FRILO Software
A NEMETSCHEK COMPANY

Slope Failure Analysis BBR

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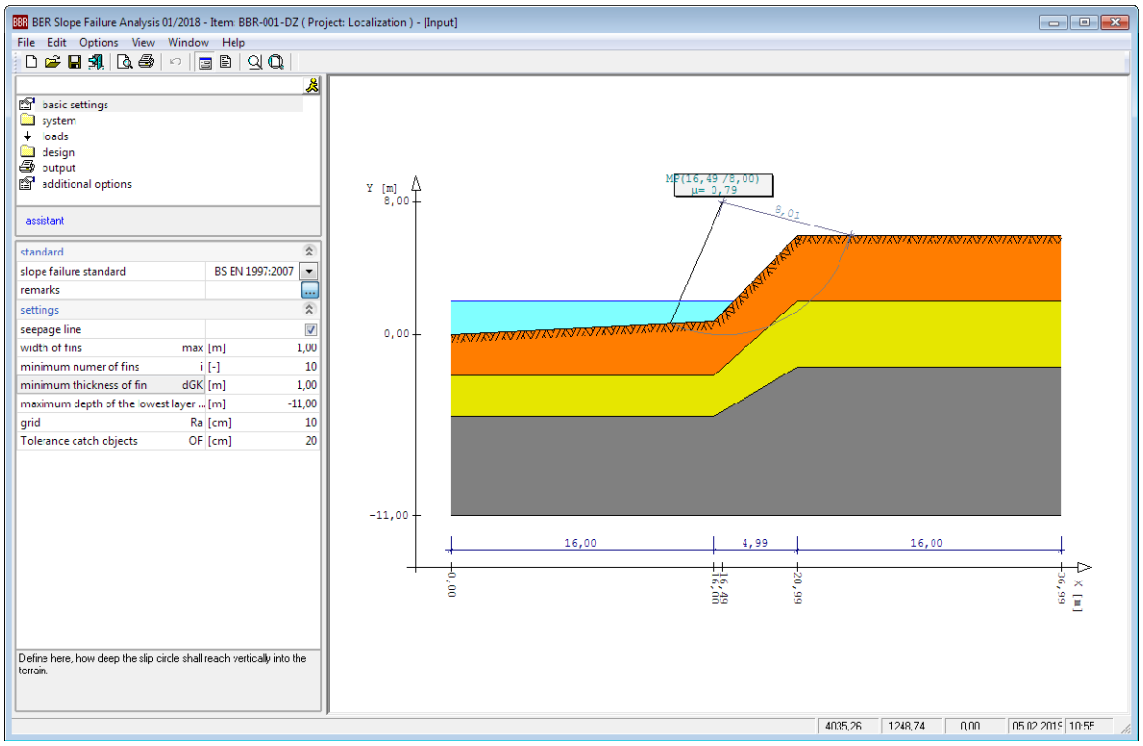


Slope Failure Analysis BBR

Contents

Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage www.frilo.com ▸ Support ▸ Articles/Information ▸ Basic operating instructions.

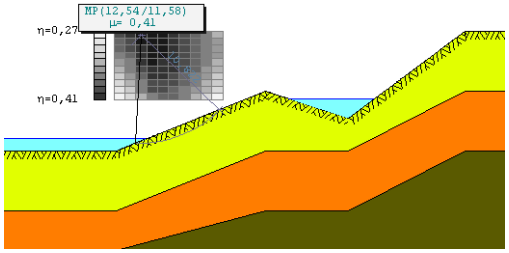
Application options

Scope of performance

The BBR software calculates the slope failure resistance of defined grounds and displays it in the form of utilization.

Definition options:

- Definition of a polygonal ground profile, soil layers as well as ground water presence
- Permanent and variable loads applying to the ground
- Several water removal actions



For the calculation of the utilization, the method of slices is used in accordance with BISHOP. The utilization is calculated for a slip circle, which is determined by its centre and its radius.

A wizard is available to facilitate the definition of the ground parameters. It generates the structural system from the essential parameters.

In addition to this, you can define a rectangular or circular area for various slip circle centres. Depending on your specifications, the software performs a slip circle variation in order to determine the shape and position of the decisive slip circle.

Available standards

- DIN EN 1997-1 [2009-09] with DIN EN 1997-1 [2010-12] NA
- ÖNORM EN 1997-1 [2009-05] with ÖNORM B 1997-1 [2007-11]
- BS EN 1997-1 [2004] with National Annex [2004]
- DIN 1054 [2005-01] in combination with DIN 4084 [2009-01]

Limits of application

The BBR application is suitable for slope failure analyses in accordance with the method of slices by Bishop. Only circular failure mechanisms are available. You can optionally work with one, two or no constraint points. It is possible to define several hills and valleys with lakes. However, only clockwise rotating slip circles that cause the slope to slip to the left are examined in combination with these landscape models. Anti-clockwise rotating slip circles that cause the slope to slip to the right are not examined.

Basis of calculation

Standards DIN, DIN EN, ÖNORM EN and IS EN are described in the german manual only: BBR.pdf

Basis of calculation as per NA to BS EN 1991-1-4:2004

Actions and loads

Loads are always defined as characteristic values. Permanent and variable actions are available.

Verification method

The software uses the verification method 3 in combination with BS EN 1997-1 [2004] and the specified values.
This corresponds to the combination **A2 + M2 + R3**. (The combination coefficients ψ are not used in this calculation.)

Safety factors for actions in accordance with BS EN 1990 [2002], Table NA.A1.2(C)

Actions		Symbol	Values
Duration	Condition		A2
Permanent	Unfavourable	γ_G	1.00
	Favourable	γ_G	1.00
Variable	Unfavourable	γ_Q	1.30
	Favourable	γ_Q	0.00

Safety factors for resisting forces in accordance with IS EN 1997-1 [2005]+AC:2009, Table NA.2:

Soil parameters	Symbol	Values
		M2
Effective shear angle (with tan φ)	γ_φ	1.25
Effective cohesion	γ_c	1.25
Specific weight	γ_γ	1.00

Slope failure resistance

In order to achieve sufficient resistance against slope failure, the relation of the design values of the actions to the resistances must be ≤ 1:

$$\mu = E_M / R_M \leq 1$$

E_M is the total of the moments acting around the centre of the currently considered slip circle.

$$E_M = r \cdot \sum_i \left(G_i + P_{vi}\right) \cdot \sin\vartheta_i + \sum M_s$$

