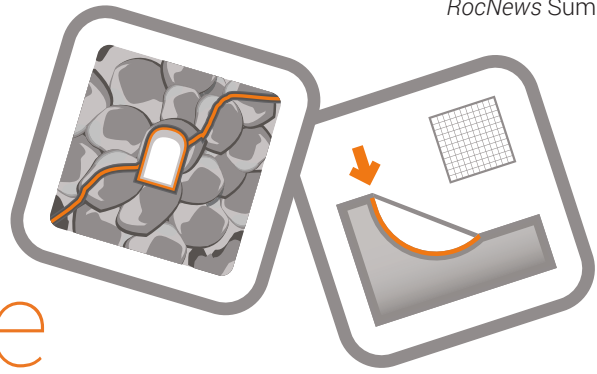


Unique Shear Strength Slope Stability Features in RS²



Perform a finite element stress analysis and slope stability analysis, using Shear Strength Reduction, on a *Slide* model in RS².

When performing a slope stability analysis, it is useful to compare the results obtained through limit equilibrium and finite element calculations. In order to facilitate this, *Slide* v6 files can be imported into RS² v9. This allows you to perform a finite element stress analysis and slope stability analysis, using Shear Strength Reduction, on a *Slide* model in RS². With the increased use of SSR for slope stability analyses, the ability to import *Slide* files into RS² is a useful feature.

A *Slide* file can be imported into RS² in two ways, either through the *File > Import > Import Slide File* option or by setting the file type to *Slide File Format* in the *Open* file dialog. This useful import feature helps users to perform a detailed analysis without needing to create two model geometries.

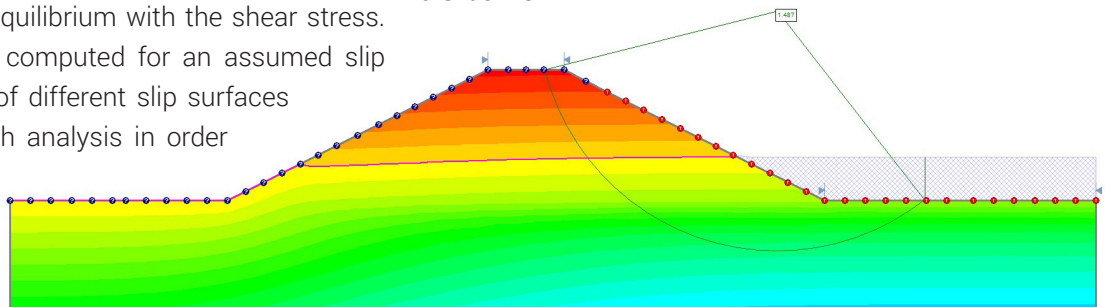
Limit Equilibrium vs Shear Strength Reduction

In a limit equilibrium (LE) analysis, the factor of safety is defined as the ratio of the shear strength of the soil divided by the equilibrium shear stress. The equilibrium shear stress is the shear stress required to maintain a slope that is "just-stable." The factor of safety represents the factor by which the shear strength must be reduced so that the reduced strength is in equilibrium with the shear stress. The factor of safety is computed for an assumed slip surface and a number of different slip surfaces must be defined in each analysis in order to locate the critical slip surface with the lowest factor of safety. The soil mass above the slip surface is

divided into a number of vertical slices and equilibrium equations are written and solved for each slice.

The Shear Strength Reduction (SSR) method is widely used to determine the factor of safety of a slope using the finite element method. The SSR method reduces the shear strength of the material until the model becomes unstable. The point of instability (model is not in equilibrium) is taken as the factor of safety of the slope.

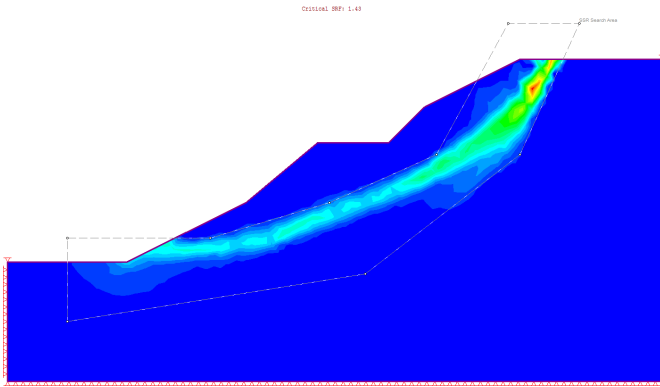
There are a number of advantages and disadvantages for both the limit equilibrium and SSR methods, and it is recommended that both types of analyses be performed when calculating the factor of safety for a slope. By allowing users to import a *Slide* file directly into RS², a lot of the complexities related to defining a finite-element model are removed. Rocscience has extensively researched the influence of different parameters on slope stability, in order to make the import of *Slide* files into RS² as simple as possible for the user. The [Importing Slide Files / SSR Analysis](#) tutorial discusses what assumptions are made when a *Slide* file is imported into RS² and goes through a detailed example. The [Import Slide File](#) help topic, from the Online Help system, also provides details on how to import a *Slide* file.



