SOLPLAN

FOUNDATION ANALYSIS SOFTWARE

SLOPE STABILITY ANALYSIS · LIMIT EQUILIBRIUM

Solstability

User Manual

Building, running and reporting slope stability analyses with Solstability.

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SPL-SS-001	Solstability — End-User Licence Agreement	Terms under which Solstability is licensed to its users.
SPL-SS-002	Solstability — User Manual	Building, running and reporting slope stability analyses with Solstability.
SPL-SS-003	Solstability — Technical Reference	Limit equilibrium methods, slip surfaces and their search, water, loads, reinforcement and verification.
SPL-SS-004	Solstability — Release Notes	Scope, requirements and known limitations of release 1.0.1.
SPL-SS-005	Solstability — Third-Party Software Notices	Open-source components distributed with Solstability and their licences.

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1 Introduction

1.1 Purpose and scope of this manual

This manual explains how to install Solstability 1.0.1, how to describe a slope in it, how to run a stability analysis, and how to check, report and exchange the results. It is written for geotechnical engineers who are familiar with the stability of slopes and with limit equilibrium methods. The methods and their equations are given in the Technical Reference (SPL-SS-003); this manual refers to it where a choice in the program depends on the theory.

1.2 What Solstability computes

Solstability computes the factor of safety of a slope by limit equilibrium: the ratio between the shear strength available along a slip surface and the shear stress needed for equilibrium. The program

- describes the ground as soil layers with interface polygons for slopes, fills and cuts, with water, loads, earthquake and reinforcement;
- analyses a circular or polygonal slip surface with the methods of Bishop, Fellenius / Petterson, Spencer, Janbu, Morgenstern-Price, Shahunyants, ITFM or Sarma;
- searches for the critical slip surface by optimization, by a grid of circles or by random trial surfaces, and shows the search on the drawing as it proceeds;
- verifies the result against a required factor of safety, partial factors of EN 1997, LRFD 2012 or the Chinese standards; and
- writes reports in PDF, Word, Excel and HTML, exports tables to Excel and CSV, and can be driven from a command line, a batch run of several projects, or an MCP server.

1.3 Conventions used in this manual

Names of menus, commands, steps, buttons and fields are printed as they appear on the screen, for example **Analysis ▸ Run Analysis**. File names and folders are printed as %APPDATA%\Solplan\Solstability. Unless stated otherwise, values are given in SI units; every input can also be entered in US units (Section 3.3).

1.4 Documentation set

Table 1.1 — Documentation of Solstability

No.	Title	Content
SPL-SS-001	End-User Licence Agreement	Terms of use, free licence and session rules
SPL-SS-002	User Manual	This document
SPL-SS-003	Technical Reference	Methods, slip surfaces and search, water, loads, reinforcement, verification
SPL-SS-004	Release Notes	Contents, requirements and known limitations of the release
SPL-SS-005	Third-Party Software Notices	Open-source components and their licences

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2 Installation, licence and start-up

2.1 Requirements

Solstability runs on Windows 10 or 11, 64-bit, with at least 4 GB of memory and 1 GB of free disk space. A connection to the internet is needed while the program is in use, for the licence. The full requirements are listed in the Release Notes (SPL-SS-004).

2.2 Installing

Run Solstability-1.0.1-Setup.exe, accept the End-User Licence Agreement and follow the setup. Setup needs administrator rights and installs into C:\Program Files\Solplan\Solstability. An upgrade is installed over the previous release; project files and settings are kept.

2.3 Licence and sign-in

Solstability is free for every holder of a solplan.id account. Create an account at solplan.id (with an e-mail address or with Google) if you do not have one. When Solstability starts it asks you to sign in; at the first sign-in the account receives its free Solstability licence automatically, and nothing has to be bought or started. The rules that affect daily work are these:

- An account can have one active session at a time. Signing in on a second computer ends the session on the first.
- Solstability checks the licence every few minutes while it runs. If the licence server cannot be reached, it warns and keeps working for a short time, so that the work can be saved.
- To work without a connection, borrow the licence beforehand in **Help ▸ Licence…** for 1 to 30 days. Return it there when you are back on-line.

Help ▸ Licence… shows the account signed in and the licence in use; **Manage account…** opens the account page at solplan.id, and **Sign out** ends the session on this computer. If the account has no active licence, Solstability offers **My licences**, **Check again**, **Sign out** (to sign in with a different account) and **Close**. Signing out of the website does not sign out the program.

NOTE Project files are always stored on your own computer. The licence service receives account and session data only, never project data (EULA SPL-SS-001).

2.4 Starting the program

Start Solstability from the Start menu (**Solplan ▸ Solstability**) or by double-clicking a project file. A new, empty project opens; **File ▸ Input examples** opens prepared examples of an embankment with and without ground water.

2.5 Files and folders

Table 2.1 — Files used by Solstability

File or folder	Content
`*.sstab`	Project file (JSON text, UTF-8). All stages, analyses, settings and pictures of a project are in one file. Saved atomically: a failed save does not damage the previous file.
`*.dxf, *.xml, *.ifc`	Interfaces exported for CAD and BIM programs; DXF and LandXML files can be imported as interfaces, and DXF as a background drawing.
`%APPDATA%\Solplan\Solstability`	Settings, the licence sign-in (encrypted for the Windows user) and the folder logs.

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3 Modelling concepts

3.1 The analysis model

A Solstability project describes one cross-section of a slope, analysed per metre of slope length. The ground is built from **soil layers**, horizontal layers of given thickness below the model top, and **interfaces**, polygons that describe the slope above the layers, an embankment placed on them or soil cut from them. Each layer and each interface polygon is assigned a **soil**. The ground surface is the upper boundary of all of them. Water, loads, earthquake and reinforcement are added to this geometry, and the **analysis** defines the slip surface, the method and the way the critical slip surface is sought.

A project can hold several **construction stages**, shown as tabs above the drawing. Each stage keeps its own water, loads, reinforcement, earthworks and analyses; the soil layers and soils are common to all stages. Click **+** to add a stage that starts as a copy of the current one; right-click a tab to rename or delete the stage. Within a stage, several **analyses** (slip surface, method, type of analysis) can be kept and compared; they are selected in the **Analysis** step.

3.2 Coordinates and sign convention

The drawing uses *x* to the right and *y* upward; *y* is an elevation, not a depth. A slope may face to the left or to the right; the program finds the direction of sliding from the slip surface. Angles of anchors, nails and loads are measured from the horizontal; their sign is explained next to each field. Forces of elements with a spacing along the slope (anchors, nails, piles) are entered per element and divided by the spacing.

3.3 Units and number entry

The system of units is chosen in **Program Options**: SI (m, kN, kPa) or US (ft, kip, ksf). Changing it converts every value of the project. The unit of each field is shown next to it. Numeric fields accept arithmetic, for example `12.5*2`, `3^2`, `sqrt(2)`, `tan(30*pi/180)`; a comma is read as a decimal point.

3.4 How changes are applied

Each data step opens a dialog that edits a draft of the project. The drawing behind the dialog shows the draft as it is edited. **OK** applies the changes as one step that **Edit ▸ Undo** reverses; **Cancel** discards them. Results of an earlier analysis are cleared when the input changes, so that results on the screen always belong to the input on the screen.

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4 The workspace

4.1 Main window

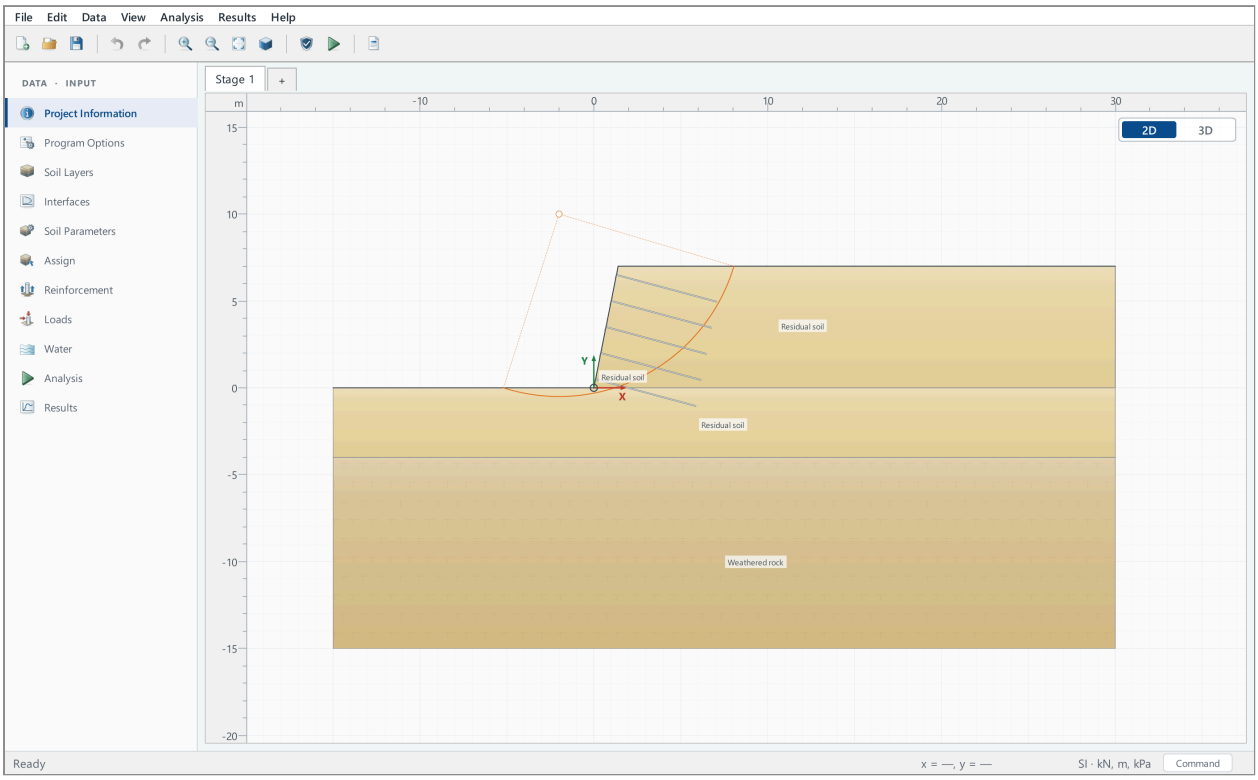


Figure 4.1 — Main window with the example project

The main window (Figure 4.1) consists of the menu bar and toolbar, the **data sidebar** on the left with the data steps in the order in which a model is normally built, the stage tabs, the **drawing** of the cross-section, and the status bar with the cursor coordinates, the units and the **Command** button that opens the command line. The drawing can be zoomed with the mouse wheel and panned by dragging with the left mouse button; **View ▸ Fit to View** shows the whole model.

After an analysis the drawing shows the slip surface and a summary of the result in its upper left corner: the factor of safety in green when the verification is satisfied and in red when it is not, the method, the slip surface and the verification (Figure 4.2). A grid or random search also draws the trial surfaces coloured by their factor of safety, with a colour scale in the upper right corner. The summary and the scale are part of a copied view and of report pictures.

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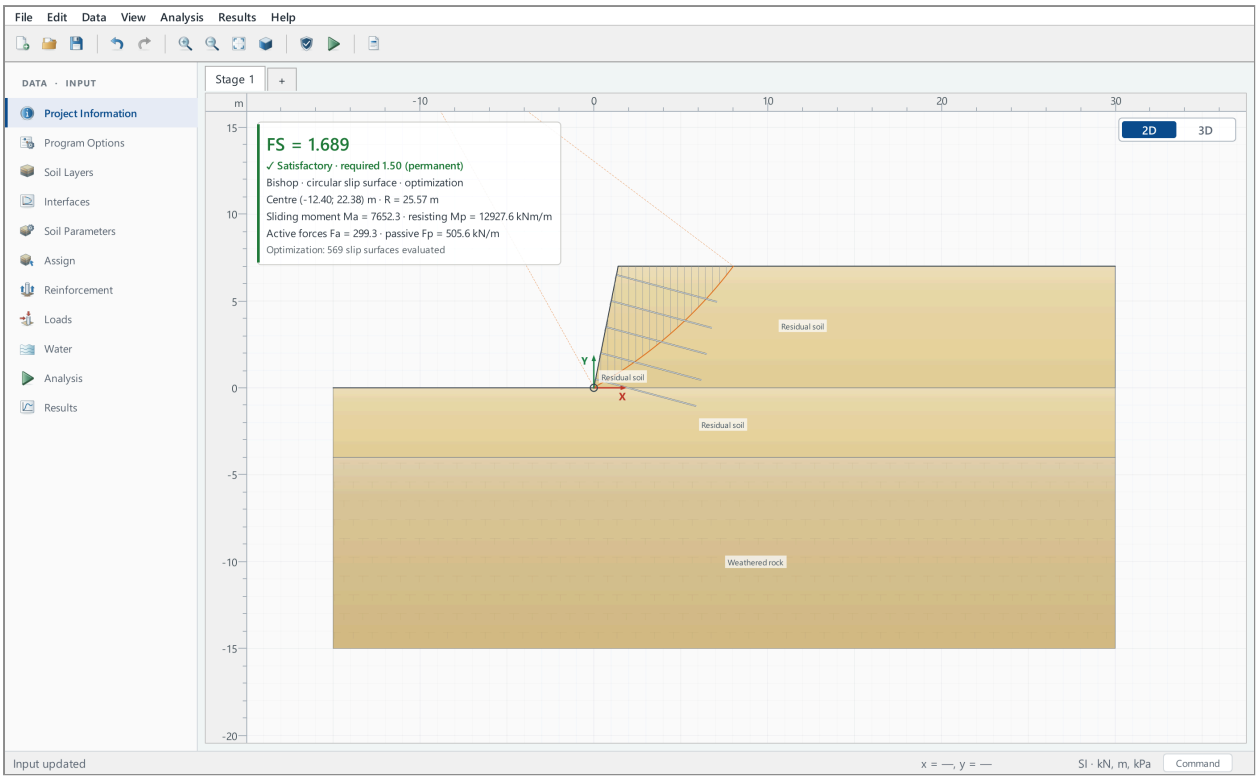


Figure 4.2 — Result on the drawing

4.2 Data steps

Table 4.1 — Data steps

Step	Content
Project Information	Name, number, client, author, date and notes of the project
Program Options	Units, verification methodology and its factors, methods compared by *all methods*
Soil Layers	Templates, layers and their thickness, the model extent
Interfaces	Interface polygons, cuts, rigid bodies and, from the second stage, stage earthworks
Soil Parameters	Soils and their strength, unit weights and water parameters
Assign	The soil of each layer and interface polygon
Reinforcement	Anchors, nails, geotextiles and stabilizing piles
Loads	Surcharges and earthquake
Water	Type of pore pressure input and its data
Analysis	Slip surface, method, type of analysis and its settings; runs the analysis
Results	Summary, tables, exports and the report

4.3 Drawing on the canvas

Points of interfaces, slip surfaces, restrictions, reinforcement and loads can be drawn with the mouse: the drawing buttons in the steps (for example **Draw interface** or **Draw circle**) start the input. Points snap to existing points, intersections, lines and the grid of the drawing settings; hold Ctrl to suspend snapping. Right-click or Enter finishes a polyline, Esc cancels; a polygon whose last point is placed on its first point closes itself. A circle is drawn by clicking two points on the ground surface and then moving the mouse to pull the radius, with a live preview; the third click sets it.

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4.4 Three-dimensional view

The **2D / 3D** switch in the top right corner of the drawing, or **View ▸ 3D View** (F3), shows the model extruded over a width of 10 m, with the reinforcement repeated at its spacing and the slip surface (the input surface, or the result after an analysis) (Figure 4.3). Drag with the middle mouse button to rotate, drag to pan, use the wheel to zoom at the cursor and double-click to fit; the X-Y-Z axes in the corner show the orientation. The view only displays the model; the analysis remains two-dimensional.

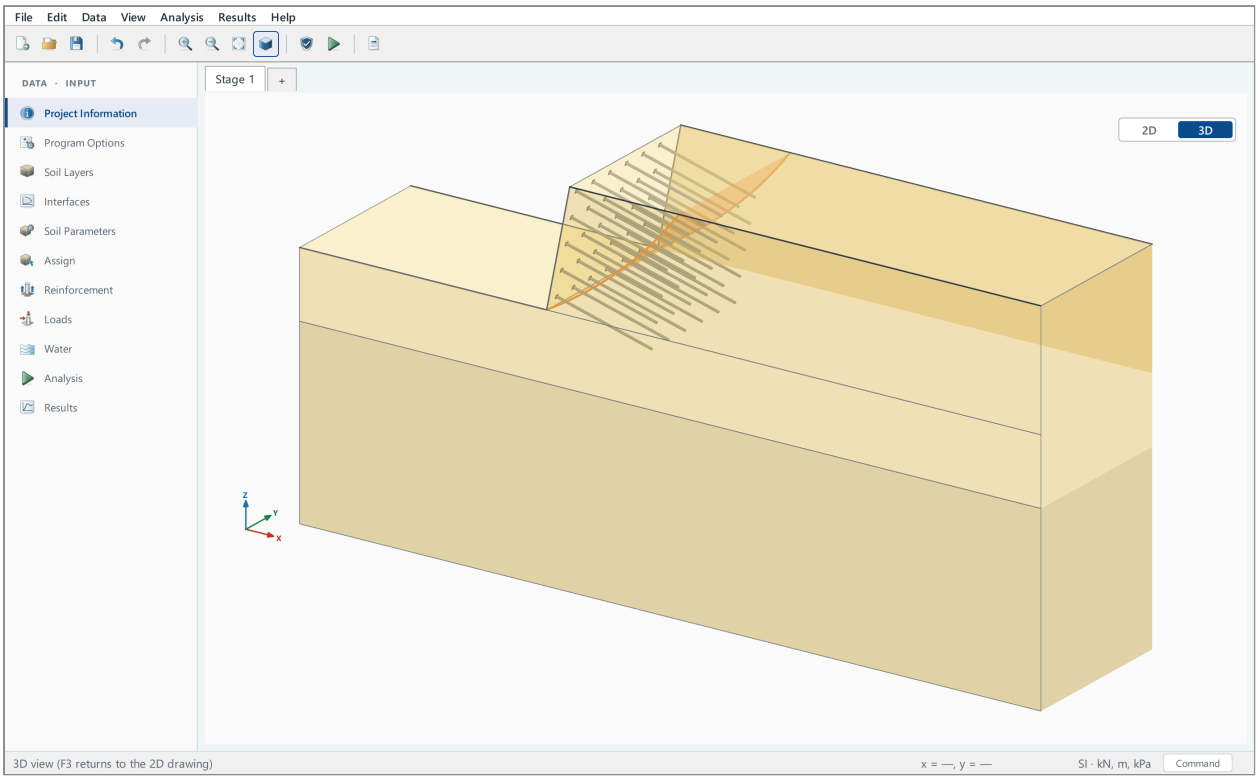


Figure 4.3 — Three-dimensional view

4.5 Reinforcement force diagrams

After an analysis, anchors, nails and geotextiles are drawn with the axial force along their length, and stabilizing piles with their shear resistance, as diagrams beside the elements. The value is written where the slip surface crosses the element: it is the force used by the analysis, the same as in the table **Reinforcement forces** of the results. An anchor carries its prestress along the free length, falling to zero along the root; a nail carries the smallest of its pull-out behind the slip surface, its tensile strength and its head resistance plus the pull-out in front; a geotextile is limited by its tensile strength and its anchorage. **View ▸ Reinforcement Forces** switches the diagrams on and off, and **View ▸ Drawing Settings** chooses their style. The diagrams show the mechanism of the analysis; the bending and shear along a pile come from a single-pile analysis, not from limit equilibrium.

4.6 Menus and toolbar

Table 4.2 — Menu commands

Command	Key	Action
File ▸ New, Open…, Save, Save As…	Ctrl+N, O, S	Project files
File ▸ Reopen		Recently used projects
File ▸ Input examples		Embankment slope, slope with ground water
File ▸ Export…	Ctrl+P	Report or results to a file
File ▸ Import interfaces (DXF / LandXML)…		Interfaces from a CAD or survey file

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Command	Key	Action
File ▸ Import background drawing (DXF)…, Clear background drawing		A drawing shown behind the model, for tracing
File ▸ Export interfaces (DXF / LandXML / IFC)…		Interfaces for CAD and BIM programs
Edit ▸ Undo, Redo	Ctrl+Z, Y	Reverse or repeat the last change
Data ▸ …		The data steps, as in the sidebar
View ▸ Zoom In, Zoom Out, Fit to View	Ctrl++, −, 0	Scale of the drawing
View ▸ 3D View	F3	Three-dimensional view
View ▸ Reinforcement Forces		Force diagrams of the reinforcement after an analysis
View ▸ Annotations…		Texts, dimensions, lines and shapes on the drawing
View ▸ Drawing Settings…		Grid, snapping and what the drawing shows
View ▸ Copy View	Ctrl+Shift+C	The drawing with the result summary to the clipboard
View ▸ Add View to Report		The drawing as a picture of the report
View ▸ Height multiplier		Vertical exaggeration of the drawing (1× to 5×)
View ▸ Data Sidebar, Command Line	Ctrl+L	Show or hide these parts of the window
Analysis ▸ Check Input	F8	Lists problems of the input
Analysis ▸ Run Analysis	F9	Runs the current analysis
Analysis ▸ Multi-File Analysis (Batch Run)…		Runs several project files
Results ▸ Results		Opens the results
Help ▸ Workflow Guide, Licence…, About Solstability	F1	Help, licence and version

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5 Getting started

This chapter takes a first model from an empty project to a verified slope in a few minutes: a single slope 8 m high in silty sand with ground water below the toe. Every value can be typed as given; the results were computed with Solstability 1.0.1.

5.1 The model

1. Start a new project with **File** ▸ **New** (Ctrl+N).
2. In the **Soil Layers** step click **Templates…**, choose *Single slope* and keep the default dimensions: **Height H** 8 m, **Slope 1V:nH** 1.5, **Toe length** 10 m, **Crest length** 12 m and **Depth below toe** 10 m. **OK** draws a slope rising from x = 10 m to 22 m; every point stays editable in the Soil Layers and Interfaces steps.
3. In the **Soil Parameters** step select the soil and click **Edit Soil**. Enter the name *Silty sand*, **Unit weight γ** 19 kN/m^3, **Saturated γsat** 20 kN/m^3, **Cohesion c'** 6 kPa and **Friction angle φ'** 28°. With a single soil the **Assign** step needs no change: the layer and the slope polygon already carry it.
4. In the **Water** step click **Templates…**, choose *Horizontal water table* and enter the **Elevation** −1 m: the table lies 1 m below the toe.

5.2 A first factor of safety

5. In the **Analysis** step keep the circular slip surface, the type *Standard* and the method *Bishop*, and enter a circle with **Centre x** 15 m, **Centre y** 17 m and **Radius** 17.5 m (or draw it with **Draw circle**). **Run Analysis** (F9) gives F = 1.879 for this circle. The value appears in the results summary on the drawing and in the **Results** step.
6. A single circle says little about the slope. Set **Analysis type** to *Optimization* and run again: starting from the circle entered, the program moves it to the critical one, here with centre (9.42, 16.36) m and radius 16.36 m after 839 evaluated circles. The factor of safety is F = 1.364, below the required 1.5 of the permanent situation: the result is shown in red, *Not satisfactory* (Figure 5.1).

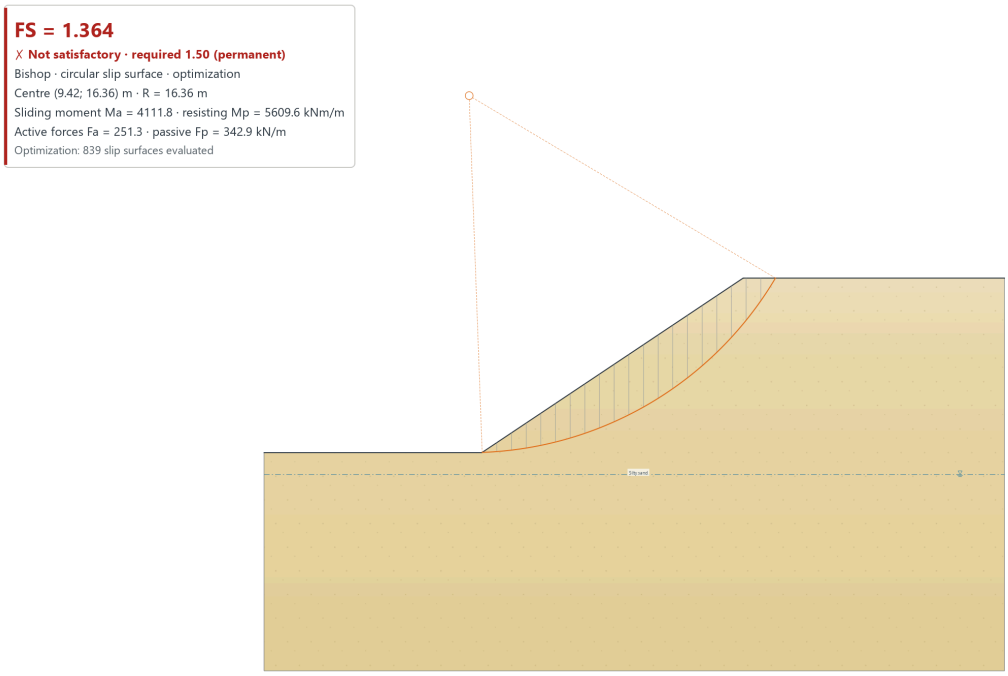


Figure 5.1 — Getting started, critical circle of the slope 1V:1.5H

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5.3 Changing the design

7. Open **Templates…** in the Soil Layers step again and click **1V:2H** before **OK**. The template replaces the interfaces and keeps the soil; the flatter slope makes the model 4 m longer, so place the water table again from the Water templates (elevation −1 m) to carry it to the new right edge.
8. Run the optimization again: the flatter slope gives F = 1.669, which satisfies the requirement; the result turns green.
9. Save the project (Ctrl+S) and open **Report…** in the Results step to print the input, the critical slip surface and the tables (Section 8.4).

The following chapters describe every step in detail; the examples in Chapter 10 continue with ground water, other search types, reinforcement, construction stages and the design standards.

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6 Building a model

6.1 Workflow

A model is built by working through the data steps of the sidebar from top to bottom: the project and its options, the soil layers and interfaces, the soils and their assignment, then reinforcement, loads and water, and finally the analysis. Each step opens a dialog; its drawing buttons let you enter points with the mouse while the dialog waits. Fields that the current choices do not use are greyed out, and their tooltip says why.

6.2 Project information

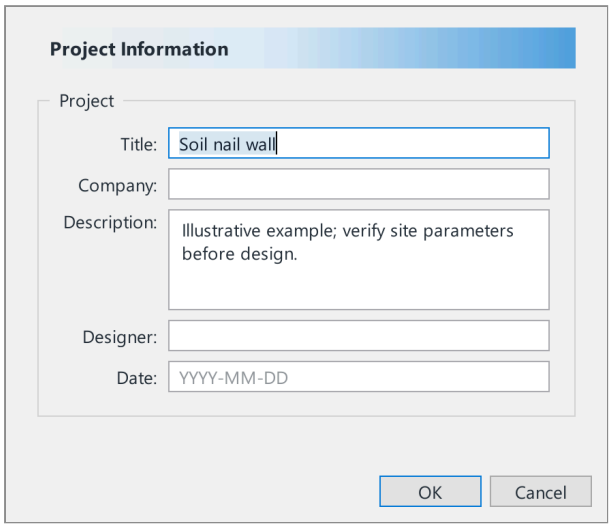


Figure 6.1 — Project Information

The name, number, client, author, date and notes of the project appear in the title of the window and on the report.

6.3 Program options

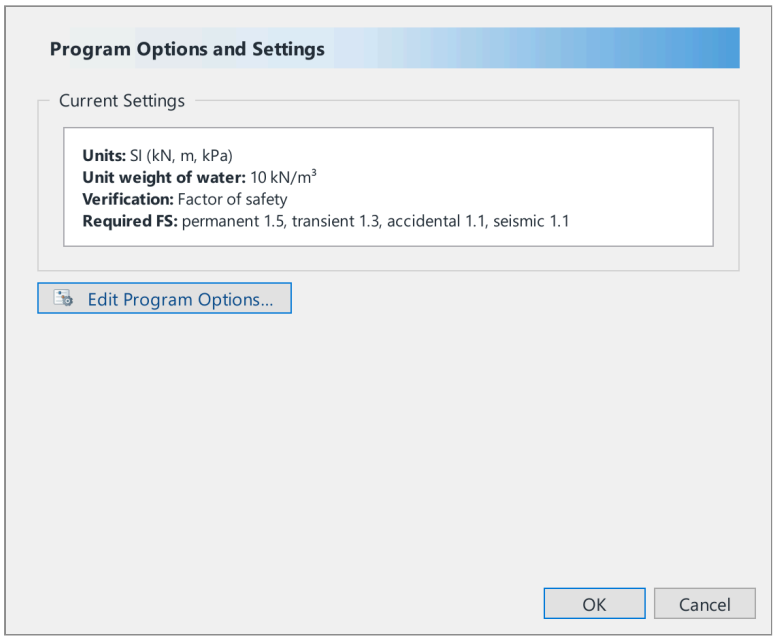


Figure 6.2 — Program Options

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The step sets the system of units and the verification methodology: factor of safety, limit states, EN 1997 with its design approach, LRFD 2012, or the Chinese standards. **Edit Program Options…** opens the settings of the methodology (Figure 6.3): the required factor of safety per design situation, the partial factors, the LRFD load and resistance factors, and the methods that *Analyse with all methods* compares for circular and polygonal slip surfaces. The verification rules are described in the Technical Reference (SPL-SS-003, Verification).

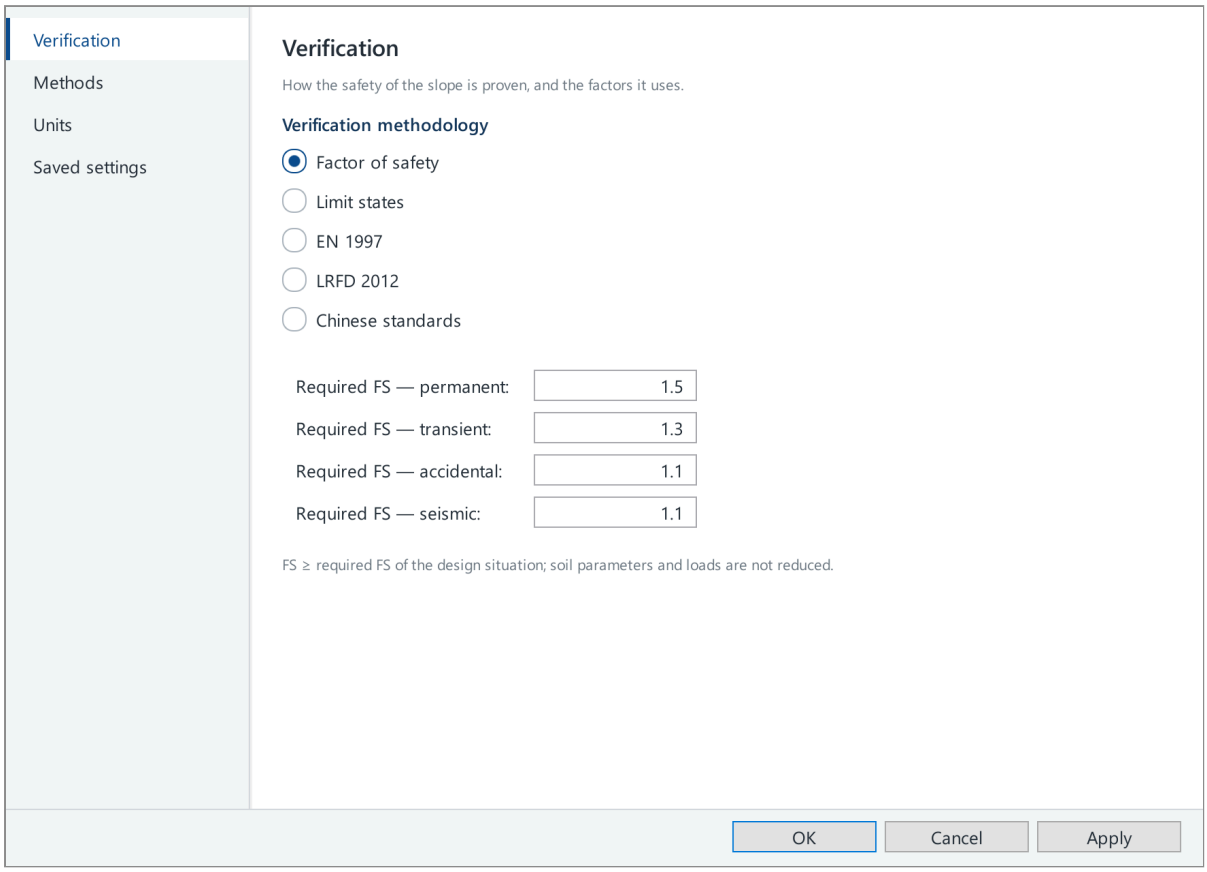


Figure 6.3 — Program Options and Settings

6.4 Soil layers

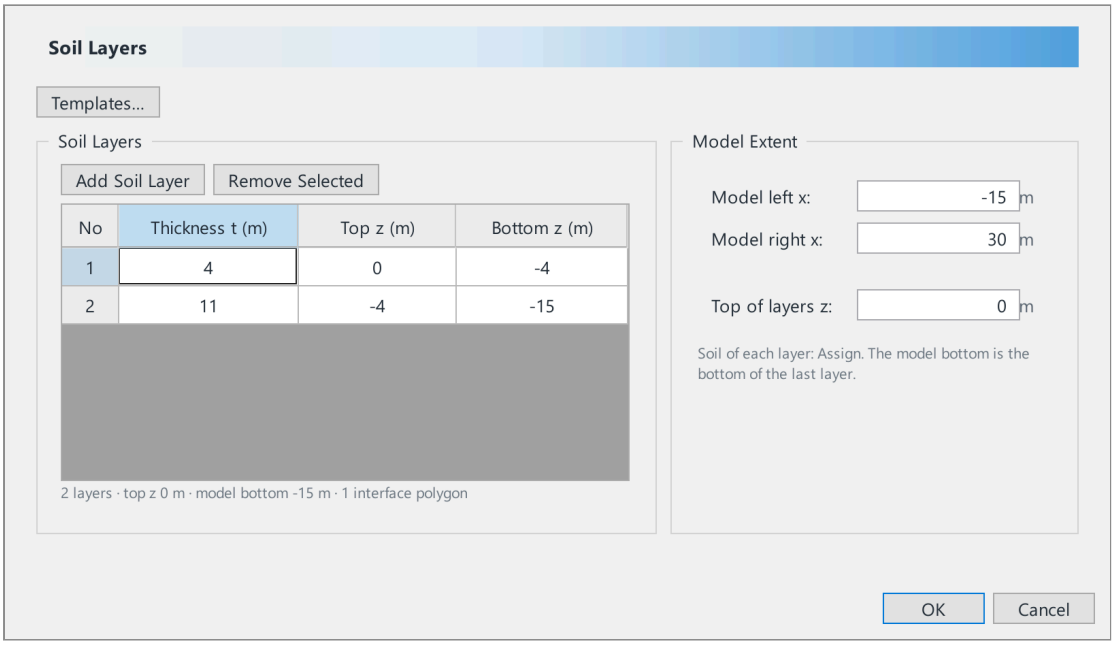


Figure 6.4 — Soil Layers

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The soil layers are horizontal bands below the **Top of layers** elevation, listed from the top with their thickness; the bottom of the model is the bottom of the last layer. **Add Soil Layer** adds a layer at the bottom, **Remove Selected** removes one. **Model Extent** sets the left and right limits of the model. **Templates…** builds a complete geometry from a few dimensions: a single or benched slope, an embankment, an excavation or a layered slope (Figure 6.5).

