GGU-CANTILEVER manual

Analysis and design of cantilever walls

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Technische Umsetzung, Layout und Vertrieb:
Civilserve GmbH, Steinfeld

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Theorie. Und Praxis.

Geotechnische Softwarelösungen können so einfach sein. Denn Theorie und Praxis lassen sich mit **GGU-Software** und den neuen Angeboten der **civilserve Academy** prima kombinieren: Knackige theoretische Aufgaben lösen und als Sahnehäubchen Ihr

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1 GGU-CANTILEVER: Preface

The **GGU-CANTILEVER** program system allows the analysis of cantilever walls.

For analysis and design both the ***global safety factors*** to DIN 1054 (old) and the ***partial safety factors*** to EC 7 may be taken into consideration. Details of special features can be found in Section 2 of this manual.

The application is designed to allow simple data input or modification. The input is immediately shown on the screen, giving you optimum control over what you are doing. Reading of the manual can mostly be dispensed with, because "**?**" buttons dealing with almost all geotechnical and program-specific problems are available in the dialog boxes. You are presented with the necessary information by clicking the "**?**" button.

The program includes convenient data input. The system is permanently displayed on the screen. Every change to the data is displayed on the screen, so that optimum control of the input data is guaranteed.

There are "**?**" and "**Info**"' buttons in the dialog boxes for many technical and program-specific questions. Click on the "**?**" buttons or "**Info**" buttons to obtain the necessary information.

The graphic output supports the true type fonts provided by WINDOWS, so that an excellent layout is guaranteed. Colour output and numerous graphic formats (BMP, TIF, JPG etc.) are supported. PDF and DXF files can also be imported via the integrated **Mini-CAD** system (see "**Mini-CAD**" manual).

The program has been extensively tested. No errors have been found. Nevertheless, liability for completeness and correctness of the program and the manual, and for any damage resulting from incompleteness or incorrectness, cannot be accepted.

2 GGU-CANTILEVER: Capabilities

GGU-CANTILEVER has the following characteristics and maximum capabilities:

- Almost any user-defined cantilever wall possible
- Base inclination of cantilever wall
- Up to 50 soil layers
- Transfer of soil properties from GGU-CONNECT
- Up to 40 berms on the active earth pressure side
- Up to 40 berms on the passive earth pressure side
- Analysis with active and increased active earth pressure and with at-rest earth pressure
- Coefficients of active earth pressure to DIN 4085
- Coefficients of passive earth pressure to DIN 4085, Streck, Caquot/Kerisel
- Additional active and passive ep calculation to Culmann is possible.
- Classical water pressure approach and, alternatively, by means of a flow conduit parallel to the wall in accordance with potential theory (analysed using finite-element methods). Inconsistencies in subsurface hydraulics apparent when using the classical approach are avoided when using flow conduits, and varying permeabilities are correctly considered as far as the approach allows. User-defined potentials can be applied at any point along the flow conduit. This allows correct, problem-free consideration of systems with several groundwater storeys and/or aquifuges, or with artesian conditions.
- Optional consideration of hydraulic gradients on the active and the passive earth pressure sides
- Consideration of pretensioning of anchors and struts possible
- Analysis of safety factors against deep-seated failure with optimisation of anchor lengths
- Analysis of stability against overturning
- Analysis of bearing capacity safety factor
- Analysis of settlements
- Analysis of sliding safety factor
- Analysis of safety against hydraulic heave
- Analysis of safety against buoyancy
- Reinforced concrete design
- Convenient interface to the stability analysis application, **GGU-STABILITY**, for quick determination of safety factor against general failure
- Analysis of static equilibrium in the EQU limit state
- Up to 50 additional earth pressure distributions
- Up to 20 area loads at any depth

- Structural analysis of the wall by means of a two-dimensional rod construction module based on finite element methods. In contrast to many other applications, the influence of inclined anchors or struts and their interactions are thus directly considered in the analysis approach. Analysis can even be performed using 2nd order theory, making the generally onerous buckling length investigation of struts and wall unnecessary. In addition, it is possible to consider loads on the struts (e.g. for auxiliary bridges additionally acting as struts) during analysis.
- Specification of up to 5 displacement boundary conditions (rotation, displacement in x or y directions) at any location
- Specification of up to 5 action boundary conditions (moment, shear force and normal force) at any location
- 20 anchor and strut sets. In defining the anchors and struts, axial stiffness and bending stiffness can be specified, so that, for example, passive soft anchors can also be incorporated.
- Consideration of pretensioning of anchors and struts
- Definition of up to 20 additional potentials for the analysis of flow conduits to the left and right of the wall for complex groundwater conditions
- Automatic computation of earth pressure redistribution in accordance with EAB recommendations
- Other earth pressure redistribution options:
- No redistribution
- Rectangle
- 2 Rectangles
- Triangle (maximum can be optionally placed at top, middle or bottom)
- Trapezoid
- Quadrilateral with maximum at anchor locations or any other location.
- User-defined polygon
- Following computation of the system the earth pressure, pore water pressure, moment, shear, normal force and bending line are displayed on the screen. The visualisation can be varied within wide limits. For example, the distributions of the potential and gradient, etc., can also be displayed.
- At anchor points, predeformations that are already present can be defined as boundary conditions.
- Legends can be displayed on screen indicating soil characteristics, general computation data, data needed for settlement analysis and the main design data. Thus, virtually all the raw data necessary for the computation are shown on screen.
- The user interface is based on WYSIWYG (***What You See Is What You Get***), which means that what you see on the screen is virtually identical with what is printed. It also means that you can print out what you see on the screen at any point during the analysis.
- The use of true-type fonts guarantees excellent layout.
- Colour presentation of virtually all system geometries. Colours can be freely determined by the user. In particular, soil strata can also be coloured according to the German DIN 4022 conventions.

- Zoom function
- **Mini-CAD** system (additional text, lines, rectangles, circles, graphics, etc).
- By clicking the "**Copy/print area**" icon on the toolbar you can copy any part of the graphics to the clipboard, or save it as an EMF file (Enhanced Metafile Format). Using the "**Mini-CAD toolbar**" or "**Header toolbar**" modules, you can insert EMF files into your graphics. Thus, the results of a slope failure analysis or of a grading analysis, for example, can easily be imported into the current graphics.

3 GGU-CANTILEVER: Licence protection

To protect the GGU software from unauthorised access, each GGU program is equipped with the ***CodeMeter software protection system*** from WIBU-Systems. Each GGU program is bound to a so-called ***CmContainer*** via a licence with the corresponding product code.

To be able to use the GGU licences in a CmContainer, a runtime environment, the ***CodeMeter Runtime Kit***, must be installed on your computer via driver software. You can obtain the current version from Software for Users - Wibu-Systems (CodeMeter User Runtime for Windows).

You can work with the following CmContainer types on your PC with the CodeMeter Runtime Kit installed (= ***CodeMeter licence server***):

- **CmStick**
  The licence for your GGU program is stored in a USB dongle.
- **CmActLicense** (soft licence, not for virtual PC/servers)
  The licence for your GGU program is stored in a licence file that is linked to the hardware of a computer.
- **CmCloudContainer**
  The licence is located on a CmCloud server of WIBU-Systems and is mirrored to your CodeMeter licence server. The advantages of this type of licence binding are described on the following website: Licence binding | GGU Software.

The GGU programs check at start-up and during runtime whether a corresponding license is available in a CmContainer.

4 GGU-CANTILEVER: Language selection

The GGU programs can be used in German and English. The program always starts with the language in which it was terminated.

The language preferences can be changed at any time in the "**Info**" menu, using the menu item "**Spracheinstellung**" (for German) or "**Language preferences**" (for English).

5 GGU-CANTILEVER: Starting the program

After starting the program, you will see two menus at the top of the window:

- File
- Info

By going to the "**File**" menu, a previously analysed system can be loaded by means of the "**Load**" menu item, or a new one created using "**New**". After clicking the "**New**" menu item a dialog box opens for specifying general preferences for your new system. You then see eight menus in the menu bar:

- File
- Editor 1
- Editor 2
- System
- Evaluation
- Graphics preferences
- Page size + margins
- Info

After clicking one of these menus, the so-called menu items roll down, allowing you access to all program functions.

The program works on the principle of ***What you see is what you get***. This means that the screen presentation represents, overall, what you will see on your printer. In the last consequence, this would mean that the screen presentation would have to be refreshed after every alteration you make. For reasons of efficiency and as this can take several seconds for complex screen contents, the screen is not refreshed after every alteration.

If you would like to refresh the screen contents, press either [**F2**] or [**Esc**]. The [**Esc**] key also resets the screen display to your current image zoom, which is usually preset to 1.0, which corresponds to an A3 or A4 sheet in most GGU programs (see menu item "**Graphics preferences/Refresh and zoom**").

6 Tips and tricks

6.1 GGU-CANTILEVER: "?"- and "Info" buttons

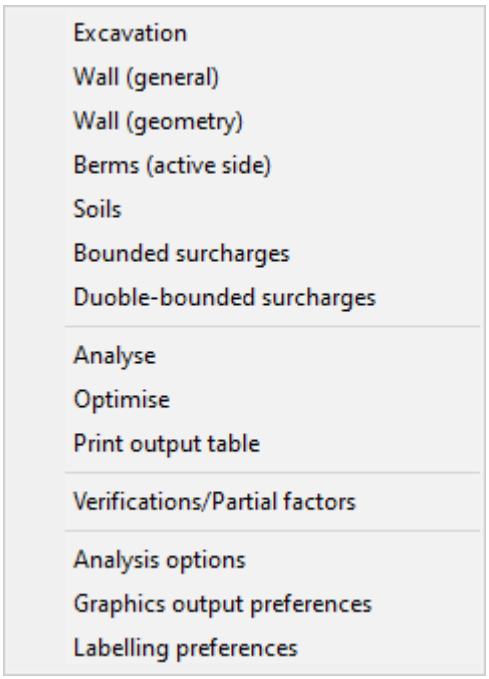
Reading of the manual can mostly be dispensed with, because

"**?**" buttons or "**Info**" buttons

dealing with almost all geotechnical and program-specific problems are available in the dialog boxes. You are presented with the necessary information by clicking the buttons.

6.2 GGU-CANTILEVER: Keyboard and mouse

If you click the right mouse button anywhere on the screen a context menu containing the principal menu items opens.



If you double-click in the system graphics with the left mouse button you will see a message box with the results at the selected depth. This gives you a quick overview of the results for any desired depth.

By double-clicking the left mouse button on legends or **Mini-CAD** objects, the editor for the selected element immediately opens, allowing it to be edited.

In most dialog boxes, the buttons for leaving the box or buttons for decisive functions are marked thickly and can be reached by clicking the [**Enter**]/[**Return**] key.

In dialog boxes in which you have to make entries, e.g. change soil properties, the quickest way to jump to the next input box is to use the [**Tab**] key. The previous value is marked and can be overwritten directly with the new entry. You do not have to move to the box with the mouse and delete the old entry in advance.

In input boxes with numerical values, you can use the calculation operations listed in “**Tips and tricks: Mathematical functions in input boxes with numbers**” to change them.

You can scroll the screen with the keyboard using the cursor keys and the [**Page up**] and [**Page down**] keys. After activating the zoom functions, click on an area of the screen to enlarge or reduce the display by a factor of 2. Alternatively, by clicking and dragging the mouse while holding down the [**Ctrl**] key, you define a window section which is then displayed in full screen. By clicking and dragging the mouse while holding down the [**Shift**] and [**Ctrl**] keys, you zoom into your system graphic, i.e. you change the scale of your system representation.

You can also use the mouse wheel to zoom in or out or to move the screen display. When the program is started for the first time, the default setting for mouse wheel operation is activated according to Windows conventions:

- Mouse wheel up = move screen image up
- Mouse wheel down = move screen image down
- [**Shift**] + mouse wheel up = move screen image right
- [**Shift**] + mouse wheel down = move screen image left
- [**Strg**] + mouse wheel up = enlarge screen image (zoom in)

[**Strg**] + mouse wheel down = reduce screen image (zoom out)

If you want to change the system coordinates and the scale of your system using the mouse wheel, activate the "**Mouse wheel operation with global coordinates**" check box in the dialog box of the "**Graphics preferences/Zoom info**" menu item. If you close the program with this setting, the setting is still activated the next time you start it. You can now use the following mouse wheel functions to change the system:

- [**Shift**] + mouse wheel up = move system graphics up
- [**Shift**] + mouse wheel down = move system graphics down
- [**Shift**] + [**Strg**] + mouse wheel up = move system graphics right
- [**Shift**] + [**Strg**] + mouse wheel down = move system graphics left
- [**Strg**] + mouse wheel up = enlarge system graphics (change of scale)
- [**Strg**] + mouse wheel down = reduce system graphics (change of scale)

From a zoomed representation you return to the full screen with [**Esc**]. You can undo a change in scale or system coordinates with [**F9**] (= menu item "**Page size + margins/Auto-resize**").

You can view the changed system coordinates in the menu item "**Page size + margins/Manual resize (editor)**" and, if necessary, adjust them manually by entering more precise numbers.

6.3 GGU-CANTILEVER: Function keys

Some of the function keys are assigned program functions. The allocations are noted after the corresponding menu items. The individual function key allocations are:

- [**Esc**] refreshes the screen content and resets the screen section to your current image zoom, which is preset to 1.0. This is useful, for example, if you have used the magnifying glass function to display sections of the drawing on the screen and want to quickly return to the overall view.
- [**F1**] opens the manual file.
- [**F2**] refreshes the screen without altering the current magnification.
- [**F11**] activates the menu item "**Move objects**", which appears in the GGU programs under various menu titles, e.g. "**Page size + margins**", "**Graphics preferences**" or "**Output preferences**".

In this GGU program, the following function keys are also assigned to program functions:

- [**F4**] opens the menu item "**Evaluation/Main output summary** ".
- [**F5**] opens the menu item "**System/Analyse**".
- [**F6**] opens the menu item "**Evaluation/Interim results**".
- [**F7**] opens the menu item "**Evaluation/Bearing capacity**".
- [**F8**] opens the menu item "**System/Optimise**".
- [**F9**] opens the menu item "**Page size + margins/Auto-resize**".

6.4 GGU-CANTILEVER: Mathematical functions in input boxes with numbers

In input boxes for numerical values, you can use the following arithmetic operations (also in combinations) to determine the desired value or to adjust the existing value. After pressing the [**Return**] or [**Enter**] key, the calculated value is inserted.

Function	**Input**
Add:	
5 + 12,18	5 + 12,18
Subtract:	
25,74 - 12,18	25,74 - 12,18

Multiply:	
5,23 · 4,18	5,23*4,18
π · 2,5³	PI*2,5^3
Divide:	
5,23 / 4,18	5,23/4,18 or 5,23:4,18
Exponentiate:	
25	2^5
Radify:	
Root of 27	w(27) or 27^(1/2)
5th root of 81,5	81,5^(1/5)
Sine, cosine, tangent etc.	
sin(32°)	sin(32)
cos(5,23°)	cos(5,23)
tan(45°)	tan(45)
arctan(1,0)	atan(1,0) = 45°
Natural logarithm:	
ln(4,53)	ln(4,53) = 1,5107
Exponential function:	
e1,5107	ep(1,5107) = 4,53

6.5 GGU-CANTILEVER: "Copy/print area" icon

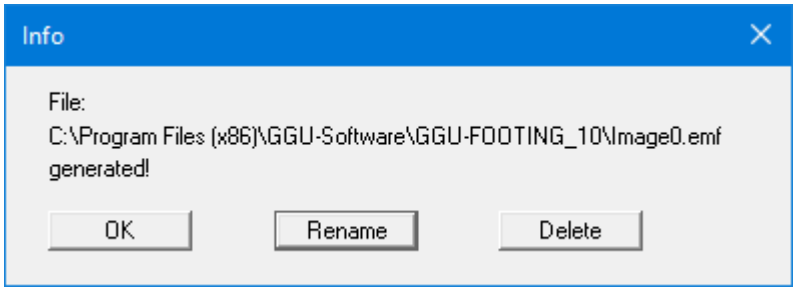
A dialog box opens when the "**Copy/print area**" icon

in the menu toolbar is clicked, describing the options available for this function. For example, using this icon it is possible to either copy areas of the screen graphics and paste them into the report, or send them directly to a printer.

In the dialog box, first select where the copied area should be transferred to: "**Clipboard**", "**File**" or "**Printer**". The cursor is displayed as a cross after leaving the dialog box and, keeping the left mouse button pressed, the required area may be enclosed. If the marked area does not suit your requirements, abort the subsequent boxes and restart the function by clicking the icon again.

If "**Clipboard**" was selected, move to the MS Word document (for example) after marking the area and paste the copied graphics using "*Edit/Paste*".

If "**File**" was selected, , the following dialog box appears after defining the area, shown here as an example for the **GGU-FOOTING** program:



The default location of the file is the folder from which the program is started (here: GGU-FOOTING_10) and, if several files are created, the file is given the file name "**Image0.emf**" with sequential numbering. If the
"**Rename**" button in the dialog box is clicked, a file selector box opens, and the copied area can be saved under a different name in a user-defined folder. Saving can be aborted by pressing the "**Delete**" button.

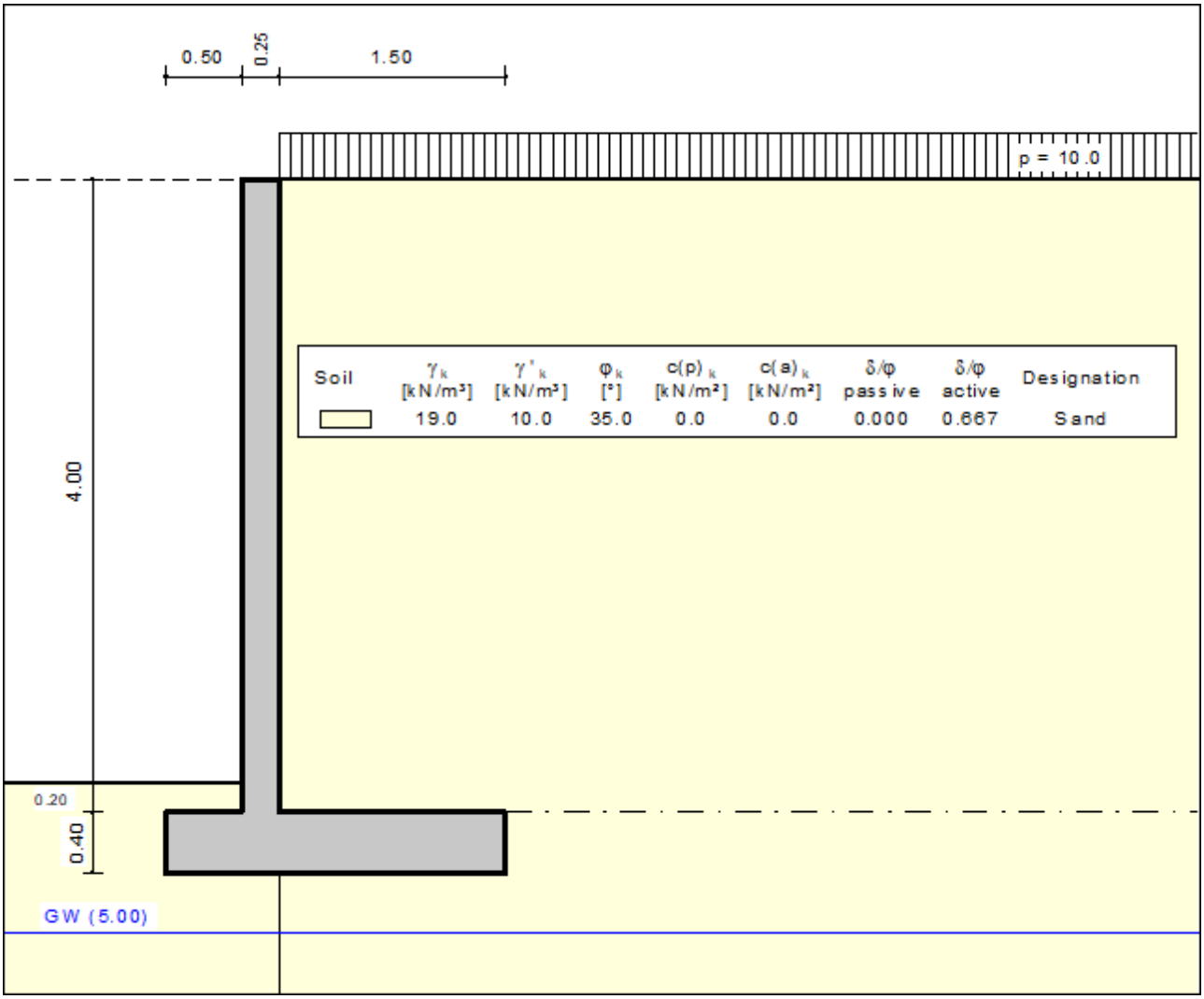
If the "**Printer**" button was pressed in the first dialog box, a dialog box for defining the printer settings opens after marking the area. Following this, a dialog box for defining the image output settings opens. After confirming the settings, the defined area is output to the selected printer.

