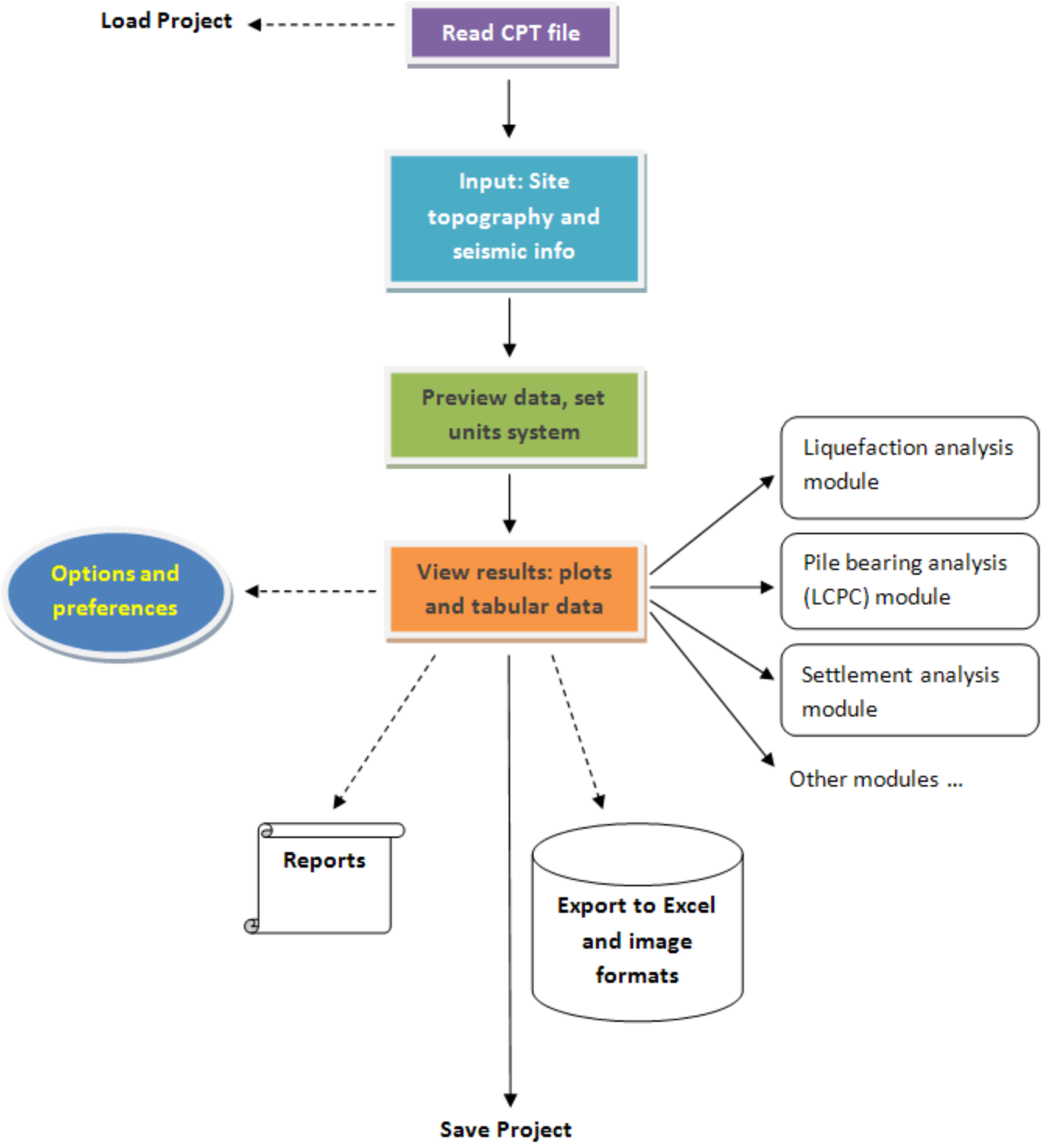
# 4. Contents

## 4.1 Introduction to NovoCPT

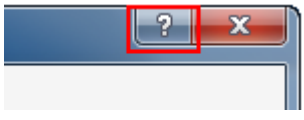
This computer program is designed for processing cone penetration test data and performing interpretations of raw data to probe the soil behavior and estimate soil physical and mechanical properties. It should be noted that due to complexity of CPT test and wide variety of available methods of interpretations, user should completely be aware of soil mechanics concepts behind any method chosen and used in NovoCPT. We recommend reading the references(See 2.) used in designing and development of this software.

The following steps are necessary for cone penetration test processing in NovoCPT program:




## 4.2 Using Help

### Activating Help

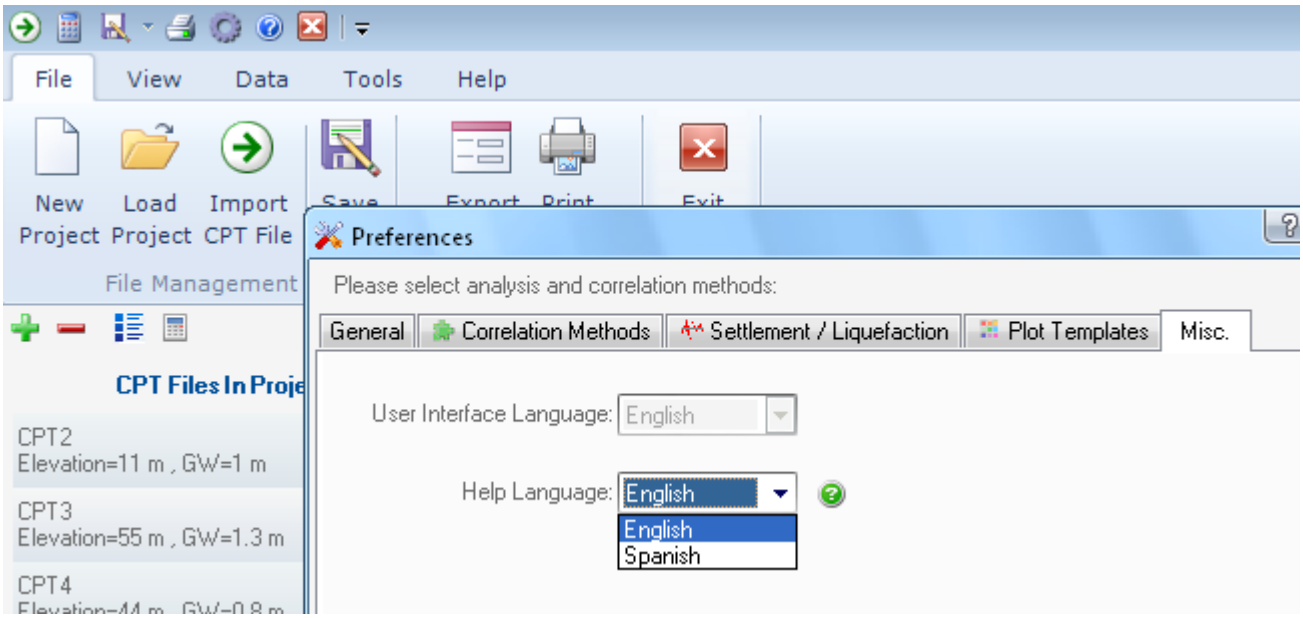


Help button is placed at the top-right corner of all pages, as shown on this screenshot. In order to get the help content associated with the page, please click on this button.

### How to Choose Help Language?

Most of our help files are available in both **English** and **Spanish** language. In order to choose your desired language please click on Help ▸ Help menu (as shown below) and choose your language from the list. Please notice that Help language could be different from the program user-interface language(See 4.10).

The entire help content is also available in PDF format and is presented through User Manuals menu.




## 4.3 Getting Started ...

text here

## 4.4 General Tips for NovoCPT Users

NovoCPT is an intuitive software program to assist you saving the analysis time and gaining more reliable results. Tens of features are incorporated into NovoCPT which helps you during your analysis. Please read the following Q/A prior to working with NovoCPT:

**Q:** Does every page in NovoCPT has an associated help text?

Yes, please click on the button on right-top corner of each page to access its help text.

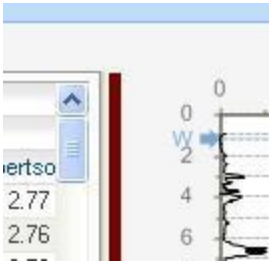
**Q:** How can I minimize the software window and come back to other Windows application?

Please use the button on right hand side corner of the page.

**Q:** How to access the toolbar and menu commands?

This can be done by the new smart toolbar (also called Ribbon). Please hover your mouse on main menu items (File, CPT Test, View, etc.) on the toolbar and click, to see more commands. To have the toolbar always visible, double-click on menu items to toggle them on/off.

**Q:** How to change the size of tables and charts?
Use the grip between the tabular dataset and the charts. Hold the left mouse button on the grip (red area on the illustration) and move to either side.




**Q:** Is there any way to save the tabular results to Microsoft Excel files?
Yes. Please read this article(See 4.7.2) for more explanations.

**Q:** How can I transfer the charts to my report or to other Windows applications?
The easiest way is to save the charts as image formats (JPG, BMP, PNG, GIF, etc.); Please read this article(See 4.7.2) for instructions on how to save the charts to image. Once you have created images from your charts, you may insert them into all Windows based programs.

**Q:** I noticed that when I open a NovoCPT project or import CPT data file, only qc, fs, u2, N60 and SBT charts are plotted. How can I plot other soil parameters?
Actually NovoCPT calculates more than 30 soil parameters and you can plot all of them. To do this, please right click on each chart, and choose Replace menu to select the desired parameter. Alternatively you can use View menu from the top toolbar to set the chart properties. Read this article(See 4.7.3.1) for more.

**Q:** How can I compare two or more parameters in the same charts?
Right click on the chart and choose Insert menu to select overlying parameter. To remove a parameter from the chart, click Remove from the popup menu.

**Q:** How can I set the methods / formulas used during the CPT interpretations?
Please read this article(See 4.10) to see how you can change NovoCPT preferences.

## 4.5 How to Change Units?

NovoCPT supports both Metric and Imperial units. To switch between units system, please click on Tools ▸ Options menu and then use the drop-down list at the bottom-left corner of the page to choose your desired unit system.

## 4.6 Data Entry

### 4.6.1 Starting a New Project

To start a new CPT project, click on File ▸ New Project button from toolbar. This will clear all data currently imported into NovoCPT. A project can include many CPT tests, whereas all of them share the same Site Data(See 4.6.6) and each CPT test has a corresponding Borehole(See 4.6.5).

