

# ***RocData***

Strength analysis of rock and soil masses  
using  
the Generalized Hoek-Brown, Mohr-  
Coulomb, Barton-Bandis and Power Curve  
failure criteria

## **User's Guide**

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# Table of Contents

<b>Welcome to RocData!</b> .....	<b>3</b>
<b>Introduction</b> .....	<b>4</b>
Generalized Hoek-Brown Criterion .....	5
Barton-Bandis Criterion .....	5
Power Curve Criterion .....	6
Mohr-Coulomb Criterion .....	6
Summary of Strength Models and Stress Data Types Analyzed .....	7
<b>How Can I Use RocData?</b> .....	<b>8</b>
Determine Strength Parameters .....	8
Generalized Hoek-Brown Criterion .....	8
Barton-Bandis Criterion .....	8
Power Curve Criterion .....	8
Mohr-Coulomb Criterion .....	8
Plot Failure Envelopes .....	8
Estimation of Input Parameters .....	8
Triaxial Lab Test Data .....	9
Triaxial Field Test Data .....	9
Direct Shear Test Data .....	9
Curve Fitting .....	9
Equivalent Mohr-Coulomb Parameters .....	10
Stress Sampler .....	10
Instantaneous MC Sampler .....	11
Other Generalized Hoek-Brown Rock Mass Parameters .....	11
Project Settings: Selection of Failure Criterion and Units .....	11
Export Data / Images .....	11
Display Options .....	11
<b>Quick Tour of RocData</b> .....	<b>12</b>
Entering Input Data .....	12
Interactive Data Input .....	12
Pick Dialogs .....	12
Lab Test Data .....	13
Triaxial Field Test Data .....	13
Viewing of Test Data on Plots .....	13
Estimating Input Parameters for the Hoek-Brown Criterion .....	15
Estimating Input Parameters for the Barton-Bandis Criterion .....	17
Estimating Input Parameters for the Mohr-Coulomb Criterion .....	19
Failure Envelope Plots .....	21
Right Click Menu .....	22
Hoek-Brown Parameters .....	22
Other Generalized Hoek-Brown Rock Mass Parameters .....	22
Power Curve Parameters .....	23
Mohr-Coulomb Parameters .....	24
Equivalent Mohr-Coulomb Parameters for Curved Failure Envelopes .....	24
Failure Envelope Range .....	25

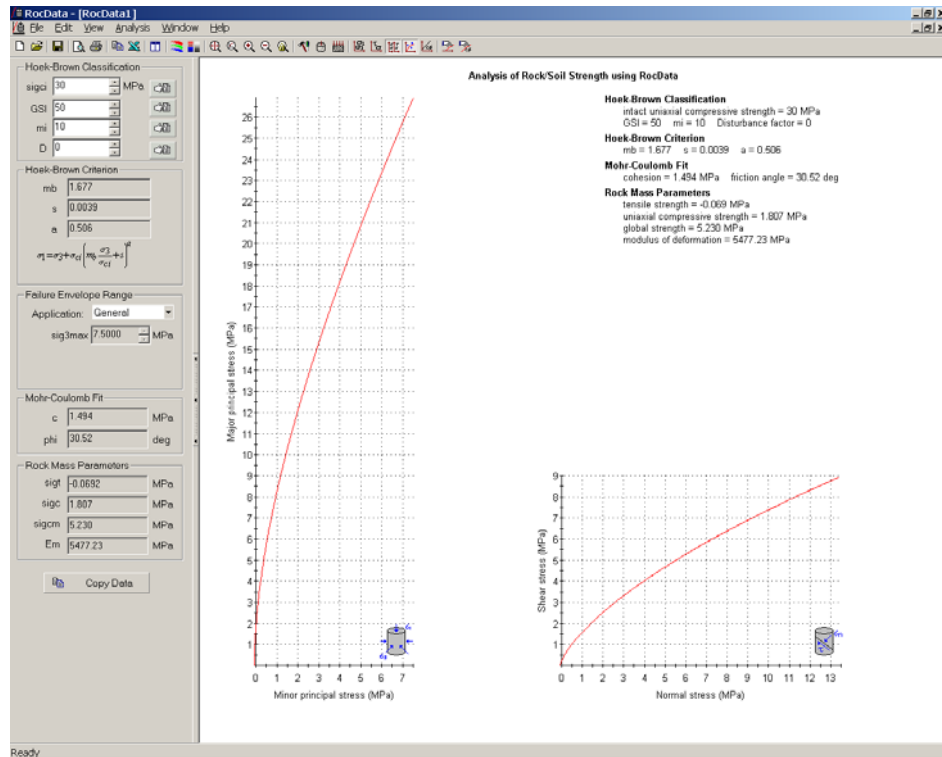
Analysis of Triaxial Test Data .....	25
Analysis of Field (Rock Mass) Triaxial Data .....	27
Analysis of Direct Shear Test Data.....	28
Analysis with Strength Models for fitting both Triaxial and Direct Shear Data .....	30
Fitting of Different Strength Criteria to a Dataset.....	30
Issued Caution when Switching between Data Types .....	31
Selection of Curve Fitting Technique.....	31
Stress Sampler .....	33
Instantaneous Mohr-Coulomb Sampler.....	34
Exporting Data / Images .....	35
One Click Export to Excel .....	35
Display Options.....	37
Mogi's Line .....	37
Zoom Extents .....	38
Project Settings.....	39
<b>Documentation .....</b>	<b>40</b>
<b>Tutorials .....</b>	<b>41</b>
Example 1 – Hoek-Brown Strength Envelope for a Tunnel in Undisturbed Rock (D = 0).....	41
Example 2 – Hoek-Brown Strength Envelope for a Slope Application in Highly Disturbed Rock (D = 1).....	43
Example 3 – Hoek-Brown, Power Curve and Mohr-Coulomb Analysis of an Intact Rock Triaxial Dataset.....	45
Example 4 – Generalized Hoek-Brown Analysis of Field Data .....	47
Example 5 – Mohr-Coulomb and Power Curve Analysis of a Direct Shear Dataset.....	49
<b>References .....</b>	<b>52</b>

# Welcome to RocData!

**RocData** is a software program for determining soil and rock mass strength parameters through analysis of laboratory or field triaxial or direct shear data. The program can fit the linear Mohr-Coulomb strength criterion and three other non-linear failure criteria – the generalized Hoek-Brown, Barton-Bandis and Power Curve strength models – to test data.

**RocData** includes built-in tables for estimating typical strength parameters for various rock and soil types. This feature, combined with an intuitive interface, rapid response to user inputs, and immediate plotting of strength curves, facilitates parametric studies of strength behaviour.

**RocData** is a product of Rocscience Inc.



Rocscience produces many other software products for geotechnical, mining and civil engineering applications. Visit [www.rocscience.com](http://www.rocscience.com) to find out about the other Rocscience programs.

# Introduction

Lack of data input on soil and rock mass properties is a major obstacle often encountered in the numerical modeling of geotechnical structures and excavations. The usefulness of elaborate constitutive models, and powerful numerical analysis programs, is greatly limited, if engineers cannot obtain or estimate reliable geotechnical input parameters.

**RocData** helps to remedy this situation. It provides tools for quickly and easily testing out hypotheses on four of the most widely used and accepted strength models for soils and rock. The program can be used to determine strength models that best describe laboratory or field data.

**RocData** is designed to aid engineers, especially at the preliminary stages of design. It provides simple and intuitive implementations of the Generalized Hoek-Brown, Barton-Bandis, Power Curve and Mohr-Coulomb failure criteria. The program enables users to easily visualize the effects of changes in input parameters on rock and soil failure envelopes.

In addition, **RocData** comes with built-in tables of typical strength parameter values for various rock and soil types, compiled from very credible sources. This allows users to readily obtain reliable estimates of the strength properties of a wide variety of rocks and soils.

The task of determining rock and soil mass properties is usually not an end in itself. It is carried out in order to obtain input material properties for use in limit equilibrium or numerical analysis of geotechnical structures.

The material properties determined from **RocData** can be used as input for analysis programs such as **Phase2** (finite element stress analysis and support design for excavations) and **Slide** (limit equilibrium slope stability analysis). (**Phase2** and **Slide** are programs also developed by Rocscience.)

There are several different models for describing the strength of materials. In rock and soil mechanics, the most popular models are the Generalized Hoek-Brown, Mohr-Coulomb, Barton-Bandis and Power Curve failure criteria. They are briefly described next.

### ***Generalized Hoek-Brown Criterion***

This empirical failure criterion establishes the strength of rock in terms of major and minor principal stresses. It predicts strength envelopes that agree well with values determined from laboratory triaxial tests of intact rock, and from observed failures in jointed rock masses.

**RocData** implements the most recent update (the 2002 edition) of the Generalized Hoek-Brown criterion. This edition resolves some formerly troublesome issues including:

- The applicability of the criterion to very weak rock masses, and
- The calculation of equivalent Mohr-Coulomb parameters, from the Hoek-Brown failure envelope

The Generalized Hoek-Brown criterion is non-linear and is expressed as

$$\sigma_1' = \sigma_3' + \sigma_{ci} \left( m_b \frac{\sigma_3'}{\sigma_{ci}} + s \right)^a, \text{ where}$$

$\sigma_{ci}$  is the uniaxial compressive strength of the intact rock material,

$$m_b = m_i \exp\left(\frac{GSI - 100}{28 - 14D}\right),$$

$$s = \exp\left(\frac{GSI - 100}{9 - 3D}\right), \text{ and}$$

$$a = \frac{1}{2} + \frac{1}{6} \left( e^{-GSI/15} - e^{-20/3} \right).$$

*GSI*, known as the Geological Strength Index, relates the failure criterion to geological observations in the field.  $m_i$  is a material constant for intact rock, while  $m_b$  and  $s$  are rock mass constants.

### ***Barton-Bandis Criterion***

The Barton-Barton failure criterion is an empirical relationship widely used to model the shear strength of rock discontinuities. It is very useful for fitting a strength model to field or laboratory shear test data of discontinuities. The Barton-Barton criterion has the non-linear form

$$\tau' = \sigma_n' \tan \left[ \phi_b + JRC \log_{10} \left( \frac{JCS}{\sigma_n'} \right) \right],$$

where  $\phi_b$  is the basic friction angle,  $JRC$  is the joint roughness coefficient and  $JCS$  is the joint compressive strength.

### ***Power Curve Criterion***

A substantial amount of experimental evidence suggests that the failure envelopes of many geotechnical materials, ranging from clays and rockfill to rock discontinuities and rock masses, are not linear, particularly in the range of small normal stresses. Commonly, the relationship between shear and normal stresses of such curved envelopes can be described with the Power Curve model

$$\tau' = a(\sigma_n' + d)^b, \text{ where}$$

$a$ ,  $b$  and  $d$  are the parameters of the model.

In some literature, the Power Curve is written in the form

$$\tau' = AP_a \left( \frac{\sigma_n'}{P_a} + T \right)^n,$$

which involves only non-dimensional model parameters  $A$ ,  $T$  and  $n$ . Atmospheric pressure is often used as the normalizing constant  $P_a$ .

The Power Curve model in **RocData** can be fit to both triaxial and direct shear data.

### ***Mohr-Coulomb Criterion***

This is the most common failure criterion encountered in geotechnical engineering. Several geotechnical analysis methods and programs require use of this strength model. The Mohr-Coulomb criterion describes a linear relationship between normal and shear stresses (or maximum and minimum principal stresses) at failure.

The Mohr-Coulomb criterion implementation in **RocData** can be used to analyze both direct shear and triaxial test data. The Mohr-Coulomb criterion for triaxial data is expressed as

$$\sigma_1' = \frac{2c' \cos \phi'}{1 - \sin \phi'} + \frac{1 + \sin \phi'}{1 - \sin \phi'} \sigma_3', \text{ where}$$

$c'$  is the cohesive strength, and  $\phi'$  is the friction angle.