7 First steps using a worked example

7.1 GGU-CANTILEVER: Example system

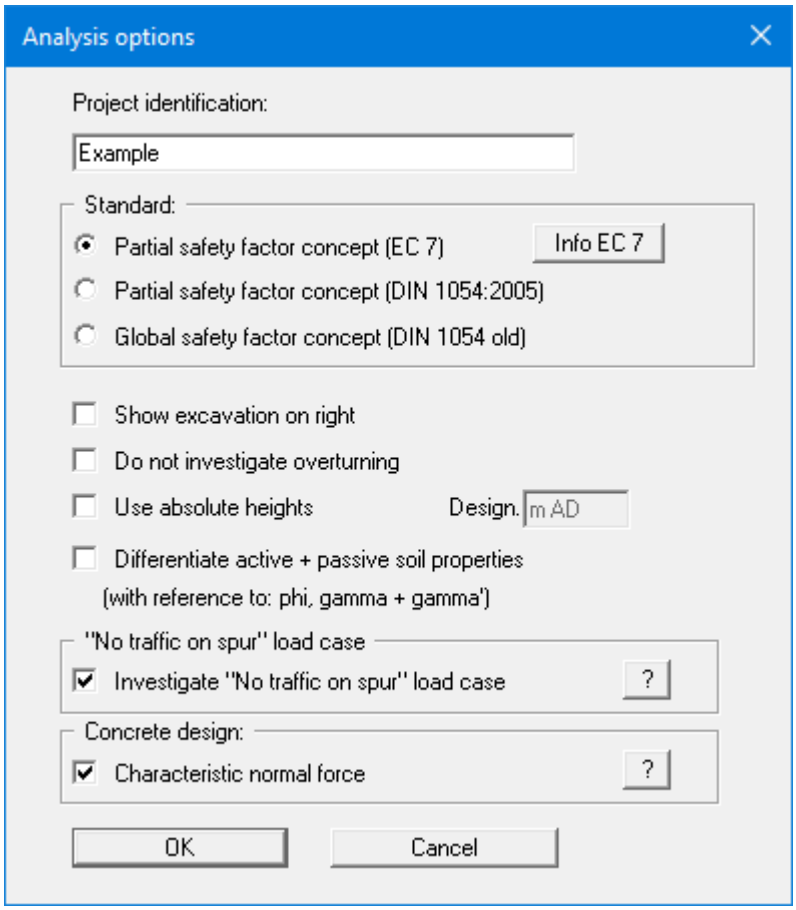
Knowing from experience that having to work one's way through a software manual can be very tiresome, the following sections provides a short description of the main functions, which will quickly enable you to carry out a cantilever wall analysis. Details, when needed, will be found in the appropriate chapter of this manual.

The following cantilever wall will be analysed:



7.2 GGU-CANTILEVER: Step 1: Select analysis options

After starting the program, the logo is displayed. Select the menu item "**File**/**New**". The following dialog box will appear:

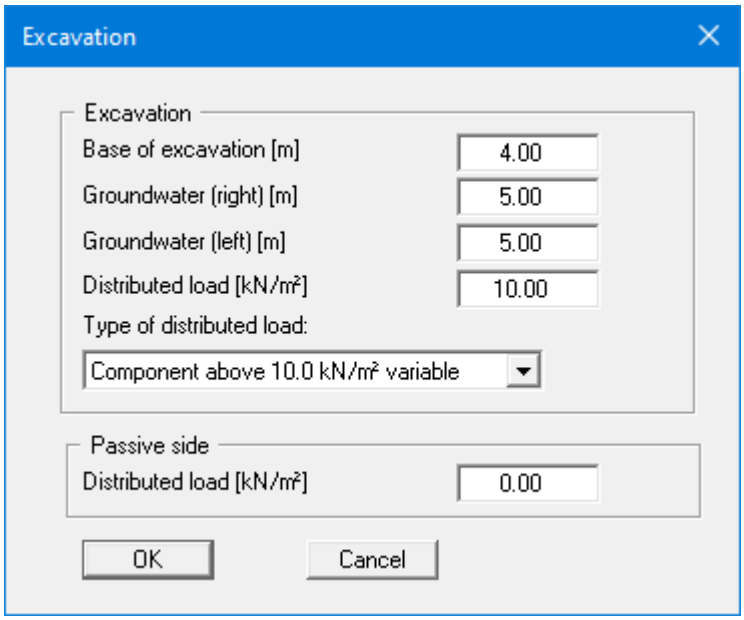


If you select the "**Use absolute heights**" check box, you can enter all depths or heights in **m AD** (heights are positive upwards). If you leave this box unselected, the top of the wall is assumed at **0.0** m (height/depth) and all input of layer depths etc. is positive downwards. If, however, you want to work with absolute heights, enter the appropriate depths correspondingly altered. Thanks to ***WYSIWYG*** there is no danger of using incorrect data since all input is immediately visible on the screen. In this example the check box "**Use absolute heights**" is not selected.

Select the buttons shown in the above dialog box and click "**OK**". A new system is displayed on the screen and the complete menu bar is activated.

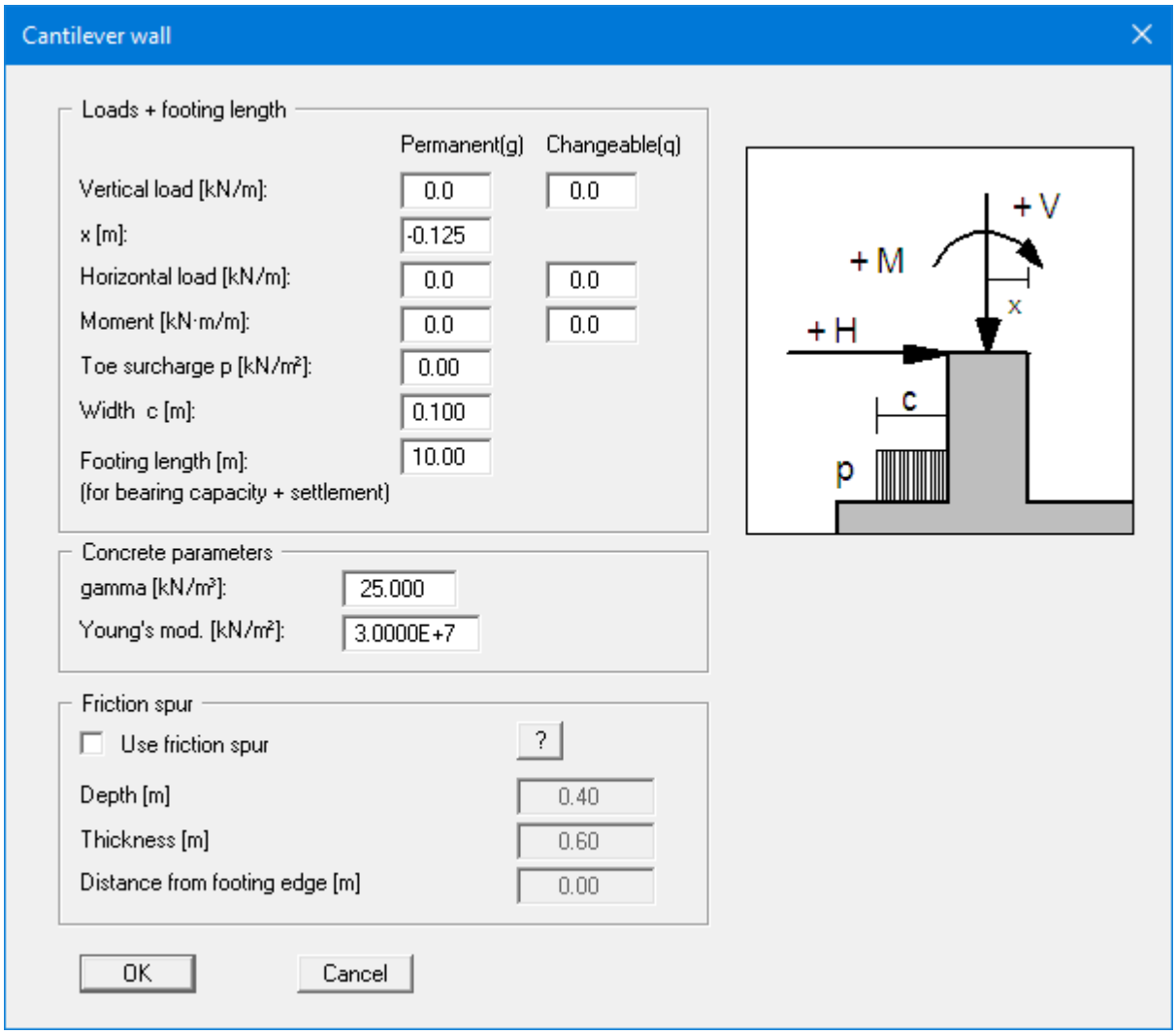
7.3 GGU-CANTILEVER: Step 2: Define the excavation

Go to "**Excavation**" in the "**Editor 1**" menu. The following dialog box will appear. Enter the figures shown below:



7.4 GGU-CANTILEVER: Step 3: Define load on cantilever wall

From the "**Editor 1**" menu select "**Wall (general)**".



In the dialog box, define the size of any existing "**Vertical load**" or "**Horizontal load**" acting on the top of the wall. When using the partial safety factor concept, the loads are entered separately as "**Permanent(g)**" and "**Changeable(q)**" loads. Define the location of the vertical load from the top right edge of the cantilever wall using the "**x [m]**" value. It is also possible to define a moment acting on the wall and an additional load on the toe.

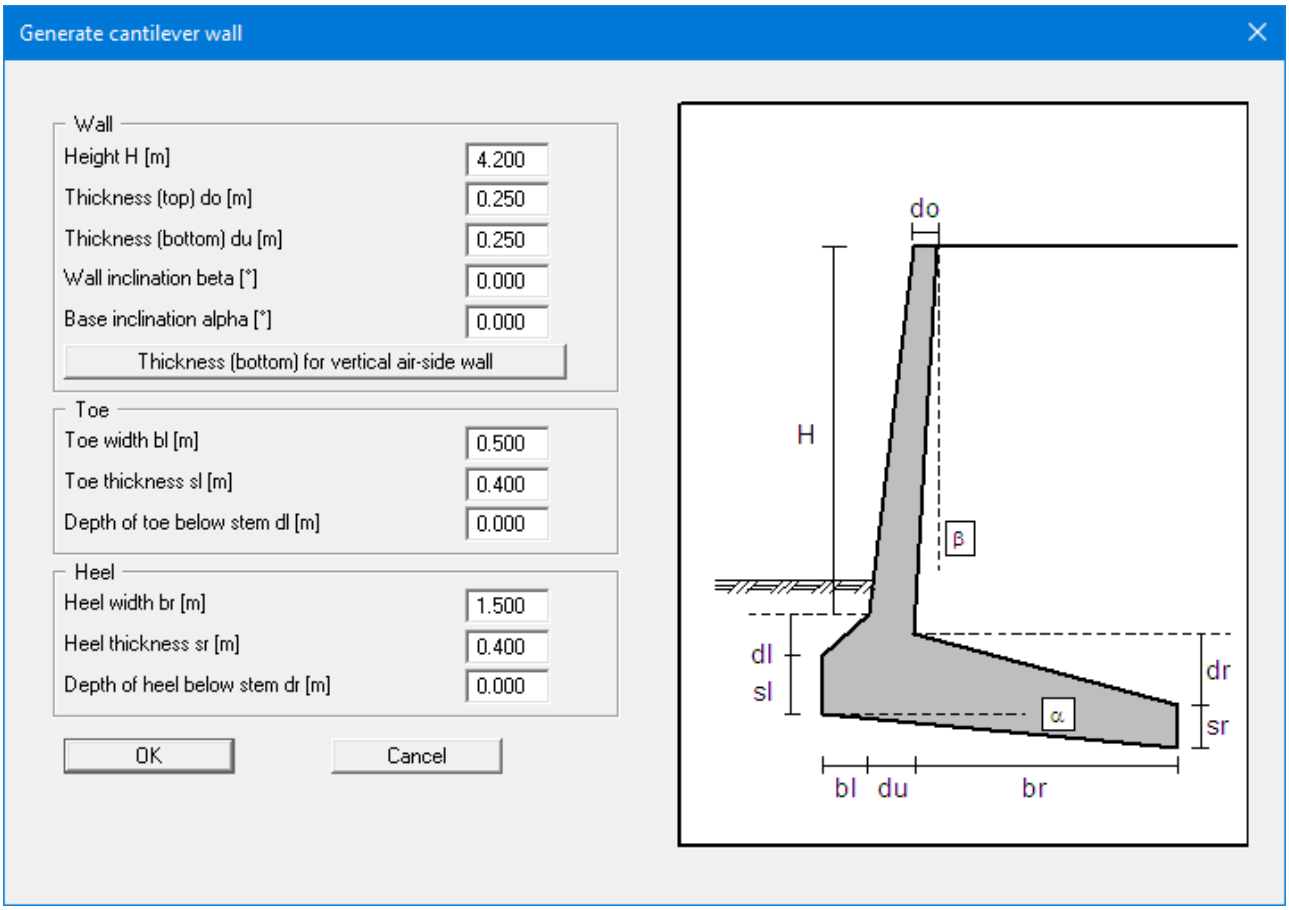
Input of a "**Footing length**" influences bearing capacity failure and settlement analyses only.

Enter the concrete values in the lower section of the dialog box. "**Young's mod.**" designates the Young's modulus of the concrete. This value is required for the structural analysis of the cantilever wall.

You can use a friction spur to increase the passive earth pressure and thus increase the sliding safety. With high walls, the active earth pressure is often greater than the passive earth pressure. The effect is then reversed.

7.5 GGU-CANTILEVER: Step 4: Define geometry of cantilever wall

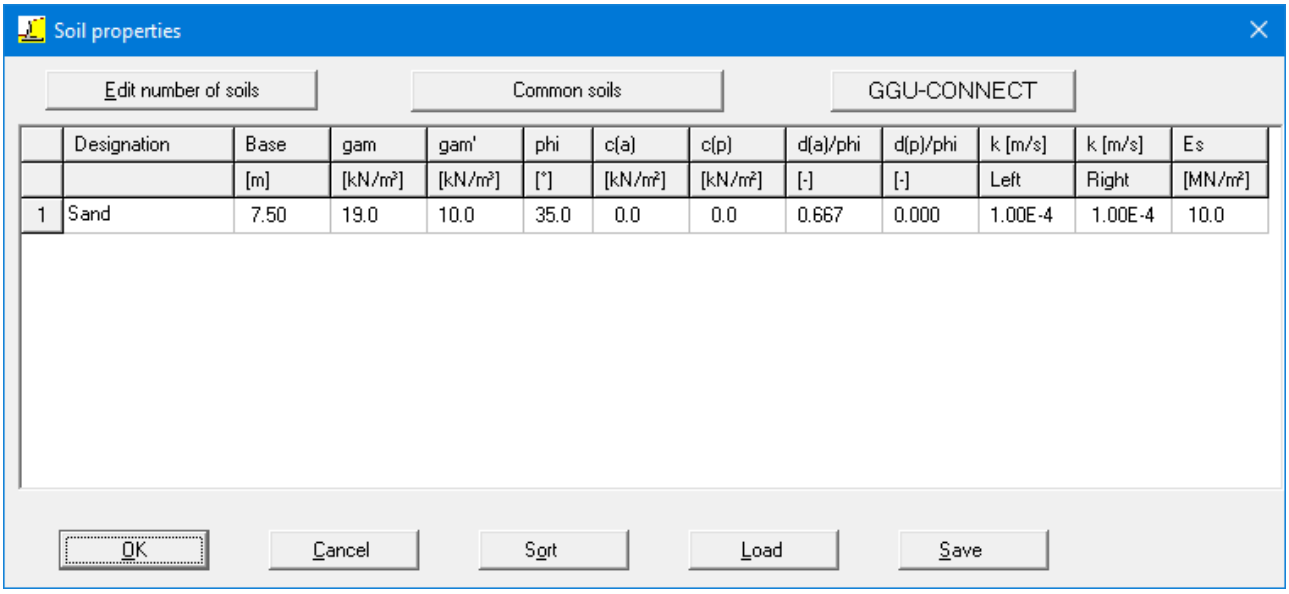
From the "**Editor 1**" menu select "**Wall (geometry)**".



The graphics visualise all necessary input, so no further descriptions are necessary here.

7.6 GGU-CANTILEVER: Step 5: Define soils

Go to "**Editor 1**" menu and select "**Soils**". Change the number of soils by clicking "**Edit number of soils**" and enter **1**.

