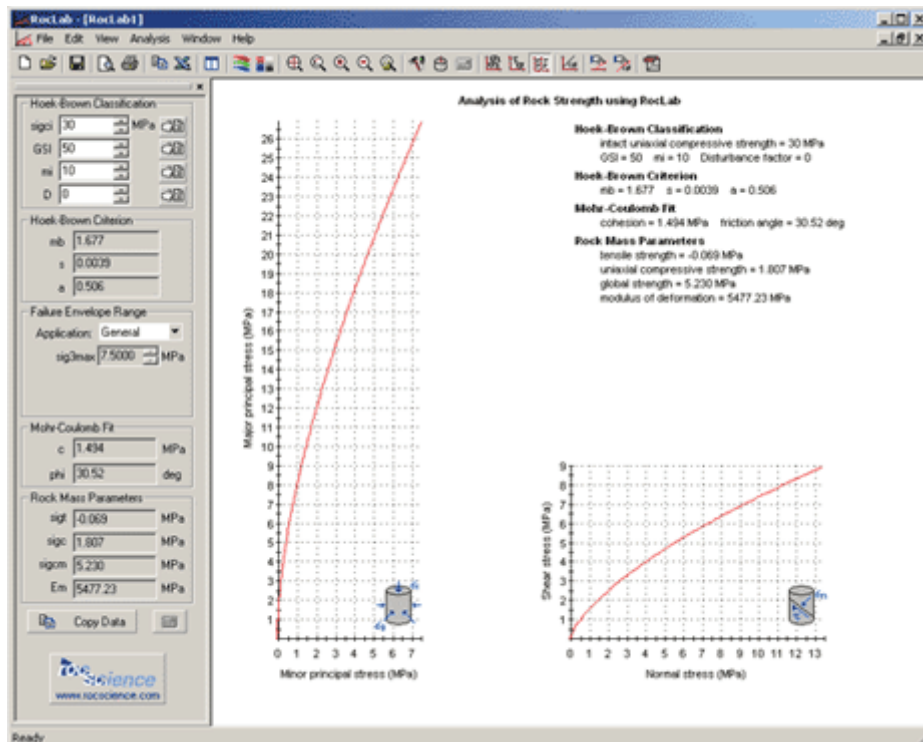


# RocLab 1.0

## Rock Mass Strength Analysis using the Generalized Hoek-Brown failure criterion

*RocLab* is a software program for determining rock mass strength parameters, based on the latest version of the generalized Hoek-Brown failure criterion. *RocLab* provides a simple and intuitive implementation of the Hoek-Brown failure criterion, allowing users to easily obtain reliable estimates of rock mass properties and to visualize the effects of changing rock mass parameters on the failure envelopes.



The reference is available in PDF format, when you install the program. The rock mass properties determined by *RocLab* can be used as input for numerical analysis programs such as *Phase<sup>2</sup>* (finite element stress analysis and support design for excavations) or *Slide* (limit equilibrium slope stability analysis).

While *RocLab* 1.0 will continue to be offered as a free program, recent improvements and future developments are included in *RocData* 4.0. A comparison chart, *RocLab* 1.0 versus *RocData* 4.0, highlights the features in both programs.

Go to [Downloads](#) to get your free copy of *RocLab*. The *RocLab* Manual is available in both [English](#) and [Spanish](#).

# Data Input/Output: Hoek-Brown Input and Output Parameters

Using the following Hoek-Brown classification parameters as input:

- the unconfined compressive strength of intact rock  $\sigma_{ci}$
- the geological strength index GSI
- the intact rock parameter  $m_i$  and
- the disturbance factor D

*RocLab* determines the generalized Hoek-Brown strength parameters of a rock mass:

- $m_b$
- $s$
- $a$

The image shows a software interface for inputting Hoek-Brown parameters. It is divided into two sections: 'Hoek-Brown Classification' and 'Hoek-Brown Criterion'. In the 'Hoek-Brown Classification' section, there are four input fields: 'sigci' with a value of 30 and a unit of MPa, 'GSI' with a value of 50, 'mi' with a value of 10, and 'D' with a value of 0. Each field has a small pick button to its right. In the 'Hoek-Brown Criterion' section, there are three input fields: 'mb' with a value of 1.677, 's' with a value of 0.0039, and 'a' with a value of 0.506.

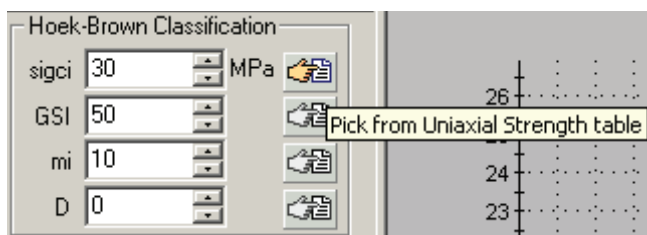
*Input  $\sigma_{ci}$ , GSI,  $m_i$ , and D to calculate the Generalized Hoek-Brown failure envelope parameters  $m_b$ ,  $s$  and  $a$*

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## Data Input/Output: Estimation of Input Parameters

Each of the 4 input parameters ( $\sigma_{ci}$ , GSI,  $m_i$  and D) can be conveniently estimated from built-in charts and tables, based on rock type, geological conditions, etc.

These charts and tables are accessed by selecting the pick button located beside each of the input parameter edit boxes in the side bar.



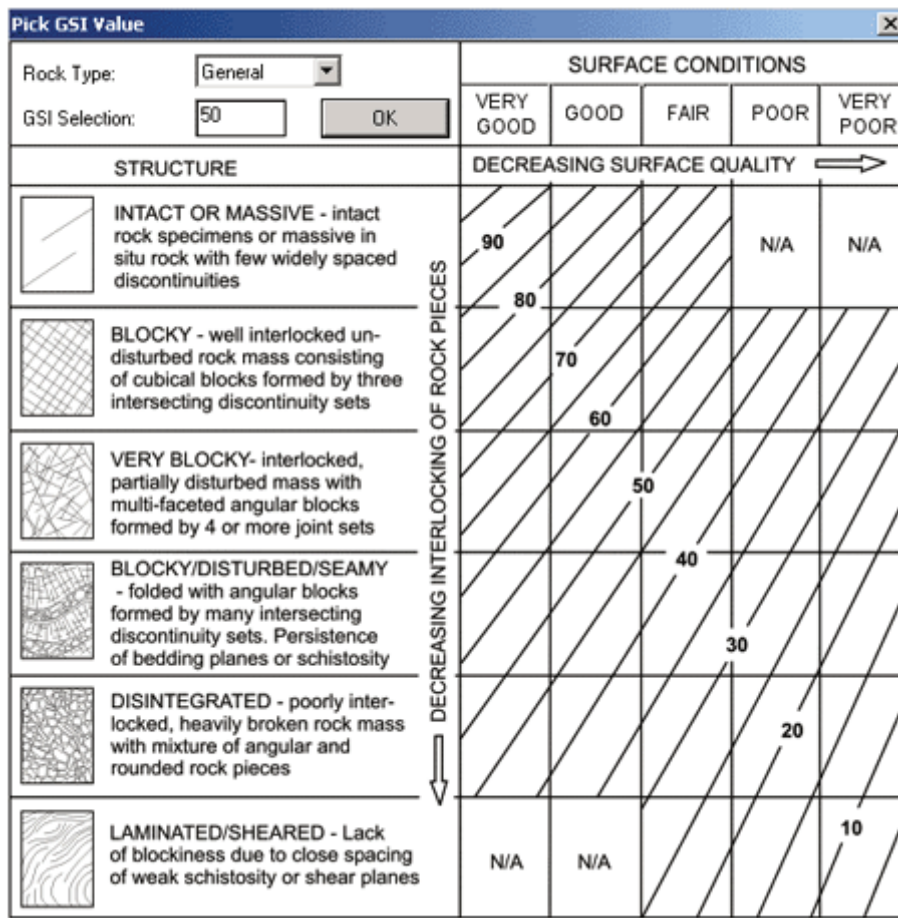
Click on the "Pick" buttons located beside the input parameters in the side bar

When you select a "Pick" button, a table or chart will appear, allowing the user to determine a suitable value for the desired parameter. Once a value is selected in the dialog, the value will be automatically loaded into the input data area and the RocLab calculation will be carried out automatically.

