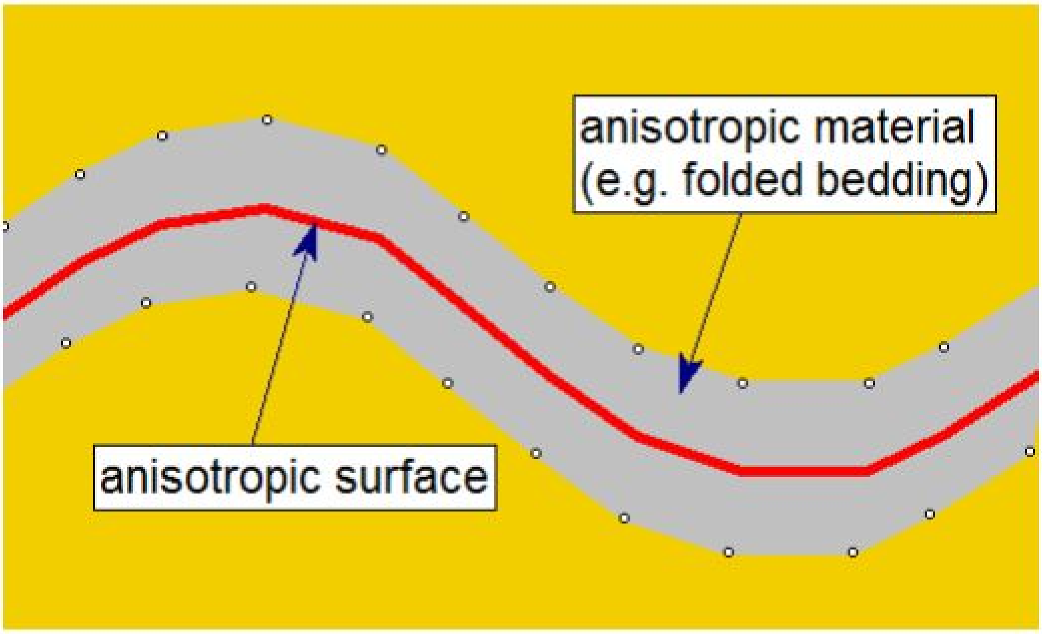
Anisotropic Surface

1. Introduction

This tutorial demonstrates a new feature in Slide2 which makes it much easier to model material layers with anisotropic (directional) strength properties, which are also curved or folded. For such materials, you can now define a surface which follows the curvature of the layer and is used to determine the orientation of the anisotropy at any point within the material. We refer to this as an anisotropic surface.



Anisotropic surface used to define orientation of anisotropy

The anisotropic surface allows Slide2 to determine the local orientation of anisotropy with respect to any slip surface which passes through the material so that the correct strength properties are applied to a given slice base on the slip surface.

The anisotropic surface option can only be used with the following strength models in Slide2:

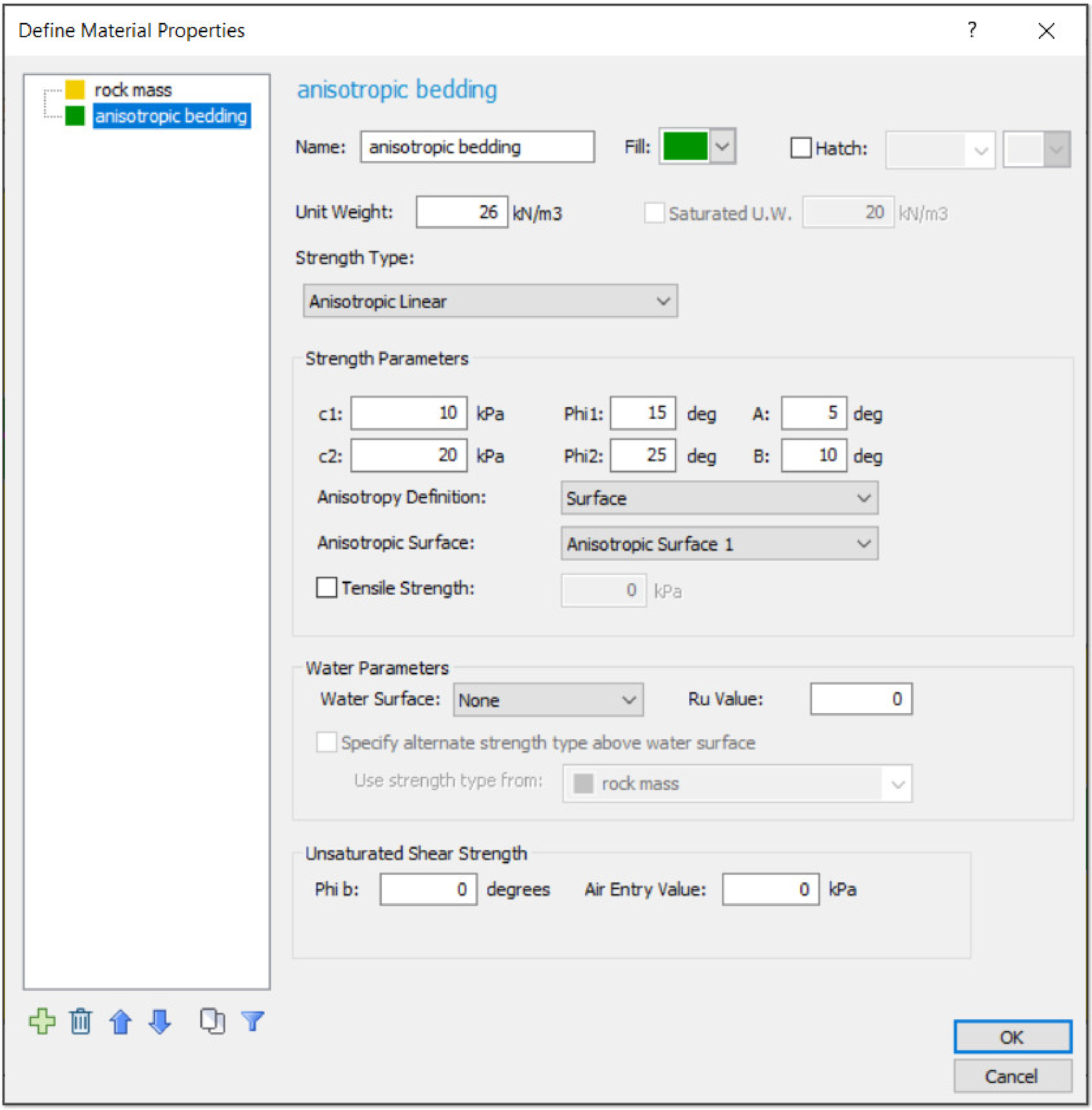
• Anisotropic Linear

• Snowden Modified Anisotropic Linear

The surface must be assigned in the Define Materials dialog as shown below.

- Name = anisotropic bedding

- Unit Weight = 26
- c1 = 10, c2 = 20
- Phi1 = 15, Phi2 = 25
- A = 5, B = 10
- Anistropy Definition = Surface, Anistropic Surface = Anistropic Surface 1

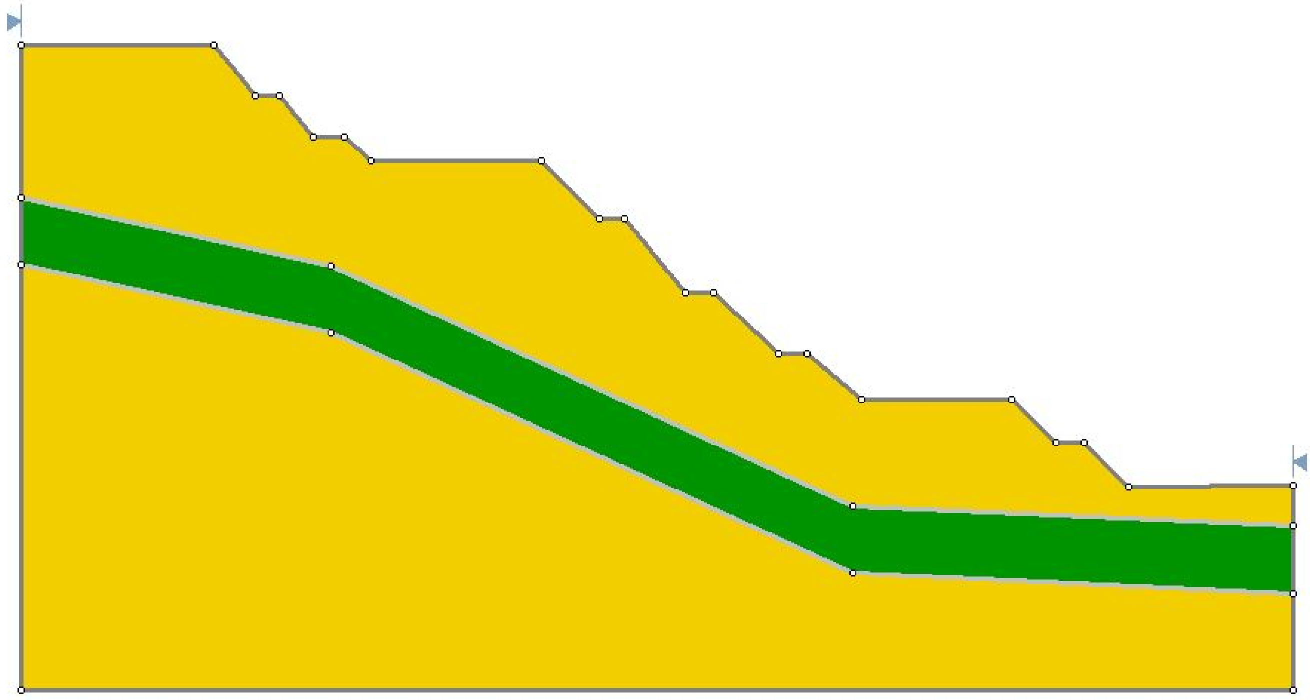


Assignment of anisotropic surface in Define Materials dialog

2. Add Anisotropic Surface

For this tutorial, we will read in a starting file with all properties already defined except for the anisotropic material.

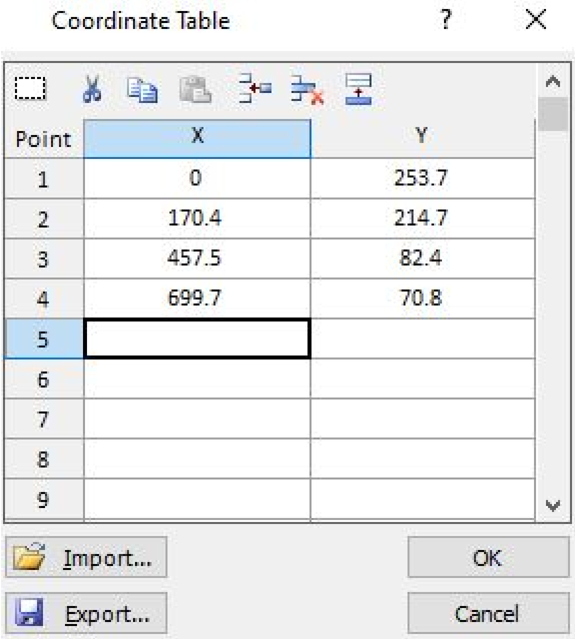
From the Slide2 main menu, select **File > Recent Folders > Tutorials** and read in the file *Tutorial 32 Anisotropic Surface – starting file* from the installation folder. You should see the following



The green material layer will be defined as an anisotropic material, with changing the direction of anisotropy defined by an anisotropic surface.