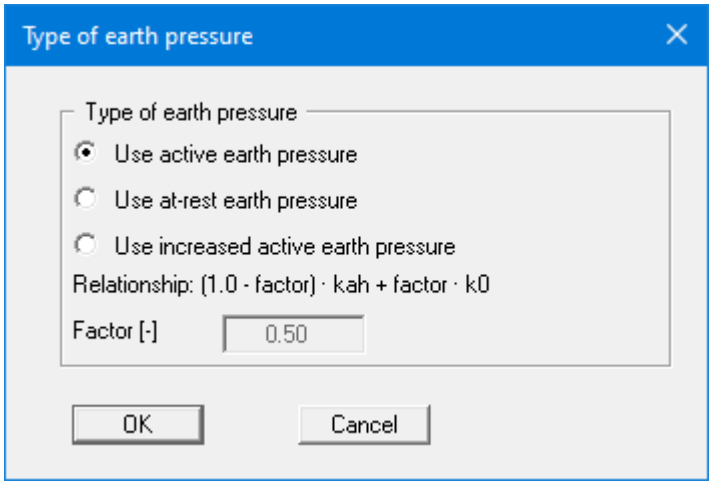


	Designation	Base	gam	gam'	phi	c(a)	c(p)	d(a)/phi	d(p)/phi	k [m/s]	k [m/s]	Es
		[m]	[kN/m³]	[kN/m³]	[°]	[kN/m²]	[kN/m²]	[-]	[-]	Left	Right	[MN/m²]
1	Sand	7.50	19.0	10.0	35.0	0.0	0.0	0.667	0.000	1.00E-4	1.00E-4	10.0

Enter the values given in the above dialog box. You can enter differing cohesion and friction angles for the active (a) and the passive sides (p).

7.7 GGU-CANTILEVER: Step 6: Define type of earth pressure

Go to the "**Editor 1**" menu and select "**Type of earth pressure**".

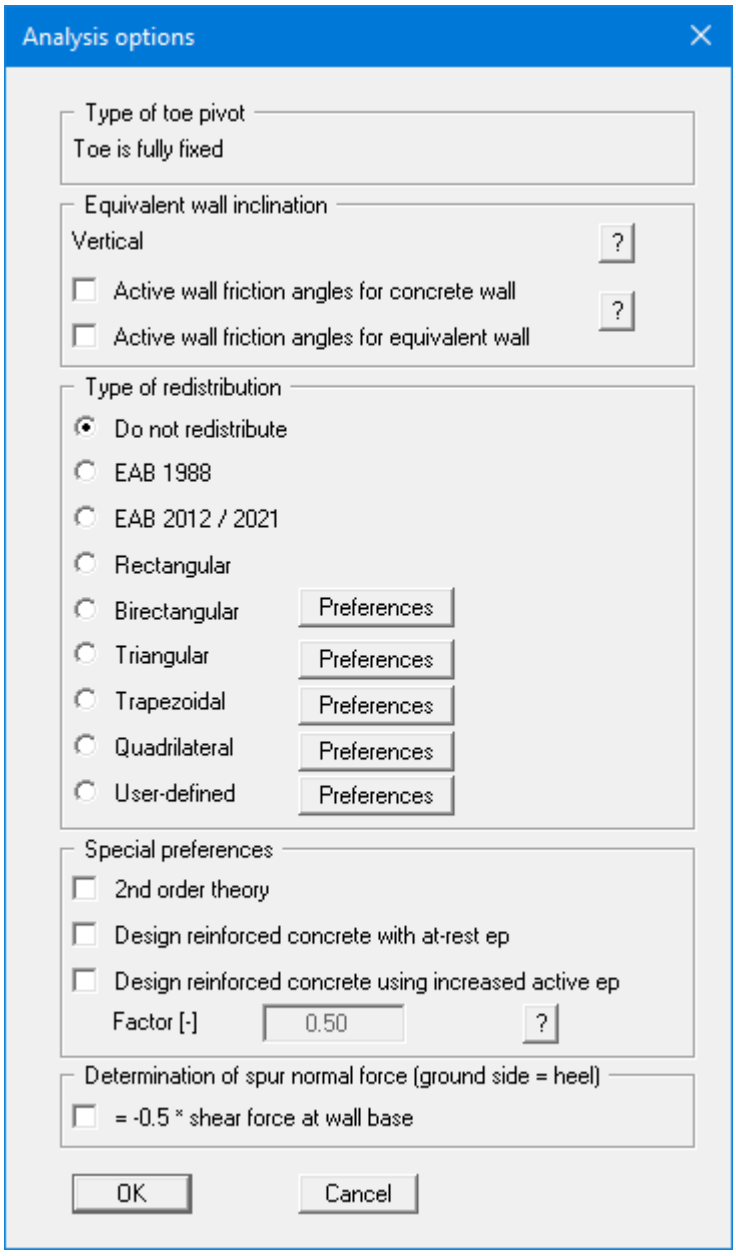


The necessary command buttons are already selected, so you need not change anything. The same applies to the remaining menu items in "**Editor 1**". However, you should click these items and look at them, in order to familiarise yourself with them.

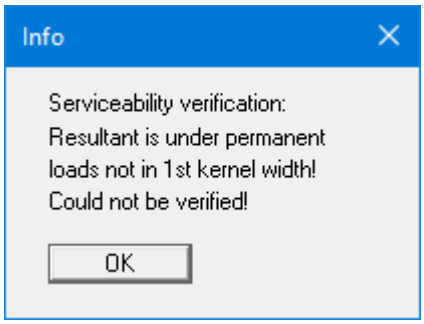
This completes data input.

7.8 GGU-CANTILEVER: Step 7: Analyse and design the system

Now select the "**Analyse**" menu item from the "**System**" menu.



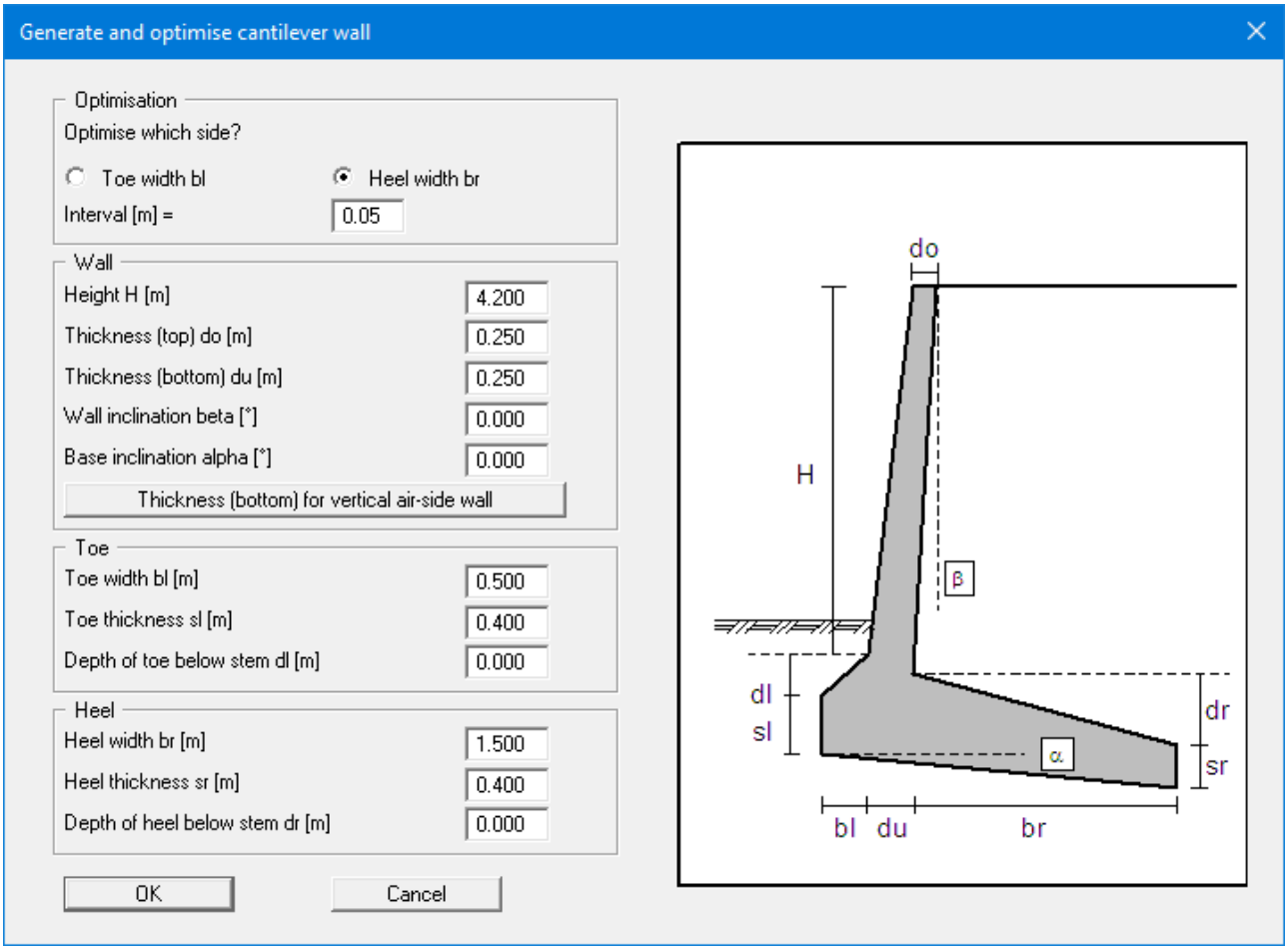
After clicking the "**OK**" button the analysis begins. The program first performs an intensive plausibility check of the data input. Once the analysis is complete, you will receive the following message for the system entered:



After confirming with "**OK**", the dialog box for reinforced concrete design compliant with EC 2 will be displayed. For the example, accept the proposed specifications in the dialog box. A description of the design can be found in the "**System/Design defaults**" menu item. Once design is complete, the results are presented in information boxes and then visualised graphically on the screen.

7.9 GGU-CANTILEVER: Step 8: Optimise system

To correct the displayed error in the serviceability analysis, select the "**System/Optimise**" menu item. You will first see the dialog box for the analysis, which you accept with the default settings. You can then optimise the cantilever wall:



Accept the proposed specifications and carry out the optimisation. The program then proposes an increase in the spur width (right) from 1.50 m to 1.60 m. Accept the proposal and then carry out design once more.

7.10 GGU-CANTILEVER: Evaluate and visualise the results

Amongst other things, four legends are displayed on the screen, containing the soil properties, and the most important analysis data and analysis results as well as the results of the settlement analysis.

If you don't like the legend positions, they can be easily altered. Go to the "**Move objects**" menu item in the "**Graphics preferences**" menu and follow the instructions there. The size of the legends can be altered by changing the font sizes in the individual dialog boxes.

Besides the system, the earth pressures, action effects, etc. are displayed for the whole height of the wall. These entries can also be edited. Go to the "**Graphics output preferences**" menu item in the "**System**" menu. Further evaluations can be displayed by going to the "**Evaluation**" menu.

The diagram can be printed on the selected printer ("**File/Print and export**" menu item). You can also print off a detailed protocol ("**File/Print output table**" menu item). The zoom function (see "**Graphics preferences/Zoom info**" menu item) allows you to magnify selected areas of the graphic. Double-clicking in the graphics at a particular point will cause a box to appear containing the corresponding state variables.

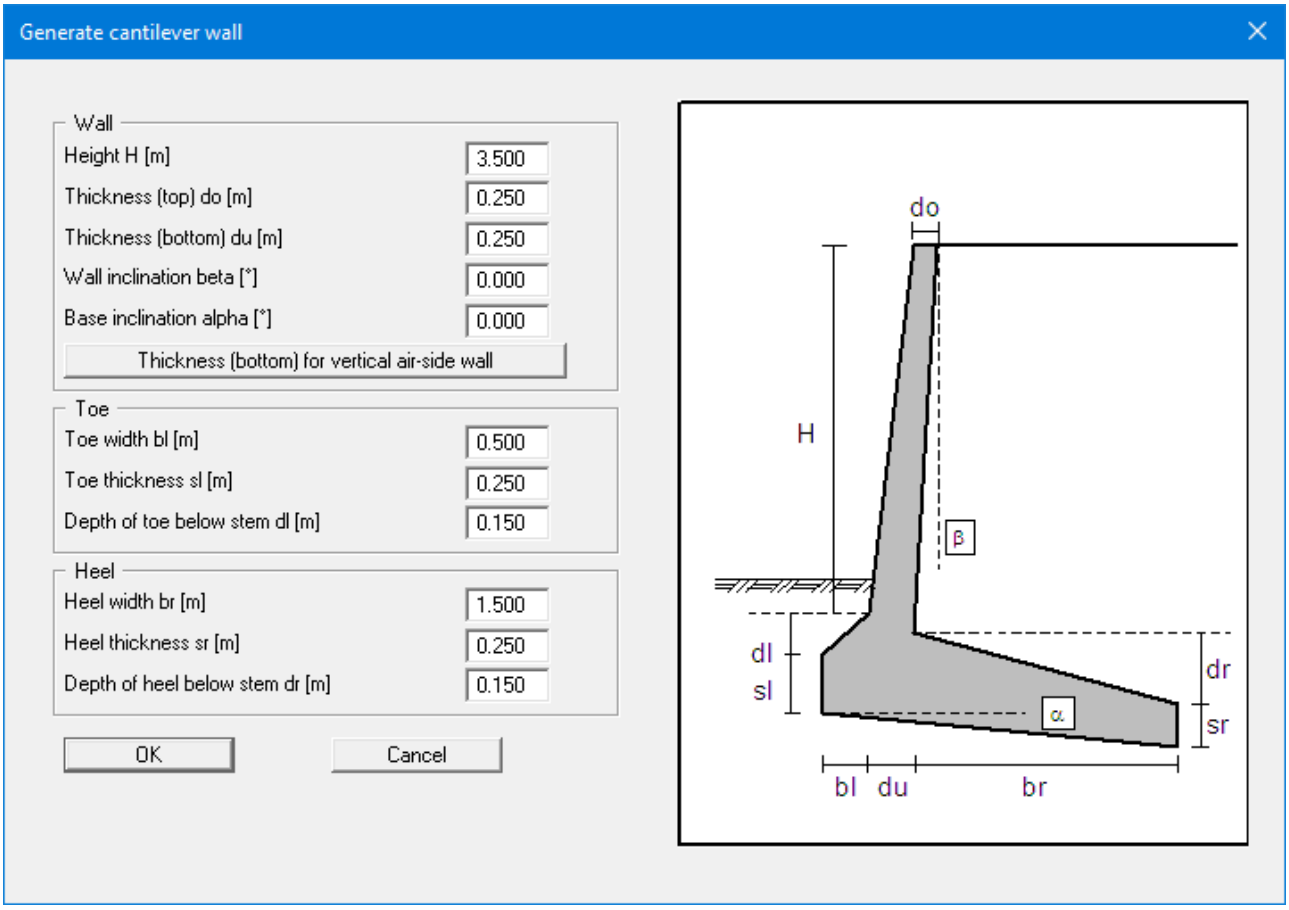
To further clarify the analysis results the graphics can be supplemented with text and graphic elements using the "**Mini-CAD**" module. You can save your work to a file. Go to the "**Save as**" menu item in the "**File**" menu.

8 Theoretical principles

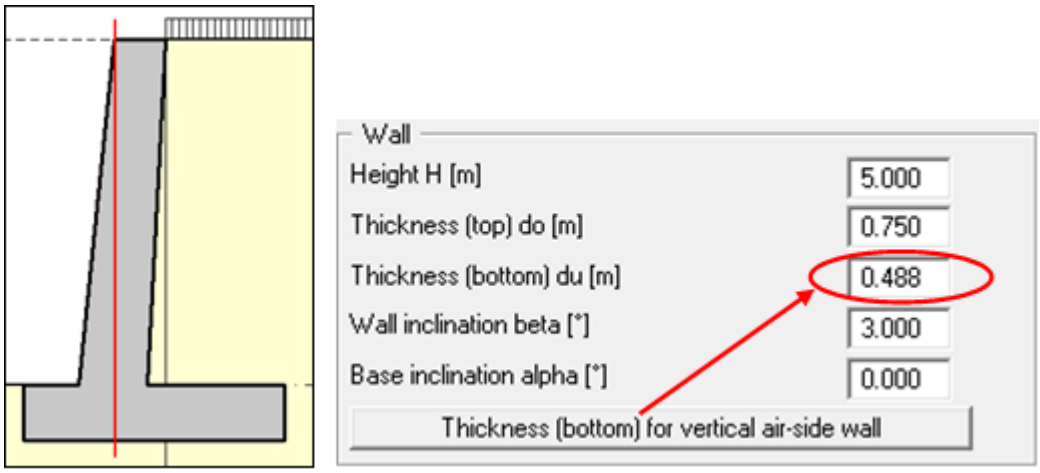
8.1 Cantilever wall

8.1.1 GGU-CANTILEVER: Definition of cantilever wall

The cantilever wall is defined via the menu item "**Editor 1/Wall (geometry)**". The graphics visualise all necessary input.

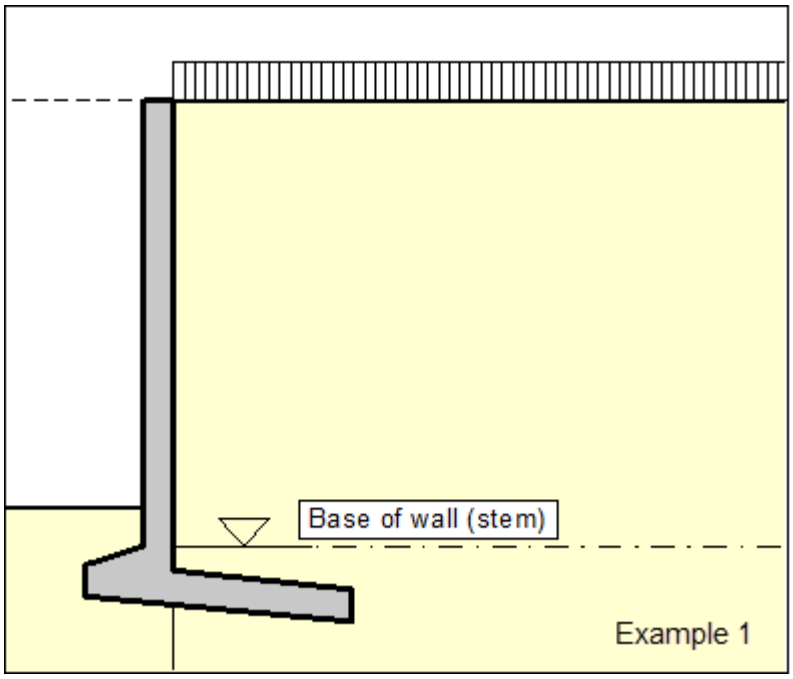


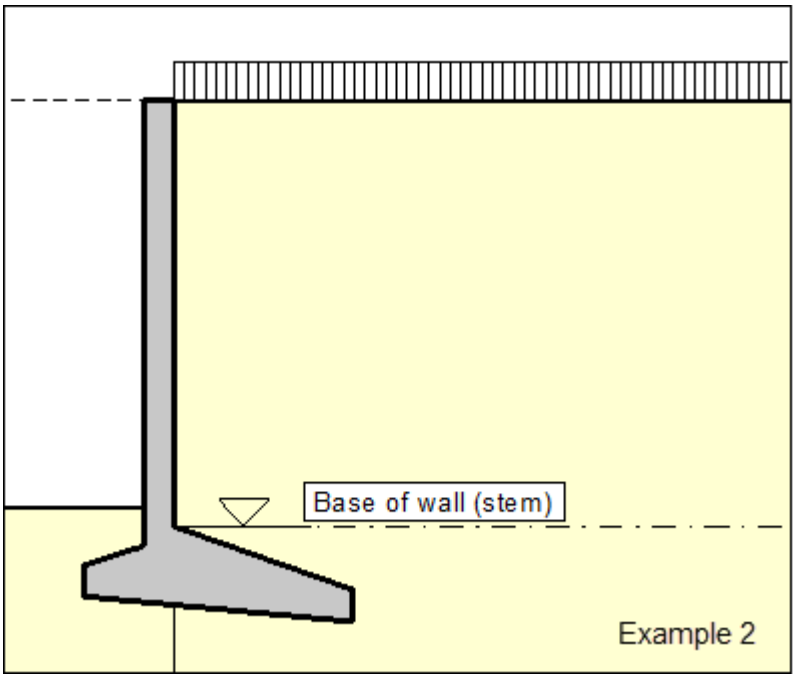
You can use the "**Thickness (bottom) for vertical air-side wall**" button to determine the required "**Thickness (bottom) du**" for an inclined wall. Starting from the upper left corner of the angled cantilever wall, the program extends the air-side wall downwards to determine the lower wall thickness.