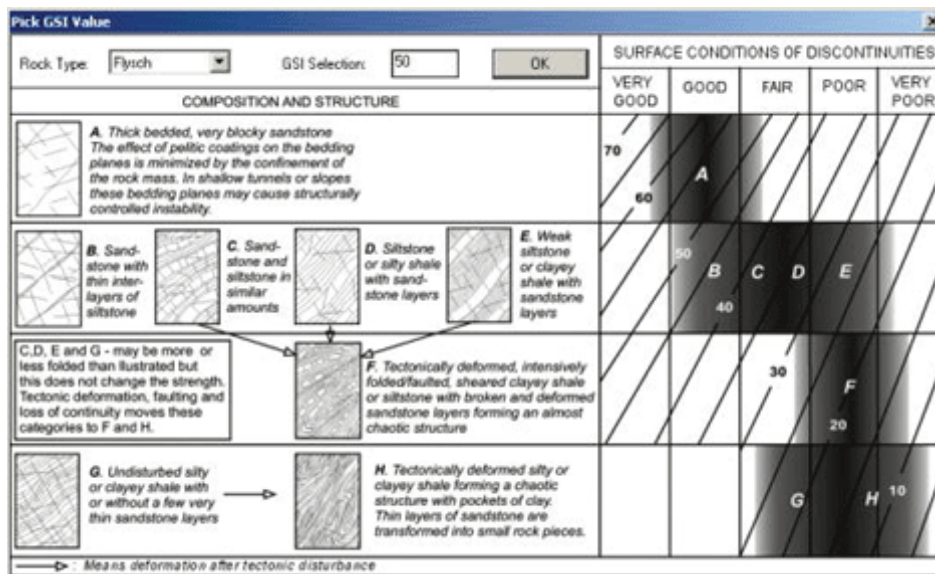
Field Estimate of Strength	Examples	Strength (MPa)
Specimen can only be chipped with a geological hammer.	Fresh basalt, chert, diabase, gneiss, granite, quartzite.	>250
Specimen requires many blows of a geological hammer to fracture it.	Amphibolite, sandstone, basalt, gabbro, gneiss, granodiorite, limestone, marble, rhyolite, tuff.	100-250
Specimen requires more than one blow of a geological hammer to fracture it.	Limestone, marble, phyllite, sandstone, schist, shale.	50-100
Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single blow from a geological hammer.	Claystone, coal, concrete, schist, shale, siltstone.	25-50
Can be peeled with a pocket knife with difficulty, shallow indentation made by firm blow with point of a geological hammer.	Chalk, rocksalt, potash.	5-25
Crumbles under firm blows with point of a geological hammer, can be peeled by a pocket knife.	Highly weathered or altered rock.	1-5
Indented by thumbnail.	Stiff fault gouge.	0.25-1

Uniaxial Compressive Strength (sigci):  MPa

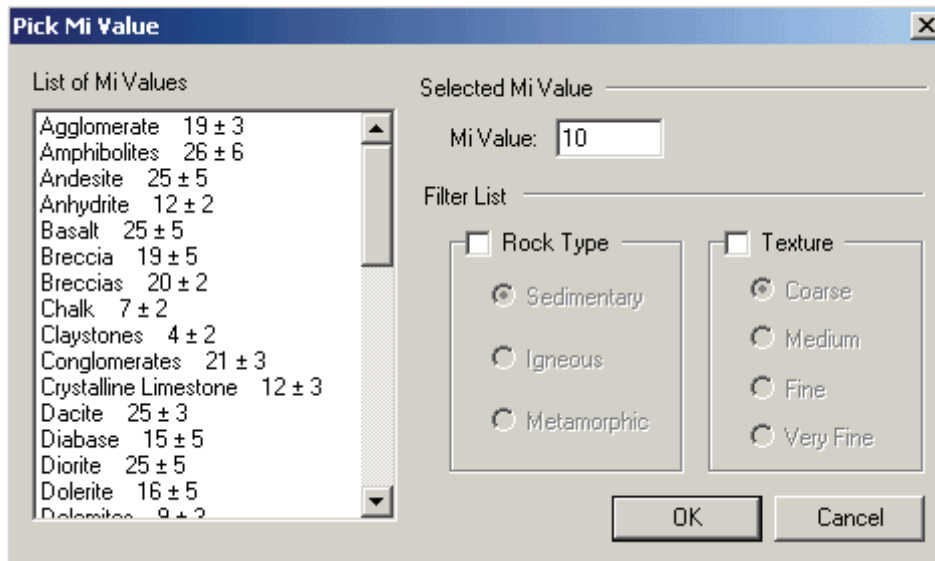
*Intact Uniaxial Compressive Strength Chart*



