

GRCgrouting

Manual ground reaction curve with grouted zone around tunnel



Tunnel passage under the Baltic Sea at subway project in Stockholm

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SOFTWARE LICENCE: See Apple EULA

General presentation

The GRCgrouting program was made to be an, easy to use, tool for civil engineers. The main advantage with the GRCgrouting program is its simplicity, its availability on both iOS and macOS platforms and its uniqueness. The program will run on Apple Macintosh machines running MacOS Ventura or later. A version of the software will also run on iOS 16 or later but with some limitations especially regarding the user interface.

The original version of the softwares was written during the beginning of the 1990's so a lot of things has changed. Most significant is the dramatic increase of computing power. Today a full run of a case is done in a second and this has made it unnecessary to store calculation results so the only files available and possible to store are input files (simple text files).

The present version of the program only calculates the ground reaction curves. If the program sell's and the costumers are interested support response from shotcrete and/or rock bolts might be implemented.

The difference between the iOS version an the macOS version is mainly in the user interface. Since macOS can handle many windows and overall menus its a bit easier to use. The possibility for a separate input window to set up what to plot made it possible to plot the development of different stresses and deformations around the tunnel. These plots are only for the exceptionally interested and has very limited practical use. It should be noted that the calculations are identical for both versions. The useful plots are those of the ground reaction curves.

The theory behind the program was originally developed during 1991 to back calculate rock mass properties from measured deformations during construction of a TBM-drilled tunnel in very weak rock. The theory was later presented as an article at the conference "Grouting in Rock and Concrete, Widmann (ed) © 1993 Balkema, Rotterdam, ISBN 90 5410 350 7". The article "An analytical solution to ground reaction curves for grouted tunnels" can be downloaded from the website psiconsab.se.

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The Menubar (macOS)

The menubar has most of the standard parts that's recommended by Apple and some application specific parts for control of the program.

File

The File menu takes care of opening and saving of files, printing and closing

Save input

This menu item will only be seen when there is **inputdata** to save. Choose it and you will get the standard save dialog. Print the name you want to give the file in the edit field and choose the save button.

Open input

Open input will display the standard choose file box. Just select the **inputfile** you want to open and double click or choose the open button.

Print Text Window

(if TextWindow frontmost and there are text in the TextWindow)
Print content of the text window

Print GraphWindow (if GraphWindow frontmost)

Print content of the graph window

Close

Closes the front most window (if both the GraphWindow and the TextWindow are closed the program will terminate).

Edit

SetUpPlot

Brings up the set up plot window

SetUpInput

Brings up the window to define the rock properties, initial stresses and geometry of the tunnel to be studied.

If Text Window is frontmost

Cut

Copy

Paste

Delete

Select all

If Graph Window is frontmost

Copy GraphWindow

Window

TextWindow

Brings the TextWindow to the front.

GraphWindow

Brings the GraphWindow to the front. Results

Interface (mainly valid for both iOS and macOS)

