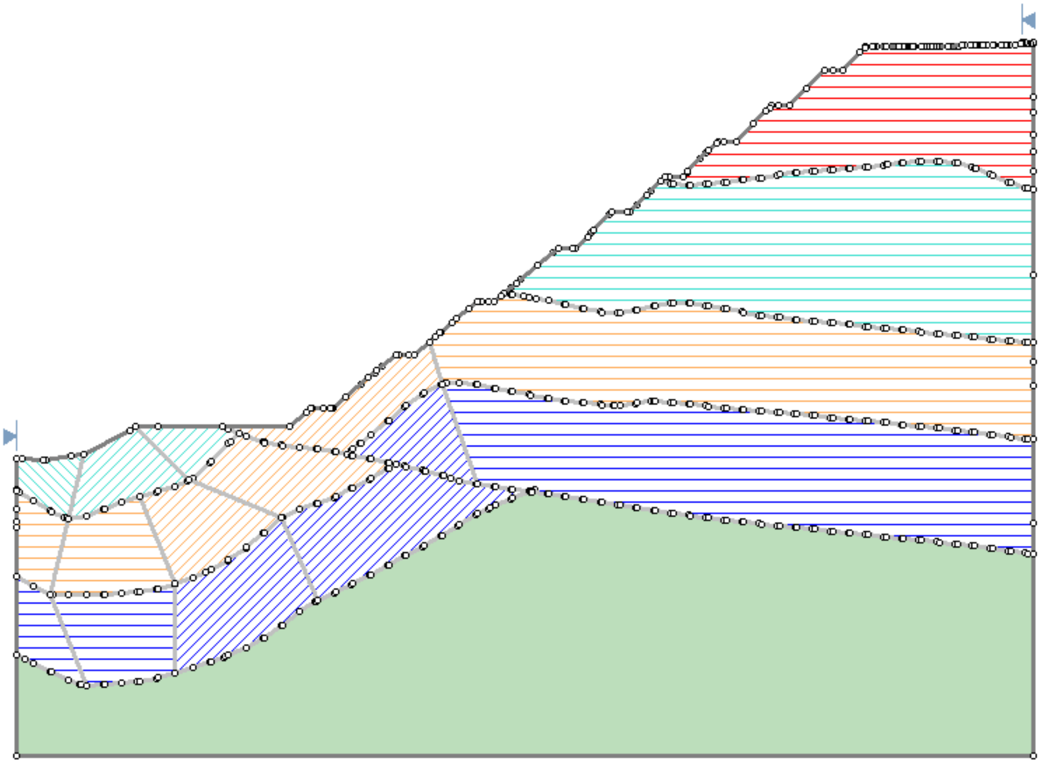
Snowden – Rocscience Collaboration

Rocscience always welcomes and encourages feedback from our software users. With each program upgrade, the majority of new functionality is a direct result of the many suggestions and requests that we continually receive from our customers and colleagues worldwide. Special requests for specific new features are always seriously considered, and implemented whenever possible.

This article describes a recent addition to the strength modeling options in *Slide* (our limit equilibrium slope stability program) requested by **Snowden Geotechnical Engineering (Snowden)** in Australia. The anisotropic linear strength models were implemented based on recommendations and specifications developed by Snowden. These models were originally developed for analysis of slopes in the highly anisotropic bedded rock masses of the Pilbara iron ore formations in Western Australia. They are nevertheless applicable to similar rock masses elsewhere. These models include:

- Anisotropic Linear Strength (implemented in 2007)
- Snowden Modified Anisotropic Linear Strength (new 2011)

