Slope Failure Analysis – BBR+

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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 in the Campus-download-section.

Application options

Scope of services

The BBR+ program determines the slope failure safety of a defined area and displays this in the form of a degree of utilization.

The BISHOP slice method is used to determine the degree of utilization. The utilization is determined for a slip circle, which results from the definition of center and radius.

To simplify the terrain input, an assistant has been implemented, which generates a system from a few essential parameters.

It is also possible to define a rectangular area for various slip circle centers. Depending on the user's specifications, a slip circle variation can be carried out so that the form and position of the decisive slip circle can be determined quickly.

Possible definitions

- Polygonal input of terrain, soil layers and groundwater course.
- Permanent and variable loads on the terrain.
- Multiple drainage systems.

Standards

- DIN EN 1997-1 with NA
- ÖNORM EN 1997-1 with NA
- DIN 1054 combined with DIN 4084

Application limits

The proof of slope failure carried out in the BBR+ program is based on the BISHOP slice method. Only circular fraction figures are possible. The program offers the possibility of working with one, two or no constraint points. It is possible to define multiple hills and valleys.

Calculation bases

Actions and loading

Loads are always entered characteristically. Permanent and variable actions are available.

Verification method

The program uses DIN 4084 or DIN EN 1997-1 combined with DIN 1054 or ÖNORM B 1997-1 for Eurocode 7 with German and Austrian application documents.

Verification method 3 is used, with a combination of partial safety factors according to EN 1997-1 from A2 + M2 + R3.

Safety factors according to DIN EN 1997-1 and DIN 1054

Safety factors on actions from DIN 1054, Table A2.1:

Action: GEO-3		BST-P	BST-T	BST-A
Permanent	γ_G	1,00	1,00	1,00
Variable	γ_Q	1,30	1,20	1,00

Safety factors for resistance values from DIN 1054, Table A2.2:

Resistance: GEO-3		BST-P	BST-T	BST-A
Shearing resistance factor for un-/drained soil	γ_φ , $\gamma_{\gamma u}$	1,25	1,15	1,10
Cohesion c‘ of drained soil and shear strength c_u of undrained soil	γ_c , γ_{cu}	1,25	1,15	1,10

Safety factors according to ÖNORM B 1997-1

Safety factors for actions ÖNORM B 1997-1, Table 16:

Action		Symbol	Values		
Duration	Condition		BS 1	BS 2	BS 3
Permanent	Unfavourable	γ_G	1,00	1,00	1,00
	Favourable	γ_G	1,00	1,00	1,00
Variable	Unfavourable	γ_Q	1,10	1,10	1,10
	Favourable	γ_Q	0,00	0,00	0,00

Safety factors for resistance values ÖNORM B 1997-1, Table 17:

Soil parameters	Symbol	Value for consequence class								
		CC 1			CC 2			CC 3		
		BS 1	BS 2	BS 3	BS 1	BS 2	BS 3	BS 1	BS 2	BS 3
Effective angle of shearing resistance	γ_φ	1,10	1,05	1,00	1,15	1,10	1,05	1,30	1,20	1,10
Effective cohesion	γ_c	1,10	1,05	1,00	1,15	1,10	1,05	1,30	1,20	1,10
Weight density	γ_γ	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00

Slope failure stability

In order to achieve sufficient safety against failure, the ratio of the design values of the actions and resistances must be ≤ 1:

$$\mu = {}^{E_M}/_{R_M} \leq 1$$

E_M is the sum of the acting moments around the center of the currently considered slip circle:

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

R_M is the sum of the resisting moments around the center of the currently considered slip circle:

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

From the above formulas it is clear that the utilization µ is on the left as well as on the right.

Therefore, an iterative procedure is used to find the result. Utilization is estimated and this estimate is used for calculation and verification. This process is repeated until the deviation from the previous iteration step is less than 3%. This accuracy of 3% can be changed in the "Design" input menu.

Input

The values and control parameters are entered in the menu on the left-hand side. The effect of the entries can be checked immediately in the graphic on the right-hand side. Before the first entry, you can change the units of measurement (cm, m ...) via File ▸ Program settings if required.

Assistant

The most important key data of the system (soil layers and terrain) can be entered quickly with the Assistant, which can then be edited/adapted in the left input area and/or in the interactive graphic interface.

Note: *The Assistant appears by default/automatically when the program starts, but can be switched off if required.*

In the Assistant you can define one to three slopes and specify the number and thickness of the soil layers. The soil layers initially all have the same distance to each other and standard properties, which can be modified later.

Input options in the 3D graphics

A general description of the input options in the graphics window can be found in the document „Operating Basics PLUS".

- A click with the left mouse button selects a graphic element.
- After selection, the graphic element can be moved by "Drag & Drop".
- Double-clicking on a graphic element opens the corresponding input dialog with the associated parameters.
- A click with the right mouse button on a graphic element opens the appropriate context menu.
- The dimension chains can be edited directly.
- The individual points can be edited/moved in the graphic (see fig. below).
- The texts at the top left of the graphics window are sensitive and can be clicked on (text links).
- Graphically moving the slip circle center to view all possible slip circles and their utilization.
- Simple treatment of superimposed points/lines through appropriate graphic mapping.