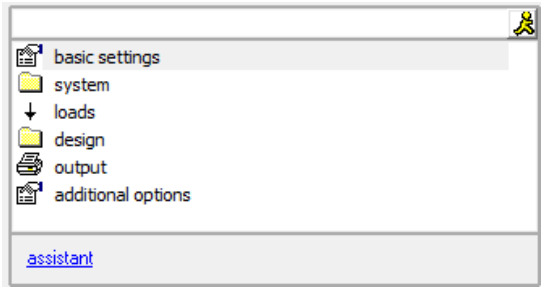
R_M is the total of the moments acting around the centre of the currently considered slip circle.

$$R_M = r \cdot \sum_i \frac{\left(G_i + P_{vi} - u_i \cdot b_i\right) \cdot \tan\varphi + c_i \cdot b_i}{\cos\vartheta_i + \mu \cdot \tan\varphi_i \cdot \sin\vartheta_i}$$

It is obvious in the formulae above that utilisation μ is indicated on the left as well as on the right side of the equations. Therefore, iteration is used to solve the problem. Utilisation is estimated and the calculation and verification is based on the estimation. This process is continuously repeated until the deviation from the previous iteration step is below 3 %.

Data entry

Wizard



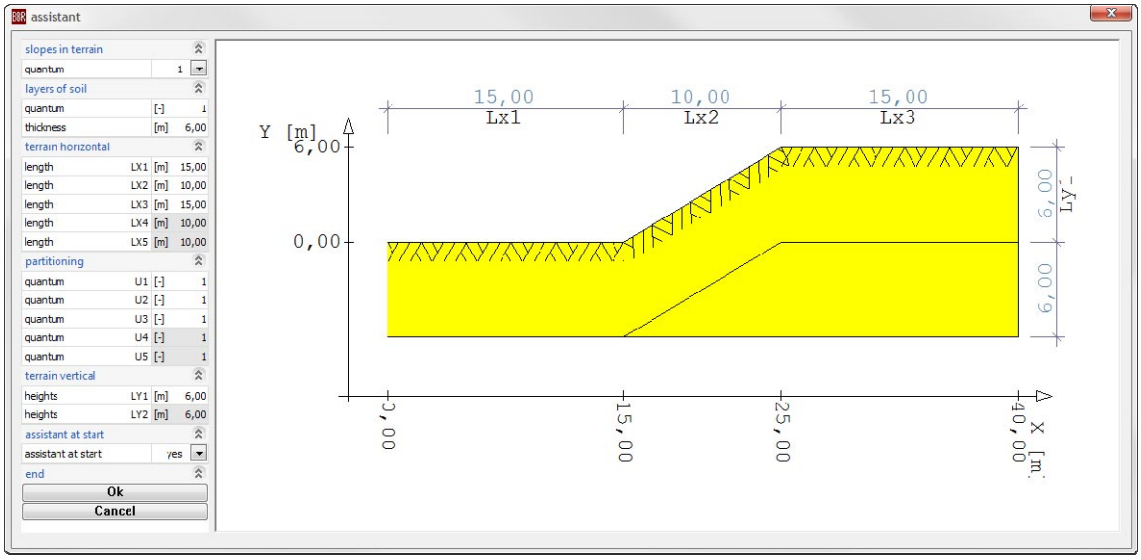
The definition wizard is automatically launched when you start the software. Set the option "Wizard at program start" to "No" to disable the automatic starting of the wizard. When accessing a template item, the wizard is not launched by default.

You can launch the wizard manually at any time in the area where you define the basic parameters.

The definition wizard shall facilitate the parameter setting in standard cases. It is often helpful to generate a structural system using the wizard and refine it subsequently with the help of the other available definition functions.

In the wizard, you can define one or two abrupt typographical changes and determine the number and thickness of the soil layers. Initially, the soil layers all have the same distance and standard properties that can be adjusted subsequently.

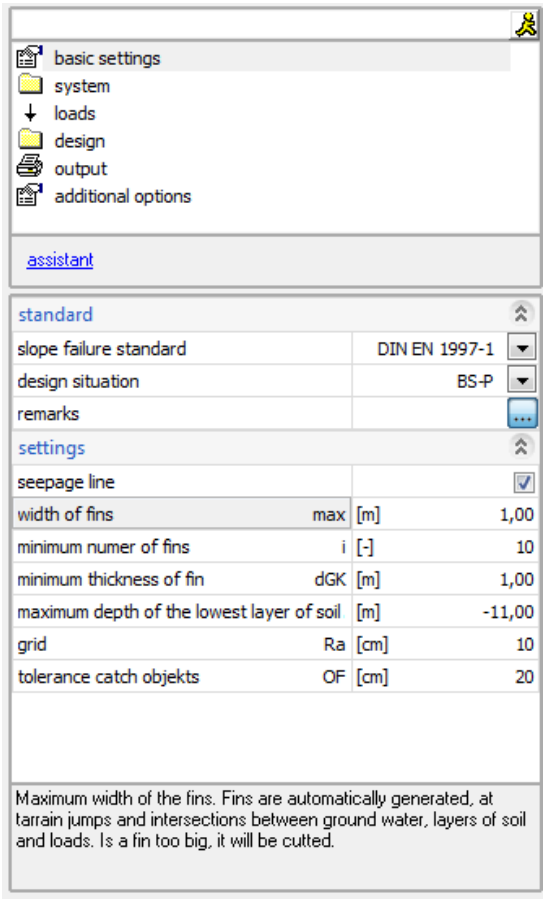
Each ground section can be subdivided.



Basic parameters

Standard

Selection of the design standard and a design situation as well as a consequence class if required by the selected standard.



Settings

Seepage line — optional activation of ground water (tick the option).

Width of slices — maximum width of the slices.
The software generates automatically slices at abrupt changes in the ground surface and at various intersections of the ground water line and the soil layers and loads. If a slice exceeds the specified maximum slide width it is subdivided.

Min. number of slices — some slope failure codes require the specification of a minimum quantity. If the specified minimum quantity is not achieved, additional slices are generated until the condition is satisfied.
Attention: the software does not check compliance with the specified minimum quantity.

Min. thickness of slices — defines how far the slip circle penetrates the ground in orthogonal direction. This is done to prevent that slip circles with a penetration depth of 1 cm and a radius of 5 cm for instance are examined.