The direct shear formulation of the criterion is expressed by the equation

$$\tau' = c' + \sigma_n' \tan \phi'.$$

### **Summary of Strength Models and Stress Data Types Analyzed**

The table below summarizes the strength criteria in **RocData** and the types of data each can be applied to:

<b>Strength Model</b>	<b>Type of Stress Data</b>	
	<b>Triaxial</b>	<b>Direct Shear</b>
Generalized Hoek-Brown	X	
Barton-Bandis		X
Power Curve	X	X
Mohr-Coulomb	X	X

# How Can I Use RocData?

The following tasks can be accomplished with **RocData**.

## **Determine Strength Parameters**

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### ***Generalized Hoek-Brown Criterion***

Determine the Generalized Hoek-Brown strength parameters of a rock mass (**mb**, **s** and **a**), based on the following input data:

- unconfined compressive strength of intact rock **sigci**
- the intact rock parameter **mi**
- the geological strength index **GSI**
- the disturbance factor **D**

### ***Barton-Bandis Criterion***

Determine the Barton-Bandis strength parameters *JRC* and *JCS* of a discontinuity based on direct shear test results and the following input:

- basic friction angle of the discontinuity **f<sub>b</sub>**

### ***Power Curve Criterion***

Determine the Power Curve strength parameters of a soil or rock (mass) (*a*, *b* and *d*, or alternatively *A*, *T* and *n*).

### ***Mohr-Coulomb Criterion***

Determine the Mohr-Coulomb strength parameters, **c** (cohesive strength), and **f** (friction angle) of a soil or rock (mass).

## **Plot Failure Envelopes**

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Plot the failure envelopes of the four strength models in principal and / or shear-normal stress space.

- Interactively change the parameters of the various strength models to see how they influence the failure envelopes

## **Estimation of Input Parameters**

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For the Generalized Hoek-Brown, Barton-Bandis and Mohr-Coulomb failure criteria, conveniently estimate the strength parameters of various rock and soil types using charts and tables built into **RocData**.

## Triaxial Lab Test Data

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Determine the intact rock parameters (**sigci** and **mi**) of the Hoek-Brown criterion, the parameters (**c** and **phi**) of the Mohr-Coulomb criterion, or the Power Curve parameters **a**, **b** and **d** (or alternatively **A**, **T** and **n**) from triaxial lab test data.

The triaxial data

- Can be imported from Microsoft Excel through the clipboard, from tab-delimited or comma separated value text files, from **RocLab** or **RocData** files, or
- Entered into the program directly using a built-in spreadsheet

## Triaxial Field Test Data

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For the Generalized Hoek-Brown criterion, determine the rock mass parameters (**mb**, **s** and **a**) from triaxial field test data on rock mass strength, with the uniaxial compressive strength, **sigci**, and the disturbance factor, **D**, as input.

Field data can be imported in the manner described above for triaxial lab data.

## Direct Shear Test Data

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Determine the parameters (**c** and **phi**) of the Mohr-Coulomb criterion, (**JCS** and **JRC**) of the Barton-Bandis criterion, or (**a**, **b**, **d** or alternatively **A**, **T** and **n**) of the Power Curve model from direct shear test data. For the Barton-Bandis criterion the basic friction angle, **phib**, must be supplied as input.

Direct shear data can be imported in the manner described above for triaxial lab data.

## Curve Fitting

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**RocData** provides three methods for fitting strength models to test data. The **Levenberg-Marquardt** method is the default technique for fitting all strength criteria to data points. This robust algorithm has become the standard for non-linear regression. It is very reliable in practice, and has the ability to converge quickly from a wider range of initial guesses than other typical methods.

Users can also fit strength models to data using the **Simplex** method. The Simplex method is one of the best curve fitting methods, and has a reputation for being very reliable.

**Linear Regression** (linear least-squares) curve fitting is the third technique provided in **RocData**. It can be used to only fit the Hoek-Brown criterion for intact rock, and the Mohr-Coulomb strength model to lab data.

The following table summarizes which curve fitting methods are available for the different strength models:

Strength Model	Curve Fitting Method		
	Levenberg-Marquardt	Simplex	Linear Regression
Hoek-Brown (lab data / intact rock)	X	X	X
Generalized Hoek-Brown (rock mass / field data)	X	X	
Barton-Bandis	X	X	
Power Curve	X	X	
Mohr-Coulomb	X		X

**RocData** calculates the sum of the square of the vertical distances of the given data points from a fitted curve, known as “**Residuals**” in the program. This value is a measure of how well a strength criterion fits a given data set.

### Equivalent Mohr-Coulomb Parameters

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For the non-linear strength criteria (Hoek-Brown, Barton-Bandis and Power Curve), calculate equivalent Mohr-Coulomb strength parameters (cohesion and friction angle).

- The best-fit Mohr-Coulomb strength envelope is determined over a stress range that you can define based on your application (i.e. tunneling or slope stability).
- Plot the equivalent Mohr-Coulomb failure envelope in principal and / or shear-normal stress space

### Stress Sampler

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Graphically sample any failure envelope to determine specific stress (principal, shear or normal stress) values at any point along the envelope.

## **Instantaneous MC Sampler**

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Graphically determine the instantaneous Mohr-Coulomb parameters at any point along any of the curved (non-linear) failure envelopes.

## **Other Generalized Hoek-Brown Rock Mass Parameters**

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**RocData** calculates rock mass parameters such as tensile strength, uniaxial compressive strength and deformation modulus for the Generalized Hoek-Brown criterion.

## **Project Settings: Selection of Failure Criterion and Units**

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Select a failure criterion or switch between criteria using the Project Settings dialog. In the dialog you can also supply a title for your **RocData** project.

The Project Settings dialog also allows analyses to be carried out in either Metric or Imperial units. In Metric, the available stress units are Megapascals (MPa), Kilopascals (kPa) and Tonnes per square metre (tsm). In Imperial, the stress units may be either Kilopounds per square foot (ksf), Kilopounds per square inch (ksi), Pounds per square foot (psf), Pounds per square inch (psi) or Tons per square foot (tsf).

## **Export Data / Images**

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Export data for further analysis or report writing:

- Copy the data and / or plots to the clipboard for easy import into Microsoft Word or your favourite word processor or image-editing program
- Copy the data and / or plots directly into Microsoft Excel
- Save the plots to a JPEG, BMP, EMF or WMF image file
- Print and Print Preview capabilities.

## **Display Options**

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Numerous Display Options to customize the appearance of your plots:

- Change colors, fonts, line thickness.
- Grid overlay.
- Add plot title and show input data directly on plots.
- Zooming.
- Plot Mogi's line (transition from brittle to ductile failure).
- Grayscale for output to black and white printers

# Quick Tour of RocData

The following “quick tour” of **RocData** will familiarize the user with the features of the program.

## Entering Input Data

The primary means of user interaction with **RocData**, is with the sidebar (Docking Form) data input area. The sidebar input area for the Generalized Hoek-Brown method is shown below. The sidebar is used for data input, and for displaying calculated output parameters.

Hoek-Brown Classification

sigci 30 MPa

GSI 50

mi 10

D 0

Hoek-Brown Criterion

mb 1.677

s 0.0039

a 0.506

$$\sigma_1 = \sigma_3 + \sigma_{ci} \left( m_b \frac{\sigma_3}{\sigma_{ci}} + s \right)^a$$

Failure Envelope Range

Application: General

sig3max 7.5000 MPa

Mohr-Coulomb Fit

c 1.494 MPa

phi 30.52 deg

Rock Mass Parameters

sigt -0.0692 MPa

sigc 1.807 MPa

sigcm 5.230 MPa

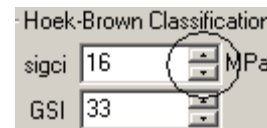
Em 5477.23 MPa

Copy Data

Input data can be entered in various ways:

### Interactive Data Input

- You can click on the arrows with the mouse to change the input data. All output data is immediately recalculated, and the failure envelope plots are redrawn.



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

### Pick Dialogs

- You may also enter input parameters using the “Pick” dialogs. When you select a Pick button , you will be presented with a dialog, in the form of a chart or table, which guides you to estimate an appropriate value for the input parameter. Upon selecting OK in the dialog, the selected parameter value will be loaded into the sidebar data input area. **RocData** proceeds to automatically calculate all output data, and update the

failure envelopes.

### ***Lab Test Data***



- For the Generalized Hoek-Brown criterion, you may determine values of **sigci** and **mi**, from triaxial lab test data for intact rock. This is done with the **Use Lab Data** option, as described in a later section. When you select Apply or OK in the “Calculate sigci, mi from Lab Data” dialog, the **RocData** calculation is carried out, and all output values and failure envelopes are updated. The Mohr-Coulomb and Power Curve criteria can be also used to fit triaxial lab data.
- The Mohr-Coulomb, Barton-Bandis and Power Curve criteria can as well be used to fit direct shear test data through selection of the **Use Lab Data** option.

### ***Triaxial Field Test Data***

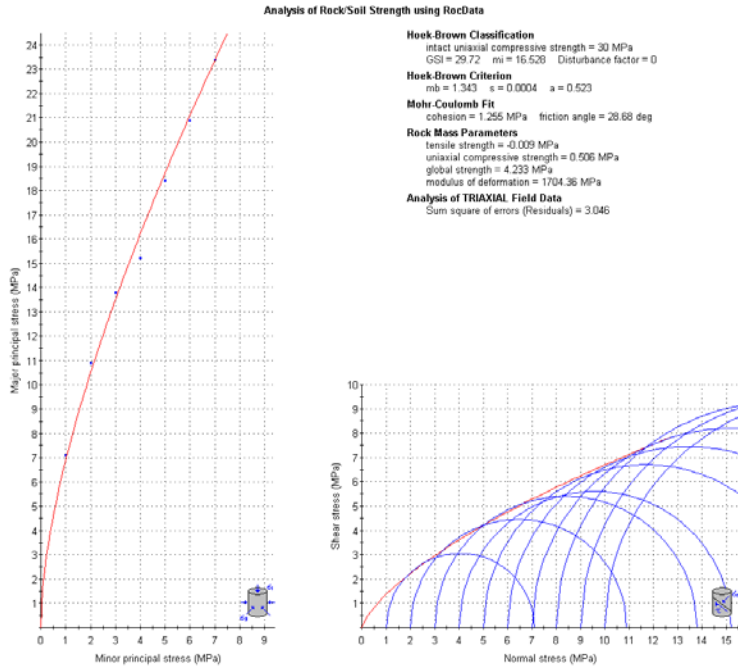


- Given **sigci** and **D** values, the Generalized Hoek-Brown model can be fit to triaxial field test (rock mass) data.

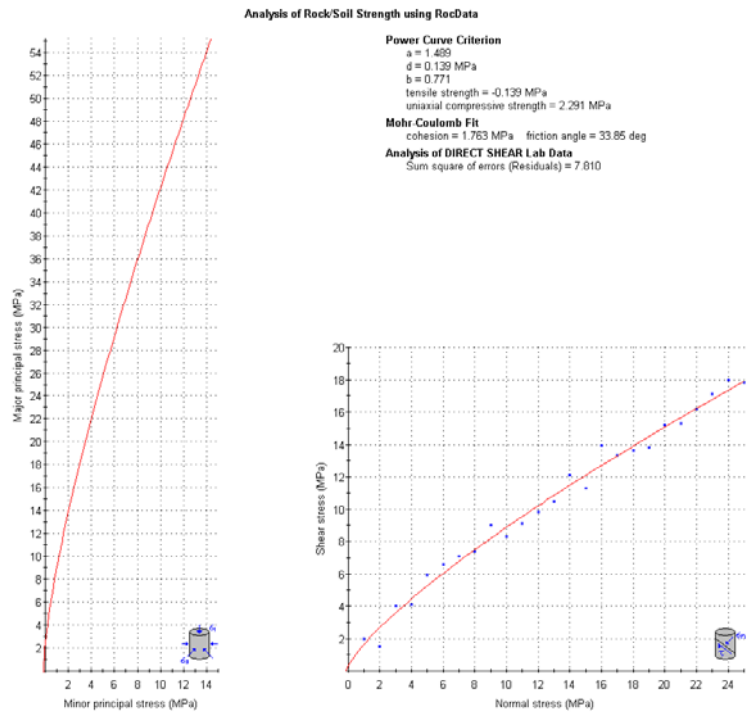
### ***Viewing of Test Data on Plots***



- When test data is analyzed, the data points can be plotted in **RocData**'s main view, in addition to the failure envelopes. The data points can be toggled on and off by selecting the Plot Test Data option. For triaxial test data, the lab or field data is plotted as points in principal stress space, and as Mohr circles in direct shear space. For direct shear data, test data is only plotted as points in direct shear space. Examples of such plots of triaxial and direct shear test data are shown below.