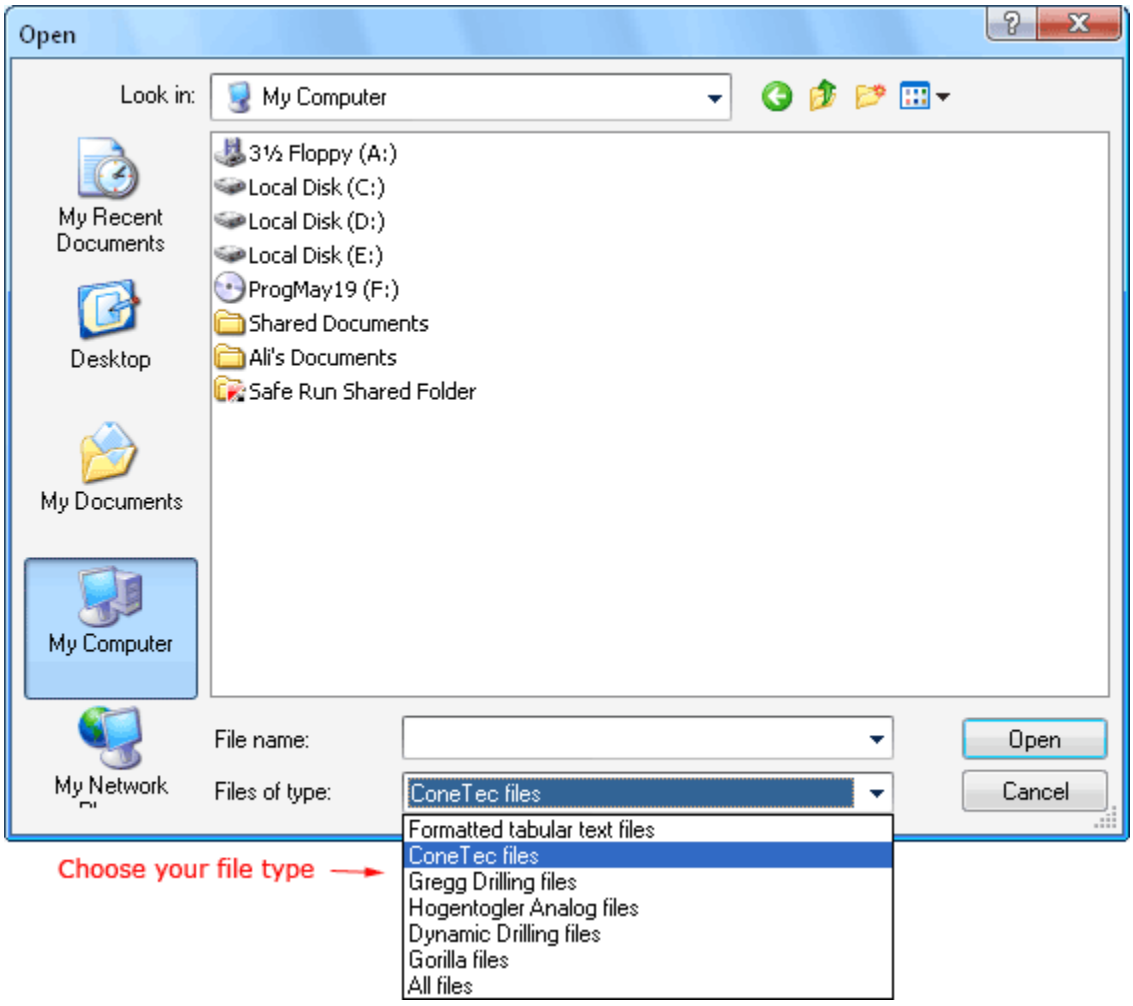
### 4.6.2 Importing From CPT Data File

Since during interpretation and process of CPT data, we deal with huge number of records, data are usually collected during the test by means of electronic devices and stored into files. These files usually contain a few lines of header (including cone type, project info, etc.) and follows with actual test data. NovoCPT currently covers the following formats:

- ConTec files (*.cor)
- GreggDrilling files (*.cor)
- Hogentogler Analog files (*.cpd)
- Dynamic Drilling files (*.cor)
- Gorilla files (*.gru)

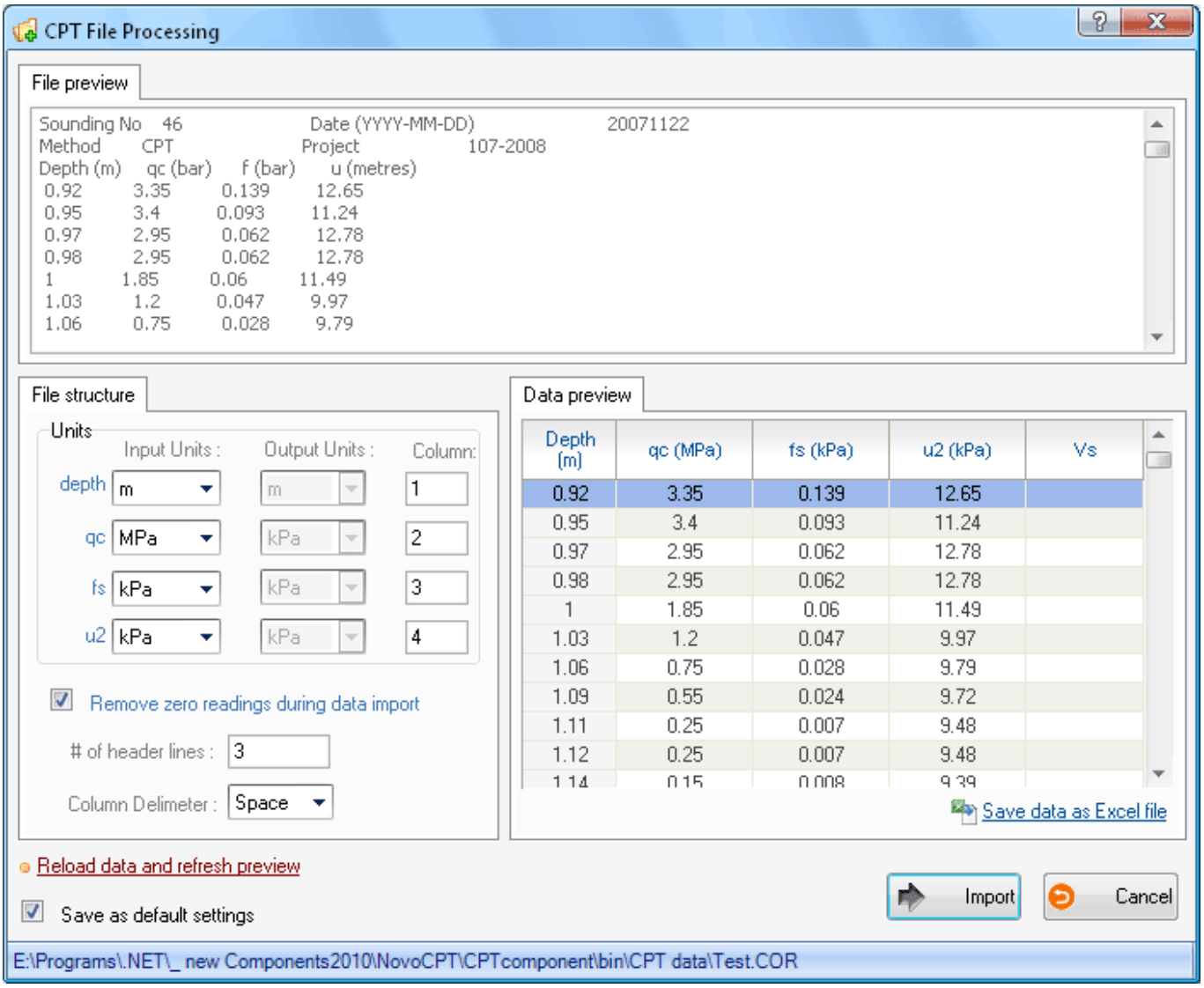
- Any tabular formatted text file

The delimiter between numbers in each line of the file can be comma, semicolon, space, tab and pipe character (|). You can import several files in each project. Once data are imported into NovoCPT, you can still edit(See 4.6.7) the dataset. To import a CPT data file, please first specify the file type as shown below:




You can import several CPT files by selecting more than one file in this dialog. However, please notice that all the files in a project should have the same units, header lines, columns of data, delimiter, etc. otherwise the import leads to failure or incorrect results.

Then choose the file from your hard disk and press Open button. A dialog appears with the following sections:




## File Preview

Shows contents of the original CPT file.

## File Structure

Use this section to define the input file and output units as well as specifying the columns holding the corresponding data. Usually Depth, $q_C$, $f_S$ and $u_2$ are stored in first to fourth column of the file; however of your file contains more data, you can set the column# representing each data.

In version 1.6.1 and later, output data can be presented in both Metric (SI) and Imperial unit systems.

## Remove zero readings during data import

In some cases, records with variable depth but zero test readings are stored in the file which may be an indicative of a drill-out before pushing the cone. If this options is selected, such data will be ignored during data processing.

## # of Header Lines

As described before, this sets the number of lines which should be read to reach the beginning of the actual dataset.

### Column Delimiter
Is the delimiter used to separate depth, $q_C$, $f_S$ and $u_2$ in each line of data within the file.

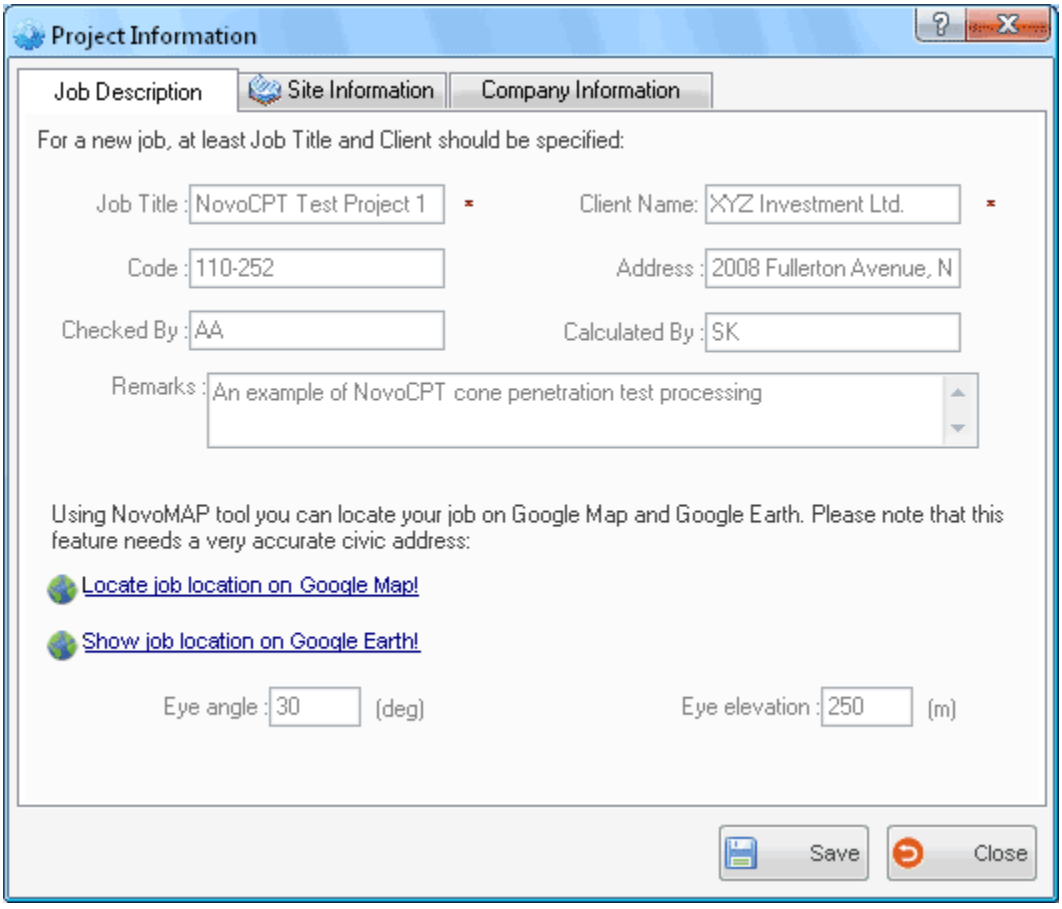
### Data Preview
Shows a preview of the imported data.

### Reload data and refresh preview
Use this button only when you have changed one of the above-mentioned settings and want to see the preview of the imported data.