Max. depth of lowest soil layer
limits the penetration of the slip circle into the subsoil.

Grid — defines the invisible grid in the background of the graphical representation. If you move polygon points of the seepage line, the ground profile or of waters etc. with the help of the mouse, the associated coordinates are rounded (matched to the grid).

Object capture tolerance — when defining your system graphically with the mouse, this value determines how accurate you need to set polygon points of a seepage line to the bank of a water, for instance, to make the points coincide exactly.

Structural system

Double-clicking on the "System" option accesses the sub-menu.

Soil layers, the ground profile etc. are defined via tables. The individual rows (e.g. the number of soil layers) can be customized with the functions "Insert", "Delete" and "Delete all".

Use the arrow buttons (left , right) to navigate in the table.

Soil layers

The number of soil layers can be adjusted via the options "Insert", "Delete" and "Delete all".

If editing of the last soil layer is finished, the software prompts whether additional soil layers should be generated.

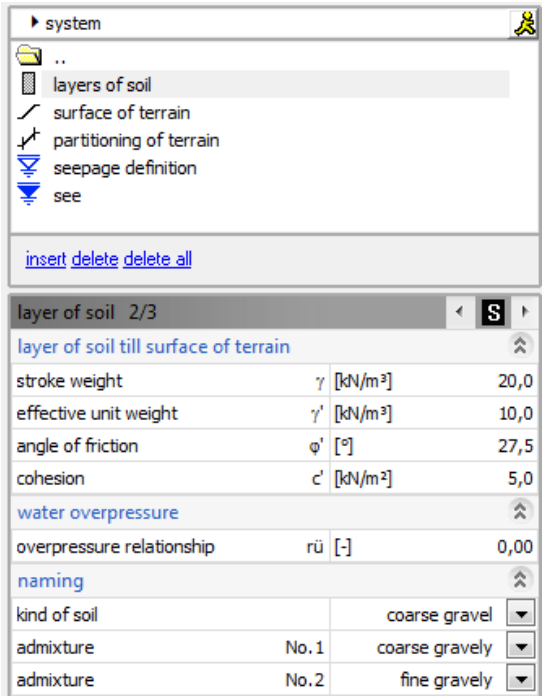
The specific weight, the specific weight under buoyancy, the friction angle and the cohesion shall be defined characteristically for each soil layer.

You can also define the excess pore water pressure ratio. According to "Konrad Simmer – Grundbau 1", freshly loaded soil has a tendency to settle and reduce the pore portion. If the pores are filled completely or partly with water, excess pore water pressure occurs. The excess pore water pressure is determined in the expression:

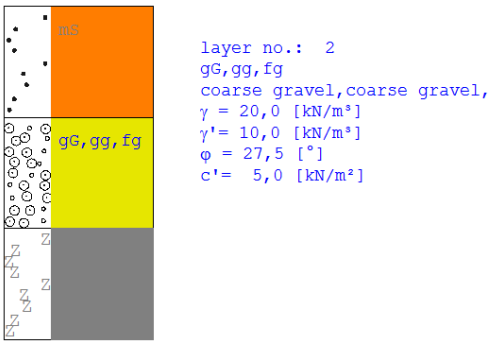
$$\Delta u = r\ddot{u} \cdot \gamma \cdot h'[kN/m^2]$$

In this equation, rü=0 means consolidated, rü=1 means saturated with water and freshly loaded.

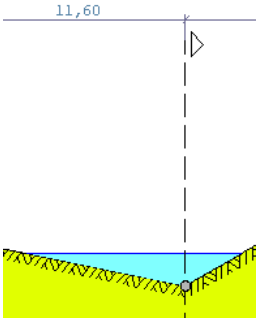
The specifications concerning the soil type and the admixtures are only required for the representation and designation of the soil layers. They have no influence on the calculation.



Ill. coloured representation of the soil layers.



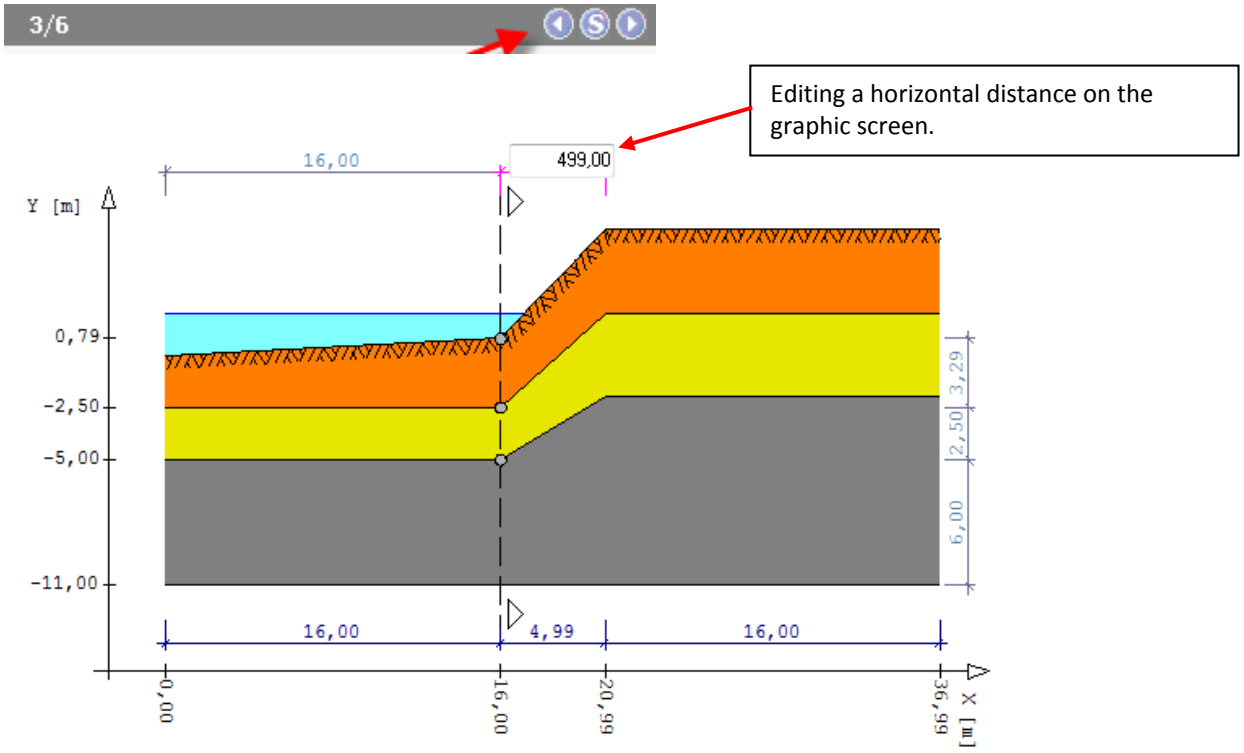
Ground profile



In the "Ground profile" area, you can define the slope, the ground top level as well as the run of the sol layers in the ground. The ground surface is defined as a polygonal line. When you edit a polygonal point ( ), an associated section is shown on the graphic screen (see illustration) and dimensioning is applied.