Select **Add Anisotropic Surface** from the toolbar or the **Boundaries** menu. Right-click and select Coordinate Table from the popup menu. Enter the following coordinates in the dialog.

Point	X	Y
1	0	253.7
2	170.4	214/7
3	457.5	82.4
4	699.7	7



Select **OK** in the dialog, then right-click and select **Done**.

You should see the following. The Anisotropic Surface is the pink line through the center of the green material layer.

Anisotropic surface added to model

Note

An Anisotropic Surface is NOT a material boundary. It is an independent modelling entity and does NOT get intersected with the model boundaries or interact with other model geometry.

LOCATION OF ANISOTROPIC SURFACE

The exact location of the anisotropic surface is not critical, however, it should be placed such that it best represents the average orientation of the bedding throughout the material.

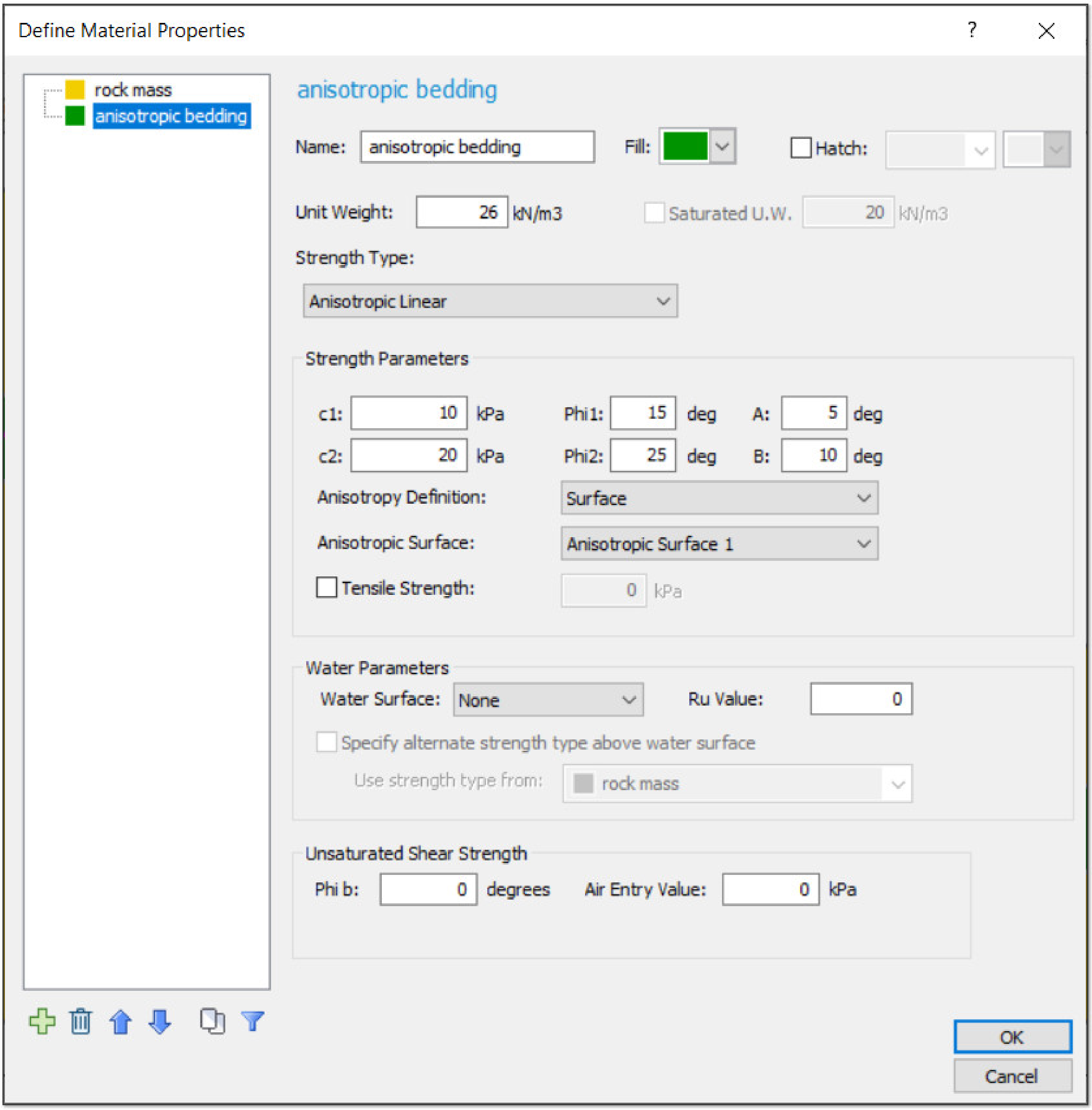
Typically an Anisotropic Surface should be defined near the "middle" of the corresponding anisotropic material region, as shown in the above figure; or it could be coincident with one of the material boundaries (e.g. either the upper or lower boundary of the anisotropic material).

Remember that an Anisotropic Surface is only used to define the orientation of the weak bedding plane direction. In this example, the anisotropic layer has constant thickness and is well defined. For highly folded regions the anisotropic surface may not be so well defined and you may have to estimate a “best-fit” surface or divide the region into smaller areas with different material assignments.

3. Assign Anisotropic Surface

To assign the anisotropic surface to the green material layer, we will use the Anisotropic Linear strength model in the **Define Materials Properties** dialog.