When all settings are done and data preview looks to be consistent with your actual data, press Import button. This will open the main page of NovoCPT and will start the analysis.

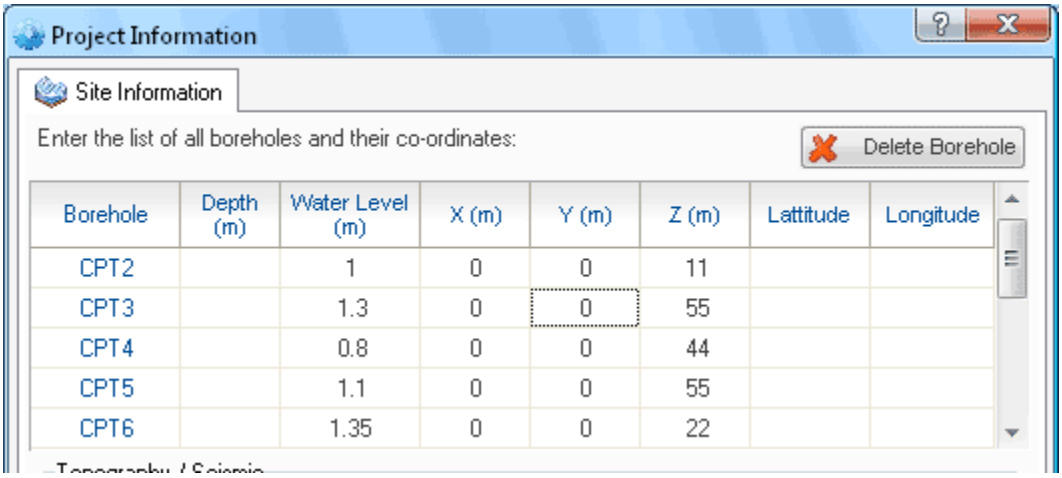
## 4.6.3 Loading NovoCPT Projects
To load one of your previous NovoCPT projects, click on File ▸ Load Project button from the toolbar and locate the file on your computer. This will load all data; it should be noted that preferences (including correlation methods) are not saved with each project and changing the preferences may affect previously saved files.

## 4.6.4 Project Information
Use Data ▸ Project Information from the toolbar to edit job information, boreholes list, site topography and your company information. This data will be used in report headers and footers. At least job title and client name should be entered before leaving this dialog page.



### 4.6.5 CPT Borehole Data

Use Data ▸ Test Properties from the toolbar to edit each CPT borehole properties including total depth, groundwater level and co-ordinates of the borehole in which CPT test is carried out. To delete a borehole, select it in the table and press Delete Borehole button.




| Borehole | Depth (m) | Water Level (m) | X (m) | Y (m) | Z (m) | Lattitude | Longitude |
|---|---|---|---|---|---|---|---|
| CPT2 | | 1 | 0 | 0 | 11 | | |
| CPT3 | | 1.3 | 0 | 0 | 55 | | |
| CPT4 | | 0.8 | 0 | 0 | 44 | | |
| CPT5 | | 1.1 | 0 | 0 | 55 | | |
| CPT6 | | 1.35 | 0 | 0 | 22 | | |

### 4.6.6 Site Data

To change the site data including topography and seismic information, click on Data ▸ Site Topography button from the toolbar. This data should be entered when starting a new project and includes the following sections:

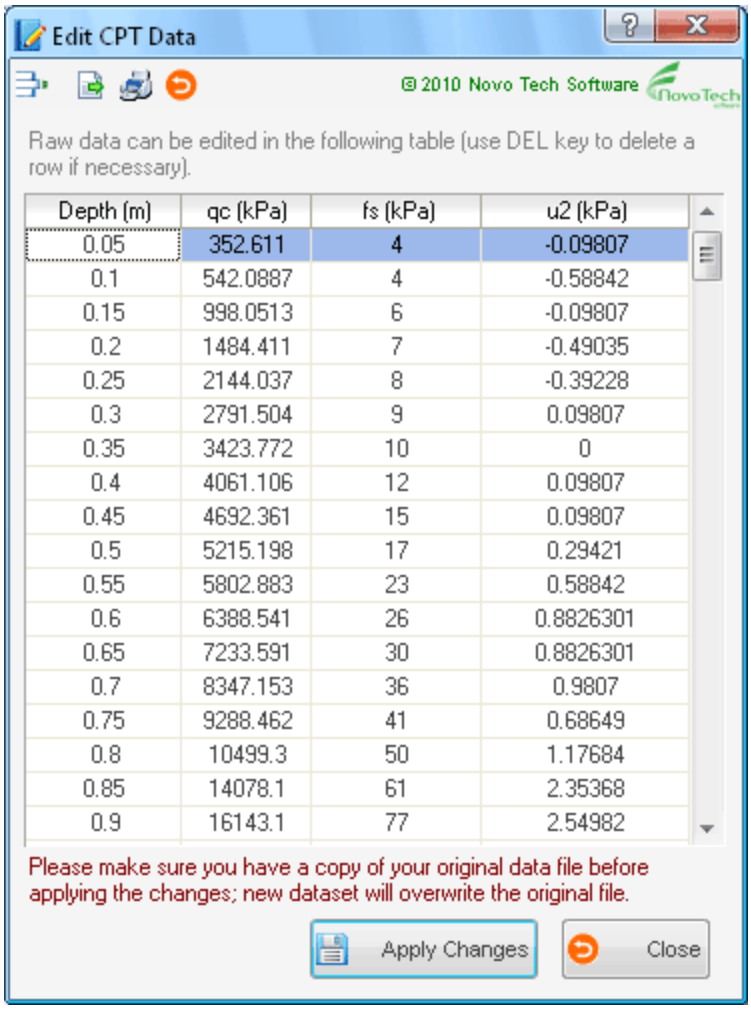

Site Topography:
Determines the response of the site to the post-liquefaction lateral spreading, according to *Zhang, Robertson and Brachman 2004*. The ground slope is recommended to be entered more than 0.2 %

Seismic Information
This data is directly used during the liquefaction assessment analysis and consists of PGA and Magnitude of the design earthquake as well as. Please note that groundwater level is entered in borehole table.

### 4.6.7 Editing the Raw Data

To edit the CPT dataset, click on Data ▸ Edit Raw Data from the toolbar.

- To edit the data in a cell, simply double-click on it
- To print table, use the corresponding button on the toolbar
- To delete a row (or a set of rows) of data, use your mouse to highlight the row(s) and then click on the very first button on the toolbar
- To save the current data into Microsoft Excel file, use the second button on the toolbar




Click on Apply Changes button to save the changes. This will re-calculate the CPT dataset and updates the charts.

### 4.6.8 Viewing the Original CPT File

Use

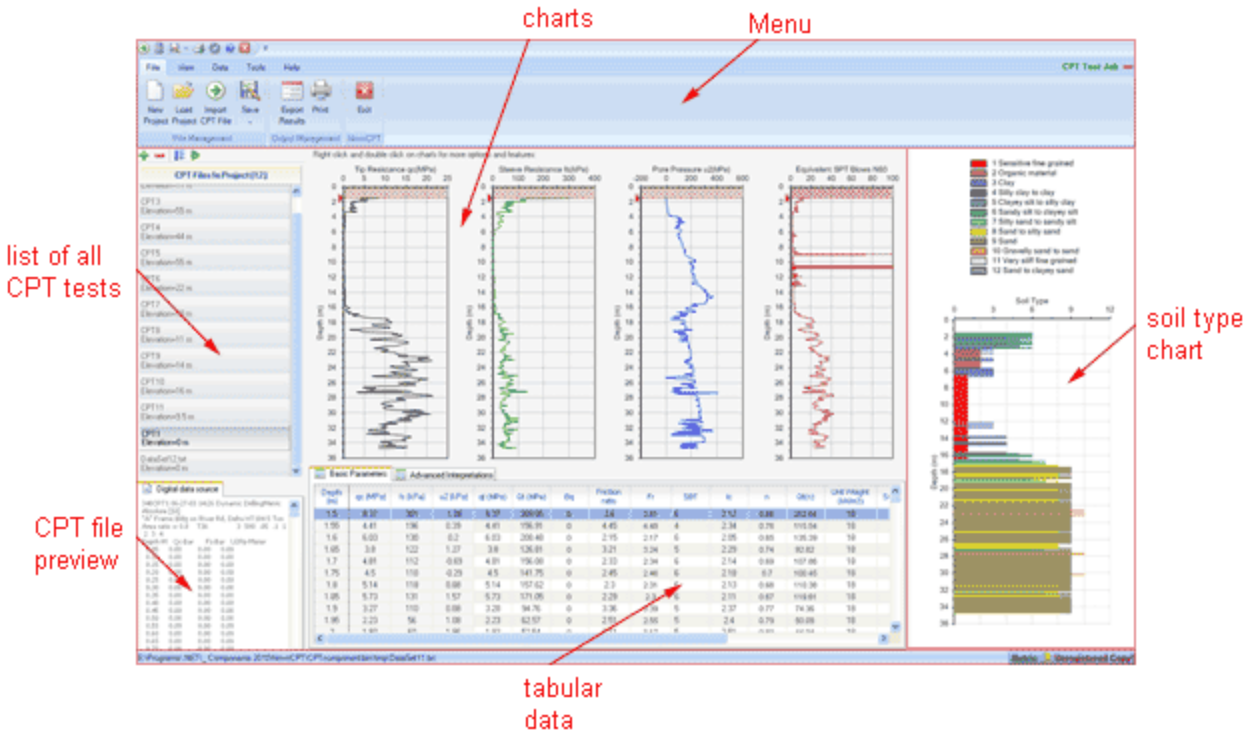
### 4.6.9 Saving the Projects

Please click on File ▸ Save from the toolbar to save the current project data. All NovoCPT data is saved in files with "ncpt" extension.