*Plot of triaxial data on failure envelopes*



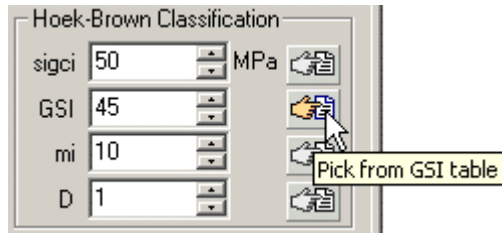
*Plot of direct shear data on failure envelopes*

## Estimating Input Parameters for the Hoek-Brown Criterion

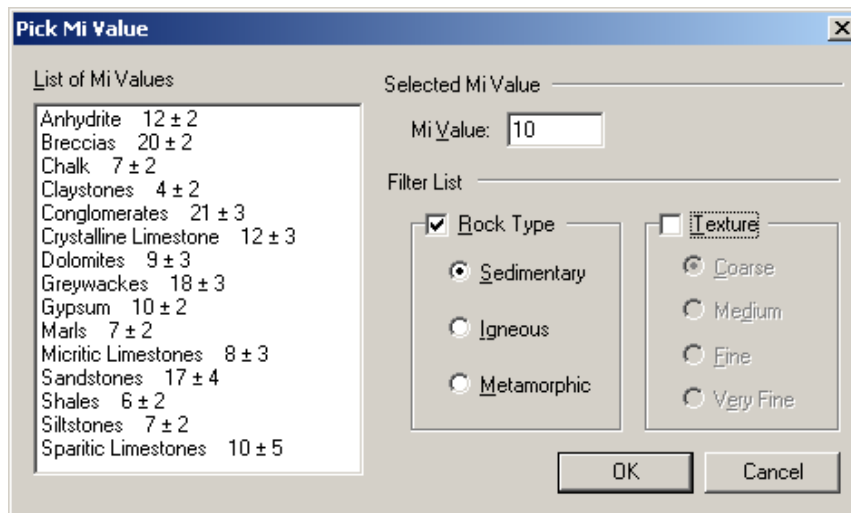
Each of the parameters used as input for the Hoek-Brown criterion – **sigci**, **mi**, **GSI** and **D** – can be estimated using convenient charts and tables built into **RocData**.



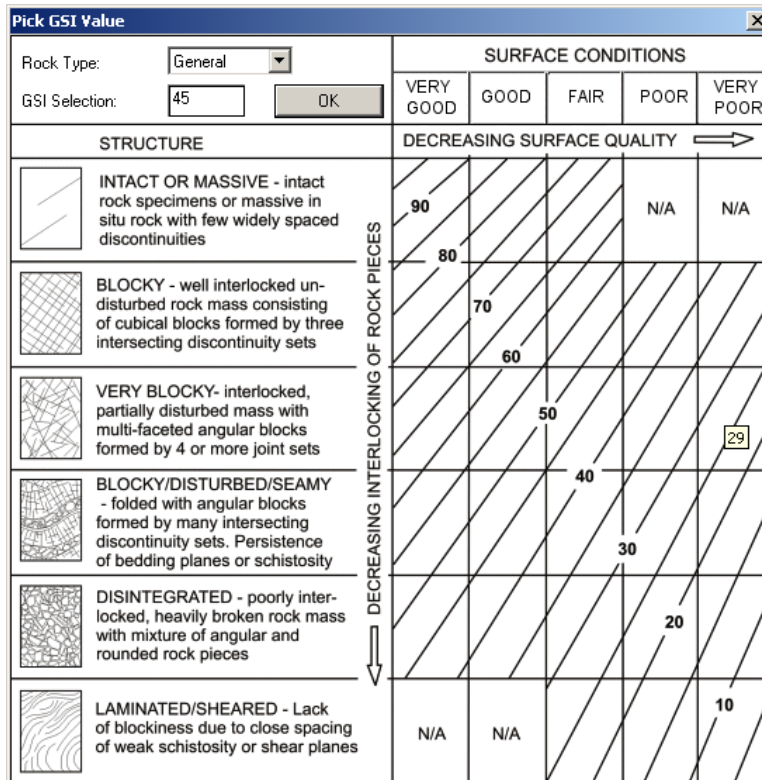
These charts and tables are accessed by selecting the “Pick” button located beside each of the input parameter edit boxes in the sidebar (docking form).



When you select a Pick button, a table or chart will appear, allowing you to determine a suitable value for the desired parameter. For example, the dialogs for estimation of **mi** and **GSI** (Rock Type = *General*) are shown below.



Once you have determined a value, select OK in the Pick dialog. The value will be automatically loaded into the docking form, and the **RocData** calculation will automatically be carried out (i.e. output parameters and failure envelopes will be re-calculated using the selected input data).



*GSI chart (Rock Type = General)*

Select the Pick button for each of **sigci**, **mi**, **GSI** and **D**, and experiment with the dialogs.

Notice that there are TWO distinct GSI charts:

- One for general rock mass types, and
- A second for weak, heterogeneous rock mass types such as flysch, which extends the useful range of GSI down to values as low as 5.

For further information about the Hoek-Brown classification parameters **sigci**, **mi**, **GSI** and **D**, please consult Ref.1.


## Estimating Input Parameters for the Barton-Bandis Criterion


Each of the parameters used as input for the Barton-Bandis criterion – **phib**, **JRC**, and **JCS** – can be estimated using convenient charts and tables built into **RocData**.




These charts and tables are accessed by selecting the “Pick” button located beside each of the input parameter edit boxes in the sidebar.

Barton-Bandis Classification

phib  deg 

JRC  

JCS  MPa  Pick from JRC table

$$\tau = \sigma_n \cdot \tan \left[ \phi_0 + JRC \log_{10} \left( \frac{JCS}{\sigma_n} \right) \right]$$

When you select a Pick button, a table or chart will appear, allowing you to determine a suitable parameter value. The dialogs for estimating **phib** and **JRC** are provided below as examples.

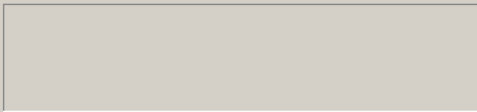
Basic Friction Angle for Rocks

List of basic friction angle (phib) values

Rock	Moisture	SigN range (MPa)	Phib (degrees)
Amphibolite	dry	0.1 - 4.2	32
Basalt	dry	0.1 - 8.5	35 - 38
Basalt	wet	0.1 - 7.9	31 - 36
Conglomerate	dry	0.3 - 3.4	35
Chalk	wet	0.0 - 0.4	30
Dolomite	dry	0.1 - 7.2	31 - 37
Dolomite	wet	0.1 - 7.2	27 - 35
Gneiss (schistose)	dry	0.1 - 8.1	26 - 29
Gneiss (schistose)	wet	0.1 - 7.9	23 - 26
Granite (fg.)	dry	0.1 - 7.5	31 - 35
Granite (fg.)	wet	0.1 - 7.4	29 - 31
Granite (c.g.)	dry	0.1 - 7.3	31 - 35
Granite (c.g.)	wet	0.1 - 7.5	31 - 33
Limestone	dry	0.0 - 0.5	33 - 39
Limestone	wet	0.0 - 0.5	33 - 36

Filter List:  Moisture

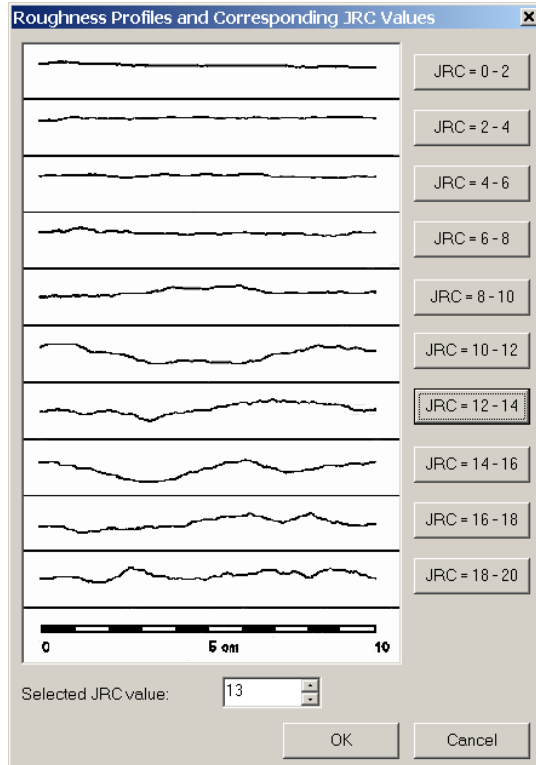
Dry  Wet

Reference: 

Selected phib value:  degrees

OK Cancel

*Phib dialog*



### *JRC dialog*

Once you have determined a value, select OK in the Pick dialog. The value will be automatically loaded into the sidebar input data area, and the **RocData** calculation automatically carried out.

The material list in the **phib** dialog can be filtered by moistened state (dry or wet), while the list in the **JCS** dialog can be filtered into properties for rocks and those for soils.

Select the Pick button for each of **phib**, **JRC**, and **JCS**, and experiment with the dialogs.

## Estimating Input Parameters for the Mohr-Coulomb Criterion

Mohr-Coulomb parameters **c** and **phi** can be estimated using RocData's conveniently built in tables.

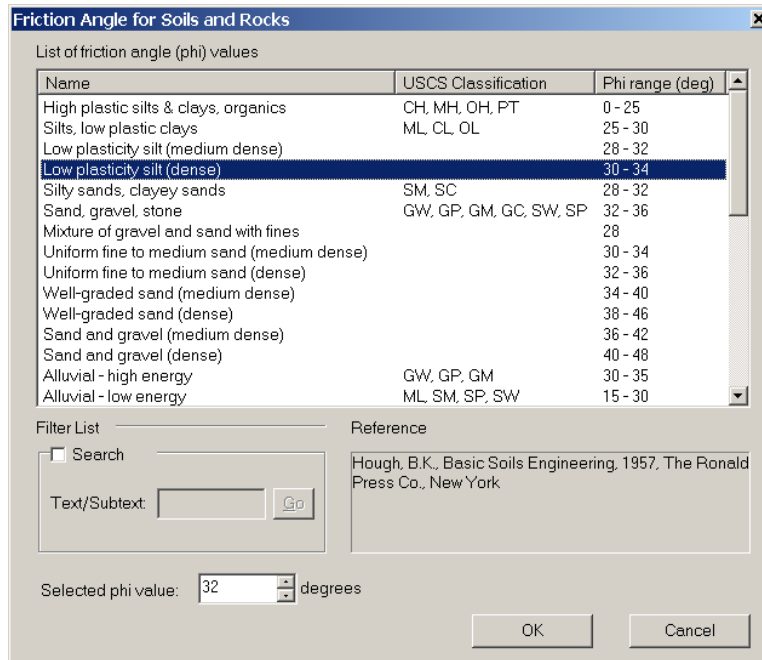


These tables are accessed by selecting the “Pick” button located beside each of the input parameter edit boxes in the sidebar.