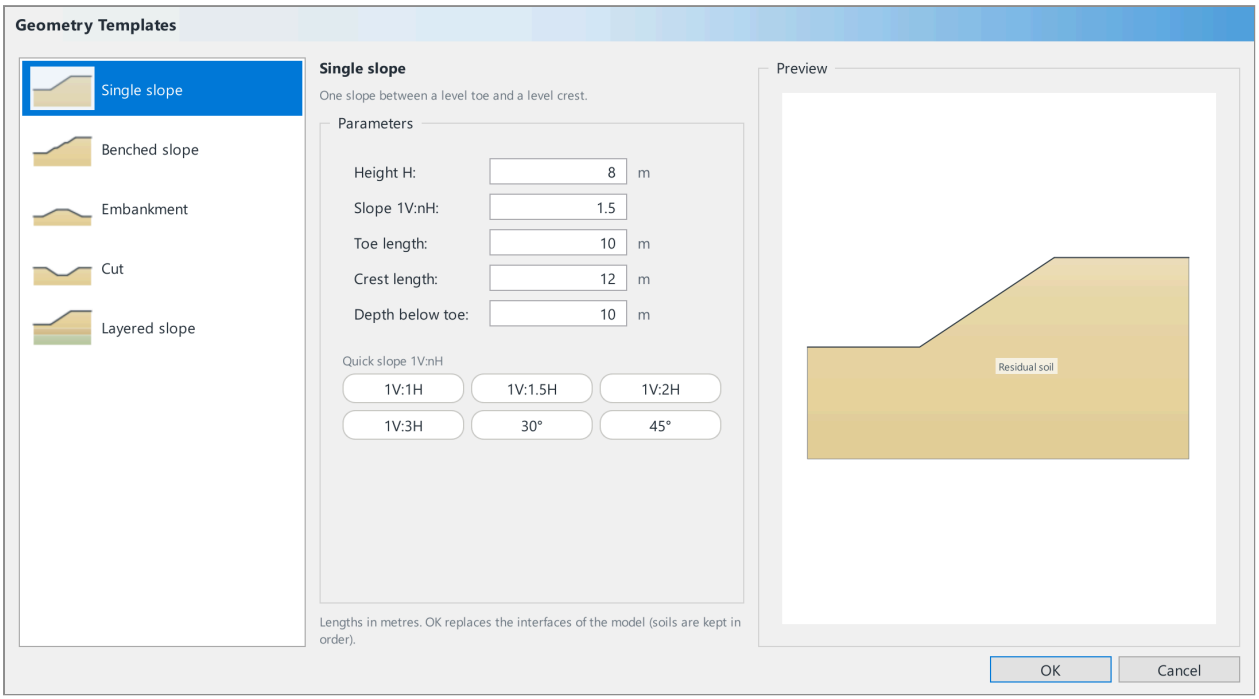


Figure 6.5 — Geometry Templates

6.5 Interfaces

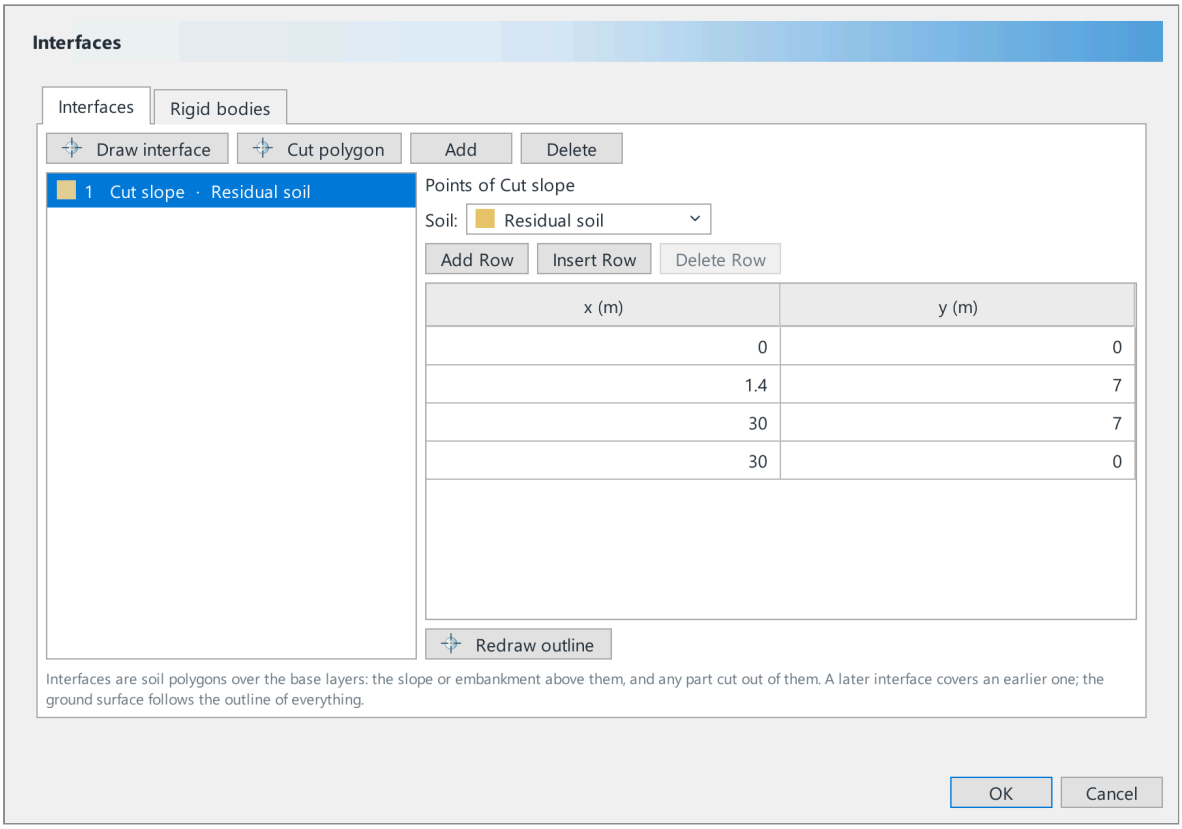


Figure 6.6 — Interfaces

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Interface polygons describe the slope above the layers, fills placed on them and soil to be removed. A polygon is entered as a list of points or drawn with **Draw interface**; it closes itself when its last point is placed on its first. **Cut polygon** draws a polygon that removes soil from the layers and the other polygons, for example to form a cut slope. Each polygon carries the soil chosen in its row. The tab **Rigid bodies** holds regions of very high strength that the circular search avoids, such as a retaining wall or bedrock (Figure 6.7, **Draw new rigid body**). From the second construction stage the tab **Stage earthwork** adds an embankment or an earth cut in that stage. Interfaces can also be imported from DXF or LandXML (**File ▸ Import interfaces**), and a DXF drawing can be shown in the background for tracing.

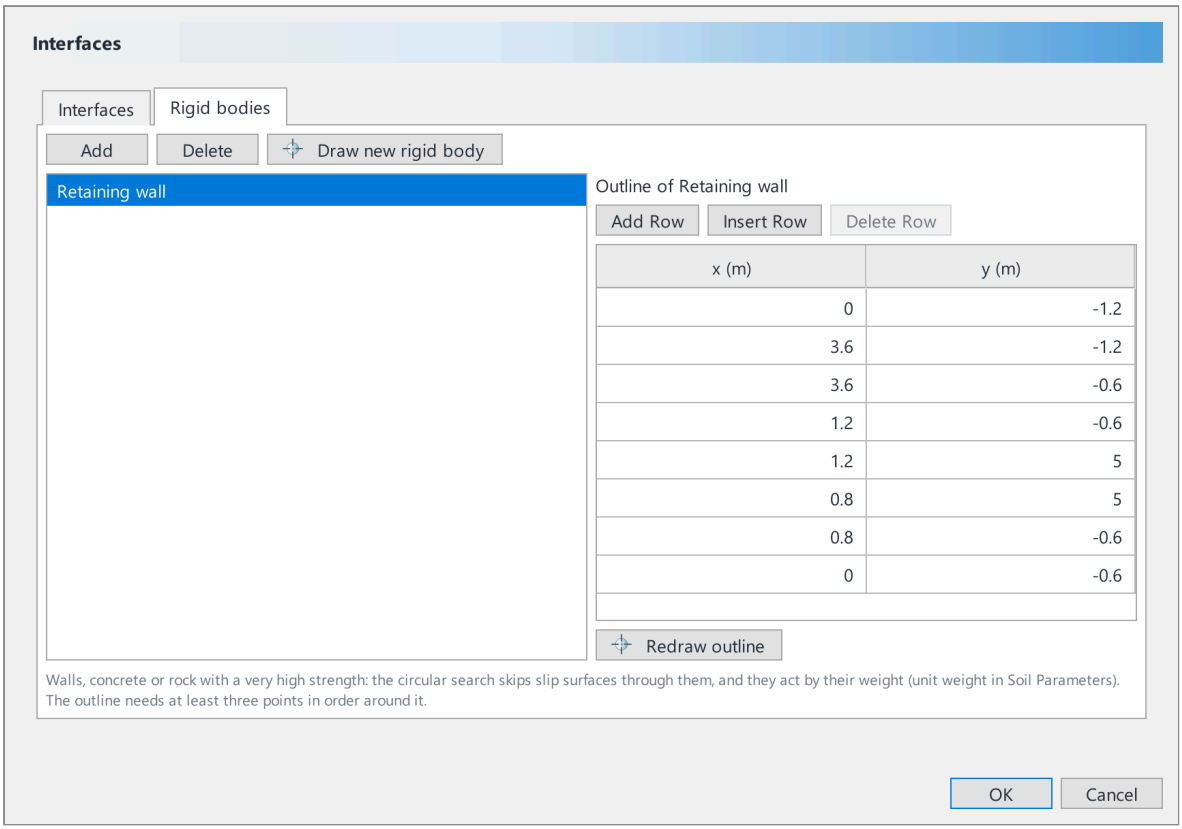


Figure 6.7 — Interfaces, rigid bodies

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6.6 Soil parameters

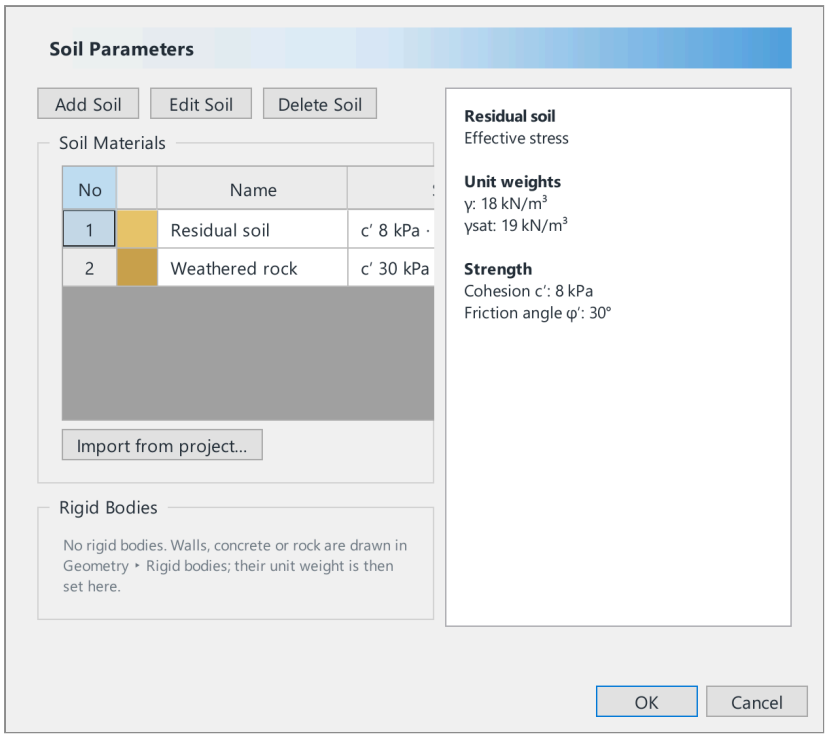


Figure 6.8 — Soil Parameters

The list holds the soils of the project. **Add Soil**, **Edit Soil** and **Delete Soil** manage them; **Import from project…** copies soils from another project. The soil dialog (Figure 6.9) holds the unit weight above water γ and the saturated unit weight γ_{sat} (or the porosity, for the uplift pressure), the stress state (effective stress with c' and φ', or total stress with c_u), and the optional anisotropy of strength along a foliation, a coefficient r_u of its own, the coefficient X for rapid drawdown, a piezometric surface of its own and a pore pressure constant, the bond of nails in the soil and whether the soil is incompressible. With the uplift computed from the porosity the resulting saturated unit weight is shown below the inputs. A typical soil can be picked to fill first estimates; they are textbook values and do not replace site data.

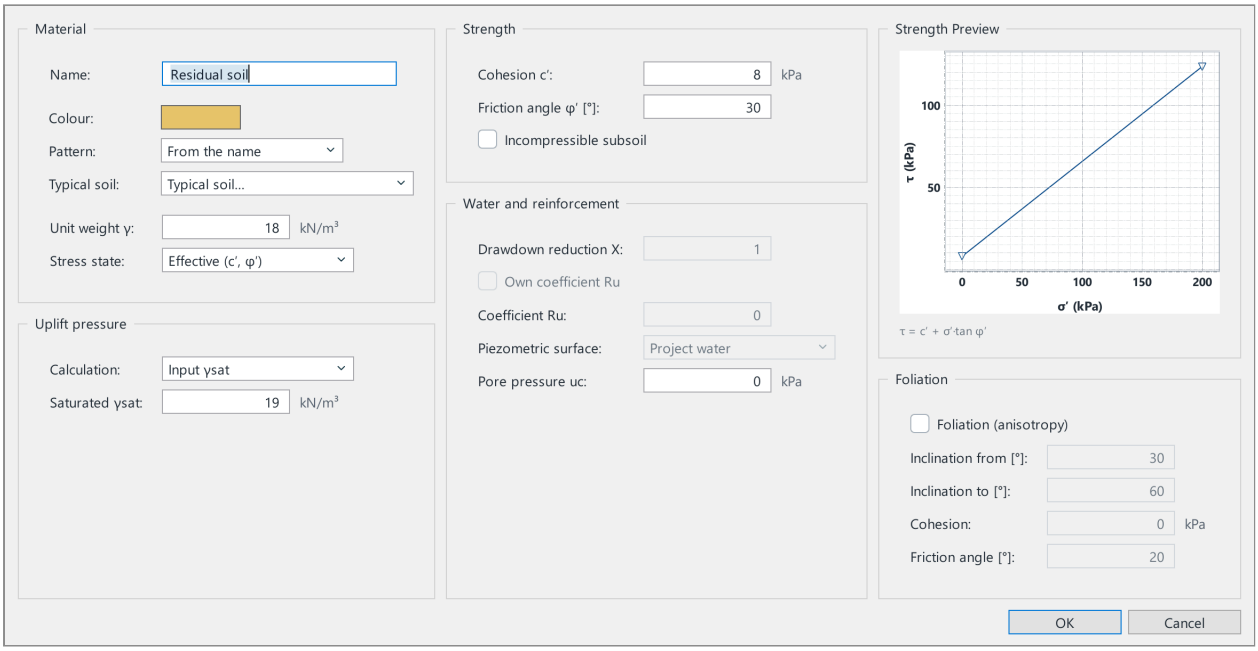


Figure 6.9 — Soil material

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6.7 Assign

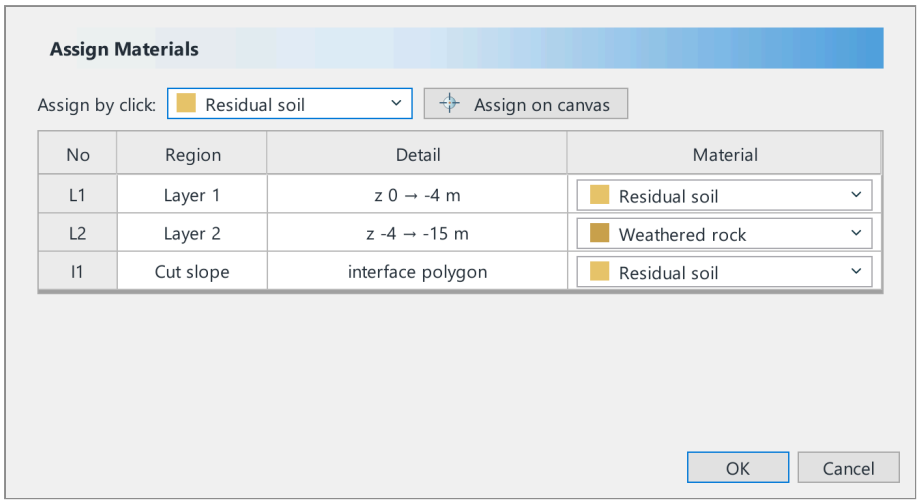


Figure 6.10 — Assign

Each soil layer (L) and each interface polygon (I) is given a soil, in the table or with **Assign on canvas** by clicking the regions. The drawing colours each region with its soil.

6.8 Reinforcement

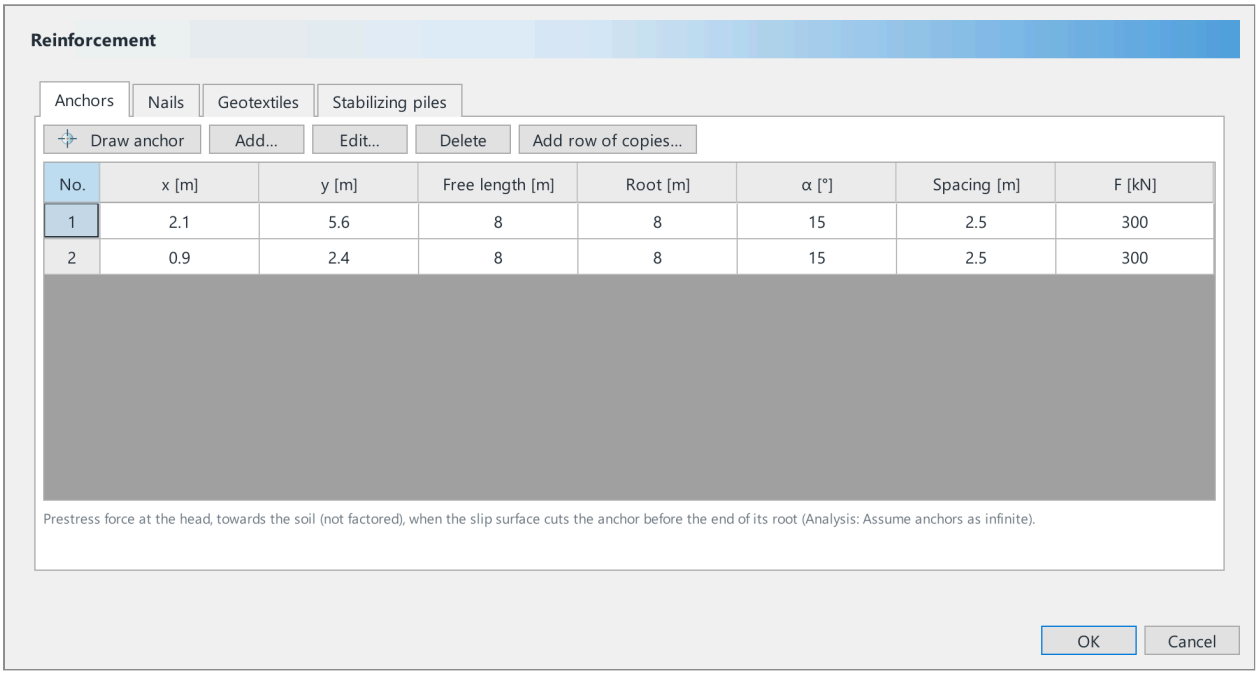


Figure 6.11 — Reinforcement, anchors

The step has a tab for each kind of element: anchors, nails, geotextiles and stabilizing piles. Elements are added with **Add…** or drawn on the canvas (**Draw anchor**, **Draw nail**, **Draw geotextile**, **Draw pile**), edited with **Edit…** and repeated with **Add row of copies…** (a number of copies at a given offset). The editor of each element shows a drawing that explains its quantities and changes with the options chosen (Figure 6.12). Values that the program computes from the input, such as the pull-out resistance of a nail along its length, the tensile strength of a bar or the bearing capacity of a geotextile, are shown in the box *Computed by the program* below the drawing.

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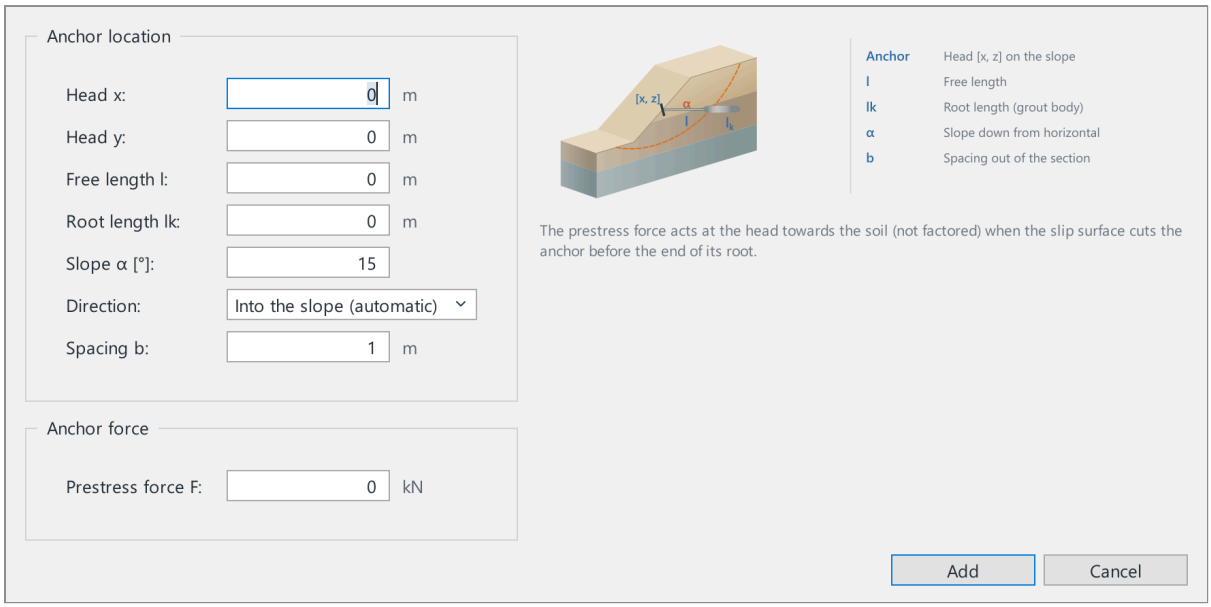


Figure 6.12 — New anchor

- **Anchors**: head position, length of the free part and of the root, inclination, prestress force and spacing. With *Assume anchors as infinite* in the analysis every anchor acts and the required free length is reported.
- **Nails**: head position, length, inclination and spacing; pull-out resistance entered, from the bond of the nail or of the soil, from the effective stress or by HA 68/94; tensile strength entered or from the bar diameter and yield strength; head resistance or a free head.
- **Geotextiles**: end points, tensile strength, and pull-out resistance entered, calculated with an interaction coefficient, or from the anchorage length; an end can be fixed; the force inclination factor turns the force from the direction of the geotextile (0) to the tangent of the slip surface (1).
- **Stabilizing piles**: position, length, spacing, shear resistance, its direction (perpendicular to the pile or parallel to the slip surface) and distribution along the pile (constant, linear, or a shear demand table with a multiplication factor), and the section for the drawing. The shear demand table comes from a single-pile analysis (Section 6.8.1).

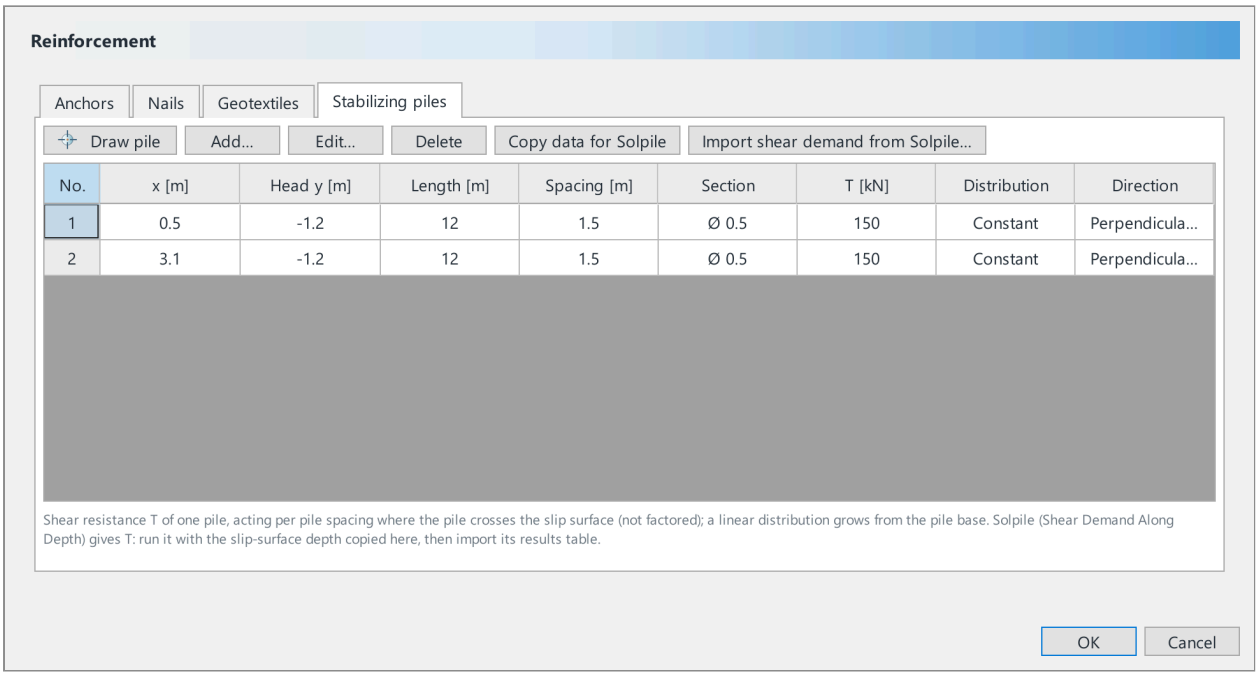


Figure 6.13 — Reinforcement, stabilizing piles

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6.8.1 Shear resistance of piles from a single-pile analysis

The resistance of a pile row depends on the depth at which the slip surface crosses the piles. Run the slope analysis, then use **Copy data for Solpile**, which copies, for each pile, the depth of the slip surface below the pile head and the soil layers along the pile. Enter them in the single-pile analysis and compute the shear demand along the pile for a soil movement above the slip surface. Read the resulting table of section length and shear back with **Import shear demand from Solpile…** (from the clipboard or a CSV file), in the step or in the pile editor: the pile takes the whole table, and every trial slip surface of the search uses the shear at its own depth, multiplied by the factor of the pile. With the command line the same is **import demand <file> <pile>**.

6.9 Loads

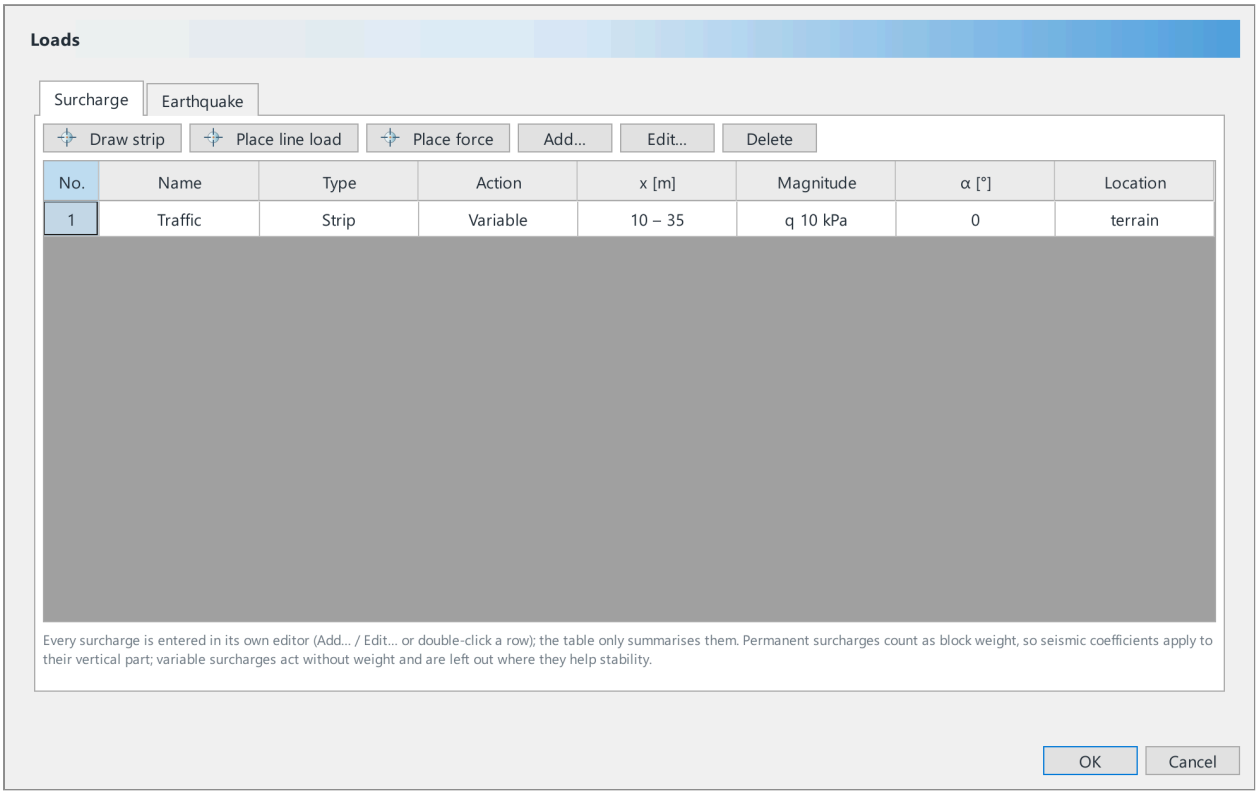


Figure 6.14 — Loads, surcharges

Surcharges are strip, trapezoidal, concentrated or line loads on the terrain or at a given elevation, with an inclination and a kind (permanent, variable or accidental). They are added with **Add…** or placed on the canvas with **Draw strip**, **Place line load** and **Place force**. The tab **Earthquake** (Figure 6.15) switches the pseudo-static earthquake on and sets the coefficients, directly, according to a seismic standard, or with **From EN 1998-5…** from the design ground acceleration. The coefficients that the analysis uses are shown when they follow from a standard.