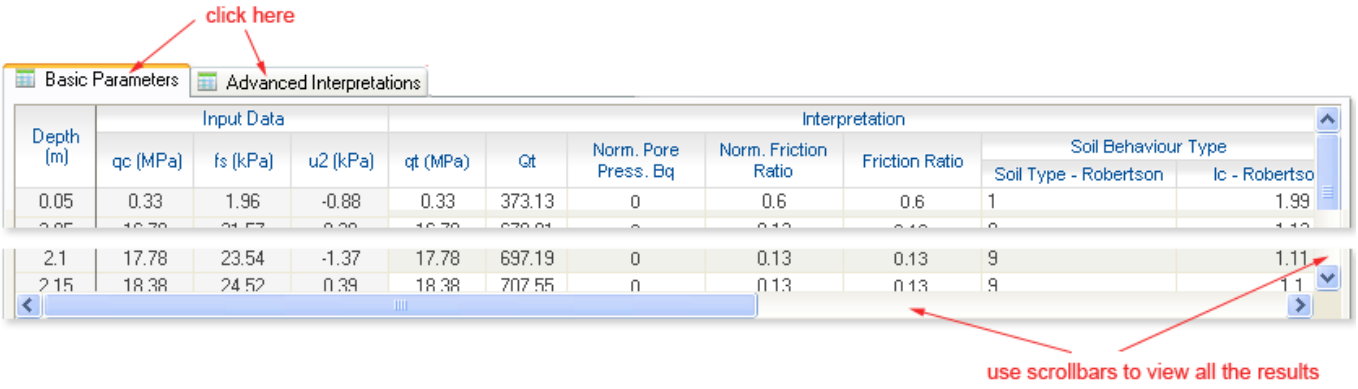
## 4.7 Analysis Results

### 4.7.1 Tabular Data

When the CPT data file is imported or l(See 4.6.2)oaded(See 4.6.2), and processed, the analysis results are presented in a tabular format and presented in charts. Most of the soil parameters are presented on the main page, as shown below while others are accessible through Tools menu:




Other analysis such as pile bearing capacity and settlement analysis may be accessed through separate pages by using the Tools menu on the toolbar. The tabular data are presented in tables; the first column of each table is depth of that specific reading. Other columns are illustrated below:




"Basic Parameters" table:

$q_c$ : Cone tip resistance as it is read during the test
$f_s$ : Cone sleeve friction as it is read during the test
$u_2$ : Pore water pressure as it is read during the test
$q_t$ : Corrected cone tip resistance = $q_c + (1-\alpha)*u_2$ where $\alpha$ is net area ratio (~ 0.8); please read this article(See 4.10) for more information
$Q_t$ : Normalized cone resistance = $(q_t - \sigma_v)/\sigma'_v$
$B_q$ : Normalized pore pressure ratio = $(u_2-u_0)/(q_t - \sigma_v)$
Fr : Normalized friction ratio = $f_s/(q_t - \sigma_v)$
Rf : Friction ratio = $f_s/q_t * 100$
Ic : Soil type index (based on Robertson 1986)
$Q_{tn}$ : Normalized cone resistance (based on iterative procedure proposed by Robertson 2010) = $(q_t - \sigma_v)/P_a * (P_a/\sigma'_v)^n$ where $P_a$ is the atmospheric pressure ~ 100 kPa
n : Exponent of $Q_{tn}$ normalization (based on iterative procedure proposed by Robertson 2010)
$S_v$ : Total overburden stress ($\sigma_v$)

$S'_v$ : Effective overburden stress ($\sigma'_v$)
$S_u$ : Undrained shear strength for fine-grained soils
Fines Content : Percent passing sieve #200 (silty and clay)
$N_{60}$ : Equivalent SPT blow counts
$N_{1(60)}$ : Equivalent overburden-corrected SPT blow counts = $N_{60}$ * $C_n$ (Liao & Whitman method)

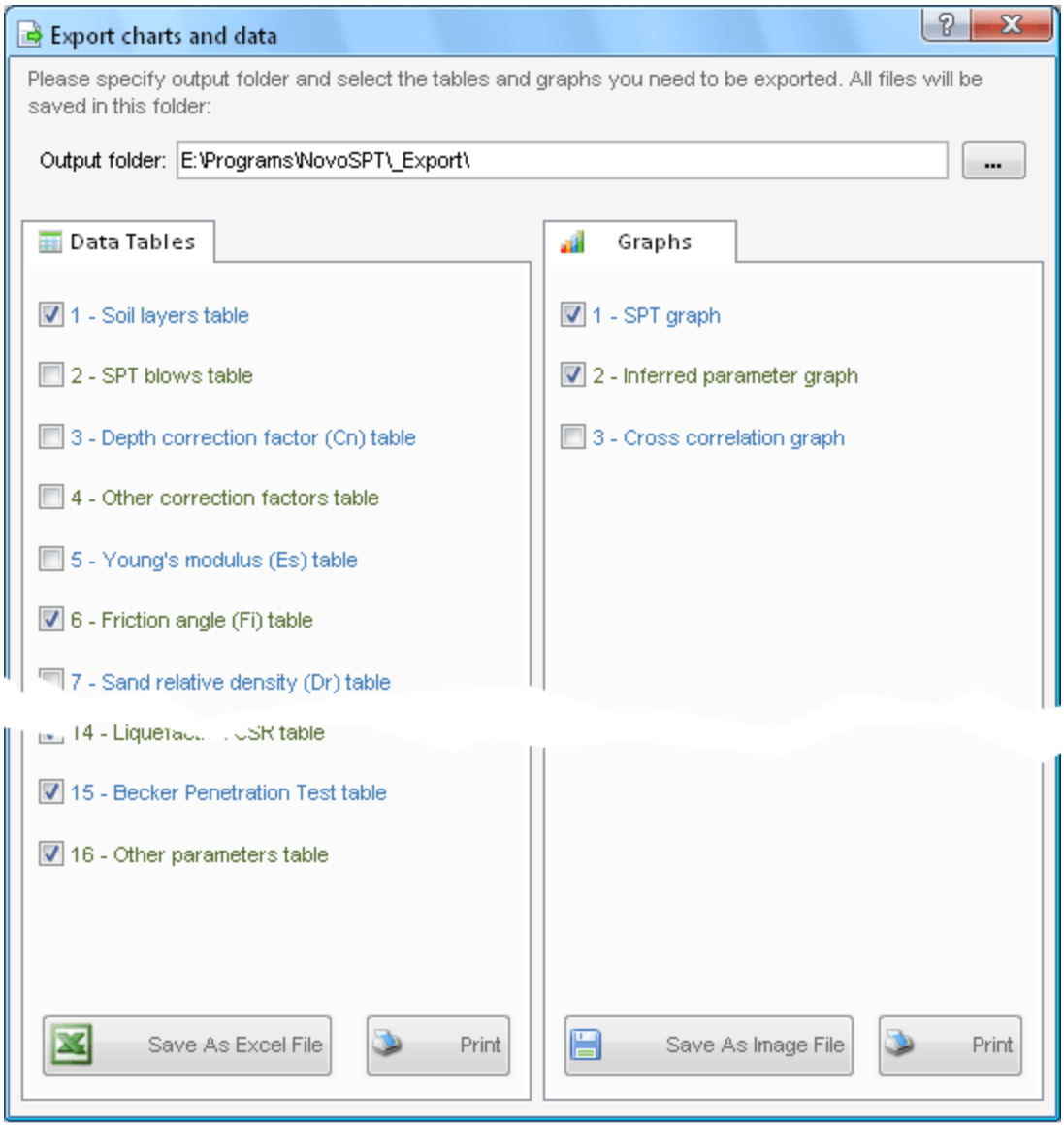
"Advanced Parameters" table:
Hydraulic Conductivity : Coefficient of permeability of the soil (K)
e : Void ratio
$C_c$ : Coefficient of compression for consolidation settlement *
$D_r$ : Relative density of soil *
$E_s$ : Modulus of elasticity, used for elastic settlement
$K_o$ : Coefficient of earth pressure at rest
M : Constrained modulus
$S_t$ : Sensitivity of clay
OCR : Over-consolidation ratio
$\Phi$ : Friction angle of soil
$G_{max}$ : Maximum shear modulus
$V_S$ : Shear wave velocity

* use this values with cautious, confirm consistency of the results with other formulas and methods

### 4.7.2 Exporting the Results

Most of the users have already setup their spreadsheets and would rather keep their reports in the same format. To do this, they need to export the analysis results into other popular formats such as Microsoft Excel.

To export the results click on button form toolbar. A dialog similar to the following screenshot will appear. List of all data tables and charts of the analysis results, will be provided on left and right panels, respectively (see below).




Please select the items you want to export. Then specify the output folder. You can change this folder by clicking on ... button.

### Exporting Data Tables

Tables can be saved as Microsoft Excel or may be directly sent to the printer.

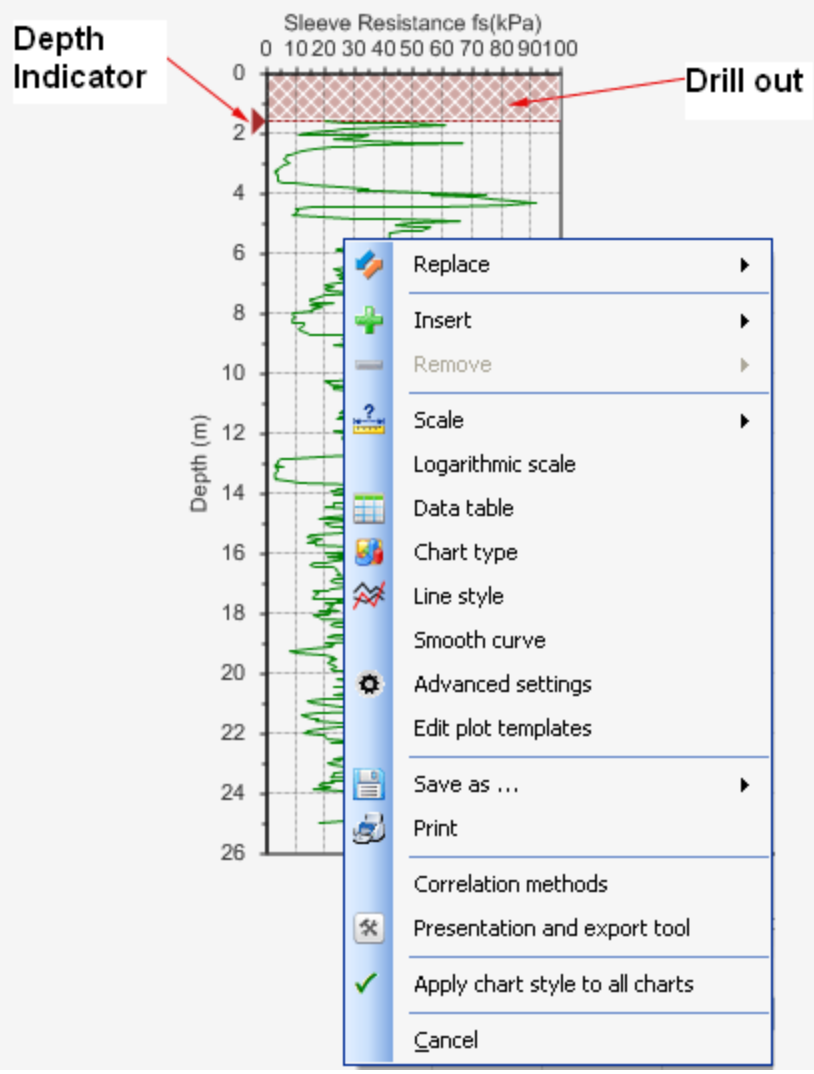
### Exporting Graphs (Charts)

All charts may be saved with image formats such as BMP, PNG, JPG, etc or to be printed.

## 4.7.3 Working with Charts

### *4.7.3.1 Charts Settings*

All charts on top portion of the page, can be customized. There are four charts which are reserved for showing the soil parameters and one chart (on right part of the page) shows the Soil Behavior Type indexes. You may change the colors, line styles, chart type and more for each chart. The simplest way is to right-click on the chart and use the popup menu. The following screenshot illustrates the menu items:




**Replace** : use this menu if you want to plot another parameter. In this case the current parameter(s) shown on the chart will be erased and replaced with the selected parameter.

**Insert** : to overlay another parameter to the existing plots. For example if the chart is currently showing $\sigma_v$ (total overburden stress) and you want to compare $\sigma'_v$ (effective overburden stress) with this $\sigma_v$, simply click on Insert menu and choose S'v (for a complete list of symbols and terms used in NovoCPT, please see this article(See 4.7.1)).

**Remove** : to remove a parameters from the chart.

**Scale** : to change the scale of horizontal and vertical axis of the chart.

**Logarithmic scale :** changes the logarithmic scale of horizontal axis of the chart. For example for hydraulic conductivity or OCR you may prefer to use logarithmic scale.

**Data Table** : shows the X,Y pairs of data for each plot.

**Chart Type** : a variety of different chart types including bar, column, XY scatter, line, Gannt, etc are available and you can change the chart type for presentation purpose. We recommend using XY Scatter or line charts.

