Rocscience

Auto Refine Search

Circular Methods

Grid Search

Simulated Annealing

Slope Search

Local Optimization

Path Search

Cuckoo Search

Block Search

Non-Circular Methods

Critical Slip Surface
Search Methods
in Slide 7.0

The primary goal of a slope stability analysis, is to determine the potential slip surface which has the overall minimum factor of safety, and therefore to determine the overall safety of the slope design.

In *Slide* version 7.0 there are several different search methods which are available, which automate the task of searching for either circular or non-circular slip surfaces.

Each of these search methods have many different options available to the user. When taken as a whole, the different search methods and options in *Slide*, constitute a very powerful toolkit, enabling users to efficiently locate the most critical slip surfaces for a slope stability model.

Introduction

One of the most important aspects of a limit equilibrium slope stability analysis, is the search for the critical slip surface with the lowest safety factor. Unfortunately, users often do not carry out the critical slip surface search as thoroughly as they should be doing. In particular:

1. Users do not always take advantage of the wide range of search methods and techniques which are available in *Slide*.
2. Users sometimes incorrectly apply searching techniques, or use inappropriate search methods for the problem they are trying to analyze.

Slide 7.0 has numerous search options available, including new global optimization methods which can greatly simplify the effort and improve results. This article provides an overview of the new search methods and recommendations on how to obtain best results.

Topics Covered:

Search Methods in *Slide*

The primary goal of a slope stability analysis, is to determine the potential slip surface which has the overall minimum factor of safety, and therefore to determine the overall safety of the slope design.

In *Slide* version 7.0 there are several different search methods which are available, which automate the task of searching for either circular or non-circular slip surfaces.

Each of these search methods have many different options available to the user. When taken as a whole, the different search methods and options in *Slide*, constitute a very powerful toolkit, enabling users to efficiently locate the most critical slip surfaces for a slope stability model.

Circular Search Methods

There are THREE search methods available for CIRCULAR slip surfaces:

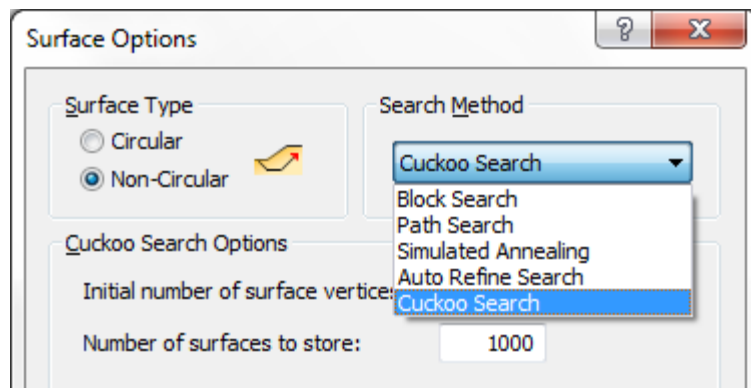- Grid Search
- Slope Search
- Auto Refine Search
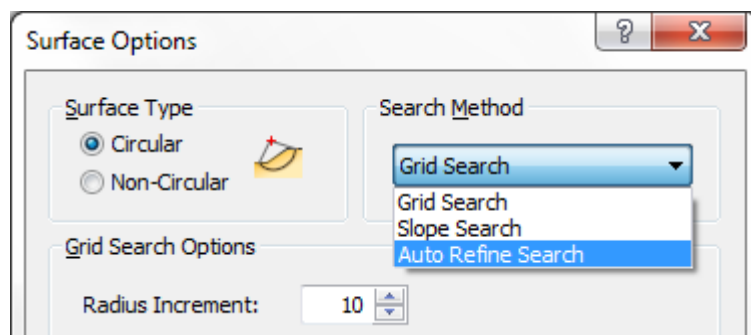
If the Composite Surfaces option is enabled this allows for automatic searching of composite circular / non-circular surfaces.

Non-Circular Search Methods

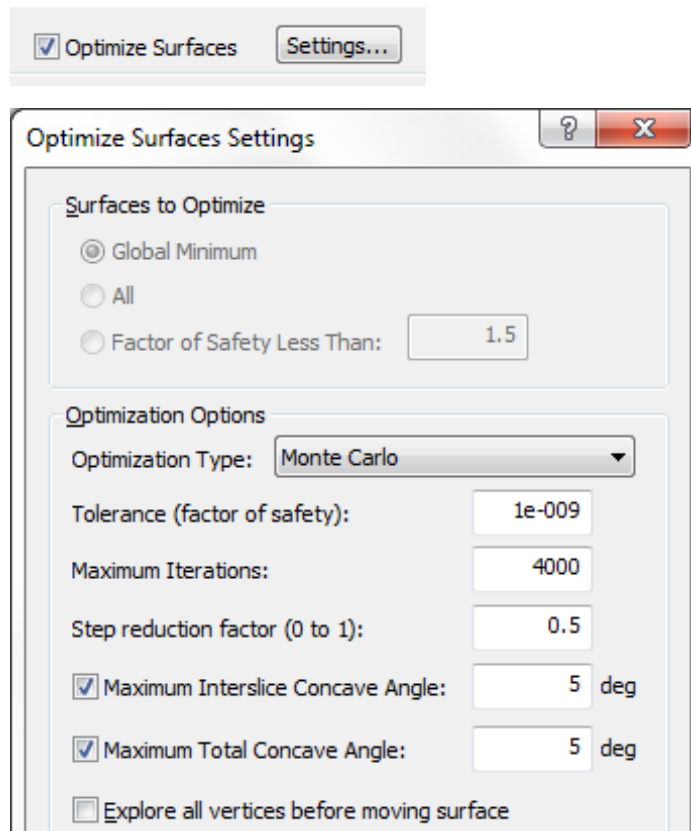There are FIVE search methods available for NON-CIRCULAR slip surfaces:

- Path Search
- Block Search
- Auto Refine Search
- Simulated Annealing
- Cuckoo Search

Non-Circular Local Optimization

For non-circular surfaces, an additional local optimization search can be applied to find slip surfaces with an even lower safety factor.

- Monte Carlo Optimization

The Optimization search is recommended for ALL non-circular search methods.

Why so many different methods?

Well there's 20 years of history here.

Grid Search

In the beginning … there was the Grid Search. The first version of *Slide* (2.0) only analyzed circular slip surfaces and only provided the Grid Search.

Non-circular methods

Slide 3.0 analyzed non-circular slip surfaces, so the Block Search method was added. Later versions of *Slide* offered additional circular and non-circular search options: Path Search, Auto Refine, Slope Search, Composite surfaces.

Local Optimization

A method of improving results for non-circular surfaces, Local Monte Carlo optimization, based on random walk method, was found to improve non-circular search results. It was implemented as an add-on to the primary non-circular search methods (Block search / Path Search) although it can be considered a search method in its own right.

Global Optimization methods

In the effort to make searching simpler and more powerful, global optimization methods were developed. *Slide* 5.0 offered the Simulated Annealing method and *Slide* 7.0 offered the Cuckoo Search. These methods are capable of finding critical slip surfaces with no user input, using the default search parameters. When combined with Optimization results can be improved even further.

You certainly don't have to use all methods or all search options for every model. However, you should ALWAYS try more than search method (at least 2 or 3) and compare results. This will often lead to a better understanding of different possible failure modes, surfaces or modeling issues which affect the final result.

Circular or Non-Circular?

The first question which presents itself is – do I analyze for CIRCULAR or NON-CIRCULAR failure surfaces. As a rule of thumb:

- **Circular Surfaces** – strictly speaking, are usually only applicable for homogeneous (single material) slopes, or simple multi-material slopes. Although more complex slopes may exhibit near-circular failure modes. Also useful for initial analysis of more complex slopes.
- **Non-Circular Surfaces** – most slope analyses will require a non-circular surface search, particularly for models with thin weak layers, anisotropic materials or other complex models.

Global versus Local Optimization methods

A Global Optimization method is one which (ideally) tests all possible regions in a given search space, does not get trapped in local minima (i.e. has the ability to escape from a local minimum) and finds the true global minimum (or maximum) of a function.

In *Slide*, the two newest search methods for non-circular surfaces are considered Global Optimization methods:

- **Cuckoo Search**
- **Simulated Annealing**

Search methods in *Slide* such as Block Search and Path Search may be considered Local Optimization methods, however with the correct usage and supplementary Optimization search, they can also be successful at finding the global minimum.