The tables for **c** and **phi** are shown below. Using the search option in the dialogs, you can quickly locate the parameters for a material of interest.

Name	USCS Classification	Cohesion range (MPa)
Sandy gravel with silty or clayey fines		0.001
Mixture of gravel and sand with fines		0.003
Low plasticity silt		0.002
Medium to high plasticity silt		0.003
Low plasticity clay		0.006
Medium plasticity clay		0.008
High plasticity clay		0.01
Organic silt or clay		0.007
Alluvial - high energy	GW, GP, GM	0
Alluvial - low energy	ML, SM, SP, SW	0 - 0.024
Eolian - dune sand	SP	0
Eolian - loess	ML, SM	0.024 - 0.048
Glacial - till	SM, ML	0.048 - 0.192
Glacial - outwash	GW, GP, SW, SP, SM	0 - 0.048
Glacial - glaciolacustrine	ML, SM, SP	0 - 0.144

*Cohesion, c, values for a variety of rock and soil types*



*Friction angle, phi, values for various soil and rock types*

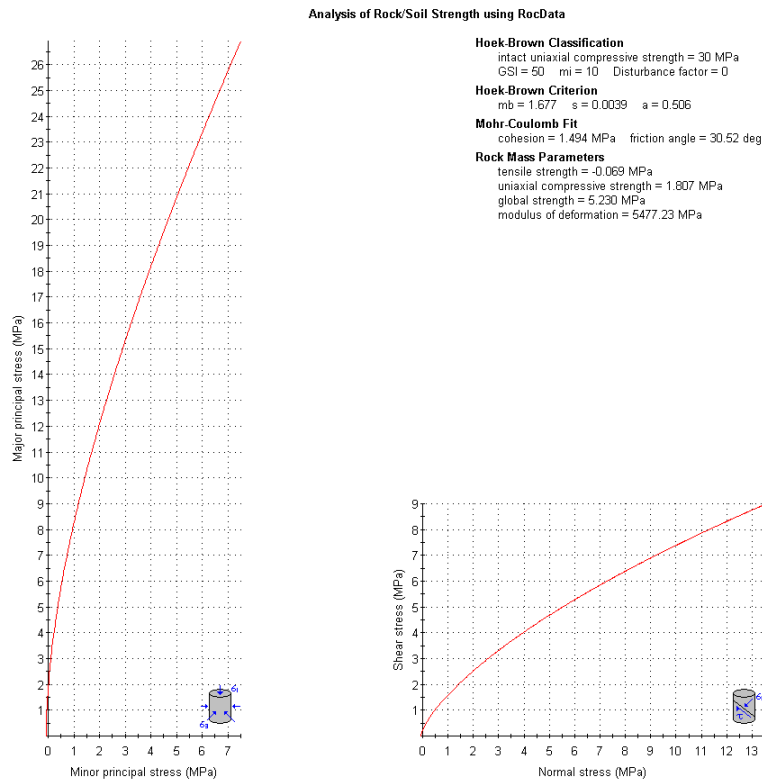
Select the Pick button for **c** and **phi** to experiment with the dialogs.

## Failure Envelope Plots

RocData plots failure envelopes in two different spaces:

- Principal stress space (sigma1 vs. sigma3)
- Shear – Normal stress space (sigma normal vs. Tau)

The strength curves plotted correspond to the current data in the docking form. By default, BOTH principal stress AND shear-normal plots are displayed.



However, you 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 menu.

Various additional display / analysis options are available, including:

- Display of equivalent Mohr-Coulomb envelope
- Stress sampler / Instantaneous Mohr-Coulomb sampler
- Customization of plot appearance with Display Options (eg. grid overlay, line thickness, fonts etc), and zooming

### **Right Click Menu**

*TIP* – most of the plot display options, are also conveniently available in the right-click menu, if you right-click the mouse anywhere in the plot display area.

### **Hoek-Brown Parameters**

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For a given set of input parameters (**sigci**, **GSI**, **mi** and **D**), **RocData** calculates the parameters of the generalized Hoek-Brown failure criterion (**mb**, **s** and **a**).

These are displayed in the sidebar, as shown below. The Generalized Hoek-Brown failure envelopes plotted in **RocData** are generated using the values of **mb**, **s** and **a** shown on the sidebar.

The screenshot shows a sidebar with two sections. The top section, titled "Hoek-Brown Classification", contains 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 icon to its right. The bottom section, titled "Hoek-Brown Criterion", contains 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. Below these fields is the mathematical equation for the failure criterion: 
$$\sigma_1 = \sigma_3 + \sigma_{ci} \left( m_b \frac{\sigma_3}{\sigma_{ci}} + s \right)^a$$

These parameters are calculated using the latest version of the Hoek-Brown failure criterion. For a definition of these parameters, and the equations that define them, please see Ref. 1.

### **Other Generalized Hoek-Brown Rock Mass Parameters**

---

At the bottom of the sidebar for the Generalized Hoek-Brown criterion, you will notice that the following rock mass parameters are also calculated:

- **Sigt** (rock mass tensile strength)
- **Sigc** (uniaxial rock mass compressive strength)
- **Sigcm** (global rock mass compressive strength)
- **Em** (rock mass modulus of deformation)

Rock Mass Parameters		
sigt	-0.0692	MPa
sigc	1.807	MPa
sigcm	5.230	MPa
Em	5477.23	MPa

For the definitions of these parameters, and the equations used to calculate them, please see Ref. 1.

In particular, you will notice that there are two calculated values of rock mass compressive strength– **sigc** and **sigcm**. For a discussion of how these two parameters are defined, and how they may be used, please see Ref. 1 – section 5: *Rock Mass Strength*.

### Power Curve Parameters

For a given set of input parameters (**a**, **b** and **d**), **RocData** calculates the parameters of the non-dimensional version of the Power Curve criterion (**A**, **T** and **n**), and the tensile and uniaxial compressive strengths (**sigt** and **sigc**) of corresponding to the input parameters. These are displayed in the sidebar, as shown below.

Power Curve Classification		
a	1	
d	0	MPa
b	0.7	
$\tau = a(\sigma_n + d)^b$		
Non-Dimensional Power Curve		
Pa	0.1	MPa
A	1.995	
T	0	
n	0.7	
$\tau = AP_a \left( \frac{\sigma_n}{P_a} + T \right)^n$		
Strength Parameters		
sigt	0	MPa
sigc	0	MPa

## Mohr-Coulomb Parameters

For a given set of input parameters (**c** and **phi**), **RocData** calculates the uniaxial compressive strength **sigc**.

Mohr-Coulomb Classification

c 1 MPa

phi 35 deg

sigt -0.5 MPa

$$\sigma_1 = \frac{2c \cos \phi + 1 + \sin \phi}{1 - \sin \phi} + \frac{1 - \sin \phi}{1 - \sin \phi} \sigma_3$$
$$\tau = c + \sigma_n \tan \phi$$

Failure Envelope Range

Application: Custom

sig3max 7.5000 MPa

Strength Parameters

sigcm 3.842 MPa

## Equivalent Mohr-Coulomb Parameters for Curved Failure Envelopes

In addition to the parameters of the non-linear failure criteria (the Generalized Hoek-Brown, Barton-Bandis and Power Curve models), **RocData** always calculates Mohr-Coulomb parameters (cohesion and friction angle) equivalent to a currently specified strength model.

Since most rock engineering software is still written in terms of the Mohr-Coulomb failure criterion, the calculation of these equivalent Mohr-Coulomb parameters is an important feature of **RocData**.

Failure Envelope Range

Application: Tunnels

sig3max 0.6642 MPa

Unit Weight 0.026 MN/m3

Tunnel Depth 50 m

Mohr-Coulomb Fit

c 0.367 MPa

phi 49.98 deg

Failure Envelope Range

Application: Custom

sig3max

- General
- Tunnels
- Slopes
- Custom



The corresponding Mohr-Coulomb envelope can be viewed by selecting the Mohr-Coulomb Envelope option from the toolbar or the Analysis menu.

### ***Failure Envelope Range***

It is important to note that the **Failure Envelope Range** option has a direct effect on the calculated Mohr-Coulomb parameters.

- For details about the Mohr-Coulomb fitting procedure, and the significance of the Failure Envelope Range option, see Ref. 1 (section 4: *Mohr-Coulomb Criterion*, and section 6: *Determination of  $\sigma'_3$  max* )
- The General option is available only for the Generalized Hoek-Brown criterion. When the Failure Envelope Range option is set to this option, notice that  $\sigma_{3max} = \sigma_{ci} / 4$ . This is based on the empirical observation that the stress range associated with brittle failure, occurs when  $\sigma_3$  is less than about one-quarter of  **$\sigma_{ci}$** .
- When the Failure Envelope Range option = Custom, you may enter any value of  $\sigma_{3max}$  or  $\sigma_{Nmax}$ .
- The Failure Envelope Range has NO effect on the calculated parameters of a non-linear failure envelope.

The appropriate stress range (maximum  $\sigma_3$  value) over which equivalent Mohr-Coulomb parameters must be obtained depends on the application, i.e. the type of geotechnical excavation being designed or analyzed. Based on the principles outlined in Ref. 1, **RocData** estimates maximum  $\sigma_3$  values for tunneling and slope design applications.

### **Analysis of Triaxial Test Data**

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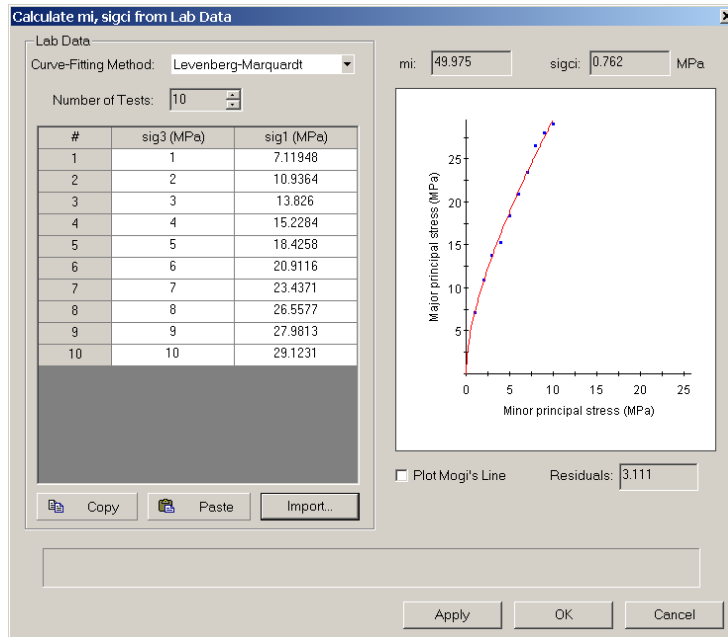
A fundamental feature of **RocData**, is its ability to input triaxial stress test data ( $\sigma_1 / \sigma_3$  data pairs), in order to determine strength parameters. Three of the failure criteria in the program – the Generalized Hoek-Brown, the Mohr-Coulomb and the Power Curve – allow analysis of triaxial test data. Such analysis is performed as follows:



1. Select the **Use Lab Data** option from the **Analysis** menu or the toolbar.
2. The data can be entered in a spreadsheet, or imported from a file, as shown in the dialog below.
3. A curve fit is then performed on the data, using the Levenberg-Marquardt, Simplex or Linear Regression curve fitting techniques,

and values of **sigci** and **mi** (Hoek-Brown strength of intact rock data), **c** and **phi** (Mohr-Coulomb strength), or **a**, **b** and **d** (Power Curve strength) are obtained. These calculated strength parameters are known as 'best-fit' values.