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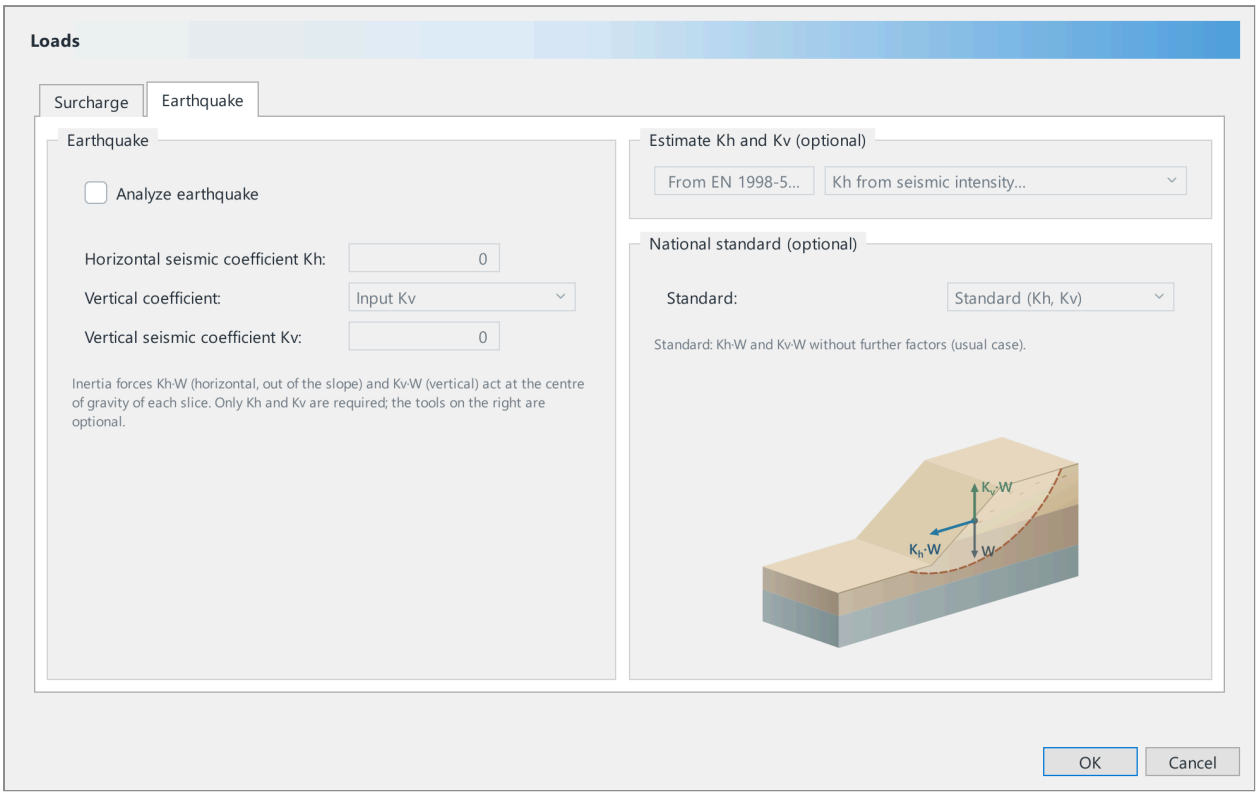


Figure 6.15 — Loads, earthquake

6.10 Water

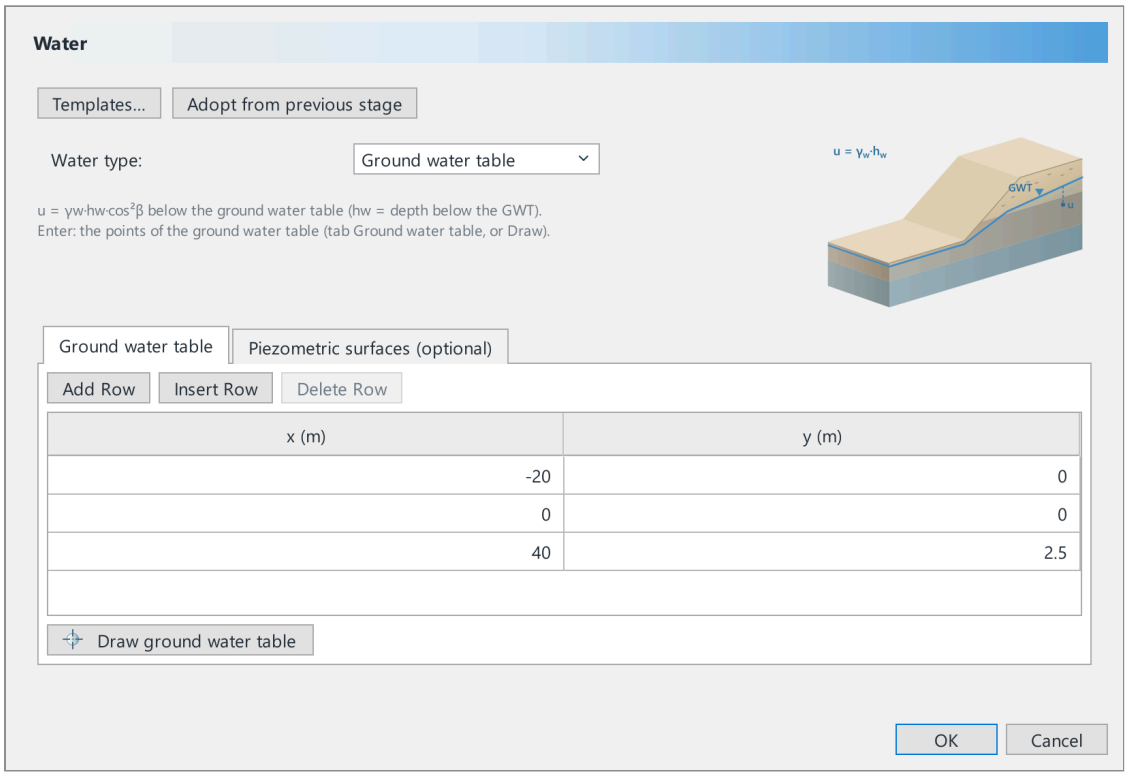


Figure 6.16 — Water

The type of water input is no water, a ground water table, a coefficient r_u, rapid drawdown (an original and a new table), a ground water table with a suction surface, or pore pressure isolines. Lines are entered as points or drawn (**Draw ground water table**); **Templates...** places a horizontal table, a table following the slope or water outside the

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slope from a few dimensions. Water above the ground surface acts as a load. The tab **Piezometric surfaces** holds further surfaces; a soil that selects one of them in its parameters (*Piezometric surface*) takes its pore pressure from it instead of the project water, and a soil may add a pore pressure constant u_c.

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7 Reference of the data steps and dialogs

This chapter lists every field, check box, button, tab and table column of the data steps and dialogs of Solstability, with its meaning, in every state of the dialogs (each verification methodology, water type, type of analysis and element option). The screenshots show the dialogs with the example project of the User Manual. Fields that a current choice does not use are hidden or shown in grey with a tooltip that tells why. The tables of the steps share the buttons Add Row, Insert Row and Delete Row.

7.1 Project Information

The step holds the name, number, client, author, date and notes of the project. They are printed on the cover of the report and do not affect the analysis.

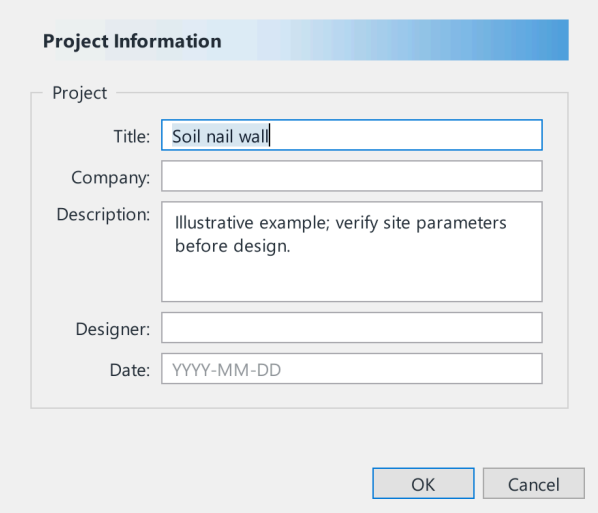


Figure 7.1 — Project Information

7.2 Program Options

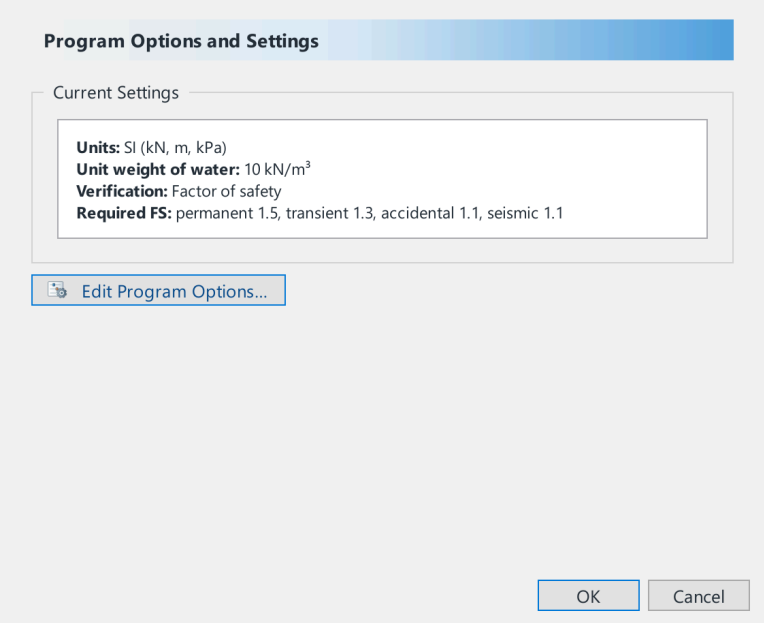


Figure 7.2 — Program Options

Table 7.1 — Program Options: fields and buttons

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Name	Meaning
Edit Program Options…	opens the dialog Program Options and Settings; the step itself shows a summary of the current options

7.3 Program Options and Settings

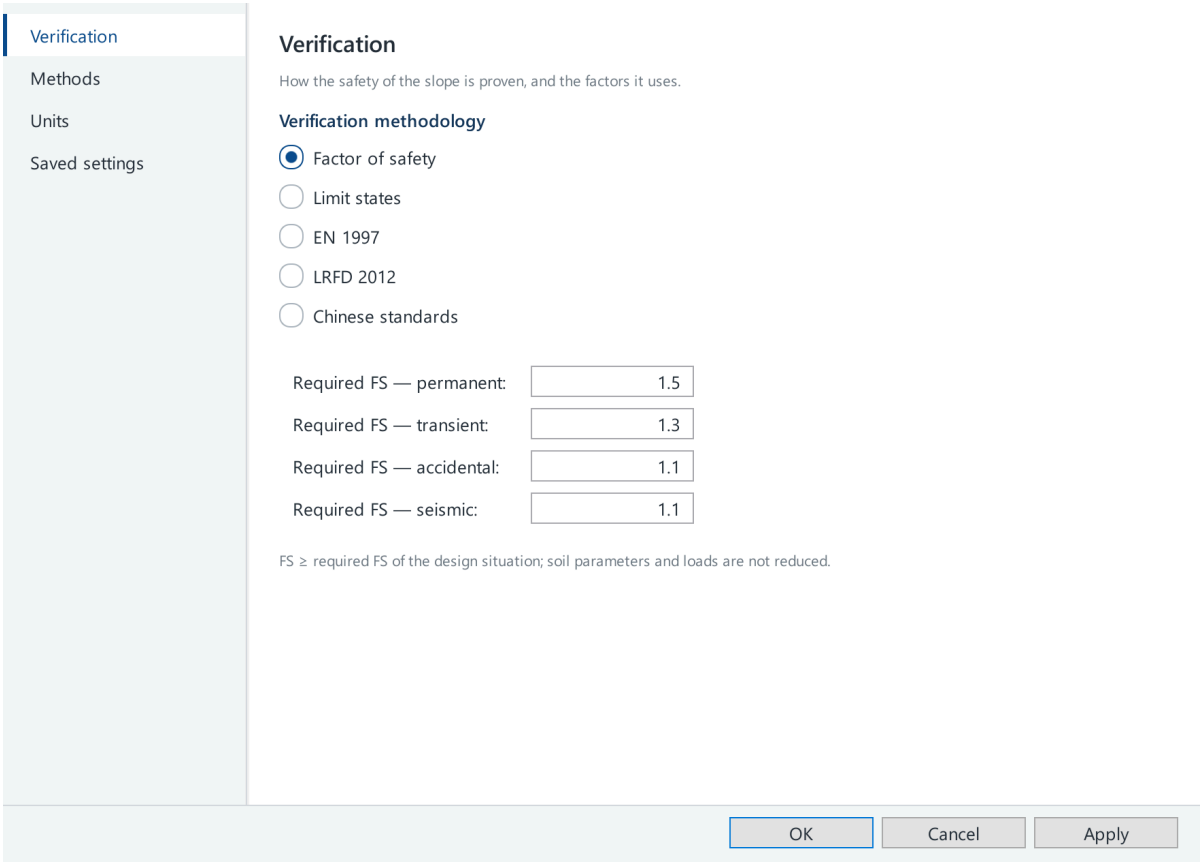


Figure 7.3 — Program Options and Settings

Table 7.2 — Program Options and Settings: fields and buttons

Name	Meaning
Required FS — permanent:	required factor of safety in the permanent design situation
Required FS — transient:	required factor of safety in the transient design situation
Required FS — accidental:	required factor of safety in the accidental design situation
Required FS — seismic:	required factor of safety in the seismic design situation
Factor of safety	verification methodology: the factor of safety is compared with the required value of the design situation
Limit states	verification methodology: the strength is reduced by partial factors and the sliding and resisting forces are compared with an overall stability factor
EN 1997	verification methodology of Eurocode 7: design approach 1, 2 or 3 with the partial factors of EN 1997-1
LRFD 2012	verification methodology of AASHTO LRFD 2012: load factors on earth surcharge and live load and a resistance factor, for Service I and Extreme Event I
Chinese standards	verification methodology of the Chinese slope codes: the required factor of safety depends on the design situation and on the shape of the slip surface
Bishop	method compared by Analyse with all methods (circular surfaces)

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Name	Meaning
Fellenius / Petterson	method compared by Analyse with all methods (circular surfaces)
Spencer	method compared by Analyse with all methods
Janbu	method compared by Analyse with all methods
Morgenstern-Price	method compared by Analyse with all methods
Shahunyants	method compared by Analyse with all methods (polygonal surfaces)
ITFM (implicit)	method compared by Analyse with all methods (polygonal surfaces)
ITFM (explicit)	method compared by Analyse with all methods (polygonal surfaces)
Sarma	method compared by Analyse with all methods (polygonal surfaces)
Unit weight of water:	unit weight of water γw used for pore pressure and water loads
SI (meters, kilonewtons, kilopascals)	SI units; changing the system converts every value of the project
US Customary (feet, kips, ksf)	US customary units; changing the system converts every value of the project
Save current as…	saves the current options under a name, available to every project on this computer
Delete	deletes the selected saved settings
Reduction of tan φ′:	partial factor dividing tan φ′ (limit states)
Reduction of c′ (and cu):	partial factor dividing c′ and cu (limit states)
Overall stability γs — permanent:	overall stability factor of the permanent situation (limit states)
Overall stability γs — transient:	overall stability factor of the transient situation (limit states)
Overall stability γs — accidental:	overall stability factor of the accidental situation (limit states)
Overall stability γs — seismic:	overall stability factor of the seismic situation (limit states)
Design approach (EN 1997):	design approach 1 (combinations 1 and 2), 2 or 3 of EN 1997-1; the partial factors of the approach are applied to soil strength, unit weights, loads and resistance
Partial factor on water γw:	partial factor on the unit weight of water and the pore pressure (EN 1997)
Earth surcharge ES min:	minimum load factor on the weight of soil (LRFD)
Earth surcharge ES max:	maximum load factor on the weight of soil (LRFD)
Live load LL min:	minimum load factor on live (variable) loads (LRFD)
Live load LL max:	maximum load factor on live (variable) loads (LRFD)
Resistance factor φSS:	resistance factor of overall slope stability (LRFD); the factor of safety must be at least 1/φSS

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7.4 Soil Layers

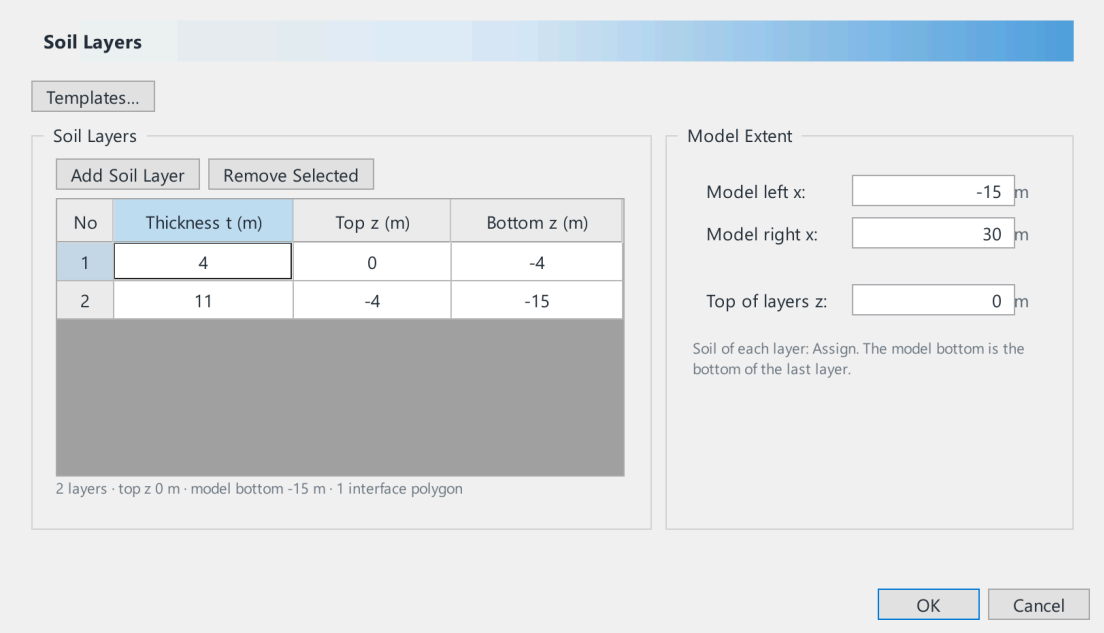


Figure 7.4 — Soil Layers

Table 7.3 — Soil Layers: fields and buttons

Name	Meaning
Model left x:	left limit of the model
Model right x:	right limit of the model
Top of layers z:	elevation of the top of the uppermost soil layer
Templates…	opens Geometry Templates, which builds a complete geometry from a few dimensions
Add Soil Layer	adds a layer below the lowest one
Remove Selected	deletes the selected layer
No	number of the row
Thickness t (m)	thickness of the layer
Top z (m)	elevation of the top of the layer, from the layers above
Bottom z (m)	elevation of the bottom of the layer; the bottom of the last layer is the bottom of the model

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7.5 Geometry Templates

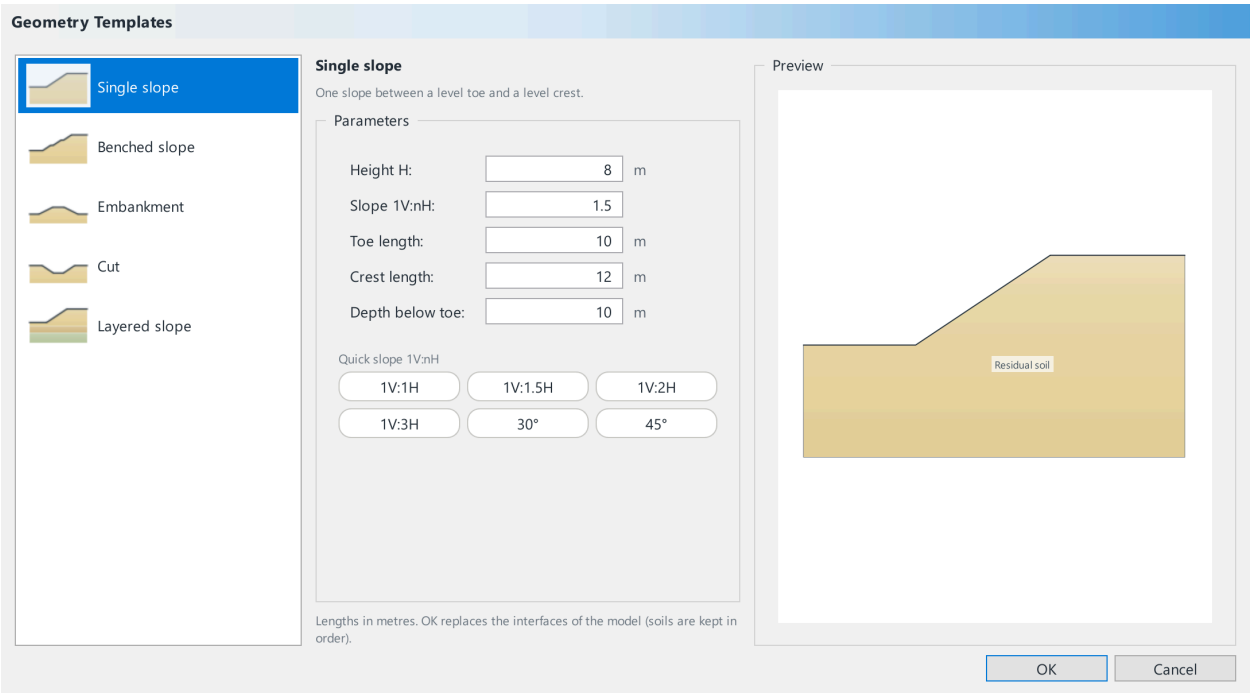


Figure 7.5 — Geometry Templates

Table 7.4 — Geometry Templates: fields and buttons

Name	Meaning
Height H:	height of the slope from toe to crest
Slope 1V:nH:	inclination of the slope as horizontal run n per unit of height
Toe length:	length of the level ground in front of the toe
Crest length:	length of the level ground behind the crest
Depth below toe:	depth of the model below the toe
1V:1H	sets the slope to 1V:1H (45°)
1V:1.5H	sets the slope to 1V:1.5H
1V:2H	sets the slope to 1V:2H
1V:3H	sets the slope to 1V:3H
30°	sets the slope to 30° from the horizontal
45°	sets the slope to 45° from the horizontal

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7.6 Interfaces

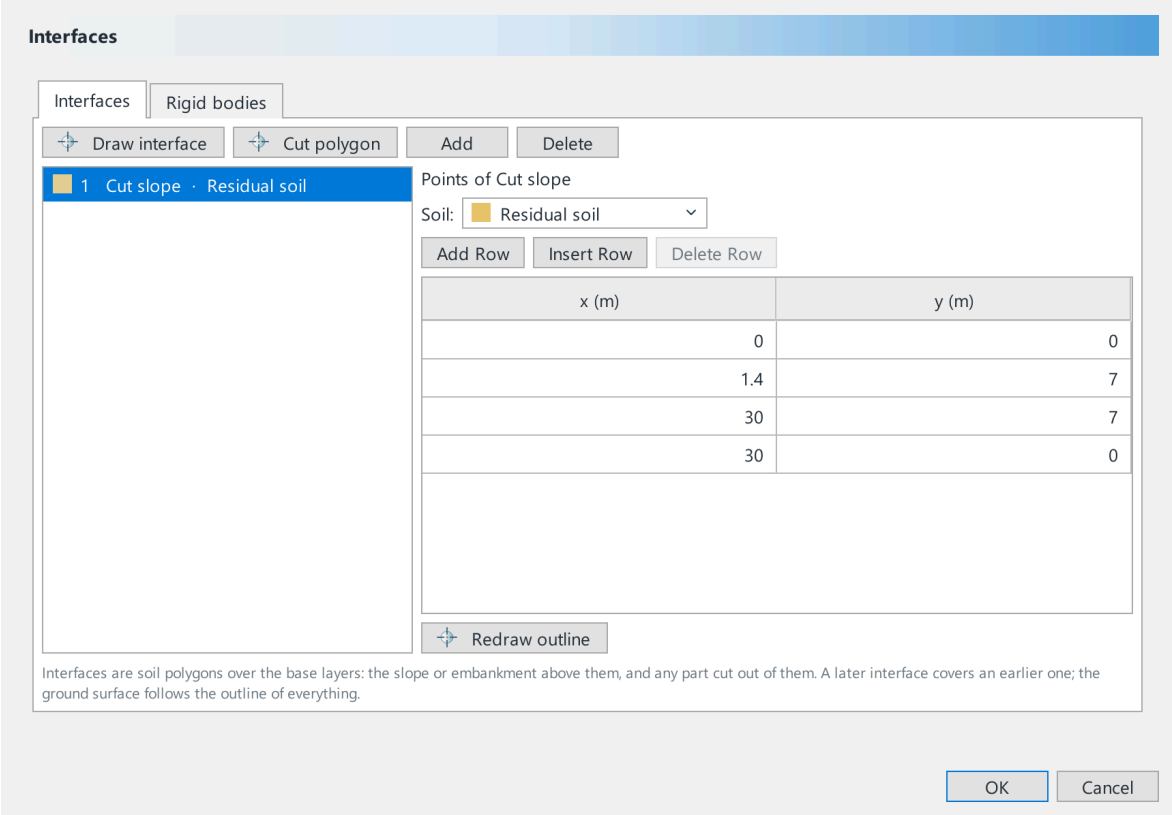


Figure 7.6 — Interfaces

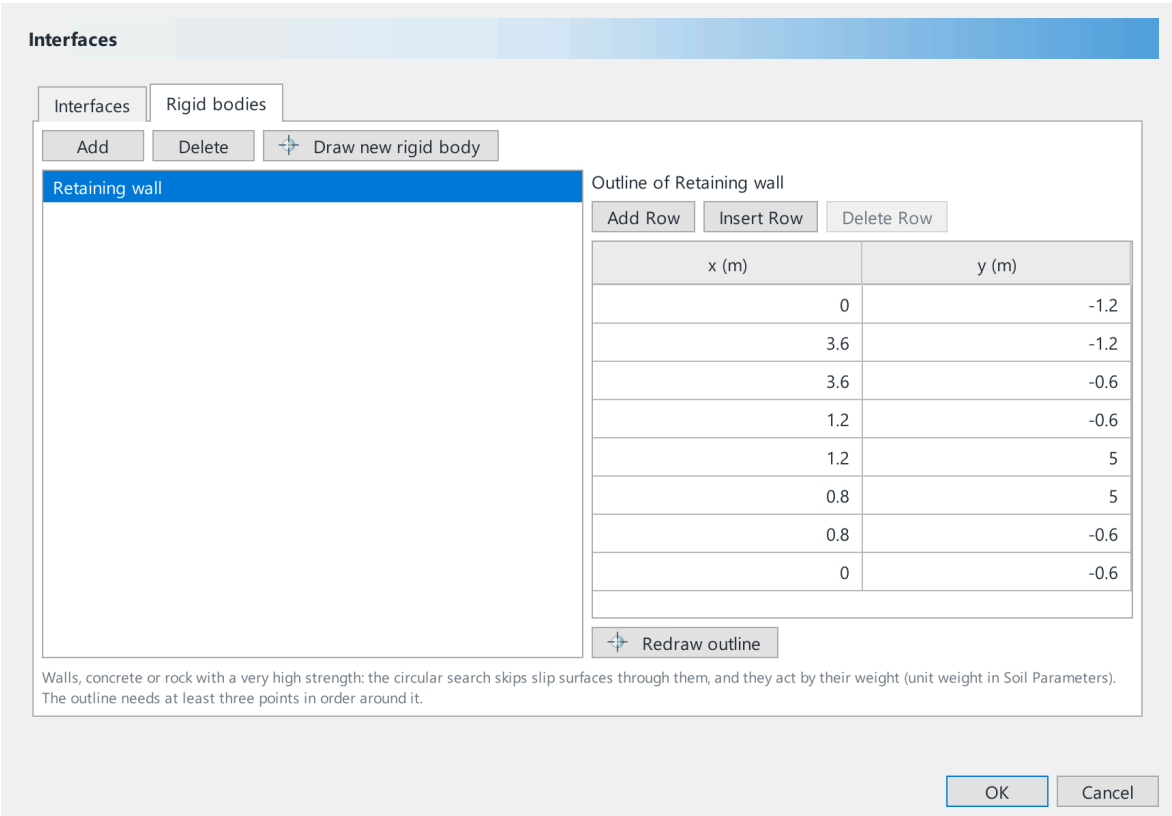


Figure 7.7 — Interfaces

Table 7.5 — Interfaces: fields and buttons

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Name	Meaning
Interfaces	tab of the interface polygons: slopes above the layers, embankments and cuts
Rigid bodies	tab of the rigid bodies (walls, rock, structures of very high strength)
Add	adds the element with the values entered (the dialog title starts with New) or applies the changes (Edit)
Delete	deletes the selected row
Draw new rigid body	draws a rigid body on the canvas
Add Row	adds a row at the end of the table
Insert Row	inserts a row above the selected row
Delete Row	deletes the selected row
x (m)	x coordinate of a point
y (m)	elevation of a point
Draw interface	draws a new interface polygon on the canvas
Cut polygon	draws a line across a layer or an interface; the part above the line is cut away, or the polygon is split in two
Redraw outline	draws the outline of the selected polygon again

7.7 Soil Parameters

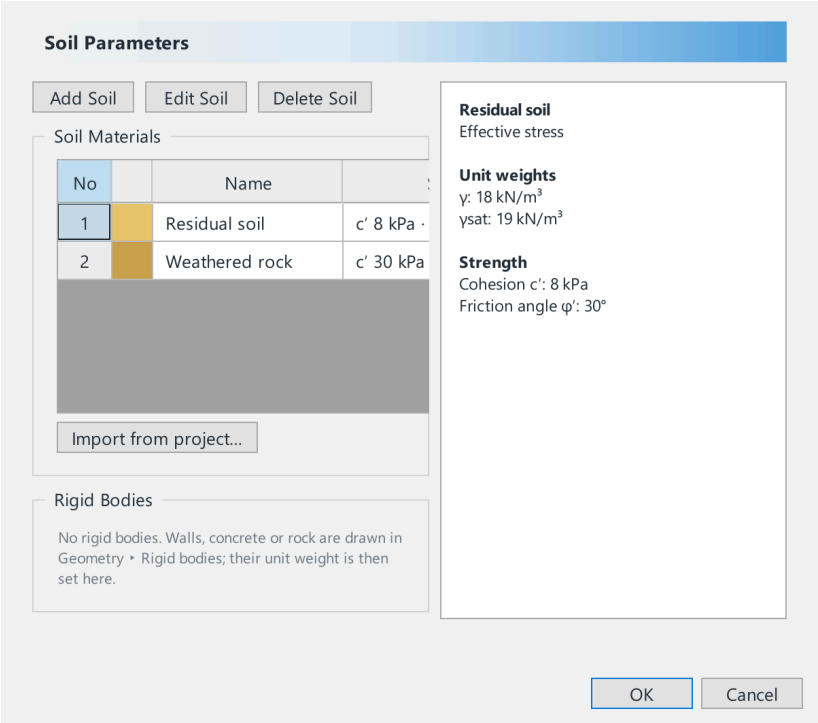


Figure 7.8 — Soil Parameters

Table 7.6 — Soil Parameters: fields and buttons

Name	Meaning
Add Soil	adds a soil
Edit Soil	opens the soil dialog Soil Material of the selected soil (also by a double-click on the row)
Delete Soil	deletes the selected soil; layers and polygons that used it become unassigned
No	number of the row

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Name	Meaning
Name	name of the soil
Strength	summary of the strength parameters of the soil
Status	OK, or a note when a value needed by the analysis is missing or out of range
Import from project…	copies soils from another Solstability project