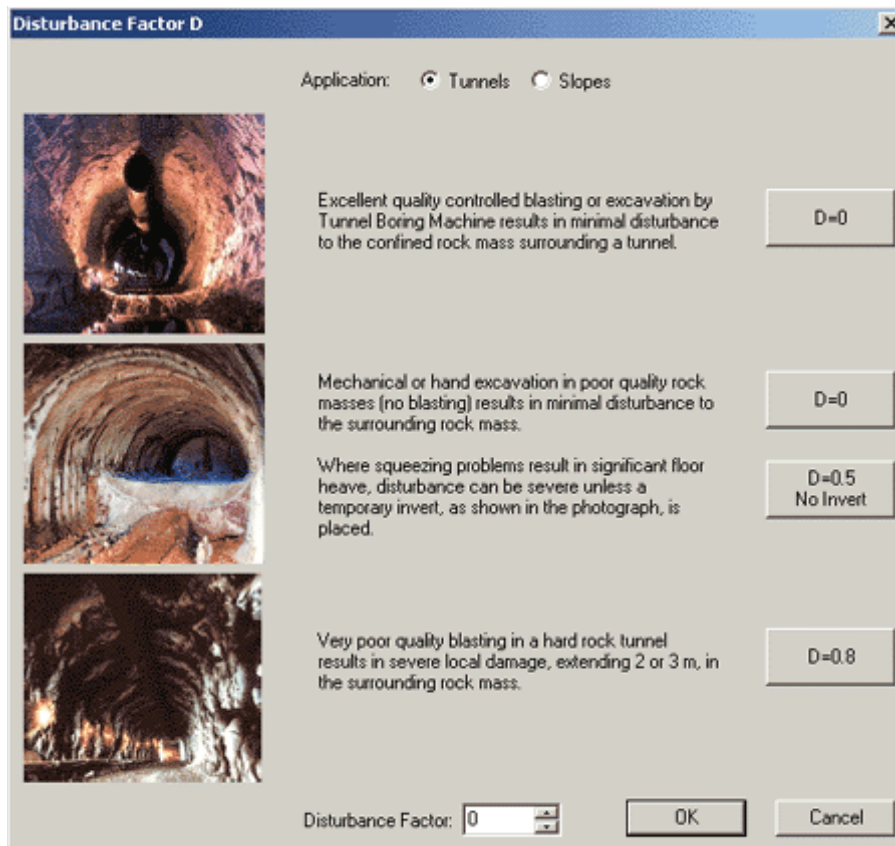
GSI chart for General rock type



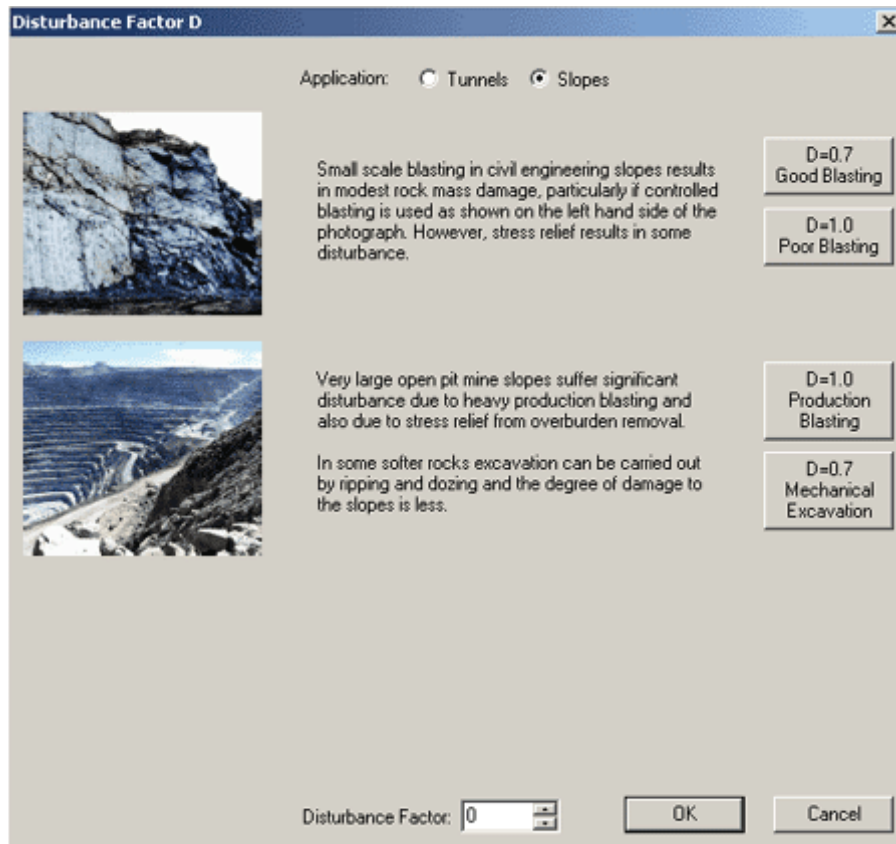
GSI chart for Flysch rock type



*Pick Mi Value chart*



*Pick Disturbance Factor dialog for both "Tunnels" and "Slopes" applications*



*Pick Disturbance Factor dialog for both "Tunnels" and "Slopes" applications*

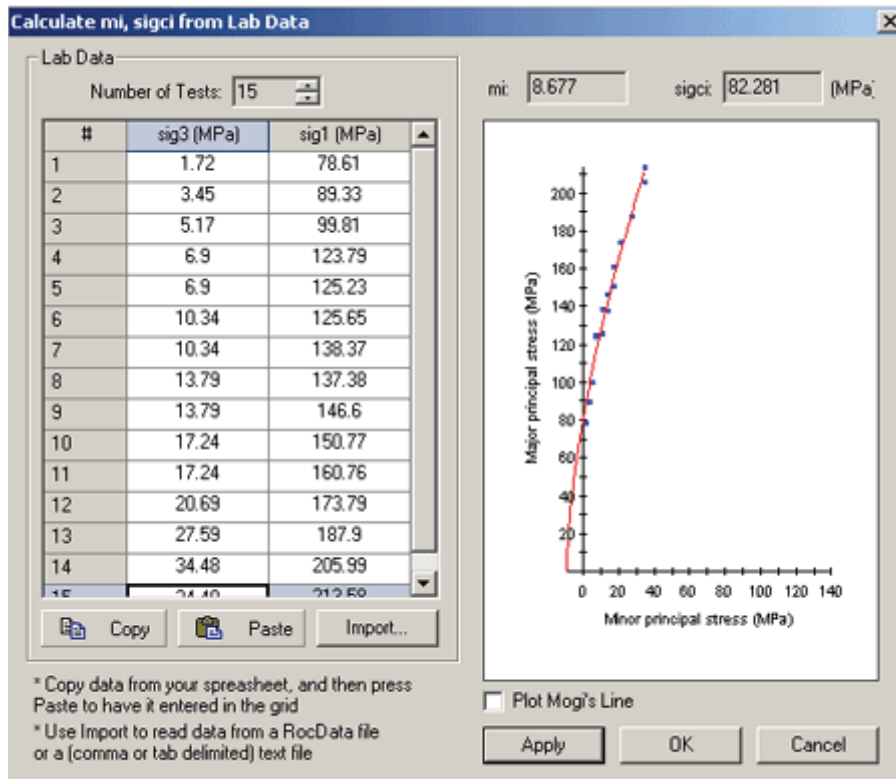
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## Data Input/Output: Triaxial Lab Data Input

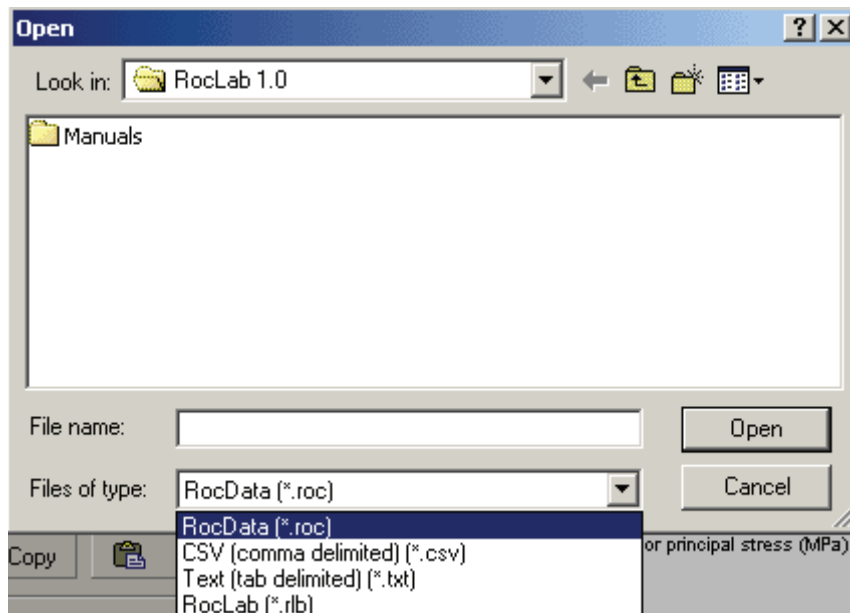
Another feature of *RocLab* is the ability to input triaxial lab test data ( $\sigma_1 / \sigma_3$  data pairs) in order to determine the intact rock parameters  $\sigma_{ci}$  and  $m_i$ .

The data can be entered directly into a spreadsheet in the dialog, pasted from the clipboard, or the data can be imported from various file formats, by selecting the Import button.

The parameters  $\sigma_{ci}$  and  $m_i$  are obtained by performing a curve fit of the lab data, using the Marquardt-Levenberg fitting technique. Obtaining values of  $\sigma_{ci}$  and  $m_i$  from triaxial lab test data is recommended, if such data is available. If triaxial lab data is not available, values of  $\sigma_{ci}$  and  $m_i$  can always be estimated in *RocLab*, using the Pick dialogs.