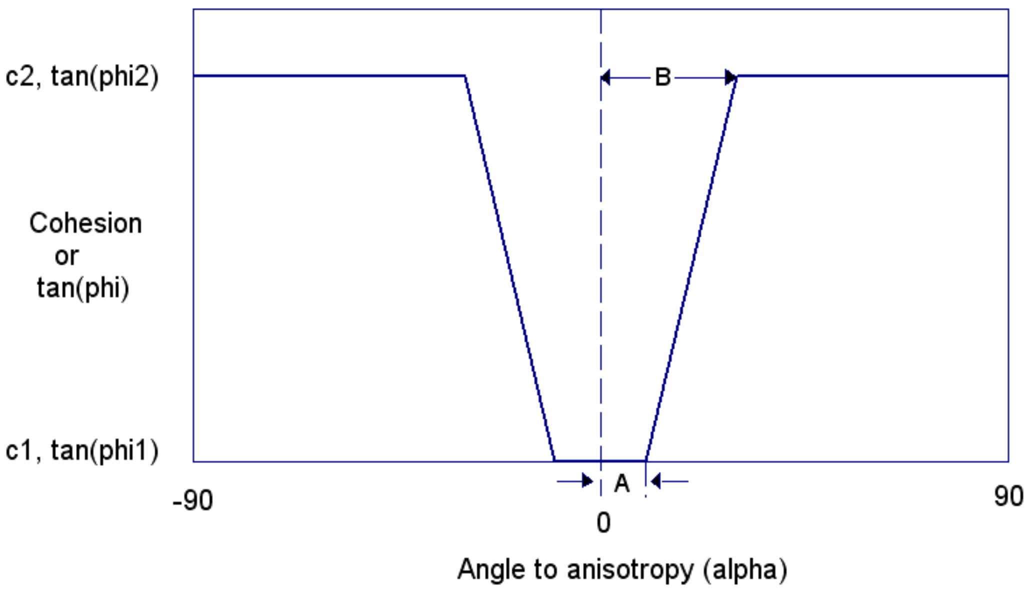


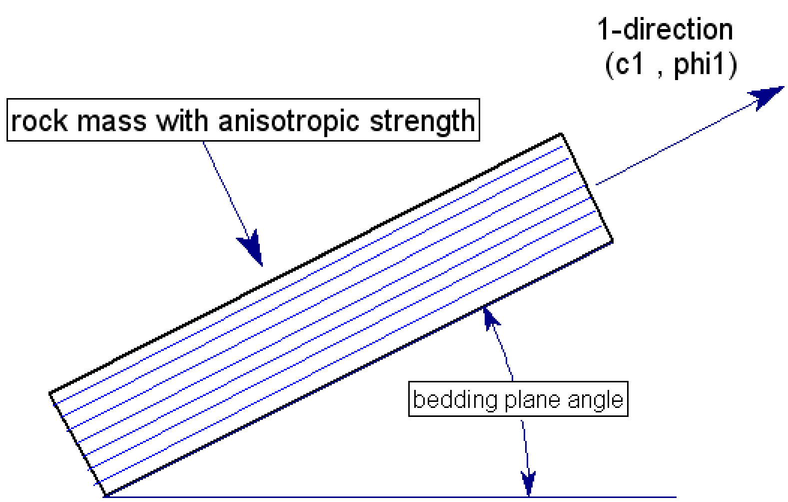
Slope model with anisotropic rock structure