7.8 Soil Material

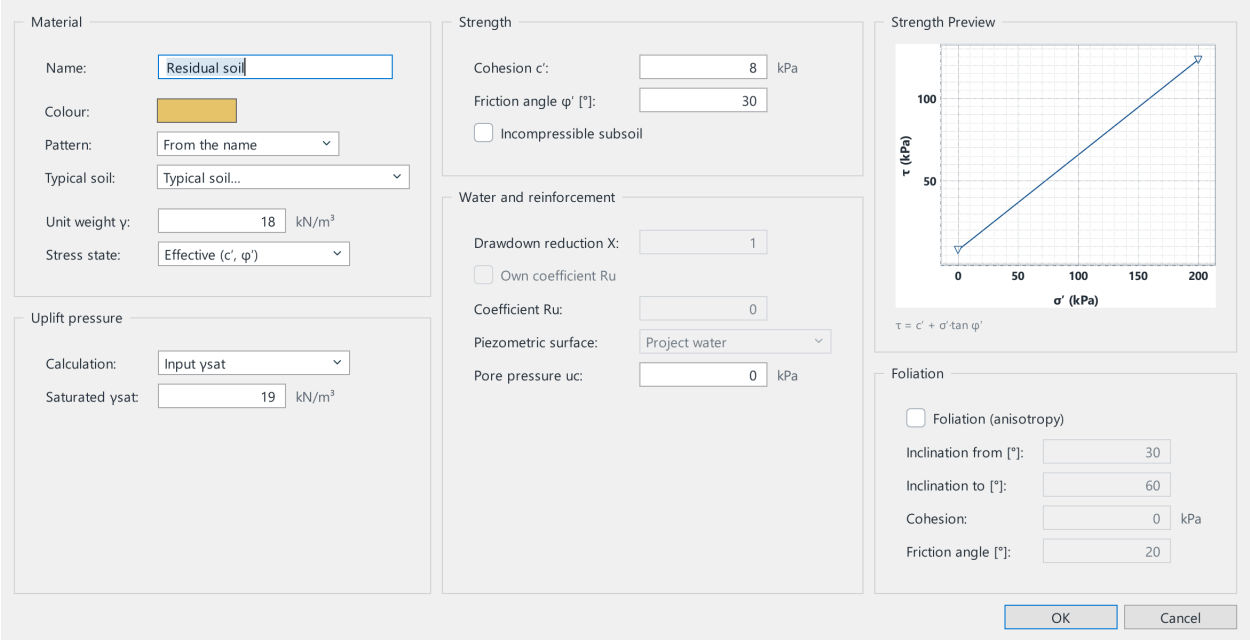


Figure 7.9 — Soil Material

Table 7.7 — Soil Material: fields and buttons

Name	Meaning
Name:	name of the soil
Unit weight γ:	unit weight above the water table
Stress state:	effective stress (c′, φ′) or total stress (undrained strength cu, φ = 0); in total stress the pore pressure, uplift and foliation are not used
Calculation:	uplift: saturated unit weight entered, or computed from the unit weight of solids and the porosity
Saturated γsat:	unit weight below the water table
Cohesion c′:	effective cohesion
Friction angle φ′ [°]:	effective angle of internal friction
Incompressible subsoil	the slip surface may not enter this soil
Drawdown reduction X:	share of the pore pressure that drops during rapid drawdown (water type Rapid drawdown); 1 = the full drop
Own coefficient Ru	the soil has its own pore pressure coefficient Ru (water type Coefficient Ru)
Coefficient Ru:	pore pressure coefficient of the soil, u = Ru·σv
Piezometric surface:	pore pressure of the soil from its own piezometric surface (Water step) instead of the project water
Pore pressure uc:	constant pore pressure added at every point of the soil; a negative value is a suction
Foliation (anisotropy)	the soil has a weaker strength along a foliation

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Name	Meaning
Inclination from [°]:	start of the range of base inclinations in which the foliation strength applies
Inclination to [°]:	end of the range of base inclinations in which the foliation strength applies
Cohesion:	cohesion along the foliation
Friction angle [°]:	angle of friction along the foliation
Undrained cohesion cu:	undrained shear strength (total stress)
Solids γs:	unit weight of the solid particles (uplift from porosity)
Porosity n:	porosity (uplift from porosity): γsat = (1 − n)·γs + n·γw

7.9 Assign

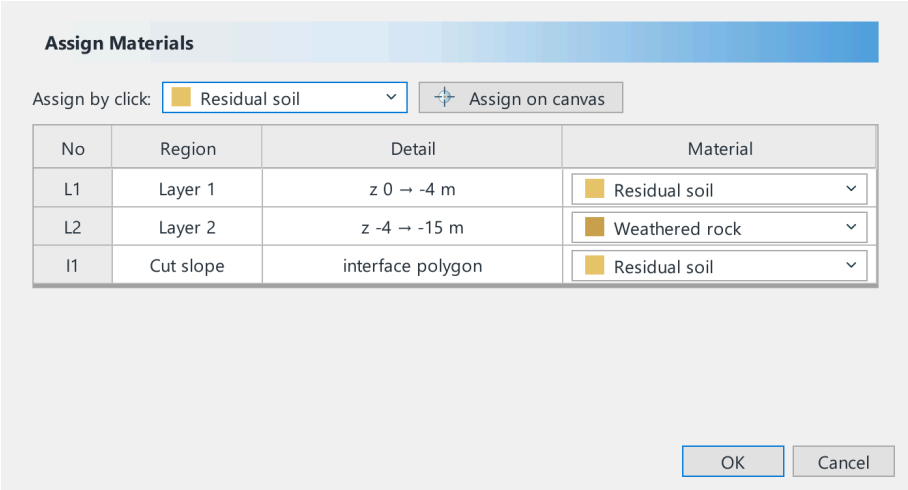


Figure 7.10 — Assign

Table 7.8 — Assign: fields and buttons

Name	Meaning
Assign on canvas	click layers and polygons on the canvas to give them the soil chosen in the list
No	number of the row
Region	layer or interface polygon
Detail	position and size of the layer or polygon
Material	soil of the layer or polygon

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7.10 Reinforcement

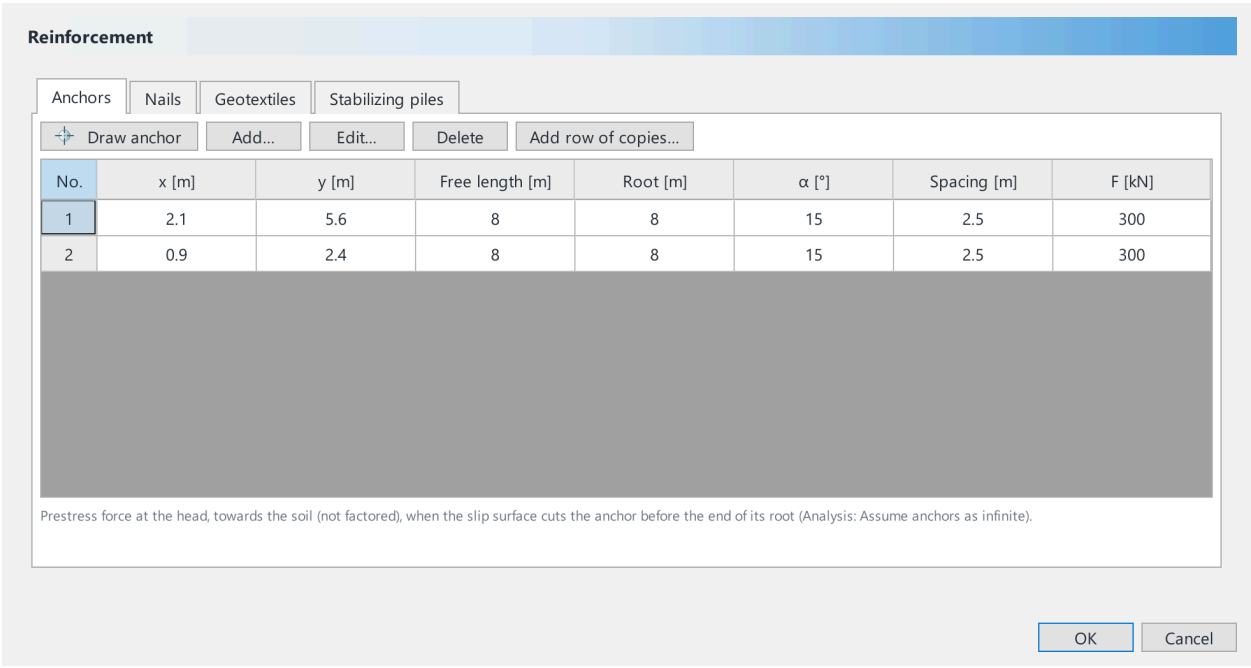


Figure 7.11 — Reinforcement

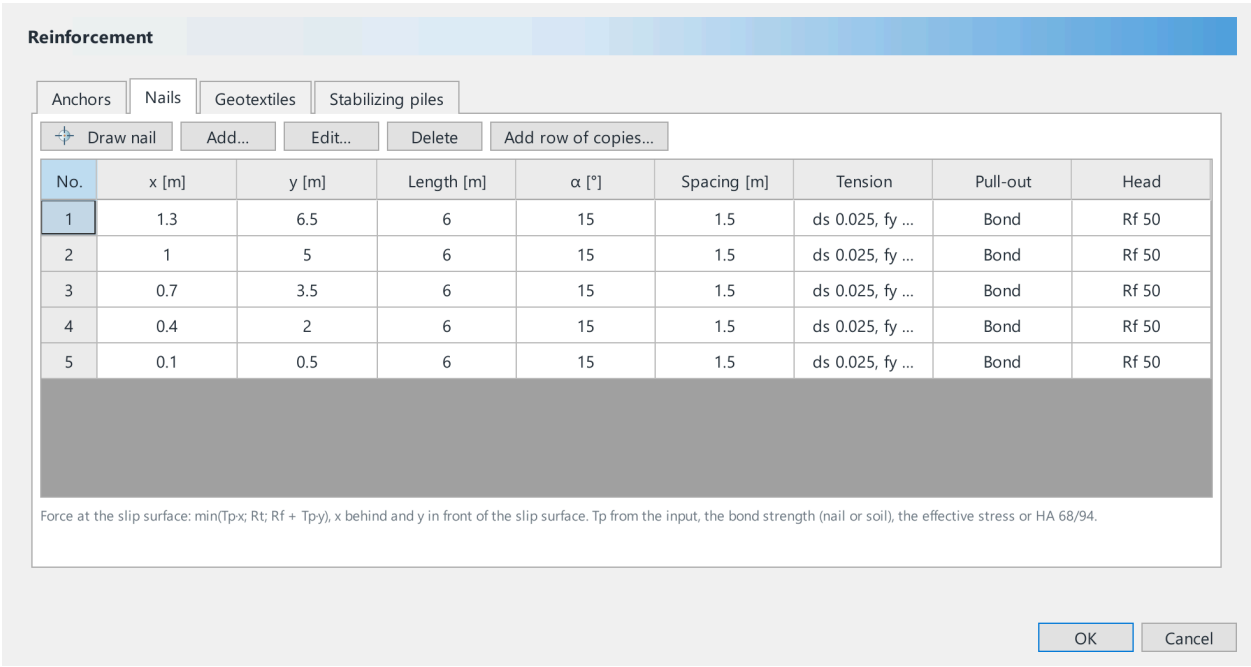


Figure 7.12 — Reinforcement

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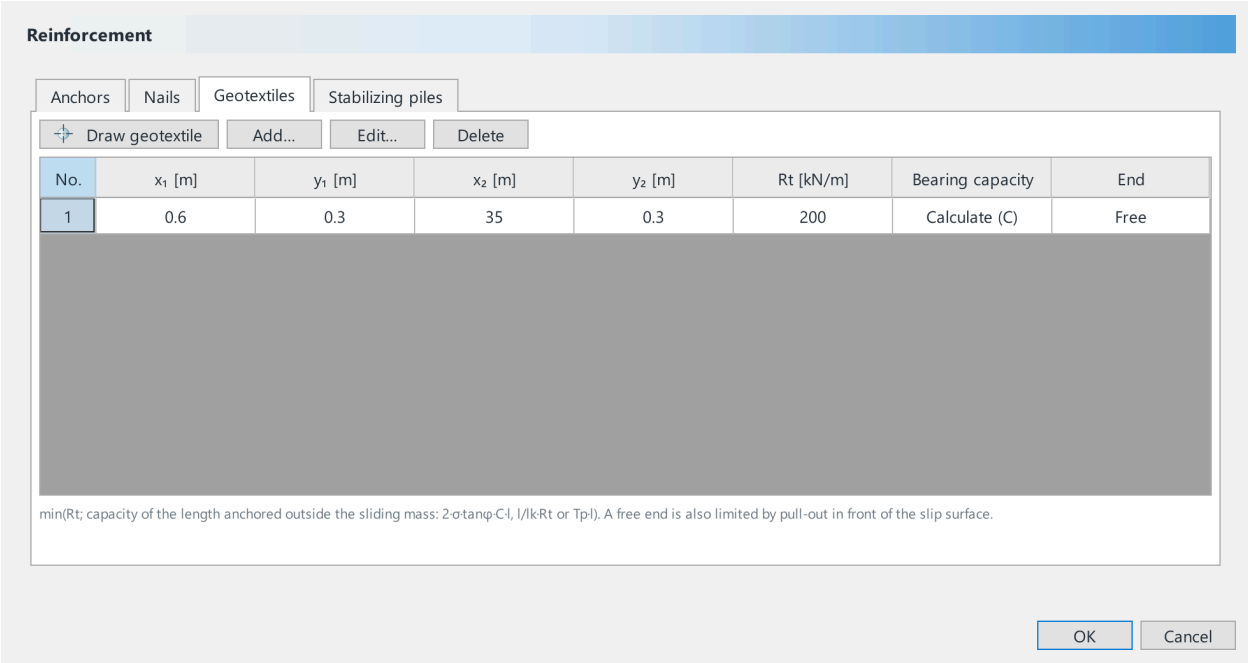


Figure 7.13 — Reinforcement

Table 7.9 — Reinforcement: fields and buttons

Name	Meaning
Anchors	tab of the anchors
Nails	tab of the soil nails
Geotextiles	tab of the geotextiles
Stabilizing piles	tab of the stabilizing piles
No.	number of the row
x [m]	x of the head
Head y [m]	elevation of the pile head
Length [m]	length of the element
Spacing [m]	spacing of the elements along the slope
Section	cross-section of the pile
T [kN]	shear resistance of one pile
Distribution	distribution of the shear resistance along the pile
Direction	side to which the element runs from its head, or the direction of the passive force of a pile
Draw pile	places a pile on the canvas
Add…	opens the dialog of a new element of the current tab
Edit…	opens the dialog of the selected element (also by a double-click on the row or on the element in the drawing)
Delete	deletes the selected row
Copy data for Solpile	copies, for every pile, the depth of the slip surface below the ground and the forces, for an analysis of the pile in Solpile
Import shear demand from Solpile…	reads the shear resistance of the piles from a Solpile result
x_1 [m]	x of the start
y_1 [m]	elevation of the start
x_2 [m]	x of the end

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Name	Meaning
y_2 [m]	elevation of the end
Rt [kN/m]	tensile strength of the geotextile
Bearing capacity	how the pull-out capacity is obtained
End	which ends of the geotextile are anchored
Draw geotextile	draws a geotextile on the canvas
y [m]	elevation of the head
α [°]	inclination from the horizontal, positive downward
Tension	tensile strength of the nail
Pull-out	pull-out resistance of the nail
Head	strength of the nail head
Draw nail	draws a nail on the canvas
Add row of copies…	copies the selected anchor or nail several times with a constant shift
Free length [m]	free length of the anchor
Root [m]	root (bond) length of the anchor
F [kN]	prestress force of one anchor
Draw anchor	draws an anchor on the canvas

7.11 New anchor

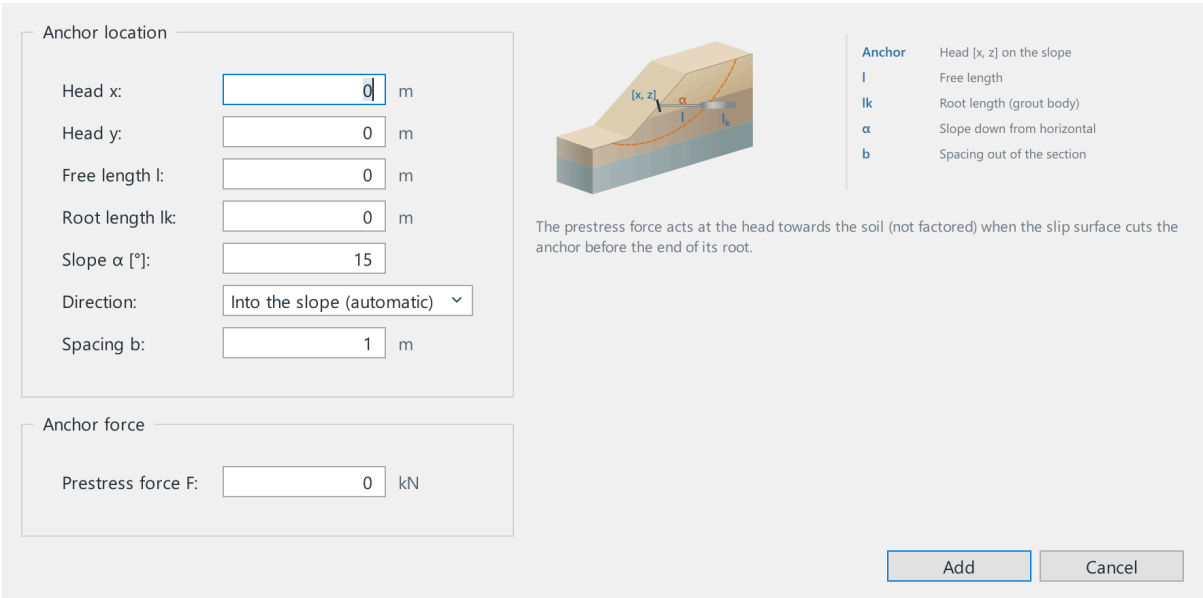


Figure 7.14 — New anchor

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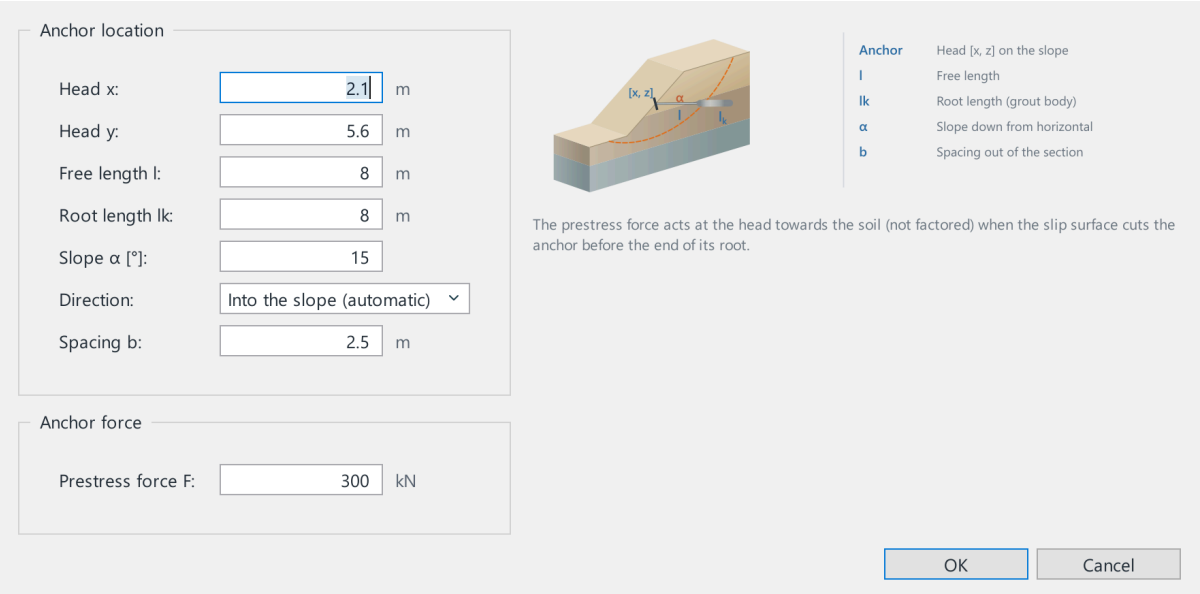


Figure 7.15 — New anchor

Table 7.10 — New anchor: fields and buttons

Name	Meaning
Head x:	x of the anchor head
Head y:	elevation of the anchor head
Free length l:	length of the free part of the tendon
Root length lk:	length of the root (grouted bond length)
Slope α [°]:	inclination of the anchor from the horizontal, positive downward
Direction:	side to which the anchor runs from its head; Automatic: into the slope
Spacing b:	spacing of the anchors along the slope; the force per metre is F/b
Prestress force F:	force of one anchor
Add	adds the element with the values entered (the dialog title starts with New) or applies the changes (Edit)

7.12 Row of copies

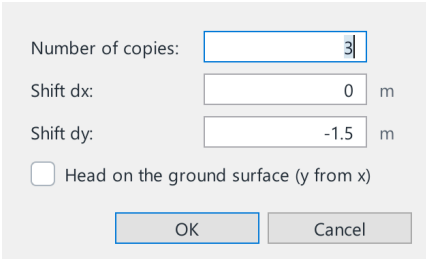


Figure 7.16 — Row of copies

Table 7.11 — Row of copies: fields and buttons

Name	Meaning
Number of copies:	number of copies added
Shift dx:	horizontal shift between copies
Shift dy:	vertical shift between copies
Head on the ground surface (y from x)	places every head on the ground surface at its x

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7.13 Loads

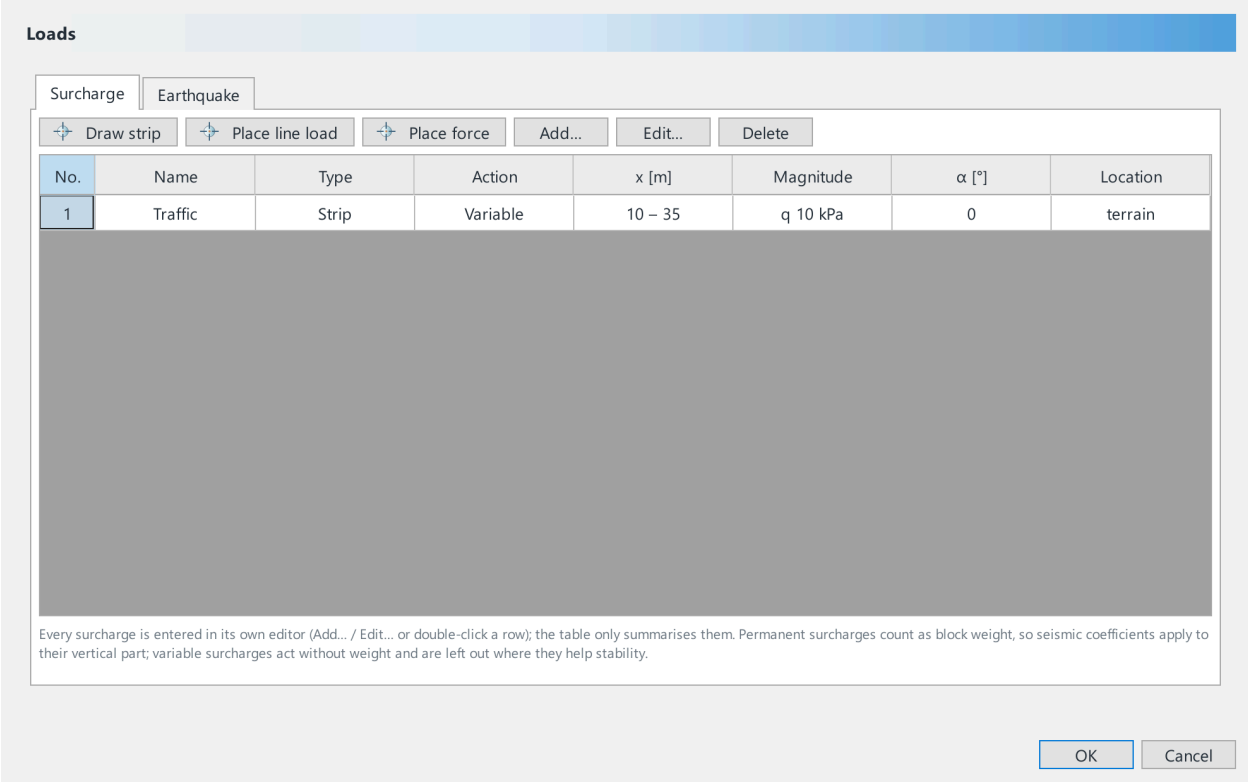


Figure 7.17 — Loads

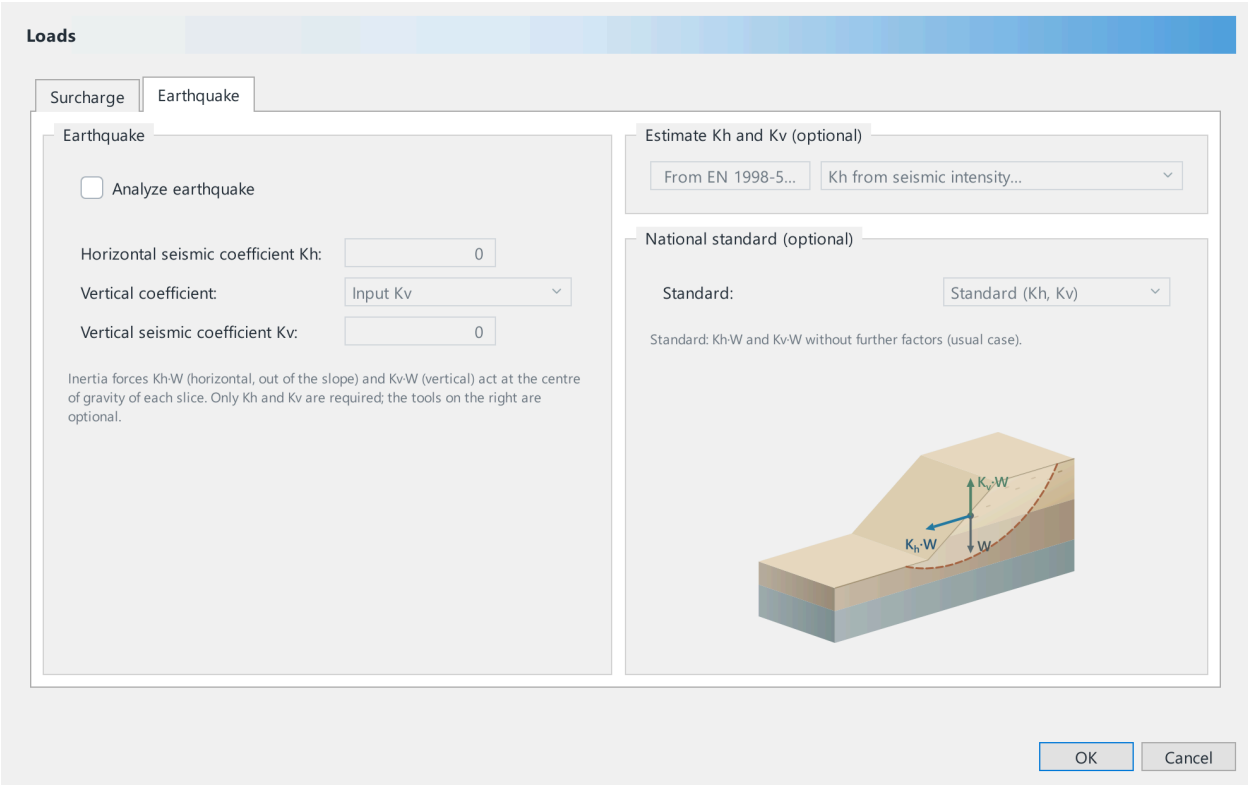


Figure 7.18 — Loads

Table 7.12 — Loads: fields and buttons

Name	Meaning

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Name	Meaning
Surcharge	tab of the surcharges
Earthquake	tab of the earthquake
Analyze earthquake	includes the earthquake in the analysis
Horizontal seismic coefficient Kh:	horizontal seismic coefficient
Vertical coefficient:	vertical coefficient entered, or ±2/3 of Kh
Vertical seismic coefficient Kv:	vertical seismic coefficient, positive downward
Standard:	seismic standard: Kh and Kv as entered, or the distribution and factors of GB 50111-2006, NB 35047-2015, GB 50330-2013 or JTG B02-2013
From EN 1998-5…	computes Kh and Kv from the ground acceleration of EN 1998-5
No.	number of the row
Name	name of the surcharge
Type	strip, trapezoidal, concentrated force or line load
Action	permanent, variable or accidental
x [m]	x of the start (and end) of the surcharge
Magnitude	magnitude of the surcharge
α [°]	inclination of the surcharge from the vertical
Location	on the ground surface or at a given elevation
Draw strip	draws a strip surcharge on the canvas
Place line load	places a line load on the canvas
Place force	places a concentrated force on the canvas
Add…	opens the dialog of a new element of the current tab
Edit…	opens the dialog of the selected element (also by a double-click on the row or on the element in the drawing)
Delete	deletes the selected row
Importance coefficient Ci:	importance coefficient of the Chinese seismic standards
Comprehensive influence factor Cz:	comprehensive influence factor of the Chinese seismic standards
Meeting coefficient C0:	combination coefficient of the vertical action (GB 50111, NB 35047)
Dynamic distribution αi:	shape of the dynamic distribution coefficient over the height (NB 35047)
αi at the bottom (b):	dynamic distribution coefficient at the lowest point (NB 35047)
αi at the top (a):	dynamic distribution coefficient at the highest point (NB 35047)
Horizontal acceleration factor αw:	horizontal acceleration factor (GB 50330)
Vertical acceleration factor ag:	vertical acceleration factor (GB 50330)

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7.14 New surcharge

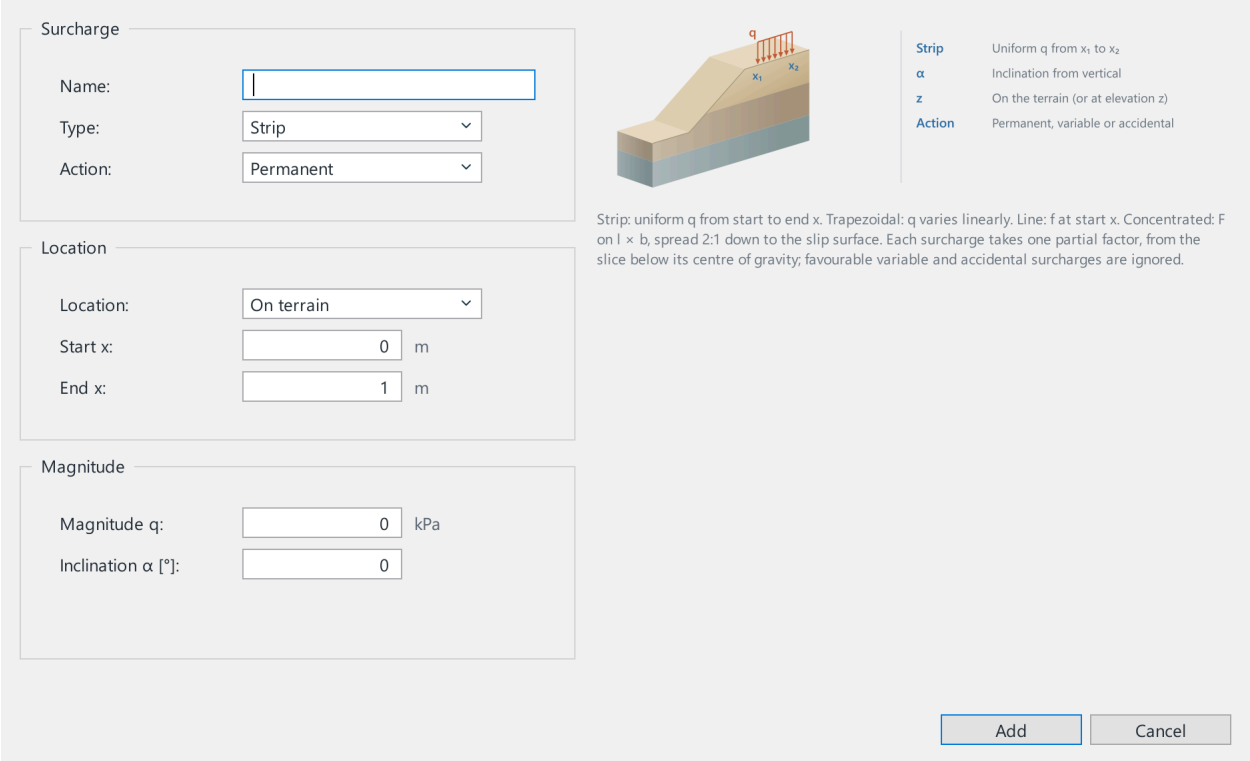


Figure 7.19 — New surcharge

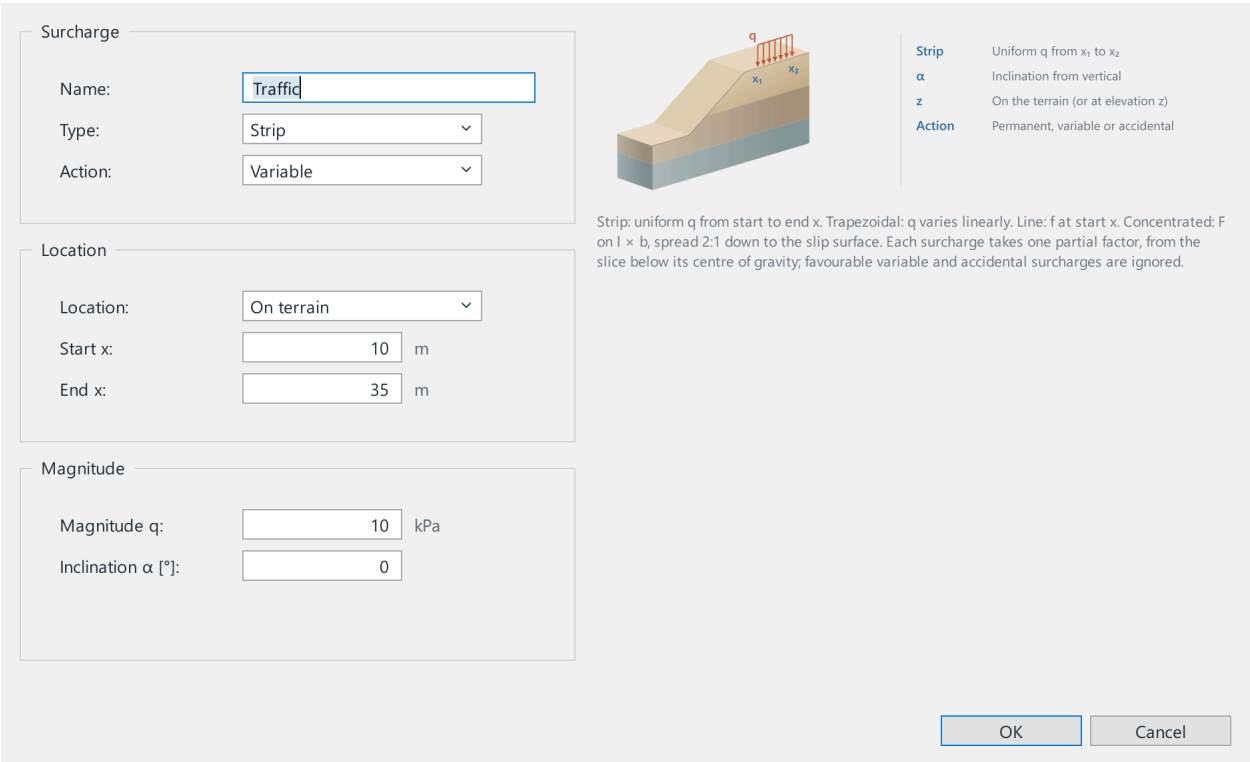


Figure 7.20 — New surcharge

Table 7.13 — New surcharge: fields and buttons

Name	Meaning
Name:	name of the surcharge

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Name	Meaning
Type:	strip, trapezoidal, concentrated force or line load
Action:	permanent, variable or accidental; an accidental surcharge acts only in the accidental situation
Location:	on the ground surface, or at elevation z (a surcharge inside the soil acts only when the slip surface passes below it)
Start x:	x of the start of the surcharge (or of a force or line load)
End x:	x of the end of a strip or trapezoidal surcharge
Magnitude q:	pressure of a strip surcharge, or at the start of a trapezoidal one
Inclination α [°]:	inclination from the vertical, positive towards +x; the vertical part acts as weight, the horizontal part as a weightless force
Add	adds the element with the values entered (the dialog title starts with New) or applies the changes (Edit)
Elevation z:	elevation of a surcharge inside the soil
Magnitude q at end:	pressure at the end of a trapezoidal surcharge
Length l (along x):	footprint of a concentrated force along x; 0 = a point force
Width b (across):	footprint across the section; the force spreads 2:1 down to the slip surface
Magnitude F:	concentrated force, or the force per metre of a line load