Fig.:
The context menu when right-clicking on a point

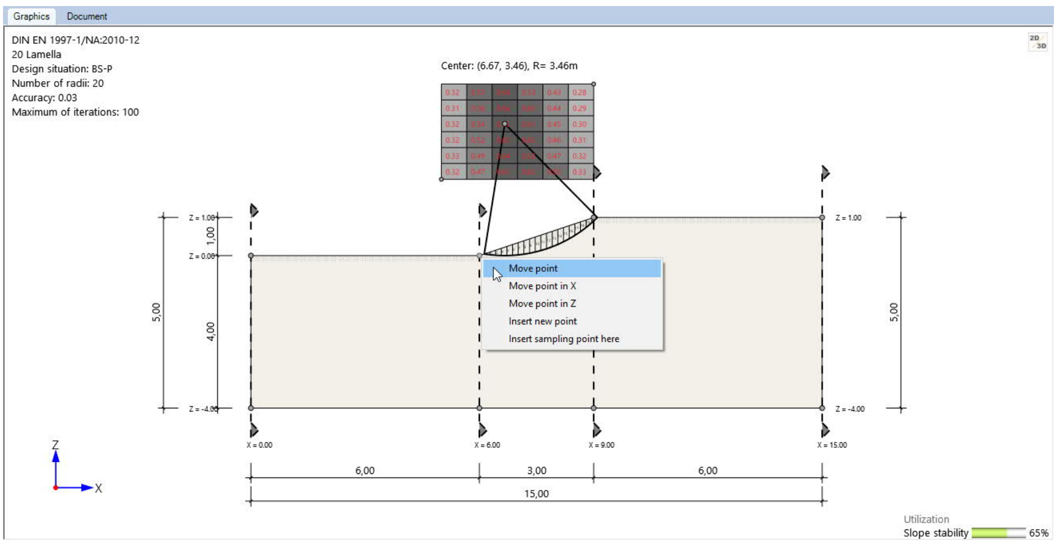


Fig.:

Display of a tool tip after selecting an object with the left mouse button

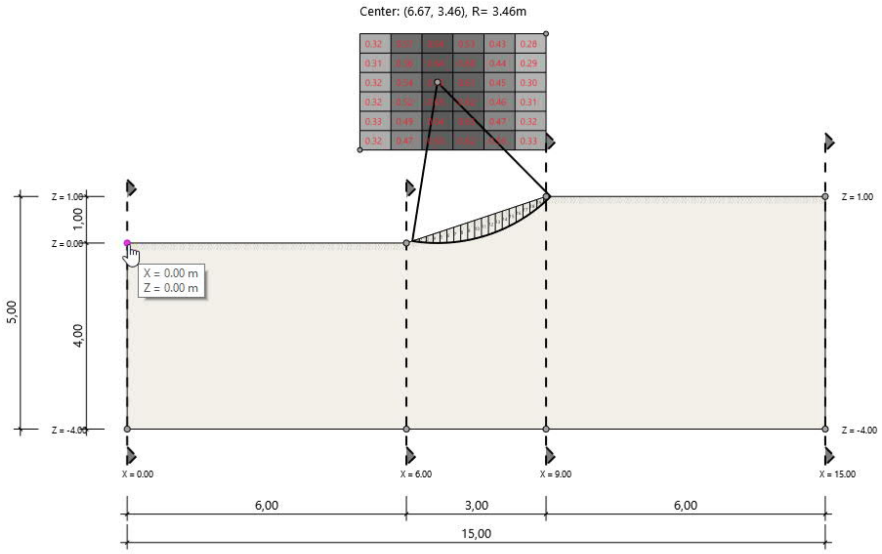
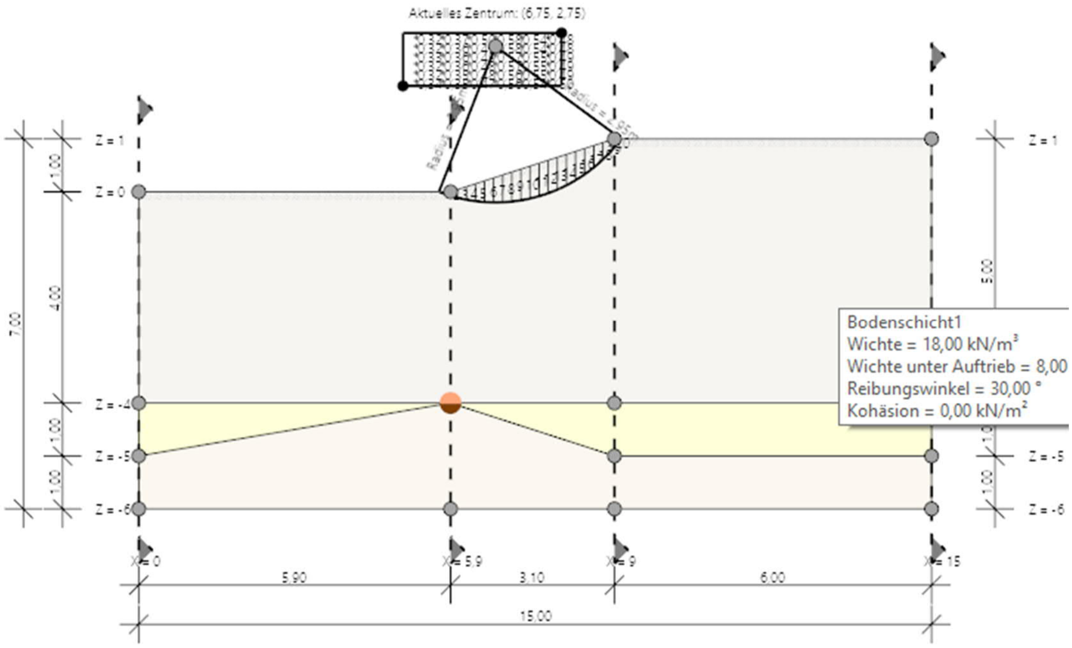