The horizontal distances to the neighbouring polygon points on the ground surface can be edited directly on the graphic screen by double-clicking on the corresponding dimension value.

Moreover, you can move the grey polygon points with the mouse: click on the polygon point you want to move, drag it with the mouse to the desired position and click again to drop it there. You can switch and enable one point after the other via the arrow keys in the data-entry section.



The number of ground profile polygons can be adjusted via the options "Insert", "Delete" and "Delete all".

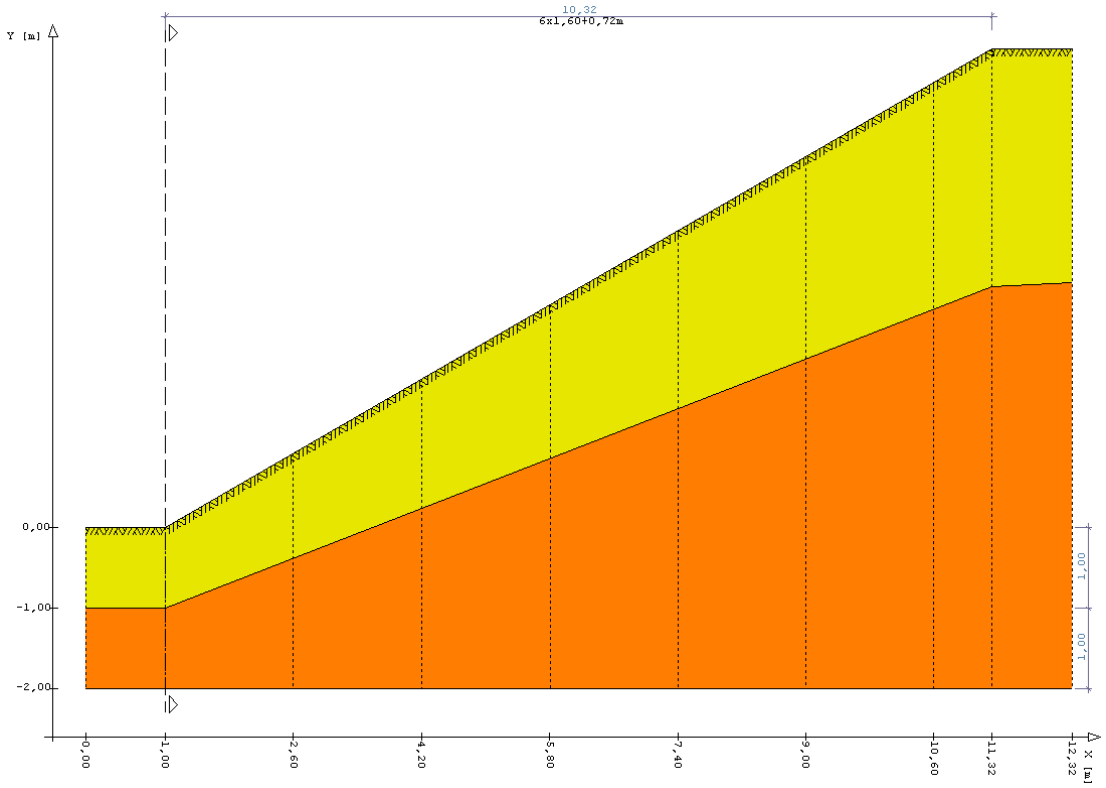
You can edit the currently active polygon point in the data-entry section below the ground profile section. Moreover, you can define the inclination of the slope on the right of the currently active polygon point as rise/run ratio or as inclination in the "Right gradient" menu. The entry of the soil layer ordinates allows you to specify the depth of the soil layer limits for the currently active polygon point. Alternatively, you can define the layer thickness in the "Soil layer thickness" menu. "Adjacent ground sections" correlate with the horizontal dimension chains in the graphic screen and define the distances to the adjacent polygon points. The layer thickness dimensions are given in the right vertical dimension chains.

2/4			
terrain development			
X		[m]	16,00
Y		[m]	0,79
slope right			
incline of slope	β	[°]	46,24
incline of slope	1	[-]	0,96
layers of soil ordinates			
layer	01 Y	[m]	-2,50
layer		[m]	-5,00
layer		[m]	-11,00
thicknes of layers of soil			
layer thickness		[m]	3,29
thicknes of layer of soil		[m]	2,50
thicknes of layer of soil		[m]	6,00
next parts of terrain			
bri		[m]	4,99
ble		[m]	16,00