A Local Optimization method is one which does not necessarily test all possible solutions, and may get "trapped" in a local minimum without finding the true global solution.

The following figure illustrates local versus global minimum for a one-dimensional function.
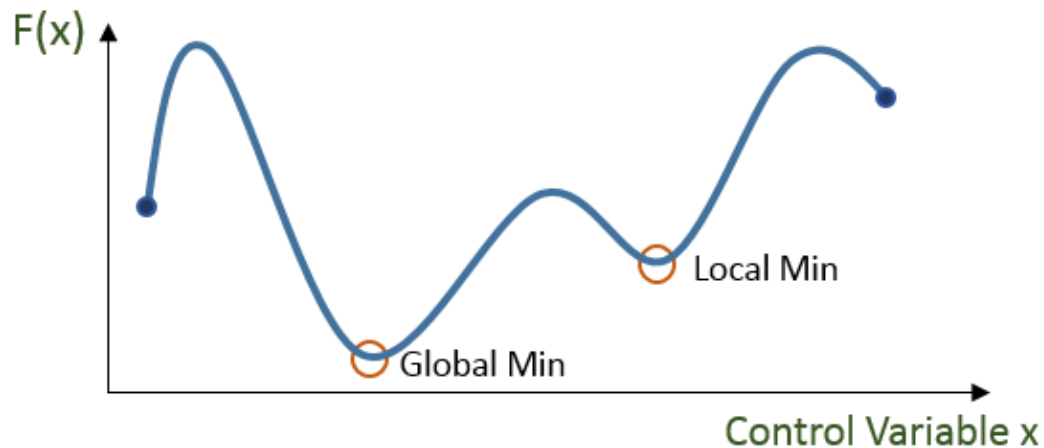
For a typical slope stability problem, the real solution space is multi-dimensional, with highly non-linear and non-smooth behavior of the function evaluating the factor of safety (FS) for failure surfaces. Many local minima solutions may exist, so a powerful global optimization method is necessary to solve complex slope stability models.

Circular Search Methods

There are three search methods in *Slide* for CIRCULAR slip surfaces:

1. Grid Search
2. Slope Search
3. Auto Refine Search

If utilized properly, these should all locate the same (or very nearly the same) critical slip surface. If the searches have been carried out thoroughly, there is no reason that these three methods should give different results for the critical CIRCULAR slip surface.

For example the figure below shows results for Grid Search, Slope Search and Auto Refine Search for a simple homogeneous slope. Using only the default search parameters, the critical slip surface and safety factor is nearly identical for all three methods.
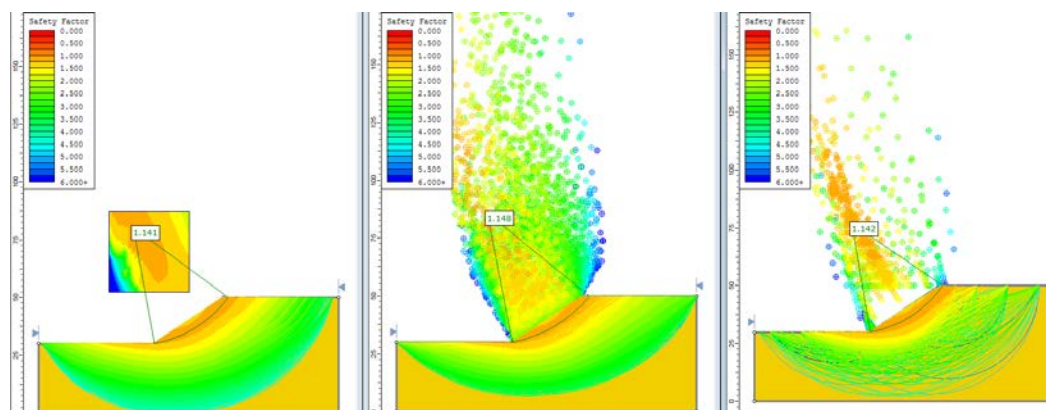
Therefore, the choice of which method to use, is really a matter of user preference.

- Most users prefer to use a Grid Search, since it is a very commonly used method in slope stability analysis, and is familiar to most users.

- The Auto Refine Search method uses a simple but effective algorithm for iteratively refining the search area on the slope, until the critical surface is located.

- The Slope Search is an alternative search method, which allows the user to define the search in terms of areas of the slope surface, rather than a grid of slip centers.

Each of the above methods can be used with the Composite Surfaces option, in order to search for composite circular / non-circular slip surfaces, such as those formed along a bedrock / soil interface.

When searching for CIRCULAR slip surfaces, try more than one method. Compare results and experiment with different search options. If each method gives very nearly the same critical slip surface, then this is a good indication that you have located the true critical circular slip surface. For further details about each search method, please see the *Slide* Help system.

Non-Circular Search Methods

The majority of *Slide* models will require a search for non-circular slip surfaces. The suggested order of preference, considering accuracy, speed and ease of use:

1. Cuckoo Search
2. Simulated Annealing
3. Auto Refine (non-circular)
4. Block Search
5. Path Search

ALL of the above methods should be used with the supplementary Optimization search in order to improve results.
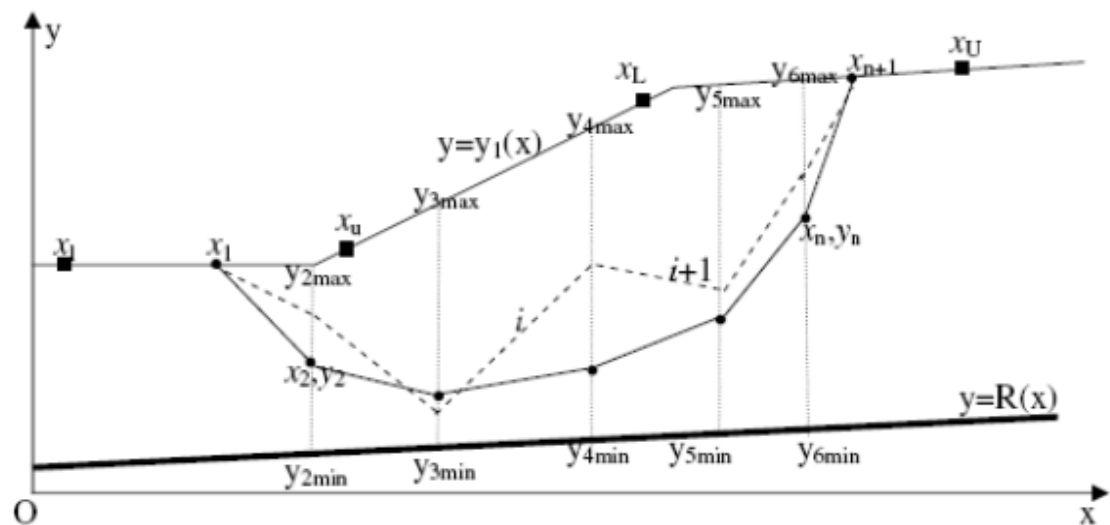
Simulated Annealing

Annealing is a physical process applied to metals and other materials, whereby a material is heated to a certain temperature and then cooled slowly in order to achieve changes in material properties. Annealing of metals is typically done to increase ductility to allow forming and fabrication processes. The main control parameters of the annealing process are the temperature and the rate of cooling.

Simulated annealing is a mathematical analog of physical annealing, so-called because the main control variable is often referred to as the temperature. As the optimization solution proceeds, a temperature reduction or rate of cooling is specified. The method is capable of "climbing out of" local minima, and avoids getting trapped in local "valleys", and can find the global minimum of a multi-dimensional input function.

The Simulated Annealing method as applied to slope stability, starts off with the generation of an initial trial slip surface, as shown below. The input variables are the slip surface coordinates. As the vertices are moved the safety factor is re-computed for each new slip surface. Intermediate solutions are accepted or rejected based on the change in safety factor and an acceptance criterion, until a stable solution is reached.

Practically speaking, the Simulated Annealing (and Cuckoo search) options in *Slide* are "black box" search methods. Unlike other search methods in *Slide*, the main control parameters do not have a direct physical correlation to the slope stability model. So often the analysis is run using the default control parameters.