Fig.:

Model with superimposed points. A click on the upper hemisphere selects the point of the upper soil layer and vice versa.



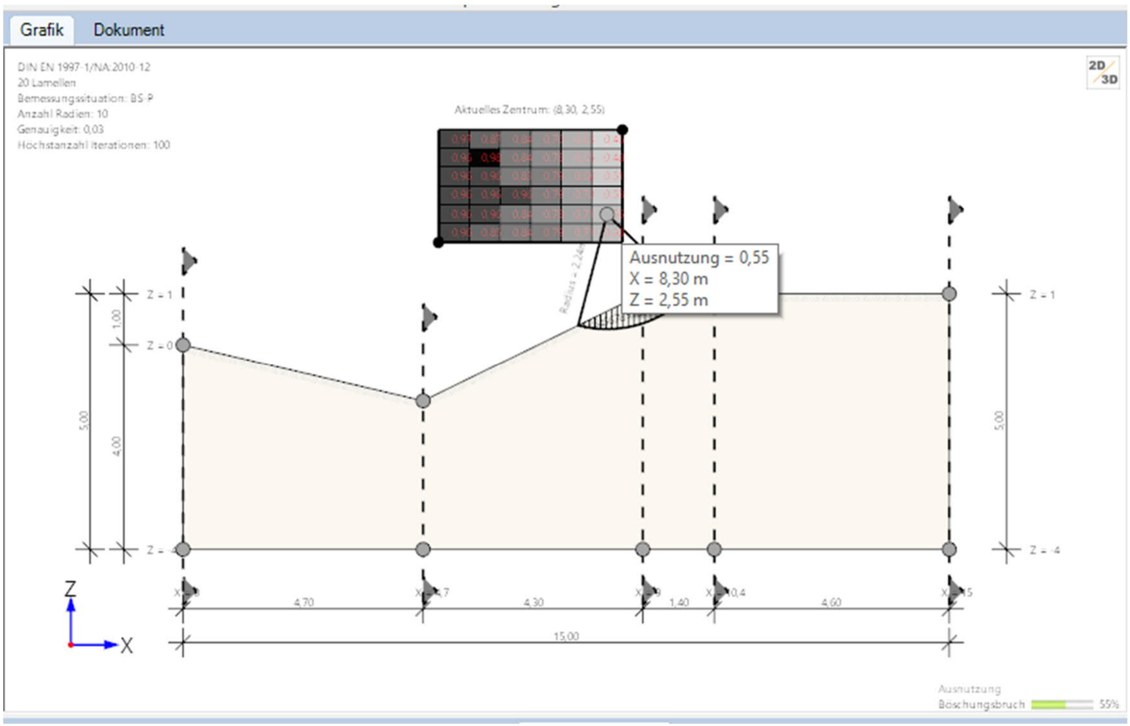


Fig.: Shifting of the center point of the slip circle and corresponding representation of the associated utilization and the slip circle

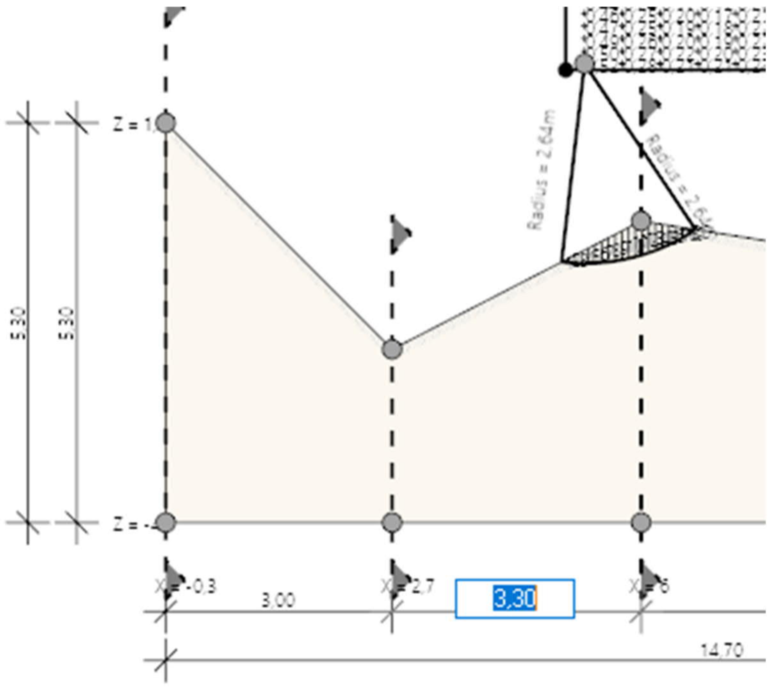
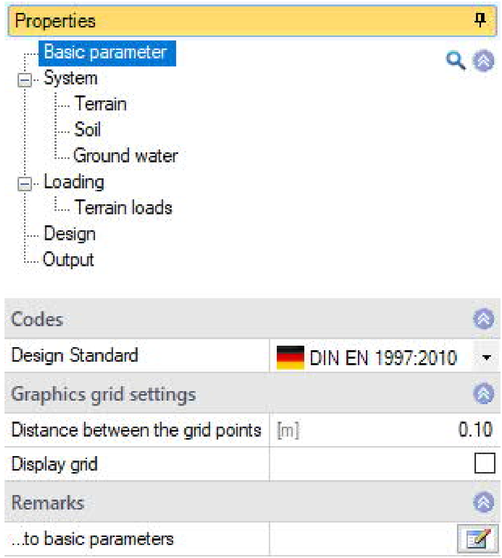