Ground division

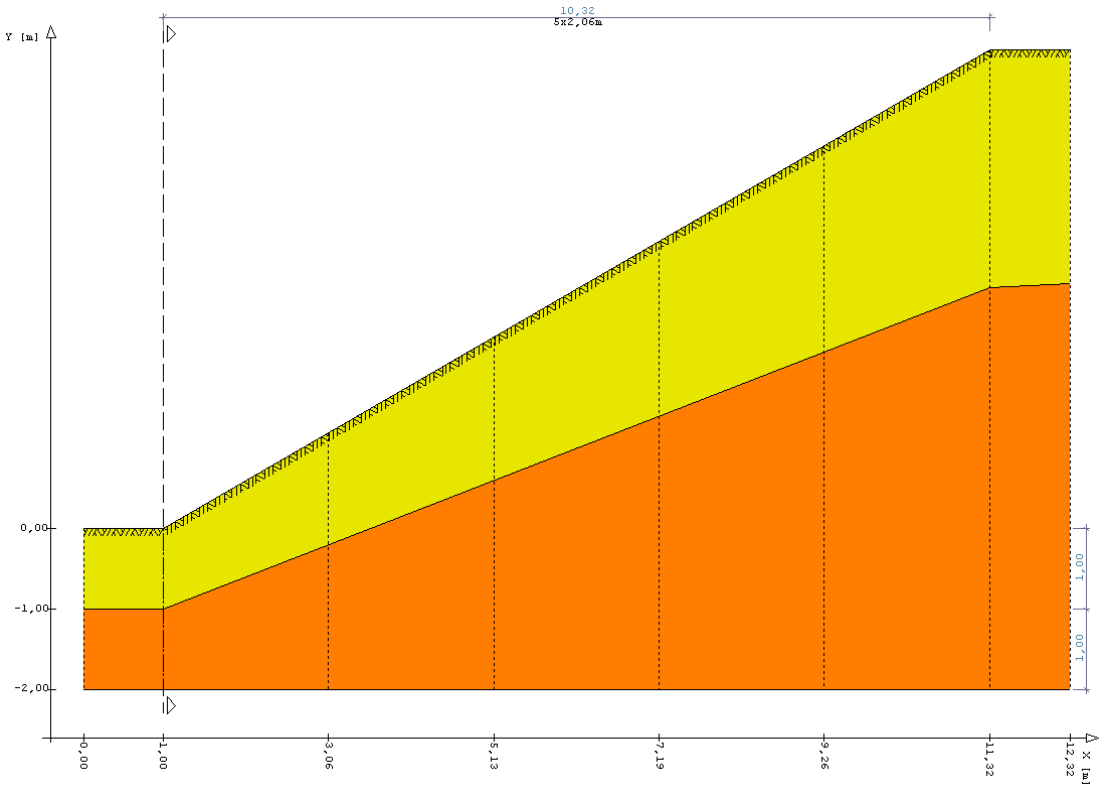
The division of the ground between two polygon points provides a possibility to influence the generation of additional slices for the calculation. This option allows you to refine the calculation locally and facilitates the tracing of verifications from other sources.

The division can optionally be defined via the number of sections or the distance (length of the sections). You can select/edit the ground point at which the division shall start via the arrow keys or by clicking on the S button in the displayed table.



Example 1: the illustrations above and below show the graphic screen and the data-entry field for the division variant "Distance". The distance of 10.32 m length is divided in sections of 1.60 m each. The result is six sections with a length of 1.60 m and a remainder with a length of 72 cm.

point of terrain 2/4			S
terrain development			
X		[m]	1,00
Y		[m]	0,00
partitioning			
kind			in distance
number	n	[-]	6
distance	bu	[m]	1,60
next terraint parts			
bri		[m]	10,32

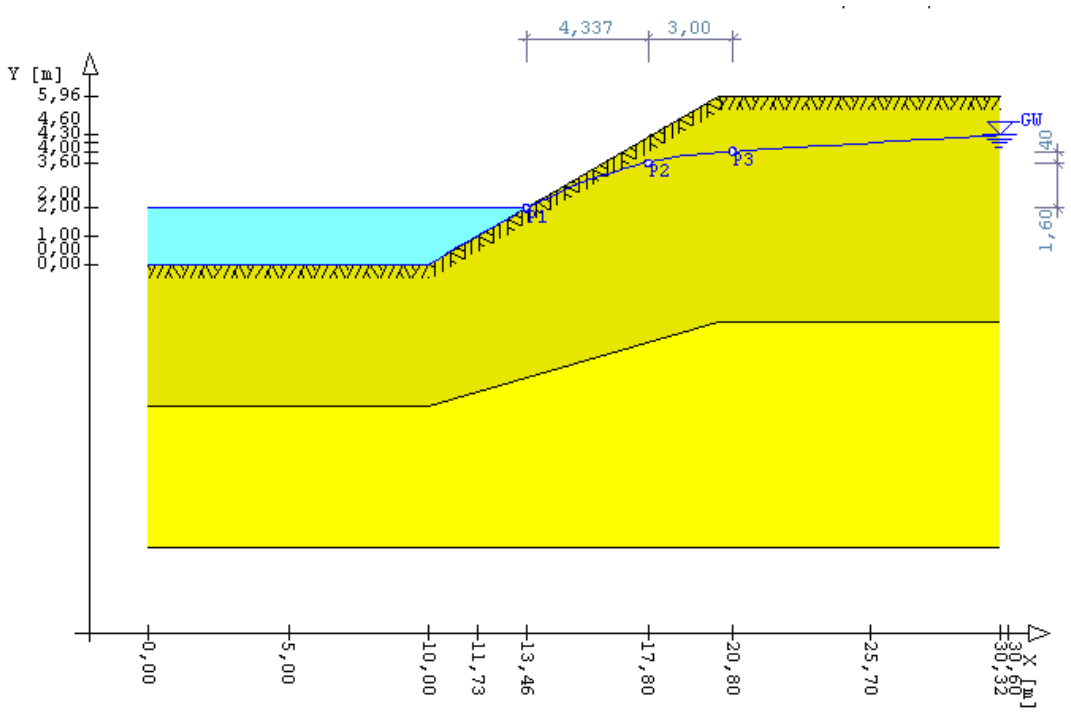


Example 2: the division variant "Number": the distance of 10.32 m is divided into five sections. The resulting section width is 2.06 m

point of terrain 2/4			
terrain development			
X		[m]	1,00
Y		[m]	0,00
partitioning			
kind			in number
number	n	[-]	5
distance	bu	[m]	2,06
next terraint parts			
bri		[m]	10,32

Definition of the seepage line

The setting of the seepage line parameters allows you to define ground water. Ground water is represented via rational functions of straight lines and parabolas.