7.15 Water

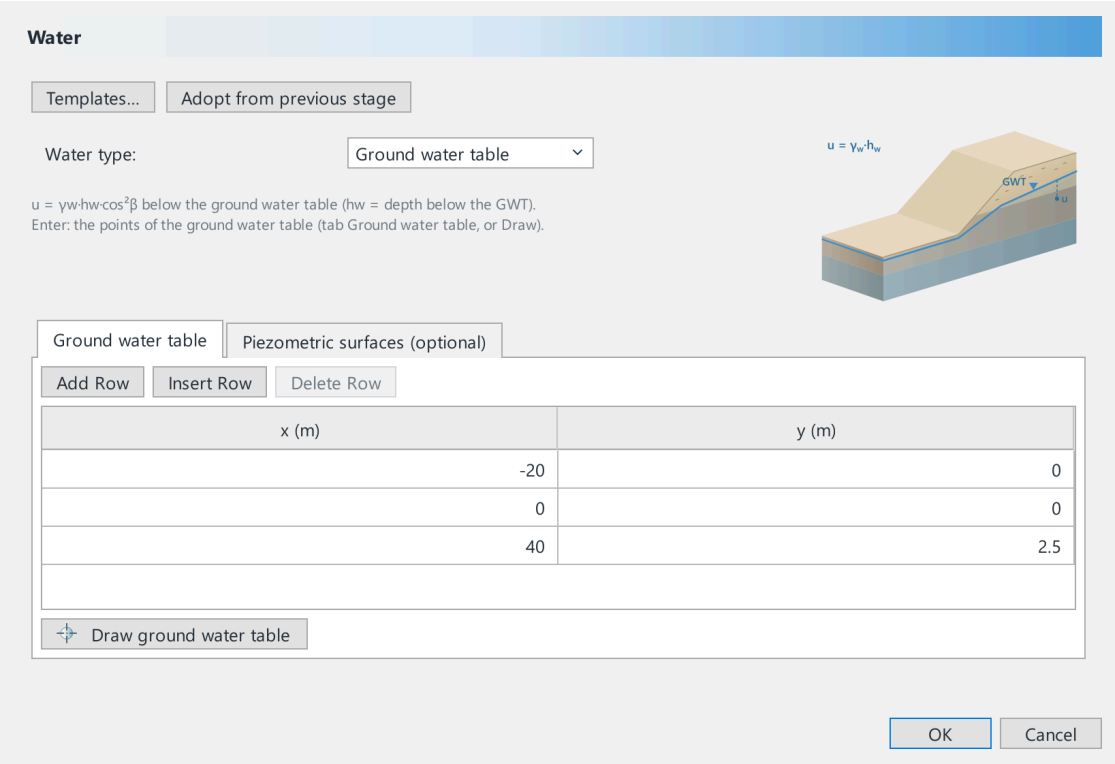


Figure 7.21 — Water

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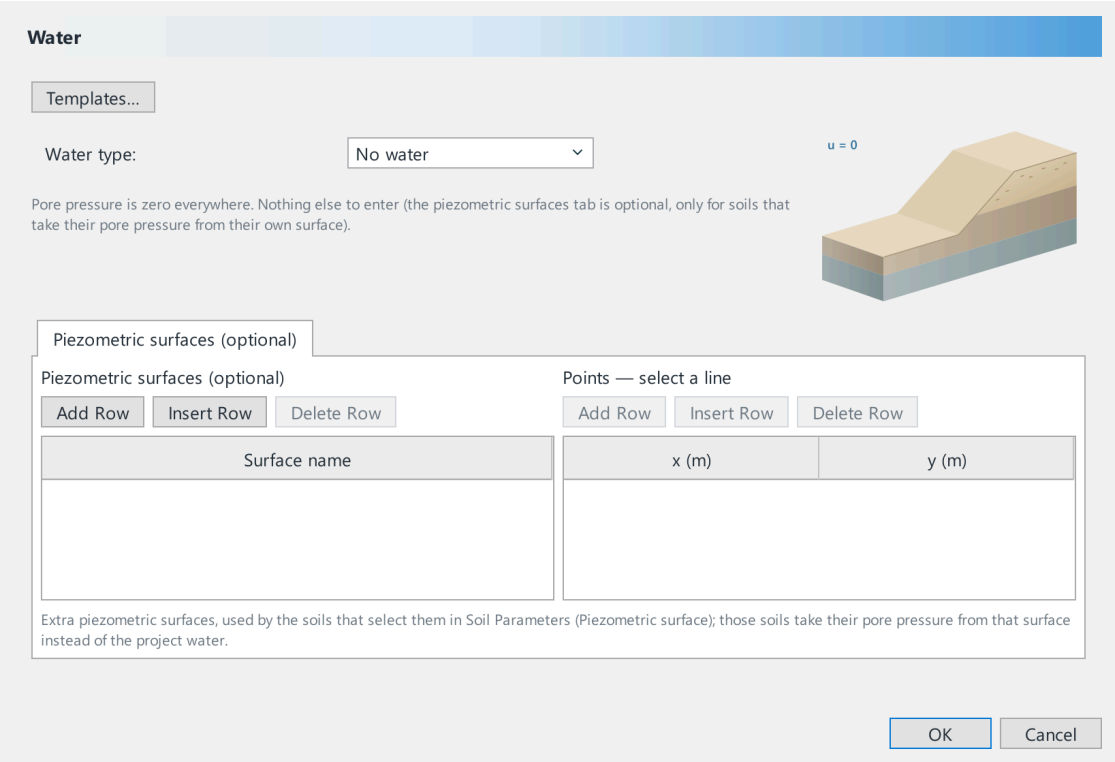


Figure 7.22 — Water

Table 7.14 — Water: fields and buttons

Name	Meaning
Ground water table	tab of the points of the water table
Piezometric surfaces (optional)	tab of the piezometric surfaces that soils may use instead of the project water
Water type:	no water, ground water table, coefficient Ru, rapid drawdown, ground water table with a suction surface, or pore pressure isolines
Templates…	opens Water Templates with common water tables
Add Row	adds a row at the end of the table
Insert Row	inserts a row above the selected row
Delete Row	deletes the selected row
Surface name	name of the piezometric surface
x (m)	x of a point
y (m)	elevation of a point
Draw ground water table	draws the water table on the canvas
Ru interfaces	tab of the lines with their Ru below the ground surface (type Coefficient Ru)
Original GWT	tab of the water table before the drawdown (type Rapid drawdown)
Suction surface	tab of the surface down to which the pore pressure is negative (type GWT and suction surface)
Pore pressure isolines	tab of the lines of equal pore pressure (type Pore pressure isolines)
Ru at the ground surface (type Ru):	pore pressure coefficient at the ground surface
Coefficient Ru	coefficient Ru of the line
Draw original gwt	draws the original water table on the canvas
Draw suction surface	draws the suction surface on the canvas
Pore pressure u (kPa)	pore pressure of the isoline

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7.16 Water Templates

The water templates set a ground water table of a common shape (no water, horizontal, following the slope, water in front of the slope) from the geometry of the model; every point stays editable.

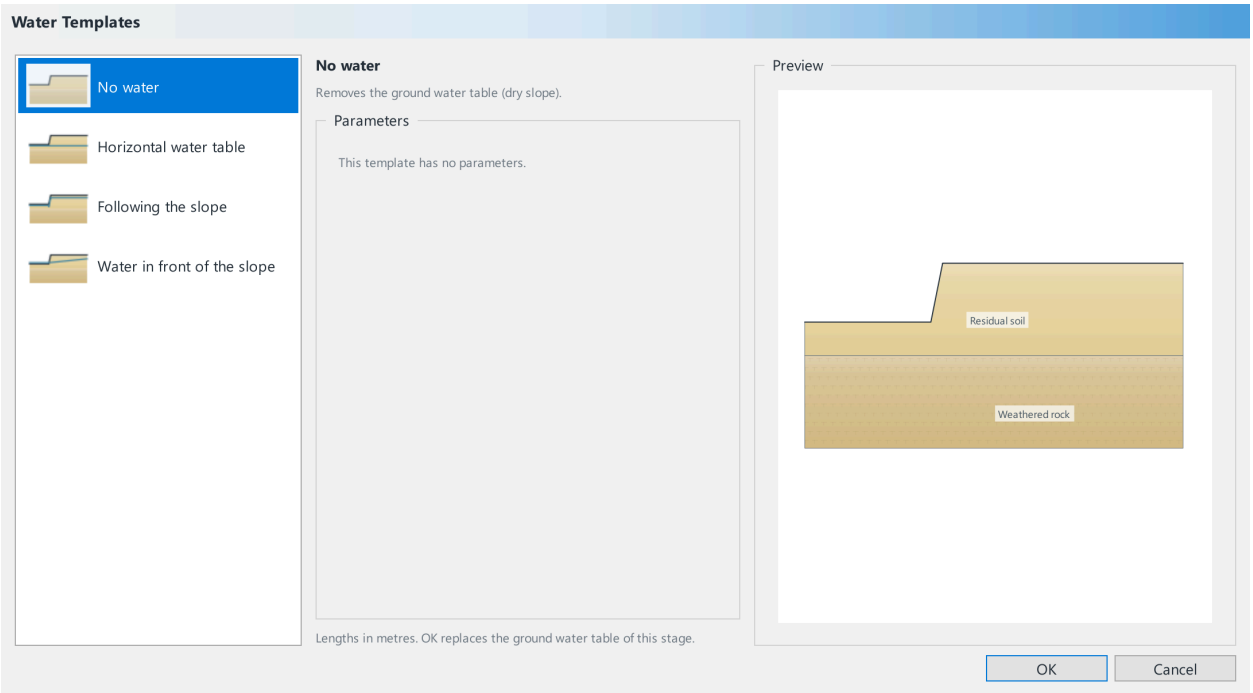


Figure 7.23 — Water Templates

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7.17 Analysis

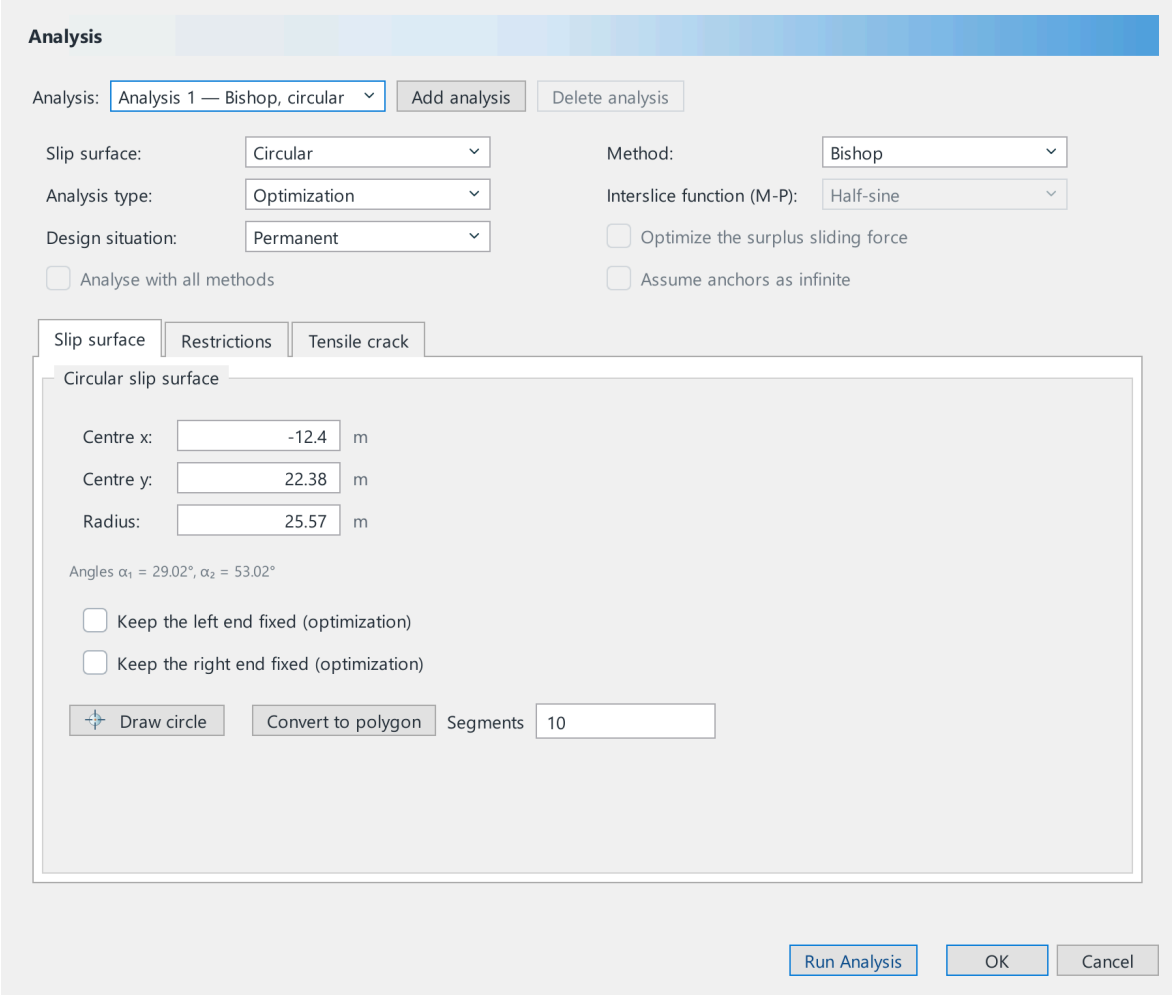


Figure 7.24 — Analysis

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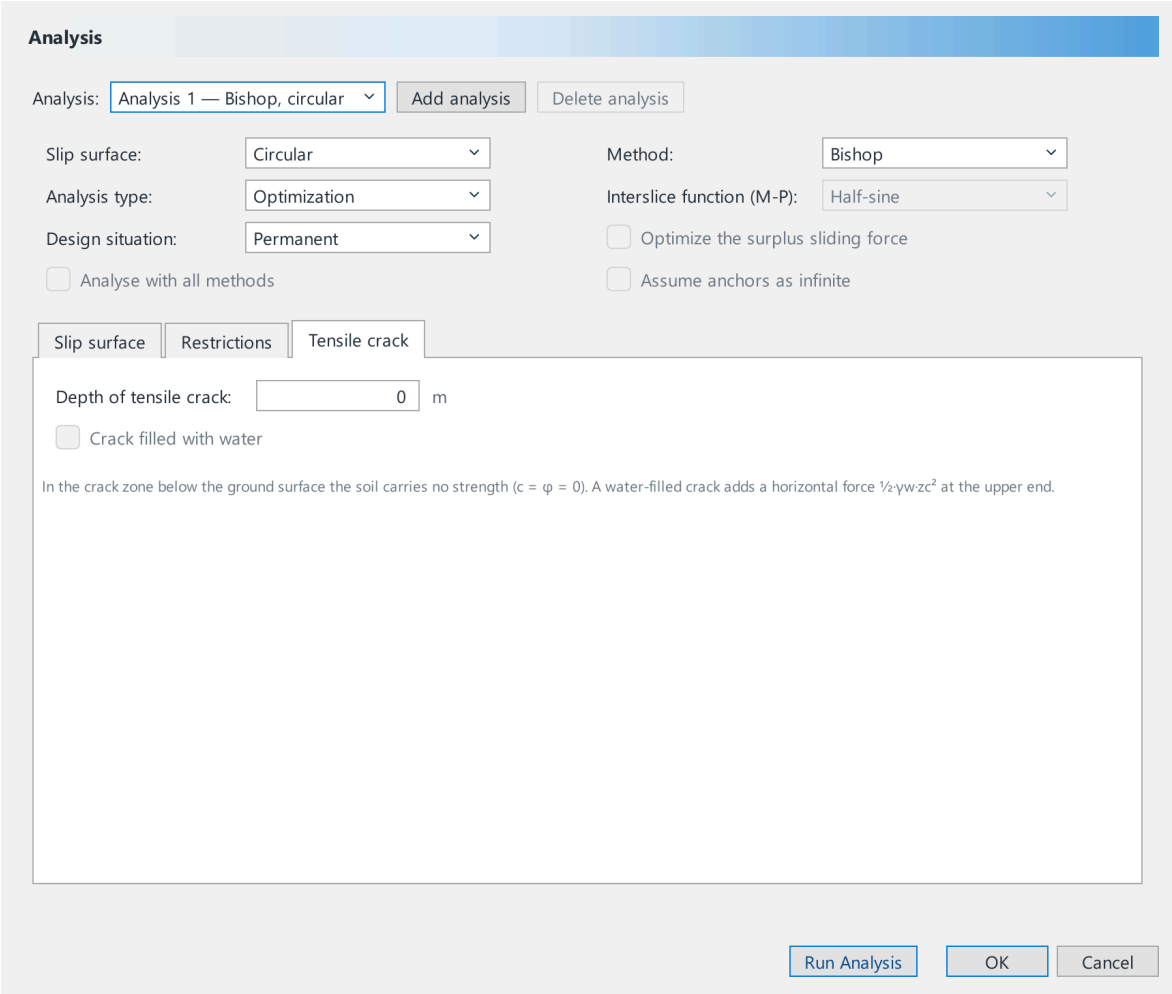


Figure 7.25 — Analysis

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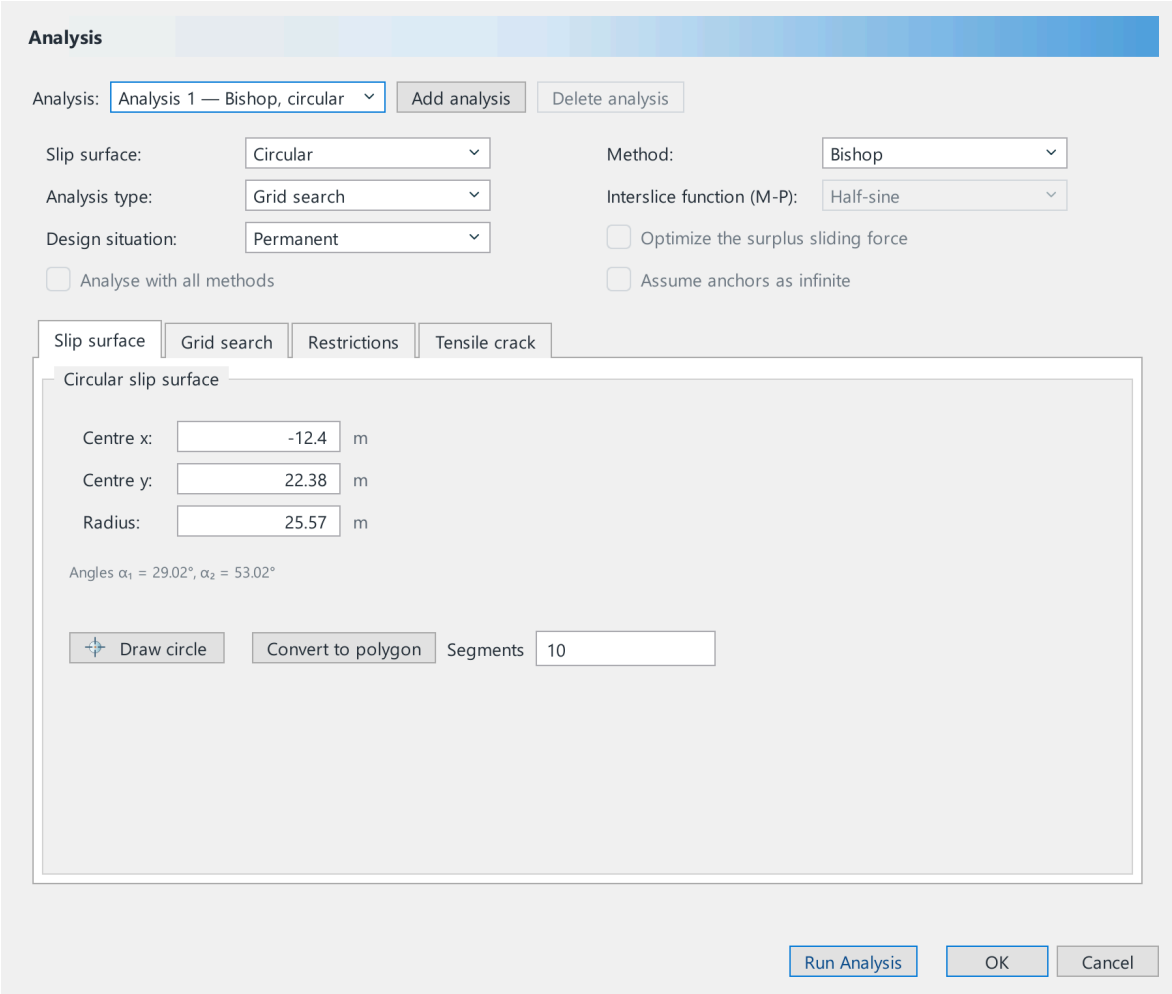


Figure 7.26 — Analysis

Table 7.15 — Analysis: fields and buttons

Name	Meaning
Slip surface	tab of the input slip surface
Tensile crack	tab of the tensile crack
Analysis type:	standard (the given surface), optimization, grid search (circles) or random search
Design situation:	permanent, transient, accidental or seismic; selects the required factor of safety and the partial factors
Analyse with all methods	compares all methods of Program Options on the input slip surface (standard analysis)
Method:	limit equilibrium method
Interslice function (M-P):	shape of the interslice force function of Morgenstern-Price
Optimize the surplus sliding force	with ITFM, the optimization looks for the largest surplus sliding force while the design factor of safety is not reached
Assume anchors as infinite	anchors always act and the required free lengths are computed; unchecked, the free and root lengths decide whether an anchor acts
Depth of tensile crack:	depth of the crack zone below the ground surface, in which the soil carries no strength
Crack filled with water	a water-filled crack adds a horizontal force ½·γw·zc² at the upper end
Centre x:	x of the centre of the circle

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Name	Meaning
Centre y:	elevation of the centre of the circle
Radius:	radius of the circle
Add analysis	adds an analysis to the stage (slip surface, method and type of analysis)
Delete analysis	deletes the current analysis
Draw circle	draws the circle on the canvas: two points on the ground, then the radius
Convert to polygon	turns the circle into a polygonal slip surface
Run Analysis	runs the current analysis (F9)
Grid search	tab of the grid of circles
Restrictions	tab of the restriction segments
Repetitions along x:	number of grid positions on each side of the centre along x
Step along x:	spacing of the grid along x
Repetitions along z:	number of grid positions on each side of the centre along z
Step along z:	spacing of the grid along z
Rotation [°]:	rotation of the grid of centres
Repetitions of radius:	number of radii on each side of the input radius
Step of radius:	step of the radius
Add Row	adds a row at the end of the table
Insert Row	inserts a row above the selected row
Delete Row	deletes the selected row
x_1 (m)	x of the start of the segment (or of a box centre line)
y_1 (m)	elevation of the start
x_2 (m)	x of the end
y_2 (m)	elevation of the end
Random search deflects	in a random search the trial surfaces are deflected up or down at the segment
Draw restriction segments	draws restriction segments on the canvas
Refine grid	halves the steps around the critical circle
Random search	tab of the random search
Slip surface:	circular or polygonal slip surface
Polygonal surfaces:	irregular surfaces or sliding blocks
Number of blocks:	number of sliding blocks generated
Segment length:	length of the straight segments of which the trial surfaces are built
h (m)	height of the box of a sliding block
x (m)	x of a point of the polygonal slip surface
y (m)	elevation of a point of the polygonal slip surface
Optimization	restraint of the point during optimization: free, fixed, or only along x or y
Draw polygonal slip surface	draws the polygonal slip surface on the canvas
Convert to circle	turns the polygon into the circle through its points
Keep the left end fixed (optimization)	the left end of the polygon keeps its position
Keep the right end fixed (optimization)	the right end of the polygon keeps its position
Initiation points:	number of initiation points on the ground surface
Surfaces per point:	number of surfaces generated from each initiation point

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Name	Meaning
Initial direction from [°]:	one limit of the direction of the first segment
Initial direction to [°]:	other limit of the direction of the first segment; 0 and 0 = automatic
Limit the depth	keeps the trial surfaces above a lowest elevation
Lowest elevation y:	lowest elevation of the trial surfaces (otherwise the bottom of the model)
Automatic (toe side → crest side)	initiation and termination ranges from the toe and crest sides of the ground surface
Initiation from x:	start of the range of initiation points
Initiation to x:	end of the range of initiation points
Termination from x:	start of the range in which the surfaces must end
Termination to x:	end of the range in which the surfaces must end

7.18 Results

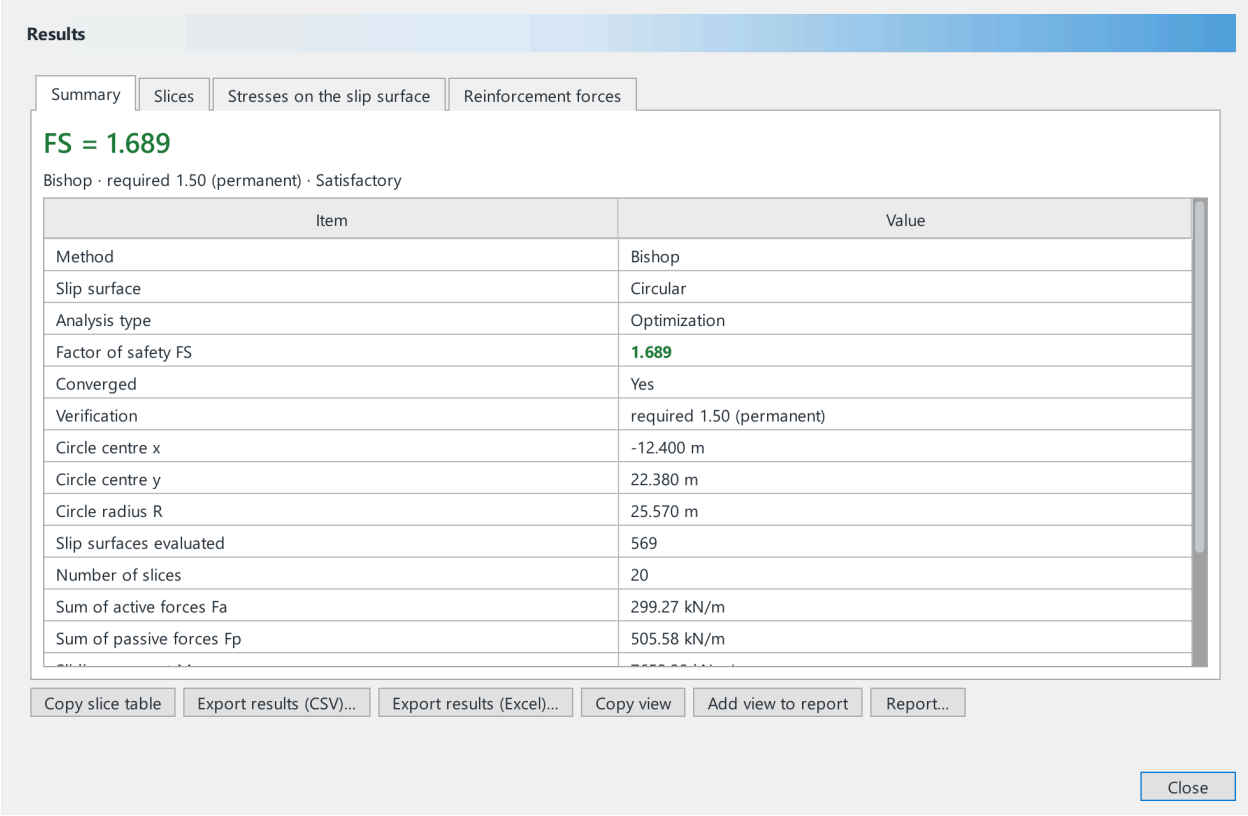


Figure 7.27 — Results

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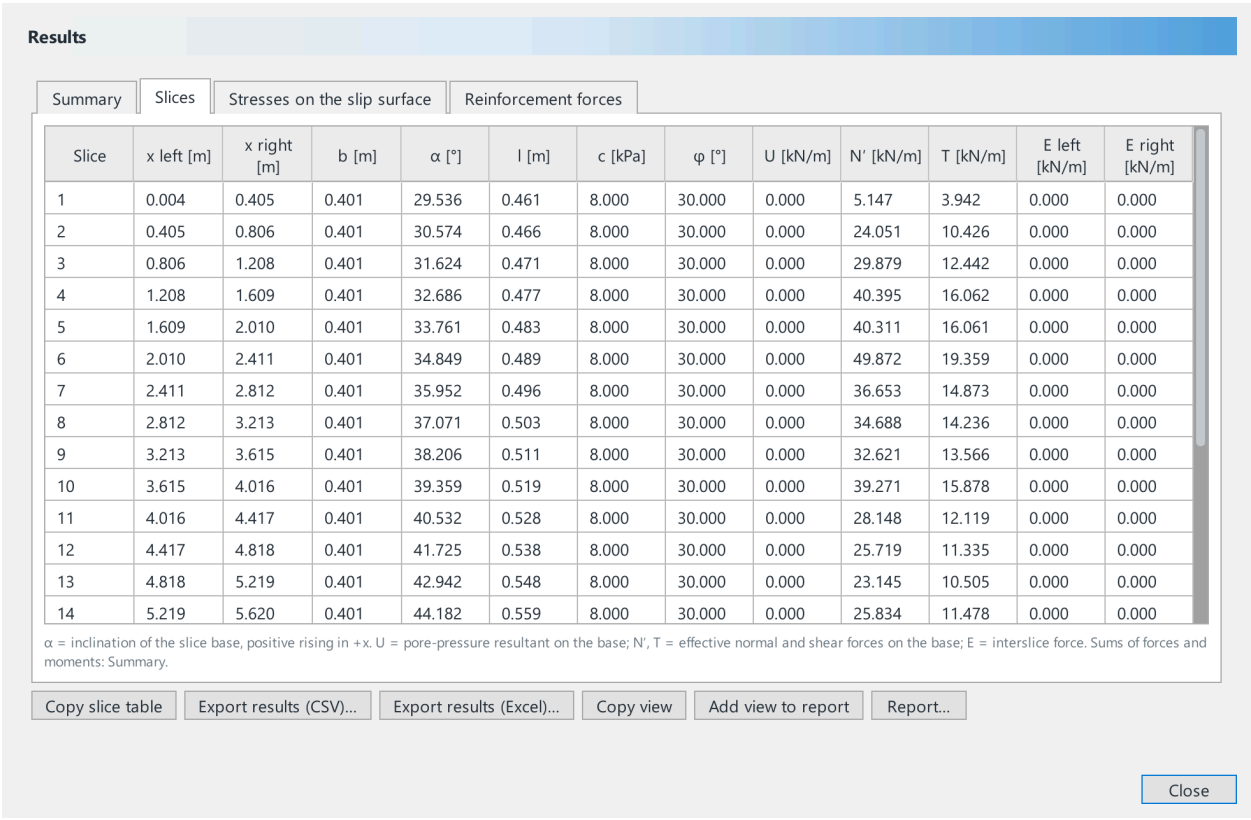