Fig.: Changing a section length by editing the dimension chain in the graphic

Basic parameters

Standards



Here you select the design standard on which the proof of structural safety is based.

Note: *In the case of Eurocodes, the national version of the European standards is referred to at the same time as the respective national annex.*

Graphics grid settings

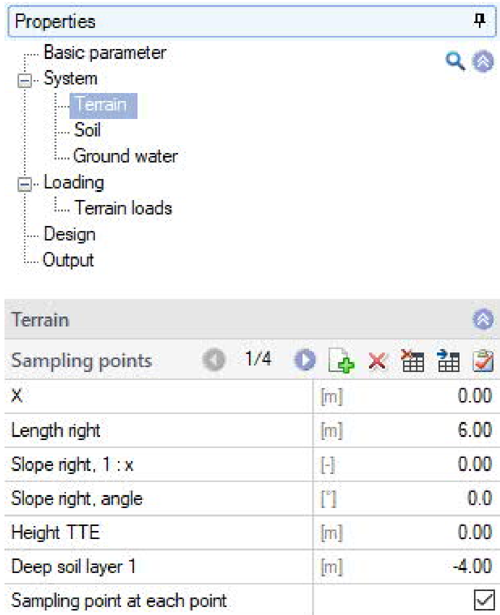
A rectangular snap grid can be defined here and displayed in the graphic in order to increase drawing speed and efficiency. The distance between the grid points can be set as a parameter.

The grid is a rectangular pattern of lines or dots covering the XZ plane. Working with the grid is a bit like underlining a drawing with a piece of graph paper. You can use the grid to align objects and see the spaces between them. The grid does not appear in the plotted drawing.

Grid snap constrains the movement of the mouse to the intervals you specify. When moving terrain/groundwater points with the mouse, the grid serves as a snap point (the grid is displayed in the background).

System

Remarks on the system



You can enter and format remarks using an Editor. These appear with the system data in the output.

Terrain

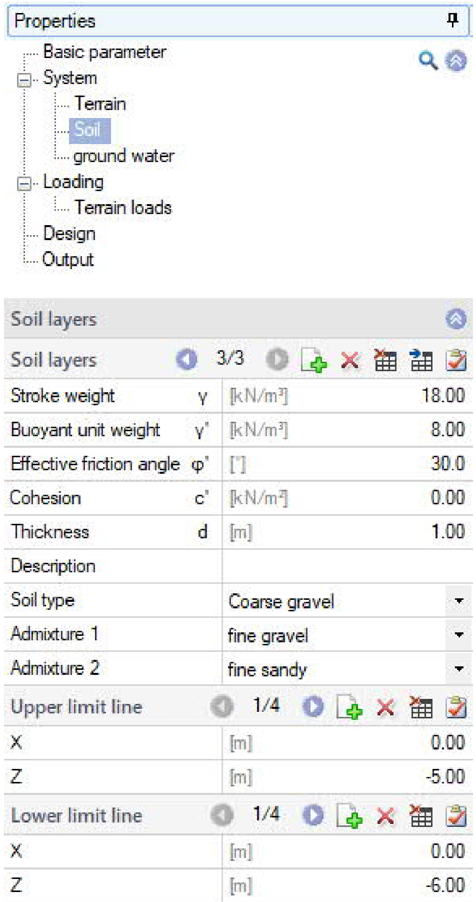
An input table is displayed via the "Sampling points" tab below the graphic. Alternatively, you can also use the Table entry on the left.

Use the green "plus" symbol to create a new table row.