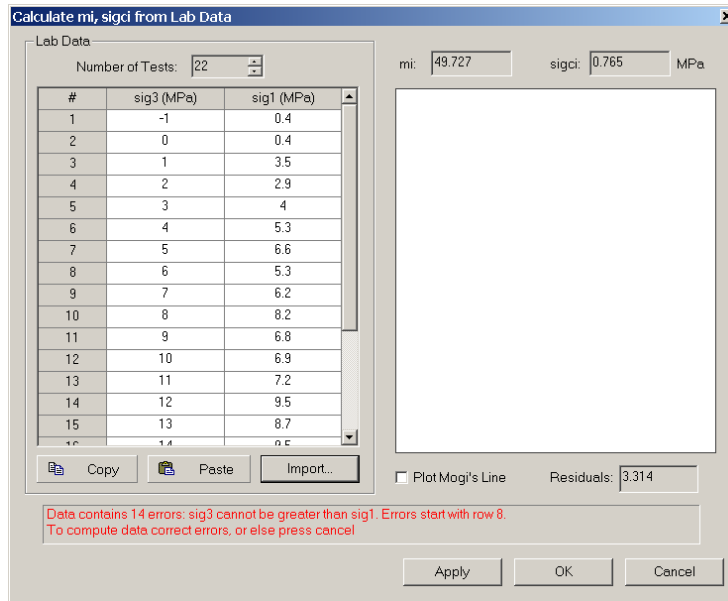
4. After entering the data, select OK in the dialog, and the 'best-fit' values will be used to calculate the failure envelopes and other parameters of the selected strength model.



*Example showing fitting of the Hoek-Brown criterion to intact rock lab data.*

Obtaining actual values of strength parameters from triaxial lab test data is always recommended. It should be emphasized that a large number of test results is not always necessary, and good results can be obtained from a relatively small number of data points (eg. 6 or 7 triaxial tests).

If triaxial lab data is not available, parameter values can always be estimated in **RocData**, using the Pick dialogs described previously. If incorrect data pairs (i.e. data for which sig3 exceeds sig1) are accidentally imported into triaxial data analysis, the curve fitting calculations are not carried out, and an error notice is issued. An example is shown below.

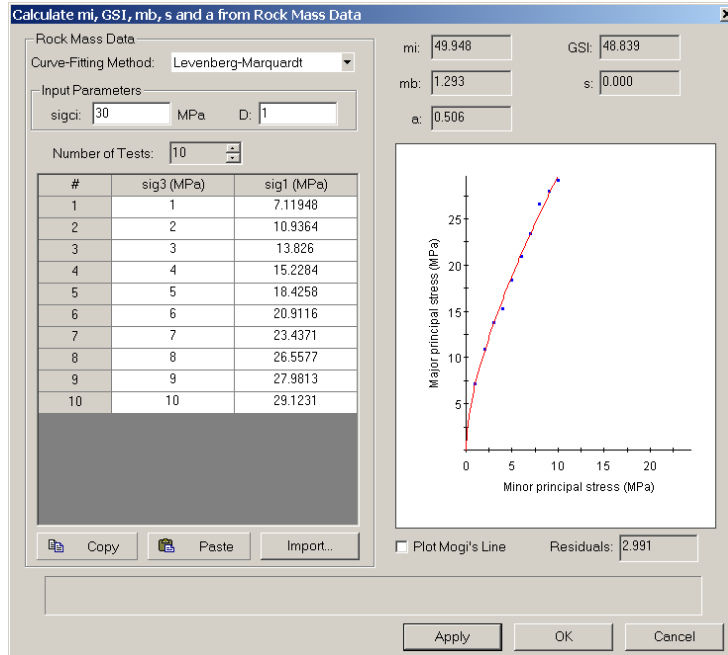


*Errors issued in dialog when a direct shear data set is incorrectly loaded as triaxial data.*

### ***Analysis of Field (Rock Mass) Triaxial Data***



The Generalized Hoek-Brown strength model can be fit to triaxial field data. The procedure is the same as above except the **Use Rock Mass Data** option has to be employed. In addition, the analysis of field data requires entry of intact rock uniaxial strength, **sigci**, and disturbance factor, **D**, as input.



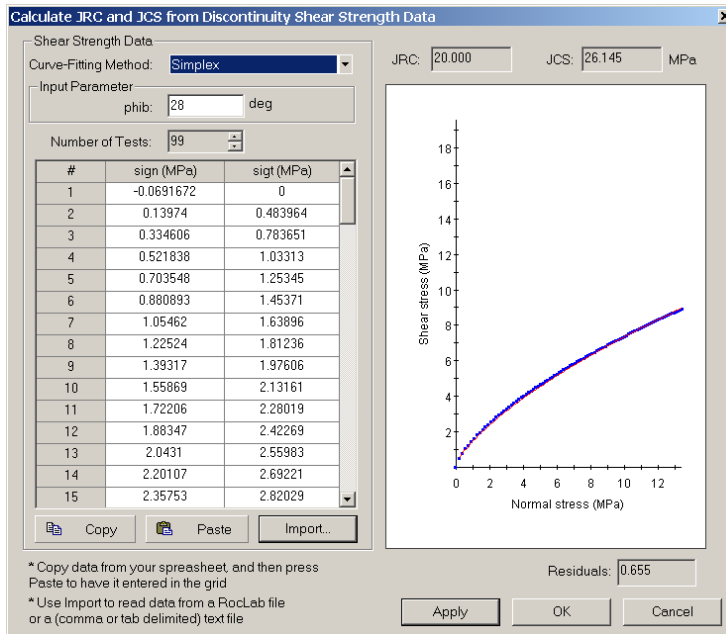
*Fitting of the Generalized Hoek-Brown criterion to triaxial field test data*

## Analysis of Direct Shear Test Data

**RocData** can be used to fit the Mohr-Coulomb, Barton-Bandis and Power Curve strength criteria to direct shear (shear-normal) test data. Such analysis is performed as follows:



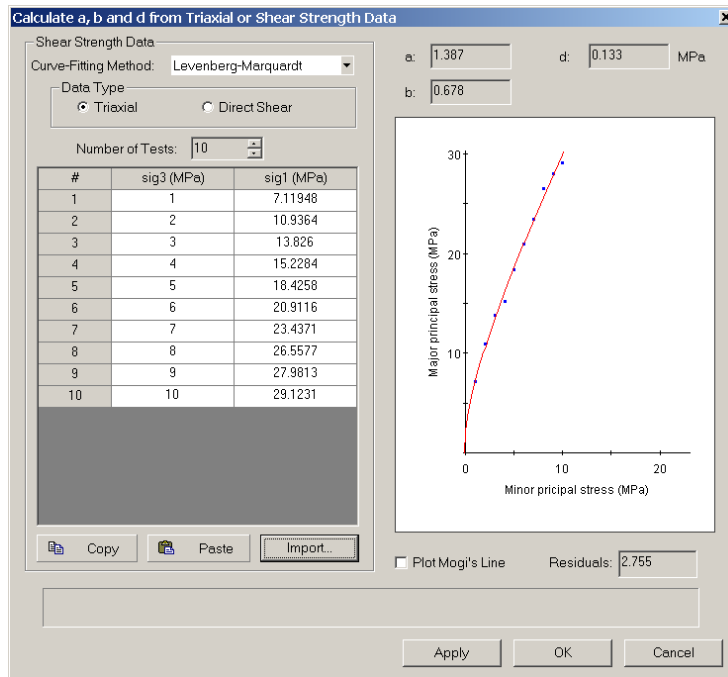
1. Select the **Use Lab Data** option from the **Analysis** menu or the toolbar.
2. The data can be entered in a spreadsheet, or imported from a file, as shown in the dialog below.
3. A curve fit is then performed on the data, using the Levenberg-Marquardt, Simplex or Linear Regression curve fitting techniques, and values **c** and **phi** (Mohr-Coulomb strength), **JRC** and **JCS** (Barton-Bandis strength), or **a**, **b** and **d** (Power Curve strength) are obtained. (Fitting of the Barton-Bandis criterion to direct shear data requires the input of the basic friction angle, **phib**.)
4. After entering the data, select **OK** in the dialog, and the computed 'best-fit' values will be used to calculate the failure envelopes and other parameters of the selected strength model.



*Example showing Simplex fitting of the Barton-Bandis criterion to direct shear data.*

## Analysis with Strength Models for fitting both Triaxial and Direct Shear Data

The Mohr-Coulomb and Power Curve strength criteria can be fit to both triaxial and direct shear data. At the top of the data analysis dialogs for these criteria, there are two radio buttons for selecting the required data type.



*Notice the radio buttons in the upper left corner of the dialog for selecting the type of data to be analyzed for Power Curve strength parameters. In the example shown, the strength model was fit to triaxial data.*

## Fitting of Different Strength Criteria to a Dataset

**RocData** allows users to test the fit of different strength models to a given test dataset. Such analysis is performed as follows:



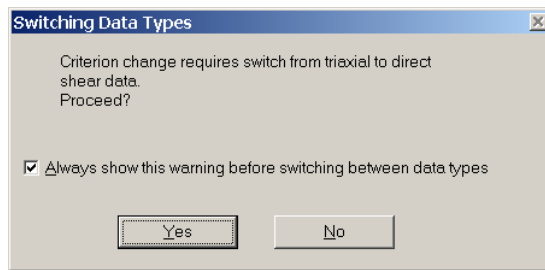
1. Select the **Project Settings** option from the **Analysis** menu or the toolbar. Select the desired strength model from the resulting dialog.
2. Next select the **Use Lab Data** option from the **Analysis** menu or the toolbar, and enter the test data as previously described.

3. To test the fit of a different strength model to the same data, go to the **Project Settings** dialog and select the new strength model. Click the OK button in the **Project Settings** dialog.
4. The data dialog for the selected strength criterion is immediately opened, with the previously entered data points automatically transferred.

### ***Issued Caution when Switching between Data Types***

The Generalized Hoek-Brown strength model in **RocData** can be fit only to triaxial data, while the Barton-Bandis model can be applied only to direct shear data. As a result, when a user attempts to switch to one of these models while analyzing a data type that is incompatible, the program alerts the user on the inconsistency.

If the user chooses to proceed with the switch, the new data analysis dialog is opened, but without any data. The data type switch warning can be turned off if desired by selecting the “Do not show warning again” checkbox.

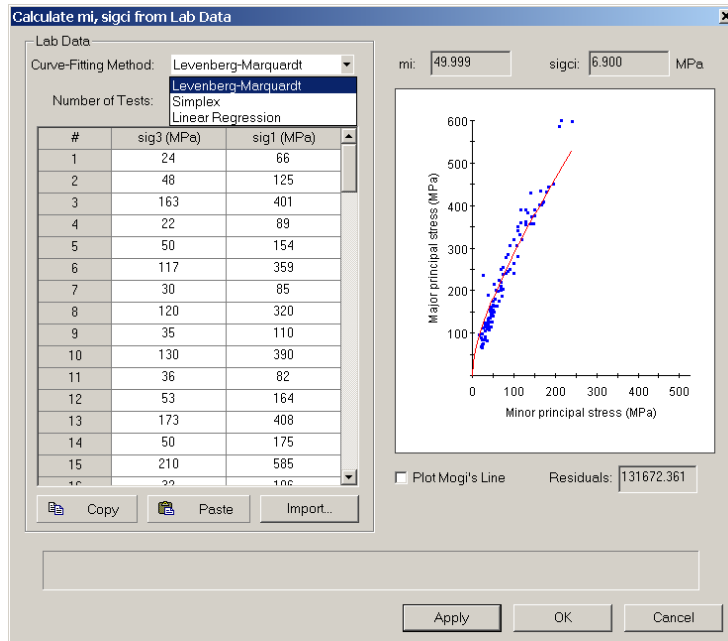


*Data type switch warning dialog*

### **Selection of Curve Fitting Technique**

---

For every strength criterion in **RocData** there are at least two techniques available for fitting the criterion to test data. Curve fitting techniques can be selected from the dropdown menu in the upper left corner of every data analysis dialog.