Calculating  $sigci$  and  $m_i$  from Lab Data



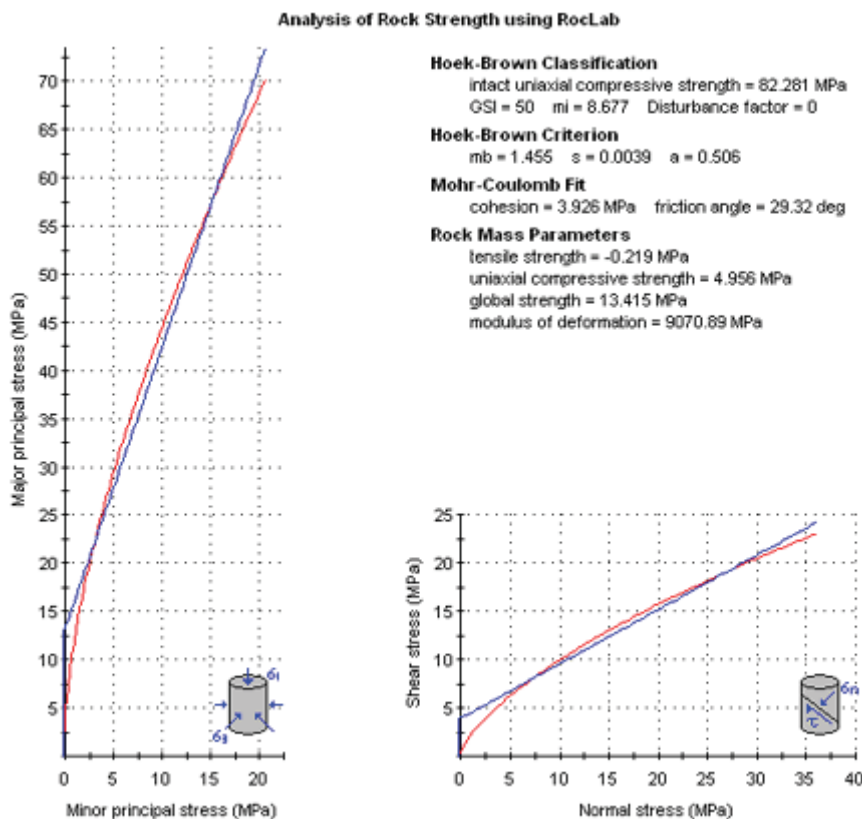
Import Triaxial lab Data from Microsoft Excel, RocData or RocLab Files

## Data Input/Output: Equivalent Mohr-Coulomb Parameters

In addition to the Hoek-Brown failure criterion parameters ( $m_b$ ,  $s$  and  $a$ ), *RocLab* always calculates equivalent Mohr-Coulomb parameters (cohesion and friction angle) for the rock mass. The best-fit Mohr-Coulomb strength envelope is determined over a stress range that the user can define based on the application (i.e. tunneling or slope stability).

Hoek-Brown Criterion	
$m_b$	1.455
$s$	0.0039
$a$	0.506
Failure Envelope Range	
Application:	Slopes
$\sigma_{3max}$	1.1548 MPa
Unit Weight	0.026 MN/m <sup>3</sup>
Slope Height	50 m
Mohr-Coulomb Fit	
$c$	0.847 MPa
$\phi$	51.82 deg

The calculated Mohr-Coulomb parameters are listed in the sidebar



The corresponding Mohr-Coulomb envelope (the blue curve) can be viewed on the plot as well



## Data Input/Output: Rock-mass Parameters Calculation

*RocLab* calculates rock-mass parameters such as tensile strength, uniaxial compressive strength, global strength and deformation modulus.

Rock Mass Parameters		
sigt	-0.219	MPa
sigc	4.956	MPa
sigcm	13.415	MPa
Em	9070.89	MPa

*Calculated rock-mass parameters are listed in the sidebar*

### Rock Mass Parameters

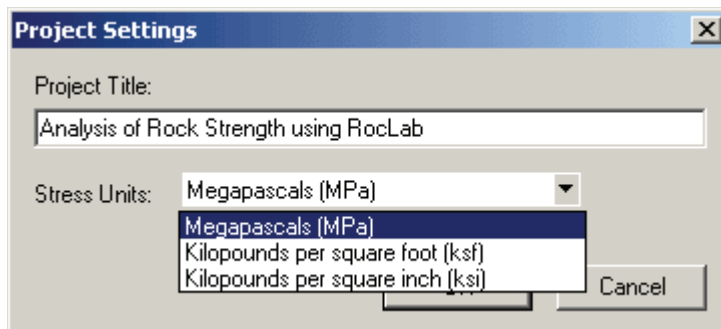
tensile strength = -0.219 MPa  
uniaxial compressive strength = 4.956 MPa  
global strength = 13.415 MPa  
modulus of deformation = 9070.89 MPa

*Rock-mass parameters can be listed on the plot by toggling the "display options"*

---

## Data Input/Output: Metric and Imperial Units

*RocLab* allows the user to work with either Metric or Imperial units. All data entries and calculations will change accordingly once the unit system is switched in the Project Settings Dialog Box. The user can choose between megapascals (MPa, metric), Kilopounds per square foot (ksf, Imperial) and Kilopounds per square inch (ksi, Imperial) unit systems.

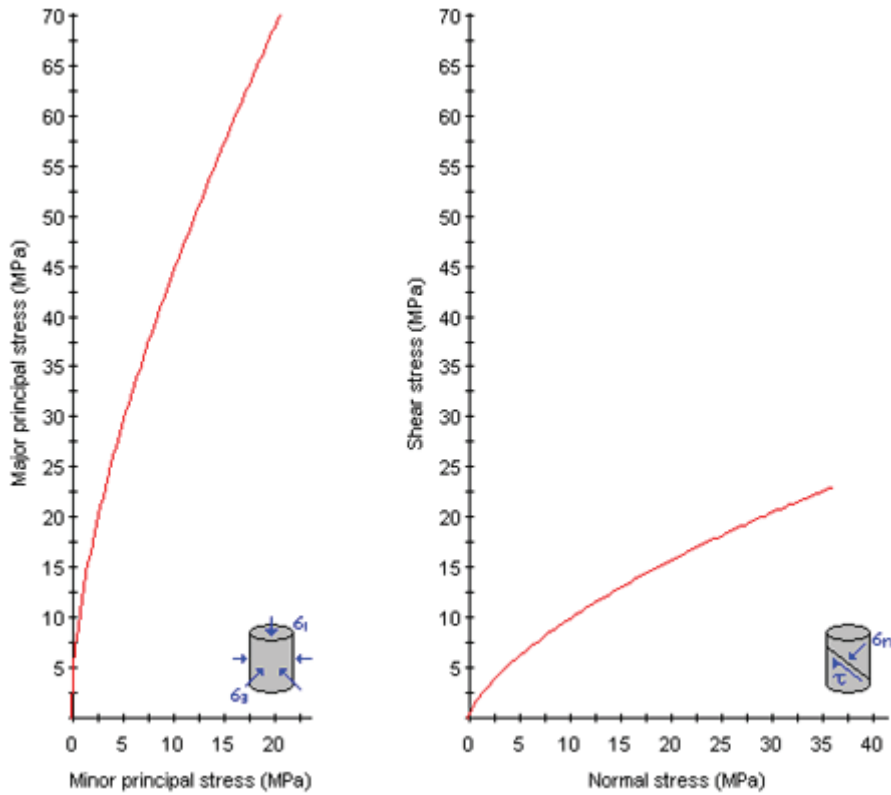


*Switch the Stress Units in the Project Settings Dialog*

---

## Display Capabilities: Failure Envelope Plots

RocLab plots the rock mass failure envelopes in both principal stress space ( $\sigma_1$  vs.  $\sigma_3$ ) and shear-normal stress space ( $\sigma_{\text{normal}}$  vs.  $\tau$ ). By default, both principal stress and shear-normal plots are displayed, but the user can choose to display either plot type on its own by selecting the desired plot type from the toolbar, the Analysis menu or the right-click pop-up menu.