**Line style** : allows you to change the line style of the curve.

**Smooth curve** : allows you to toggle between smooth (Bezier method) or line curve.

**Advanced settings** : shows the chart property page which enables you to change most of the above-mentioned properties in one dialog.

**Edit plot templates** : you can change the default settings of each parameters plot including style, color, chart type, captions, etc.

**Save as ...** : to save the chart to image files such as JPG, BMP, PNG, etc.

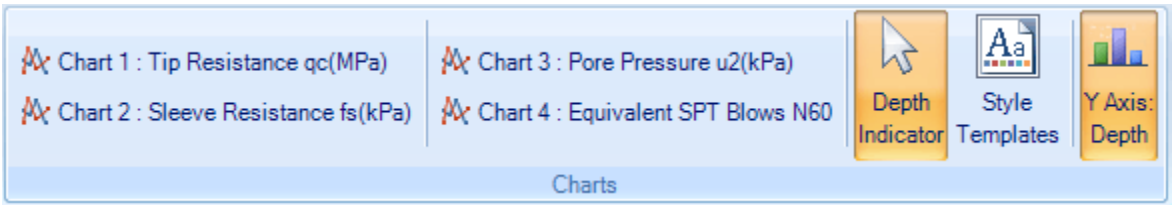
**Print** : directly prints the chart

**Correlation methods** : opens the Options page(See 4.10) to change the correlation methods used for CPT for interpretations of data

**Presentation and export tool** : this is a very useful feature and shows the chart in another page, so that you can

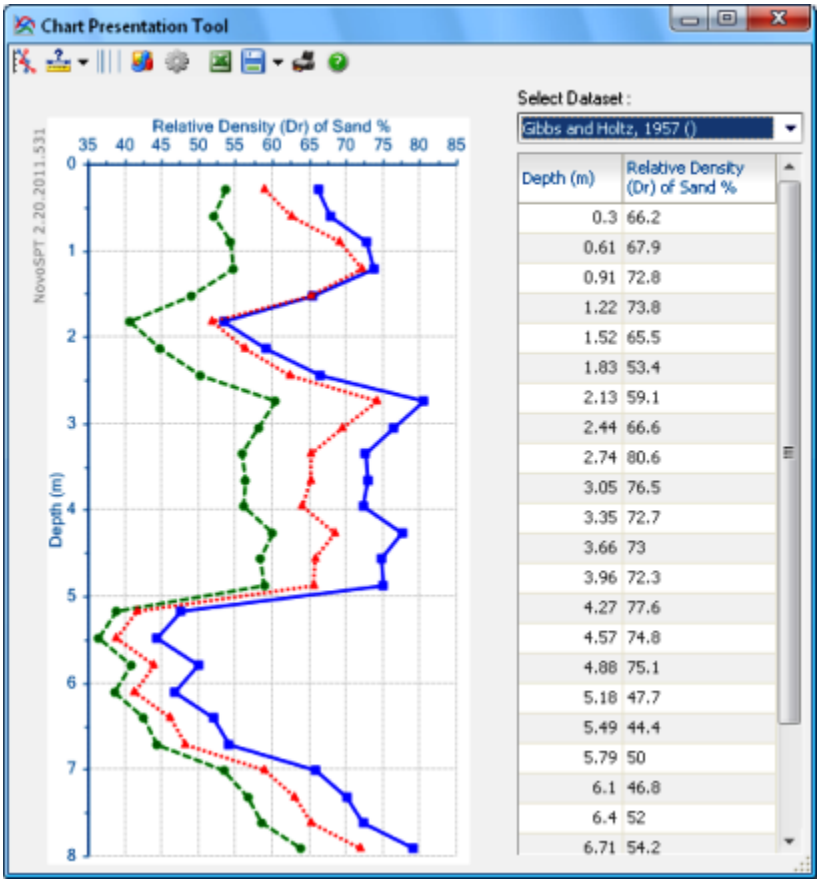
resize the page and the chart, see the data table besides the chart, change its settings, print, save as Excel and more.
**Cancel** : closes this menu

You can also change the access the above-noted features by clicking on View menu (as shown below). You can switch between Depth and Elevation for vertical axis by clicking on corresponding button on toolbar (see below).




### *4.7.3.2 Chart Presentation Tool*

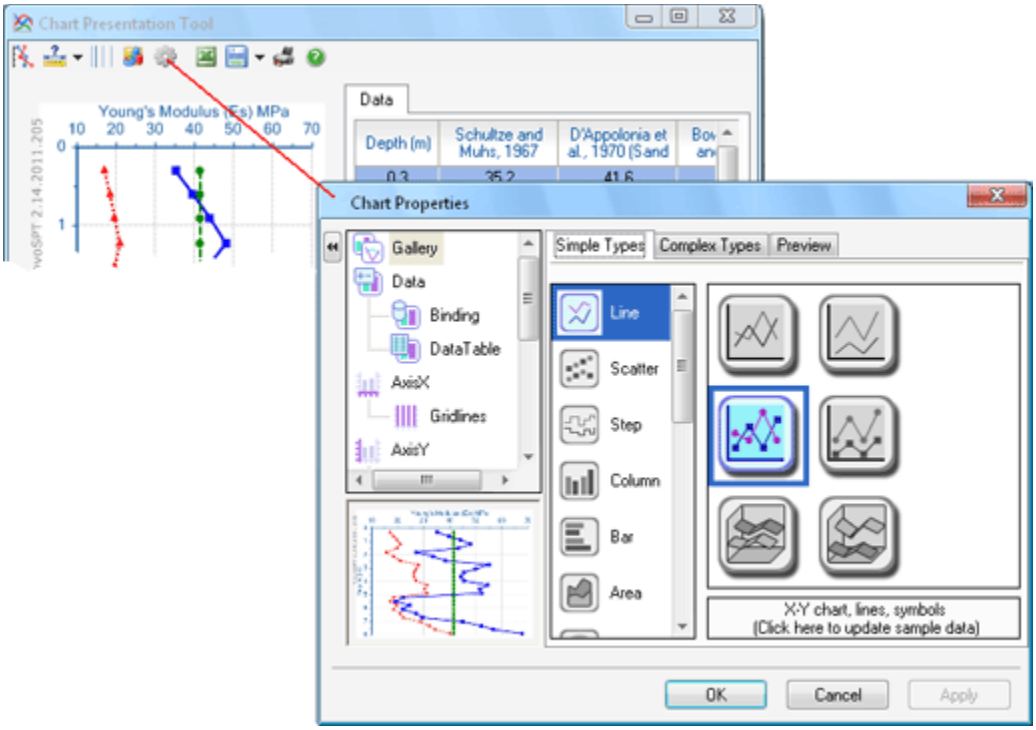
We understand that presentation of the analysis results is very important to our users. Everywhere in Novo Tech Software programs when you click on a chart, a new dialog appears containing the chart and its associated data. In the following example, the corresponding dataset is shown on right and can be scrolled horizontally and vertically to view all data. In addition, toolbar buttons provide you with more features:




- To change line styles of the plot
- To change the scale (minimum, maximum and gridlines) of each axis. Please click on small arrow on right side of the icon to open the dropdown menu
- To toggle between normal/logarithmic scale for horizontal axis
- To change the chart type
- To open the advanced settings page for the chart
- To save the dataset table as Microsoft Excel file
- To save the chart as text and graphic format
- To print the chart
- Opens this help page

**How can I change the appearance of the chart such as legend, chart type, etc?**

You can configure almost everything in the chart by clicking on button from the toolbar. This will open the following dialog box:

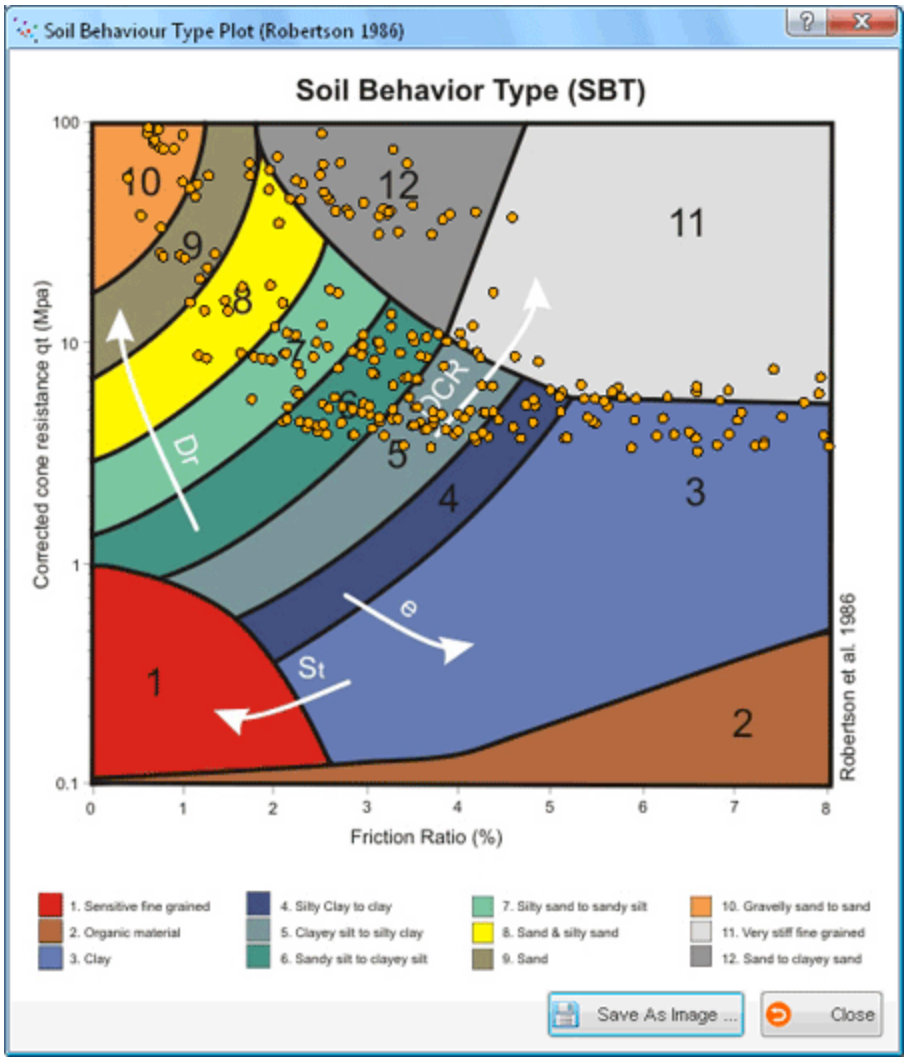



Click on the desired element from the list located on the left side of the page; more options will be shown on the right portion. Click on OK button to apply your changes.