Sampling points / vertical section

X	X coordinate of the vertical section
Length right	The length right of the cut to the next cut
Slope right, 1 : x	The slope of the ground level to the right of the section, 1 meter difference in elevation over x meters of horizontal length
Slope right, angle	The slope of the ground level to the right of the section, represented as an angle in degrees
Height TTE	The height of the terrain top edge at this section
Deep soil layer x	The thickness of the xth soil layer in this section
Sampling point at each point	Automatically places a cut at each model point

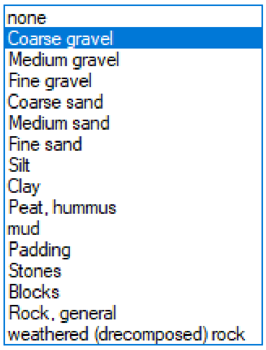
Soil



A clear input table is displayed via the "Soil" tab below the graphic. Alternatively, you can also use the Table entry on the left.

Use the green "plus" symbol to create a new table row.

Soil layers



Density, density under buoyancy, angle of friction and cohesion are to be entered characteristically for each soil layer.

Thickness d Thickness/height of this soil layer

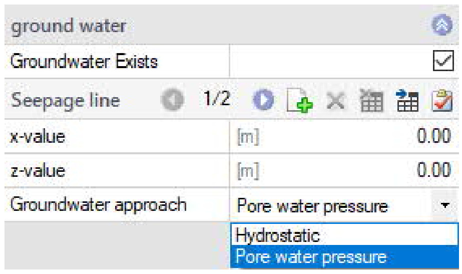
You can also enter your own name for the soil layer and select the soil type and admixture (see selection list).

Upper/lower limit line

The upper/lower limit line has already been defined under "Terrain" via Slope/Terrain top edge.

Here you can adapt/edit the individual points again if necessary, whereby the pure X/Z coordinates of the points are to be specified here. Depending on personal preference, you can also move the points directly in the graphic.

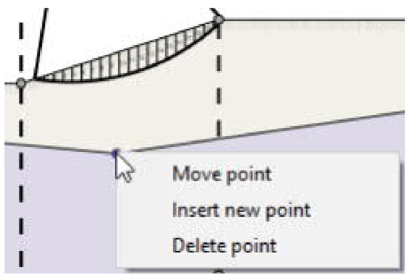
Ground water



Ground water exists Check this option to show the ground water parameters.

If ground water is activated, you can define the seepage line. Use the green "plus" symbol to create a new point and enter its x/z coordinates. The points are shown in blue in the graphic and can also be moved there directly: click once to select a point, then the point can be moved with the mouse - alternatively the point can be clicked with the right mouse button to open the context menu with the related functions.
See also Basic parameters - Graphics Grid.

Ground water approach The ground water can be taken into account either via pore water pressure as an internal force or hydrostatically as water pressure and external force in the slope failure analysis.



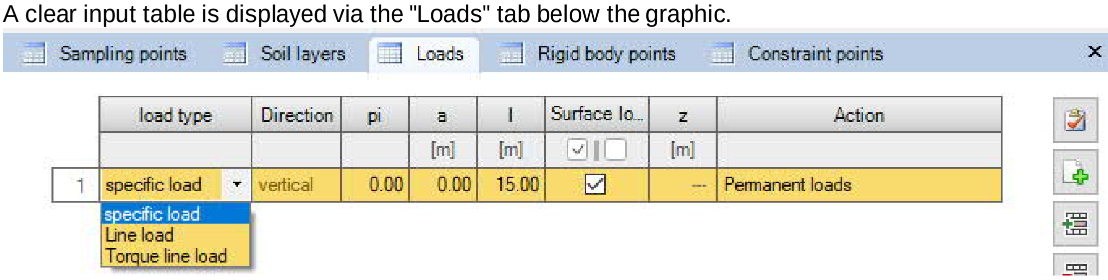
Loading

Remarks on the actions

You can enter and format comments using an [Editor](). These appear under "Loading" in the output.

Loading

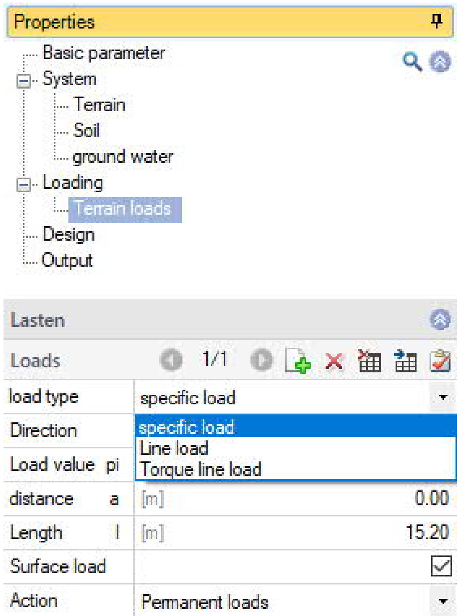
A clear input table is displayed via the "Loads" tab below the graphic.



Alternatively, you can also use the [Table entry]() on the left.

Use the green "plus" symbol to create a new table row.