A limit equilibrium slope stability analysis with seepage in *Slide*.

Shear Strength Reduction in RS^2

By default, an SSR analysis considers the stability of the entire model when the analysis is computed, and the analysis will report the global minimum factor of safety for the problem. However, there are circumstances when



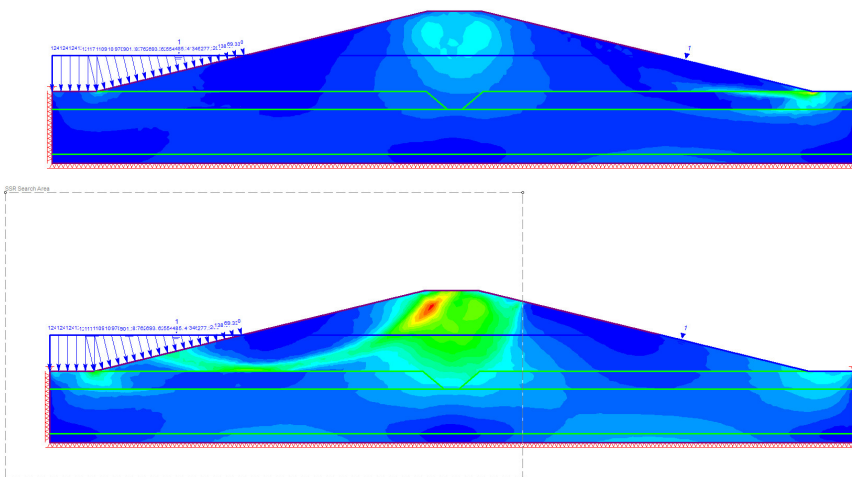
SSR Search Area in RS^2

you may wish to focus on the stability of a particular area of the model.

In a limit equilibrium analysis there are ways to focus the stability search on a specific area, by defining two sets of slope limits, specifying a minimum depth of slip surface, or further constraining the generation of slip surfaces. In order to be able to replicate the LE results with the finite element method, a similar capability needs to exist. For this reason, in RS^2 we have introduced the SSR Search Area option, which allows you to apply the SSR analysis to a particular region of a model. You can also exclude regions with the SSR Exclusion Area option.

SSR Search Area

The SSR Search Area is a useful option, unique to RS^2 , which allows you to define a rectangular or polygonal



Results before and after using the SSR Search Area option.

area anywhere on the model, and only the selected area of the model will be considered for the SSR Analysis. Models where this feature could be most useful include embankment and multi-bench slope models. In the case of a dam or an embankment, you may want to analyze the stability of the upstream and downstream sides of a model independently. In a multi-benched slope model, it is useful to be able to analyze individual benches or regions of the slope. In general, a single SSR Search Area is used, although it is possible to define multiple areas. In the case of multiple search areas, only the most critical SRF value is reported.

SSR Exclusion Area

The SSR Exclusion Area works in an identical way as the SSR Search Area option, except in reverse. Rather than defining a rectangular or polygonal search area, you are excluding an area from the search. An example of where an SSR Exclusion Area would be useful is in an open pit mine; with the SSR Exclusion Area option you can exclude the individual benches on a benched slope in order to analyze a more deep seated region of the model.

Once added to a model, both the SSR Search and Exclusion Areas can be edited as desired. You can resize, delete, or move these areas. Another useful feature is the ability to increase the density of the finite element mesh within the SSR Search Area.

Modeling Support in RS^2 for an SSR Analysis

Support Implementation in *Slide* and RS^2

In limit equilibrium, in order for support to have an effect on a given slip surface, the support must intersect the slip surface. If the support does not intersect the slip surface, it has no effect on the safety factor for that surface. When support intersects a slip surface, a force is applied at the point of intersection of the slip surface with the support. The magnitude of the support force depends on the Force Diagram of the support, which is generated based on the support properties specified. The Force Diagram does not represent the true state of stress or loading mobilized by a given support element - it represents the maximum available force a support element can theoretically apply to a sliding

mass. In *Slide*, and limit equilibrium analysis in general, displacements and strains are not considered. In order to realistically model the interaction of support and slope, and to calculate actual strains and loading mobilized within the support, more sophisticated analysis methods (such as finite element methods) are required.

In RS^2 , strains and displacements are taken into account, and you can obtain the load distribution within the support. As a result of strain/deformation of the soil or rock mass in RS^2 , force is induced in the support.