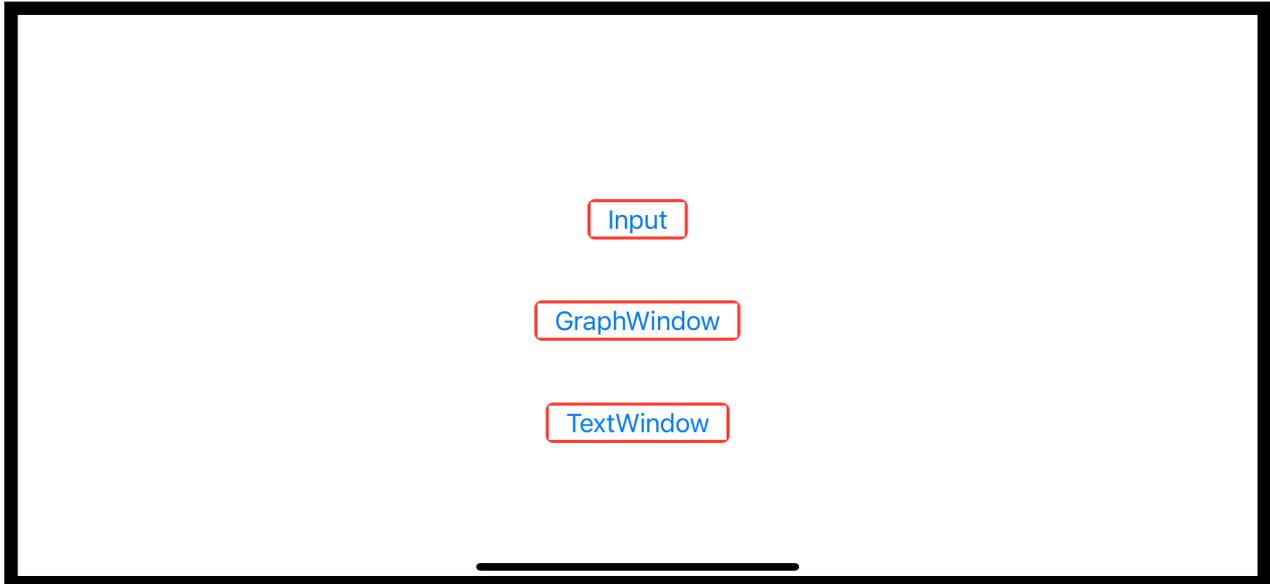


Figure 1: Main choice screen only in iOS.

iPhones and other iOS devices does not have the menu system of Mac computers or all the space that is available on a computer screen so the user interface has to be made differently.

The upper button (Input) moves on to the input screen which will be explained below.

The middle button (GraphWindow) moves on to a screen where most of the action takes place. The lower button moves on to the text screen which contains the text output of the program (not the same as on macOS).

Lets start with the input screen:

Eg [GPa]	μ g [-]	\varnothing g [°]	Cg [MPa]	Er [GPa]	μ r [-]	\varnothing r [°]	Cr [MPa]	Psi [°]	Po [MPa]	rg [m]	ri [m]	Nstep [-]
1,0	0,2	20,0	0,4	0,8	0,2	15,0	0,2	15,0	2,0	10,0	6,0	100

Next Prev Ok Cancel Reset

Figure 2: Input screen. In principle the same for iOS and macOS.

This screen contains the same edit fields as on macOS but has two additional buttons. “Next” and “Prev”. The button “Next” steps one step forward and the button “Prev” steps one step backward. For further explanation of the edit fields see Page 6 below.

Pressing the middle button in the Main choice screen (GraphWindow) brings up a screen showing basically the same as the “GraphWindow” on the Mac version but with some additional buttons as seen and explained below in Figure 3:

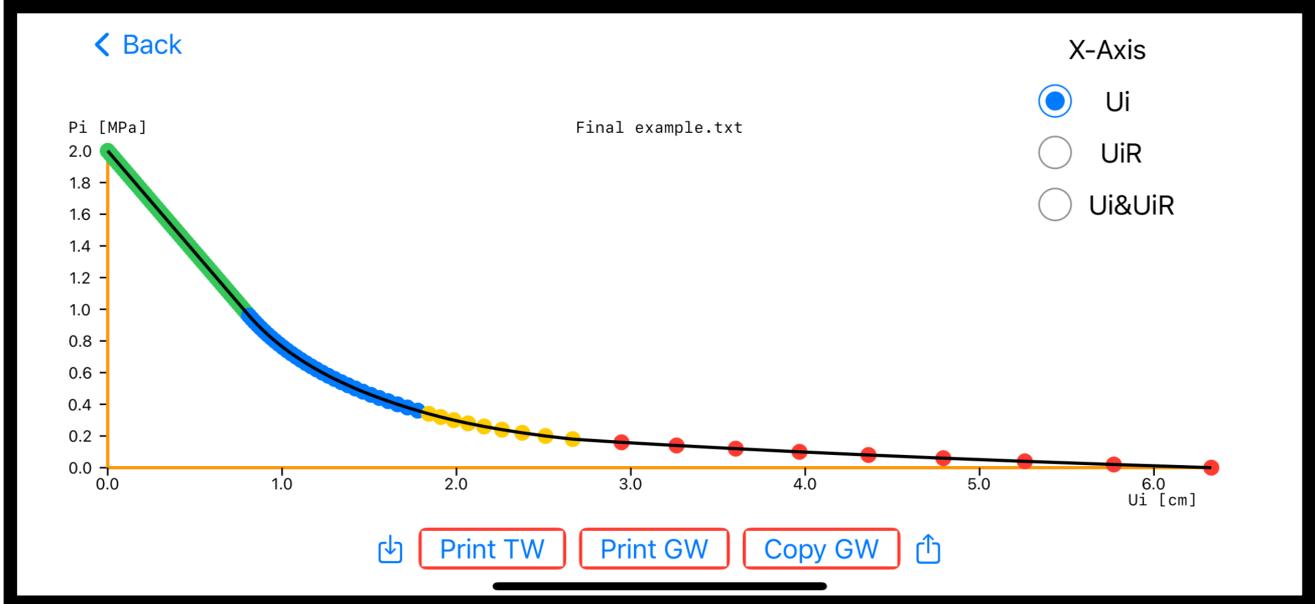
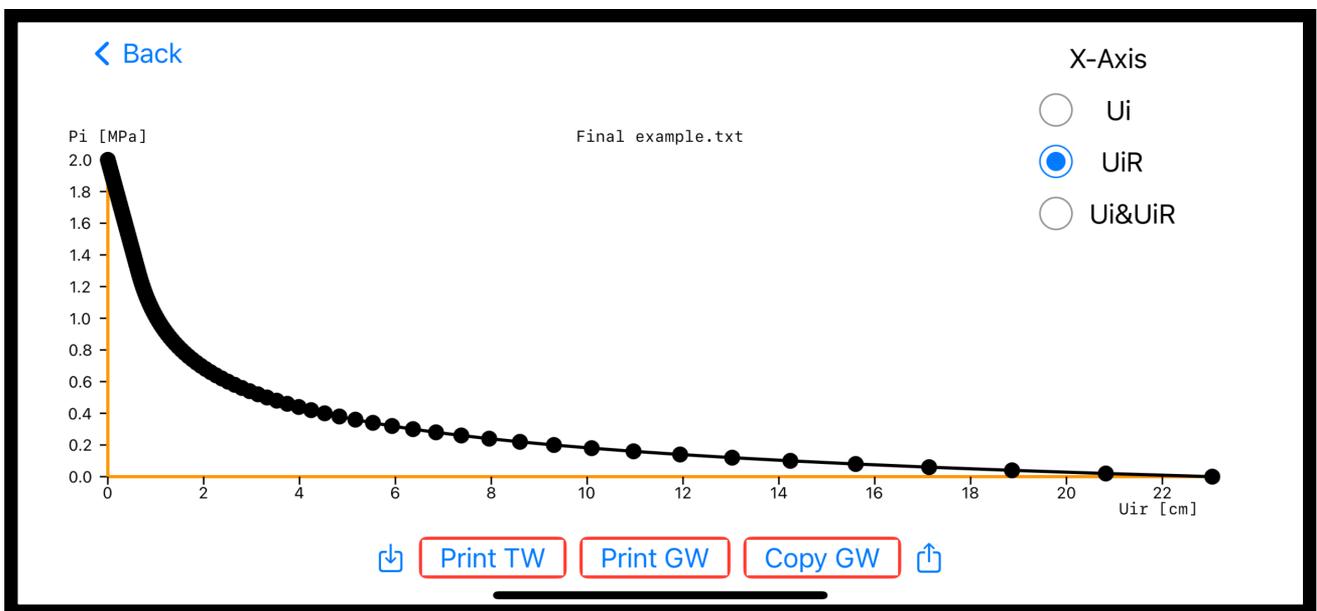


Figure 3: Main action screen (GraphWindow) with action buttons.

The “Print TW” button sends the text in the text window to a printer using “AirPrint”, “Print GW “ button sends the graph in the window (without buttons) to “AirPrint” and Copy GW” will place a .pdf version of the graph in the window (without buttons) in the clip board. If there are any text in the text screen an additional button “Print TW” will be visible. This button sends the text in the text screen to a printer using “AirPrint”.

The meaning of coloring of the graph is presented in the Mac section Page 8 (you might have to read the article ”An



analytical solution to ground reaction curves for grouted tunnels” to fully understand)

Pressing a button under the ”X-Axis will plot different sets of ground reaction curves. Pressing the ”Ui” button will plot the ground reaction curve with the effect of the grouted zone included as seen in Figure 3 above.

Figure 4: Pressing the ”UiR” button will show the ground reaction curve without the effect of the grouting around the tunnel.

