Developer's Tip

Speeding up Slope Stability Calculations involving Generalized Hoek-Brown Materials

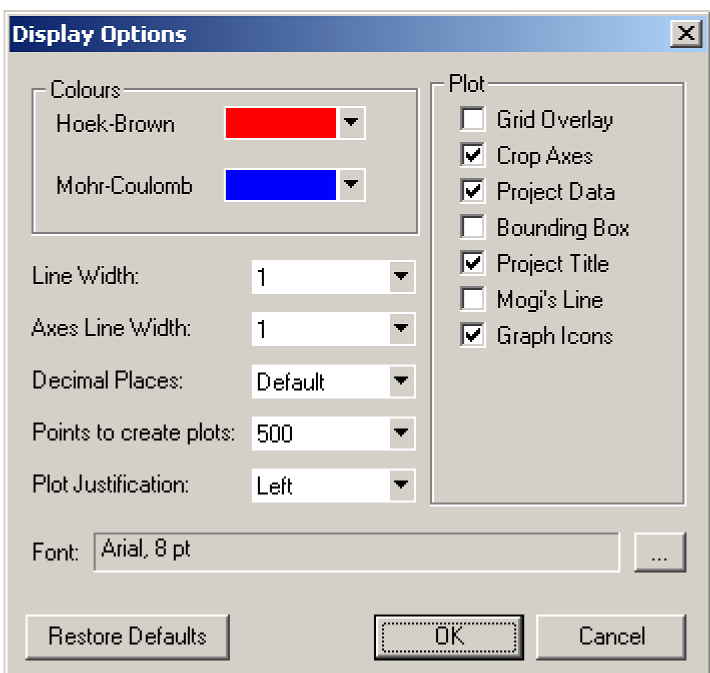
In limit-equilibrium slope stability analysis, material strength is most readily expressed in terms of shear and normal stresses acting along a failure surface. The Generalized Hoek-Brown for rockmass strength, however, is formulated in terms of major and minor principal stresses. Therefore, to use this criterion in slope stability analysis, as is possible in *Slide*, the principal stresses of the criterion have to be translated into shear and normal stresses. This transform is done through equations first formulated by Balmer (1952).

Due to the nature of the Balmer equations, the conversion of principal stresses to shear-normal stresses is computationally intensive. This considerably slows down slope stability analysis involving Generalized Hoek-Brown materials. Fortunately, in *Slide*, it is possible to significantly improve the computational speed of such analyses through combined use of the program's Shear/Normal strength function and the free Rocscience program *RocLab*. *RocLab* allows users to easily determine Hoek-Brown and Mohr-Coulomb strength parameters of rockmasses and intact rock samples.

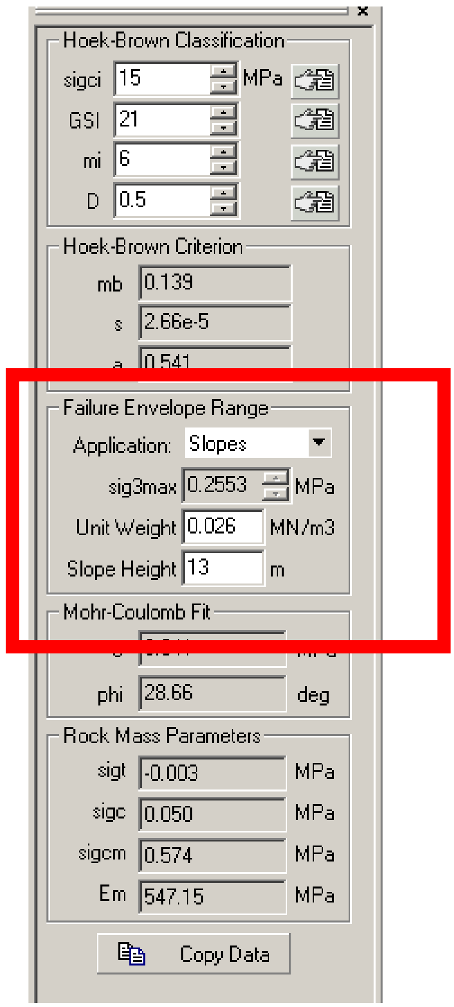
The procedure for speeding rock slope stability calculations is simple. It involves generating a discrete number of points from the Generalized Hoek-Brown criterion, converting those principal stress values to shear/normal stresses and importing them into *Slide*. *Slide* then uses these discrete shear/normal stress points to calculate failure surface strengths. It interpolates for strength values that lie in-between the imported points.

The exact steps for combining *RocLab* and *Slide* are as follow:

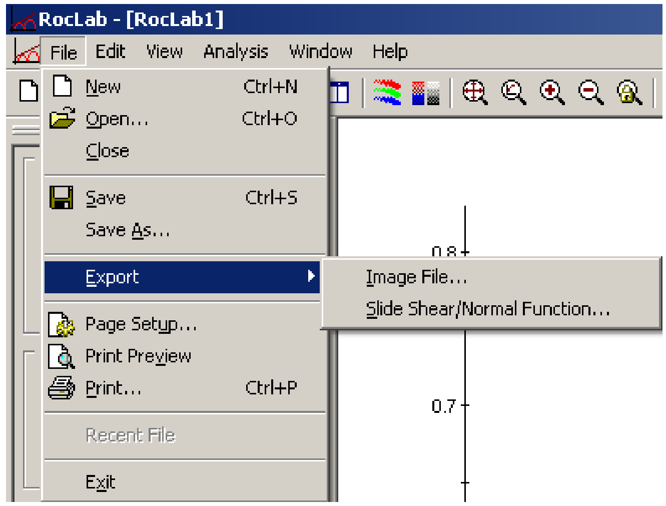
1. In *RocLab* enter appropriate Generalized Hoek-Brown strength parameters for the rockmass of interest. Open the **Display Options** dialog and specify the number of points from the strength envelope you would like exported. We recommend a minimum of 200 points.