Some key points about simulated annealing:

- Developed in the 80s (Kirkpatrick et al, 1984) and based on statistical mechanics for molecular simulations
- Initially applied for combinatorial optimization, soon extended to continuous functions
- The controlling parameter in simulated annealing is the coefficient T also referred to sometimes as the temperature.
- This coefficient is directly related to the probability of moving up-hill.
- At the start of the search, the coefficient is set to a high value and all moves are accepted.
- As the method progresses, this coefficient is lowered and the only downhill moves are accepted.
- Annealing relies on the concept of an acceptance probability – at every move, even if the function value increases, there is a probability of moving uphill. This allows the optimization to escape local minima and keep exploring the solution space.

In *Slide*, a version of simulated annealing referred to as **Very Fast Simulated Annealing** (VFSA) / Adaptive simulated annealing (ASA) is implemented (Ingber, 1989).

Although global optimization methods are good at converging to the region of a global minimum, they are very slow in later stages, due to asymptotic convergence issues. For this reason, the VFSA in *Slide* is combined with a local optimizer (a local Monte-Carlo walk initially developed by Greco, 1996), with vertex insertion capabilities. The combined VFSA + local optimization is referred to as **Hybrid Simulated Annealing** (HSA).

Hybrid Optimization

F(x)

STAGE 1 – Global Search   STAGE 2 – Local Search

X
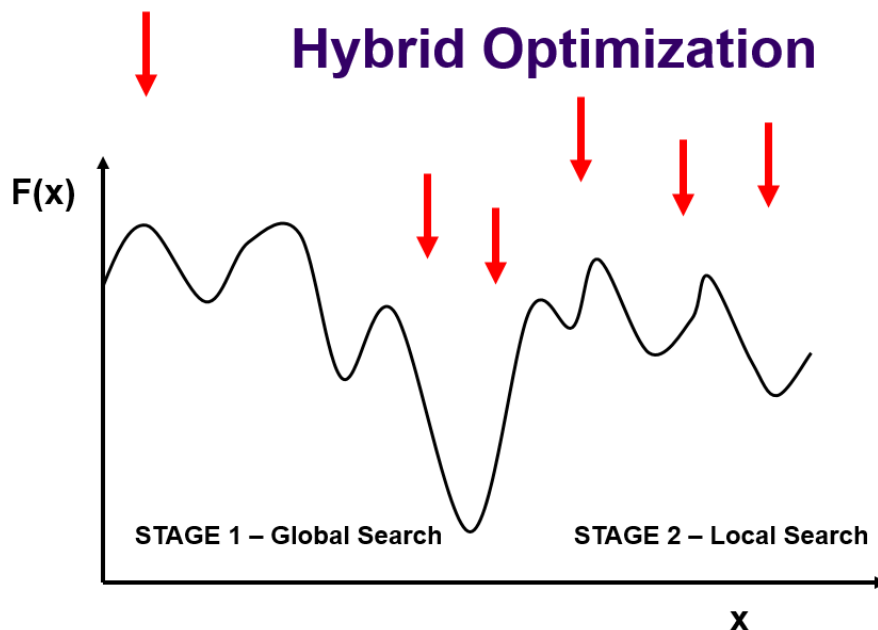
The method combines the robustness of a global optimizer in gravitating towards the region of the global minimum, and the speed and accuracy of a local optimizer in narrowing down to the final solution.

For details on the development of the Simulated Annealing method in *Slide* see:

[Global Optimization of General Failure Surfaces in Slope Stability Analysis by Hybrid Simulated Annealing](#)

Cuckoo Search

The **Cuckoo Search** is a new global optimization search method in *Slide* and was introduced in version 7. It has been found to be much faster than Simulated Annealing, and in many cases also finds a lower safety factor slip surface. For this reason, the Cuckoo Search is recommended as the initial and primary search method which should always be tried first for a slope model with non-circular failure modes.

Cuckoo egg in Rosefinch nest[1]

Cuckoo Search is a recent global optimization algorithm developed by Xin-She Yang and Suash Deb in 2009, inspired by the natural parasitic but successful behaviour of the Cuckoo species by laying their eggs in the nests of other host birds (of other species). In the short amount of time since inception, Cuckoo Search has been successfully applied to many different types of problems, obtaining better solutions than those which exist in literature. It has outperformed some more traditional global optimization algorithms such as Particle Swarm and Harmony Search under standard test functions—taking less function evaluations to achieve the same level of solution accuracy.

In *Slide* version 7.0 an improved variant of Cuckoo Search, coupled with the Local Monte-Carlo (LMC) optimizer is implemented. Cuckoo Search incorporates a random walk and random solution generations to escape local minima, while LMC is a local explorer optimizing an existing failure surface through constantly varying the position of each polyline vertex. Various refinements were also made on top of the Improved Cuckoo Search specific to the problem at hand.

For details on the development of the Cuckoo Search method in *Slide* see:

[Locating General Failure Surfaces in Slope Analysis via Cuckoo Search](#)

A general flowchart of the algorithm is shown below.

As with Simulated Annealing, the Cuckoo search method in *Slide* is largely a "black box" search method. No user input is required, and the main control parameters do not have a direct physical correlation to the slope stability model. So often the analysis is run using the

[1] Photograph courtesy Arne Ader, Loodusemees Ltd

default control parameters. Fortunately the default search results are usually excellent.

You must always remember that no search method, including Cuckoo Search, is 100 percent reliable in all cases, so it is ALWAYS recommended to try other search methods (e.g. Simulated Annealing and Auto Refine) to verify the location and safety factor of the critical slip surface.
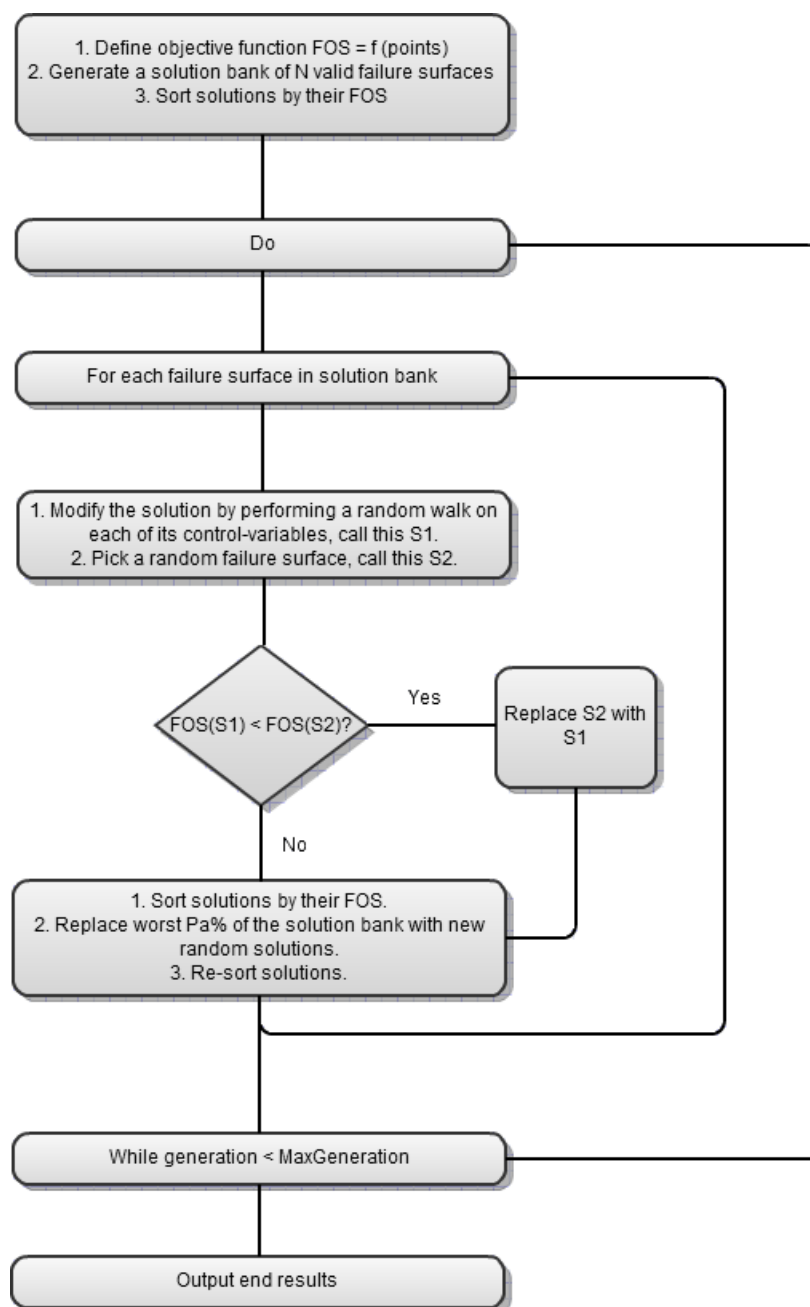

Flowchart of Cuckoo Search algorithm in Slide

Auto Refine (Non-Circular)

The **Auto Refine** search option for **non-circular** surfaces, is another effective search method which requires no user input to run. An iterative approach is used, so that the results of one iteration, are used to narrow the search area on the slope in the next iteration.