*Both Principal stress and Shear-Normal stress plots are displayed by default*

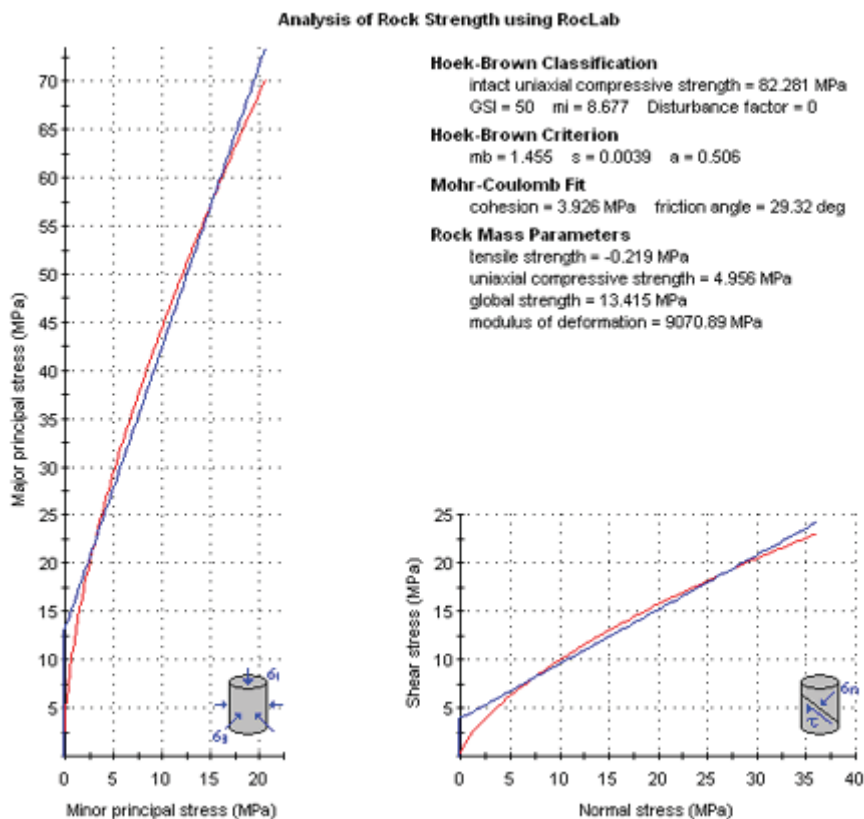
---

## Display Capabilities: Equivalent Mohr-Coulomb Parameters

In addition to the Hoek-Brown failure criterion parameters ( $m_b$ ,  $s$  and  $a$ ), RocLab always calculates equivalent Mohr-Coulomb parameters (cohesion and friction angle) for the rock mass. The best-fit Mohr-Coulomb strength envelope is determined over a stress range that the user can define based on the application (i.e. tunneling or slope stability).

Hoek-Brown Criterion	
$m_b$	1.455
$s$	0.0039
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Application:	Slopes
$\sigma_{3max}$	1.1548 MPa
Unit Weight	0.026 MN/m <sup>3</sup>
Slope Height	50 m
Mohr-Coulomb Fit	
$c$	0.847 MPa
$\phi$	51.82 deg

The calculated Mohr-Coulomb parameters are listed in the sidebar



The corresponding Mohr-Coulomb envelope (the blue curve) can be viewed on the plot as well

## Display Capabilities: Interactive Data Input

If the user click on the arrows with the mouse to change the input data, the *RocLab* calculations are instantly performed. All output data is immediately recalculated, and the failure envelope plots are redrawn each time the mouse is clicked on either the up or the down arrow.



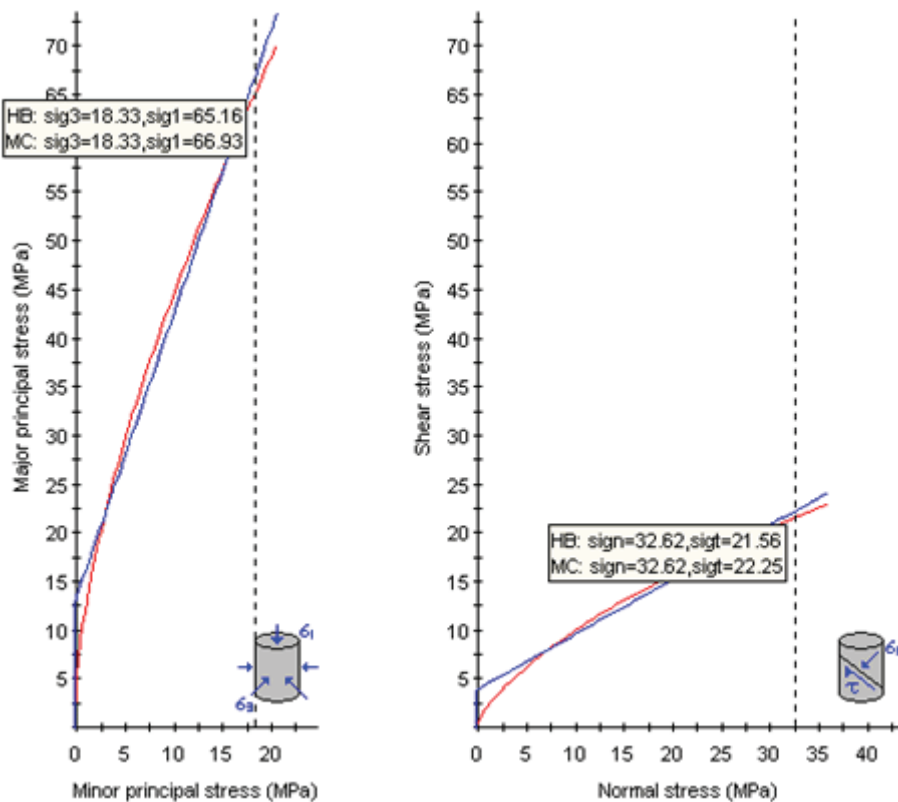
*Interactive Data Input by clicking on the up/down arrows*

This allows the user to interactively observe the effect of parameter changes, on the shape of the failure envelopes, and the output values.

---

## Display Capabilities: Stress Sampler

The stress sampler option allows the user to graphically obtain the exact stress coordinates at any point along the failure envelopes.