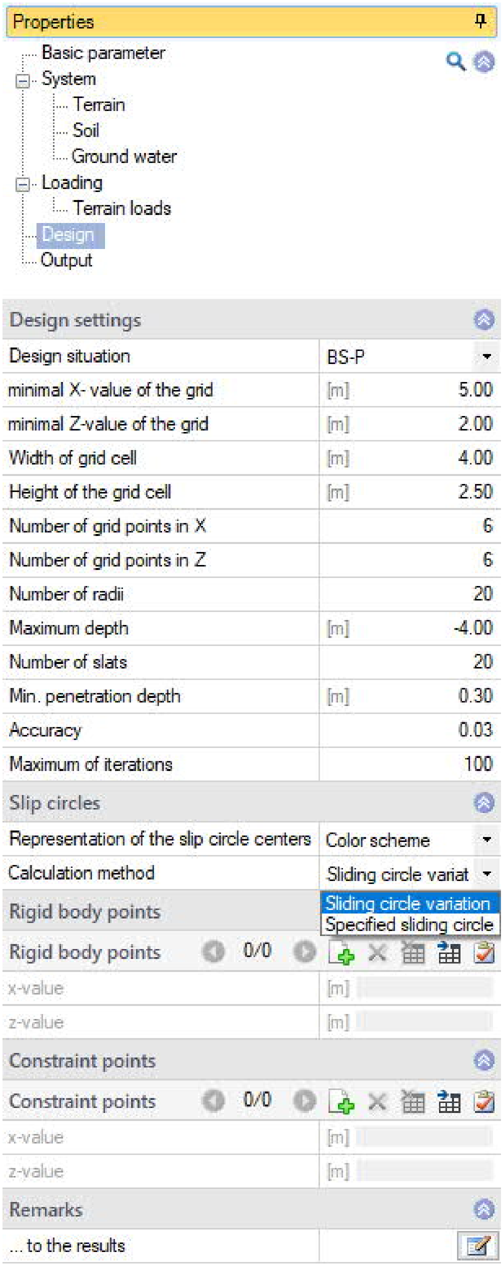
Load type	Area, line and moment line loads are available for selection.
Direction	With line loads, you can choose between vertical and horizontal load directions.
Load value pi	Input of the load value.
Distance a	Distance of the beginning of the load from the left edge.
Length l	In the case of area loads, the length of the load.
Surface load	Remove the marking to be able to enter an attack depth z.
Action	Here you assign an action group to the load.



Design

Remarks

You can enter and format comments using an Editor. These appear under "Results" in the output.



Design settings

Design situation	Selection BS-P / BS-T (permanent or temporary design situation)
Minimal value ...	X or Z coordinate of the bottom left point of the grid of the slip circle centers.
Grid width/height	Width/height in X or Z direction of the grid of the center points of the slip circle.
Number of grid points	Number of positions in the X or Z direction at which the center point of the slip circle should be located. The midpoints are evenly distributed.
Number of radii	Number of radii of the radii to be examined. The radii are evenly distributed between the minimum and maximum radius. The minimum radius results from the condition that the slip circle intersects the terrain, the maximum radius results from the depth of the soil layers entered.
Maximum depth	Absolute depth (related to the coordinate system) down to which slip circles should be checked.
Number of slats	The finer the slat division, the more accurate the result. Normally, a fineness of 20 slats is sufficient. The actual number of slats used also depends on constraint points, such as layer boundaries or load application points, and therefore does not have to match the value given here exactly.
Min. penetration depth	In order to rule out circles that are too superficial and too small, a minimum penetration depth can be specified for all slip circles.
Accuracy	The specified tolerance for stopping the iteration (corresponds to the deviation between the degree of utilization μ assumed by the program and the degree of utilization μ calculated in the next iteration step)
Maximum number of iterations	Here you specify the maximum number of iteration steps after which the iteration is terminated.