8.1.2 GGU-CANTILEVER: Determination of wall loads for reinforced concrete design

The program first analyses the loads on the wall above the footing. The base of the wall (stem) is marked by a dashed line. This is shown on two examples below:





Earth pressure is calculated to the stem as shown in the figures. The result is the load on the wall above the footing zone. The wall is then designed to EC 2 (reinforced concrete design) using this result.

8.2 GGU-CANTILEVER: Soil properties

Up to 50 soil layers can be taken into consideration. For each layer the following parameters must be given:

- depth in metres below top of the wall, or absolute depth,
- unit weight [kN/m³] of moist soil γ,
- unit weight [kN/m³] of buoyant soil γ',

- friction angle [°],
- cohesion (active and passive) [kN/m²],
- active angle of wall friction as the ratio δa/φ,
- passive angle of wall friction δp/φ,
- permeability to the left and right of the wall [m/s],
- constrained modulus Es.

Permeability is taken into consideration in a calculation of subsurface hydraulic conditions via flow conduits (see “**Theoretical principles: Water pressure approach using flow conduits**”).

If you activate the "**Differentiate active + passive soil properties**" check box in the dialog box in "**File/New**" or "**Editor 1/Analysis options**", you can enter differing friction angles and unit weights for the active and the passive sides.

If you are already working with **GGU-CONNECT**, you can also import soil properties from your subsoil layer model that you have created in **GGU-CONNECT**.

Further explanations can be found under the menu item “**Editor 1 / Soils**”.

8.3 GGU-CANTILEVER: Active earth pressure

8.3.1 Active earth pressure is analysed to DIN 4085. DIN 4085 provides two relationships for the coefficients of earth pressure kah (friction) and kch (cohesion). Alternatively, there is the option of determining the cohesion coefficient from kch = kah-2, a method often found in older literature.

In addition, calculation of the active earth pressure after Culmann is possible. The calculations use a slice method with planar slip surfaces.

8.4 GGU-CANTILEVER: At-rest earth pressure

The at-rest earth pressure coefficient is calculated compliant with DIN 4085:2017.

8.5 GGU-CANTILEVER: Increased active earth pressure

The coefficient of increased active earth pressure, keh, is obtained from the coefficient of active earth pressure and at-rest earth pressure:

keh = (1.0 - f) · kah + f · k0

0.0 ≤ f ≤ 1.0

8.6 GGU-CANTILEVER: Passive earth pressure

The coefficient of passive earth pressure can be calculated using several methods:

- DIN 4085:2017,
- DIN 4085: 2017 planar slip surfaces,
- Streck,
- Caquot/Kerisel,
- DIN 4085:2017 planar slip surfaces/Caquot/Kerisel,
- Culmann.

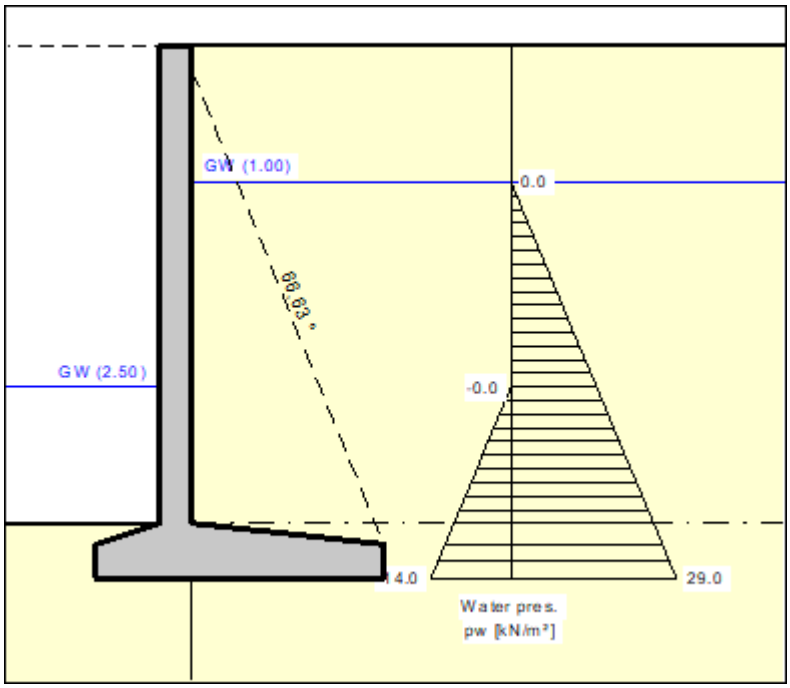
The earth pressure after Culmann is acquired by varying the slip surface angle (see Piling Handbook 1977). The forces at the earth pressure wedge are calculated using a slice method.

DIN 4085:2017 stipulates that planar slip surfaces may be adopted for analysis up to a friction angle ≤ 35° and a wall friction angle ≤ -2/3 phi. This returns more favourable earth pressure coefficients.

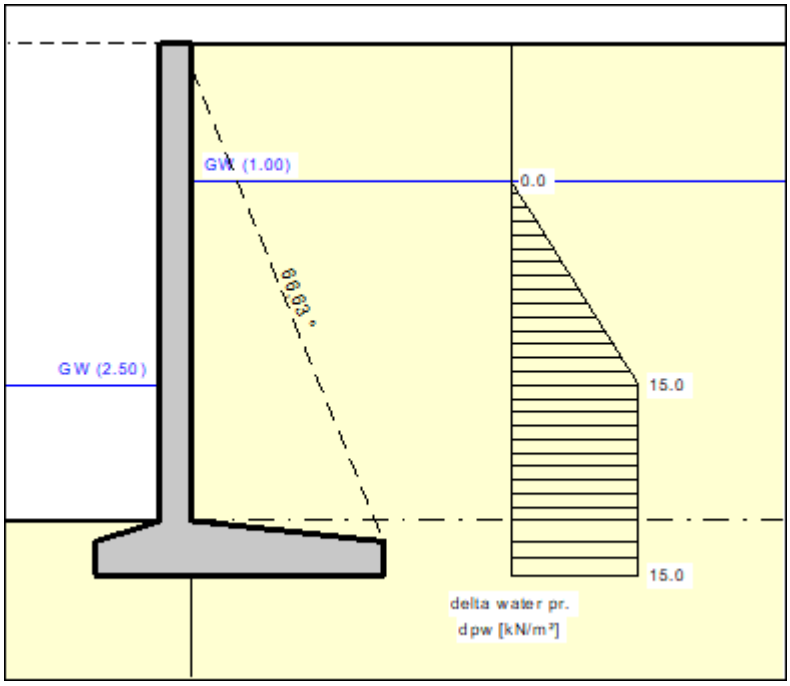
8.7 Water pressure

8.7.1 GGU-CANTILEVER: Classical water pressure approach

Water pressure can be effective on the active and passive sides of the cantilever wall. The classical water pressure approach corresponds to the following illustration.



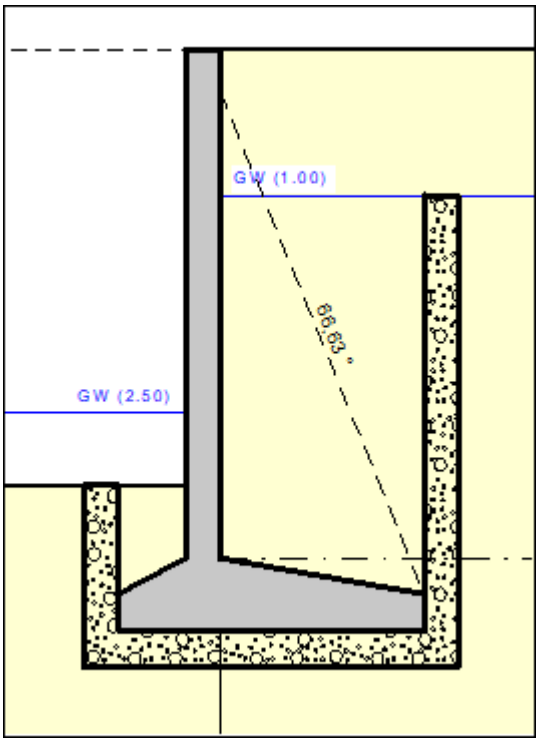
The resulting water pressure load is shown in the next figure.



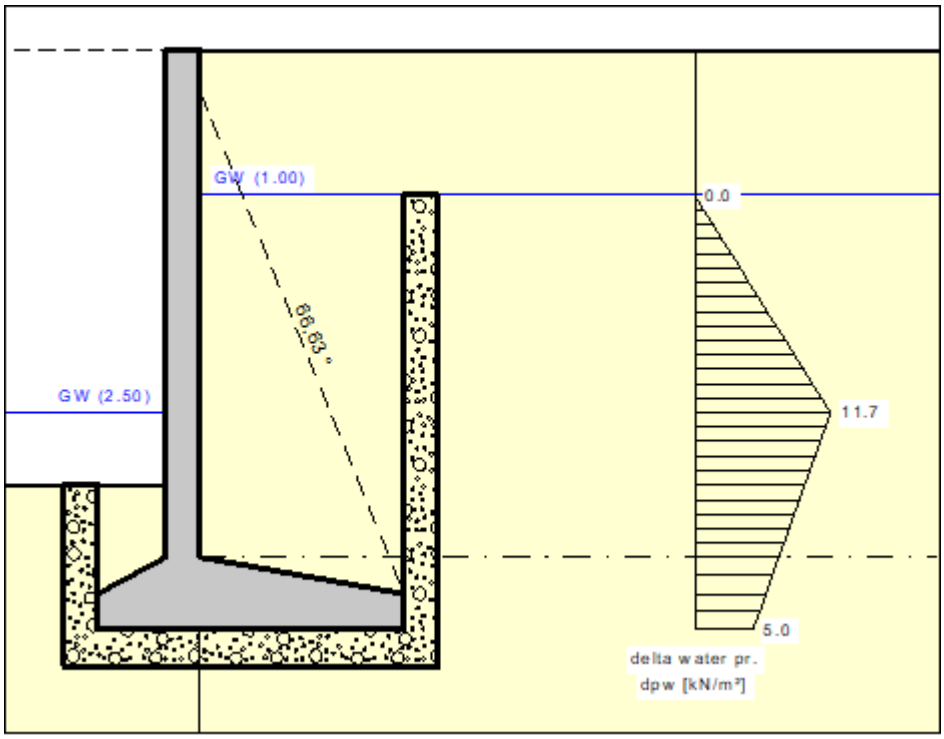
However, the classical approach does not take the permeability of the soil into consideration. The gradients on the active and passive sides are obtained by assuming a linear reduction in pressure.

8.7.2 GGU-CANTILEVER: Water pressure approach using flow conduits

Beside the classical water pressure approach, **GGU-CANTILEVER** also allows analysis of walls around which groundwater can percolate. To facilitate this, a flow conduit is calculated on the active and on the passive side. The permeabilities within the flow conduit can be specified separately for each soil layer.



The system of the three flow conduits results from the spur widths. The resulting water pressure load is therefore as shown in the following figure.



If you select the water pressure approach using flow conduits, the potentials *h* at the height of both water levels will be automatically adopted as boundary conditions. In the simplest case of a global permeability value the result is linear pressure dissipation along the flow conduit. Besides the water pressures, the hydraulic gradients will also be calculated and can be selected for consideration in the calculations of active and passive earth pressures.

An approach using flow conduits is, however, much more interesting for use with variable permeabilities. In this case, the water pressures are correctly determined in accordance with potential theory by employing a small finite element module within **GGU-CANTILEVER**. You can still define additional potentials at any location to the left or right of the cantilever wall. This allows correct, simple consideration of several groundwater storeys or confined aquifers. In addition, employing user-defined potential definitions allows you to create or model any kind of water pressure distribution.

8.7.3 GGU-CANTILEVER: Recommendation for water pressure approach

The classical water pressure approach is valid when the toe of the wall is embedded in a layer of ***low permeability***. Otherwise the difference in water pressure at the wall toe (see Figure for Classical water pressure approach) has no physical meaning, but nevertheless provides conservative design values.

The classical water pressure approach and the approach using flow conduits (under uniform conditions of permeability) both assume a linear pressure drop along the wall. Given ***uniform permeability***, this can lead to an underestimate of the hydraulic gradient, since the two-dimensional flow to which the wall is subjected is not taken into consideration (see also EAU). Using flow conduits, with additionally defined potentials at the toe of the wall, this can be corrected.

For soils with ***non-uniform permeability*** above the wall toe, the water pressure approach using flow conduits should always be preferred. If doubts remain, you will have to carry out a two-dimensional groundwater analysis according to the EAU. The potentials determined at the wall can be incorporated into flow conduits.

If an ***impermeable layer*** occurs at the base of the wall there will be no hydraulic gradient along it. Nevertheless, when using the classical approach, a linear reduction in water pressure is assumed in the literature, which really amounts to unnecessarily doing the same thing twice.

8.7.4 GGU-CANTILEVER: What is a potential?

In subsurface hydraulics the potential (h) is composed of:

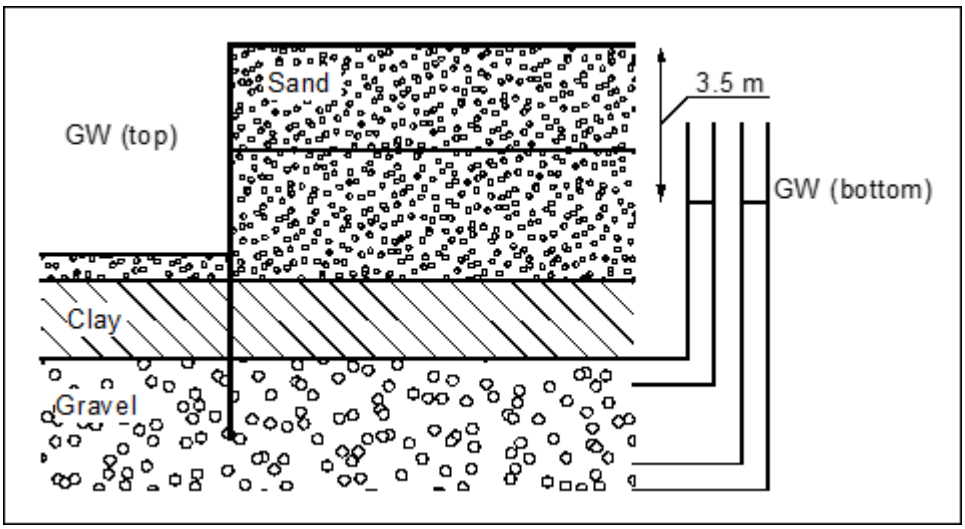
- the elevation head (y) of the point under consideration (in metres) and
- the water pressure (u) at the point under consideration (in metres).

If p is the water pressure in kN/m² at a particular point, then water pressure, u (in metres) = p/γw (γw = unit weight of water ≅ 10.0 kN/m³).

h = p/γw + y

h = potential [m]
p = water pressure [kN/m²]
y = elevation head [m]

An example:



In this example, two permeable soil layers are separated by a low-permeability layer (clay). In the excavation, groundwater is kept at the base level. The groundwater in the gravel layer below the clay is under pressure and rises to 3.5 m below the top of the wall (represented in the diagram by the water levels in the two standpipes on the right). The lowest point in the right-hand standpipe is at a higher water pressure than that in the left-hand standpipe, but both have the same potential of 3.5 m below the top of the wall. Because potential is a function of the elevation head and the water pressure [m], the left-hand standpipe makes up for its lower water pressure by its greater elevation head.

If you want to calculate such a system using flow conduits, it is sufficient to enter a potential of 3.5 m below the top of the wall for any point within the layer of gravel. The potential above the layer of clay is defined by groundwater levels to the left and right of the wall. This boundary condition is used automatically by the program. Together with the permeabilities, the program calculates the potentials along the flow conduit resulting from these boundary conditions. From the calculated potentials (h), water pressure (p) and also the gradient (i) can now be determined. Applying the above formula for p:

$$p = \gamma w \cdot (h - y)$$

For the gradient (i) we have:

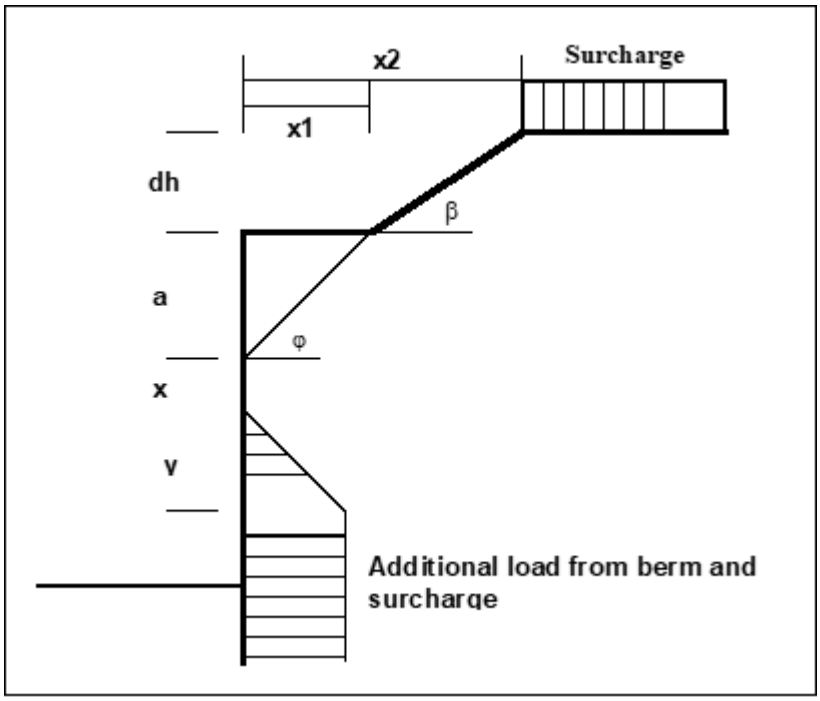
$$i = \Delta h / \Delta L$$

Δh = potential difference between two points
ΔL = distance between the two points

Using flow conduits, the load-decreasing effect of the upwardly directed hydraulic gradient on passive earth pressure can now be taken precisely into consideration.