Anisotropic Linear Strength Model

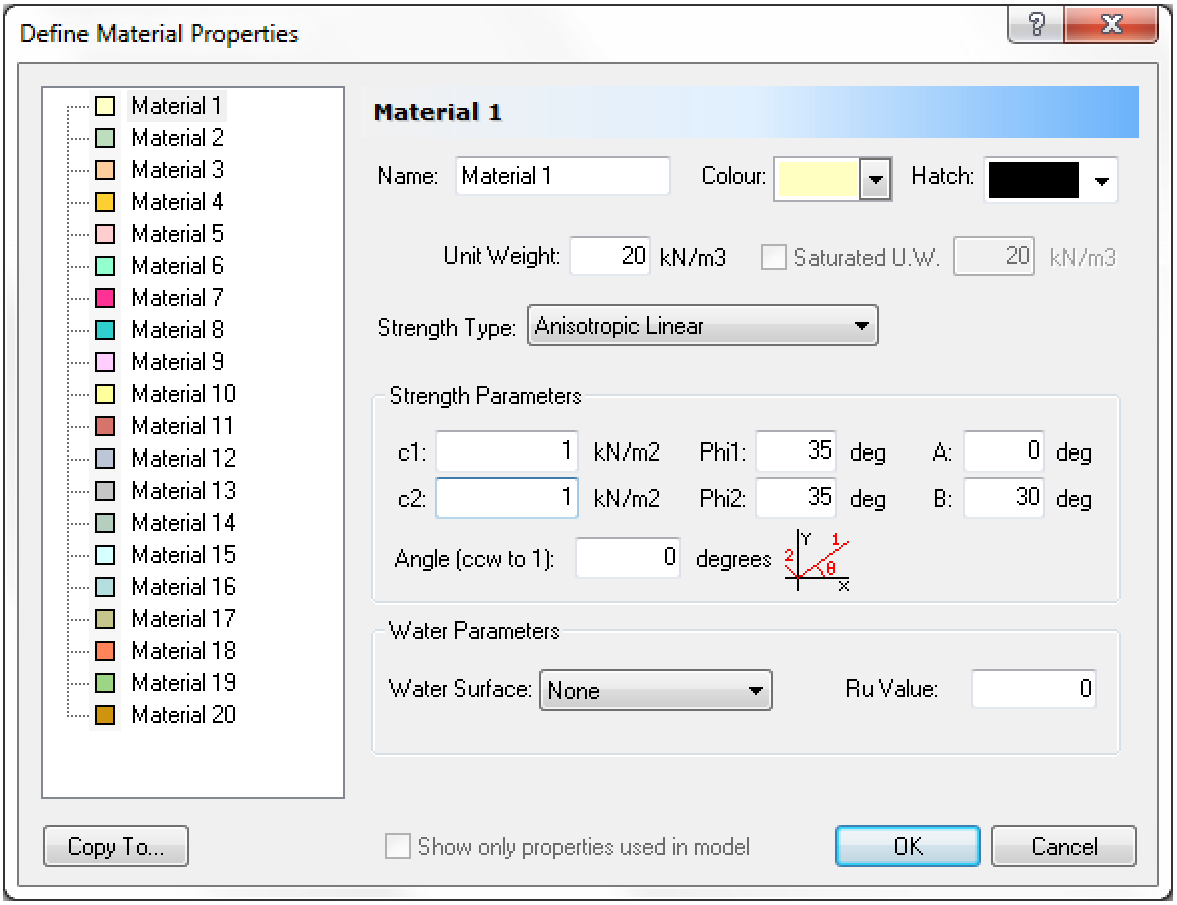
Snowden has been a user of Rocscience software for many years. In 2007 Snowden contacted Rocscience about implementing a new anisotropic strength model in our limit equilibrium slope stability program *Slide*. This is now referred to as the **Anisotropic Linear** model.

The **Anisotropic Linear** model is based on the Mohr-Coulomb criterion, and assumes that the minimum shear strength occurs in the direction of the bedding planes, and is given by cohesion and friction angle c1, phi1. As the angle to the bedding plane is varied, there is a linear increase in strength until the maximum rock mass strength is achieved, given by c2, phi2.





The **Anisotropic Linear Strength** model is intended to simulate the behaviour of certain anisotropic rock masses with a predominant weak bedding orientation. The parameters A and B allow the user to define a linear transition from bedding plane strength to rock mass strength, with respect to shear plane orientation.