New parameters are calculated as soon as a curve fitting method is selected from the dropdown menu.

The following table summarizes the curve fitting methods available for the different strength models:

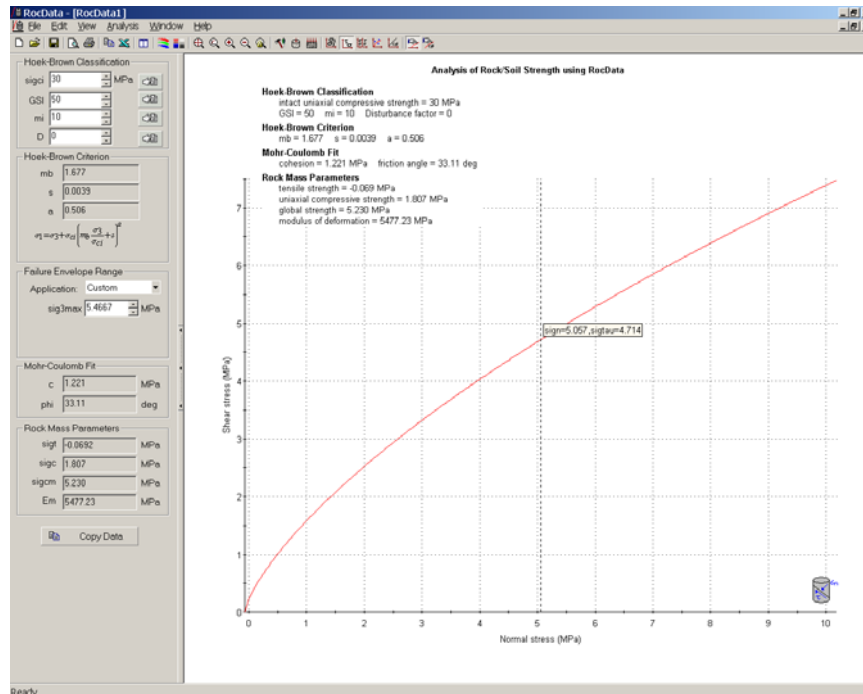
Strength Model	Curve Fitting Method		
	Levenberg-Marquardt	Simplex	Linear Regression
Hoek-Brown (lab data / intact rock)	X	X	X
Generalized Hoek-Brown (rock mass / field data)	X	X	
Barton-Bandis	X	X	
Power Curve	X	X	
Mohr-Coulomb	X		X

## Stress Sampler

The **Stress Sampler** option allows the user to graphically obtain the exact stress coordinates at any point along the failure envelopes. This is done as follows:



1. Select the **Stress Sampler** option from the toolbar, the right-click menu or the **Analysis** menu.
2. Single click the left mouse button, at any value of  $\sigma_3$  (on the principal stress plot), or any value of normal stress (on the shear-normal stress plot).
3. The stress coordinates will be displayed, corresponding to the value of  $\sigma_3$  or normal stress, at which the mouse was clicked. A vertical dotted line will be displayed on the plots, to mark the location.
4. Alternatively, if you click and HOLD the left mouse button on either of the plots, and DRAG the mouse left or right, the stress coordinates of the failure envelopes will be continuously displayed, as you move the mouse.
5. NOTE: if the equivalent Mohr-Coulomb envelopes are also displayed, then the stress coordinates of BOTH the non-linear strength, and equivalent Mohr-Coulomb envelopes will be displayed.

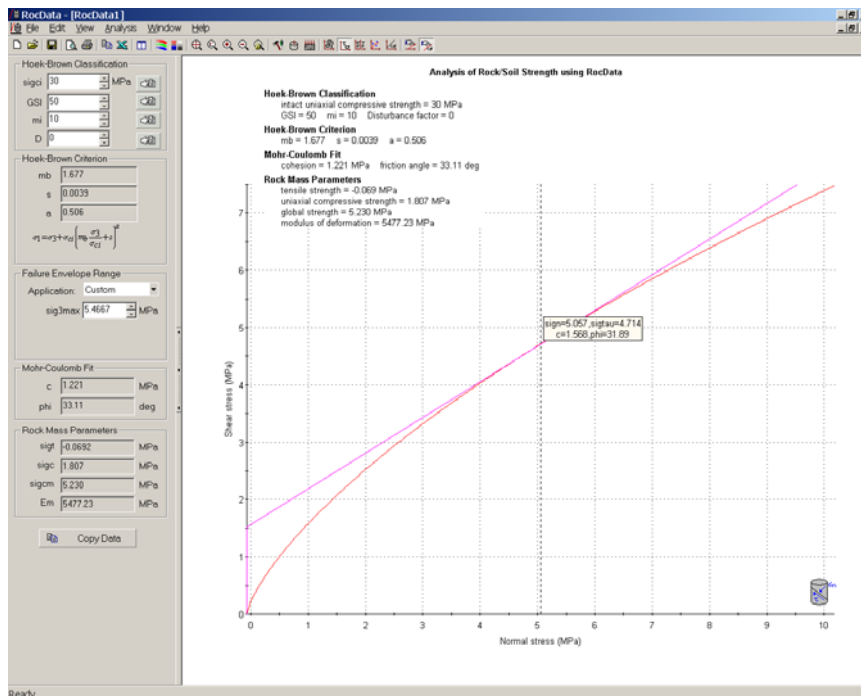


## Instantaneous Mohr-Coulomb Sampler

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 a curved failure envelope. This is done as follows:



1. Select the **Instantaneous MC Sampler** option from the toolbar, the right-click menu or the **Analysis** menu.
2. Single click the left mouse button, at any value of  $\sigma_3$  (on the principal stress plot), or any value of normal stress (on the shear-normal stress plot).
3. The instantaneous Mohr-Coulomb envelope (tangential line) will appear on the plots, for the value of  $\sigma_3$  or normal stress, at which the mouse was clicked. The instantaneous values of cohesion and friction angle will be displayed, as well as the stress coordinates. A vertical dotted line will be displayed on the plots, to mark the location.
4. Alternatively, if you click and HOLD the left mouse button on either of the plots, and DRAG the mouse left or right, the instantaneous Mohr-Coulomb envelope and coordinates, will be continuously displayed, as you move the mouse.



## Exporting Data / Images

---

The **RocData** analysis results and failure envelope plots can be exported to other programs for report writing, further analysis, etc. This can be done in various ways.



- The **Copy Data** option in the sidebar or the **Edit** menu, will copy the contents of the sidebar (i.e. all input and output parameters) to the clipboard. From the clipboard, this can be pasted into a word processor or spreadsheet. This provides a handy analysis summary.
- The **Copy** option in the toolbar or the **Edit** menu, will copy an image of the current failure envelope that is displayed, to the clipboard. From the clipboard, this can be pasted into reports or image editing programs, etc.
- The failure envelope plots can also be saved directly to a JPEG, BMP, EMF or WMF image file, with the **Export Image File** option. This is available in the **File** menu, or the right click menu. (An image of this option is displayed below.)

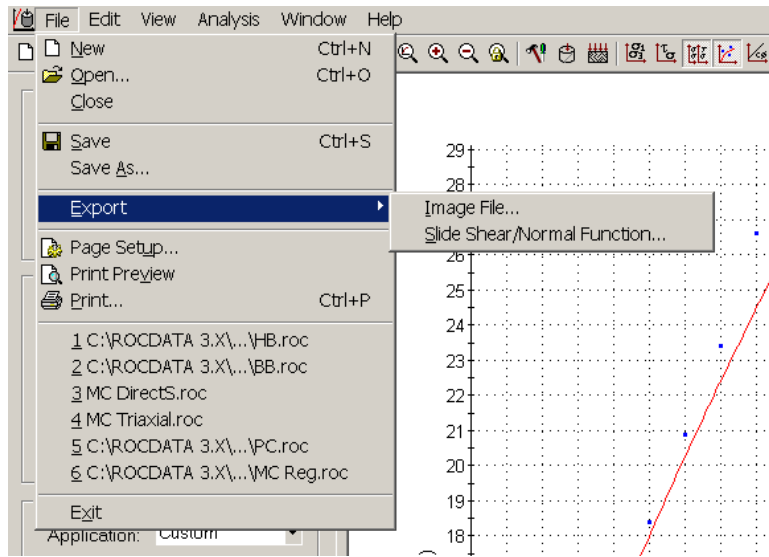
### *One Click Export to Excel*

The most powerful data export feature is the following – with a single mouse click, all data AND plots can be exported to Microsoft Excel. To do this:



1. Select the **Export to Excel** toolbar button.
2. If you have Excel installed on your computer, the Excel program will be automatically started, and all analysis input and output data will be exported to an Excel spreadsheet.
3. Failure envelope plots will then be generated in Excel.
4. This all takes place with a single mouse click!!!

Note that the plots, which are generated in Excel, correspond to the failure envelope plot(s) that you are currently viewing. For example, if you are only viewing the shear-normal plot, then only the shear-normal data and plot will be generated in Excel. If you are viewing both plots (principal stress and shear-normal), then both plots will be generated in Excel. In addition, if the equivalent Mohr-Coulomb envelope is displayed, this will also be plotted in Excel. Finally, note that the number of data points used to create each failure envelope is controlled in the **Display Options** dialog in **RocData**.



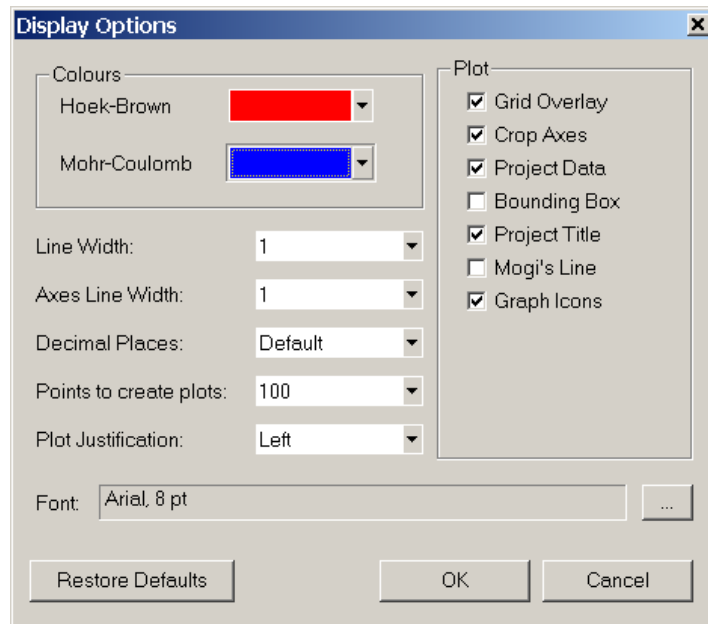
*The Export option in the File submenu*

## Display Options

The appearance of the Failure Envelope plots may be customized with Display Options, zooming, and other options.



- Display Options is available in the toolbar, the **View** menu, and also in the right-click menu (if you right-click the mouse anywhere in the Failure Envelope display area).



Most of the Display Options are self-explanatory, and it is left to the user to experiment with the options. However, we will note the purpose of the following options:

### *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.

### ***Zoom Extents***

The **Zoom Extents** option will automatically scale the axes of the failure envelopes for the Generalized Hoek-Brown criterion, so that all possible failure envelopes, for the current value of **sigci**, will be visible on the plot.

This corresponds to maximum values of **GSI** (= 100) and **mi** (= 40).



1. To demonstrate this, select the **Zoom Extents** option.
2. Use the interactive arrow buttons, to increase the value of **GSI** to 100, and the value of **mi** to 40.
3. Observe the failure envelope plots. When **GSI** = 100 and **mi** = 40, the extent of the principal stress envelope will correspond to the maximum extent automatically calculated by the **Zoom Extents** option.