1. Select **Define Material Properties** from the toolbar or the Properties menu.
2. Select the **Anisotropic Bedding** material, choose the **Anisotropic Linear** strength type.
3. Enter the parameters below for c1, phi1, c2, phi2, A, B.
    - c1 = 10, c2 = 20
    - Phi1 = 15, Phi2 = 25
    - A = 5, B = 10
4. Select **Anisotropy Definition = Surface**.
5. Select **Anisotropic Surface = Anisotropic Surface 1** (this is the surface we just defined in the previous section).

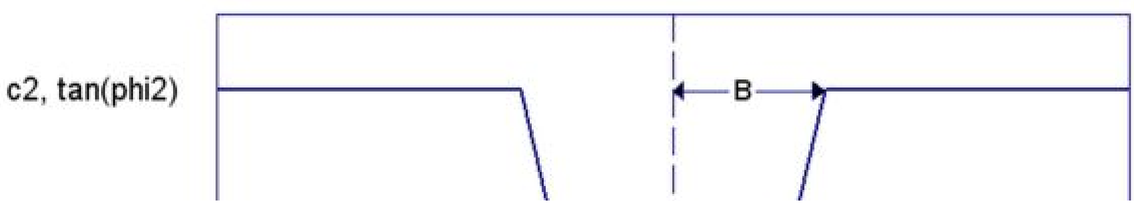


The **Anisotropic Linear** strength model defines the following strength envelope:

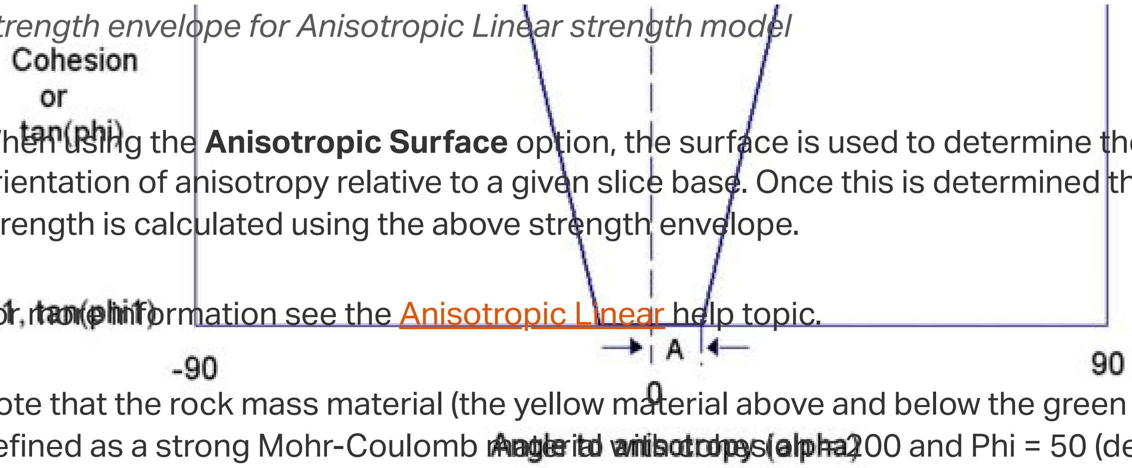
• c1 and phi1 define the minimum strength of the anisotropic material over an angular range of A degrees with respect to the bedding plane orientation

• c2 and phi2 define the maximum strength of the anisotropic material for slice base angles greater than B from the bedding plane orientation

• For slice base angles between A and B a linear transition is assumed between the weak bedding plane strength and the maximum strength.



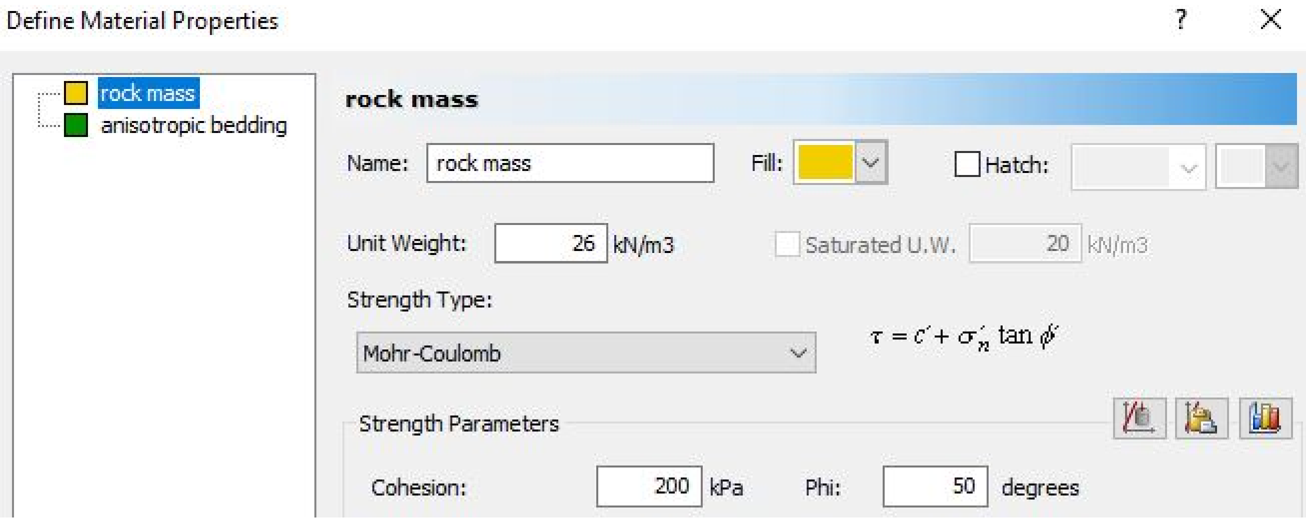
Strength envelope for Anisotropic Linear strength model



When using the **Anisotropic Surface** option, the surface is used to determine the local orientation of anisotropy relative to a given slice base. Once this is determined the shear strength is calculated using the above strength envelope.

For more information see the Anisotropic Linear help topic.