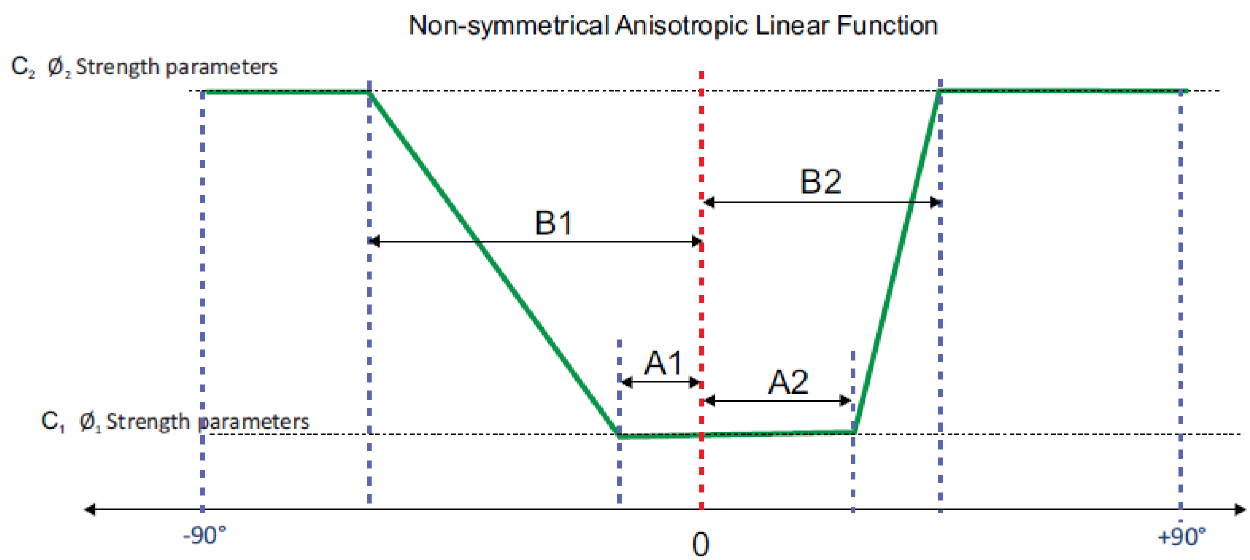


For further information see the Anisotropic Linear help topic.

Snowden Modified Anisotropic Linear Model

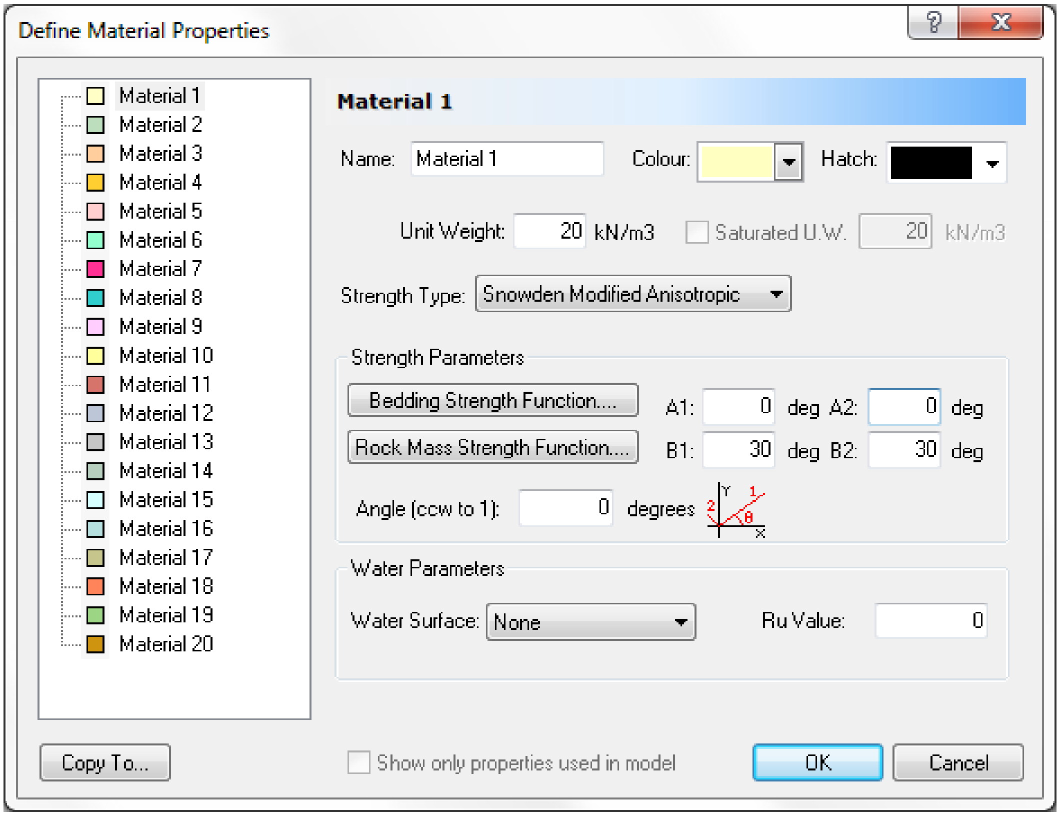
In 2011 Snowden made some refinements to the original Anisotropic Linear model, and this was implemented in *Slide* as the **Snowden Modified Anisotropic Strength** model. The Snowden Modified Anisotropic strength model is an extension of the Anisotropic Linear strength model. There are two main differences between the models.