The Auto Refine Search option for Non-Circular surfaces is based on the Auto Refine Search option for Circular surfaces, with an additional step which converts the circular surfaces into piece-wise linear surfaces.

1. The Auto Refine Search for Non-Circular surfaces first generates circular surfaces, using the algorithm described for the Auto Refine (Circular) search.
2. Each circle is converted into a non-circular (piece-wise linear) surface using the Number of vertices along surface and the safety factor is calculated for the non-circular surface.

The Number of vertices along surface is used to convert circular surfaces into piece-wise linear surfaces, by sub-dividing the circular arc into approximately equal divisions, and joining the resulting vertices with straight line segments. For example, if the Number of vertices = 4, a circle will be converted into a piece-wise linear surface with 3 segments, as illustrated below.
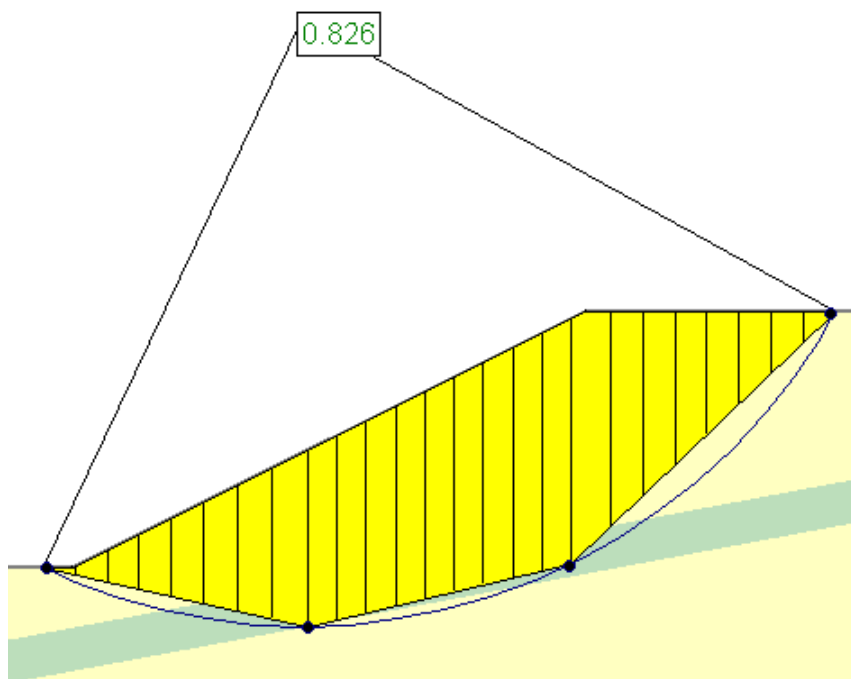

The **Optimization** search is ON by default for the Auto Refine (non-circular) option. Optimization should always be applied as it typically will improve results significantly by finding a lower safety factor slip surface.

For more information on the **Auto Refine Search** click here.

Block Search

The **Block Search** is a search method which requires the user to define one or more search objects to define the area of the slope to be searched. Search objects include windows, lines, polylines or points. Slip surface vertices are randomly generated on or within the search objects, and joined to form non-circular slip surfaces.

- The advantage of the Block Search is that it allows the user to define the search area.
- The disadvantage is that user input is always required; it takes some experience to learn how to use the search objects to get the best search results; and it may not be obvious where to search especially for models without obvious weak layers.
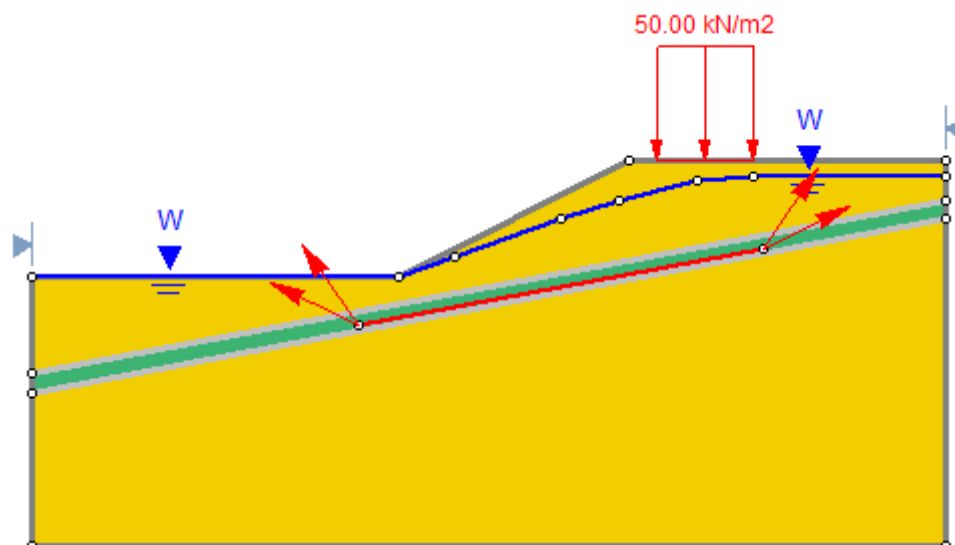
Block search polyline object defined in weak layer

Block search can be useful when you know in advance where you would like to concentrate the search. For example, very thin weak layers. It can also be used for planar failure search by adding a point search object at the toe of a slope for example.

It is highly recommended to use the **Optimization** search option together with the Block Search to improve results. By default the Optimization search is OFF so that you may first see results of the Block Search alone. If you re-run the analysis with Optimization turned ON, the critical slip surface may travel outside the block search objects, as Optimization is not constrained to remain within the original block search objects.

For more information on the **Block Search** click here.

Path Search

The **Path Search** is a fast, general non-circular search method which is useful if you are not sure about the shape or location of slip surfaces for a model. If you use the default search parameters, with no user input at all, this will often give you an idea of where the critical slip surfaces are located. Then, based on the results using the default search parameters, you can begin to narrow the search, using the options provided with the Path Search.

The Path Search generates slip surfaces by first randomly generating a point on the slope, then generating segments to form a non-circular surface which intersects the slope at a higher elevation.

The Path Search uses random numbers to generate the slip surfaces. It is a brute force method with no feedback mechanism, so relies on randomly discovering low safety factor surfaces.
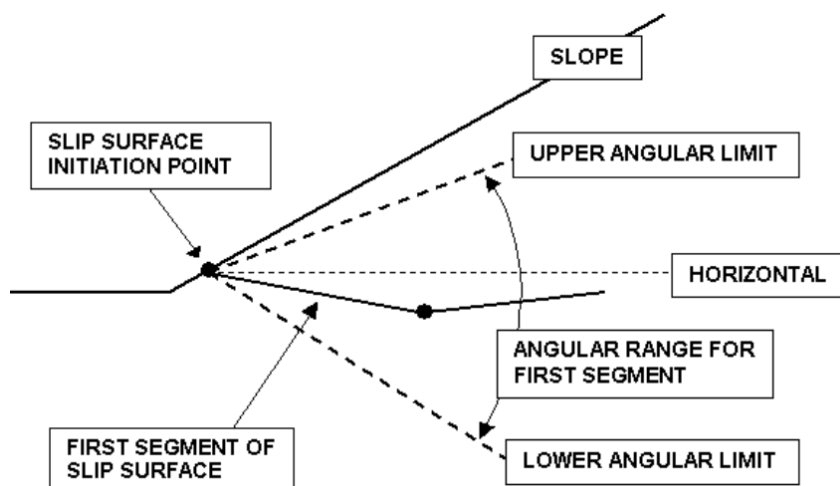
The Path Search is not well suited for models with very thin weak layers or anisotropic materials. Fine tuning of the search parameters (slope limits, segment length, angular ranges) can improve the results. A large number of trial surfaces also helps!