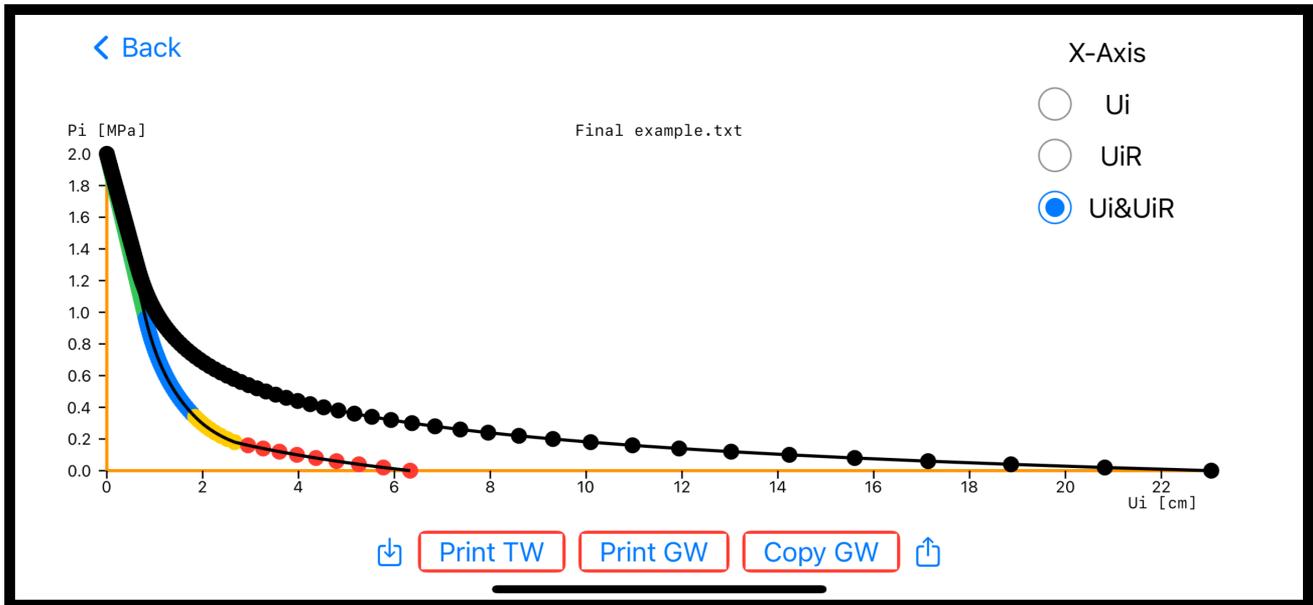


Figure 5: Pressing the "Ui&UiR" button will show both the ground reaction curve without the effect of the grouting around the tunnel and the ground reaction curve with the effect.

A down arrow button "⌵" on the left side opens a screen to read a file from the iPhone storage or from iCloud (example files and other files can be uploaded from psiconsab.se).

The up arrow button "⌶" on the right side is for storing the input file either in the iPhones internal storage or on iCloud.

The remaining of this manual is in principle valid for both macOS and iOS.

SetUpInput menu ("Input button on iOS)

The following window will show:

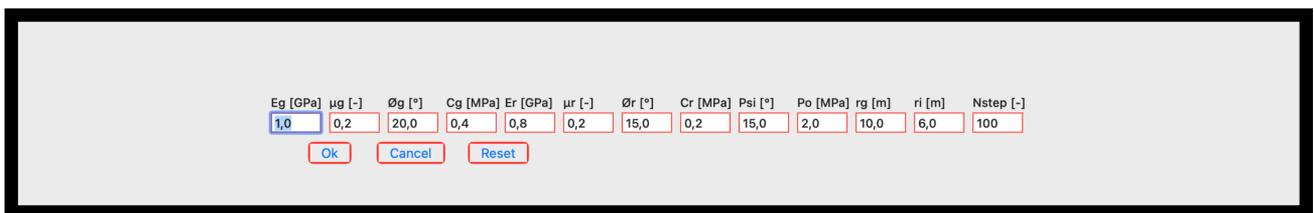


Figure 6: Typical input window macOS. .

This window is for setting up the tunneling case to be studied. You walk around the different edit fields with the mouse, the up and down arrow-keys, return key or the tab key ("Next" and "Prev" buttons on iOS).