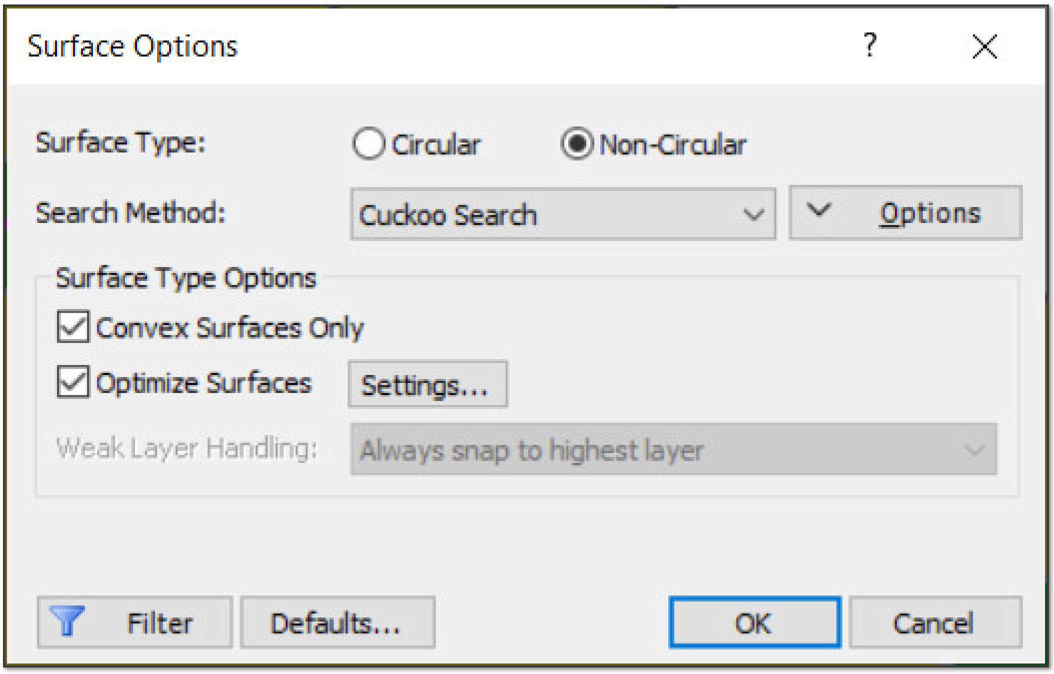
Note that the rock mass material (the yellow material above and below the green layer) is defined as a strong Mohr-Coulomb material with c = 200 and Phi = 50 (degrees.)



Select **OK** in the Define Material Properties dialog.

4. Surface Options

Select **Surface Options** from the **Surfaces** menu.



The surface options are:

• Non-circular

• Cuckoo Search

• Surface Altering Optimization

Select **Cancel** in the **Surface Options** dialog.