Although it is turned OFF by default, the **Optimization** search is always recommended for the Path Search. After you run the initial analysis you should always turn ON the Optimization search, and you will most likely find a lower safety factor surface.

For more information on the **Path Search** click here.
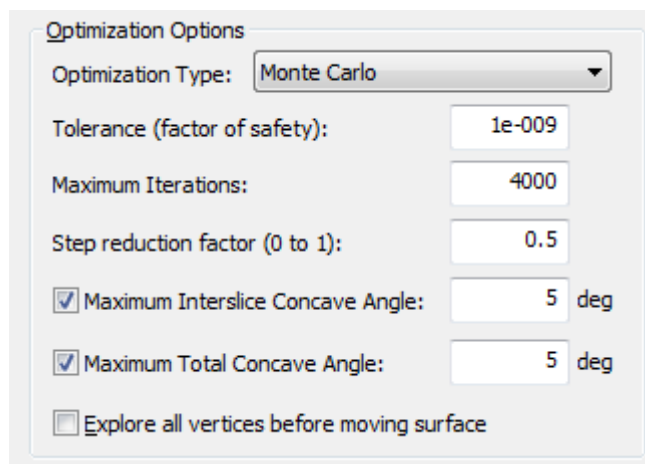
Optimize Surfaces

The **Optimize Surfaces** option is a very powerful search technique which allows you to search for lower safety factor slip surfaces, using the surfaces generated by a non-circular search or specific user-defined slip surfaces, as a starting point.

To enable the Optimize Surfaces option:

1. Select the Optimize Surfaces checkbox in the Surface Options dialog.
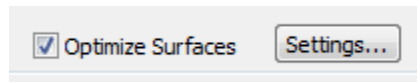
2. Various analysis options are available by selecting the **Settings** button beside the Optimize Surfaces checkbox.

The Optimize Surfaces option is recommended for ALL NON-CIRCULAR SEARCH METHODS in *Slide* (i.e. Block Search, Path Search, Simulated Annealing, Auto Refine, Cuckoo), as it usually locates a lower safety factor surface, compared to the results without optimization.

The Optimize Surfaces option is based on a Monte Carlo technique, often referred to as "random walking" (Greco, 1996).

Although the option is referred to as "optimization" in *Slide*, it can also be considered an additional Search Method. It does not require that a non-circular search be carried out. It can be used as an independent search method, starting with only a single, user-defined non-circular slip surface, as a starting point for the optimization search.

For more information on the **Optimization Search** click here.

Summary of Non-Circular Search Methods

All search methods, if used properly, should arrive at a good solution, though not necessarily the same solution. So why choose one method over another? The following table summarizes the advantages and disadvantages of each non-circular method.

| Method	Advantages	Disadvantages
Cuckoo Search	• Very fast global optimization method • Finds best solution most of the time • Requires no user input • Good for all types of models	• Black box method • Few user controlled parameters
Simulated Annealing	• Global optimization method • Finds best solution most of the time, with optimization • Requires no user input • Good for all types of models	• Black box method • Control parameters have no physical correlation to slope • Takes time, slower than Cuckoo Search
Auto Refine (non-circular)	• Very fast general search method • With optimization can find good solution • Requires no user input	• May not find global minimum for complex geometry, anisotropic materials • Requires optimization to improve results
Path Search	• Very fast general search method • With optimization can find good solution • Requires no user input	• Not well suited for thin or irregular weak layers, anisotropic materials • Control parameters require some experience • Requires optimization to improve results
Block Search	• Very fast search method • User control of search areas • Good for very thin or irregular weak layers • With optimization can find good solution	• Requires user defined block search objects • Some experience required with use of search objects • Requires optimization to improve results
Local Optimization	• Improves results for ALL non-circular search methods	• Additional time required for solution

Limits and Filters

Another important aspect of slip surface searching which should not be overlooked, are the various limits and filters which can be applied to the analysis.
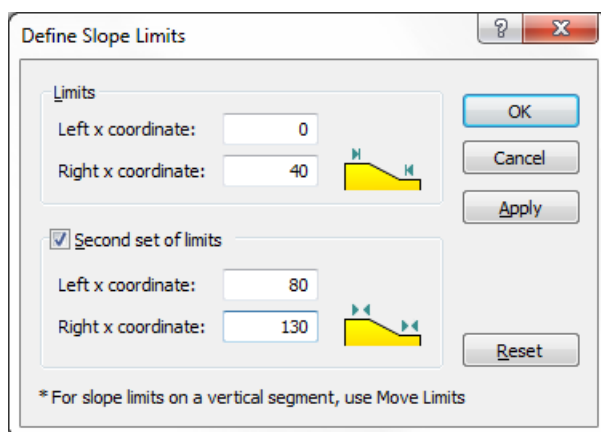
Slope Limits

The **Slope Limits** are used in all slip surface search methods. These are displayed as green triangular markers on the slope surface, and serve two purposes:

- **Filter** – for all search methods, all slip surfaces must intersect the slope within the defined slope limits
- **Surface Generation** – for some search methods (e.g. Grid Search, Auto Refine, Path Search) the slope limits are also used to generate slip surfaces
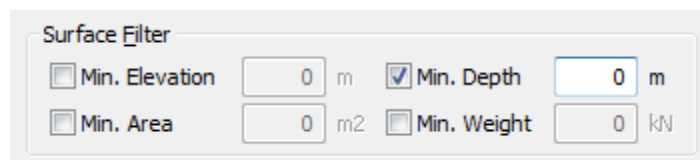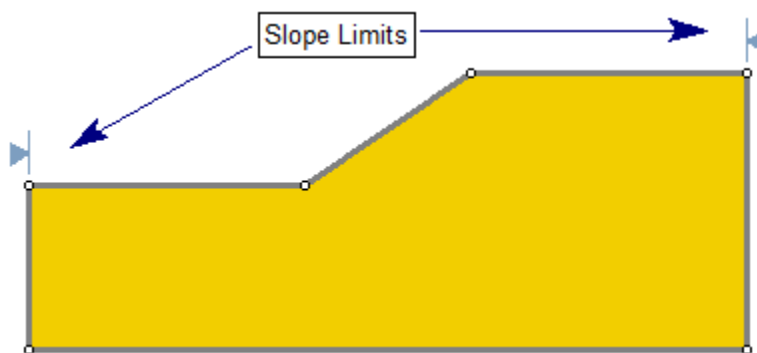

You can define one or two sets of slope limits. Two sets allows you to specify the entry and exit regions of all slip surfaces.

Slope limits can be easily moved by right-clicking on a limit, selecting **Move Limits** and dragging with the mouse. This allows you to easily analyze individual benches on a benched slope, for example, by moving the slope limits to the desired bench.

Filters

In the **Surface Options** dialog, several options are available which allow you to filter out slip surfaces based on various criteria.

For example, the **Minimum Depth** option allows you to filter out (discard) very shallow slip surfaces which are sometimes generated along a slope surface (e.g. translational failure).

The **Minimum Area** or **Minimum Weight** options allow you to filter out very small slip regions.

The **Minimum Elevation** option allows you to specify a lower bound y-coordinate for all slip surfaces.

The **Convex Surfaces Only** option allows you to exclude non-convex surfaces from the analysis.

In general the surface filter options can be very useful for filtering out surfaces which are of no significance to the analysis or which may interfere with the search for significant critical slip surfaces.

Composite Surfaces Option

If you use any one of the three CIRCULAR surface search methods (Grid Search, Slope Search or Auto Refine Search), with the Composite Surfaces option turned ON, then this allows you to automatically generate composite circular / non-circular slip surfaces, which follow the shape of the lower edge of the external boundary.