8.8 GGU-CANTILEVER: Berms

The program can handle 40 berms on both the active and the passive sides of the wall. The berms may include surcharges. The effect on earth pressure is taken into consideration according to the Piling Handbook (Krupp Hoesch Stahl).



The following relationships apply for the parameters x and y:

x = kah0 / (kah β - kah0) · a

y = kah0 / (kah β - kah0) · x

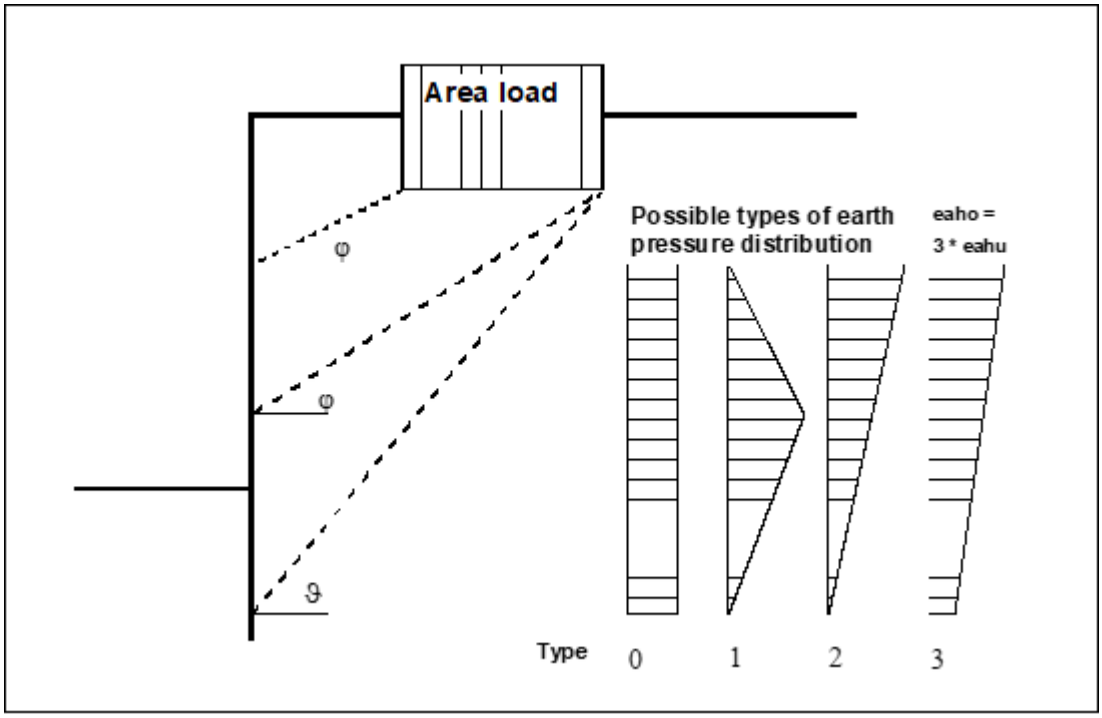
Δeahu = γ · dh + surcharge

γ = unit weight of soil in the berm area

If the angle β is greater than φ, it is assumed that β = φ for analysis. Berms on the passive side are dealt with in the same manner.

8.9 GGU-CANTILEVER: Area loads

Up to 20 area loads can be positioned on the active side at any height.



The slip surface angle for the active earth pressure resulting from the self-weight of the soil is adopted for analysis compliant to DIN 4085.

$$\vartheta_{ag} = \varphi + \arctan\left(\frac{\cos(\varphi - \alpha)}{\sin(\varphi - \alpha) + \sqrt{\frac{\sin(\varphi + \delta_a) \cdot \cos(\alpha - \beta)}{\sin(\varphi - \beta) \cdot \cos(\alpha + \delta_a)}}} \right)$$

When there are several soil layers, the program moves from layer to layer applying the appropriate angles of friction. The type of the resulting earth pressure distribution can be specified in 4 different ways.

For at-rest earth pressure, the area loads are calculated by increasing by the factor k0/kah in compliance with DIN 4085 Section 6.4.3.

Alternatively, it is possible to determine the demands placed on a wall from area loads using the theory of elastic half-space. The two load concentration factors "**3**" and "**4**" can be taken into consideration (see also the following Figure).

- For over consolidated, cohesive soils the concentration factor "**3**" applies, where:
  eop = q/π · (β2 - β1 + cosβ1 · sinβ2 - cosβ2 · sinβ2)
- For non-cohesive soils, or for cohesive but not over consolidated soils, the concentration factor "**4**" applies, where:
  eop = q/4 · (sin³β2 - sin³β1)

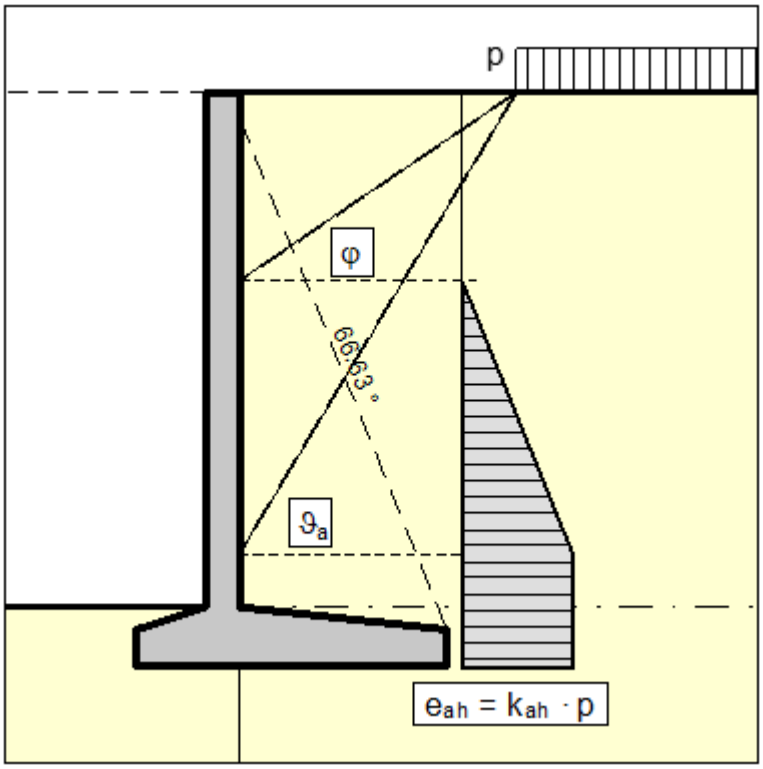
Regarding the kind of earth pressure, area loads can be defined independent of the global preferences (see menu item "**Editor 1/Type of earth pressure**").

8.10 GGU-CANTILEVER: Loads with limited plan dimensions

Loads with limited plan dimensions can be reduced compliant with "Piling Handbook" Figure 4.20 (page 64) or DIN 4085:2017-08 (page 17), see menu item "**Editor 2/Area loads**".

8.11 GGU-CANTILEVER: Bounded surcharges (active side)

Up to 40 bounded surcharges can be positioned at any height on the active side.

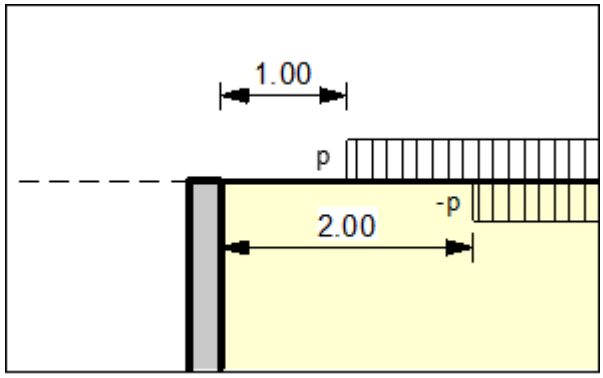


The earth pressure coefficient k is acquired from kah for active earth pressure and from k0 for at-rest earth pressure. If this option is activated, the resulting earth pressure is then redistributed.

If negative values are entered, e.g. to generate a double-bounded surcharge, the linear component between φ and ϑ may not be adopted.

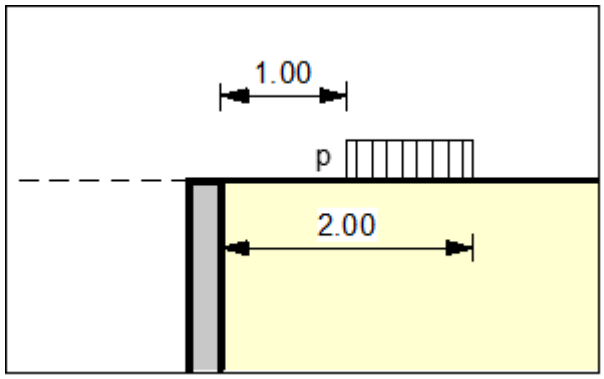
8.12 GGU-CANTILEVER: Double-bounded surcharges (active side)

If two bounded surcharges are defined as follows:



- Bounded surcharge 1:
  begins at x = 1,00 m and has the value p.
- Bounded surcharge 2:
  begins at x = 2,00 m and has the same value as surcharge 1 but with a negative sign
  (see the explanation under "**Theoretical principles: Bounded surcharges (active side)**").

A double-bounded surcharge, which acts because of p at x = 1.00 to x = 2.00, is thus defined as the result of earth pressure analysis. However, the graphics are not satisfactory and may be irritating for an examiner. Double-bounded surcharges were therefore introduced.

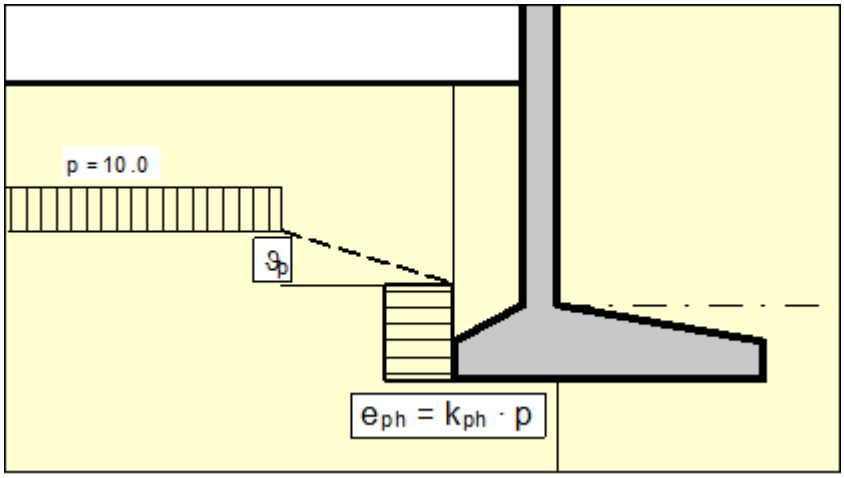


The same result is achieved as for the definition provided by the first figure above but with ***improved graphics***.

The area loads described in the ***Theoretical principles*** are based on different assumptions for the resulting earth pressure, so the definition of a double-bounded surcharge does not provide the same result as an equivalent area load.

8.13 GGU-CANTILEVER: Bounded surcharges (passive side)

Up to 40 bounded surcharges may be adopted at any height on the passive side. The passive earth pressure is computed as follows:



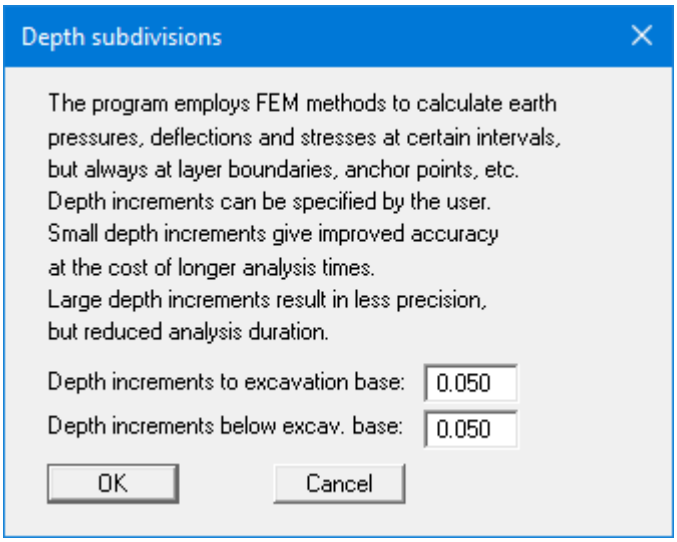
8.14 GGU-CANTILEVER: Double-bounded surcharges (passive side)

Double-bounded surcharges on the passive side can be modelled using two bounded surcharges (also see “**Theoretical principles: Double-bounded surcharges (active side)**”). Double-bounded surcharges on the passive side were only implemented due to the ***better graphical representation***.

8.15 GGU-CANTILEVER: Structural system

The structural analysis required to determine the state variables (displacement, moment, shear force and normal force) is by means of a rod construction module, which treats the cantilever wall and any anchors and struts as a single structural system. The wall is taken into consideration as a rod construction, running along the centroid of the cantilever wall. The base of the structural system corresponds to the top of the footing as shown in the 2 figures in “**Theoretical principles: Determination of wall loads for reinforced concrete design**” (Base of wall (stem) Example 1/Example 2). Full fixation is assumed.

The wall is analysed using the finite-element method. The size of the finite elements (rods) can be defined in the menu item "**System/Depth subdivisions**".



The setting in the dialog box assumes subdivision into 0.05 m long rods. Empiricism indicates that this produces sufficiently accurate results. A reduction in these values is not necessary.

The stiffness EI of the wall is acquired from E·d³/12, where d is the horizontal thickness of the wall in the section under consideration. The stiffness of each element is assumed as constant, where the thickness is the thickness at the centre of the section. The remaining values of any anchors or struts can be specified before beginning the analysis. If anchors or struts exist in the system, the point of acting is automatically placed in the centroid axis.

Using FEM produces equation systems in which the number of unknowns is a function of the number of rods. The solution to the equation system is acquired in **GGU-CANTILEVER** using Cholesky's method, which is also employed in other GGU programs and is numerically highly stable.

8.16 GGU-CANTILEVER: Design

When you begin an analysis, the program requires the stiffnesses of the cantilever wall and any anchors and struts present. The stiffness EI of the wall is acquired from E·d³/12, where d is the thickness of the wall in the section under consideration. The stiffness of each element is assumed as constant, where the thickness is the thickness at the centre of the section. The remaining values of any anchors or struts can be specified before beginning the analysis.

The program first computes the internal forces of the cantilever wall above the footing (see figures in "**Theoretical principles: Determination of wall loads for reinforced concrete design**" - Base of wall (stem) Example 1/Example 2). The wall is then designed using the identified internal forces.

The earth and water pressures are then calculated for the entire system with footings. Together with the self weights and area loads, bounded or double-bounded surcharges, stability analysis can now be performed:

- calculation of bearing capacity safety to DIN 4017
- calculation of sliding safety

- calculation of overturning safety
- calculation of settlements to DIN 4019
- calculation of hydraulic heave safety
- calculation of buoyancy safety
- calculation of heave of anchor soil

By going to the menu items "**Editor 1/Verifications/Partial factors**" and "**Editor 1/Buoyancy + Hydraulic heave**", you can select the verification to be performed.

The settlement analysis can be activated or deactivated by going to "**Editor 2/Settlements**".

8.17 GGU-CANTILEVER: Action and displacement boundary conditions

The program automatically sets the boundary conditions shown in the figure under "**Theoretical principles: Structural system**". However, it is also possible to specify additional boundary conditions at any point on the wall. All six state variables can be defined as boundary conditions:

- displacement along x-axis,
- displacement along y-axis,
- rotation,
- horizontal force,
- vertical force,
- moment.

8.18 GGU-CANTILEVER: Pretensioning

Personal experience has shown that discussions surrounding the necessity for considering pretensioning are never-ending. Independently, the program enables pretensioning for anchors/struts to be taken into consideration using the "**Editor 2/Pretensioning**" menu item.

For anchors, pretensioning must be entered as positive. Faulty input is pointed out before analysis begins. From a structural perspective, the program inserts an action boundary condition equivalent in size and direction to the pretensioning force into the system at the appropriate depth.

Anchors are generally pretensioned at 80% and more of the resulting anchor force. This can be modelled with sufficient accuracy using a high axial rigidity EA without pretensioning. If you wish to analyse more precisely, specify the axial rigidity EA according to the selected anchor and define a pretensioning force. Following analysis, the selected pretensioning force must be examined against the results. This generally requires an iteration process by the user.

The same applies to struts.

8.19 GGU-CANTILEVER: Predeformations

When a number of excavation phases are under study, deformations from a previous phase can be implemented as lowering of supports at the new anchor points for the next phase. According to the EAB (R 11), however, such studies are not usually necessary.

In a continuous beam analysis, it is a simple matter to introduce the corresponding support displacements. In a rod framework application that does not consider anchors and struts as mere supports (see Figure 19 in "**Theoretical principles: Structural system**"), the same lowering of the support must be introduced at the anchor toe as at the anchor head, otherwise a large proportion of the resultant load would be transferred to the anchor. Thus, apart from being able to define displacement boundary conditions, the program also offers a menu item dealing with predeformations. If you wish to enter predeformations ***by hand***, or need to, this must be done as displacements under predeformations and not as displacement boundary conditions. Of course, once this is done, the program takes care of the rest. You also have the option of automatically adopting predeformations from a previous analysis.

Designing a retaining wall involves a multitude of different adjustments, making it all too easy to lose one's bearings. The program is thus designed to ask numerous questions, which, apart from controlling correct entry of data, also check plausibility, special preferences, and compatibility with the EAB. When a data entry error is recognised, a warning box appears, and analysis is put on hold. Responses to inconsistencies in respect to plausibility or special preferences always offer two options:

- accept warning and start analysis,
- accept warning and do not start analysis.

When the program draws your attention to special preferences, the dialog box is always designed so that simply pressing [**Return**] will not terminate the analysis.

The program is designed for a high degree of user interaction, with the aim of avoiding erroneous and unwanted preferences (see above). Batch processing for the background processing of several files simultaneously is incompatible with this concept. Therefore, the program does not create a single dataset when dealing with several construction phases. All phases must be dealt with in separate datasets. The only disadvantage of this is the treatment of predeformations. If you want predeformations from a previous construction phase to be automatically taken into consideration, this previous phase must already have been analysed (obviously) and be available as a dataset (on your hard disk). This dataset must be given as the dataset from which the predeformations are to be determined for the new construction phase. Since there is no re-analysis of the old phase, this dataset and the results obtained with it must be saved. If you should mistakenly select a dataset that contains no results, the program will inform you of this. Otherwise, there are no restrictions. The name of the file with the predeformations is saved with the current dataset, where it is available for future use.

8.20 GGU-CANTILEVER: Earth pressure redistribution

Classical earth pressure redistribution is not appropriate for braced or tied-back cantilever walls. Earth pressure calculated according to classical theory must be redistributed.