### 4.7.4 Soil Behavior Type Charts

#### *4.7.4.1 Robertson 1986*

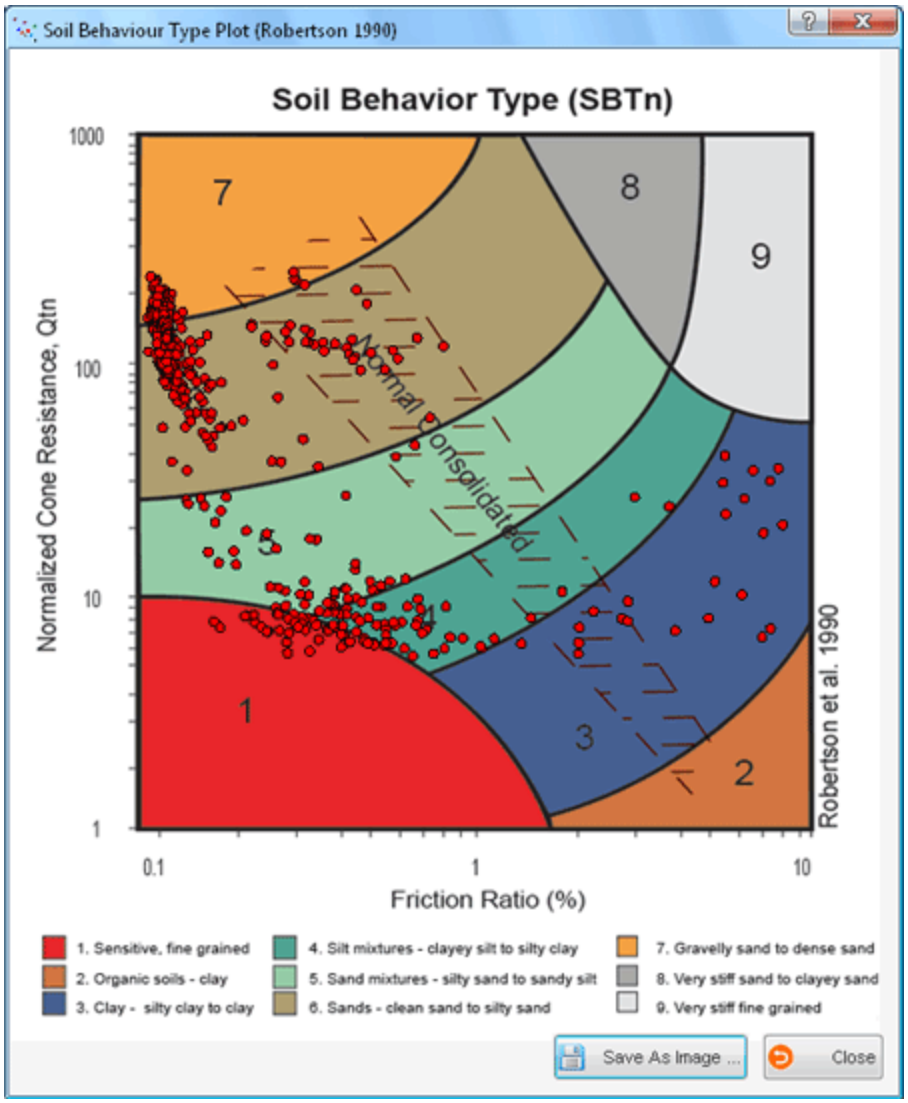
NovoCPT performs the CPT data interpretation based on "*Robertson 1986*", "*Robertson 1990*" and "*Jefferies and Been 2006*" methods. To see the *Robertson 1986* soil behavior type scatter chart, please click on Tools ▸ Robertson 1986 button from the toolbar. This will show the following page:




- Each circle on the graph represents one row of data (at a specific depth).
- To save the graph as an image (for further use in your reports), click on Save as image... button at the right-bottom corner of the page

### *4.7.4.2 Robertson 1990*

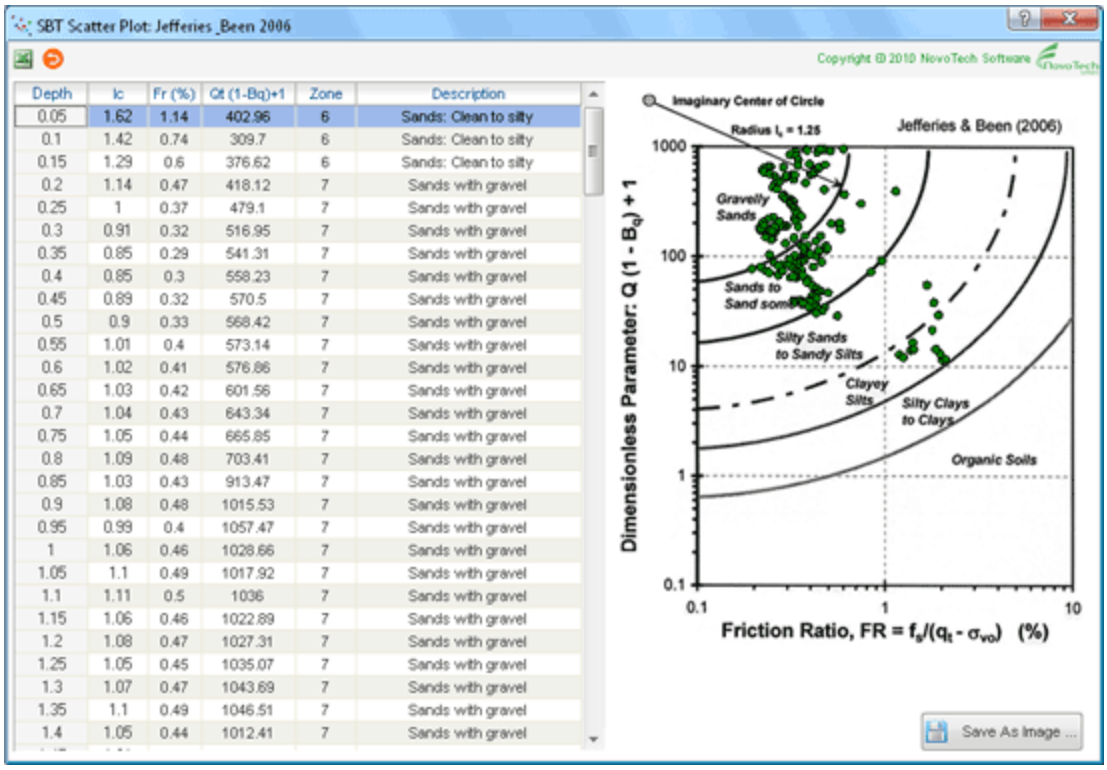
NovoCPT performs the CPT data interpretation based on "*Robertson 1986*", "*Robertson 1990*" and "*Jefferies and Been 2006*" methods. To see the *Robertson 1990* soil behavior type scatter chart, please click on Tools ▸ Robertson 1990 button from the toolbar. This will show the following page:




- Each circle on the graph represents one row of data (at a specific depth).
- To save the graph as an image (for further use in your reports), click on Save as image... button at the right-bottom corner of the page

### *4.7.4.3 Jefferies & Been 2006*

NovoCPT performs the CPT data interpretation based on "*Robertson 1986*", "*Robertson 1990*" and "*Jefferies and Been 2006*" methods. To see the "*Jefferies & Been 2006*" soil behavior type chart, please click on Tools ▸ Jefferies & Been 2006 button from the toolbar. This will show the following page:




- Each circle on the graph represents one row of data (at a specific depth).
- To save the graph as an image (for further use in your reports), click on Save as image... button at the right-bottom corner of the page

## 4.8 CPT Tools

### 4.8.1 Liquefaction Analysis Tool

This tool is designed to analyze the potential of liquefaction based on CPT data. The procedure of liquefaction assessment in NovoCPT, is based on recommendations proposed in "Guide to Cone Penetration Testing(See 2.)" (*Robertson 2009*). Tabular data is presented at each depth and all the dataset is plotted versus depth on different charts. Columns of analysis results table are described below:

$S_v$ : Total overburden stress ($\sigma_v$)
$S'_v$ : Effective overburden stress ($\sigma'_v$)
$R_d$ : Stress reduction factor in simplified *Seed and Idriss 1971* formula
$D_r$ : Relative density of soil (based on *Tatsuoka et al. 1990*)
$\gamma_{max}$ : Maximum shear strain, estimated from Dr and liquefaction safety factor, at each depth
$\varepsilon_v$ : Volumetric strain (for settlement analysis), estimated from Dr and $\gamma_{max}$, at each depth (read this article(See 5.5))
Kc : Fines content correction factor (*Robertson & Wride 1998*) for $Q_{tn}$
CSR : Cyclic stress ratio, please read this article(See 5.2) for more information
CRR : Cyclic resistance ratio (based on *Robertson 2009* method), please read more(See 5.1)
Safety Factor : Liquefaction safety factor = CRR / CSR * MSF
MSF : Magnitude scaling factor
Lateral Displacement : Accumulation of the Post-liquefaction lateral displacement of the site, estimated based on *Zhang, Robertson and Brachman (2004)* method (from the bottom of the model (the lowest depth in CPT dataset) up to that specific point). Please read this article(See 5.4) for more information.
$S_r$ : Residual shear strength

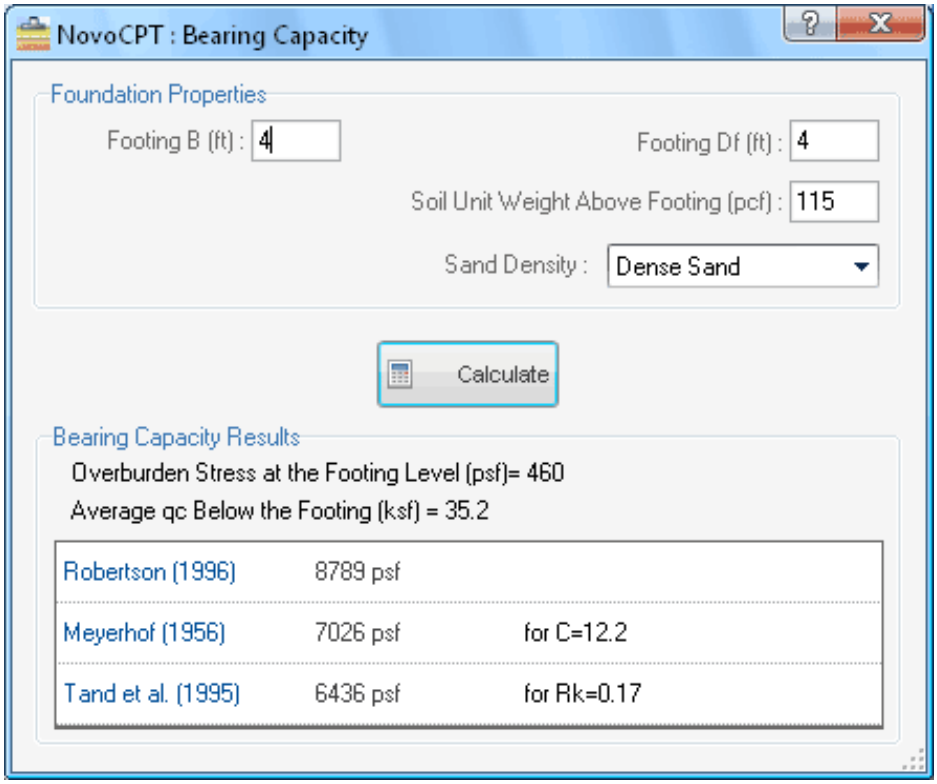
Liquefaction Behavior : Behavior of soil according to *Robertson 2009* definition

To export, print and save the results use the toolbar buttons (more information here(See 4.7.2)). By default, safety factor against liquefaction is assumed as unity and the region for safety factors less and greater than this value are colored by dark red and dark green on the safety factor chart. To change the required safety factor, use the textbox at the bottom of the page and then press Update button to redraw the chart.

Please notice that liquefaction is only assessed for those soil types which are set in NovoCPT preferences page(See 4.10) to be potentially liquefiable.

### 4.8.2 Bearing Capacity Analysis Tool

Use Tools ▸ Bearing Capacity Analysis from the toolbar to calculate the bearing capacity of shallow footings. Sand density will be used only for Robertson (1996) method. C is recommended as 12.2 by Meyerhof (1956). Rk varies between 0.14 to 0.2 by Tand et al. (1995) which is assumed 0.17 in NovoCPT.