In order to use this method:

1. You will have to modify the model geometry, so that the lower boundary of the weak layer, is coincident with the lower edge of the external boundary.
2. Then run the Grid Search, Slope Search or Auto Refine Search, with the Composite Surfaces option turned ON.
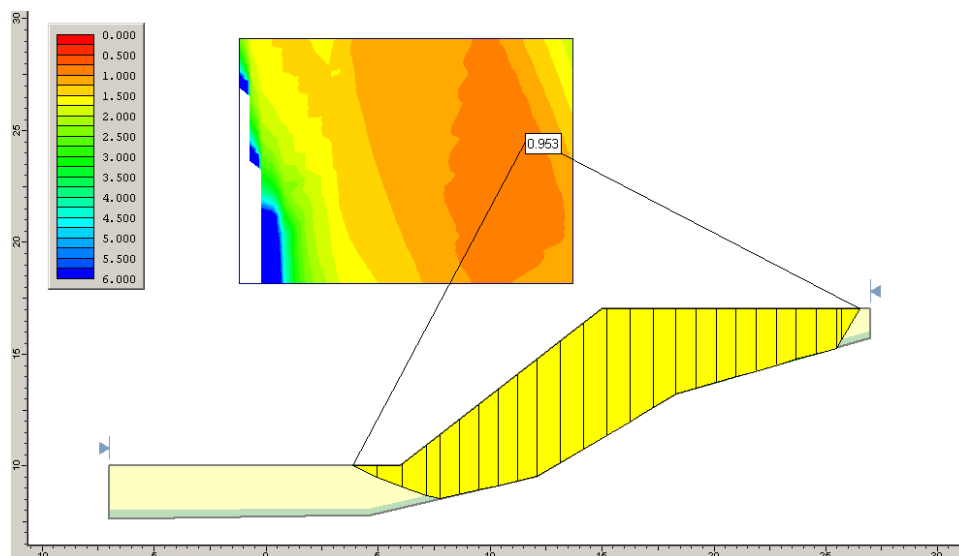
Grid Search used with Composite Surfaces option.

Depending on the model, the Composite Surfaces option may sometimes result in a lower safety factor critical surface than even a non-circular search. So the Composite Surfaces option is another useful option in the *Slide* searching toolkit.

More information about the Composite Surfaces option can be found in the *Slide* Help system.

Recommended Approach to Search Methods

Since the addition of the Global Optimization search methods (Cuckoo Search and Simulated Annealing), the following general approach is recommended for the critical surface search for slope stability models with *Slide*.

Circular Search

1. **Circular** > **Auto Refine** (or **Grid Search** or **Slope Search**)

   A circular surface search is a good starting point, even for models with a non-circular failure mode. A circular search can be performed very quickly, and should give you some idea of the possible failure modes of the slope. For weak layer or anisotropic models, this is optional, but it never hurts to run a circular analysis as a first step.

   Recommended analysis methods for circular slip surfaces: **Bishop / Spencer / GLE**

Non-Circular Search

2. **Non-Circular** > **Cuckoo Search + Optimization**

   Most slope models will require a non-circular surface search. The Cuckoo Search is the recommended starting point. Other methods are suggested below.

   Recommended analysis methods for non-circular slip surfaces: **Janbu / Spencer / GLE**

3. **Non-Circular** > **Simulated Annealing + Optimization**
4. **Non-Circular** > **Auto Refine** or **Path Search + Optimization**
5. For very thin weak layers, **Block Search** + **Optimization** may be warranted
6. Check for tension (on slip surface and interslice). If present, apply tension crack or other remediation method (e.g. Tensile Strength option) and re-run analyses.

Finite Element Shear Strength Reduction

7. Run SSR slope stability analysis (finite element) with *RS2* and compare with limit equilibrium results.

To summarize:

- At least TWO search methods should always be tried.
- For non-circular start with Cuckoo Search and also try other methods.
- Local Optimization Search should always be enabled.

Example 1 – Simulated Annealing versus Cuckoo Search

This example will compare Simulated Annealing with the Cuckoo Search and point out some issues which may arise. The model is a large scale slope with multiple material layers of varying thickness and strength.

In Figure 1 below, the results of **Simulated Annealing** are shown. A critical FS = 0.98 is obtained for a very large sliding mass which exits the slope through a weak layer (pink material).
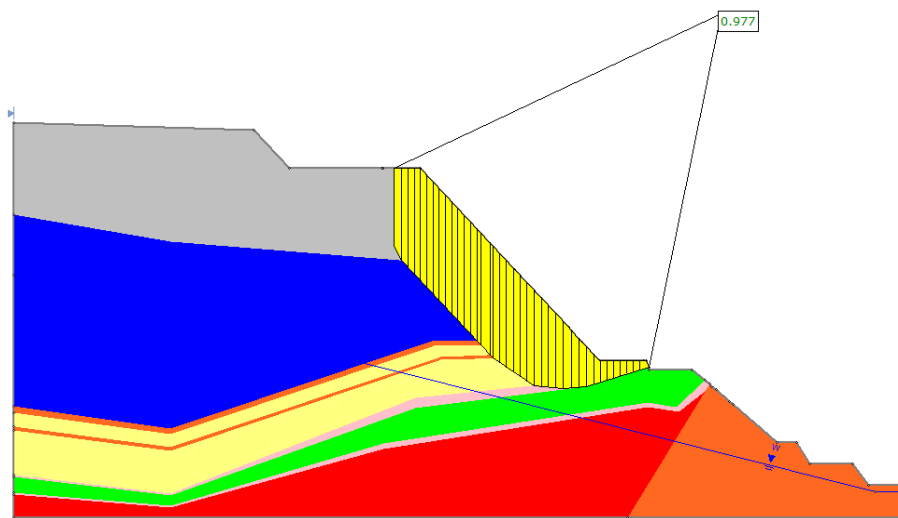

Figure 1 – Simulated Annealing with Optimization

If we run the **Cuckoo Search** with default parameters, we obtain the following result. You'll have to zoom in to see it. The Cuckoo Search has found a very small local failure, FS = 0.16 on the face of a bench where the weak layer daylights.
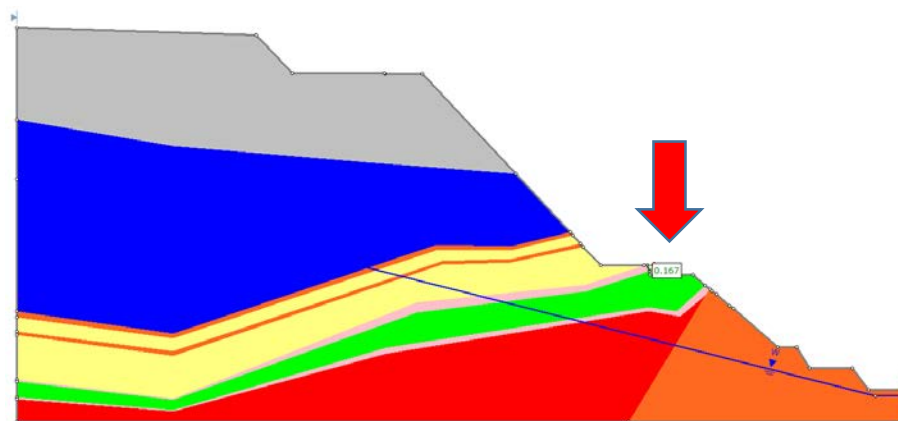

Figure 2 – Cuckoo Search with no filters

Numerically speaking this is the Global Minimum failure surface for the slope, with an extremely low safety factor.
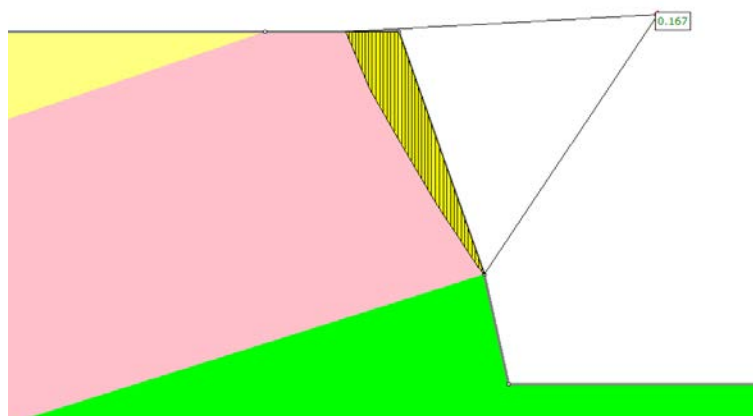
Figure 3 – Zoom in to local bench failure found by Cuckoo Search