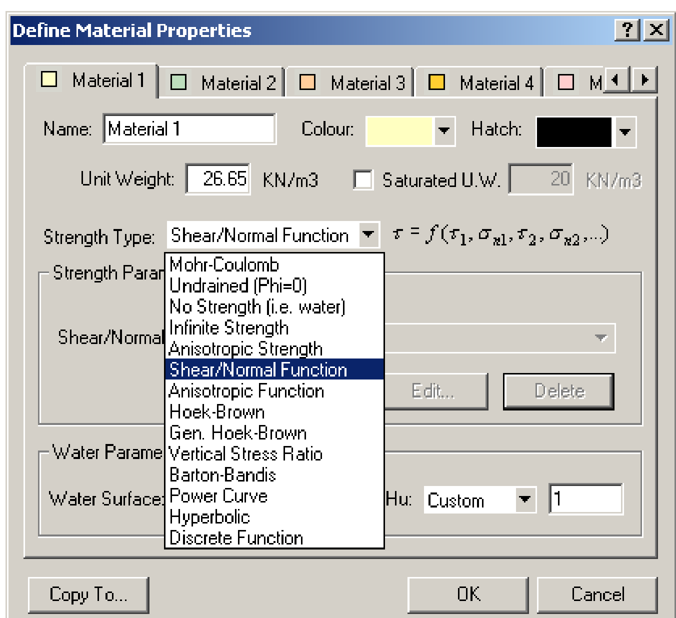
Since the Generalized Hoek-Brown strength envelope is curved, it is important to generate failure points from a stress range appropriate to your slope problem. You can automatically obtain an appropriate range by selecting the **Slopes** option from the **Application** item under the **Failure Envelope Range** (on the main docking form). This option requires you to specify a slope height and unit weight of slope material, which the program uses to compute a suitable stress range.



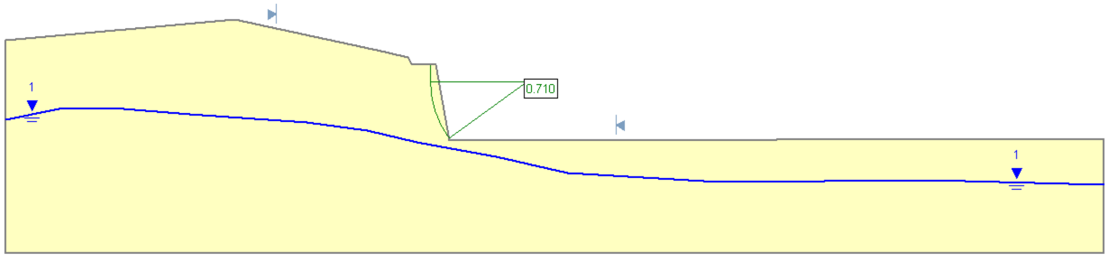
2. Select the **Export** option under the **File** menu of the program, and from the ensuing sub-menu select **Slide Shear/Normal Function**. You will then be required to specify a file name under which the exported shear normal stresses, equivalent to points from your Generalized Hoek-Brown strength model, will be stored.



3. In the **Define Material Properties** dialog of *Slide*, select **Shear/Normal Function** as the strength type for your rockmass. Click on the **New** button under the strength parameters section. In the ensuing dialog, click on the **Import** button, select the file with your shear/normal stress points, and click **Open**. Now click **OK**. The discrete shear/normal stress points have been assigned as the strength model for your material and you can proceed to run an analysis.



We tested the improvements in speed and any possible losses in accuracy of the above-outlined approach by computing a rock slope model with Generalized Hoek-Brown material on a Pentium IV 1.6 GHz with I GB RAM.



Hoek-Brown Parameters
GSI = 21
UCS = 15 MPa
$m_i = 6$
Disturbance Factor, $D = 0.5$

We compared three cases: one case of using the Generalized Hoek-Brown strength model in Slide, and two cases of different numbers of exported shear/normal stress points, 200 points in one and 500 points in the other. The model examined 4500 circular failure surfaces and involved calculation of the factors of safety from the Bishop, Lowe-Karafiath, and Spencer methods.

The results of our testing are provided in the table below.

Case	Computational Time (Seconds)	Factor of Safety		
		Bishop	Lowe-Karafiath	Spencer
Generalized Hoek-Brown model in *Slide*	319	0.705	0.696	0.710
500 shear/normal stress points	40	0.705	0.695	0.710
200 shear/normal stress points	30	0.704	0.694	0.708

Clearly the approach of combining *RocLab*'s data export feature with *Slide*'s shear/normal strength function significantly improved the speed of computations without compromising accuracy. The timesavings would be even more pronounced if it were required to analyze several slope alternatives.

Although the *RocLab*–*Slide* combined approach is very effective, we recommend that the Generalized Hoek-Brown strength model in Slide be used for final design.