You may find the **Zoom Extents** option useful for interactive demonstration of parameter changes on the failure envelope.

## Project Settings

The Project Settings dialog is used to enter a project title, to select a failure criterion or to select a measurement unit.



- The Project Settings dialog is available in the toolbar, the **Analysis** menu.

Project Settings

Project Title:  
Analysis of Rock/Soil Strength using RocData

Stress Units: Megapascals (MPa)

Strength Criterion

Generalized Hoek-Brown     Mohr-Coulomb  
 Barton-Bandis     Power Curve

OK    Cancel

The Project Settings dialog is self-explanatory, and it is left to the user to experiment with the options.

Project Settings

Project Title:  
Analysis of Rock/Soil Strength using RocData

Stress Units: Megapascals (MPa)  
Megapascals (MPa)  
Kilopounds per square foot (ksf)  
Kilopounds per square inch (ksi)

Strength Criterion

Generalized Hoek-Brown     Mohr-Coulomb  
 Barton-Bandis     Power Curve

OK    Cancel

# Documentation

The calculations in the **RocData** program, are based on the latest version of the Generalized Hoek-Brown failure criterion, as detailed in the following paper (Ref. 1):

Hoek, E., Carranza-Torres, C.T., and Corkum, B. (2002), Hoek-Brown failure criterion – 2002 edition. *Proc. North American Rock Mechanics Society meeting in Toronto in July 2002*

The program **RocData** incorporates all of the latest developments described in this paper.

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The paper should be read by all users of the Generalized Hoek-Brown criterion in **RocData!!!** The definitions and equations for all input and output parameters in **RocData**, can be found in this paper, which is available as a PDF document.

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Another useful document is the following (Ref. 2):

“A Brief History of the Hoek-Brown Failure Criterion”, by Evert Hoek.

This paper provides a brief chronological overview of the evolution of the Hoek-Brown failure criterion, and provides references to all of the significant papers which have been published. This is also recommended reading for all users of the Generalized Hoek-Brown criterion. The paper is available as a PDF document.

Finally, a set of notes by Dr. Evert Hoek, *Practical Rock Engineering*, (Ref. 3) is available on the Rocscience website, [www.rocscience.com](http://www.rocscience.com), in the form of a series of PDF documents. *Practical Rock Engineering* is recommended reading for all students of rock mechanics. Chapter 11 (Rock mass properties) should also be read by users of RocData. Note that the version of the Hoek-Brown failure criterion which is presented in the current version of *Practical Rock Engineering*, has been superceded by the latest version of the criterion (Ref. 1). However, the conceptual information is still relevant, and gives further insight into the development of the Hoek-Brown criterion.

## Tutorials

### Example 1 – Hoek-Brown Strength Envelope for a Tunnel in Undisturbed Rock (D = 0)

Consider an undisturbed in situ rock mass surrounding a tunnel at a depth of 100 meters, with the following Hoek-Brown classification parameters.

Hoek-Brown Classification	
sigci	50 MPa
GSI	45
mi	10
D	0

Enter this data in the sidebar input data area. Also, enter the following data to determine the Failure Envelope Range (sig3max), which is used to calculate equivalent Mohr-Coulomb parameters for the Hoek-Brown model.

Failure Envelope Range	
Application:	Tunnels
sig3max	1.3525 MPa
Unit Weight	0.027 MN/m <sup>3</sup>
Tunnel Depth	100 m

The resulting output will be automatically displayed in the sidebar, and the failure envelopes calculated and plotted.

Notice the equivalent Mohr-Coulomb parameters that have been calculated:

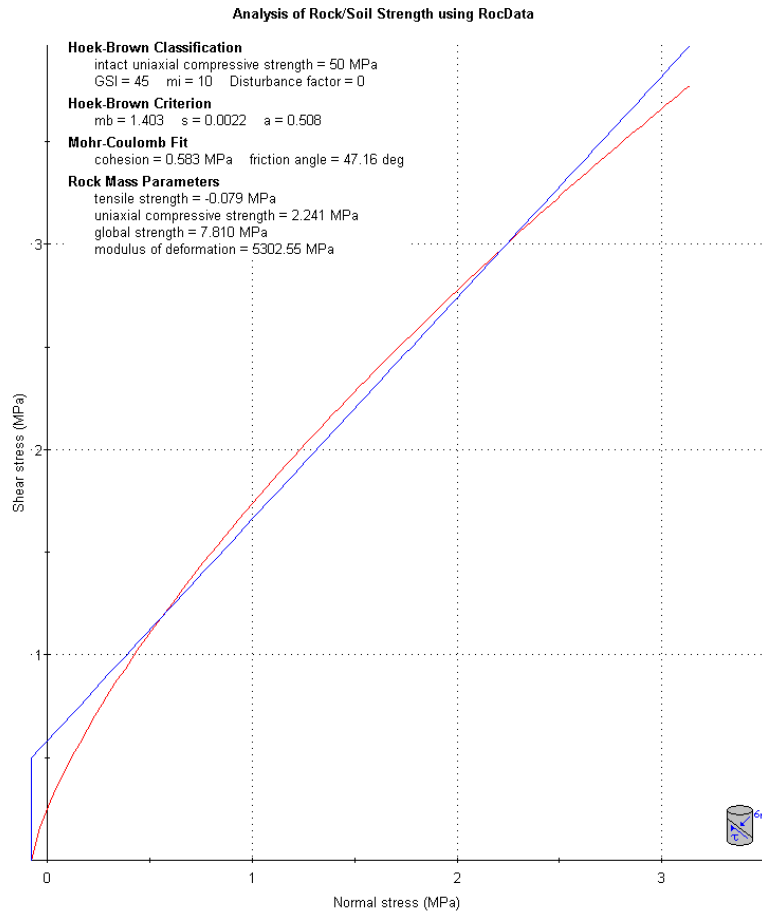
Mohr-Coulomb Fit	
c	0.583 MPa
phi	47.16 deg



The envelope corresponding to these parameters can be viewed on the plots, by selecting the Mohr-Coulomb strength envelope option, from the toolbar or the Analysis menu.



To get a better look at the MC envelope, let's view only the Normal vs. Shear stress plot. Select the Normal vs. Shear Stress option from the Analysis menu or the toolbar. This will hide the principal stress plot, and show only the Normal vs. Shear stress plot, maximized in the view.



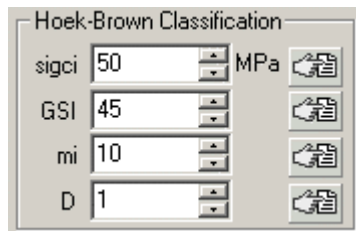
If you examine the MC envelope, you can graphically confirm the calculated values of cohesion, friction angle, and also the rock mass tensile strength **sigt**. The tensile strength is the negative value of normal stress, at the origin of the failure envelope.

## Example 2 – Hoek-Brown Strength Envelope for a Slope Application in Highly Disturbed Rock (D = 1)

---

Consider a rock mass with the same basic parameters as the previous example, but in a highly disturbed slope of 100 meters height, with a disturbance factor  $D = 1$ .

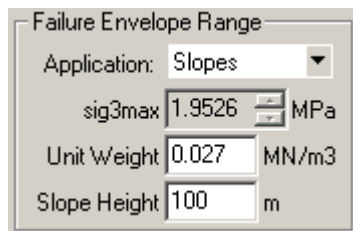
Enter disturbance factor  $D = 1$ .



Hoek-Brown Classification

sigci	50	MPa
GSI	45	
mi	10	
D	1	

Enter the following data to determine the Failure Envelope Range (sig3max):

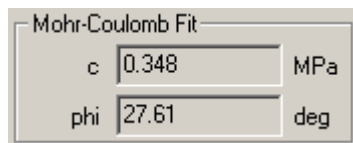


Failure Envelope Range

Application:	Slopes
sig3max	1.9526 MPa
Unit Weight	0.027 MN/m <sup>3</sup>
Slope Height	100 m

The resulting output will be automatically displayed in the sidebar, and the failure envelopes calculated and plotted.

Notice the equivalent Mohr-Coulomb parameters which have been calculated:



Mohr-Coulomb Fit

c	0.348	MPa
phi	27.61	deg

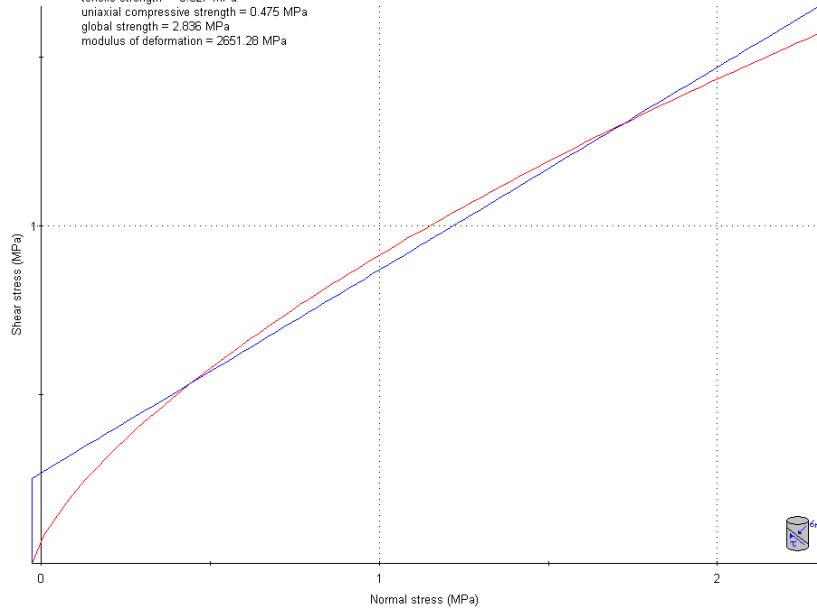
Analysis of Rock/Soil Strength using RocData

**Hoek-Brown Classification**  
intact uniaxial compressive strength = 50 MPa  
GSI = 45     $m_i = 10$     Disturbance factor = 1

**Hoek-Brown Criterion**  
 $m_b = 0.197$      $s = 0.0001$      $a = 0.508$

**Mohr-Coulomb Fit**  
cohesion = 0.268 MPa    friction angle = 31.01 deg

**Rock Mass Parameters**  
tensile strength = -0.027 MPa  
uniaxial compressive strength = 0.475 MPa  
global strength = 2,836 MPa  
modulus of deformation = 2651.28 MPa



Compare the equivalent Mohr-Coulomb parameters and envelopes, calculated in Example 1 and Example 2. This demonstrates the significant effect which the disturbance factor **D**, can have on the calculated rock mass strength.

For information about the Disturbance Factor, see Ref. 1 – section 7: *Estimation of Disturbance Factor D*.

### Example 3 – Hoek-Brown, Power Curve and Mohr-Coulomb Analysis of an Intact Rock Triaxial Dataset

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This tutorial will involve fitting three strength models – the Hoek-Brown, Mohr-Coulomb and Power Curve criteria - to a triaxial lab dataset for intact rock.



Start up **RocData** and a new analysis file will be automatically opened. If you are already in the program select the **New** option from the **File** menu or from the toolbar.



Select the **Project Settings** option (from the Analysis menu or the toolbar) and ensure that the measurement unit is set to MPa. Notice that the **Generalized Hoek-Brown** criterion is the default strength model.



Next select the **Use Lab Data** option from the **Analysis** menu or toolbar. This opens up the Hoek-Brown lab (intact) data analysis dialog. The **Levenberg-Marquardt** technique is the default curve fitting method in the dialog.

Set the number of data points to be analyzed to 5, and enter the values shown on the figure below.