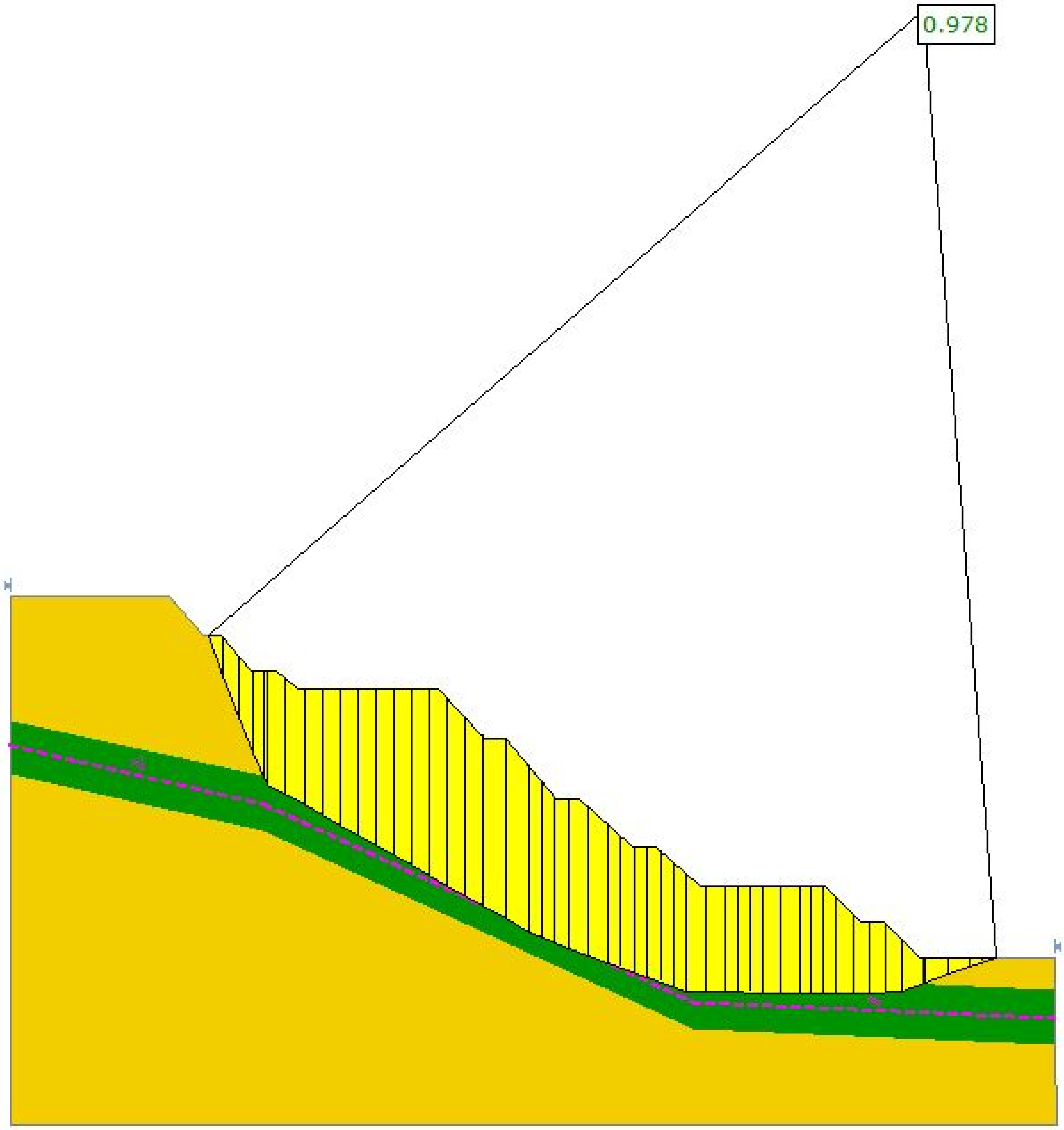
5. Compute

Save the file with a new filename, then select **Compute** to run the analysis.

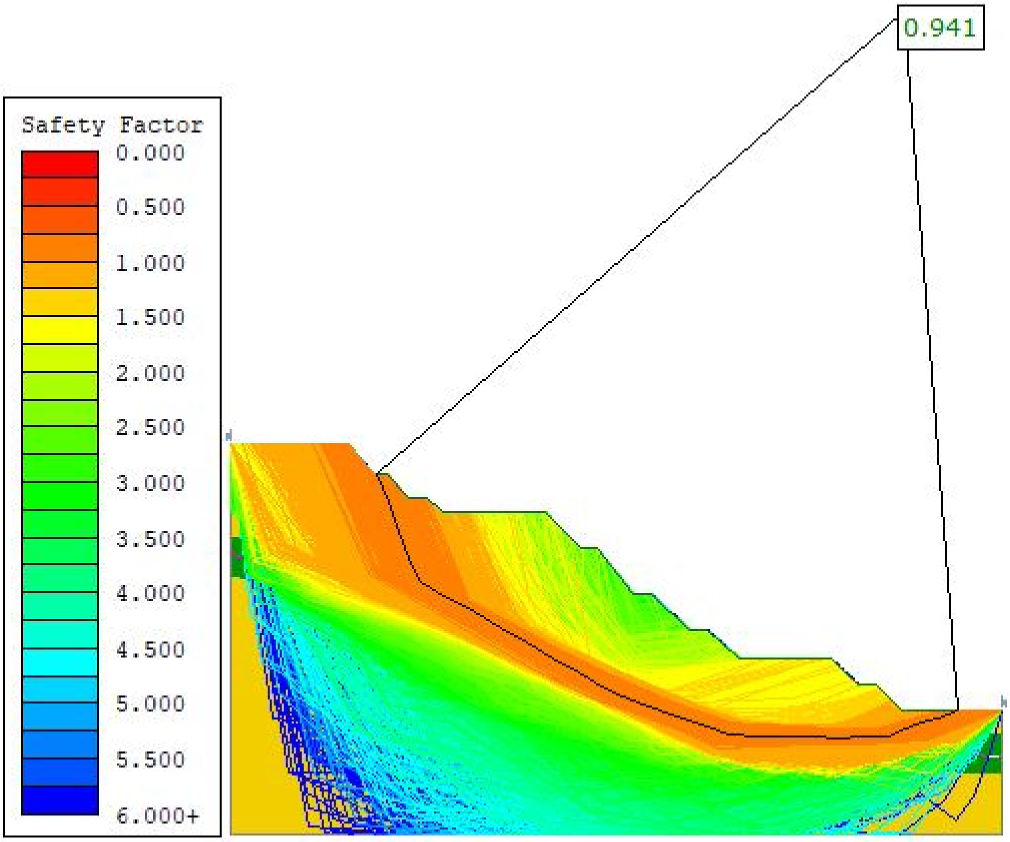
When the analysis is complete select **Interpret** to view results.

6. Results

The global minimum safety factor is around 1 for all analysis methods (Bishop, Janbu, Spencer and GLE). The results for the Janbu method are shown below, with a Global Minimum factor of safety = 0.93. The global minimum travels through the anisotropic layer and closely follows the weak orientation of the bedding as defined using the Anisotropic Surface.

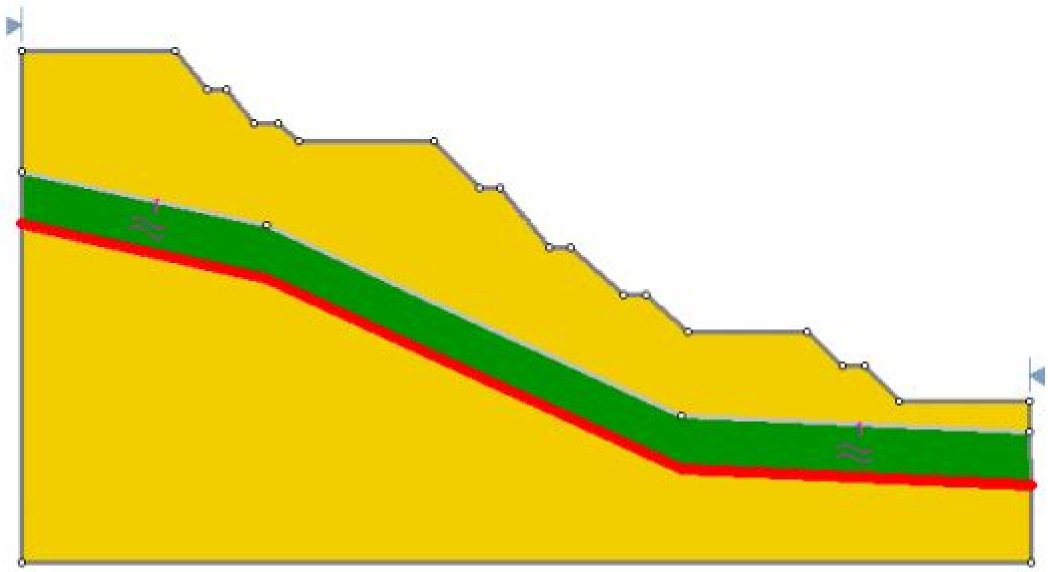


If you turn on the display of **All Surfaces** you can see how the search is concentrated along the direction of anisotropy in the anisotropic bedding material.