Figure 7.28 — Results

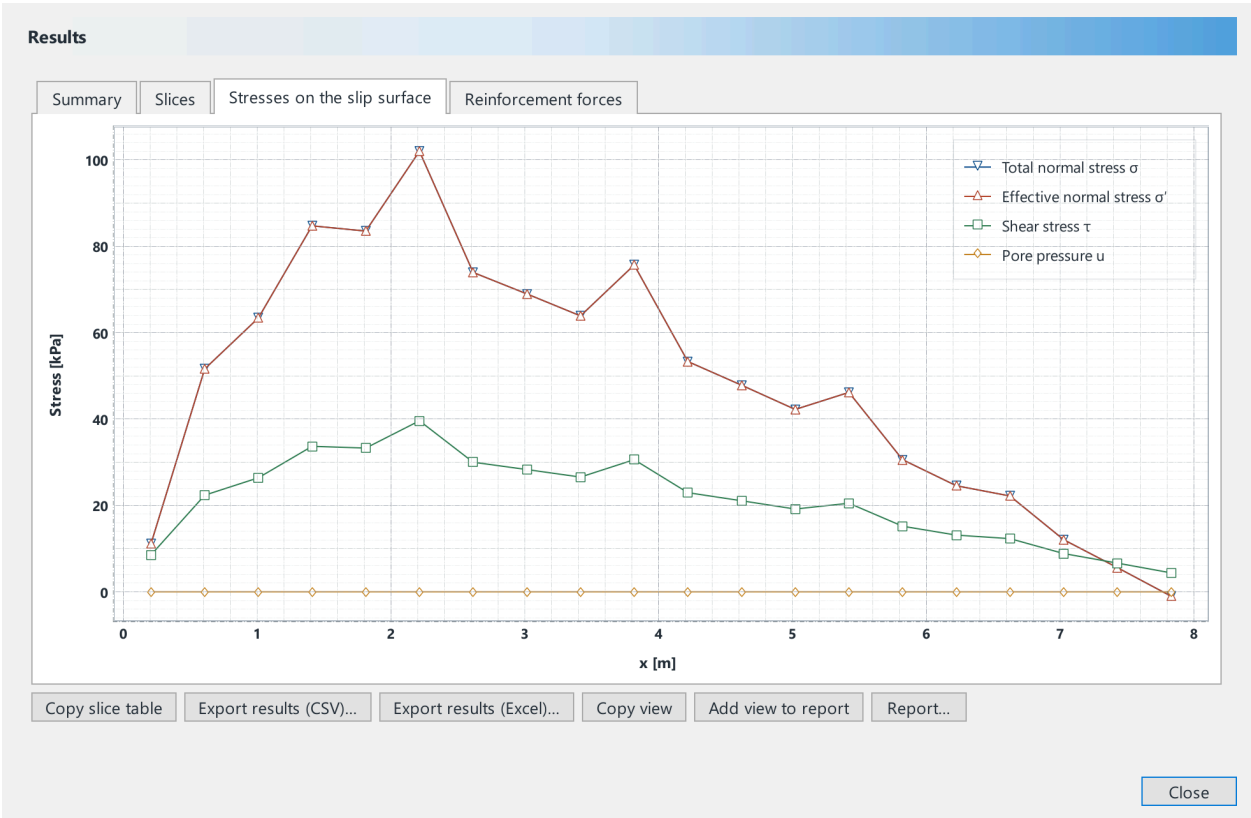


Figure 7.29 — Results

Table 7.16 — Results: fields and buttons

Name	Meaning

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Name	Meaning
Summary	page of the factor of safety, the verification and the slip surface
Slices	page of the slice table
Stresses on the slip surface	page of the normal and shear stresses along the slip surface
Anchors	page of the anchor forces and the required free lengths
Stabilizing piles	page of the forces on the stabilizing piles
Reinforcement forces	page of the forces of all reinforcement elements
Element	type and number of the element
No	number of the row
Force [kN/m]	force of the element per metre of slope
Force per element [kN]	force of one element
Acting	whether the element acts (it crosses the slip surface with enough anchorage)
Pile	number of the pile
x [m]	x of the element or the left side of a slice
Ground [m]	elevation of the ground at the pile
Slip surface [m]	elevation of the slip surface at the pile
Slip depth Ls [m]	depth of the slip surface below the ground at the pile
T [kN]	shear force of one pile
Spacing [m]	spacing of the elements
Active force [kN/m]	sliding force at the pile
Passive force [kN/m]	resisting force at the pile
Pile force for FS 1.50 [kN]	force one pile must carry for the required factor of safety
Anchor	number of the anchor
y [m]	elevation of the anchor head
Free length [m]	entered free length
Required free length [m]	free length needed for the root to lie behind the slip surface
Acting force [%]	share of the anchor force that acts
Slice	number of the slice
x left [m]	x of the left side of the slice
x right [m]	x of the right side of the slice
b [m]	width of the slice
α [°]	inclination of the slice base
l [m]	length of the slice base
c [kPa]	cohesion at the slice base
φ [°]	angle of friction at the slice base
U [kN/m]	pore water force on the slice base
N′ [kN/m]	effective normal force on the slice base
E left [kN/m]	interslice force on the left side
E right [kN/m]	interslice force on the right side
Item	quantity of the summary
Value	value of the quantity
Copy slice table	copies the slice table for a spreadsheet

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Name	Meaning
Export results (CSV)…	writes the result tables to a CSV file
Export results (Excel)…	writes the result tables to an Excel workbook
Copy view	copies the drawing with the result summary to the clipboard
Add view to report	adds the current drawing to the pictures of the report
Report…	opens the Report Builder

7.19 New nail

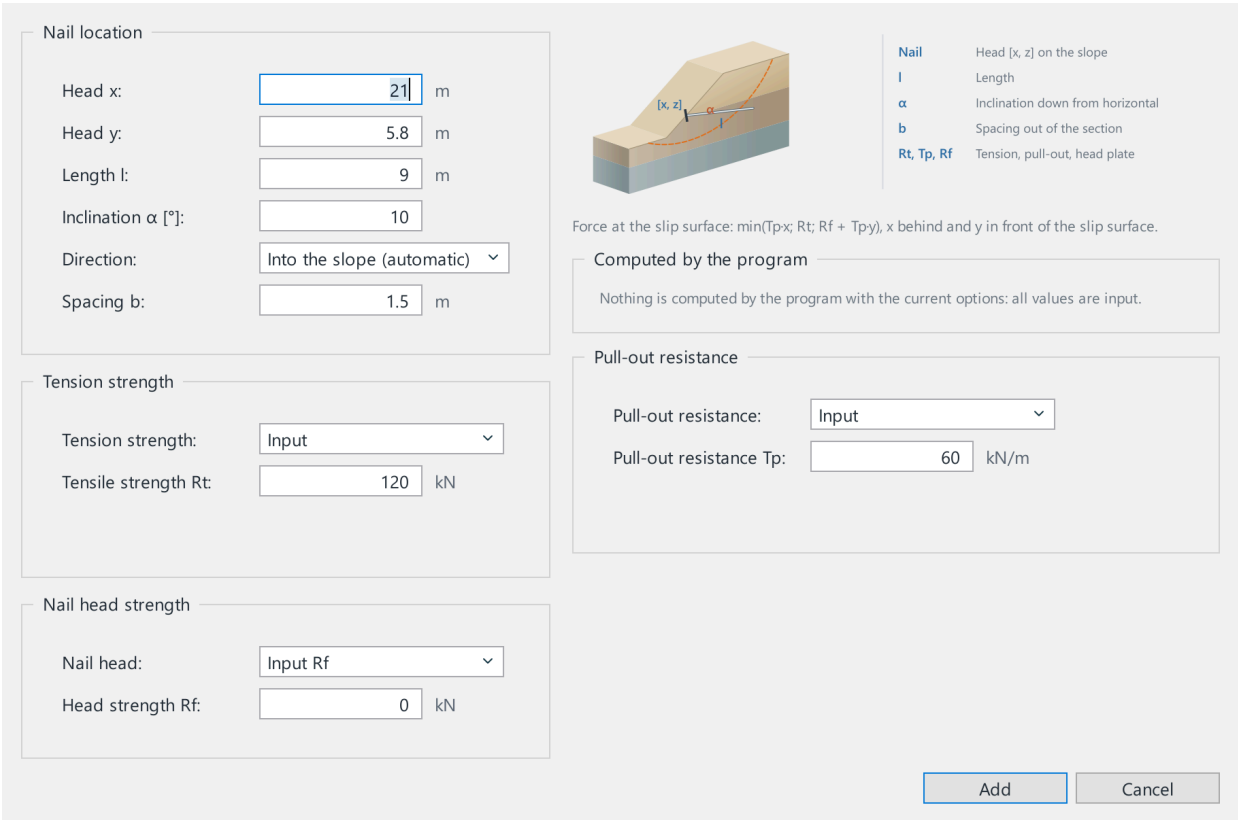


Figure 7.30 — New nail

Table 7.17 — New nail: fields and buttons

Name	Meaning
Head x:	x of the nail head
Head y:	elevation of the nail head
Length l:	length of the nail
Inclination α [°]:	inclination of the nail from the horizontal, positive downward
Direction:	side to which the nail runs from its head; Automatic: into the slope
Spacing b:	spacing of the nails along the slope
Tension strength:	tensile strength entered, or computed from the bar diameter and its strength
Tensile strength Rt:	tensile strength of one nail
Nail head:	strength of the nail head entered, or a free head without strength
Head strength Rf:	strength of the nail head (facing)
Pull-out resistance:	pull-out resistance entered, or from the bond strength, the cohesion of the soil, the effective stress or HA 68/94

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Name	Meaning
Pull-out resistance Tp:	pull-out resistance per metre of nail
Add	adds the element with the values entered (the dialog title starts with New) or applies the changes (Edit)
Hole diameter d:	diameter of the drilled hole
Bond strength qs:	bond strength between grout and soil; Tp = π·d·qs
Bar diameter ds:	diameter of the steel bar
Bar strength fy:	yield strength of the steel bar; Rt = π·ds²/4·fy

7.20 New geotextile

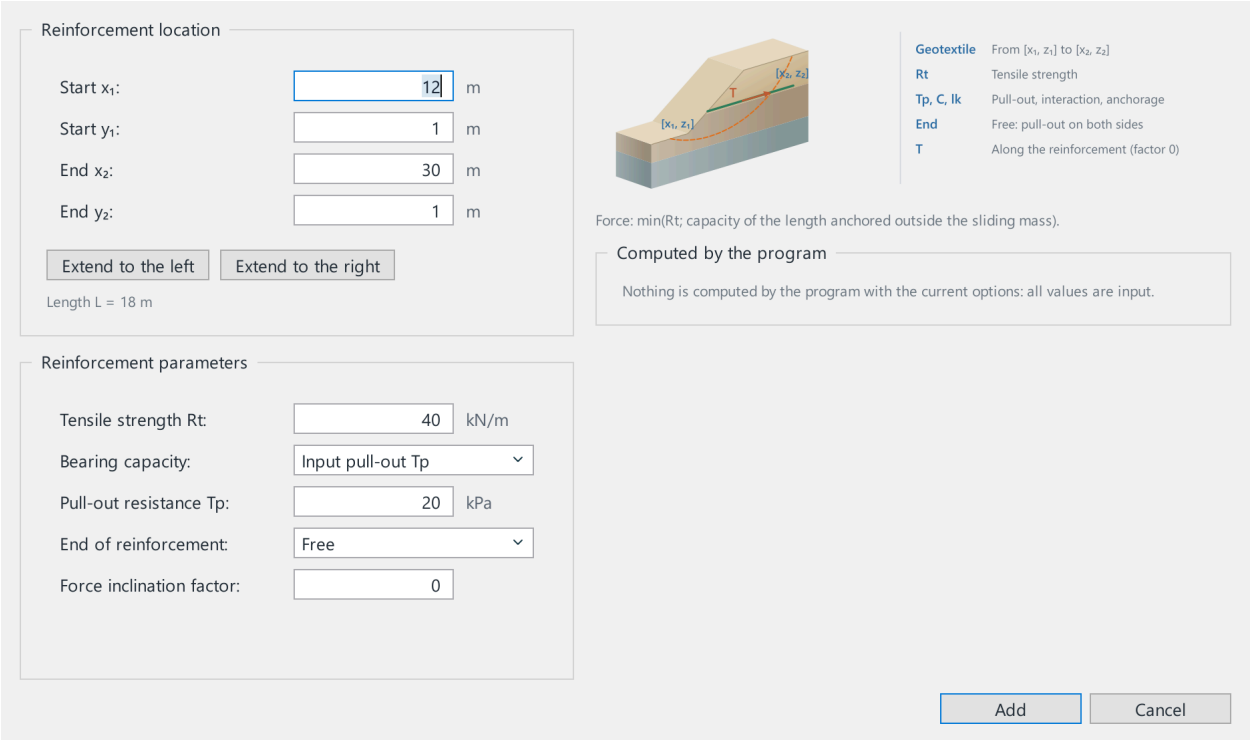


Figure 7.31 — New geotextile

Table 7.18 — New geotextile: fields and buttons

Name	Meaning
Start x_1:	x of the start of the geotextile
Start y_1:	elevation of the start
End x_2:	x of the end
End y_2:	elevation of the end
Tensile strength Rt:	tensile strength of the geotextile per metre of slope
Bearing capacity:	pull-out capacity entered, computed with a coefficient of interaction, or from an anchorage length
Pull-out resistance Tp:	pull-out resistance per metre of geotextile
End of reinforcement:	which ends are fixed; a free end is also limited by pull-out in front of the slip surface
Force inclination factor:	direction of the force: 0 = along the geotextile, 1 = tangent to the slip surface
Extend to the left	extends the start along the geotextile to the ground surface or the model edge
Extend to the right	extends the end along the geotextile to the ground surface or the model edge

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Name	Meaning
Add	adds the element with the values entered (the dialog title starts with New) or applies the changes (Edit)
Coefficient of interaction C:	ratio of the shear strength between geotextile and soil to that of the soil
Anchorage length lk:	length needed to anchor the full tensile strength

7.21 New stabilizing pile

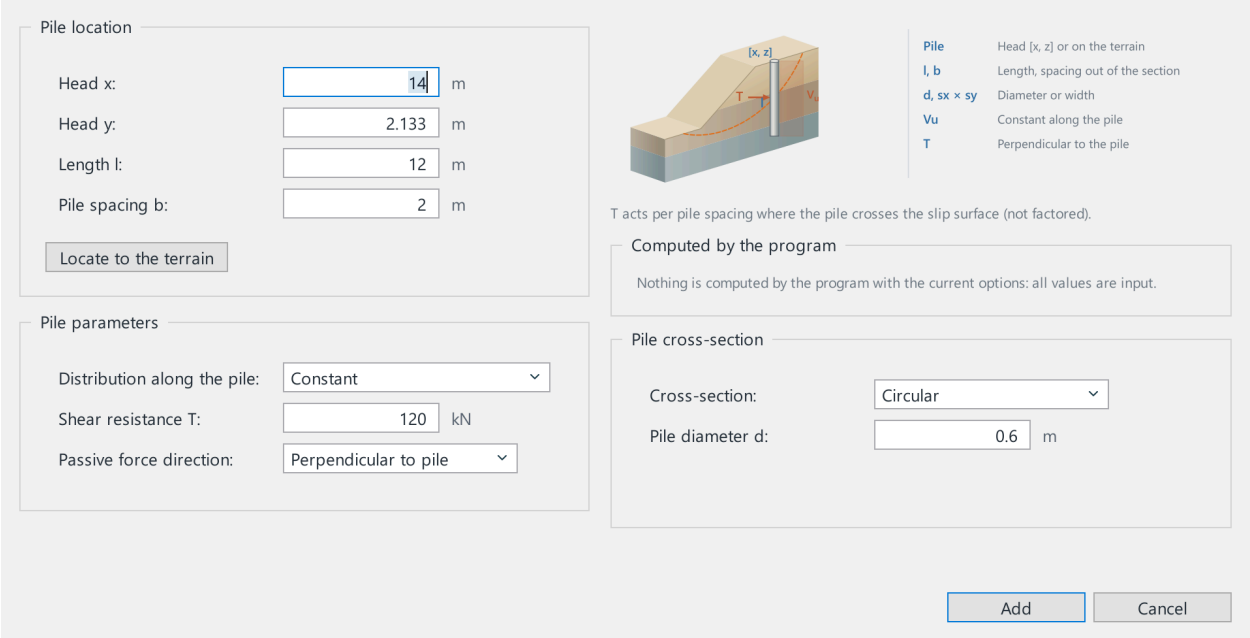


Figure 7.32 — New stabilizing pile

Table 7.19 — New stabilizing pile: fields and buttons

Name	Meaning
Head x:	x of the pile
Head y:	elevation of the pile head
Length l:	length of the pile
Pile spacing b:	spacing of the piles along the slope
Distribution along the pile:	shear resistance constant, linear from the pile base (gradient K) or from a table of shear against depth
Shear resistance T:	shear one pile carries across the slip surface
Passive force direction:	direction of the pile force: horizontal, or parallel to the slip surface
Cross-section:	circular or rectangular section (for the drawing and for Solpile)
Pile diameter d:	diameter of a circular pile
Locate to the terrain	puts the pile head on the ground surface of the active stage at x
Add	adds the element with the values entered (the dialog title starts with New) or applies the changes (Edit)
Gradient K:	rate at which the shear resistance grows from the pile base (linear distribution)
Multiplication factor:	factor on the shear of the table, for example below 1 when the shear acts above the slip surface
Import shear demand from Solpile…	reads the shear of the pile from a Solpile result
Width sx (in the section):	width of a rectangular pile in the plane of the section

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Name	Meaning
Width sy (across):	width of a rectangular pile across the section

7.22 Report Builder

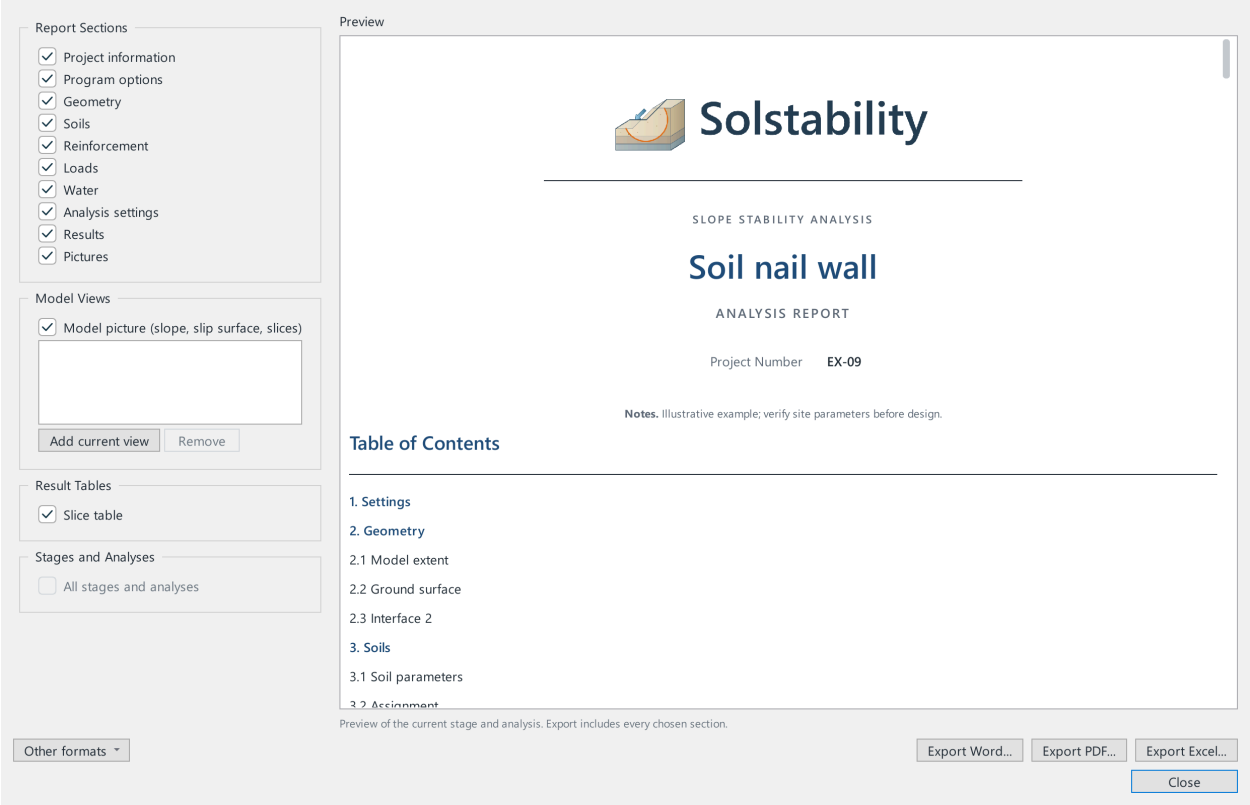


Figure 7.33 — Report Builder

The Report Builder (Results ▸ Report...) is a tree of the sections, tables and pictures of the report that are ticked for export, with the buttons Export Word..., Export PDF... and Export Excel... (Other formats for HTML). All stages and analyses adds every stage and analysis of the project to the report. The tree contains:

Project information; Program options; Geometry; Soils; Reinforcement; Loads; Water; Analysis settings; Results; Pictures; Model picture (slope, slip surface, slices); Add current view; Remove; Slice table; All stages and analyses; Other formats; Export Word...; Export PDF...; Export Excel....

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8 Analysis and results

8.1 The Analysis step

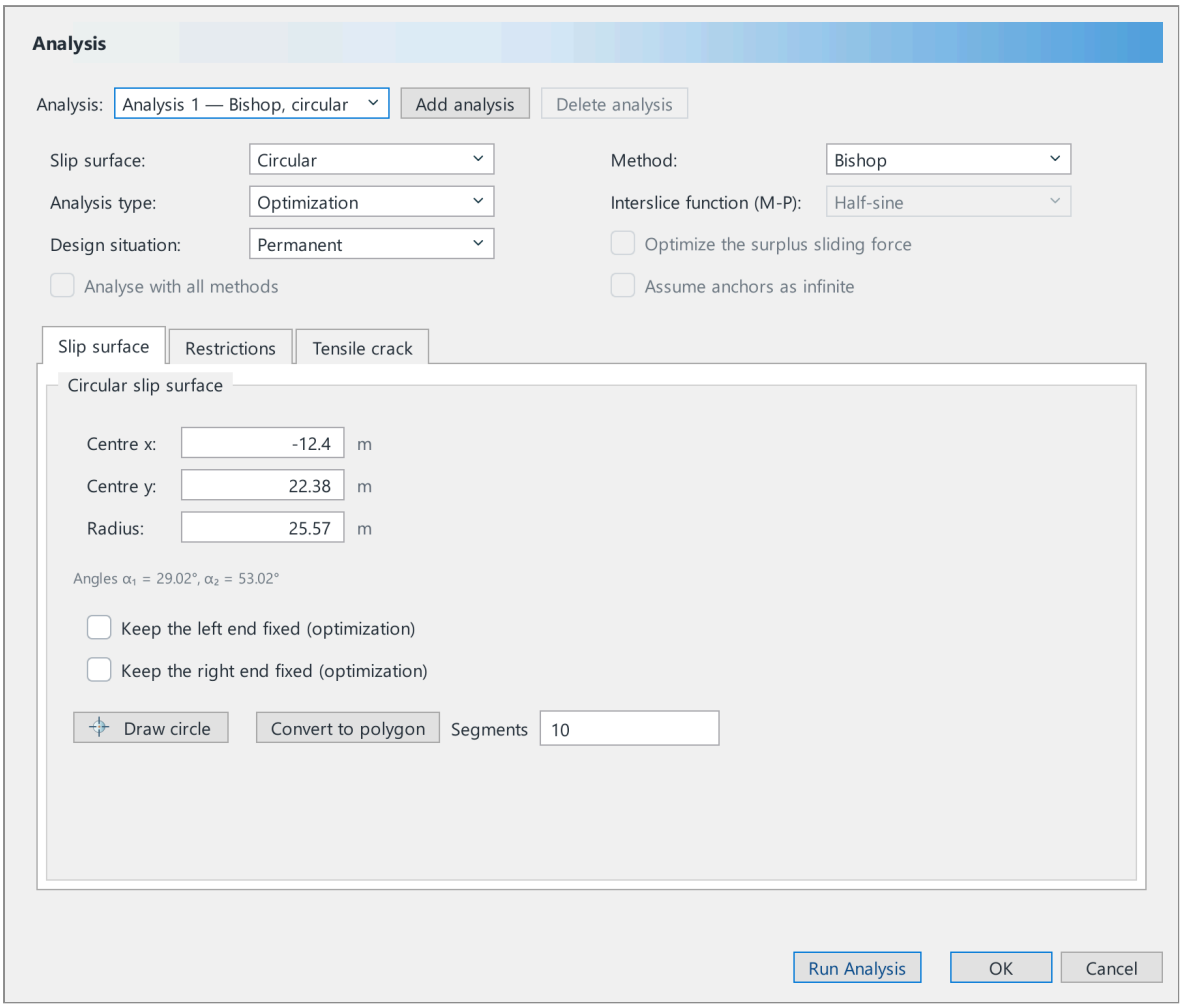


Figure 8.1 — Analysis

The upper part of the step selects the **Slip surface** (circular or polygonal), the **Analysis type**, the **Method** and the design situation. Only the inputs that the current choices use are shown: the circle or the polygon, and the tabs of the grid or random search and of the restrictions only when they apply. Several analyses can be kept in a stage with **Add analysis** and selected in the list at the top.

Table 8.1 — Types of analysis

Type	What it does
Standard	Analyses the slip surface entered. *Analyse with all methods* compares the methods chosen in the program options on that surface.
Optimization	Starts from the slip surface entered and moves it to the minimum factor of safety. Ends of a circle and points of a polygon can be fixed; polygon points can be restricted to horizontal or vertical movement.
Grid search	Evaluates a grid of circles around the circle entered (Figure 8.2): repetitions and steps of the centre along the grid *x* and *z* directions and of the radius. The most critical circle becomes the input circle; **Refine grid** halves the steps around it.
Random search	Generates trial surfaces (Figure 8.3): circles or irregular surfaces from initiation points to a termination range on the ground surface, built of segments of the given length, or sliding blocks through boxes. The ranges can be set automatically from the toe and crest sides; the depth and the initial direction can be limited, and restrictions deflect the trial surfaces up or down.

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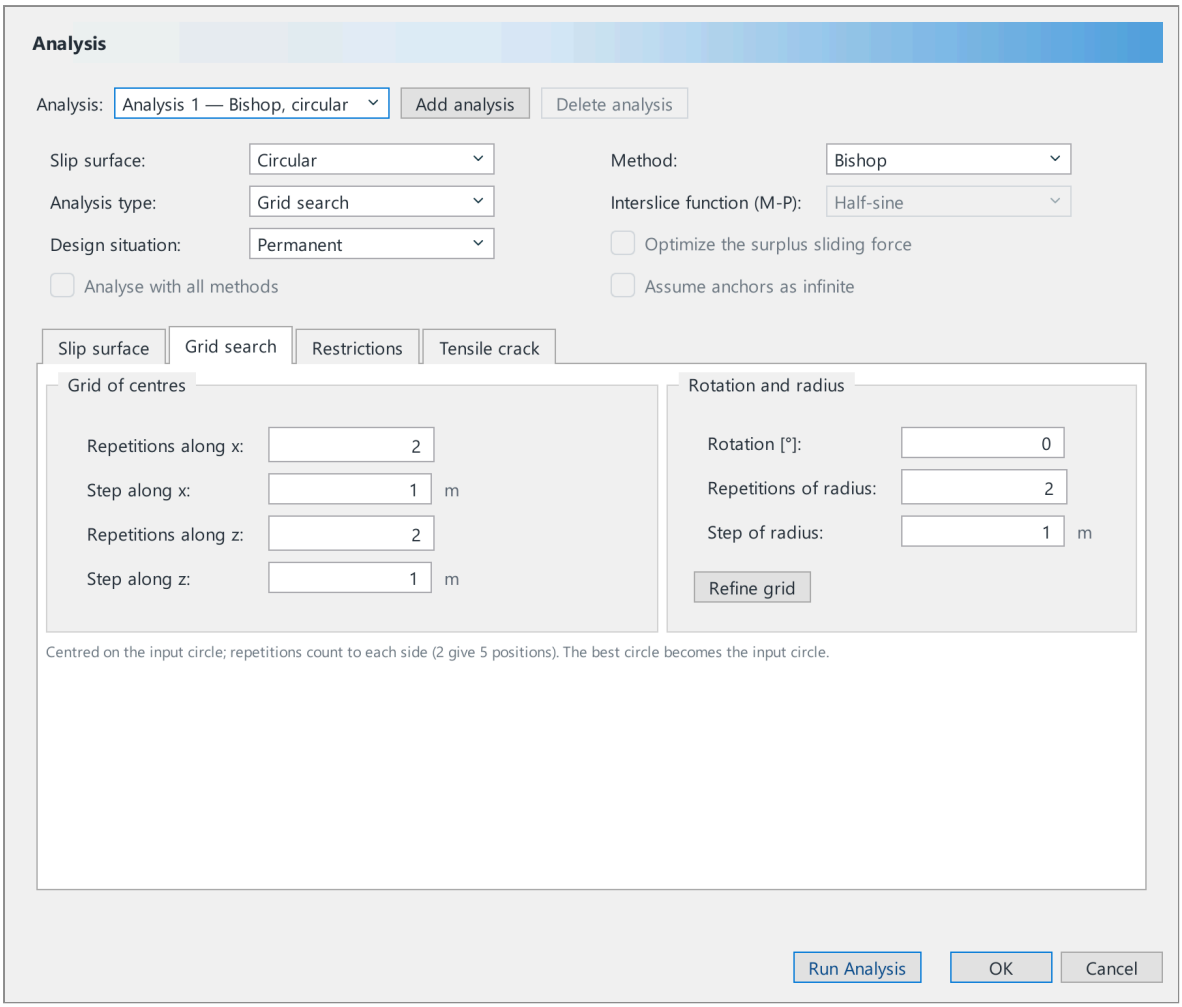


Figure 8.2 — Analysis, grid search

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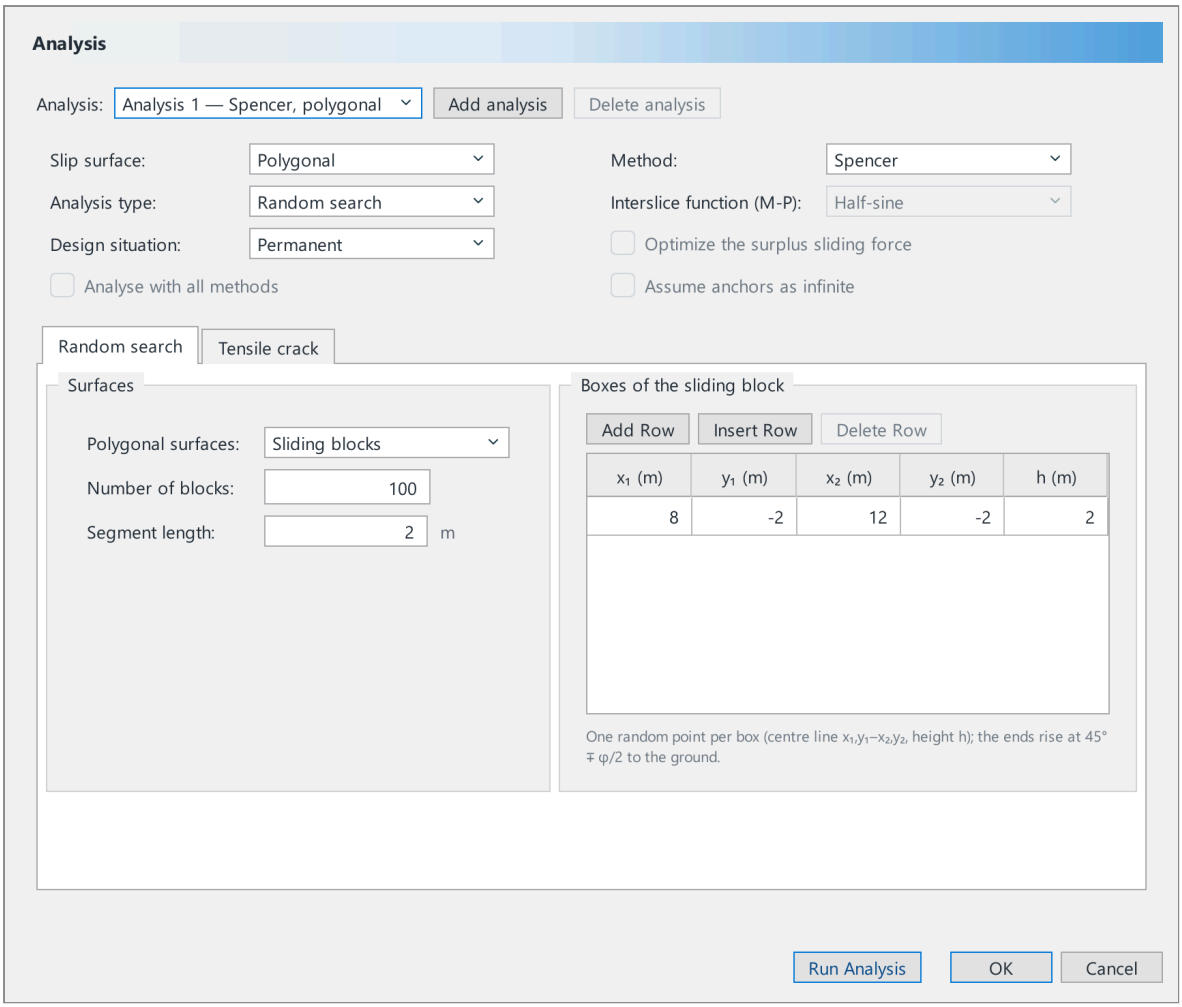


Figure 8.3 — Analysis, random search of sliding blocks

A circle is entered by its centre and radius or drawn with **Draw circle**: click two points on the ground surface, move the mouse to pull the radius, and click again. A polygon is entered as points from left to right or drawn. **Convert to polygon** and **Convert to circle** change one into the other. The tab **Restrictions** holds segments that a slip surface may not cross, and **Tensile crack** the depth of a tensile crack and whether it is filled with water.