- The bedding and rock mass strength can now be defined by non-linear shear-normal functions
- The anisotropy can be non-symmetric with respect to the bedding orientation

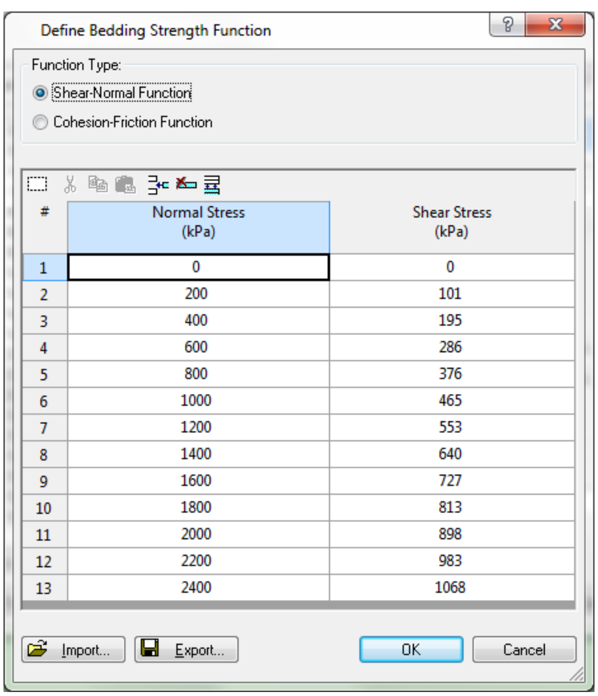


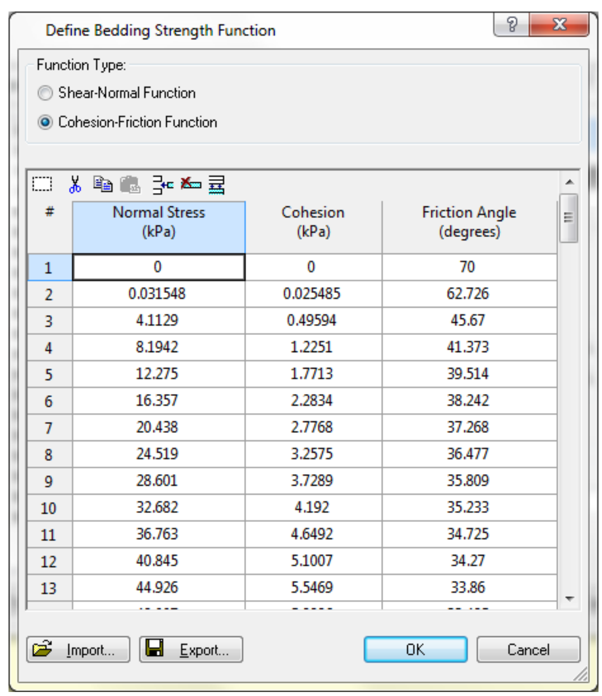
The Snowden Modified Anisotropic Strength model recognizes that c and phi for a typical rock mass and bedding plane is a function of the stress state within the rock mass and along the bedding plane. As a result, this model requires either a shear stress versus normal stress function or a function relating cohesion and friction angle to normal stress.