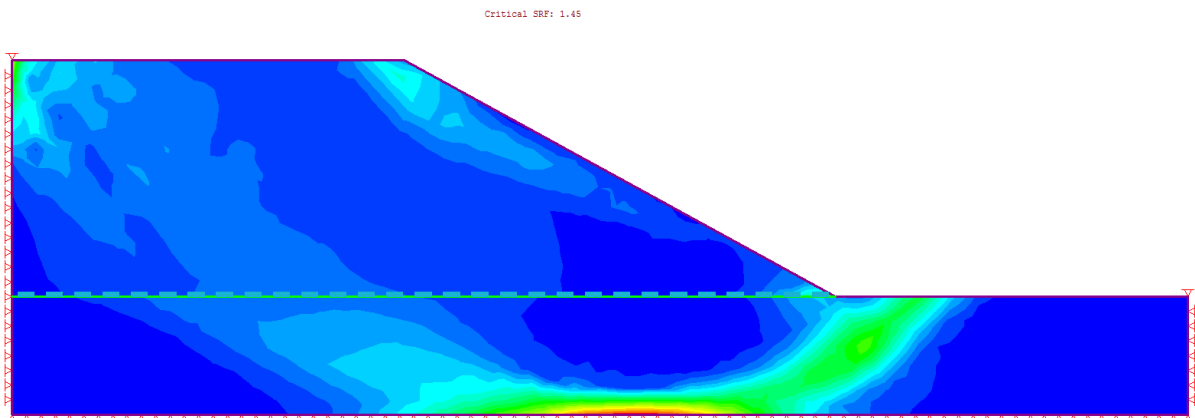
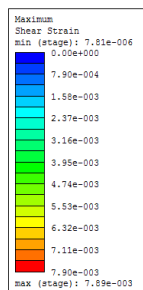
In general, modeling of support in *Slide* is useful for looking at the effect of the support system on the slope, and it is not intended to model the effect of the slope stability on the support system. Using RS^2 , you can investigate both the effect of the support on the slope and the slope on the support system.

Modeling Geotextiles for Slope Support

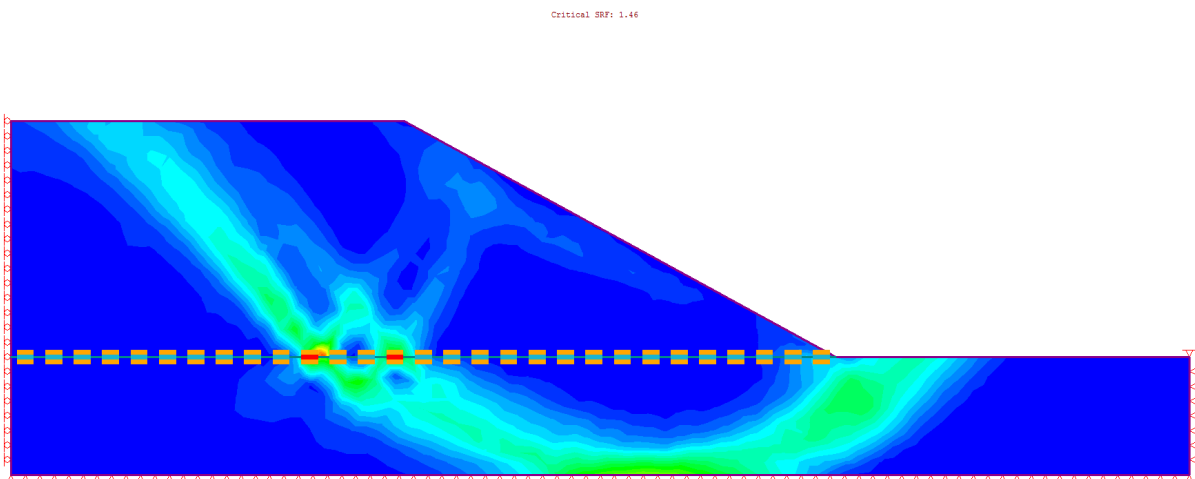
In *Slide* the magnitude of the force applied to a slip surface which intersects the geotextile is given by the minimum of the Tensile, Pullout (if applicable), and Stripping (if applicable) forces. The support force is implemented as discussed in the previous section.

RS^2 extends the modeling of geotextiles by introducing the ability to include slip. Using RS^2 , geotextile support can be modeled in three ways: no slip, slip on one side between the liner and soil layers, slip on both sides. In the case of slip, the geotextile support is modeled as a composite liner (slip/joint on one side) or structural interface (slip/joint on both sides), and the support is composed of multiple nodes that initially overlap but may separate as slip occurs on the joints.

[Tutorial 11](#) and [Tutorial 12](#) illustrate a geogrid-reinforced embankment modeled without and with slip.



Geogrid embankment with no slip



Geogrid embankment with slip