A large number of redistribution figures are programmed into the program. In addition, any form of redistribution figure can be created by defining any polygon. The figures available are given below:

- rectangle,
- 2 rectangles,
- triangle, maximum at top,
- triangle, maximum at centre,
- triangle, maximum at base,
- trapezoid,
- quadrilateral with maximum at anchor locations or at any point,
- user-defined redistribution figure by means of a polygon,
- all EAB redistribution figures.

8.21 GGU-CANTILEVER: Overturning stability

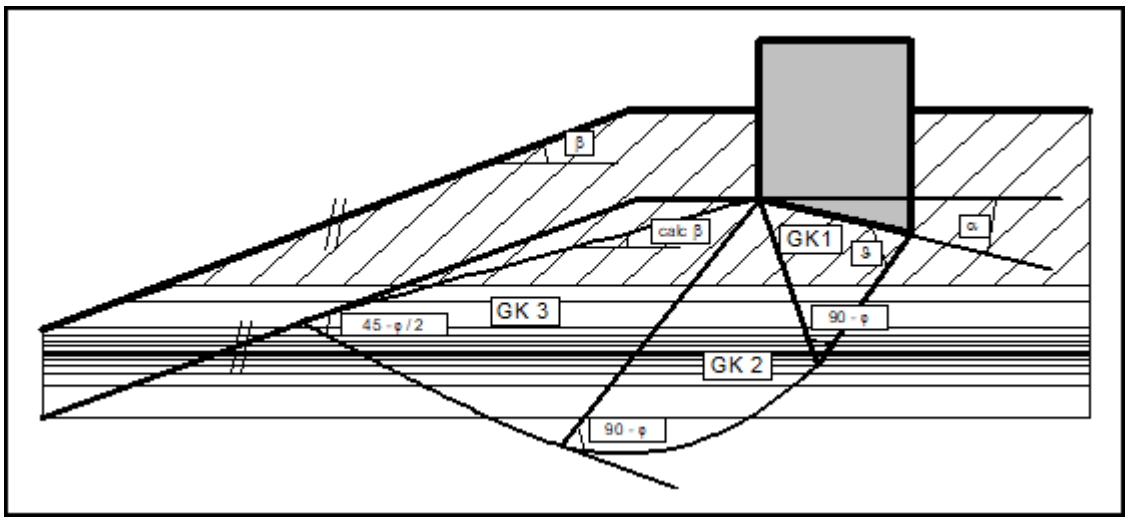
Overturning stability analysis is performed using characteristic values! The following applies:

- The resultant must remain within the 2nd kernel width under both permanent and changeable loads. Base tilt is permissible.
- The resultant must remain within the 1st kernel width under permanent loads.

8.22 GGU-CANTILEVER: Bearing capacity safety

The program analyses the bearing capacity safety to DIN 4017.

In the case of stratified subsoil, the soil parameters can be averaged above the bearing capacity failure plane in accordance with DIN 4017, which is composed of the two linear components of a logarithmic spiral. The governing parameters are summarized in the following figure:



The mean governing soil properties are determined using the following relationships:

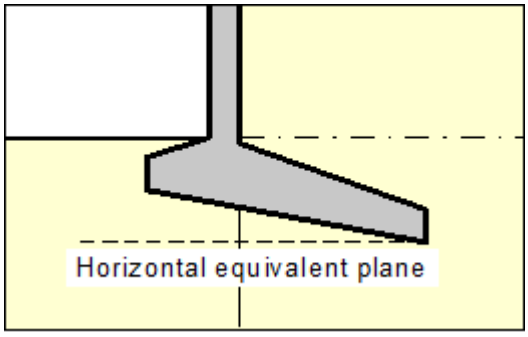
cal tan φ = Σ tan φ i · li' / Σ li
cal c= Σ ci · li' / Σ li
cal γ2 = Σ γ2i · Ai' / Σ Ai

li = length within individual layer
Ai = area of individual layer

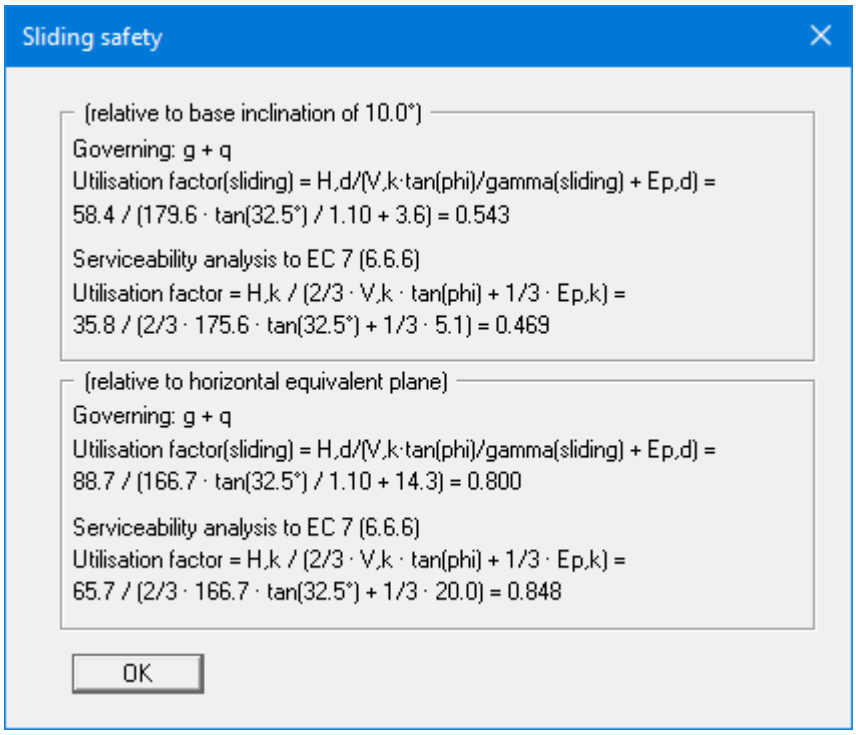
The condition for the permissibility of the mean is that the mean friction angle demonstrates a maximum deviation of 5° to the true friction angles. This condition can be checked by the program. If it is not adhered to, the program reduces the largest friction angle in stages until the condition is met.

8.23 GGU-CANTILEVER: Sliding safety

Sliding safety is computed to EC 7. In addition, the sliding safety of an equivalent horizontal plane is computed for an inclined base plane.



Sliding safety is calculated as follows in accordance with the partial safety factor concept:



8.24 GGU-CANTILEVER: General stability

General stability can be simply verified by exporting the data from this program to **GGU-STABILITY** (GGU slope stability application).

8.25 GGU-CANTILEVER: Settlements

Analysis of settlement is compliant with DIN 4019 using the relationships given in the Geotechnical Engineering Handbook (1990; Fourth Edition) (equations 8 and 14 from Section 1.7 Stress analyses). The program determines the stresses at 0.05 m intervals or at layer boundaries and numerically integrates them.

The limiting depth can be defined in three different ways:

- with a fixed, user-defined value
- as a multiple of the footing width
- as the depth at which the total vertical stress exceeds the overburden stress by x% (generally 20%)

If the base of the lowest layer is exceeded during the settlement analysis, the analysis continues using the constrained modulus of this final layer.

For settlement analyses, any preconsolidation loading in kN/m² can be subtracted from the current soil pressure. Settlement analysis will then be performed with the reduced values. The overburden pressure is also reduced by this amount when calculating the limiting depth.

8.26 Hydraulic heave

8.26.1 GGU-CANTILEVER: Hydraulic heave safety using global safety factors

The hydraulic heave safety for each layer below the excavation base is determined via a comparison of the soil weights to the flow forces at the respective layer bases.

$$\eta_N = \frac{\sum_{i=1}^{N} G'_i}{S_N}$$

- ηN = hydraulic heave safety of the layer N
- G'i = buoyant self-weight of layer i
- SN = flow force of layer N
- layer 1 (i = 1) is the uppermost layer

The minimum value of all ηN is the hydraulic heave safety of the system.

8.26.2 GGU-CANTILEVER: Utilisation factor (hydraulic heave) using partial safety factors

Using the partial safety factor concept the following must be verified:

$$S'_k \cdot \gamma_H \leq \sum_{i=1}^{N} G'^{i}_k \cdot \gamma_{g,stb}$$

- S'k = characteristic flow force on the percolated soil mass
- γH = partial factor for the flow force in favourable or unfavourable subsoil in the HYD (EC 7) limit state
- G'k = characteristic dead load of the buoyant percolated soil mass
- γg,stb = partial factor for stabilising permanent actions in the HYD (EC 7) limit state
- Layer 1 (i = 1) is the uppermost layer

The so-called utilisation factor μ can also be calculated from this relationship.

$$\mu_N = \frac{S'_k \cdot \gamma_H}{\sum_{i=1}^{N} G'^{i}_k \cdot \gamma_{g,stb}}$$

- μN = utilisation factor of layer N

Utilisation factors ≤ 1.0 mean that sufficient safety is given.

8.27 Buoyancy

8.27.1 GGU-CANTILEVER: Buoyancy safety using global safety factors

The buoyancy safety for each soil layer within the excavation is determined via a comparison of the soil weights to the water pressures at the respective layer bases. The self-weights of site plant and structures, frictional forces etc. are not included.

$$\eta_N = \frac{\sum_{i=1}^{N} G_i}{P_N}$$

- ηN = buoyancy safety of layer N
- Gi = self-weight of layer i
- PN = water pressure at base of layer N
- layer 1 (i = 1) is the uppermost layer

The minimum value of all ηN is the buoyancy safety of the system.

If the same permeability has been defined for the whole system, safety against buoyancy is not determined. In certain cases, for example, when permeability on the passive side is much greater than on the active side, the calculation of safety factors for hydraulic uplift is meaningless. If, in such, or similar cases, the message "**Buoyancy safety could not be demonstrated**" appears, you can either ignore it or set the safety against buoyancy to 1.0, which suppresses the message.

8.27.2 GGU-CANTILEVER: Utilisation factor (buoyancy) using partial safety factors

Using the partial safety factor concept the following must be verified:

$$A_k \cdot \gamma_{g,dst} \leq \sum_{i=1}^{N} G_{k,stb}^{i} \cdot \gamma_{g,stb}$$

- Ak = the characteristic hydrostatic buoyant force acting on the lower surface of the complete structure, the soil layer in question or the excavation structure

- γg,dst = partial factor for destabilising permanent actions in the UPL (EC 7) limit state
- Gk,stb = lower characteristic value of stabilising permanent actions
- γg,stb = partial factor for stabilising permanent actions in the UPL (EC 7) limit state
- layer 1 (i = 1) is the uppermost layer

The so-called utilisation factor μ can also be calculated from this relationship.

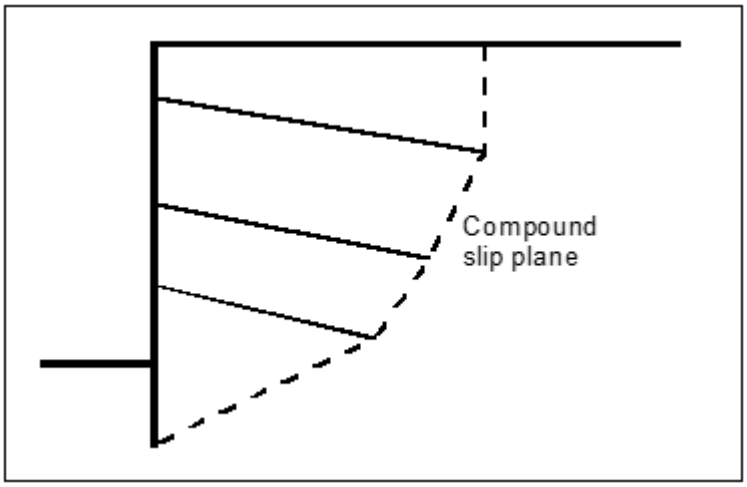
$$\mu_N = \frac{A_k \cdot \gamma_{g,dst}}{\sum_{i=1}^{N} G_{k,stb}^{i} \cdot \gamma_{g,stb}}$$

- μN = utilisation factor of layer N

Utilisation factors ≤ 1.0 mean that sufficient safety is given.

8.28 GGU-CANTILEVER: Verification of deep-seated stability

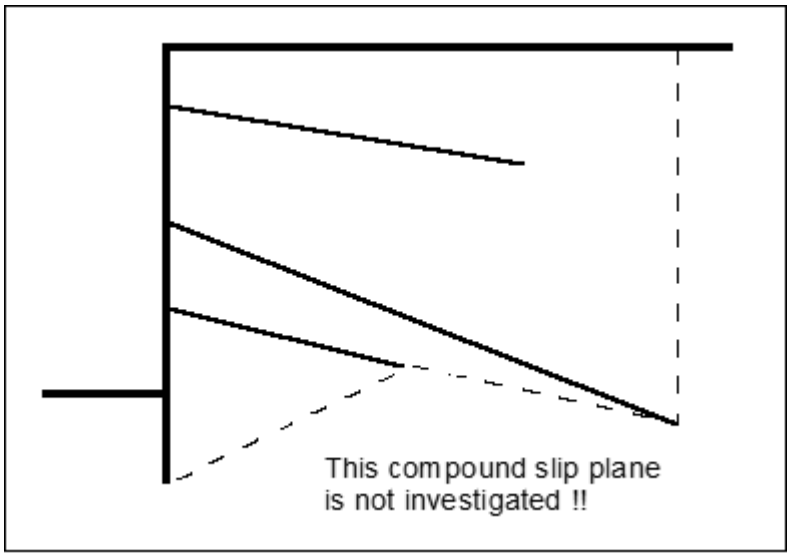
Verification of deep-seated stability is required for anchored cantilever walls. This primarily serves to determine the necessary anchor lengths. Verification uses the method described by Ranke/Ostermayer (*Bautechnik* 1968 (Construction Engineering), Issue 10). When ***verifying deep-seated stability*** each anchor is first investigated (including the influence of the remaining anchors on the slip plane). Compound slip planes, which are determined by connecting the end points of the anchors involved, are then analysed.



All possible combinations are analysed. For example, when there are four anchors:

- Slip plane passes through anchor end points:
  1,2 and 1,3 and 1,4 and 1,2,3 and 1,2,4 and 1,3,4 and 1,2,3,4 and
  2,3 and 2,4 and 2,3,4 and 3,4

The only condition is that the next anchor end point is always to the right of and above the preceding one.



These slip planes are not critical. The most unfavourable slip plane associated with each anchor is displayed on the screen with the corresponding safety factor. A safety factor of 1.5 is generally required when adopting ***global safety factors***. If this safety factor cannot be achieved or is exceeded heavily, the program can optimise individual anchor lengths.

Using ***partial safety factors***, the possible anchor force is acquired in complete analogy to global safety factors, but is divided by the passive earth pressure partial safety factor. The deep-seated stability is is given if one of the following equations applies.

Aposs,k is determined from the force polygon with permanent loads only:
$$A_{g,k} \cdot \gamma_g \leq A_{poss,k} / \gamma_{Ep}$$

Aposs,k is determined from the force polygon with permanent and changeable loads:
$$A_{g,k} \cdot \gamma_g + A_{q,k} \cdot \gamma_q \leq A_{poss,k} / \gamma_{Ep}$$

Where:

- Ag,k = characteristic anchor force from permanent loads
- Aq,k = characteristic anchor force from changeable loads

Here, too, optimisation regarding a utilisation factor of 1.0 is possible.

8.29 GGU-CANTILEVER: Heave of anchor soil

Verification of heave of anchor soil is performed like the method described in Section 7.3.4 of the Piling Handbook 1977 (Spundwand-Handbuch 1977).

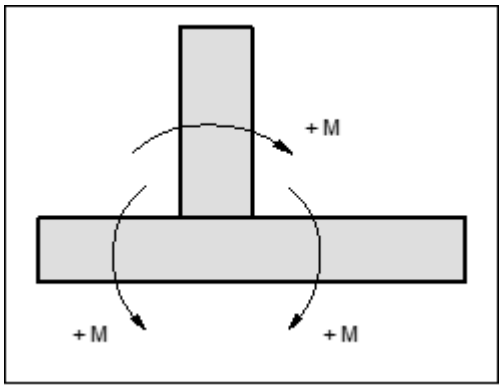
8.30 GGU-CANTILEVER: Reinforced concrete design

Reinforced concrete is designed to EC 2 or, alternatively, to DIN 1045 (old) depending on the selected safety factor concept. Reinforcement is calculated for all wall element sections (see "**Theoretical principles: Structural system**"). The output is the section with the largest reinforcement.

The stem area above the footing is designed using the wall internal forces (see "**Theoretical principles: Cantilever wall-Determination of wall loads for reinforced concrete design**").

The internal forces M and Q at the stem base/toe and heel intersections are calculated from the soil pressure and any surcharge present. The model concept is a cantilever. The normal force N results from the passive earth pressure.

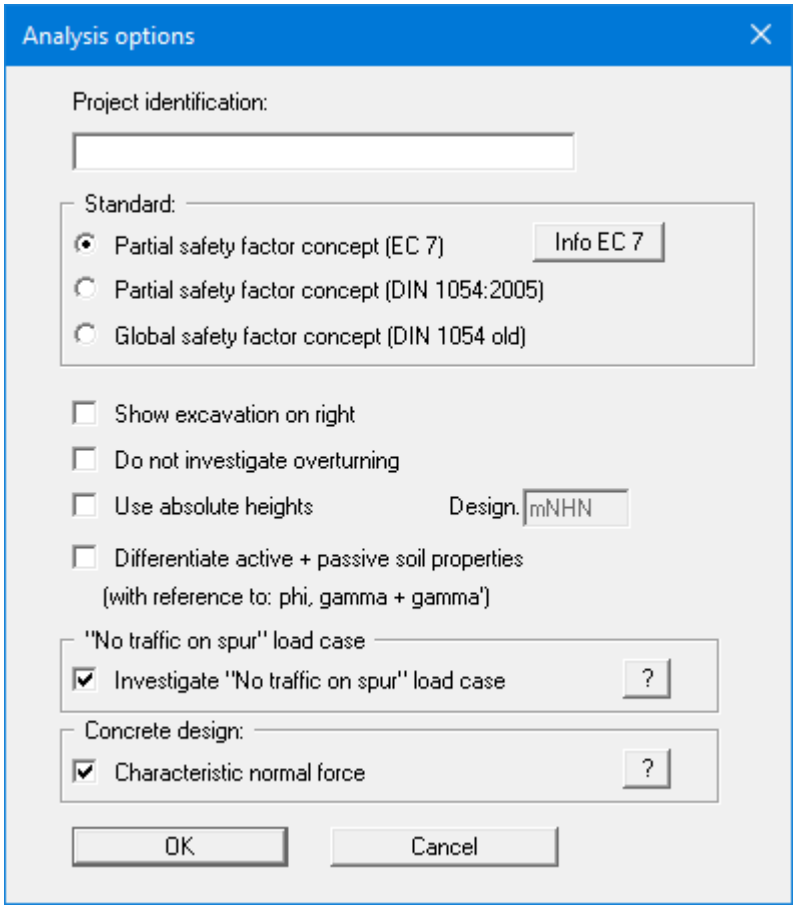
The following sign rule applies to the spur and wall moments with reinforcement:



9 File menu

9.1 GGU-CANTILEVER: "New" menu item

You can enter a new system using this menu item. You will see the following dialog box:



You can enter a dataset description ("**Project identification**") of the problem going to process, which will then be used in the ***General Legend*** (see menu item "**Graphics preferences/General legend**"). This can be particularly useful when you are working with the menu item "**Editor 2/Predeformation preferences**". Using these program functions previously saved datasets are appended to the current dataset. The existing project identifications are also shown in the appropriate dialog boxes to aid file characterisation.