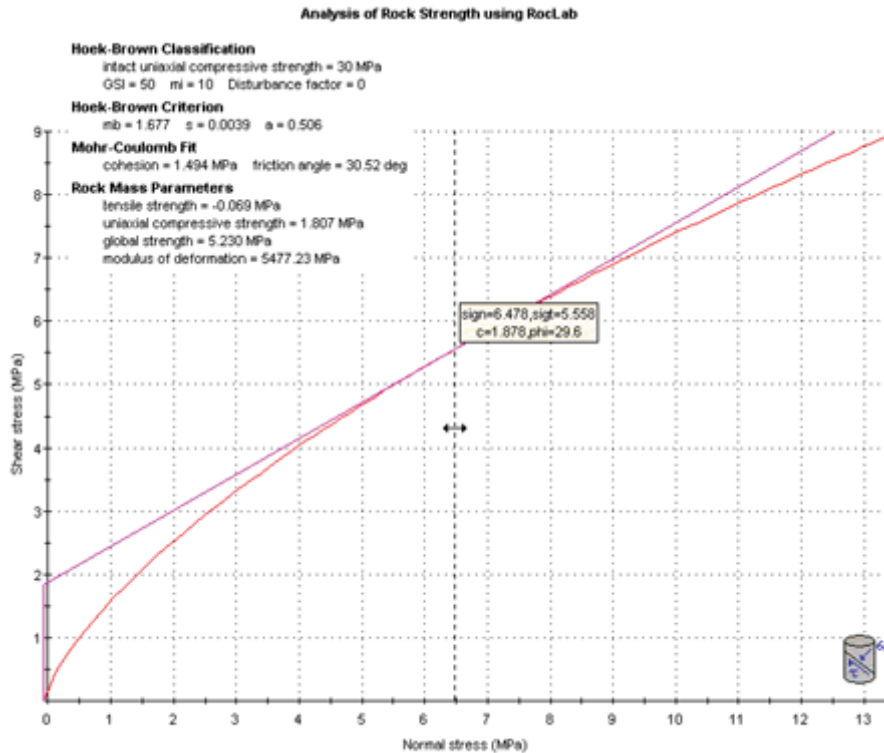


*Sample the Hoek-Brown or Mohr-Coulomb failure envelopes*

---

## Display Capabilities: Instantaneous MC Sampler

The Instantaneous Mohr-Coulomb Sampler option allows the user to graphically obtain the instantaneous Mohr-Coulomb parameters (cohesion and friction angle) at any point along the Hoek-Brown failure envelopes.

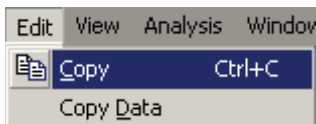


### Instantaneous MC Sampler

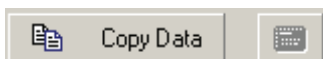
---

## Display Capabilities: Export Data/Images

*RocLab* allows the user to export data for further analysis or report writing. It lets the user copy the data / plots to the clipboard for easy import into Microsoft Word or other word processors or image editing programs.

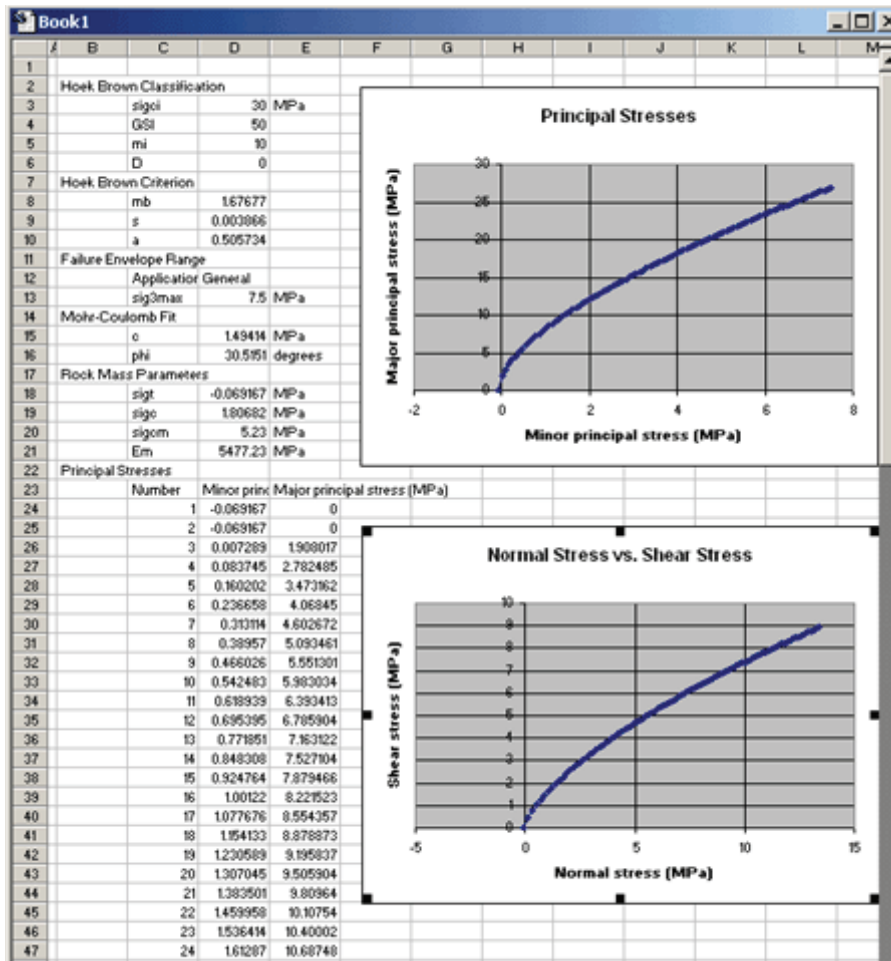


*The Copy option copies the plots and the Copy Data option copies the data to the clipboard*



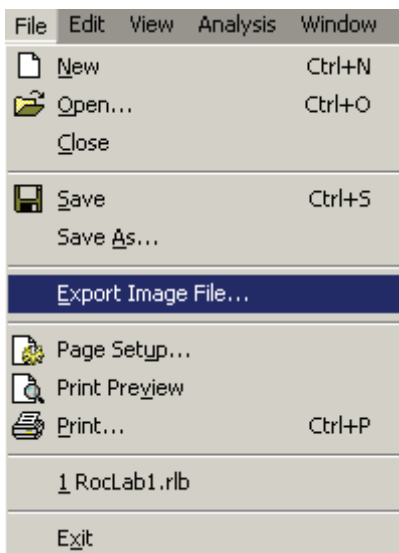
*The Copy Data function in the Sidebar*

Also, *RocLab* enables the user to export the data / plots directly into Microsoft Excel by clicking the Excel charting button on the toolbar.



A Sample Excel chart generated by RocLab

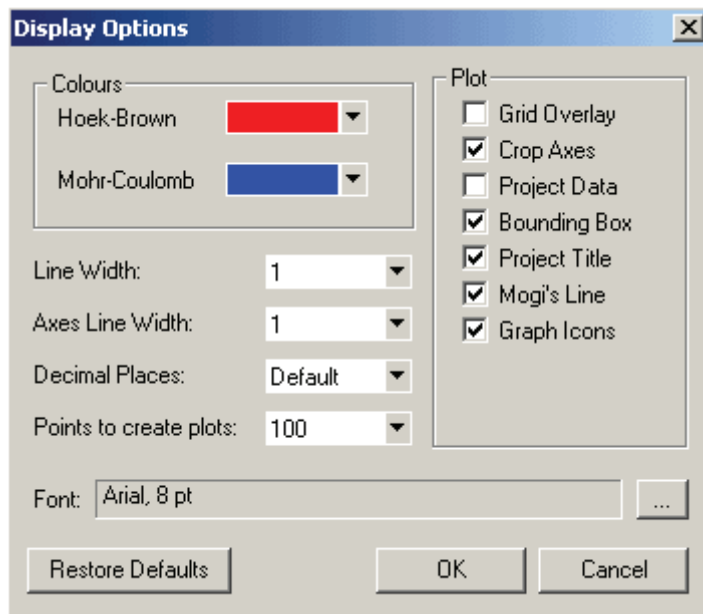
The user can save the plots to a JPEG or BMP image file using the Export Image File option under the File menu or in the right-click pop-up menu.