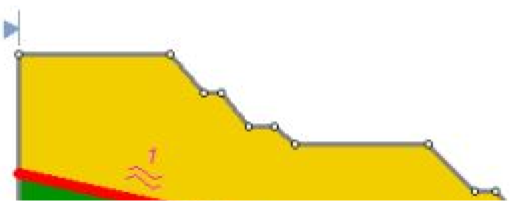


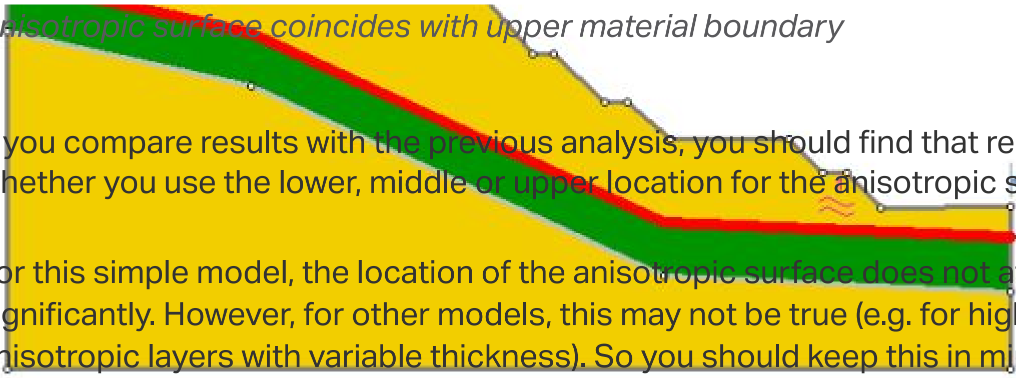
7. Location of Anisotropic Surface

As an optional exercise, re-run the analysis using a new anisotropic surface which coincides with the lower or upper material boundary of the anisotropic bedding material, as shown in the figures below.



Anisotropic surface coincides with lower material boundary





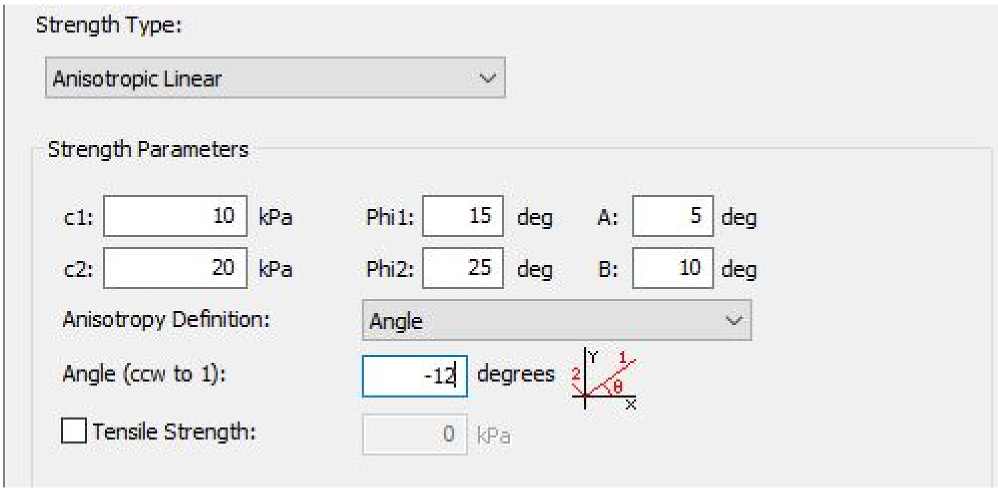
Anisotropic surface coincides with upper material boundary

If you compare results with the previous analysis, you should find that results are very similar whether you use the lower, middle or upper location for the anisotropic surface.