The second difference is in the transition from rock mass to bedding plane strength. For the Anisotropic Linear model the transition is through two parameters, A and B and is symmetric around the bedding plane orientation. In the Snowden Modified model, the transition is a function of 4 parameters, A1, B1, A2, B2. The transition can be non-symmetric as shown in the above figure.



In the Define Material Properties dialog you can define strength functions for the bedding and rock mass, using either shear-normal or normal-cohesion-friction functions.



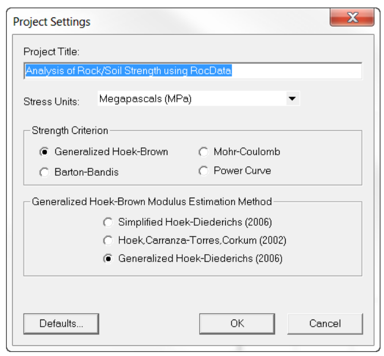


Snowden Modified Example

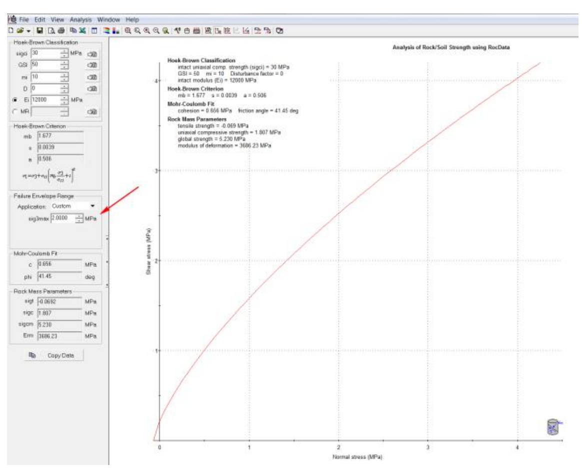
The **Snowden Modified Anisotropic** model can be used to replicate any underlying non-linear strength criterion. However, when analysing bedded rock masses, the easiest way to apply the Snowden Modified Anisotropic model is to first define the strength of the rock mass using the Generalized Hoek-Brown (GHB) failure criterion, and the strength of the bedding using the Barton-Bandis (BB) strength model. These models are two of the most common strength models used in rock engineering, and both represent the nonlinear change in strength with stress.

Once the strength is determined, it is an easy matter of using the Rocscience *RocData* program to convert both the GHB and BB strength models to Shear-Normal models. These Shear-Normal envelopes can then be imported into *Slide* using the following steps:

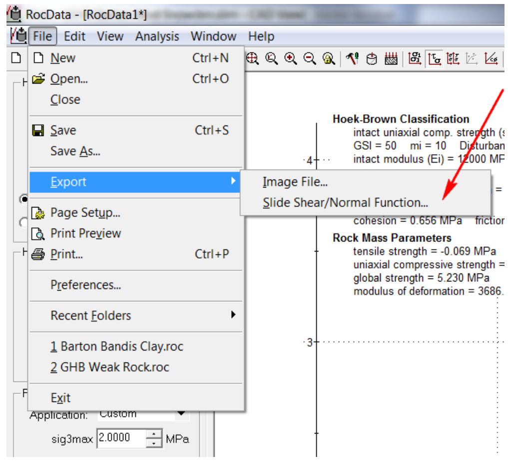
1. In the *RocData* Project Settings dialog, make sure the Generalized Hoek-Brown failure criterion is selected.