In the first group box you decide which safety concept to use for your analysis and design. Activate the standard required with the corresponding command button. Additionally, excavation visualisation to the right can be activated.

DIN 1054:2005 states that an overturning analysis may be dispensed with for Load Case 3 if sufficient bearing capacity has been demonstrated. This rule is no longer included in Eurocode 7; it is therefore always necessary to perform an overturning analysis. In justified exceptional cases, however, the analysis may be turned off using the "**Do not investigate overturning**" check box.

If you select the "**Use absolute heights**" check box, you can enter all depths and heights in **mAD** (heights are positive upwards). If this check box is not selected, the top of the wall is assumed to have a height of **0.0** and all further entries, depth of soil layers, for example, are positive downwards.

If your system uses differing soil properties on the active and the passive sides, activate the "**Differentiate active + passive soil properties**" check box in the above dialog box. You will then be presented with different input columns for entering the active and passive friction angle and unit weight soil properties in the "**Editor 1/Soils**" menu item. For better visualisation you can define the soil colours on the active and the passive sides differently using the ***Soil properties legend*** (see menu item "**Graphics preferences/Soil properties legend**").

If the normal force is a compressive force, concrete design is not conservative if the design value of the normal force is adopted. Design will adopt the characteristic normal force if the corresponding check box in the "**Concrete design:**" group box is activated.

If the safety concept has been altered using the "**File/New**" dialog box, the dialog box for specifying either the safety factors or the partial factors always opens after leaving the dialog box by clicking "**OK**". These dialog boxes can also be accessed via the menu items "**Editor 1/ Verifications/Safety factors**" or "**Editor 1/Verifications/Partial factors**". Verifications and safety factors can be modified at any time using the above menu items.

9.2 GGU-CANTILEVER: "Load" menu item

You can load a file with system data, which was created and saved at a previous sitting, and then edit the system.

9.3 GGU-CANTILEVER: "Save" menu item

You can save data entered or edited during program use to a file, to have them available later, or to archive them. The data is saved without prompting with the name of the current file. The file contains all system information. Loading again later creates the same visualisation as was present at the time of saving.

9.4 GGU-CANTILEVER: "Save as" menu item

You can save data entered during program use to an existing file or to a new file, i.e. using a new file name. For reasons of clarity, it makes sense to use "**.ggu_wst**" as file suffix, as this is the suffix used in the file requester box for the menu item "**File/Load**". If you choose not to enter an extension when saving, "**.ggu_wst**" will be used automatically.

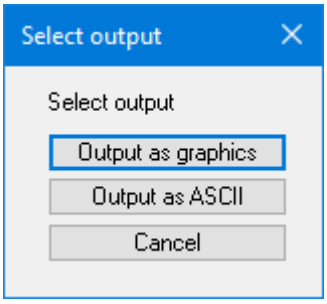
If the current system has been analysed at the time of saving, the analysis results are saved in the file. This is especially necessary if you want to use the results in this file for predeformations on other systems (see menu item “**Editor 2/Predeformation info**”). If your current system represents an intermediate construction stage, it may be expedient to enter a further description of the file in "**Project identification**", in the "**File/New**" or "**Editor 1/Analysis options**" dialog box.

9.5 "Print output table" menu item

9.5.1 GGU-CANTILEVER: Selecting the output format (Print output table)

You can have a table printed containing the current analysis results. The results can be sent to the printer or to a file (e.g. for further editing in a word processor). The output contains all information on the current state of analysis, including the system data.

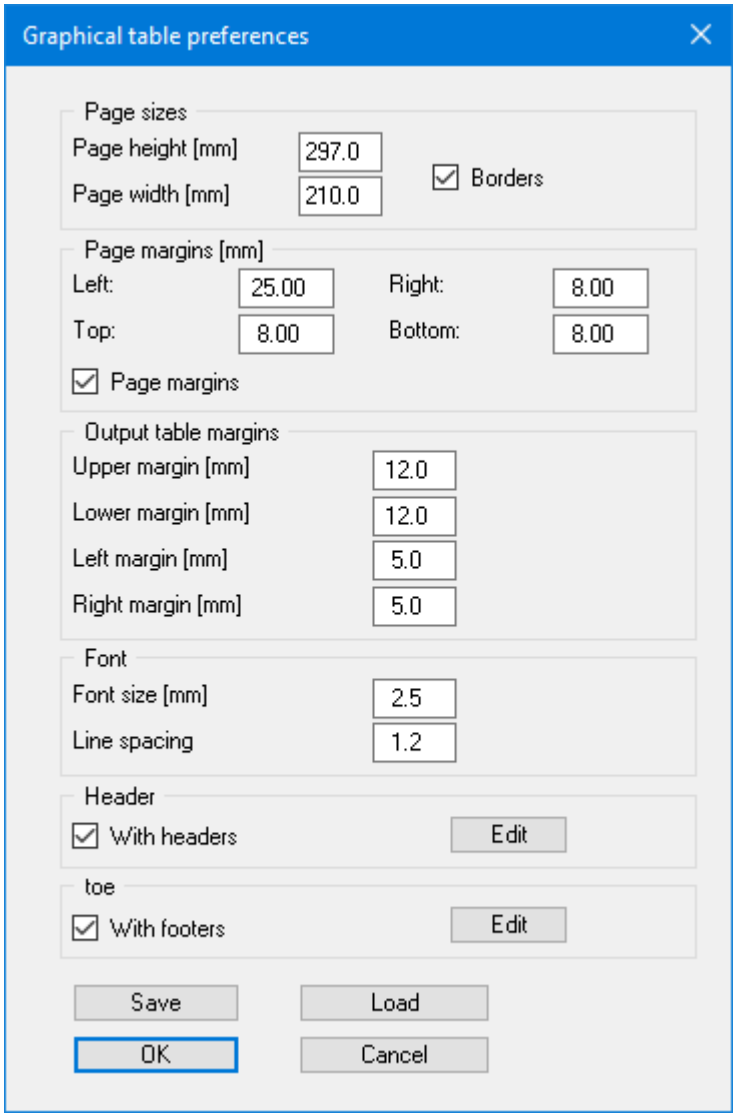
You have the option of designing and printing the output table as an annex to your report within the GGU program. To do this, select "**Output as graphics**" from the following options.



If you prefer to easily print or process the data in a different application, you can send them directly to the printer or save them to a file using the "**Output as ASCII**" button.

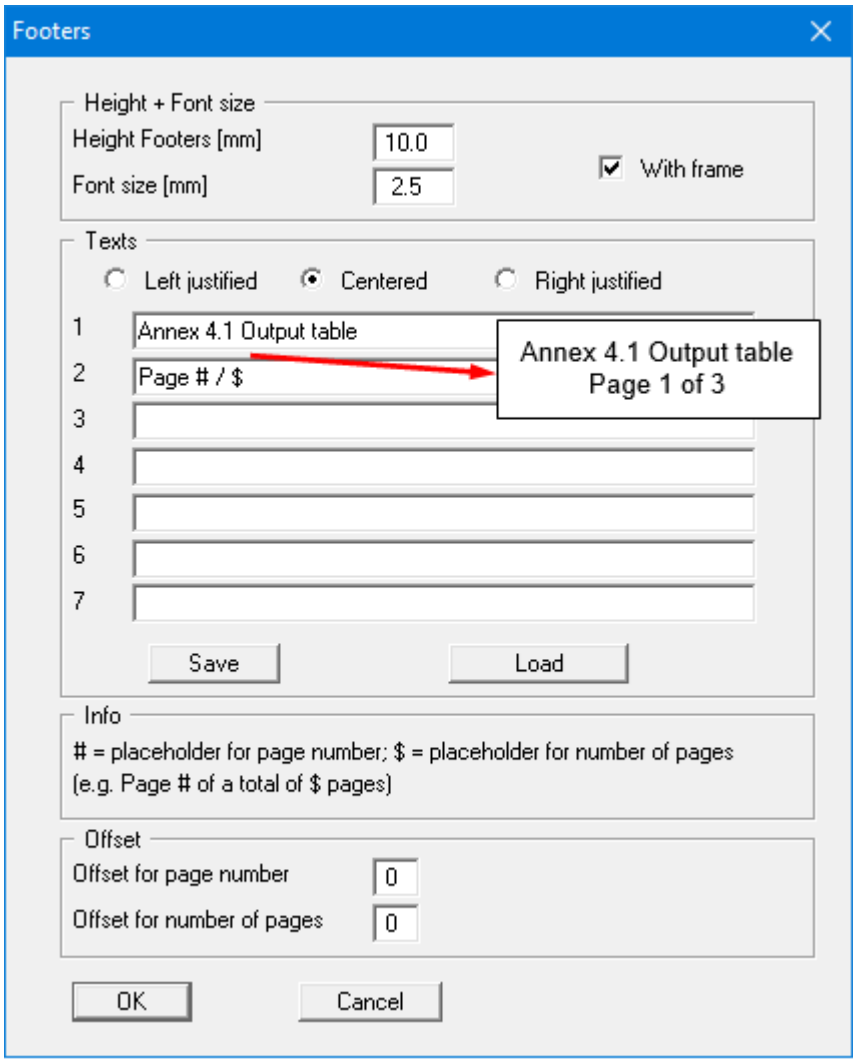
9.5.2 GGU-CANTILEVER: "Output as graphics" button (Print output table)

If you selected the "**Output as graphics**" button in the previous dialog box a further dialog box opens, in which you can define further preferences for result visualisation.

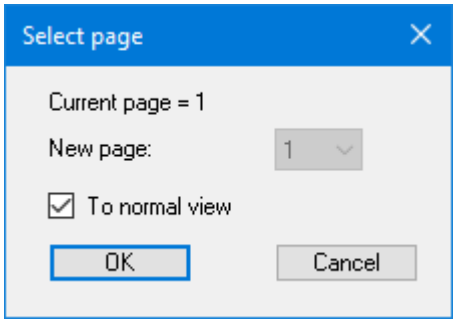


In the various group boxes of the dialog box, you can define preferences for the table output and layout. In some GGU programs a sketch of the system is integrated in the output table by activating an additional "**Incorporate graphics**" button.

If you need to add a header or footer (e.g. for page numbering), activate the appropriate check boxes "**With headers**" and/or "**With footers**" and click on the "**Edit**" button. You can then edit as required in a further dialog box. You can save your settings for the graphical output table presentation in a "**Protokoll.pin_ggu**" file at the program level so that they are loaded when the program starts. Using the "**Load**" button, the output table settings can also be subsequently loaded into an existing file, including that of another GGU program.

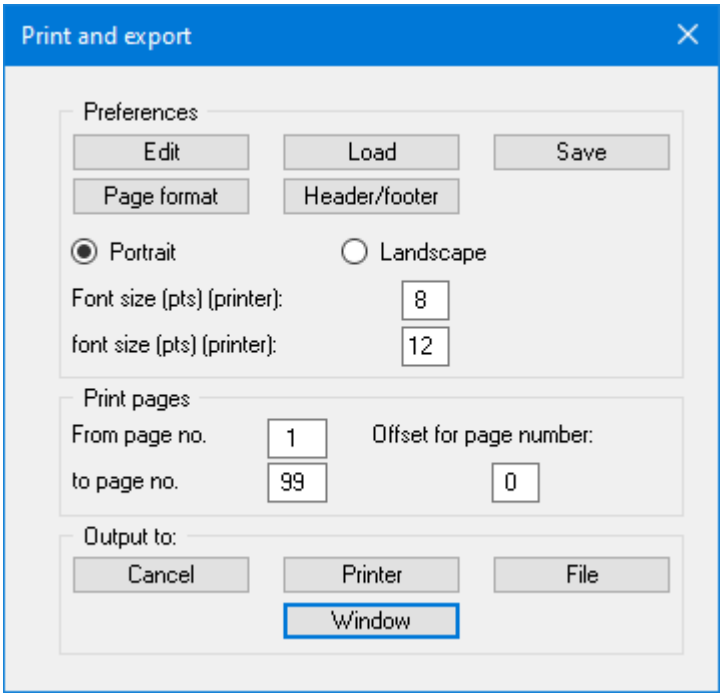


Automatic pagination can also be employed here if you work with the placeholders as described. After exiting the dialog boxes using "**OK**" you will see a further dialog box in which you can select the parameters to be used in the output table. After confirmation, the dialog box the output table is presented on the screen page by page. To navigate between the pages, use the arrow tools in the toolbar. If you need to jump to a certain page or back to the graphical visualisation, click on the tool. You will then see the following box:



9.5.3 GGU-CANTILEVER: "Output as ASCII" button (Print output table)

You can have your analysis data sent to the printer, without further work on the layout, or save it to a file for further processing using a different program, e.g. a word processing application.



In the dialog box you can define output preferences.

- "**Output preferences**" group box
  Using the "**Edit**" button the current output preferences can be changed or a different printer selected. Using the "**Save**" button, all preferences from this dialog box can be saved to a file in order to have them available for a later session. If you select the program name with the extension "**.drk**" as the file name and save this file at program level (default setting), this file will be loaded automatically the next time the program is started.
  Using the "**Page format**" button you can define, amongst other things, the size of the left margin and the number of lines per page. The "**Header/footer**" button allows you to enter a header and footer text for each page. If the "#" symbol appears within the text, the current page number will be entered during printing (e.g. "***Page*** #"). The text size is given in "**Pts**". You can also change between "**Portrait**" and "**Landscape**" formats.
- "**Print pages**" group box
  If you do not wish pagination to begin with **1** you can add an offset number to the check box. This offset will be added to the current page number. The output range is defined using "**From page no.**" "**to page no.**".

- "**Output to:**" group box
  Start output by clicking on "**Printer**" or "**File**". The file name can then be selected from or entered into the box. If you select the "**Window**" button the results are sent to a separate window. Further text editing options are available in this window, as well as loading, saving and printing.

9.6 GGU-CANTILEVER: "Export to GGU-STABILITY" menu item

The general stability can be simply verified by exporting the data to **GGU-STABILITY** (GGU slope stability application).

After clicking this menu item an appropriate file ("**.boe**") can be generated with the required **GGU-STABILITY** version status.

In addition, the wall can be exported as structural element.

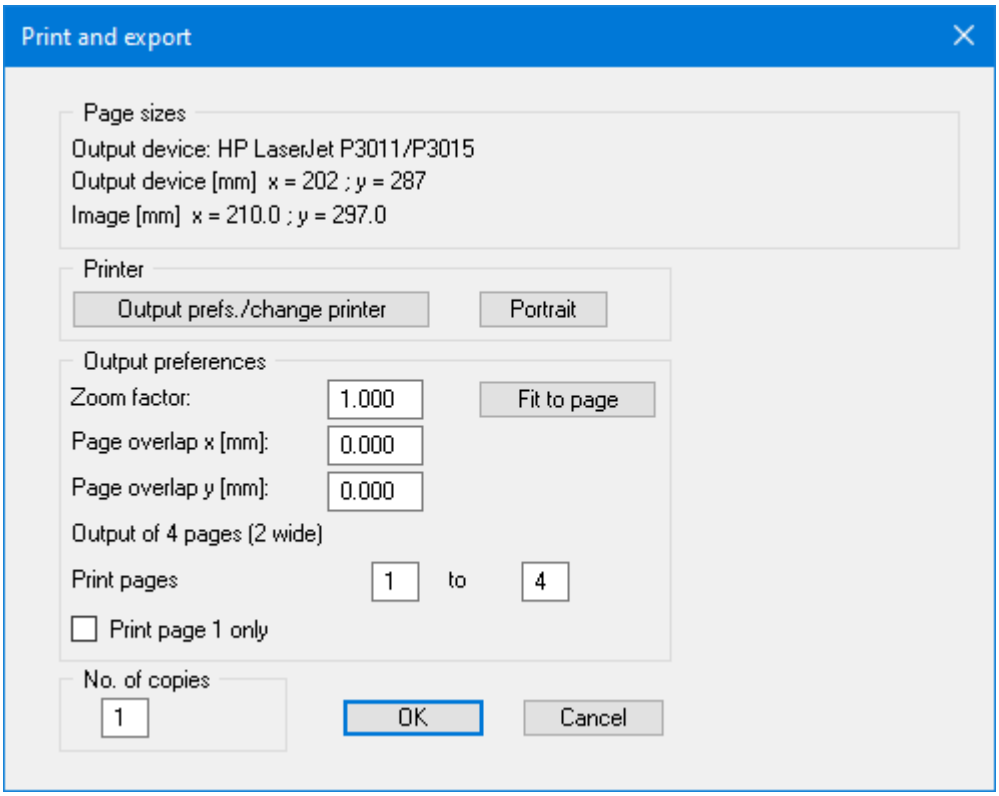
9.7 GGU-CANTILEVER: "Output preferences" menu item

You can edit output preferences (e.g. swap between portrait and landscape) or change the printer in accordance with WINDOWS conventions.

9.8 GGU-CANTILEVER: "Print and export" menu item

You can select your output format in a dialog box. You have the following possibilities:

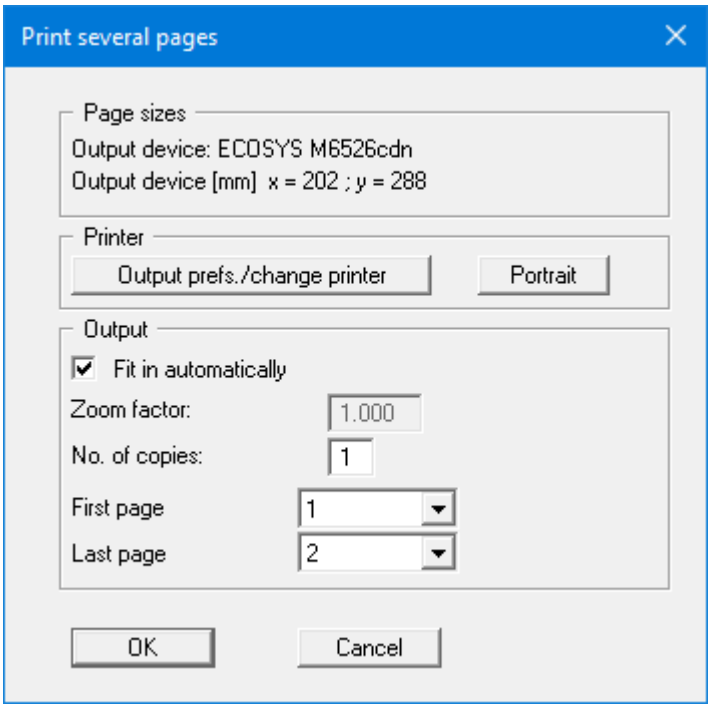
- "**Printer**"
  allows graphic output of the current screen contents (***graphical representation***) to the WINDOWS standard printer or to any other printer selected using the menu item "**File/Output preferences**". But you may also select a different printer in the following dialog box by pressing the "**Output prefs./change printer**" button.