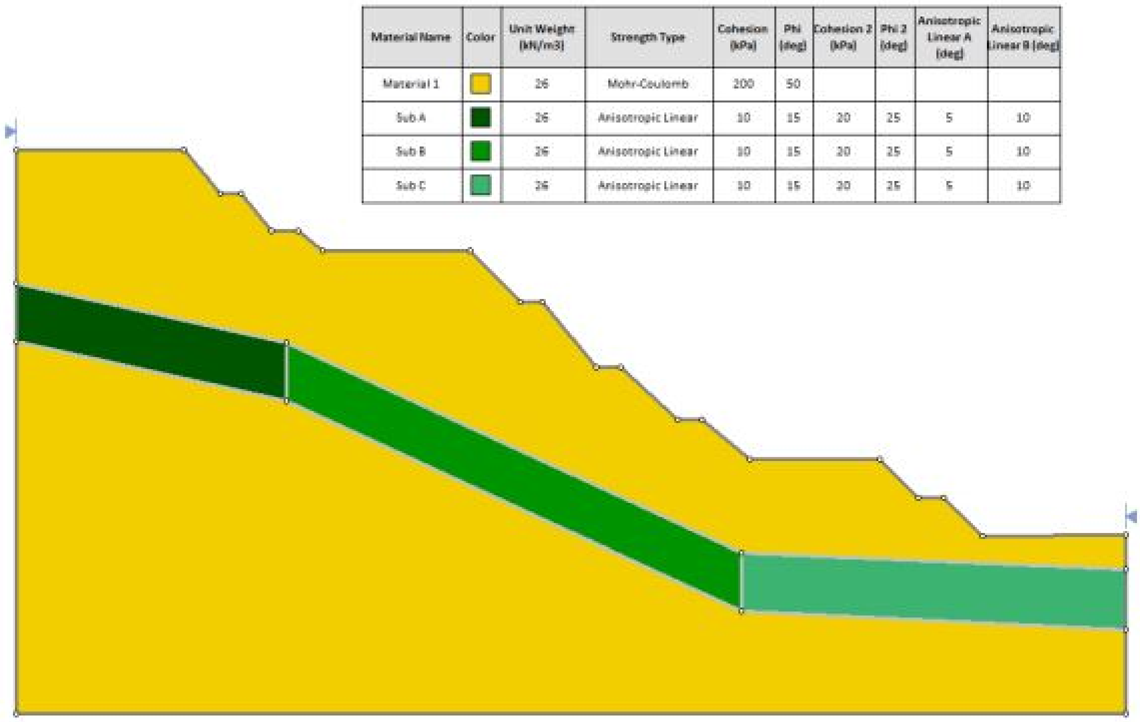
For this simple model, the location of the anisotropic surface does not affect the results significantly. However, for other models, this may not be true (e.g. for highly folded anisotropic layers with variable thickness). So you should keep this in mind when using this option for more complex models, and try more than one location for the anisotropic surface to see if results are affected. In general, the middle of the layer should be used if possible.

8. Constant Angle of Anisotropy

In earlier versions of Slide2, the Anisotropic Linear model only allowed a constant angle of anisotropy to be defined (the Anisotropic Surface option was not available).



The model used for this tutorial can be run using the constant angle option, if you divide the anisotropic material layer into three separate regions, as shown below, and assign a different material to each with a different angle of anisotropy. The strength properties of each region will be the same, only the anisotropic angle will be different.



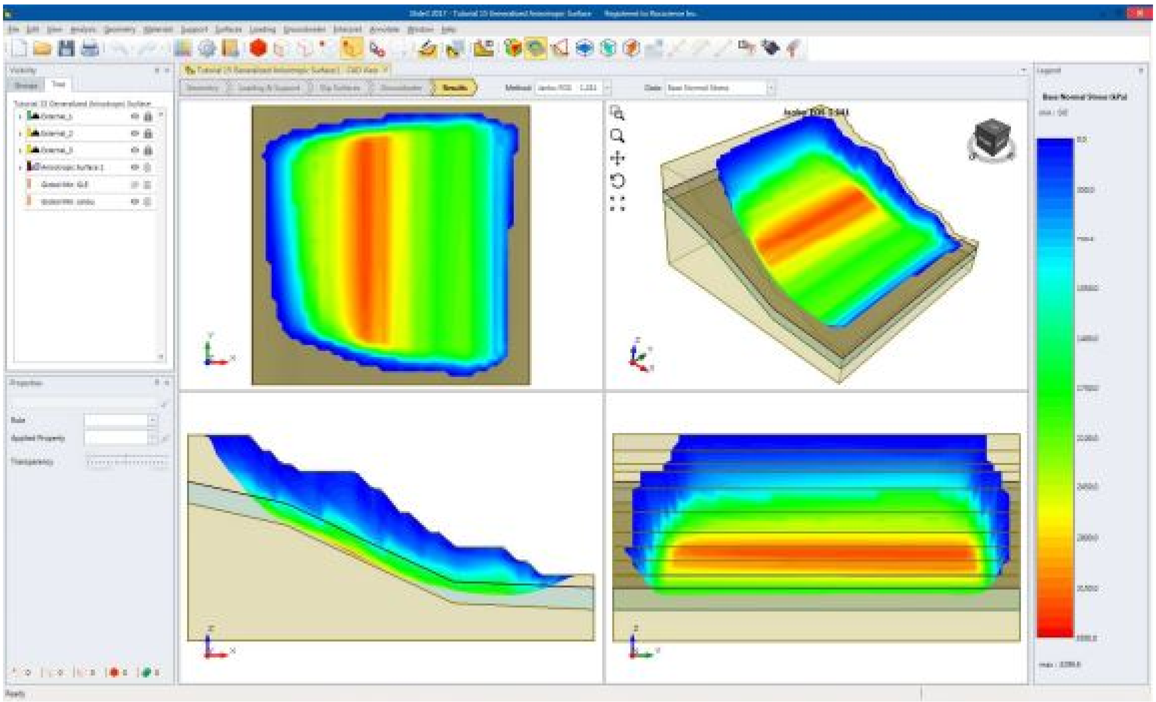
Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Cohesion 2 (kPa)	Phi 2 (deg)	Anisotropic Linear A (deg)	Anisotropic Linear B (deg)
Material 1		26	Mohr-Coulomb	200	50				
Sub A		26	Anisotropic Linear	10	15	20	25	5	10
Sub B		26	Anisotropic Linear	10	15	20	25	5	10
Sub C		26	Anisotropic Linear	10	15	20	25	5	10

If you run this version of the model, you should get very similar results to those shown using the Anisotropic Surface option. This version of the model was utilized in Slide2 Tutorial 27. The advantages of using the Anisotropic Surface option, compared to the constant angle option, are:

- Can define a folded anisotropic region as a single material
- Can carry out a probabilistic analysis for anisotropic materials without worrying about the correlation of strength properties as described in Tutorial 27.

The constant angle option is sufficient for anisotropic materials with a constant bedding angle. For folded anisotropic regions, the Anisotropic Surface option greatly simplifies the modelling procedure, reduces analysis time and simplifies data interpretation.

9. 3-Dimensional Model using Slide3


Results
Method
Data