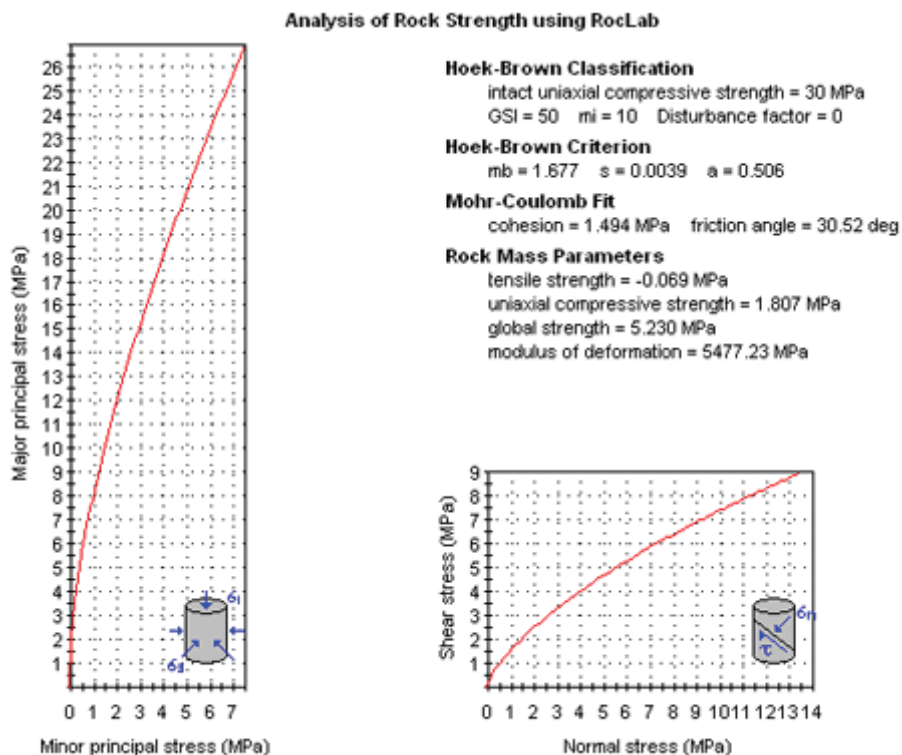
The Export Image File option under File menu

## Display Capabilities: Display Options

The appearance of the plots may be customized with Display Options, zooming, and other options. *RocLab* allows the user to change colors, fonts, line thickness of the plots and toggle grid overlay, plot title, input data, bounding box, graph icons, and Mogi's Line.



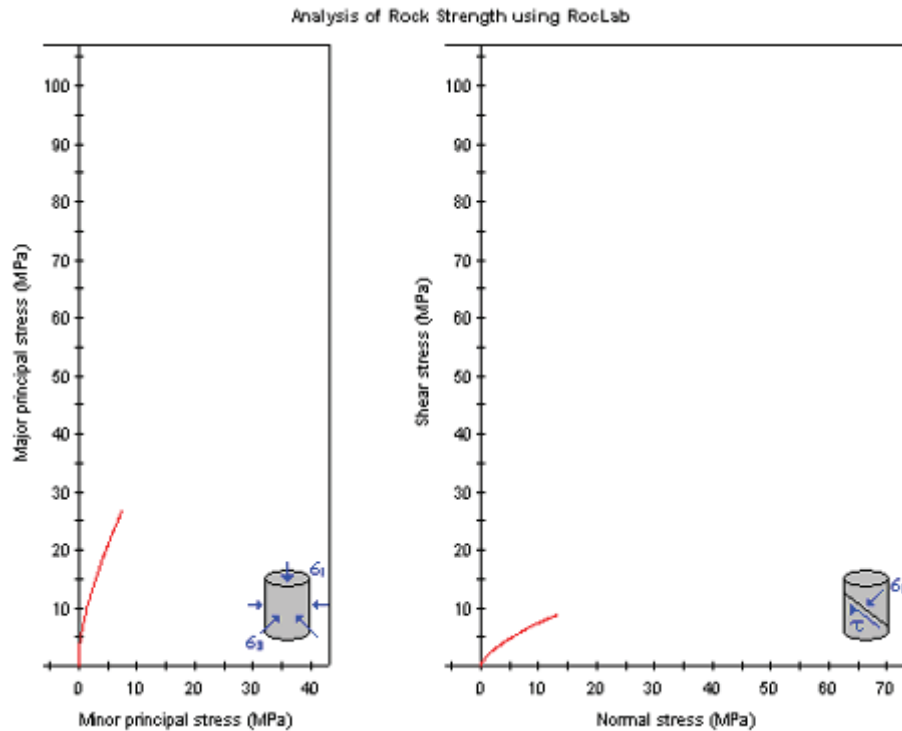
*The Display Options Dialog*



*The effect of adding grid overlay, bounding boxes, project title, graph icons, and cropping axes*

## Zooming

The Zoom options in the toolbar allow the user to customize the zooming of the plot axes. The Zoom Extents option will automatically scale the axes of the failure envelopes, so that all possible failure envelopes, for the current value of  $\sigma_{ci}$ , will be visible on the plot. The Zoom Extents option is useful for interactive demonstration of parameter changes on the failure envelope.



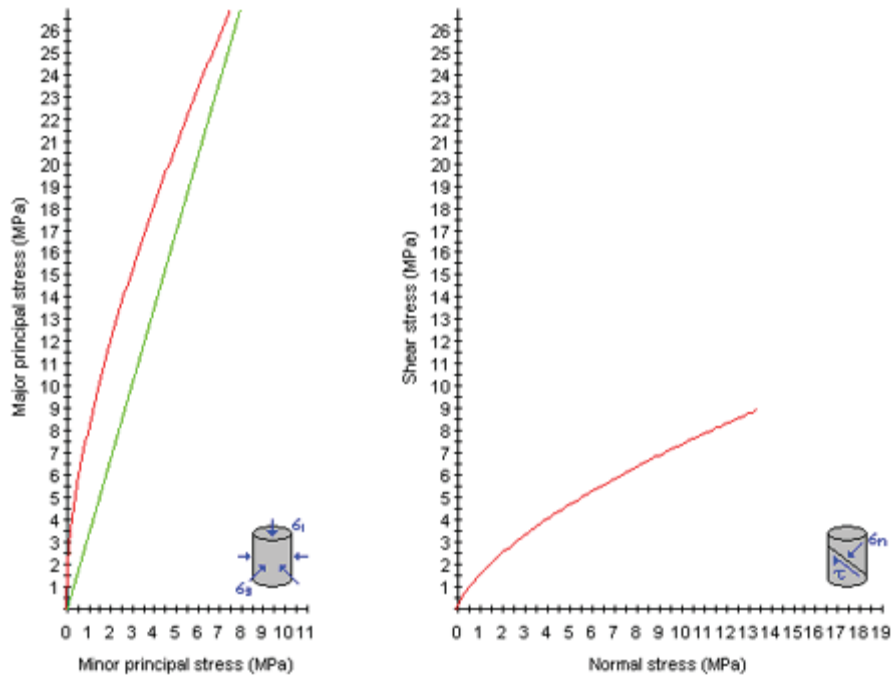
*The effect of Zoom Extents*

## Mogi's Line

Mogi's Line defines the ratio of major and minor effective principal stresses at which there is a transition from brittle to ductile failure. This line is simply defined by  $\sigma_1 / \sigma_3 = 3.4$ , and is plotted as a green line on the principal stress plot, when the Mogi's Line option is selected in the Display Options dialog.