#	sig3 (MPa)	sig1 (MPa)
1	0	15
2	3	28
3	5	49
4	16	84
5	27.5	102

Notice that each time you hit Enter on the keyboard, **sigci** and **mi** are immediately calculated for the data that has been input.

Select the **Simplex** curve fitting method and observe the immediate calculation of a new fit. Next select the **Linear Regression** curve fitting method and view the resulting parameters.

Select the **Levenberg-Marquardt** method again and click the OK button. This action applies the analysis results to the main view of **RocData** and exits the dialog.

The report at the top left corner of the main view displays all the relevant parameters of the analysis of the lab data. At the very end of the list, information is provided on the curve fitting method used and the value of the **Residuals**.

**Analysis of Rock/Soil Strength using RocData**

**Hoek-Brown Classification**  
intact uniaxial compressive strength = 15.605 MPa  
GSI = 50    mi = 14.43    Disturbance factor = 0

**Hoek-Brown Criterion**  
mb = 2.420    s = 0.0039    a = 0.506

**Mohr-Coulomb Fit**  
cohesion = 3.058 MPa    friction angle = 18.78 deg

**Rock Mass Parameters**  
tensile strength = -0.025 MPa  
uniaxial compressive strength = 0.940 MPa  
global strength = 3.243 MPa  
modulus of deformation = 3950.32 MPa

**Analysis of TRIAXIAL Lab Data**  
No. of lab data points = 5  
Sum square of errors (Residuals) = 146.085  
Current strength model is LEVENBERG-MARQUARDT 'best-fit'

Change the **sigci** value displayed on the docking form to a number of your choice; note the changes in the last line of information displayed. **RocData** warns that the currently displayed model is not a 'best-fit', i.e. is not a model produced by one of the curve fitting techniques.

**Analysis of Rock/Soil Strength using RocData**

**Hoek-Brown Classification**  
intact uniaxial compressive strength = 20 MPa  
GSI = 50    mi = 14.43    Disturbance factor = 0

**Hoek-Brown Criterion**  
mb = 2.420    s = 0.0039    a = 0.506

**Mohr-Coulomb Fit**  
cohesion = 3.356 MPa    friction angle = 20.44 deg

**Rock Mass Parameters**  
tensile strength = -0.032 MPa  
uniaxial compressive strength = 1.205 MPa  
global strength = 4.156 MPa  
modulus of deformation = 4472.14 MPa

**Analysis of TRIAXIAL Lab Data**  
No. of lab data points = 5  
Sum square of errors (Residuals) = 426.467  
Current strength model is NOT a 'best-fit'

Go into the **Project Settings** dialog, select the **Mohr-Coulomb** criterion, and click OK. Immediately the data analysis dialog for the criterion is activated. The dialog contains the intact rock data previously analyzed with the Hoek-Brown lab data option. Click the OK button to apply the analysis results and exit from the dialog.

Next select the **Power Curve** strength model from the **Project Settings** dialog. The Power Curve data analysis dialog is opened with the input data and its corresponding fit. You may save the analysis under any file name of your choice and exit the program.

This concludes the tutorial on fitting the Hoek-Brown, Mohr-Coulomb and Power Curve strength models to an intact rock lab dataset.

## Example 4 – Generalized Hoek-Brown Analysis of Field Data

This tutorial will fit the Generalized Hoek-Brown criterion to triaxial strength data for a rock mass.



Start up **RocData** and a new analysis file will be automatically opened. If you are already in the program select the **New** option from the **File** menu or from the toolbar.



Select the **Project Settings** option (from the Analysis menu or the toolbar) and ensure that the measurement unit is set to MPa and strength criterion set to **Generalized Hoek-Brown**.



Next select the **Use Field Data** option from the **Analysis** menu or toolbar. This opens up the Hoek-Brown field (rock mass) data analysis dialog.

Enter an intact rock compressive strength (**sigci**) of 50 MPa and a Disturbance Factor (**D**) of 0.5. Set the number of data points to be analyzed to 9, and enter the values shown on the figure below.

Calculate  $m_i$ , GSI,  $m_b$ ,  $s$  and  $a$  from Rock Mass Data

Rock Mass Data

Curve-Fitting Method: Levenberg-Marquardt

Input Parameters

sigci: 50 MPa D: 0.5

Number of Tests: 9

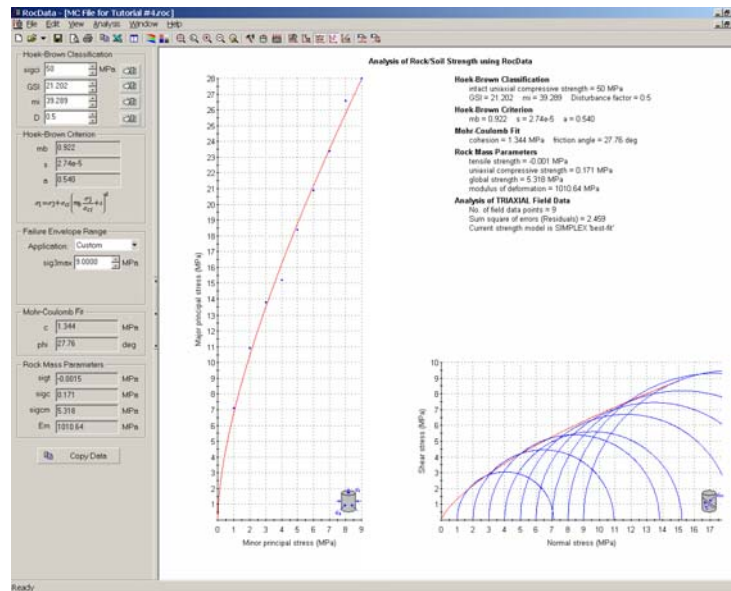
#	sig3 (MPa)	sig1 (MPa)
1	1	7.1
2	2	10.9
3	3	13.8
4	4	15.2
5	5	18.4
6	6	20.9
7	7	23.4
8	8	26.6
9	9	28.0

*Input data for the tutorial*

Select the **Simplex** curve fitting method and observe the immediate calculation of a new fit. Click the OK button to close the dialog and apply the analysis results to the **RocData** main view.



The default settings for the main view do not display the input data points analyzed. To view them select the **Plot Test Data** option from the **Analysis** menu or the toolbar.



### *Generalized Hoek-Brown analysis of triaxial field data*

Triaxial data points are shown as points on the principal space plot of the strength envelope, and as Mohr circles on the direct shear plot.

This concludes the tutorial on fitting the Generalized Hoek-Brown criterion to field (rock mass) triaxial strength data.

## Example 5 – Mohr-Coulomb and Power Curve Analysis of a Direct Shear Dataset

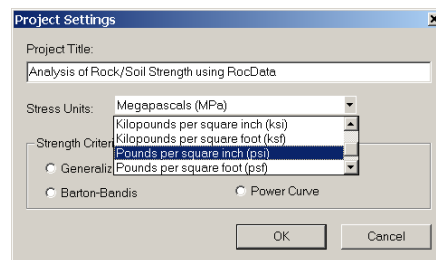
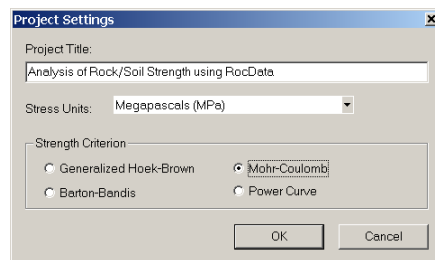
This tutorial will examine the fitting two strength models – the Mohr-Coulomb and Power Curve criteria - to direct shear stress data (measured in psi units) for a soil.



Start up **RocData** and a new analysis file will be automatically opened. If you are already in the program select the **New** option from the **File** menu or from the toolbar.



Select the **Project Settings** option (from the Analysis menu or the toolbar) and set the measurement unit to psi. Change the strength model from **Generalized Hoek-Brown** to **Mohr-Coulomb**.

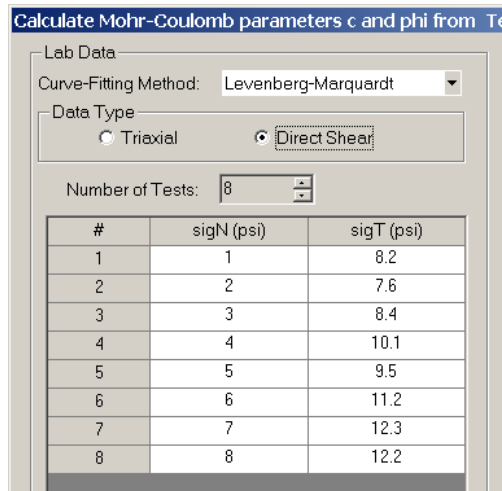


*Project Settings for the tutorial*



Next select the **Use Lab Data** option from the **Analysis** menu or toolbar. This opens up the Mohr-Coulomb lab data analysis dialog.

There are two radio buttons near the top of the dialog that enable users to select the type of data to be analyzed: triaxial or direct shear. Select the direct shear radio button. Set the number of data points to be analyzed to 8, and enter the values shown on the figure below.

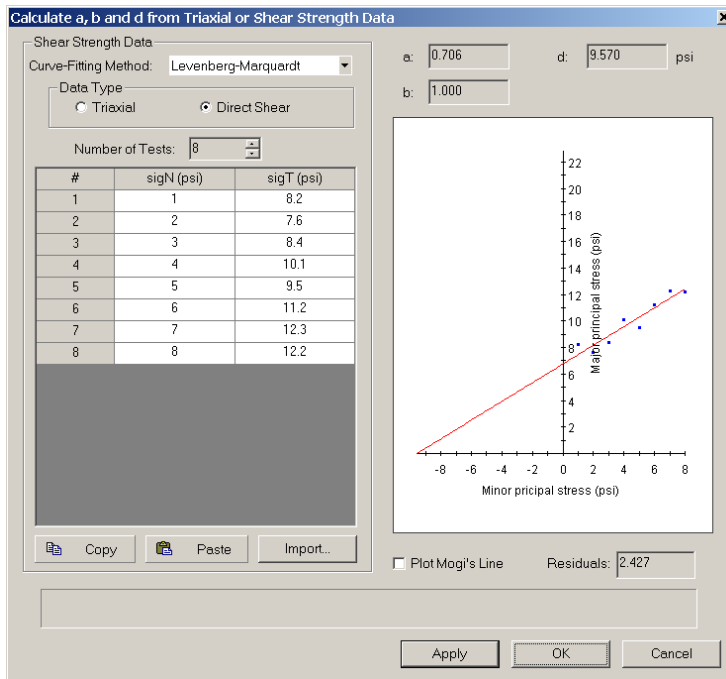


*Input data for the tutorial. On the shown dialog image notice the radio buttons for selecting the type of data to be analyzed.*

Select the **Linear Regression** curve fitting method and view the resulting parameters. (For Mohr-Coulomb data the Linear Regression and Levenberg-Marquardt methods give the same answers for practically all cases.)

Click the OK button. This action applies the analysis results to the main view of **RocData** and exits the dialog.

Go into the **Project Settings** dialog, select the **Power Curve** criterion, and click OK. Immediately the data analysis dialog for the criterion is activated. The dialog contains the intact rock data previously analyzed with the Mohr-Coulomb lab data option.



*Power Curve fit of the sample direct shear data*

This concludes the tutorial on fitting the Mohr-Coulomb and Power Curve strength models to a direct shear dataset.

## References

1. Hoek, E., Carranza-Torres, C.T., and Corkum, B. (2002), Hoek-Brown failure criterion – 2002 edition. *Proc. North American Rock Mechanics Society meeting in Toronto in July 2002.*
2. Hoek, Evert, (2002), A Brief History of the Hoek-Brown Failure Criterion, unpublished document.
3. Hoek, Evert, Practical Rock Engineering – An Ongoing Set of Notes, available on the Rocscience website, [www.rocscience.com](http://www.rocscience.com)