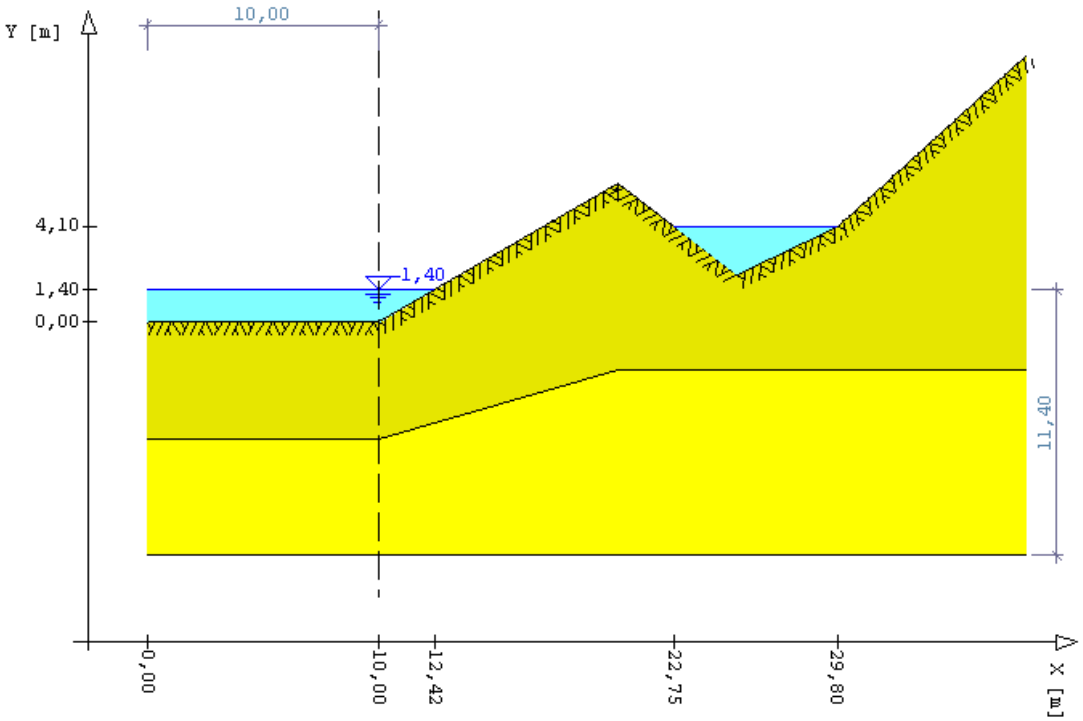
In the illustrated example, a complete seepage line is defined. It consists of straight lines and parabolas. Currently, the third function of the seepage line is selected. You can edit the coordinates of P1, P2 and P3 to influence the function graph of the parabola. Use either the four dimension chains or click left on the circles of P1, P2 or P3 and move the points with the mouse. The coordinates of all points defining the seepage line are indicated on the x- and y-axes. The object capture function supports the dropping of a seepage line point onto the polygon point of a water, the ground etc.

When activating the "Generate" button, a seepage line is generated from straight lines based on the ground polygon and any waters that have been defined. After having created the seepage line, you can customize it with the help of the mouse and the keyboard. To do this, drag the polygon points with the mouse to the desired position, toggle between the sections with the help of the arrow keys on top left of the user interface:

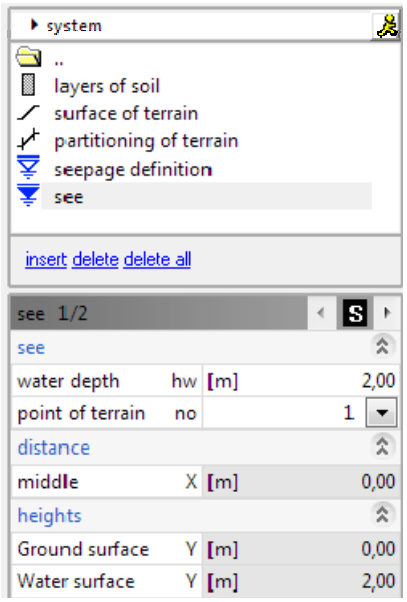
Attention! Important note: Waters and ground water are defined separately. They are both taken into account in the calculation. Water can be defined without ground water and ground water can be defined without other waters.

Waters / see

The definition of waters enables removal actions.



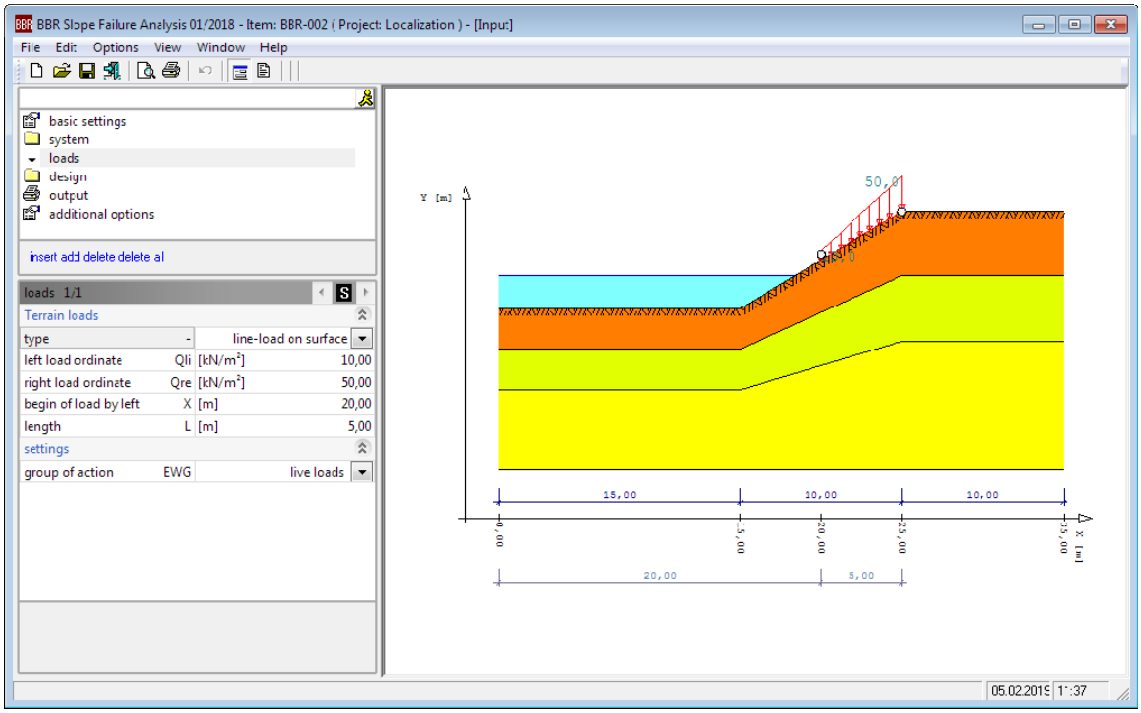
You can define any number of waters (insert...). Water is always determined by a point on the polygon ground surface line and the water depth defined for this point. The banks on the left and right are calculated and the water is shown in the graphical representation. The currently edited water is shown with a section view and the dimensioning.