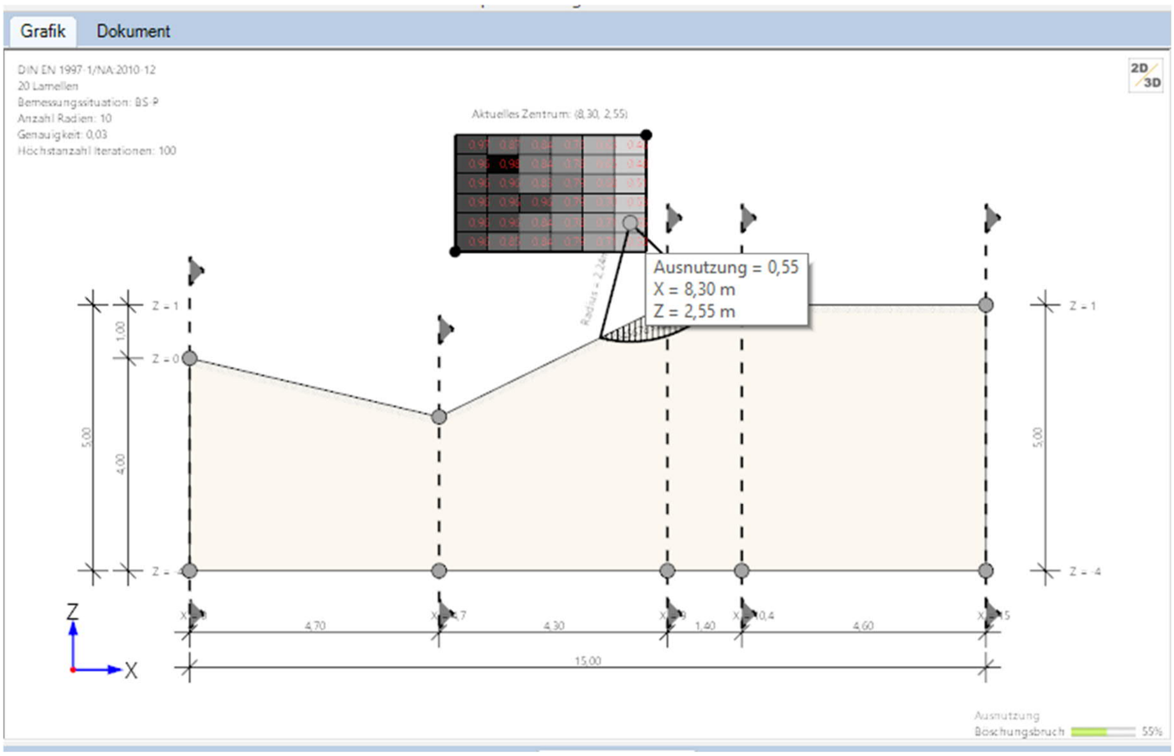
Slip circles

The representation of the slip circle centers in the graphic can only be done with numerical values or in combination with a stored color scheme.

Slip circle variation

The slip circle variation is used to calculate many slip circles and thereby find out the most unfavorable and decisive one.

To do this, rectangular areas can be selected whose grid defines the center points of the circles. The possible radii are then varied for the slip circle centers.



In the example shown, a rectangular area is examined. The grid 6 and 6 result in 36 slip circle centers. The number of radii is 10. If there are 3 or more radii, intermediate radii are examined for each center point in addition to the maximum and minimum possible radius (ie 8 intermediate radii in the example).

The minimum possible radius results from the minimum penetration depth of the slip circle in the ground - the value can be modified in the design parameters. Alternatively or additionally, the minimum penetration depth can also be controlled by defining rigid body points (see below).
The maximum glide circle is defined by the existing terrain - glide circles do not leave the defined terrain. Alternatively, a maximum penetration depth can also be specified in the design parameters.

The examination is started automatically with the "Calculate" button in the top menu or with activated "Auto-Calculation". After the end of the investigation, the result is shown in the graphic window with the degree of utilization and the relevant slip circle in the rectangular area being examined.

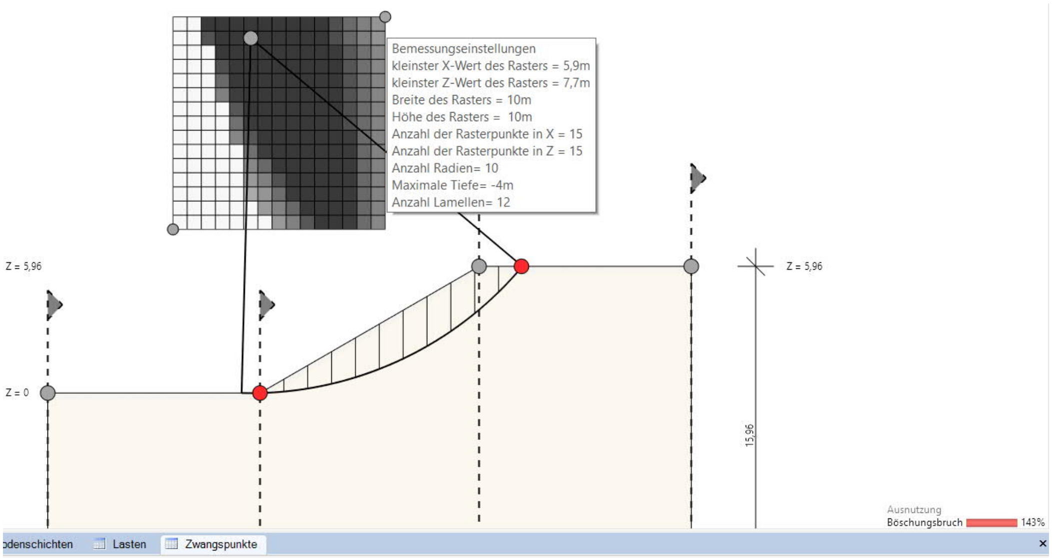
Note ! *The results in the variation are always related to the center point in each square of the grid.*

Variation example

Here, an area of 15 x 15 elements is examined and the result of the utilization is displayed for the respective element center in the form of a color scheme. Alternatively, the utilization can also be displayed in the form of a numerical value for each element.

If the examination area is now moved, the newly found circle center is used for calculation and the corresponding result is displayed. This can now result in a larger value being found for the utilization. If you select a larger number of elements in advance (e.g. 100 x 100), the probability that there will still be outliers is significantly lower.

The conclusion: the finer the mesh, the lower the probability that the maximum utilization will not be found in the defined area - this, however, requires an increased computing time.



Variation of center area

In addition to varying the possible slip circle center points within the defined rectangular grid, the specified grid itself can also be varied. To do this, the geometric dimensions of the grid can be enlarged or reduced as required in the dimensioning options.

Furthermore, the position of the grid can also be moved in the graphic using the numerical specification or with the mouse. The resulting degrees of utilization of the slip circles within the grid are recalculated simultaneously with activated auto-calculation and output directly in the graphic.