8.2 Running the analysis

Analysis ▸ Check Input (F8) lists problems of the input; the Analysis step shows the first of them and keeps **Run Analysis** disabled until they are solved. **Run Analysis** (F9) analyses the current analysis of the current stage. During an optimization or a search the status bar shows the progress; Esc stops it, and the most critical surface found so far is kept. After an optimization or a search the drawing replays it: the slip surface moves towards the critical one, or the trial surfaces appear one after another. Esc skips the replay. The critical surface becomes the input surface of the analysis, so that a following standard analysis or a refined search starts from it.

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8.3 Results

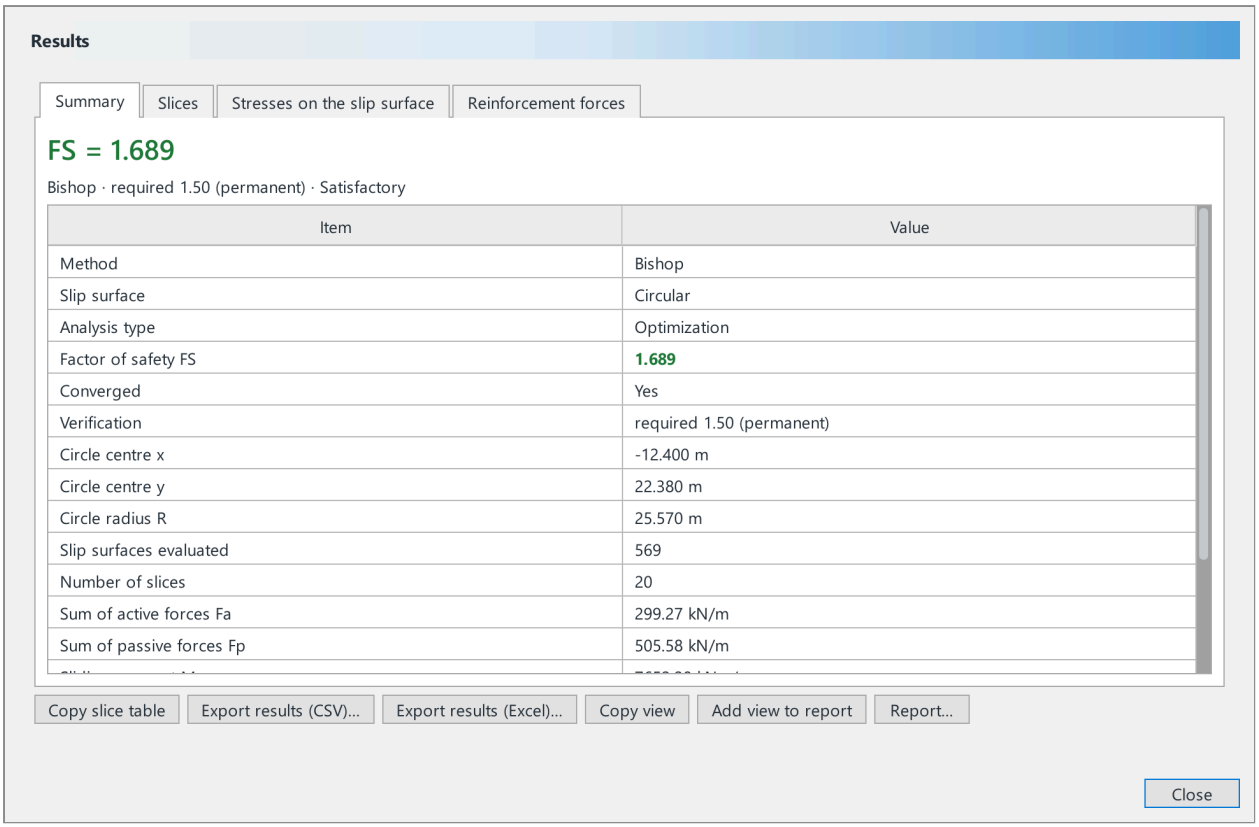


Figure 8.4 — Results, summary

The Results step shows the factor of safety and its verification, the method, the slip surface, the sums of the active and passive forces F_a, F_p and, for a circle, the sliding and resisting moments M_a, M_p about its centre (Technical Reference SPL-SS-003, Sums of forces and moments); the same values appear in the summary on the drawing. With *Analyse with all methods* a table lists these values for each method. A factor of safety that satisfies the requirement is shown in green, one that does not in red, in the summary and in every table of factors of safety (all methods, grid, the most critical random surfaces). Further tabs list the slices (Figure 8.5), plot the stresses on the slip surface (total and effective normal stress, shear stress and pore pressure per slice), show the interslice forces, the grid search or the 10 most critical surfaces of a random search, and the forces of anchors, piles and other reinforcement where present. The buttons copy the slice table, export all tables to CSV or to an Excel workbook (one sheet per table, opened in Excel), copy the drawing, add it to the report, and open the report builder.

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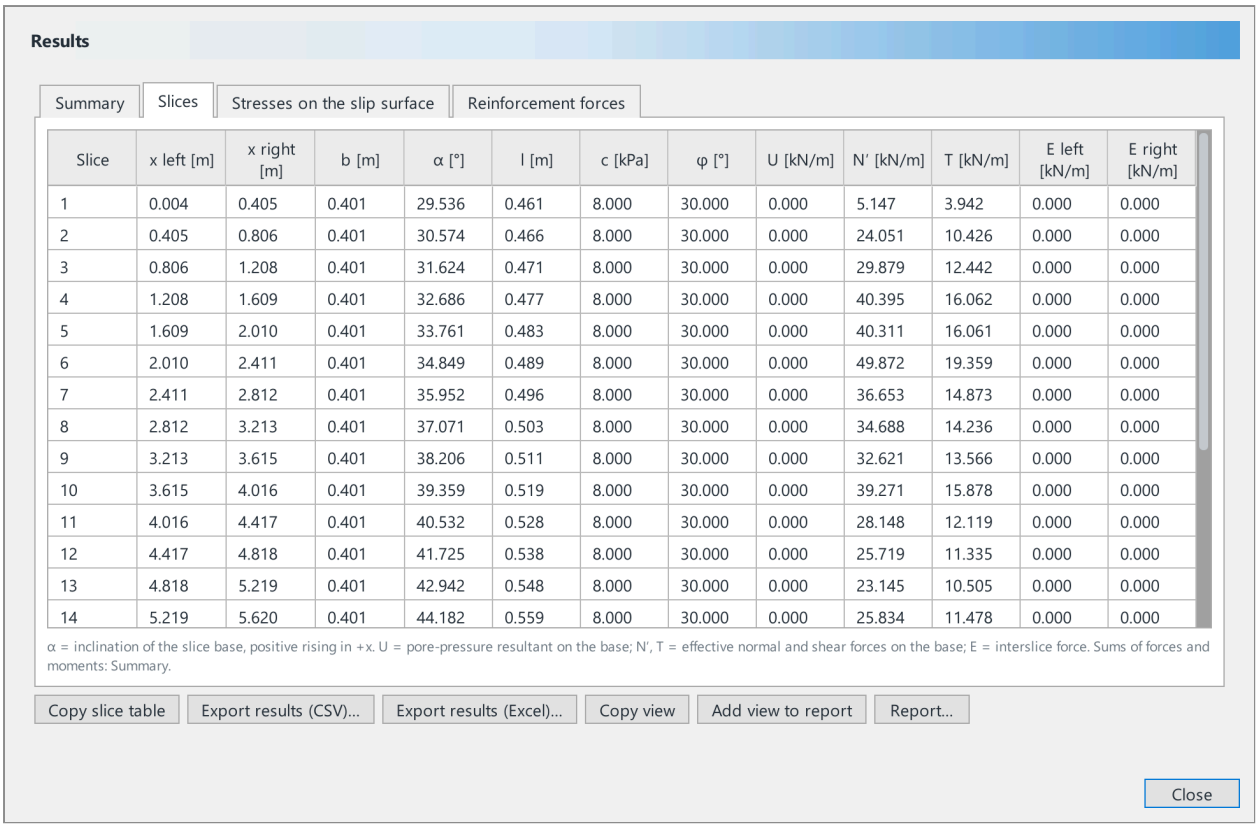


Figure 8.5 — Results, slices

Check the results before relying on them: the slip surface on the drawing should be plausible, the method should have converged (a warning says so otherwise), and the factor of safety should not change much between methods that satisfy complete equilibrium. Compare a search with a search from another start or with a grid.

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8.4 Report

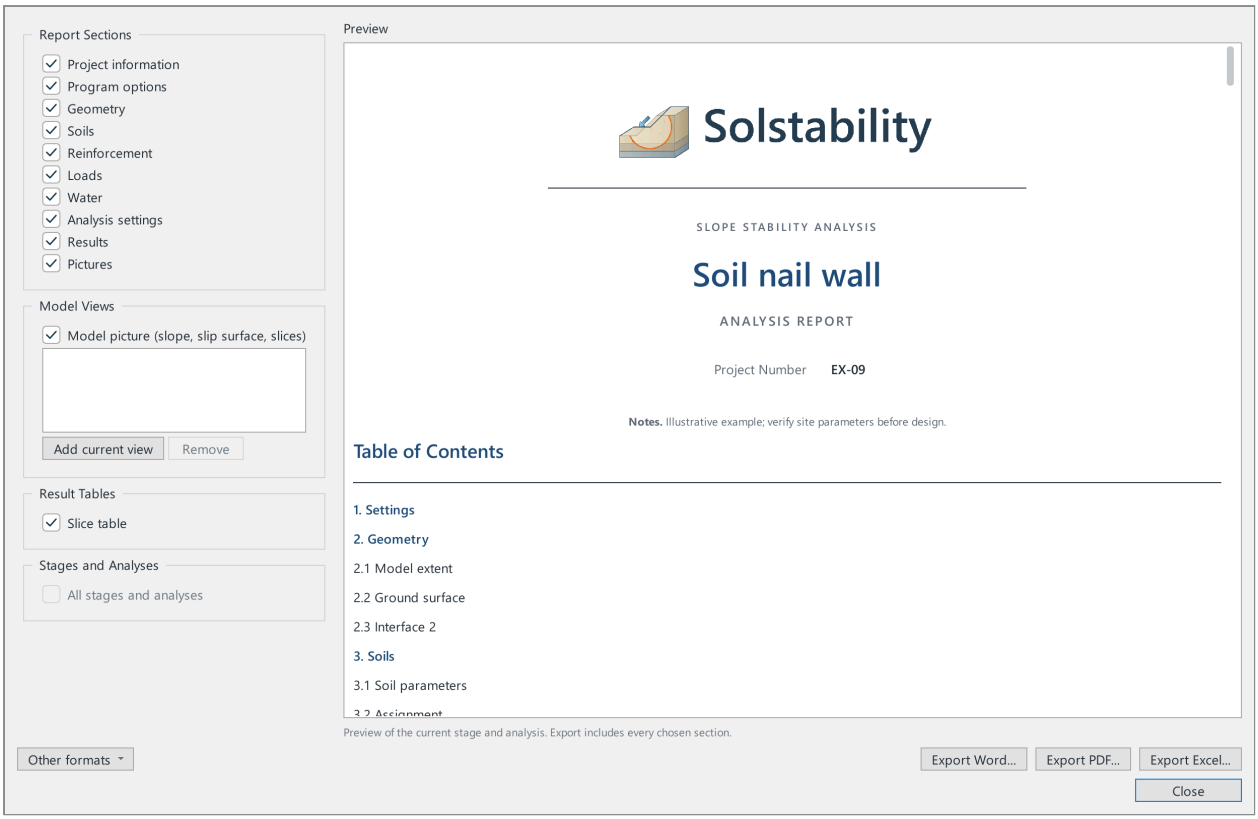


Figure 8.6 — Report Builder

The report builder selects the sections of the report — project, settings, geometry, soils, reinforcement, loads, water, analysis settings, results and pictures — and whether to include the input tables, the slice table and the drawing. The report is exported as PDF, Word, Excel (the tables, one sheet per table, opened in Excel) or HTML. Pictures added with **Add View to Report** are listed under pictures. With several stages, the report can contain all stages.

8.5 Command Line, batch analysis and the MCP server

The **Command** button of the status bar (Ctrl+L) opens a command line that reads and changes the project with text commands (Table 8.2). Type `help` for the list and `help` followed by a command for its syntax; `fields` lists the fields of a table.

Table 8.2 — Commands of the command line

Command	Use
new, open, save, info, units	Project file, information and units
list, fields, show	Read tables and values
set, add, edit, delete, row	Change values and rows of tables
layer, cut, import, stage	Soil layers, cut polygons, imported interfaces, construction stages
analysis, settings, refine, seismic, convert	Analysis settings, verification options, grid refinement, seismic coefficients, slip surface conversion
check, run, results, export, report	Check, analyse, read results and export a report (contents of the Report Builder with `with=` / `without=`), results, interfaces or a picture of the model (.png)
drawing, picture, guides	Drawing Settings (`set drawing.grid 2`), pictures of the report (Add View to Report, 2D or 3D), the background drawing
batch	Multi-File Analysis of other projects
history, replay	The command history (below); run entries again
undo, redo, help	Undo and help

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Every change is written to one command history on this computer: the commands of the command line, of scripts and of the MCP server (an assistant's tool calls with the text of their results), and the actions of the dialogs, menus and canvas, written as the equivalent commands. The command line lists the latest entries when it opens and shows new ones as they come, also those of an assistant working in the background. `history` numbers the entries and `replay 12-18` runs entries 12 to 18 again on the open project.

Analysis ▸ Multi-File Analysis (Batch Run)… analyses several project files and writes a summary table. The same tasks run without a window from the console:

Table 8.3 — Console options

Option	Use
`--batch FILE … [--out CSV]`	Analyse project files or lists of files and write the summary
`--script TXT [--keep-going]`	Run a file of commands, one per line
`--shell`	Interactive command line in the console
`--login [--email E | --google]`	Sign in from the console
`--mcp`	Start the MCP server (standard input and output)
`--version`	Print the release

The MCP server lets an AI assistant that supports the Model Context Protocol open a project, read and change the model, check and run it, read results and export reports through the tools `solstability_project`, `solstability_model`, `solstability_check`, `solstability_run`, `solstability_results`, `solstability_export` and `solstability_command`. The licence rules apply in the same way as in the window.

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9 Reference of the commands

This chapter lists every command of the Command Line, the fields of every table that the commands `list`, `add`, `edit` and `delete` work on, and the tools of the MCP server. The same commands run in the window (Ctrl+L), in a script (`--script`), in the console (`--shell`) and through the MCP tool `solstability_command`. Values are entered and shown in the display units of the project; `units` changes them.

9.1 Commands

Table 9.1 — Commands of the Command Line

Command	Syntax and use
`help`	list the commands
`new`	new [blank|slope|water] — new project (or an input example)
`open`	open <file.sstab>
`save`	save [file.sstab]
`info`	project summary
`units`	units [SI|US] — show or change the display units
`list`	list <table> — materials, anchors, nails, geotextiles, piles, surcharges, restrictions, points.N, water.points, water.original, water.suction, isolines, isoline.N, ru_isolines, ruiso.N, piezo_surfaces, piezo.N, rigid_bodies, rigid.N, regions, region.N, polygon
`fields`	fields <table> — fields, units and choices
`show`	show <path> — e.g. show analysis, show geometry.x_max
`set`	set <path> <value> — e.g. set analysis.method spencer, set assign.2 "Stiff clay"
`add`	add <table> field=value ... — e.g. add surcharges type=strip x1=30 x2=34 q=15; add rigid_bodies name=Wall gamma=24 points="18,0;20,0;20,4"
`edit`	edit <table> <row> field=value ...
`delete`	delete <table> <row>
`stage`	stage [n|add|delete n|name text|adopt water|loads|reinforcement|earthwork|assign] — construction stages (water, loads, reinforcement, soil assignment, analysis per stage)
`check`	input findings that stop the analysis
`analysis`	analysis [n|add|delete n] — several analyses (slip surface, method) per stage
`settings`	settings [list|save name|apply name|delete name] — named sets of program options
`refine`	refine — halve the grid steps around the input circle (after a grid search)
`row`	row anchors|nails <row> count=n dx= dy= [terrain=yes] — copies of a row, shifted
`layer`	layer add [t] | layer remove N | layer thickness N <t> | layer top <z> — base soil layers
`cut`	cut "x,y;x,y…" — split a soil polygon with a free line (new region keeps the soil)
`import`	import <file.dxf|file.xml> — interfaces (top line = ground surface); import soils <file.sstab>; import guides <file.dxf> — background drawing; import demand <file> <pile#> — Solpile shear demand table as the pile resistance
`seismic`	seismic alpha=… S=… [R=2] [avg=…] [kv=up|down] — Kh, Kv from EN 1998-5
`convert`	convert polygon [segments] | convert circle — convert the input slip surface
`run`	run the analysis (optimization / grid search replace the input slip surface)
`results`	results [summary|methods|slices|grid|trials|anchors|piles|reinforcement]
`export`	export <file> [all=yes] [with=a,b] [without=c] — .sstab, .json, .csv, a report .pdf/.docx/.xlsx/.html (all=yes: every stage and analysis; with/without: Report Builder contents, see 'report'), interfaces .dxf/.xml/.ifc

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Command	Syntax and use
`report`	report — the Report Builder contents for export with= / without=
`batch`	batch <file.sstab|list.txt|pattern> ... [csv=out.csv] — Multi-File Analysis
`drawing`	drawing — View > Drawing Settings (set drawing.<name> <value>)
`picture`	picture list | add [view=2d|3d] [hm=1] [title=…] | title <n> <text> | delete <n> — pictures of the report (View > Add View to Report)
`guides`	guides [clear] — the background drawing; clear removes it
`history`	history [n] — the last n commands of the window, MCP and scripts (numbered)
`replay`	replay <a>[-b] — run history entries a..b again
`undo`	undo the last change
`redo`	redo

9.2 Tables and their fields

Rows are numbered from 1. A value of a choice field is one of the listed keys; a point list is written as `"x,y;x,y;..."`.

Table 9.2 — Tables of the commands list, add, edit and delete

Table	Fields (type, unit, choices)
`materials`	name: text; gamma: float [kN/m³]; gamma_sat: float [kN/m³]; c: float [kPa]; phi: float [°]; total: bool; X: float; color: text; own_ru: bool; ru: float; incompressible: bool; foliation: bool; fol_from: float [°]; fol_to: float [°]; fol_c: float [kPa]; fol_phi: float [°]; piezo: float; uc: float [kPa]
`anchors`	x: float [m]; y: float [m]; length: float [m]; root: float [m]; angle: float [°]; spacing: float [m]; force: float [kN]; direction: choice (auto, right, left)
`nails`	x: float [m]; y: float [m]; length: float [m]; angle: float [°]; spacing: float [m]; direction: choice (auto, right, left); pullout: float [kN/m]; strength: float [kN]; pullout_mode: choice (input, bond, soil_bond, effective, ha6894); bond: float [kPa]; diameter: float [m]; strength_mode: choice (input, bar); bar_diameter: float [m]; fy: float [kPa]; head: float [kN]
`geotextiles`	x1: float [m]; y1: float [m]; x2: float [m]; y2: float [m]; strength: float [kN/m]; pullout: float [kPa]; fixed: bool; capacity_mode: choice (input, calculate, anchorage); C: float; anchorage: float [m]; inclination: float
`piles`	x: float [m]; length: float [m]; spacing: float [m]; shear: float [kN]; direction: choice (horizontal, parallel); distribution: choice (constant, linear, table); K: float; factor: float
`surcharges`	type: choice (strip, trapezoidal, concentrated, line); kind: choice (permanent, variable, accidental); x1: float [m]; x2: float [m]; q: float [kPa]; q2: float [kPa]; angle: float [°]; location: choice (terrain, depth); z: float [m]; width: float [m]; length: float [m]
`isolines`	u: float [kPa]
`ru_isolines`	ru: float
`piezo_surfaces`	name: text
`annotations`	type: choice (text, dimension, line, arrow, rectangle, circle); x1: float [m]; y1: float [m]; x2: float [m]; y2: float [m]; text: text
`earthwork`	type: choice (embankment, cut); material: text
`rigid_bodies`	name: text; gamma: float [kN/m³]
`regions`	name: text; material: text
`restrictions`	x1: float [m]; y1: float [m]; x2: float [m]; y2: float [m]; deflect: choice (up, down)

9.3 Tools of the MCP server

The server is started with `--mcp` and talks over standard input and output. Each tool returns `ok`, a text and structured data; a refused input returns `ok` = false with the reason. The licence rules of the window apply.

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Table 9.3 — MCP tools

Tool and parameters	Use
`solstability_project(action, path, kind, units)`	Project and units. action: "new" (kind = blank | slope | water) · "open" (path to .sstab) · "save" (path optional) · "info" · "units" (units = SI | US changes the display units; empty shows them).
`solstability_model(action, target, row, value, values)`	Read or change the input. action / arguments: "list" target = table (materials, anchors, nails, geotextiles, piles, surcharges, restrictions, points.N, water.points, water.original, water.suction, isolines, isoline.N, rigid_bodies, rigid.N, regions, region.N, polygon) (rigid_bodies: add with values {"name", "gamma", "points": "x,y;x,y;x,y"}; points stay in boundary order) "fields" target = table: fields, units and fixed choices "add" target = table, values = fields "edit" target = table, row = row number, values = fields to change "delete" target = table, row = row number "show" target = path, e.g. "analysis", "analysis.circle", "geometry.x_max" "set" target = path, value (display units), e.g. analysis.method = spencer.
`solstability_check()`	The findings that would stop the analysis (empty = ready to run).
`solstability_run()`	Run the analysis (Standard, Optimization, Grid search or Random search by analysis.mode; optimization and grid search replace the input slip surface).
`solstability_results(what)`	Results of the last run. what: "summary" (FS, verification, slip surface) · "methods" (all methods) · "slices" (slice table) · "grid" (grid search surfaces) · "trials" (10 most critical surfaces of a random search) · "anchors" · "piles" · "reinforcement" (forces of the reinforcement).
`solstability_export(path)`	Write a project copy (.sstab), results (.json, SI; .csv, display units) or a report (.pdf, .docx, .xlsx).
`solstability_command(command)`	Run one text command of the Solstability Command Line, e.g. "help", "info", "set analysis.method spencer", "run", "results", "undo". Returns ok, the text the GUI would print, and structured data.

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10 Examples

The examples use the input example **File ▸ Input examples ▸ Embankment slope**, an embankment 8 m high on a slope of 1 : 1.9 (rising from x = 10 m to 25 m), with two soils: a clayey fill above y = −3 m (γ = 18.5 kN/m^3, γ_{sat} = 19.5 kN/m^3, c' = 8 kPa, φ' = 24°) and a stiff clay below it (γ = 19.0 kN/m^3, γ_{sat} = 20.0 kN/m^3, c' = 15 kPa, φ' = 26°). The model extends from x = −10 m to 50 m and down to y = −15 m. The required factor of safety is 1.5 (permanent situation). The results below were computed with Solstability 1.0.1.

10.1 Example 1: circular slip surface, optimization and all methods

1. Open the example. The Analysis step holds a circle with centre (14, 20) m and radius 21 m, the Bishop method and a standard analysis. **Run Analysis** gives F = 1.726 for this circle.
2. Set **Analysis type** to *Optimization* and run again. The circle moves to the critical one, with centre (11.91, 17.93) m and radius 18.03 m, after 891 evaluated circles: F = 1.543, which satisfies the requirement (Figure 10.1).
3. Set the type back to *Standard*, tick *Analyse with all methods* and run. The critical circle is now the input circle, and the methods compare as in Table 10.1.

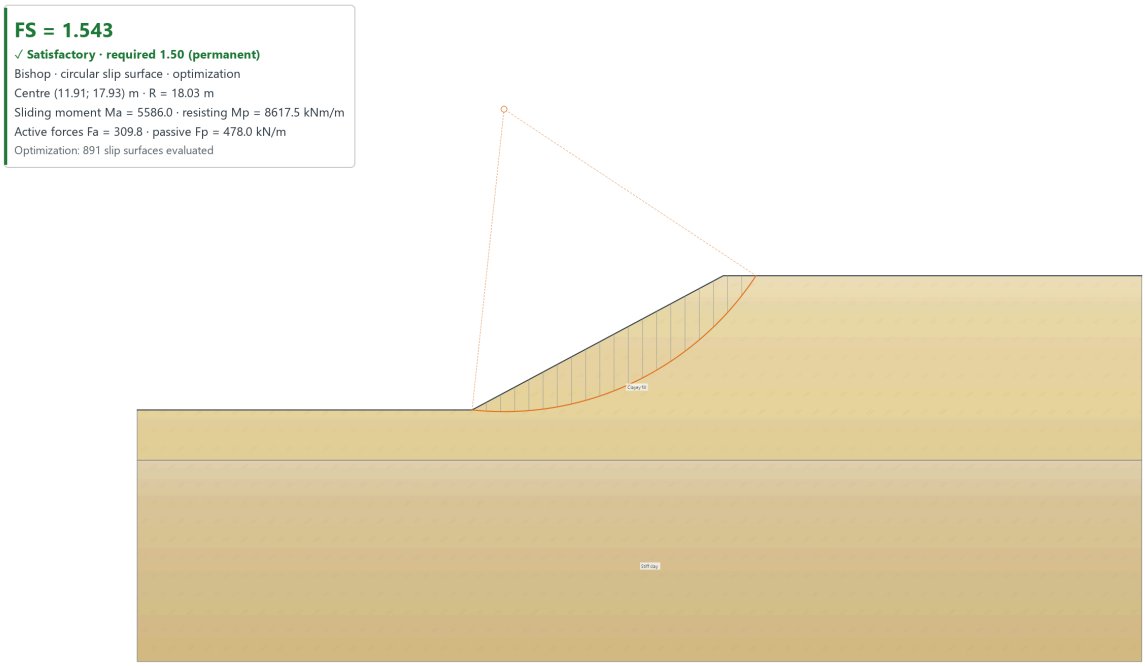


Figure 10.1 — Example 1, critical circle by optimization

Table 10.1 — Example 1, methods on the critical circle

Method	F
Bishop	1.543
Spencer	1.539
Janbu	1.539
Morgenstern-Price	1.539
Fellenius / Petterson	1.472

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The methods that satisfy complete equilibrium agree closely with Bishop; Fellenius, which neglects the interslice forces, is lower. Fellenius is not needed for design, but a large difference between the other methods would call for a closer look at the slip surface.

10.2 Example 2: ground water, grid and random search

1. Open the example and, in the Water step, enter a ground water table through the points (−10, 0), (10, 0), (25, 4) and (50, 6) m: the table lies at the ground surface at the toe and rises to 2 m below the crest at the right end of the model.
2. An optimization from the input circle gives F = 1.335: the water reduces the factor of safety of Example 1 below the requirement.
3. Set the type to *Grid search*; with the default grid of 5 × 5 centres and 5 radii around the critical circle, 125 circles give F = 1.335: no circle in the neighbourhood is more critical.
4. Set the type to *Random search* with the automatic ranges: 100 random circles from the toe side to the crest side give F = 1.352 (Figure 10.2). The random search is close to the optimization but not below it; with more surfaces per initiation point it approaches it.

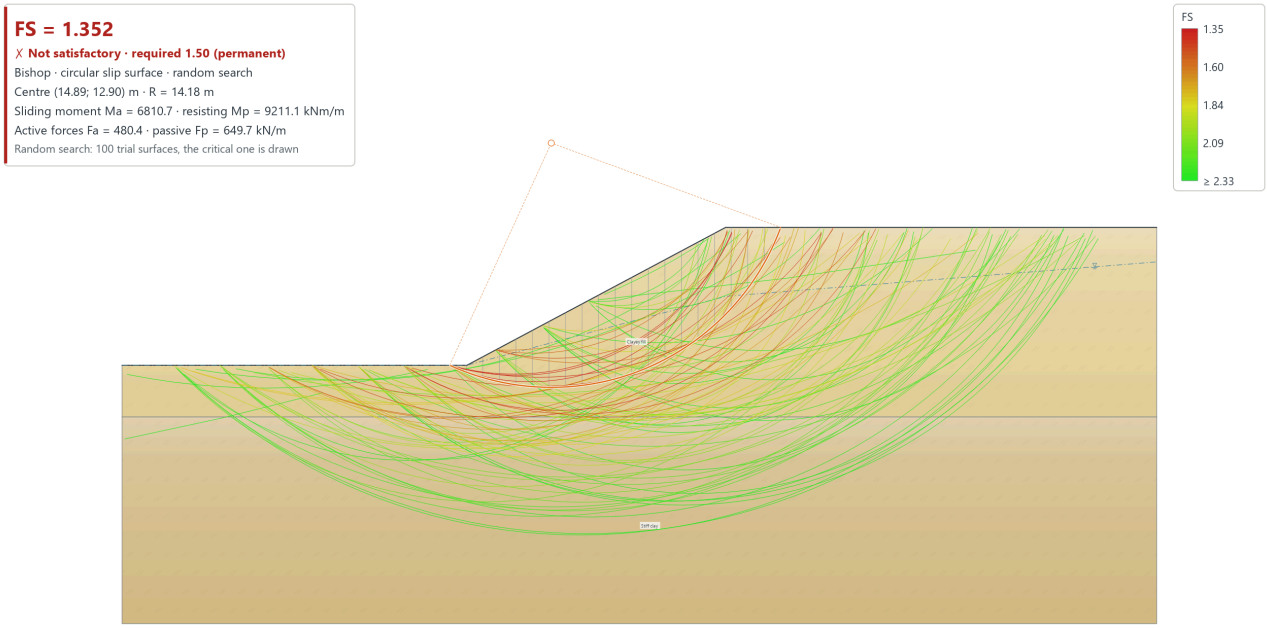


Figure 10.2 — Example 2, random search with ground water; trial surfaces coloured by their factor of safety

10.3 Example 3: polygonal slip surface

1. Open the example, set **Slip surface** to *Polygonal*, the method to *Spencer* and the type to *Random search* with *Irregular surfaces*. The search gives F = 1.811 (Figure 10.3).
2. Set the type to *Optimization*: starting from the critical random surface, the optimization moves its 14 points to F = 1.554, slightly below the critical circle of Example 1, as a polygon can follow the weaker parts of the soil more freely than a circle.