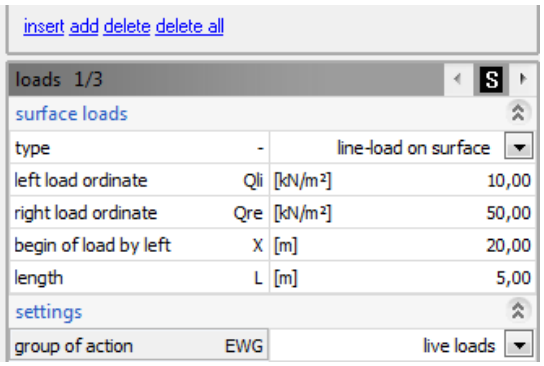
Attention! Important note: Waters and ground water are defined separately. They are both taken into account in the calculation. Water can be defined without ground water and ground water can be defined without other waters.

Loads

The load entry section allows the definition of permanent and variable actions. Only trapezoidal loads are definable. They are either projected on the ground or act directly on the ground surface.



If the mouse cursor is on the data-entry field "Loads", the graphical representation shows the currently edited load always in combination with two circles. You can control the number of loads via the "Insert", "Delete" and "Delete all" options. After completion of the editing process, you are prompted whether to generate an additional load. The currently selected load on the left can be moved in the graphic on the right via the circles shown at the bottom of the load arrow.

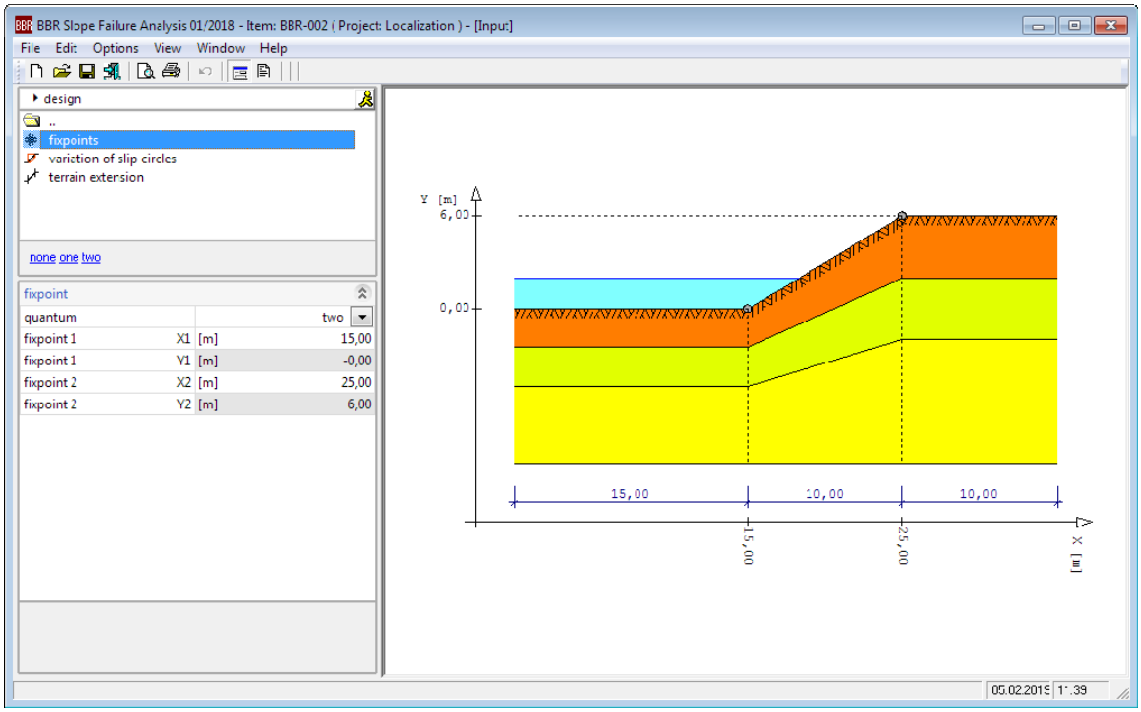


Permanent loads act always on the right of the slip circle centre. Variable loads only act unfavourably in this area.

Design

Constraint points

You can define one, two or no constraint points. Constraint points limit the number of possible slip circles considerably. With homogeneous soil, a constant slope and other homogeneous site conditions, the decisive slip circle is usually at the base of the slope. You can move the constraint points with the mouse.

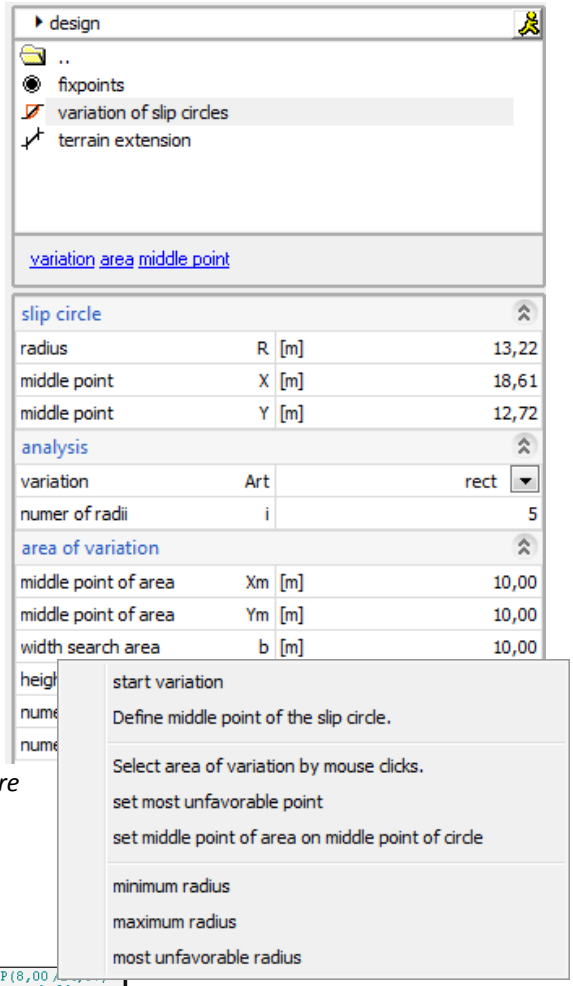


Slip circle variations

Slip circle variations ensure that a great number of slip circles is calculated and the most unfavourable and, therefore, decisive circle can be determined. For the variation, you can select circular or rectangular areas, the grid spacing of which determines the circle centres. For these circle centres, the possible radii are varied then.