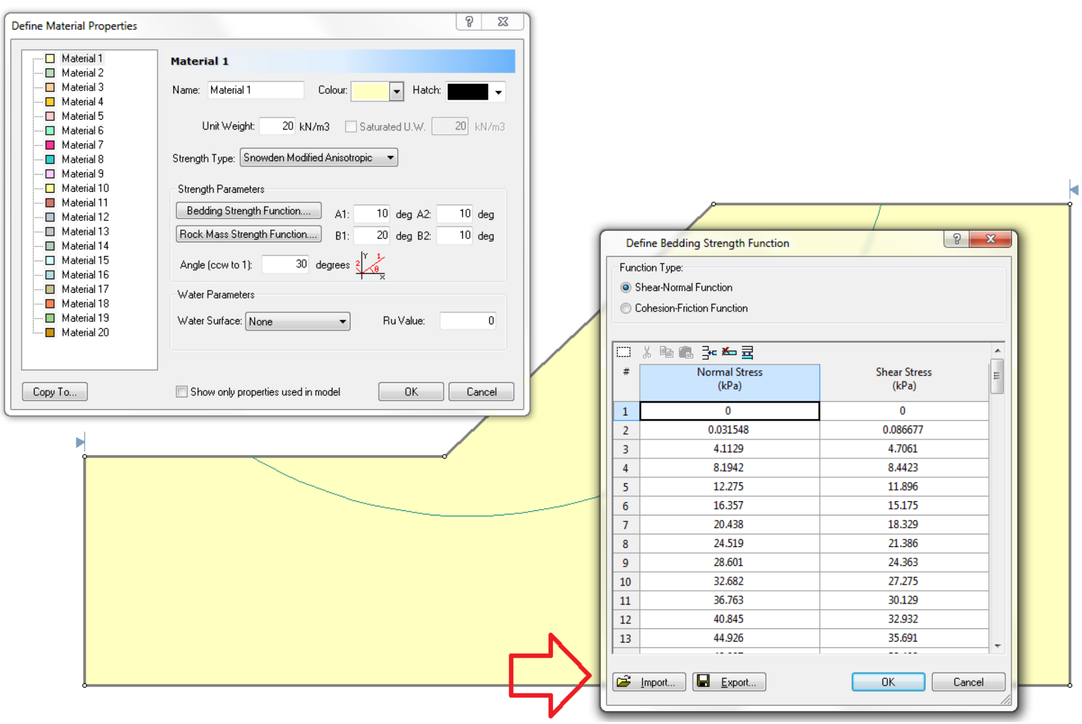
2. Enter the values for sigci, GSI, mi, D.
3. In the Failure Envelope Range, enter a Custom Application and a value of **sig3 max** for your slope. The resulting shear stress versus normal stress envelope should cover the range of effective normal stresses you anticipate on all possible failure surfaces.



4. In the File…Export menu, select the Slide Shear/Normal Function option.



5. In the *RocData* Project Settings dialog, change the strength criterion to Barton-Bandis and follow the same procedure described in steps 1-4.
6. In *Slide*, when defining the Shear-Normal functions for the Snowden Modified Anisotropic model, use the **Import** option to import the Shear-Normal function files saved in steps 4 and 5 above.



Note: This process requires version 4.011 of *RocData*.

Generalized Anisotropic versus Snowden Modified Anisotropic

Slide version 6 has other anisotropic strength models including the Generalized Anisotropic model. With this option you may assign ANY strength model in *Slide* to any angular orientation range. For example, you could create a material which has Generalized Hoek-Brown properties over one range and Barton-Bandis strength properties in another range.

This allows you to create a function similar to the Snowden Modified model, with some differences. The first is the anisotropic transition in strength. The Generalized Anisotropic model has no transition between the rock mass and bedding strength; the strength instantaneously changes from one angular range to another (equivalent to A=B for the Snowden models). Second, the Snowden model uses Shear-Normal envelopes instead of Generalized Hoek-Brown and Barton-Bandis envelopes.

Conclusion

Slide now offers no less than five different options for the modelling of anisotropic material strength. The Snowden Modified model is a powerful addition and extension of the earlier Anisotropic Linear model. The ability to define non-linear strength envelopes for the bedding and rock mass, with a gradual transition between the two is particularly useful. Other anisotropic models have an abrupt strength change at critical orientations, the Snowden model provides a more realistic transition of strength with orientation.

At Rocscience, software feature requests are always considered. Big or small, if there are improvements or new functionality that you would like to see in any of our software programs – just ask!