For this case, we should use the Filter options to filter out relatively small slip surfaces. Let's use the Minimum Depth option = 25 feet. If we re-run the analysis, we get a nearly identical result to the Simulated Annealing, FS = 0.98.
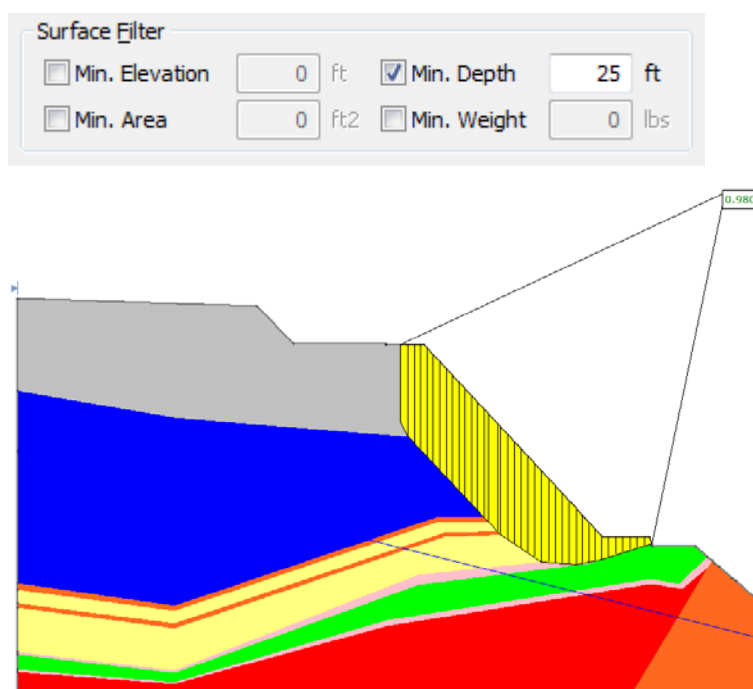

Figure 4 – Cuckoo Search with Minimum Depth filter applied

This example demonstrates the following important points:

- Cuckoo Search and Simulated Annealing are capable of finding the same result
- Cuckoo Search can be very effective at finding the true Global Minimum
- The numerical Global Minimum may not always be the most significant slip surface
- The filter options should be used when necessary to discard unwanted results from the analysis.
- For this model and in most cases, Cuckoo Search is much faster than Simulated Annealing

Example 2 – Simulated Annealing vs Path Search

In this example we have a dry embankment on top of a three layer clay foundation with water table. Using different search methods the following results were obtained:

- Simulated Annealing: FS = 1.035, multi-linear surface + tension crack
- Auto Refine: FS = 1.213, multi-linear surface + tension crack
- Path Search: FS = 1.514, near circular + tension crack

The different search methods show significant differences in safety factor and failure mode. Optimization was used for all methods.
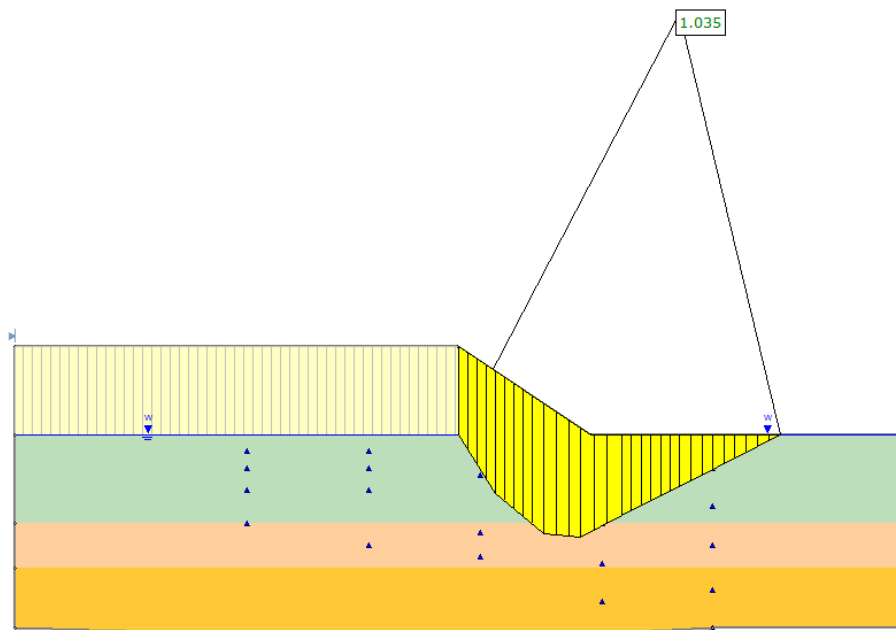

Figure 1 – Simulated Annealing

Simulated Annealing gave the lowest safety factor and a kinematically feasible slip surface. Compute time was fairly lengthy. Note that Cuckoo Search (not shown here) gave a very similar slip surface, with slightly higher safety factor, and faster compute time, compared to Annealing.
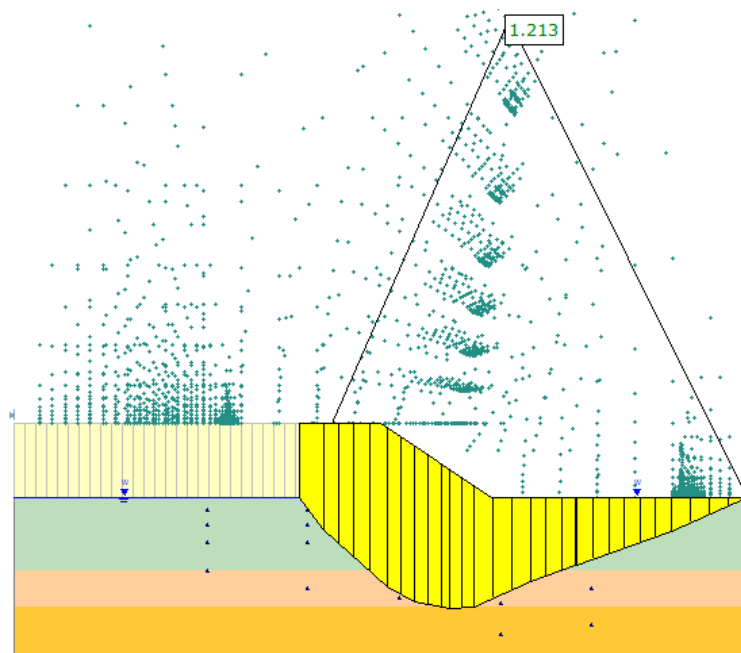
Figure 2 – Auto Refine

Auto Refine found a similar shape of sliding mass compared to Annealing, but a larger sliding mass and higher safety factor. Also note that the critical surface reaches the right slope limit, indicating that the limits should be extended.
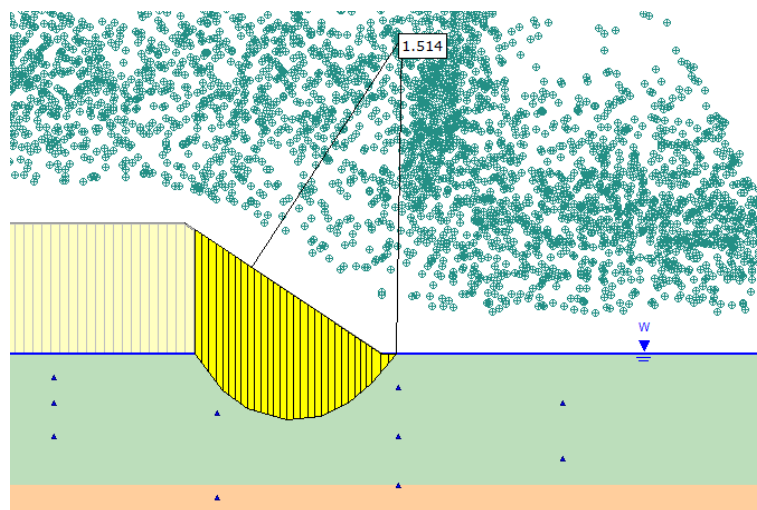

Figure 3 – Path Search

The **Path Search** performed quite poorly on this model, showing a much higher safety factor and a near-circular failure mode, compared to the other methods. The Path Search can sometimes work quite well (with many trial surfaces + optimization) and sometimes quite poorly. Adjusting the search parameters of the path search can improve results, but it may take several attempts and require some experience with the method. It is difficult to generalize on the performance of the Path Search and Auto Refine due to the infinite variety of slope variables that may be encountered.