This example examines a rectangular area. A grid spacing of 20 x 20 produces 400 slip circle centres. The number of radii amounts to 2. The possible maximum and minimum radii are examined for each centre. The possible minimum radius is determined by the minimum penetration depth of the slip circles in the soil. You can edit this value in the basic parameters. The maximum slip circle is defined by the existing ground profile. Slip circles do not go beyond the defined ground profile. With three or more radii, also radii between the possible maximum and minimum radii are examined. You can start the examination via the "Variation" option on the left side or in the GUI via the context menu option "Start variation".

When the examination is finished, the result is shown with grey hatching and the decisive slip circle is selected in the examined area.

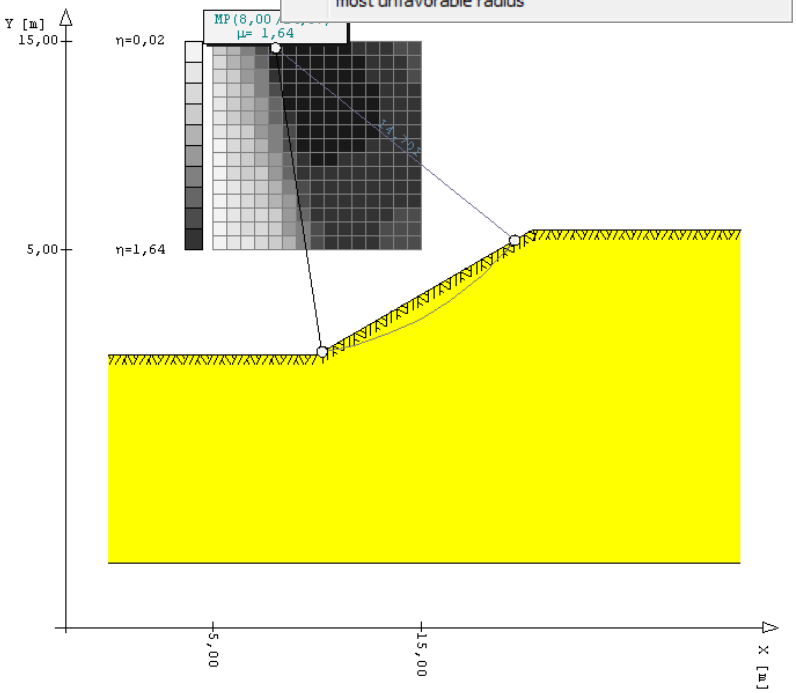


Attention! *The results in the variations always refer to the centre of each square of the grid*

<u>Example shown in the illustration on the right:</u>

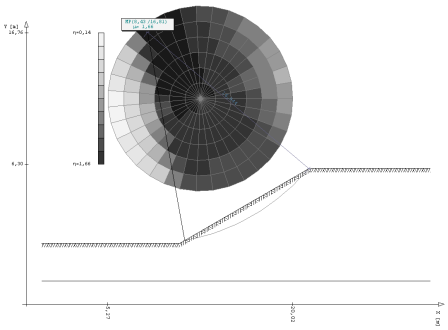
In the example, an area of 15 x 15 elements is examined and the resulting utilization is shown for each element centre. When you displace the determined circle centre, a new calculation is performed and the corresponding result is displayed. This new calculation might imply that a greater value results for the utilization. If you select a greater number of elements beforehand (e.g. 100 x 100), upwards outliers are far less probable.

Conclusion: the finer the mesh the less it is likely that the maximum utilization in the defined area is not found. This solution increases the computing time, however.



In addition to this, you can examine a circular area. The associated parameters are slightly different to those for rectangular areas.

slip circle			
radius	R	[m]	13,22
middle point	X	[m]	18,61
middle point	Y	[m]	12,72
analysis			
variation	Art		circle
numer of radii	i		5
area of variation			
middle point of area	Xm	[m]	10,00
middle point of area	Ym	[m]	10,00
radius area	r	[m]	5,00
numer of grids	nRast	[-]	3
number of sectors	nSekt	[-]	25



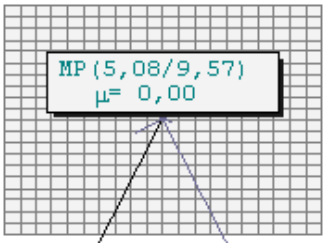
The area is defined with the help of a radius, a grid and sectors.

Context menu in the slip circle variation (right mouse button):

"Start variation" launches the examination of the defined area. The option immediately underneath allows you to set a new slip circle centre. The function "Select variation area with the mouse" is similar to the zoom function and allows you to define the variation area in the graphical user interface.

When you activate this function, the next mouse click defines the left top edge of the area.

Moving the mouse displays the new scaled area. The second mouse click delimits the area definitively. Subsequently, the grid spacing is generated.



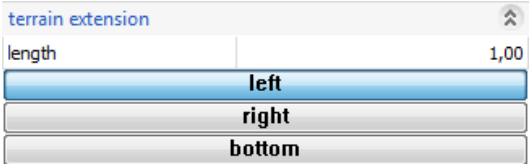
Activating the option "Assign most unfavourable point" sets the decisive slip circle of a finished examination. "Set area centre to circle centre" makes sure that the generated grid is aligned centrally to the current circle centre. The next two options allow you to select the possible minimum or maximum radius for the current circle centre. "Most unfavourable radius" adjusts the most unfavourable possible radius for the current circle centre.

The maximum radii are determined by the soil quantity that was defined. The possible minimum radii are determined by the minimum penetration depth of the slip circles. The minimum penetration depth is defined in the basic parameters.

You can move the slip circle centre and its radius with the mouse. The calculation result is updated in accordance with the motion of the mouse.

Ground extension

This function allows you to extend the maximum area to be examined if it should turn out during the design that the defined system is insufficient to adjust the decisive radius and/or slip circle centre.



Output

Output of the system data, results and graphical representations on the screen or the printer.

The output menu item in the main menu provides access to the output options:

Screen	displays the values in a text window on the screen
Printer	starts the output on the printer
Word	allows the output in the form of an RTF file. The application MS Word is launched (if installed). You can format the output individually in Word.

To start the output, click on the corresponding button.

Text - output profile

You can define additional output details that facilitate the comprehension and tracing of the calculation results. The slice subdivision, for instance, provides more detailed information on the areas into which a slice is divided due to the seepage line, soil layers etc.