Such an adjustment of the grid position is always recommended when the decisive slip circle with the greatest utilization is in the edge area of the currently defined grid. In this case, it cannot be ruled out that a slip circle with greater utilization outside the grid is possible but could not be followed in the iteration due to the current grid limits.

Specified/Default slip circle

As an alternative to the slip circle variation, a specific slip circle can also be specified. To do this, the coordinates of the slip circle center to be calculated (x and y coordinates) and the associated slip circle radius are defined. This option is used, for example, to check or recalculate a predefined decisive slip circle.

Rigid body points

In BBR+ the rigid body points constrain the minimum radius of the slip circles. The rigid body points must not lie outside the slip circles. As its name suggests, a rigid body point describes the end point of a rigid object which, due to its stiffness properties, cannot be cut above slip circles.

Such rigid bodies include structures or security measures such as:

- Foundations
- Piles
- Anchors
- Dowels
- Geosynthetics
- Columns from soil improvement measures (e.g. vibratory tamping columns, HPI columns)

... etc.

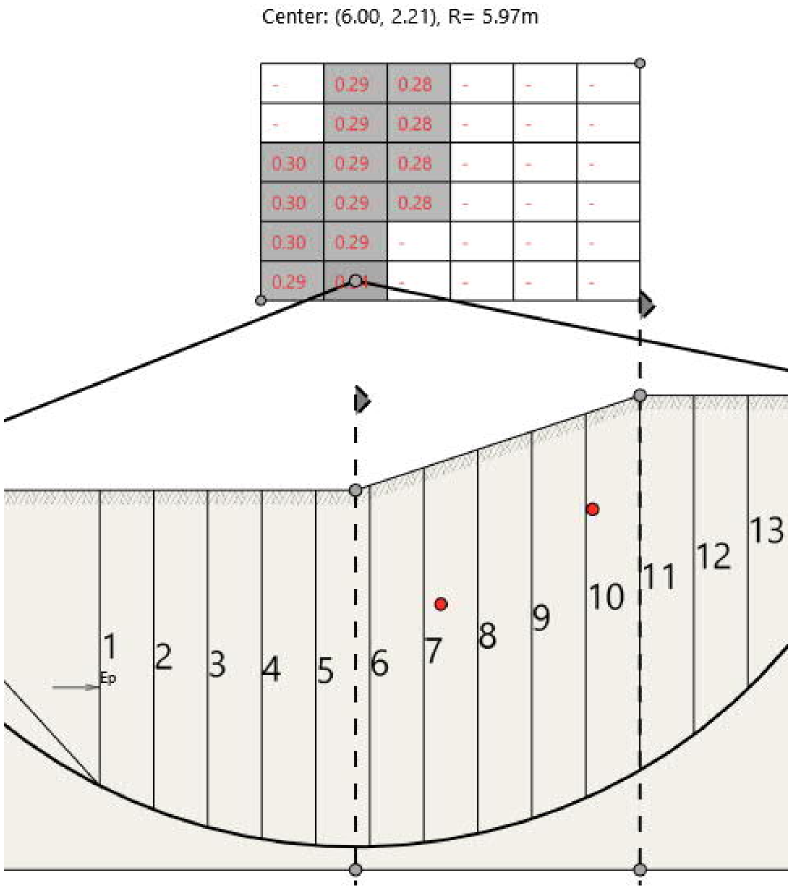
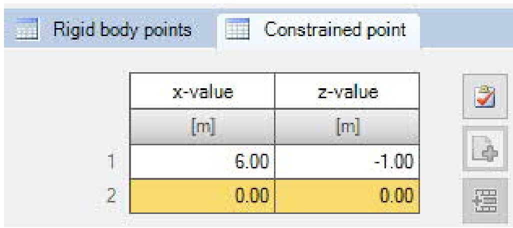


Fig.: Rigid body points in BBR+

Constraint points

One, two or no constraint points are possible. Constraint points severely limit the number of possible slip circles. In the case of homogeneous soil and a constant slope and otherwise homogeneous conditions, the decisive slip circle usually runs through the base of the slope.



The input table is displayed via the "Constraint points" tab below the graphic. Alternatively, you can also use the Table entry on the left.

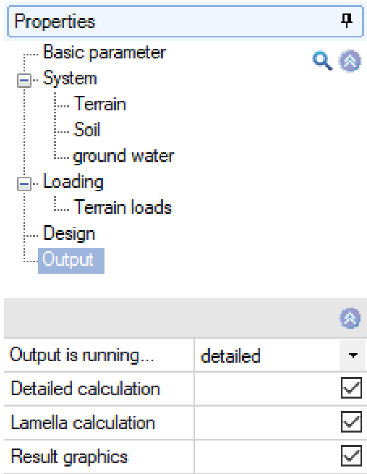
Use the green "plus" symbol to create a new table row.

The constraint points can also be moved directly in the graphic with the mouse.

Output

Output scope and options

By marking the various options, you determine the scope of the text output.



Results

The result graphics can be displayed via the "Results" tab in the top menu.

Output as a PDF document

The output document is displayed in PDF format via the "Document" tab.

See also Document Output and Printing.