The different edit fields has the following meaning:

- Eg [GPa]..... Elastic module of the grouted rock in GPa.
- μg [-]..... Poissons ration for grouted rock. Has no dimension.
- Øg [°]..... Mohr-Columbs inner friction angle for the grouted rock in degrees.
- Cg [MPa]..... Mohr-Columbs cohesion property for the grouted rock in MPa.
- Er [GPa]..... Elastic module of the original rock in GPa.
- μr [-]..... Poissons ration for original rock. Has no dimension.
- Ør [°]..... Mohr-Columbs inner friction angle for the original rock in degrees.
- Cg [MPa]..... Mohr-Columbs cohesion property for the original rock in MPa.
- Psi [°]..... Dillatance angle for both grouted and original rock in degrees.
- Po [MPa]..... Initial stress before excavation of tunnel in MPa.
- Rg [m]..... Radius until en of estimated grouted zone in meters.
- Ri [m]..... Radius of excavated tunnel in meters.

Nstep [-]..... Number of steps going from the initial stress level down to zero stress att tunnel wall.

SetUpPlot menu (the buttons "Ui", "UiR" and "Ui&UiR" on iOS)

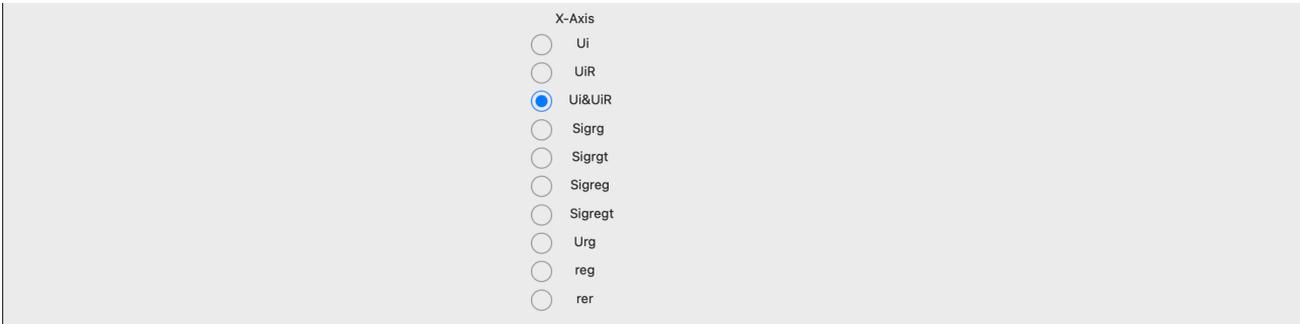


Figure 7: The set up plot window with different alternatives for plotting X-axis. Y-axis will always be Pi, the assumed radial stress on the tunnel wall, going from initial stress to zero.

The buttons gives following values on the X-axis:

- Ui..... Radial deformation of tunnel wall in centimeters for grouted tunnel.
- UiR..... Radial deformation of tunnel wall in centimeters for ungrouted tunnel.
- Ui&UiR..... Both the above.
- The following only for macOS version:
- Sigrg..... Radial stress at boundary between grouted and ungrouted rock.
- Sigrgt..... Tangential stress at boundary between grouted and ungrouted rock.
- Sigreg..... Radial stress at boundary between plasticized and intact grouted rock.
- Sigregt..... Tangential stress at boundary between plasticized and intact grouted rock.
- Urg..... Radial deformation in centimeters at boundary between grouted and ungrouted rock.
- reg..... Radius of plasticized rock in the grouted zone.
- rer..... Radius of plasticized rock in ungrouted rock.

Input data and the above numbers for above is also presented in the text window.

Final notes

A common problem with all software that calculates and do plots is invalid input data. If there are no data to plot there might be problems and if there are invalid material properties or invalid geometries both calculations and plots might create fatal errors. This program therefore uses a dummy input as stand in for input data if it is the first time the program is run on a device. The program also implements a rigorous check and will refuse to accept invalid input data.

In order to fully understand the theory behind the program it is necessary to read the article "An analytical solution to ground reaction curves for grouted tunnels" that can be downloaded from the psiconsab.se website.

The color coding of the ground reaction curve graph for grouted tunnel are as follows:

- E-E..... Green All elastic
- E-EP..... Orange All grouted rock elastic and ungrouted rock partly plasticized.
- EP-E..... Blue Grouted rock partly plasticized and all ungrouted rock intact elastic.
- EP-EP... Yellow Grouted rock partly plasticized and ungrouted rock partly plasticized.
- P-E..... Purple Grouted rock totally plasticized and all ungrouted rock intact elastic.
- P-EP..... Red Grouted rock totally plasticized and ungrouted rock partly plasticized

It should also be noted that the developed theory does not fully correspond to the "normal" ground reaction curve theory. The theory utilized here gives slightly larger deformations for P-E and P-EP cases compared with "normal" ground reaction curves.