If the principal stress failure envelope lies above Mogi's line, this indicates a brittle failure mode. If the principal stress failure envelope lies below Mogi's line, this indicates a ductile failure mode. This may occur with low values of GSI, for example.

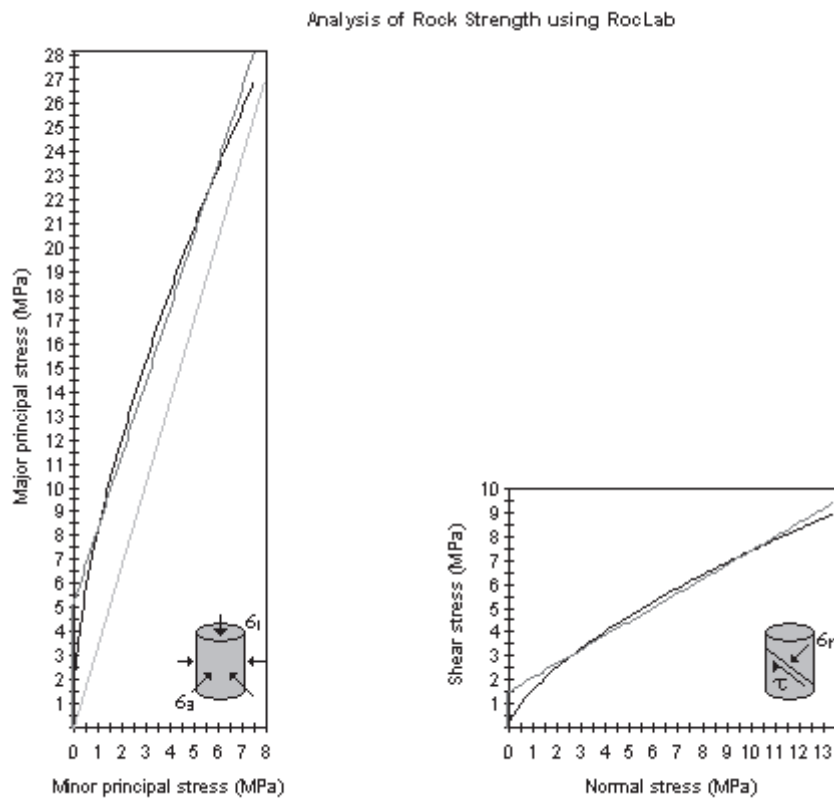




*Mogi's line is shown as a green line on the principal stress plot*

## Grayscale

The Grayscale option allows the user to convert the entire view to grayscale (black and white) with a single mouse click. This can be useful when black and white screen captures or printouts are necessary.



*Effect of grayscale*

# RocLab 1.0 – FAQs

## *I calculate a value of $m_i$ to be around 100 yet RocLab limits $m_i$ to be between 1 and 50. Why?*

1. Your values of  $m_i$  of around 100 are almost certainly associated with too small a range of confining stresses in your triaxial testing. This is a problem that I come across very frequently. The original definition of  $m_i$  is based on triaxial tests up to one half of the uniaxial compressive strength of the intact material. The following quote is from Hoek and Brown, 1997, "Practical estimates of rock mass strength" published in the Int. J. Rock. Mech. Min Sci.

"Note that the range of minor principal stress ( $\sigma_3$ ) values over which these tests are carried out is critical in determining reliable values for the two constants. In deriving the original values of  $\sigma_{ci}$  and  $m_i$ , Hoek and Brown used a range of  $0 < \sigma_3 < 0.5 \cdot \sigma_{ci}$  and, in order to be consistent, it is essential that the same range be used in any laboratory triaxial tests on intact rock specimens."

For example, if you analyze the following data set for Carrara marble using *RocLab* you obtain  $\sigma_{ci} = 82.28$  and  $m_i = 8.68$ .

1.72	78.61
3.45	89.33
5.17	99.81
6.9	123.79
6.9	125.23
10.34	125.65
10.34	138.37
13.79	137.38
13.79	146.6
17.24	150.77
17.24	160.76
20.69	173.79
27.59	187.9
34.48	205.99
34.48	213.58

Note that the maximum value of  $\sigma_3$  is too low in this case - it should be about 40 MPa but this is a real data set and it is all that I have.

On the other hand, if I analyze only the first 4 data points, up to  $\sigma_3 = 6.9$  MPa, I obtain  $\sigma_{ci} = 48.92$  and  $m_i = 32.13$ . If this data set was for hard rock I could easily get  $m_i$  values of over 100 by limiting the range of  $\sigma_3$  values.

All the values quoted in the various Hoek-Brown papers are derived from triaxial test data with the correct range of  $\sigma_3$  values - this was one of the criteria that we set in determining whether or not the data were acceptable. The typical range of  $m_i$  values is from about 5, for soft ductile rocks, to 35 for very hard brittle rocks. Hence we set the range of  $1 < m_i < 50$  in *RockLab* to cover this range.

***For the three sigma3, sigma1 laboratory strength data (0,16),(5,105.9),(20,161), why does RocLab 1.007, RocLab 1.006 and RocData 2.37 using Linear Regression and Simplex fitting give different values of mi and sigci when fitting the Hoek-Brown envelope?***

2. *RocLab* uses the Levenberg-Marquardt method, a robust algorithm that has become the standard for non-linear regression. The method is very reliable in practice, and has the ability to converge promptly from a wider range of initial guesses than other typical methods.

*RocLab* Versions 1.000 to 1.005 used a linearized form of the Hoek-Brown equation that had the effect of reducing the Levenberg-Marquardt method to linear regression. This was modified in Version 1.006 in order to take full advantage of the power of the Levenberg-Marquardt method.

We looked closely at the varying results provided by different regression algorithms, which you sent us. We judged the quality of the results using the ‘Sum Square of Errors’ (SSE) – the sum of the square of the vertical distances of the given data points from the fitted curve. (In *RocLab* Version 1.006 and up this quantity is referred to as ‘Residuals’; in some statistical literature it is known as the sum-of-squares.) The analysis indicated the following:

- i. The linear regression results (sigci=50.7 MPa and mi=17.8) given by *RocData* Version 2, the published spreadsheet of Hoek and Brown, and *RocLab* Versions 1.000 to 1.005, gave an SSE value of 1490.98
- ii. The simplex method in *RocData* that gave sigci=20.47 MPa and mi=55.46 had an SSE of 663.539
- iii. *RocLab* Version 1.007 results (sigci=20.998 MPa and mi=49.9) had an SSE of 702.858

These SSEs tell us that *RocData* and *RocLab* 1.007 found curves that better fit the data than the linear regression approaches. It may seem that *RocLab* 1.007 gave slightly worse results than the simplex method in *RocData*, but this is not so.

*RocLab* 1.007 allows mi only to range between 1 and 50. When we remove the upper limit, the program gives sigci=20.487, mi=55.44 and SSE=663.539, nearly identical to the results of the simplex method.

*RocLab* 1.007 caps the maximum value of mi at 50 because, according to Dr. Evert Hoek, mi values higher than this threshold indicate too small a range of confining stresses in triaxial testing. The following quote is from the paper ‘Practical Estimates of Rock Mass Strength’ by Hoek and Brown (International Journal of Rock Mechanics and Mining Sciences, Vol. 34, No. 8, pp. 1165-1186, 1997):

Note that the range of minor principal stress ( ) values over which these tests are carried out is critical in determining reliable values for the two constants. In deriving the original values of and , Hoek and Brown used a range of and, in order to be consistent, it is essential that the same range be used in any laboratory triaxial tests on intact rock specimens.