### 4.8.3 Settlement Analysis Tool

This tool is designed to analyze the elastic and consolidation settlement of shallow footings based on CPT data. The elastic (immediate) settlement is calculated based on methodology proposed by *Schmertmann* and the consolidation settlement is based on *Terzaghi's* 1-dimensional consolidation theory.

Please enter footing size and consolidation properties of the soil. For *Schmertmann's* method, time for long-term settlement as well as $\alpha$ should be specified, where $\alpha$ is defined as the ratio of modulus of elasticity to cone resistance ($q_c$) at each depth. When all required data is entered, press Update button. Details of calculation will be presented in Tabular Output Data and settlements are plotted on charts. To export, print and save the results use the toolbar buttons (more information here(See 4.7.2)). Columns of analysis results table are described below:

$q_c$ : Cone tip resistance as it is read during the test
$I_z$ : *Schmertmann's* influence factor
OCR : Over-consolidation ratio
e : Void ratio
$C_c$ : Coefficient of compression for consolidation settlement
$C_s$ : Coefficient of re-compression for consolidation settlement
$P_c$ : Pre-consolidation stress
$S_v$ : Total overburden stress ($\sigma_v$)
$S'_v$ : Effective overburden stress ($\sigma'_v$)
$d_p$ : Stress increase at each depth, due to the applied load on the subject footing
$dS_c$ : Consolidation settlement at an element of soil with thickness of dz
$dS_e$ : Elastic settlement at an element of soil with thickness of dz
$S_c$ : Accumulative consolidation settlement at each depth
$S_e$ : Accumulative elastic settlement at each depth
S : Accumulative total settlement at each depth

Other parameters:

Unsat. Settl. Ratio : If you wish to calculate the unsaturated consolidation settlement above the groundwater level, choose a value other than zero for this field. NovoCPT will multiply this factor by total calculated consolidation settlement above the groundwater level.
Time : This is the time in elastic settlement calculation to account for creep.
$\alpha$ : Is used for estimation of soil modulus of elasticity based on cone tip resistance $E=\alpha.qc$

Schmertmann (1970) suggested that a value of $\alpha=2$ should be applied for normally consolidated, unaged and uncemented predominantly quartz sands, and is based on a load increment from 100 to 300 kPa. It is probable that somewhat higher $\alpha$ values may be appropriate for loose sands and somewhat lower values for very dense sands.

### 4.8.4 Pile Bearing Analysis Tool (LCPC)

This tool is designed to analyze the bearing capacity of the piles based on CPT data, according to the method proposed by *Bustamante and Gianeselli (1982)* also known as LCPC Method. To read more about this method please click here.

Pile Types
According to LCPC method, the following pile types can be chosen:

- plain bored pile
- mud bored pile
- micro pile (low pressure)
- case bored pile
- pier
- barrett
- case screwed pile
- driven precast pile
- prestressed tubular pile
- driven cast pile
- jacked metal pile
- micropile (small diameter<250mm, high pressure)
- driven grouted pile (low pressure)
- driven metal pile
- driven rammed pile
- jacket concrete pile
- grouted pile (large diameter, high pressure)
- hollow auger bored pile

Safety Factors
Please specify required safety factors for friction and end bearing capacity.

Pile Geometry
Pile diameter is assumed to be uniform along the depth. Bearing capacity will be calculated along the length of the pile (limited to CPT test depth)

Select Limit fp value checkbox to apply the recommended maximum values for fp.

$$q_p = k_c \, q_{ca} \qquad f_p = \frac{q_c}{\alpha_{LCPC}}$$

Tabular data is presented at each depth and all the dataset is plotted versus depth on different charts. Columns of analysis results table are described below:

$K_C$ : End bearing factor
$\alpha$ , $f_p$ : Friction bearing factor
Soil Nature : Nature of the soil according to LCPC method' definition

Details of the calculation is presented in Tabular Output Data tab. To export, print and save the results use the toolbar buttons (more information here(See 4.7.2)).

It should be noted that weight of the pile is not deducted from the allowable bearing capacities; therefore, user should correct the final results based on the actual weight.

## 4.9 Reporting

### 4.9.1 Report Manager

This page can be used to choose the graphs you want to print. The following options are available:

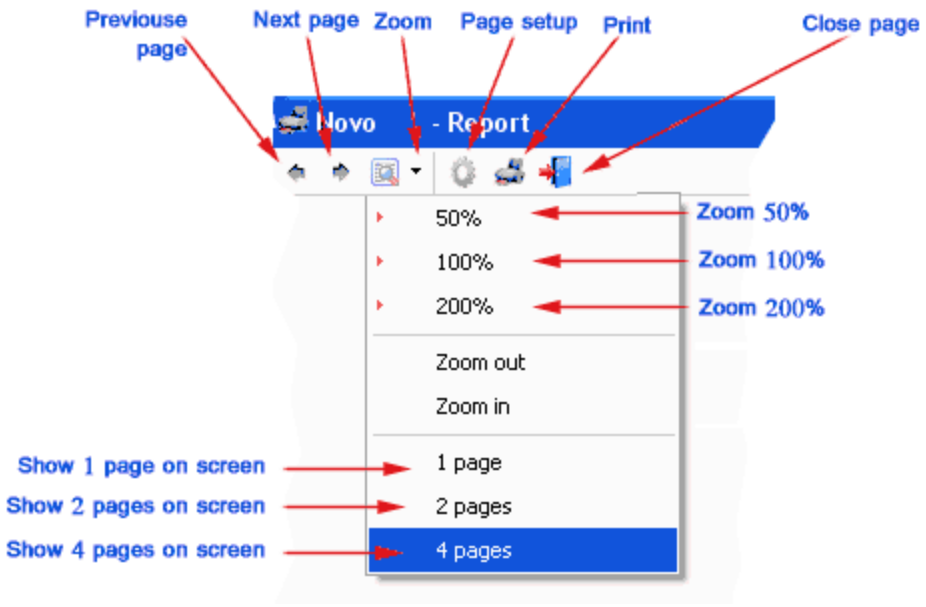
Print On-screen Graphs: Choose this option if you want to only print the graphs already shown on the screen.
Print Selected Graphs: If you prefer to choose more graphs than those plotted on the screen, choose this option and select the subject charts from the list. There is no limitation for the number of charts in each report.
# of Charts / Page: Defines the number of page which should be inserted on each page of the report.

Please select your list of charts and press Show Report button.

Only graphs are included in this report. To print tabular data, please choose toolbar Export button on each page. For more custom reports, you can save charts as images and export tabular data into Microsoft Excel format to make up your own custom report by means of other Windows applications. To learn more about exporting the results, please read this article(See 4.7.2).

### 4.9.2 Print Preview

To have a preview of the reports after all calculations are completed, click on File ▸ Print menu. All the graphs will appear on the report pages. The image below describes the toolbar buttons on this page:




To print the tabular data on each page use Export button from the toolbar; please read this article(See 4.7.2) for more information.

## 4.10 Preferences

This feature is used for setting NovoCPT preferences and is accessible from toolbar through Tools ▸ Options. Please set your favorite methods for CPT interpretations. Some specific clarifications are provided below:

Net Area Ratio $\alpha$ : is determined from laboratory calibration with a typical value between 0.7 to 0.85 and is used for calculating $q_t = q_c + u_2(1-\alpha)$
Drill-out gap : NovoCPT automatically detects the drill outs based on the depth intervals and shows the corresponding gaps in the plots. The default value for drill-out gap is 0.15 m, meaning that if interval between two subsequent depth is 0.2m for example, the depth between 0.15m to 0.2m will be recognized as a drill-out. This default value can be set by the user
Apply Normalization Approach for $Q_{tn}$ : if selected, the iterative procedure(See 5.1) proposed by Robertson 2009 will be applied to the analysis
Soil Behavior Type Unit Weights : use this tab to edit the unit weights associated with each soil type. This numbers will be used for overburden stress calculations
Use Robertson 2010 Equation (for soil unit weights): if selected, instead of the commonly used unit weight table, an equation proposed by Robertson, 2010 will be used during analysis
Potentially Liquefiable Soil Types : is used to specify the soil behavior types which are prone to liquefaction. It should be noted that CRR values(See 5.1) will only be calculated at depths having one of the "potentially liquefiable" soil types
Fine-grained Soil Definitions : is used to specify the soil behavior types which should be considered as fine-grained. These soil types will be used for consolidation settlement calculation
Plots Templates : is used to set the color, style and captions for each parameter chart. This settings will be saved in NovoCPT and will be used for next analysis as well
Units System : is used to set the unit system used for outputs and user interface presentations such as plots and tables. Both Metric and Imperial units are supported.

Press Save button when all parameters are set. NovoCPT will then re-calculate the dataset according to the new settings

User should be aware of any choice of correlation methods and formulas in this page

# 5. Appendix

## 5.1 Liquefaction Assessment Procedure

NovoCPT evaluates the factor of safety against liquefaction based on the following equation:

$$\mathbf{FS = (CRR_{7.5} / CSR) * MSF * K\alpha}$$

where $CRR_{7.5}$ is the Cyclic Resistance Ratio for earthquake magnitude of 7.5, calculated from the flowchart proposed by Robertson 2009, also shown on Figure 1 below,