Example 3 – Anisotropic Material Slope

The following slope model uses the Generalized Anisotropic material model, to define a rock mass with a weak layer oriented between 5 and 15 degrees from horizontal.
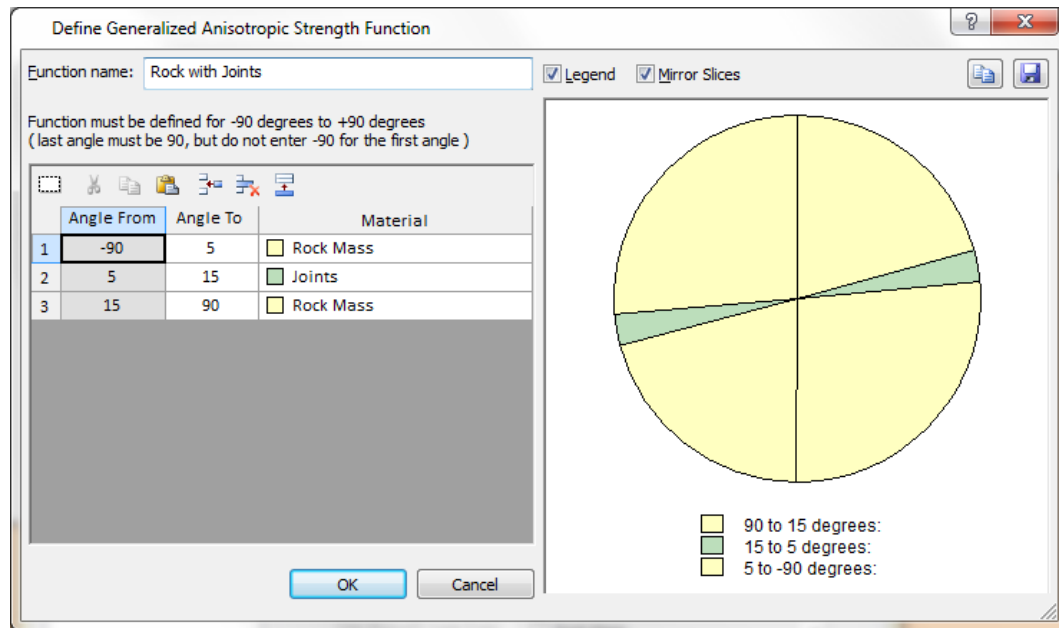
This is an example of very significant difference in safety factor and failure mode, depending on search method.

- Cuckoo: FS = 1.506, planar failure mode
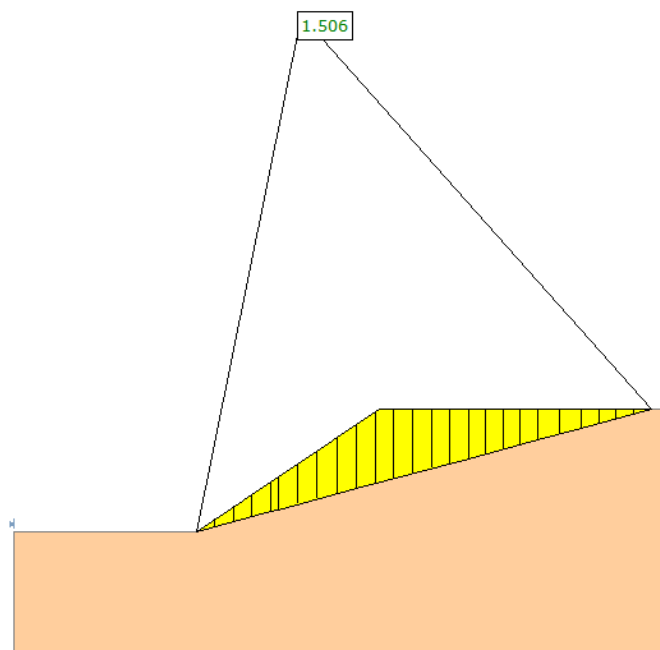- Auto Refine Search: FS = 2.750, near circular surface

Figure 1 – Cuckoo Search results

The **Cuckoo Search** with optimization, gives the lowest safety factor and a planar failure mode, which is not a surprising result. Note that Simulated Annealing gives essentially the same result.
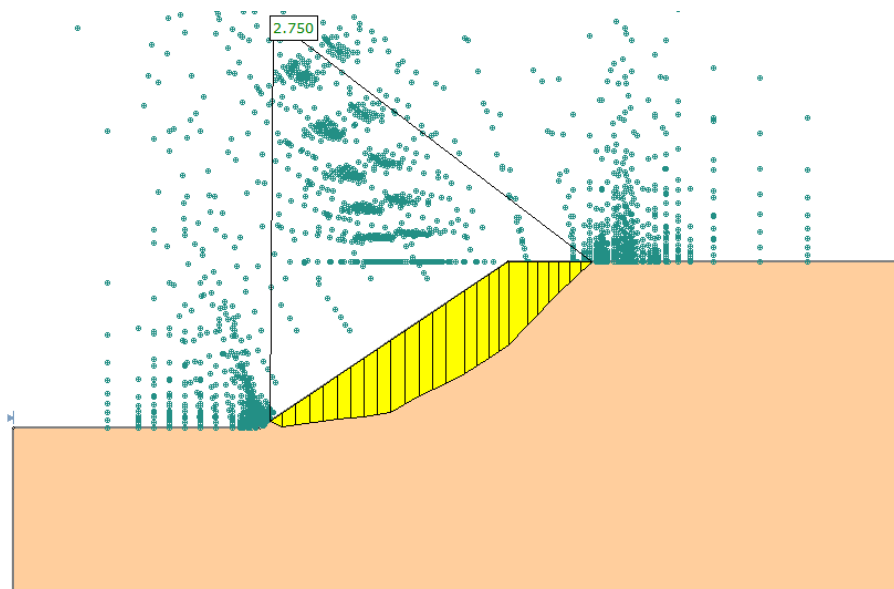

Figure 2 – Auto Refine search results

The **Auto Refine** method, with the default search parameters, shows a nearly circular failure mode and much higher safety factor than Cuckoo Search. Clearly Auto Refine is not suitable for this model with anisotropic properties.
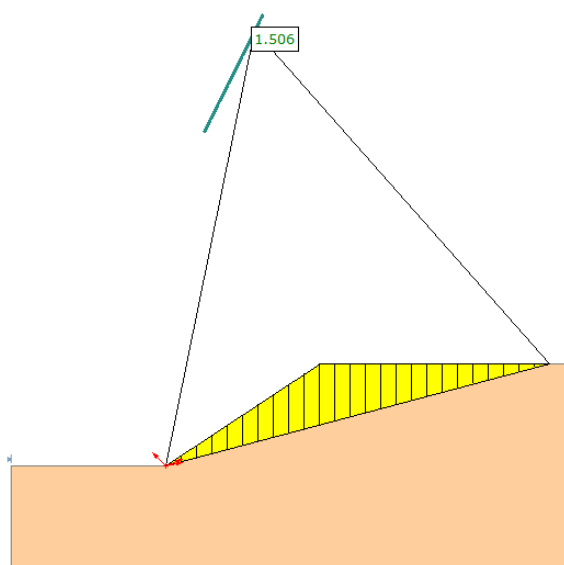

Figure 3 – Block Search results

It is worth mentioning that a **Block Search**, defined by a single point search object at the toe of the slope, with angular search range matching the anisotropy, finds the correct planar solution in about 2 seconds without optimization. However this is an exception since we know the solution in advance; in general it will be more difficult to use the Block Search for more complex anisotropic models.

Conclusion

- Always try more than one search method.

- Use search methods which are most appropriate for the model.

- Remember that all of the search methods in *Slide* are only "automatic" up to a certain point, and a thorough search will always require some thought and effort by the user. Although the Cuckoo Search and Simulated Annealing are extremely powerful methods, the validity of results always needs to be carefully evaluated by the user.

- Compared to the large investment represented by any slope stability analysis, some extra effort with the search options, which is a critical component of the analysis, is a very small price to pay.

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