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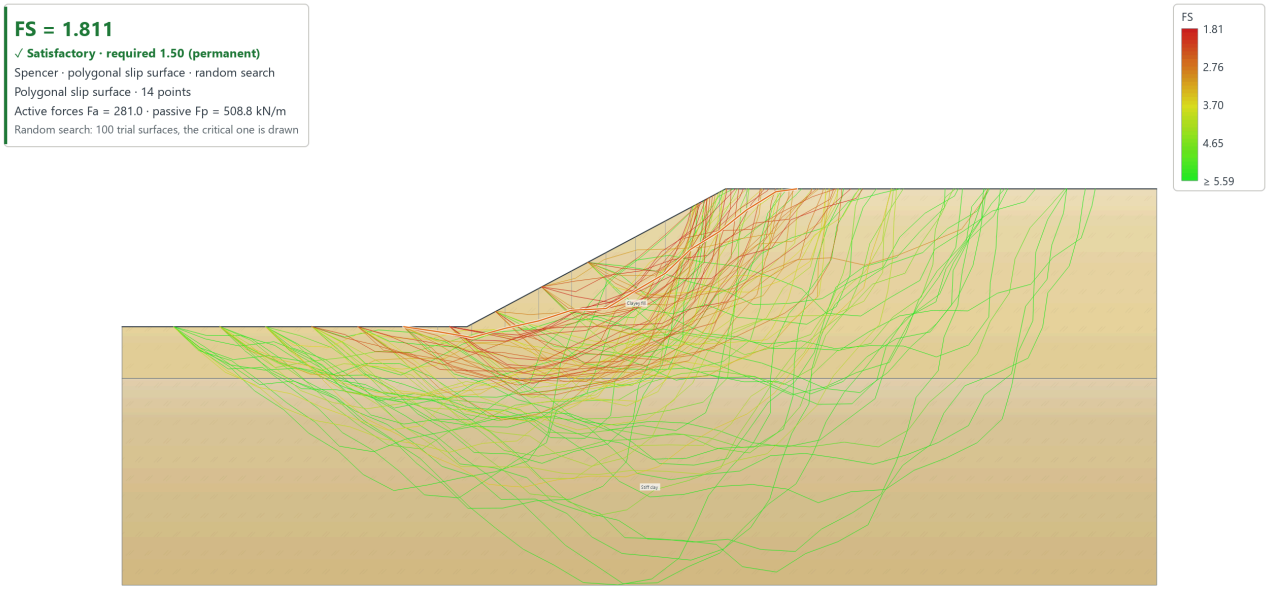


Figure 10.3 — Example 3, random search of irregular surfaces

10.4 Example 4: earthquake

On the critical circle of Example 1, select the design situation *Seismic* and, in the Loads step, switch the earthquake on with K_h = 0.15. The factor of safety drops to F = 1.144; the required factor of safety in the seismic situation is 1.10, so the slope is satisfactory under the pseudo-static load. For a design the critical surface should be searched again with the earthquake, as the most critical surface usually becomes deeper.

10.5 Example 5: construction stage with an excavation

1. Open the example with the type *Optimization*: in the first stage F = 1.543.
2. Click **+** above the drawing to add the second stage. In the Interfaces step, tab **Stage earthwork**, add an earth cut whose new ground line runs through the points (2, 0), (3, −2), (12, −2) and (13, 1.6) m: a pit 2 m deep in front of the toe whose steep back face removes the foot of the slope up to x = 13 m.
3. Run the analysis of the second stage. The optimization finds a circle through the foot of the excavation with F = 1.060: the pit brings the slope close to failure, far below the requirement, and the excavation needs support or a flatter face. The stages keep their own analyses, so both results stay available and the report can contain both.

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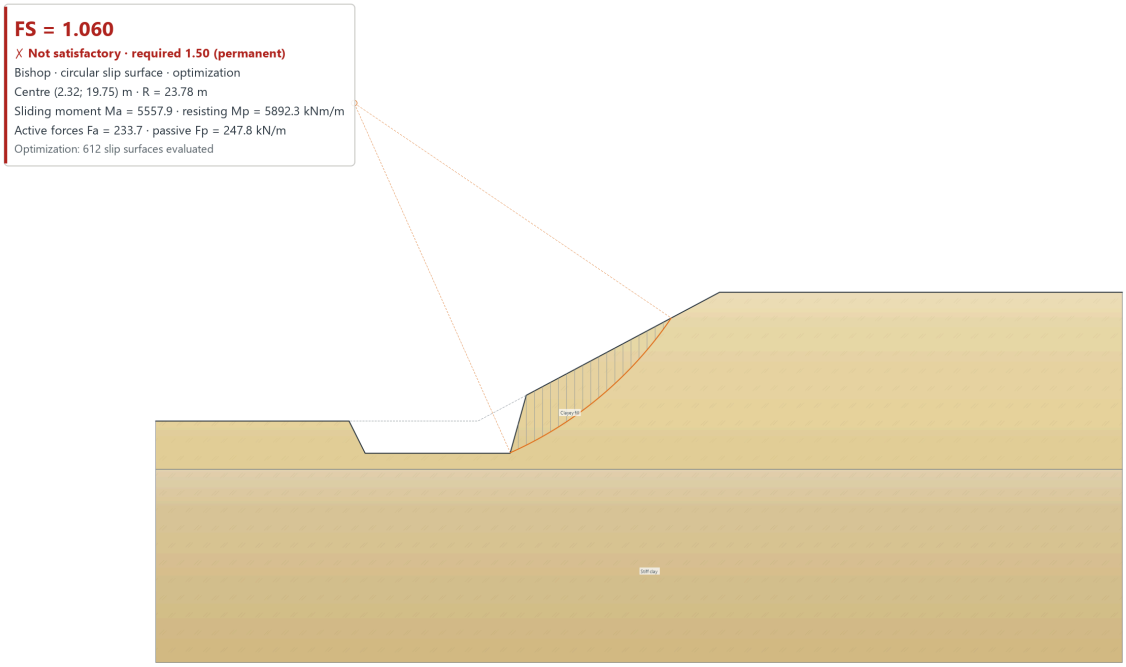


Figure 10.4 — Example 5, second stage with the excavation at the toe

10.6 Example 6: Sarma on a polygonal surface

1. Open the example and set **Slip surface** to *Polygonal*, the method to *Spencer* and the type to *Optimization*, with the polygon (0, 0), (12, −3), (22, 2) and (27.7, 8) m. The optimization moves its 4 points to $F = 1.598$.
2. Set the type to *Standard* (the critical polygon becomes the input polygon) and the method to *Sarma*: $F = 1.604$. Sarma divides the sliding body by inclined planes and requires the shear strength on them as well, so it is the method of choice for rock-like blocks and for surfaces that are not smooth; on this surface it agrees with Spencer within half a percent.

10.7 Example 7: verification according to EN 1997

On the critical circle of Example 1 ($F = 1.543$ with the factor of safety methodology), set the verification methodology in the **Project Information** step to EN 1997 and select the design approach. The analysis then uses the design values of the soil strength and the loads, and the result is a utilization: the design resistance compared with the design action, satisfactory up to 100 %.

Table 10.2 — Example 7, design approaches of EN 1997

Design approach	F with design values	Verification
DA1	1.234	DA1 · utilization 81.0 % (permanent)
DA2	1.366	DA2 · utilization 80.5 % (permanent)
DA3	1.234	DA3 · utilization 81.0 % (permanent)

DA1 and DA3 factor the soil strength (combination 2 of DA1 governs), DA2 factors the actions and the resistance; all three are satisfied with a reserve of about 20 %.

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10.8 Stabilization examples

Examples 8 to 13 each show one way of making a slope or a retaining structure safe: an anchored cut, a soil nail wall, a geotextile under an embankment, a retaining wall on piles, a counterweight berm and, for comparison, a retaining wall on a spread footing. Each example has its own model, entered in a new project (**File ▸ New**) with the data given in its first step: the base layers in the **Soil Layers** step (from the top z = 0 downward) and the slope, embankment or backfill above them as an interface polygon, drawn on the canvas with **Draw interface** in the **Interfaces** step; all points lie on a 0.1 m grid, and the elements and the water table are drawn in the same way. All of them use Bishop's method with a circular slip surface and the type *Optimization*, so that the critical circle is searched before and after the measure is added; the first search starts from a circle drawn with **Draw circle**, and the second one from the critical circle of the first, which the program keeps as the input circle. The examples check the overall stability only; the structural design of the elements and, for the walls, sliding, overturning and the bearing capacity are separate checks.

10.9 Example 8: anchored cut

1. A cut 8 m deep with a face inclined 3 : 8 (about 70°): the model runs from x = −15 m to 30 m, with the base layers residual soil 4 m and weathered rock 11 m, and the interface polygon of residual soil (0, 0), (3, 8), (30, 8), (30, 0) m. The residual soil has (γ = 18.5 kN/m^3, γ_{sat} = 19.5 kN/m^3, c' = 10 kPa, φ' = 28°) over weathered rock from y = −4 m (γ = 21 kN/m^3, c' = 30 kPa, φ' = 35°). Without support the optimization gives F = 0.842: the face cannot stand at this inclination.
2. In the **Reinforcement** step, tab **Anchors**, add two rows of prestressed anchors with their heads on the face at (2.1, 5.6) m and (0.9, 2.4) m, inclined 15°, with a free length of 8 m, a root of 8 m and a force of 300 kN at a horizontal spacing of 2.5 m, that is 120 kN/m per row.
3. The optimization with the anchors, which starts from the critical circle of step 1, gives F = 1.537, which satisfies the required 1.5 (Figure 10.5). The critical circle cuts the free length of both anchors, so each acts with its full force (Table 10.3).
4. Set the type to *Standard*, so that the critical circle becomes the input circle, and tick **Assume anchors as infinite**: F = 1.537, unchanged, because the critical circle cuts the free length of both anchors. The option matters only for circles that pass behind or through the roots; the default, with the force taken only where the circle cuts the free length, is the safer assumption.

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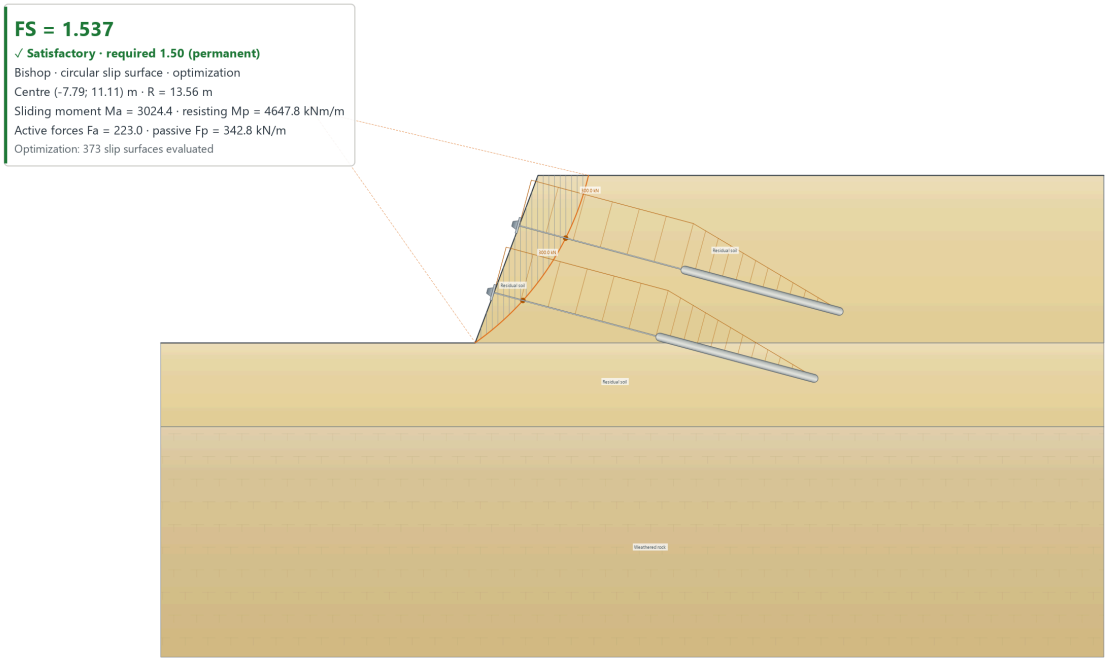


Figure 10.5 — Example 8, critical circle of the anchored cut

Table 10.3 — Example 8, forces of the anchors on the critical circle

Element	Force [kN/m]	Force per element [kN]
Anchor 1	120.0	300.0
Anchor 2	120.0	300.0

10.10 Example 9: soil nail wall

1. A cut 7 m deep with a face inclined 1.4 : 7 (about 79°): the model runs from x = −15 m to 30 m, with the same base layers as Example 8 and the interface polygon (0, 0), (1.4, 7), (30, 7), (30, 0) m. The residual soil has (γ = 18 kN/m^3, γ_{sat} = 19 kN/m^3, c' = 8 kPa, φ' = 30°) over weathered rock from y = −4 m. Without support F = 0.709.
2. In the tab **Nails** add five rows of nails with their heads on the face at (1.3, 6.5), (1.0, 5.0), (0.7, 3.5), (0.4, 2.0) and (0.1, 0.5) m (vertical spacing 1.5 m), 6 m long, inclined 15°, at a horizontal spacing of 1.5 m. The pull-out resistance follows from the bond: a drill hole of 100 mm and a bond of 100 kPa give 31.4 kN per metre of nail. The tensile strength follows from the bar: 25 mm with f_y = 420 MPa gives 206 kN. The head plate takes 50 kN.
3. The optimization gives F = 1.394 (Figure 10.6). The force of each nail is the smallest of its pull-out behind the slip surface, its tensile strength and the head plate plus the pull-out in front of the surface, so the nails carry different forces (Table 10.4).

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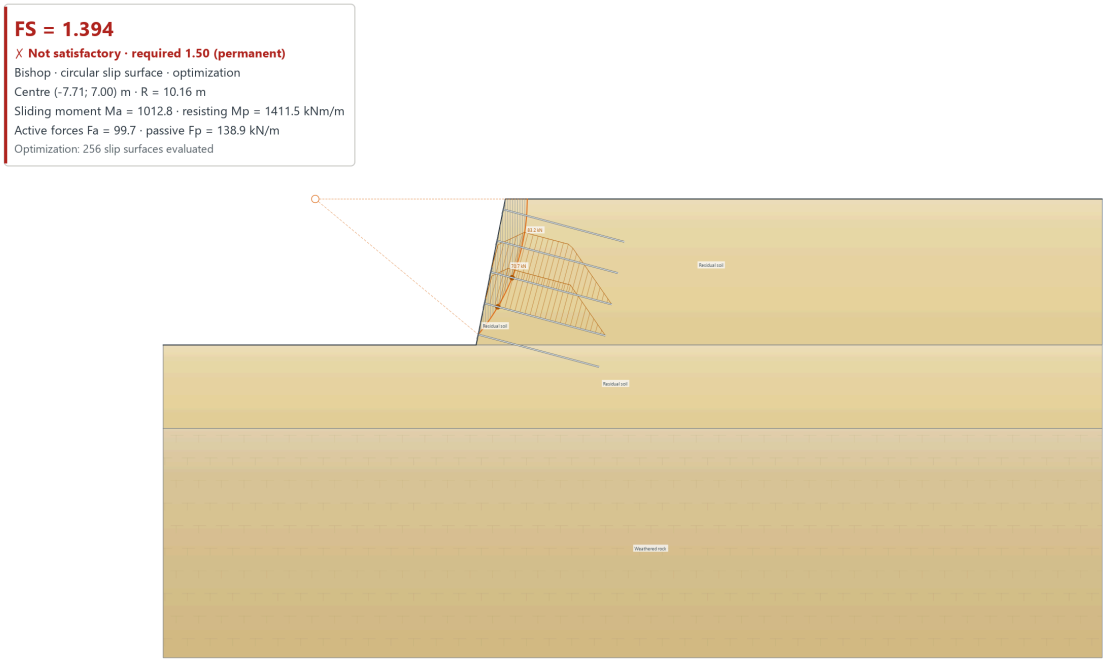


Figure 10.6 — Example 9, critical circle of the soil nail wall

Table 10.4 — Example 9, forces of the nails on the critical circle

Element	Force [kN/m]	Force per element [kN]
Nail 1	0.0	0.0
Nail 2	0.0	0.0
Nail 3	55.5	83.2
Nail 4	47.1	70.7
Nail 5	0.0	0.0

10.11 Example 10: embankment on soft clay with a basal geotextile

1. A road embankment 4 m high with a slope of 1 : 2, the interface polygon (0, 0), (8, 4), (35, 4), (35, 0) m in a model from x = −15 m to 35 m (embankment fill: γ = 19 kN/m^3, c' = 5 kPa, φ' = 30°)), on the base layers soft clay 6 m, entered with total stresses and an undrained strength c_u = 18 kPa, and dense sand 6 m. Traffic acts from x = 10 m to the right edge. It is a strip load of 10 kPa (variable). The check is made at the end of construction, so the design situation is *Transient* with a required factor of safety of 1.3. Without reinforcement F = 1.217.
2. In the tab **Geotextiles** add a geotextile at the base of the fill, at y = 0.3 m from x = 0.6 m to the right edge of the model, with a tensile strength of 200 kN/m and the capacity calculated with C = 0.8.
3. The optimization gives F = 1.464, which satisfies the requirement (Figure 10.7). The geotextile acts with 200 kN/m: its tensile strength governs, as the anchorage on both sides of the circle is long.

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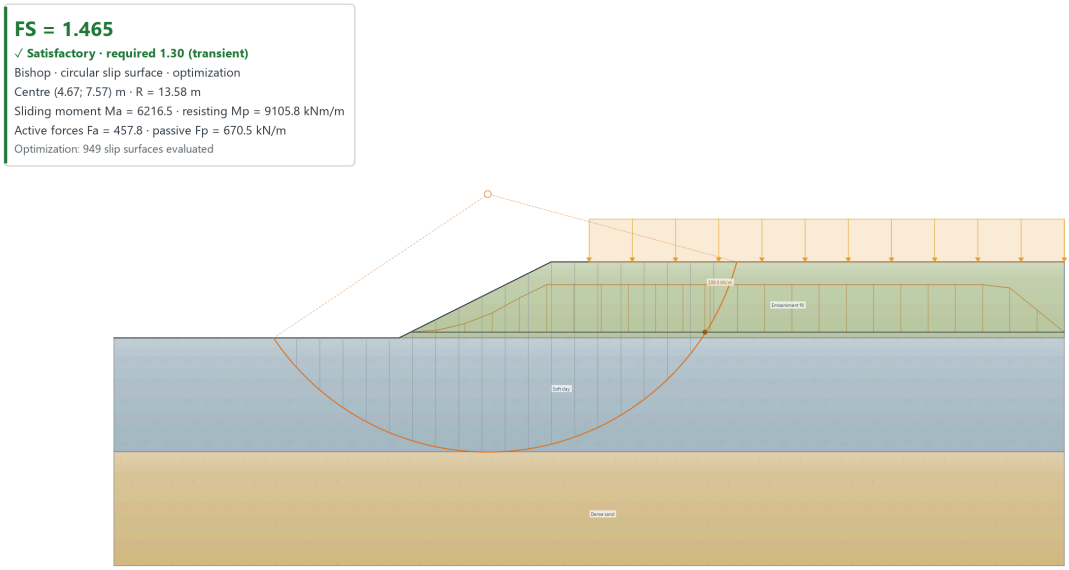


Figure 10.7 — Example 10, embankment on soft clay with a basal geotextile

10.12 Example 11: retaining wall on spun piles

1. A cantilever retaining wall retains 5 m of backfill, the interface polygon (0.8, 0), (0.8, 5), (30, 5), (30, 0) m in a model from x = −15 m to 30 m (c' = 0, φ' = 32°). Its footing is 3.6 m wide and 0.6 m thick with the base at y = −1.2 m and the stem is 0.4 m thick, with its front face at x = 0.8 m; the wall is entered in the Interfaces step, tab **Rigid bodies**, as a rigid body of concrete (γ = 24 kN/m^3). The base layers are a soft clay with c_u = 22 kPa, 8 m thick, and a stiff clay (c' = 20 kPa, φ' = 28°). On the footing alone the critical circle passes through the soft clay below it, with F = 1.183.
2. In the tab **Stabilizing piles** add two rows of spun piles of 500 mm diameter under the footing, at x = 0.5 m and 3.1 m, with their heads at the base of the footing and 12 m long, so that they reach into the stiff clay. The spacing along the wall is 1.5 m and the shear resistance of one pile is 150 kN, that is 100 kN/m per row.
3. The optimization gives F = 1.544 (Figure 10.8). Both rows are crossed by the critical circle and act with their full shear resistance (Table 10.5). The shear resistance of a pile can also be entered as a table along the pile from the shear demand analysis of Solpile.

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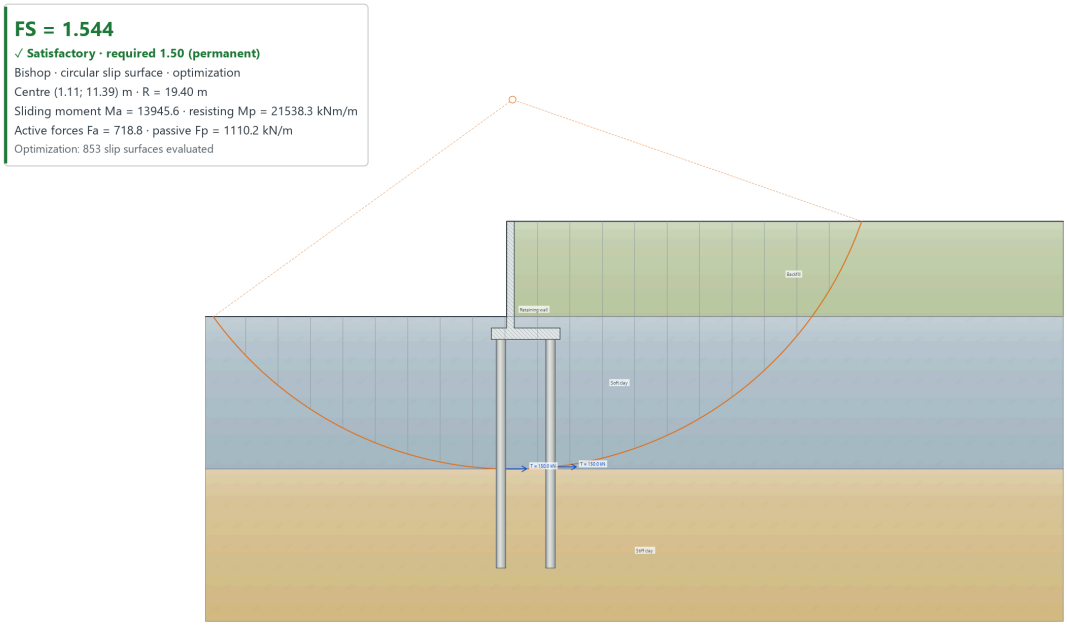


Figure 10.8 — Example 11, retaining wall on two rows of spun piles

Table 10.5 — Example 11, forces of the piles on the critical circle

Element	Force [kN/m]	Force per element [kN]
Pile 1	100.0	150.0
Pile 2	100.0	150.0

10.13 Example 12: counterweight berm

1. An embankment 6 m high with a slope of 1 : 2, the interface polygon (0, 0), (12, 6), (40, 6), (40, 0) m in a model from x = −20 m to 40 m (γ = 19 kN/m^3, c' = 5 kPa, φ' = 28°) on the base layers soft clay 6 m (c' = 6 kPa, φ' = 18°) and stiff clay 9 m (c' = 25 kPa, φ' = 26°). The ground water table lies at the ground surface in front of the toe and rises to y = 2.5 m at the right edge. In the first stage F = 1.345, below the required 1.5.
2. Click **+** above the drawing to add the second stage. In the Interfaces step, tab **Stage earthwork**, add an embankment of the embankment fill through the points (−8, 0), (−6, 1) and (2, 1) m: a berm 1 m high with a top 8 m wide in front of the toe.
3. The optimization of the second stage gives F = 1.659 (Figure 10.9). The weight of the berm acts against the rotation of the sliding body near the toe, where the slip surface rises; the stability is improved without any structural element.

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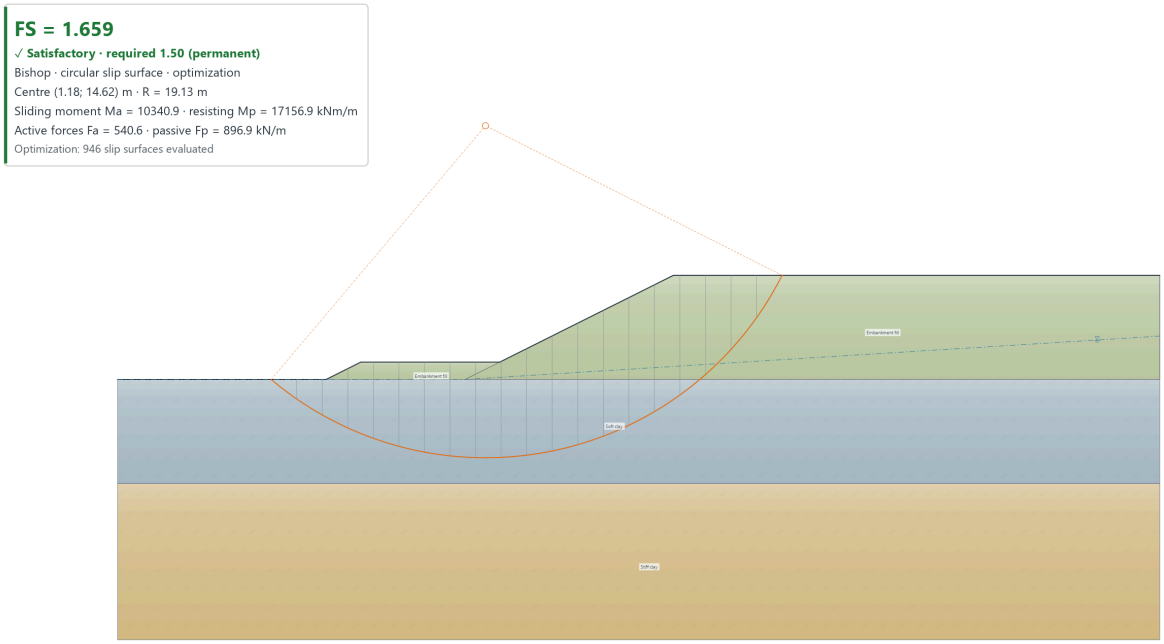


Figure 10.9 — Example 12, second stage with the counterweight berm

10.14 Example 13: retaining wall on a spread footing

1. A cantilever retaining wall retains 4 m of backfill, the interface polygon (0.7, 0), (0.7, 4), (25, 4), (25, 0) m in a model from x = −15 m to 25 m. Its footing is 3 m wide and 0.5 m thick with the base at y = −1 m and the stem is 0.4 m thick, with its front face at x = 0.7 m, entered as a rigid body like in Example 11. It stands on a base layer of stiff sandy clay 12 m thick (γ = 19 kN/m^3, c' = 15 kPa, φ' = 28°). The ground water table lies 1.5 m below the ground in front of the wall and 1.5 m above it behind the wall.
2. The optimization gives F = 2.130 for the critical circle under the footing (Figure 10.10): on a firm soil the spread footing is sufficient for the overall stability, while the soft clay of Example 11 needs the piles.

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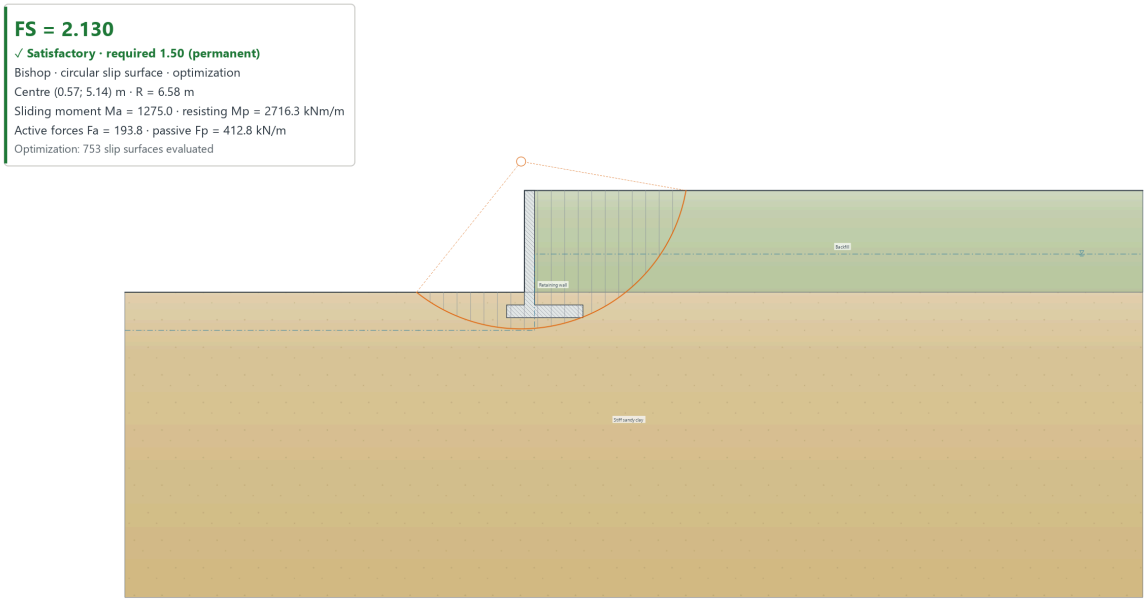


Figure 10.10 — Example 13, retaining wall on a spread footing

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11 Messages and troubleshooting

Before an analysis the program checks the input; a problem stops the run with a message that names the step and the row concerned. During and after the analysis the warnings are listed in the summary of the results, in the report and in the output of the command line. The tables below give the common messages, their cause and the remedy.

11.1 Messages that stop the analysis

Table 11.1 — Messages that stop the analysis

Message	Cause and remedy
The circle does not cut the ground surface. / The circle does not reach the ground surface on both sides.	The circle lies above the ground or ends inside the model. Enlarge the radius or move the centre; drawing the circle with **Draw circle** through two ground points avoids it.
The slip surface rises above the ground surface between its ends.	The surface leaves the soil and enters it again, for example a deep circle under a bench or a polygon point above the ground. Move the point or choose a circle that cuts the ground only at its ends.
The slip surface leaves the model at its left or right edge. / … below its bottom.	Extend the model (**Model Extent**, the thickness of the last layer) so that the slip surface stays inside it; a critical surface at the edge of the model means the model is too small.
The slip surface enters an incompressible subsoil.	A soil marked *Incompressible subsoil* may not be cut. This is intended: the search avoids it; an input surface must stay above it.
Bishop and Fellenius / Petterson need a circular slip surface. / The Sarma method needs a polygonal slip surface.	Change the method or convert the slip surface (**Convert to polygon**, **Convert to circle**).
Optimization found no admissible slip surface; check the initial slip surface …	Every trial around the initial surface was rejected (restrictions, rigid bodies, edges of the model). Start from a surface that gives a factor of safety in a standard analysis.
No slip surface of the grid is admissible; move or enlarge the grid.	The centres or radii of the grid give no circle that cuts the slope. Move the input circle, which is the centre of the grid, or change the steps.
The random search generated no admissible slip surface … / The initiation and termination ranges overlap.	Widen the initiation and termination ranges, lower the depth limit or shorten the segments; the ranges must not overlap. With the automatic ranges the program takes them from the toe and crest sides.
An initiation point of the random search lies outside the ground surface / below the depth limit.	The ranges are entered outside the model or the depth limit lies above the ground. Correct the range or the limit.
Random search of sliding blocks needs at least one box.	Add the boxes through which the block surface must pass (tab **Boxes of the sliding block**).

11.2 Warnings in the results

Table 11.2 — Warnings in the results

Warning	Meaning and what to do
The method did not converge for this slip surface; the factor of safety is not reliable.	The iteration of the method found no solution, often for steep slice bases at the crest or toe, a tension crack missing at the crest of a cohesive slope, or large concentrated forces. Check the surface, add a tension crack or compare with another method; the value shown should not be used.
The factor of safety is unrealistic (≤ 0 or ≥ 100); check the slip surface and input.	Usually a very small slip surface in a cohesive soil, or a surface that hardly moves soil. Check the input surface and the strength parameters.
The selected interslice function did not converge; the analysis used …	Morgenstern-Price converged only with another interslice function; the one used is named. The result is valid for that function.
The method converged only with the geotextile forces reduced to …	The geotextile forces are too high for the method to find equilibrium; reduce them or check their anchorage lengths.
Adjacent slip-surface segments differ by more than 10°; ITFM results may be overestimated.	ITFM needs a smooth surface. Add points to the polygon or use another method.

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Warning	Meaning and what to do
One of the block dividing planes cuts through a rigid body …	Sarma: a dividing plane passes through a rigid body, whose strength then enters the result. Move the polygon points so that the planes avoid it.
The optimization / grid search / random search was stopped …	The run was stopped with **Stop** or Esc; the result is the most critical surface found until then, not necessarily the critical one.
Pile at x = …: negative active force obtained.	The soil behind the pile pulls instead of pushing at the slip surface; the pile is placed where it does not stabilise the slope.

11.3 Practical hints

- **Factor of safety in red.** The result is compared with the requirement of the selected verification methodology and design situation; red means not satisfied. In the results tables every factor of safety (all methods, grid, the most critical random surfaces) is coloured the same way.
- **Long analyses.** An optimization or a search runs in the background with a progress window; the program stays responsive and **Stop** ends the search with the best surface found so far. The optimization of a circle evaluates its trial circles on several processor cores.
- **A critical surface at the edge of the model or at a search limit** means the true critical surface may lie beyond it: extend the model, move the grid or widen the ranges and run again.
- **Different methods give very different results.** The methods that satisfy all equilibrium conditions (Spencer, Morgenstern-Price, Sarma) normally agree within a few percent; a large difference points to a surface with sharp corners, a missing tension crack or large point forces.
- **Drawing between the snap points.** Hold Ctrl while drawing to switch the snapping to points, lines and the grid (**Drawing Settings**), or type the coordinates in the table.

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