CSR is Cyclic Stress Ratio (read this article(See 5.2)),

MSF is Magnitude Scaling Factor (also known as Km),

$K\alpha$ is the slope effect, assumed to be 1.0

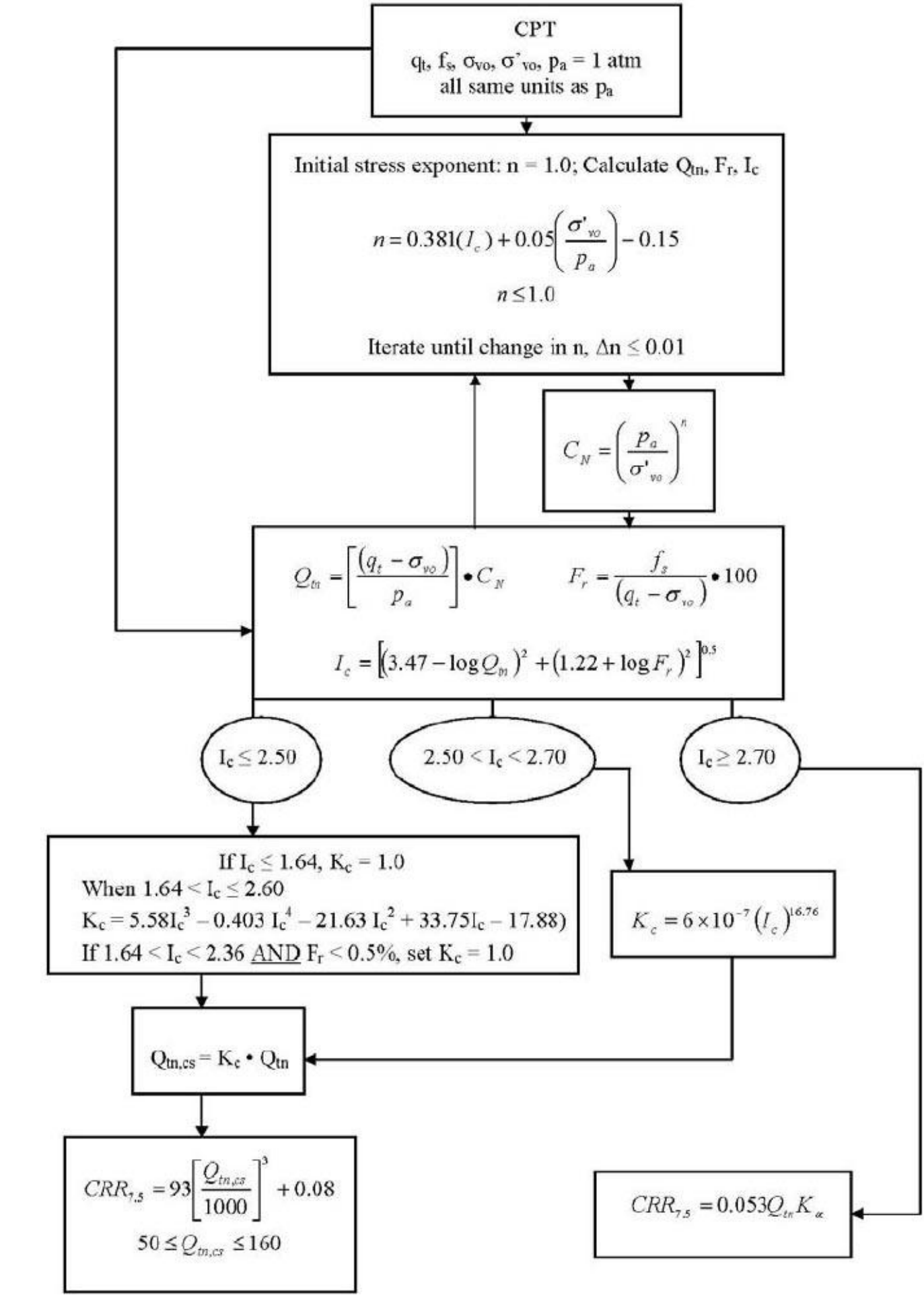

CPT
$q_t$, $f_s$, $\sigma_{vo}$, $\sigma'_{vo}$, $p_a$ = 1 atm
all same units as $p_a$
Initial stress exponent: n = 1.0; Calculate $Q_{tn}$, $F_r$, $I_c$
$n = 0.381(I_c) + 0.05\left(\frac{\sigma'_{vo}}{p_a}\right) - 0.15$
$n \le 1.0$
Iterate until change in n, $\Delta n \le 0.01$
$C_N = \left(\frac{p_a}{\sigma'_{vo}}\right)^n$
$Q_{tn} = \left[\frac{(q_t - \sigma_{vo})}{p_a}\right] \bullet C_N$
$F_r = \frac{f_s}{(q_t - \sigma_{vo})} \bullet 100$
$I_c = \left[(3.47 - \log Q_{tn})^2 + (1.22 + \log F_r)^2\right]^{0.5}$
$I_c \le 2.50$
$2.50 < I_c < 2.70$
$I_c \ge 2.70$
If $I_c \le 1.64$, $K_c = 1.0$
When $1.64 < I_c \le 2.60$
$K_c = 5.581I_c^3 - 0.403\ I_c^4 - 21.63\ I_c^2 + 33.75I_c - 17.88)$
If $1.64 < I_c < 2.36$ AND $F_r < 0.5\%$, set $K_c = 1.0$
$K_c = 6 \times 10^{-7}\left(I_c\right)^{16.76}$
$Q_{tn,cs} = K_c \bullet Q_{tn}$
$CRR_{7.5} = 93\left[\frac{Q_{tn,cs}}{1000}\right]^3 + 0.08$
$50 \le Q_{tn,cs} \le 160$
$CRR_{7.5} = 0.053 Q_{tn} K_\alpha$

Figure 1 : Flow chart to evaluate cyclic resistance ratio (CRR7.5) from CPT, after Robertson 2009

## 5.2 Cyclic Stress Ratio (CSR)

The Cyclic Stress Ratio, CSR, is given by *Seed and Idriss (1971)* as:

$$CSR_{7.5} = 0.65\left(\frac{\sigma_v}{\sigma_v'}\right)\left(\frac{a_{max}}{g}\right)(r_d)$$

Where:

$CSR_{7.5}$ : the cyclic stress ratio with reference to earthquake magnitude of 7.5

Ïƒ$_v$ : total overburden pressure at the depth considered

Ïƒ$_v$â€™ : effective overburden pressure at the same depth

$a_{max}$ : maximum horizontal acceleration at the ground surface

g : acceleration due to earthâ€™s gravity

$r_d$ : stress reduction factor (read this article(See 5.3))

## 5.3 Stress Reduction Factor (Rd)

NovoCPT covers the following methods for calculating $R_d$:

**NCEER (1997) based on Seed & Idriss (1971)**

| | |
|---|---|
| $r_d$= 1.0 - 0.00765 Z | for z â‰¤ 9.15 m |
| $r_d$= 1.174 - 0.0267 Z | for 9.15 m < z â‰¤ 23 m |
| $r_d$= 0.744 - 0.008 Z | for 23 m < z â‰¤ 30 m |
| $r_d$= 0.50 | for z > 30 m |

**Thomas F. Blake (FugroWest Inc., Ventura, California)**

$$r_d = \frac{(1.000 - 0.4113z^{0.5} + 0.04052z + 0.001753z^{1.5})}{(1.000 + 0.4177z^{0.5} + 0.05729z - 0.006205z^{1.5} + 0.001210z^{2})}$$

**Idriss & Boulanger (2006)**

$$r_d = \exp[\alpha(z) + \beta(z)\cdot M]$$

$$\alpha(z) = -1.012 - 1.126\sin\left(\frac{z}{11.73} + 5.133\right)$$

$$\beta(z) = 0.106 + 0.118\sin\left(\frac{z}{11.28} + 5.142\right)$$

**Kayen et al. (1992)**

$r_d$ = 1 - 0.012 Z

## 5.4 Post-liquefaction Lateral Spreading

The following method for estimating the post-liquefaction lateral displacements is incorporated into NovoCPT:

Zhang, Robertson and Brachman, 2004

This method is essentially based on estimating maximum cyclic shear strain of each layer during and after liquefaction which is estimated from safety factor against liquefaction (FS) and relative density of soil (Dr), When Dr can be correlated from CPT data based on the following equation (*Tatsuoka et al.,1990*):

$$Dr = -85 + 76\log(q_{c1N}) \qquad q_{c1N} \leq 200$$

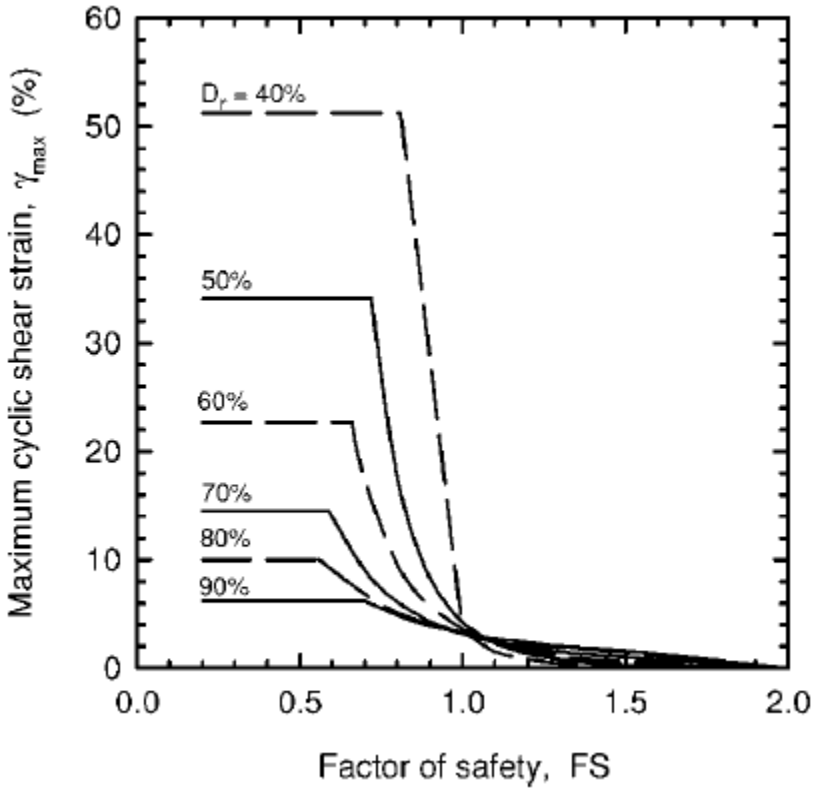



Figure 1 : maximum cyclic shear strain for post liquefaction lateral displacement proposed by Zhang, Robertson and Brachman, 2004.

Then, the Lateral Displacement Index (LDI) is calculated from the following equation:

$$LDI = \int_0^{Z_{max}} \gamma_{max} dz$$

and according to site ground sloping, the lateral displacement is estimated. To read the complete procedure proposed by authors, please read the following paper from our website:

Estimating Liquefaction-Induced Lateral Displacements Using the Standard Penetration Test or Cone Penetration Test

G. Zhang; P. K. Robertson; and R. W. I. Brachman

## 5.5 Post-liquefaction Site Settlement

Post-liquefaction settlements occur during and after earthquake shaking. For level ground conditions the amount can be computed from the volumetric reconsolidation strains induced as the excess pore water pressures dissipate. Based on the field experiences during past earthquakes, the amount of volumetric strain depends on penetration resistance and the CSR applied by the design earthquake. Curves proposed by *Ishihara and Yoshimi (1992)* are shown in Figure 1 and indicate that volumetric reconsolidation strains can range between about 4.5% for very loose sand to 1% for very dense sands. These curves are recommended for estimating post-liquefaction settlements.

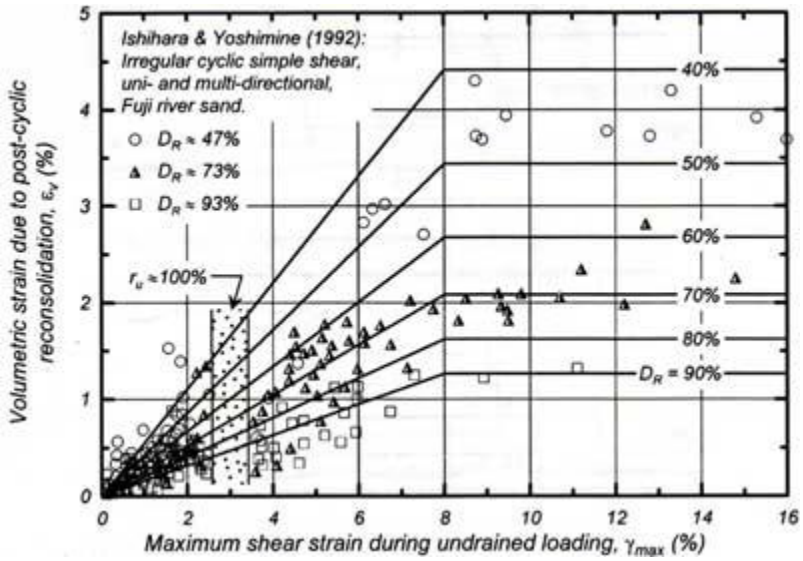



Figure 1 : Recommended relationships for volumetric reconsolidation strains as a function of maximum shear strain and relative density (Ishihara & Yoshimi 1992)

# 6. Online

## 6.1 Novo Tech Software website

http://www.novotechsoftware.com

## 6.2 Our other programs

http://www.novotechsoftware.com/products/

## 6.3 Updates

http://www.novotechsoftware.com/updatelogs/novoCPT.txt

## 6.4 Contact us

http://www.novolab2.com/web forms/contact.php