In the upper group box, the maximum dimensions which the printer can accept are given. Below this, the dimensions of the image to be printed are given. If the image is larger than the output format of the printer, the image will be printed to several pages (in the above example, 4). To facilitate better re-connection of the images, the possibility of entering an overlap for each page, in x and y direction, is given.

Alternatively, you also have the possibility of selecting a smaller zoom factor, ensuring output to one page ("**Fit to page**" button). Following this, you can enlarge to the original format on a copying machine, to ensure true scaling. You can also print only the 1st page with zoom factor = 1.0, in which case the bottom left-hand area is printed. Furthermore, you may enter the number of copies to be printed.

If you have activated the ***table representation*** on the screen, you will see a different dialog box for output by means of the "**File/Print and export**" menu item button "**Printer**".



You can select the pages of the report to be printed here. To obtain an output with a zoom factor of **1** (button "**Fit in automatically**" is deactivated), you must reduce the page format of your report page so that it lies within the printable area of the output device. To do this, use the dialog box in "**File/Print output table**" button "**Output as graphics**".

In some programs, you can transfer a representation of the system graphic to the output table if you activate the "**Print main graphic**" check box available there.

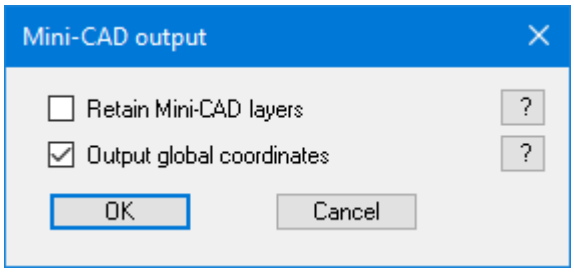
- "**DXF file**"
  allows output of the graphics to a DXF file. DXF is a common file format for transferring graphics between a variety of applications.
- "**GGU-CAD file**"
  allows output of the graphics to a file, in order to enable further processing with the **GGU-CAD** program. Compared to output as a DXF file this has the advantage that no loss of colour quality occurs during export.
- "**Clipboard**"
  The graphics are copied to the WINDOWS clipboard. From there, they can be imported into other WINDOWS programs for further processing, e.g. into a word processor. In order to import into any other WINDOWS program, you must generally use the "*Edit/Paste*" function of the respective application.
- "**Metafile**"
  allows output of the graphics to a file in order to be further processed with third party software. Output is in the standardised EMF format (Enhanced Metafile format). Use of the Metafile format guarantees the best possible quality when transferring graphics.

If you select the "**Copy/print area**" tool

from the toolbar, you can copy parts of the graphics to the clipboard or save them to an EMF file. Alternatively you can send the marked area directly to your printer (see "**Tips and tricks**").

Using the "**Mini-CAD**" program module you can also import EMF files generated using other GGU applications into your graphics (see menu item "**Graphics preferences/Mini-CAD**").

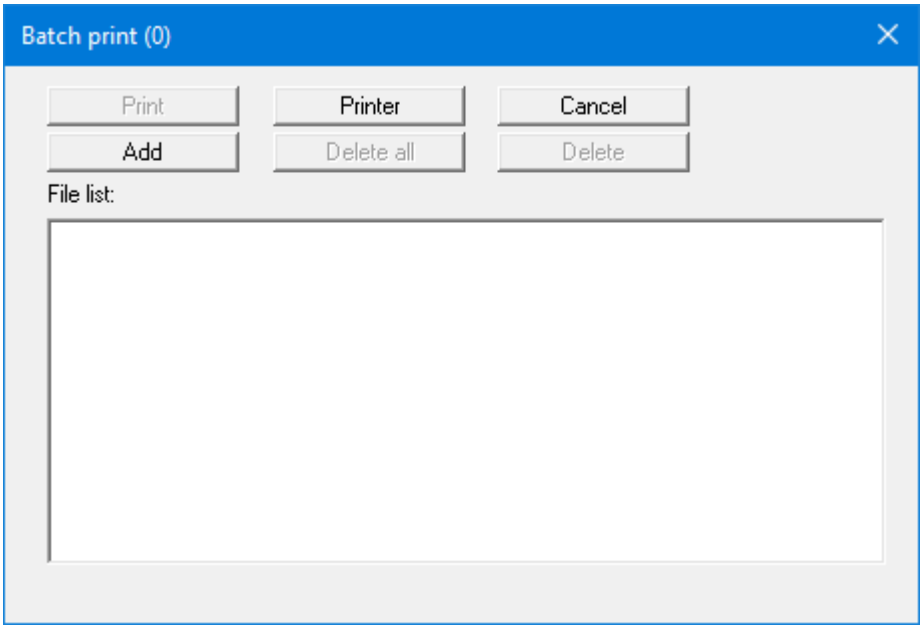
- "**Mini-CAD**"
  allows export of the graphics to a file to enable importing to different GGU applications with the **Mini-CAD** module.



If the "**Retain Mini-CAD layers**" check box is activated, the layer allocations for any existing **Mini-CAD** elements are saved. Otherwise, all **Mini-CAD** elements are saved on Layer 1 and are also inserted into Layer 1 in other GGU programs via the "**Load**" function in the **Mini-CAD** pop-up menu.
By activating the "**Output global coordinates**" check box, the present graphics are saved in the system coordinates [m]. Otherwise, they are saved in the page coordinates [mm]. If you import the **Mini-CAD** file saved using "**Global coordinates**" into a different GGU program, the coordinates are also transferred. After importing the file and pressing the [**F9**] function key (menu item "**Page size + margins/Auto-resize**") the system coordinates and the scale are corrected according to the transferred world coordinates. - "**GGUMiniCAD**"
allows export of the graphics to a file in order to enable processing in the **GGUMiniCAD** program. - "**Cancel**"
Printing is cancelled.

9.9 GGU-CANTILEVER: "Batch print" menu item

If you would like to print several appendices at once, select this menu item. You will see the following dialog box:



Create a list of files for printing using "**Add**" and selecting the desired files. The number of files is displayed in the dialog box header. Using "**Delete**" you can mark and delete selected individual files from the list. After selecting the "**Delete all**" button, you can compile a new list. Selection of the desired printer and printer preferences is achieved by pressing the "**Printer**" button.

You then start printing by using the "**Print**" button. In the dialog box which then appears you can select further preferences for printer output such as, e.g., the number of copies. These preferences will be applied to all files in the list.

9.10 GGU-CANTILEVER: "Exit" menu item

After a confirmation prompt, you can quit the program.

9.11 GGU-CANTILEVER: "1, 2, 3, ..." menu items

If you have not stored a working directory for the program icon, the program jumps to the program directory after starting to load or save a file.

Under the menu items of the File menu, the most recently edited files are listed with the respective storage path ("**1, 2, 3, ...**"). Selecting one of these files loads the selected file. The next time the "**File/Load**" or "**File/Save**" menu items are called up in the same program session, the program automatically jumps to the directory of the last file loaded.

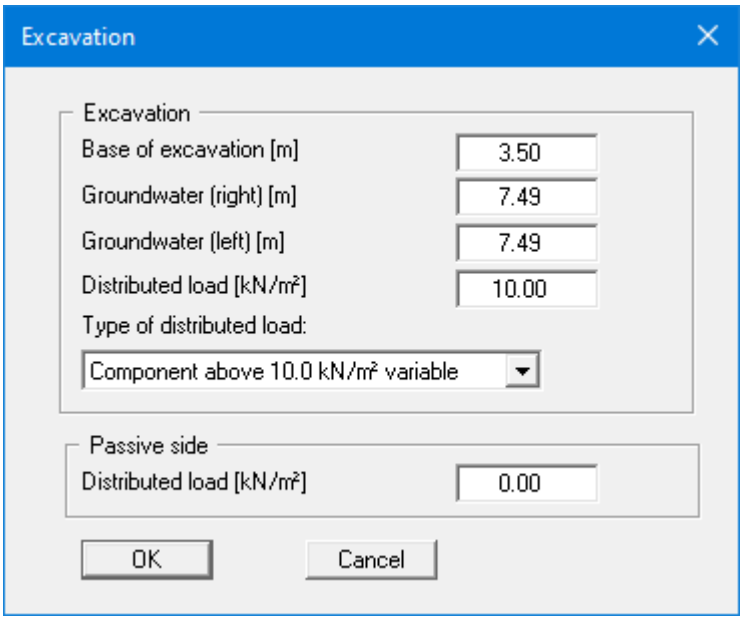
10 Editor 1 menu

10.1 GGU-CANTILEVER: "Analysis options" menu item

Using this menu item, you can edit the default preferences of the current system. The dialog box corresponds to the box in the menu item "**File/New**" (see descriptions there).

10.2 GGU-CANTILEVER: "Excavation" menu item

A dialog box opens for defining the excavation:



In the upper group box, enter the depth of the excavation base and the groundwater levels. If you checked the "**Use absolute heights**" box when defining the system, an additional entry, "**Top of wall**", appears in the dialog box for specifying the absolute position. In this case, all heights are measured in m AD or m site zero, i.e. the y-axis is positive upwards. You can then enter a value, for example, of 86.42 [m AD] in the "**Top of wall**" field. All additional data must be relative to this value, i.e. the corresponding [m AD] data must be entered.

If the height of a previously defined system is subsequently set to absolute heights, a query follows after leaving the dialog box above asking for confirmation of whether soil strata and defined elements such as anchors, for example, should be adapted to the new wall. Adaptation would mean that the depth of a soil layer entered as a positive value would be converted from, for example, 7.5 m to an absolute height of -7.5 m AD. If then, you only convert your system to [m AD], do not select any elements in the query box and press the "**OK**" button.

Moreover, a distributed load can be defined. Using the ***global safety factors***, you will see here the "**Distributed load as live load**" check box. This is only of interest for verification of deep-seated stability. If the distributed load is defined as a live load, this load will only be adopted for verification of deep-seated stability if it acts excitingly. Additionally, you can define a distributed load on the passive side.

If you are working with the ***partial safety factors***, decide whether the distributed load is "**Permanent**", "**Changeable**" or the "**Component above 10.0 kN/m² changeable**" (see the dialog box above). "**Component above 10.0 kN/m² changeable**" means, for example, that for an input of 13.5 kN/m², 10 kN/m² are adopted as permanent and 3.5 kN/m² as changeable in the analysis.

10.3 GGU-CANTILEVER: "Wall (general)" menu item

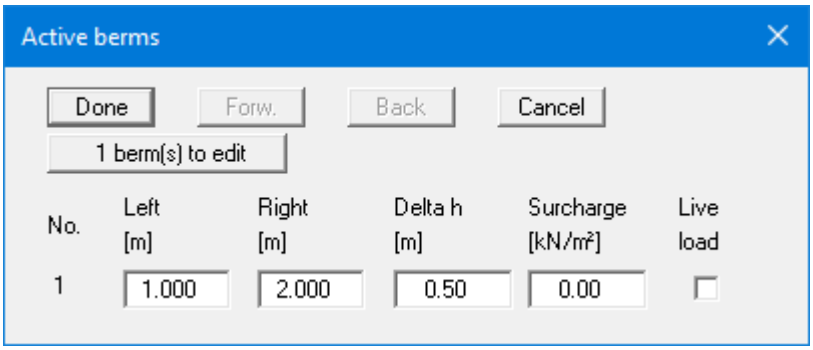
Enter the loads acting on the cantilever wall and the length of the cantilever wall. A more detailed description can be found in "**First steps using a worked example: Step 3**",

10.4 GGU-CANTILEVER: "Wall (geometry)" menu item

Enter the geometry of the cantilever wall. A more detailed description can be found in "**First steps using a worked example: Step 4**".

10.5 GGU-CANTILEVER: "Berms (active side)" menu item

You can define a maximum of ten berms on the active side.



Enter the x-ordinates of the toe and head of the berm. With "**delta h**" you define the height of the berm; whereby negative values are also permitted. Finally, a "**Surcharge**" on the horizontal surface behind the head of the berm can be entered.

If more than one berm is present in the system, click "**x berm(s) to edit**" and enter the number of berms.

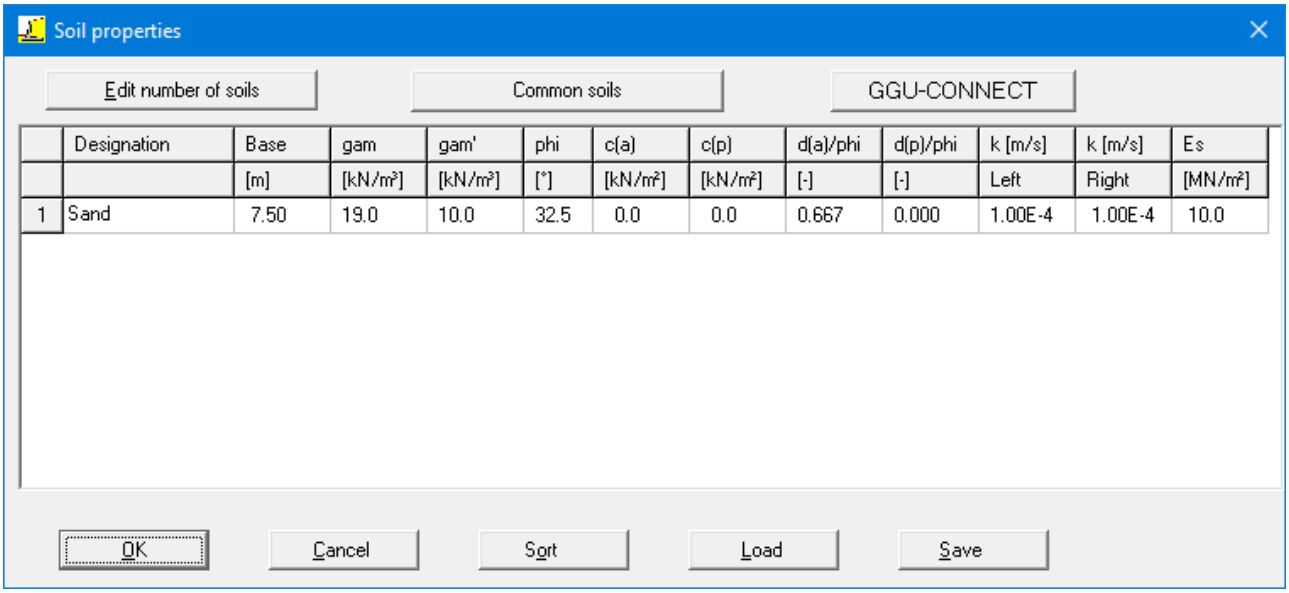
Berms may not overlap. The program checks that this condition is adhered to and warns of any errors.

10.6 GGU-CANTILEVER: "Berms (passive side)" menu item

Berms on the passive side are defined in the same manner as for the active side.

10.7 GGU-CANTILEVER: "Soils" menu item

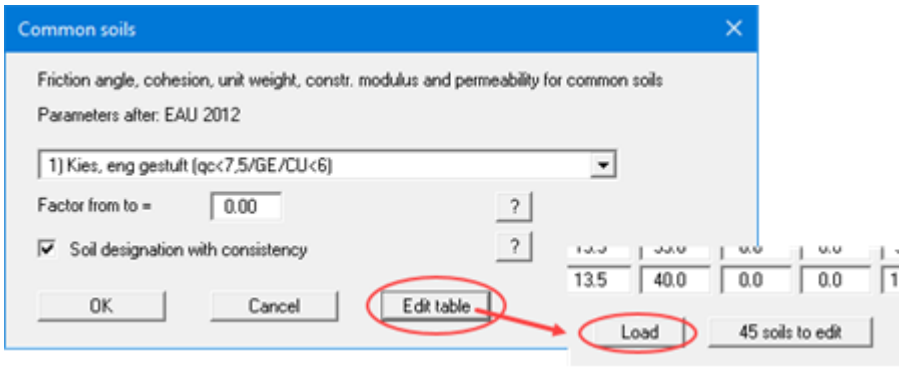
You can define the soil properties in the following dialog box:



If you would like to edit the number of soils, select the "**Edit number of soils**" or "**x soils to edit**" button and then enter the new number of soils. Using the "**Sort**" button, you can have the soils sorted according to depth. This sorting will be carried out automatically when leaving the dialog box, without the function being explicitly called-up. Erroneous input is thus impossible from the outset.

If several soils have been entered, and you would like to delete a soil which is not at the end of the list, you can assign this soil a large depth (e.g. 99.0). Then select the "**Sort**" button. The soil will now be at the end of the table and can be ***deleted*** by reducing the number of soils.

Using the "**Common soils**" button, you can easily select the soil properties of many common soils from a database or determine intermediate values.



In the dialog box, which you open by pressing the "**Common soils**" button, open the "**Soils_*english*.gng_ggu**" file when first starting the program in English ("**Edit table**"/"**Load**" buttons). Then save the data set in the "**Soils.gng_ggu**" file on the program level to open your modified database file when the program starts. You can also enter your own data ("**Edit table**"/"**x soils to edit**" button) and save it in the "**Soils.gng_ggu**" file. You can also use your adapted file in other GGU programs by means of the "**Common soils**" function if you copy the file into the appropriate GGU program folder.

All project data can be entered and managed in the **GGU-CONNECT** program. If you have already stored your drilling data as a soil strata model in your project, you can load the soil strata and properties as an xml file using the "**GGU-CONNECT**" button in the above dialog box. A brief overview of the procedure in **GGU-CONNECT** for exporting the data to the GGU analysis programs can be found here:
GGU-CONNECT - Export contents for GGU analysis programs

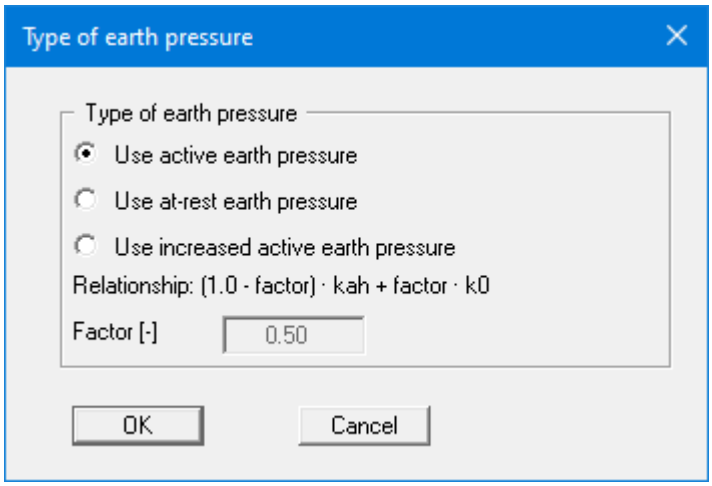
Layer depths are always with reference to the top of the wall, or are absolute heights (m AD), if this was selected in the initial dialog box of the "**File/New**" menu item.

If you have activated the "**Differentiate active + passive soil properties**" check box in the dialog box under "**File/New**" or "**Editor 1/Analysis options**", you can enter different weights and friction angles for the active and passive sides.

It is only necessary to enter permeabilities if hydrostatic pressures must be considered, and any hydraulic gradients, using flow conduits (see "**Theoretical principles: Water pressure - Approach using flow conduits**").

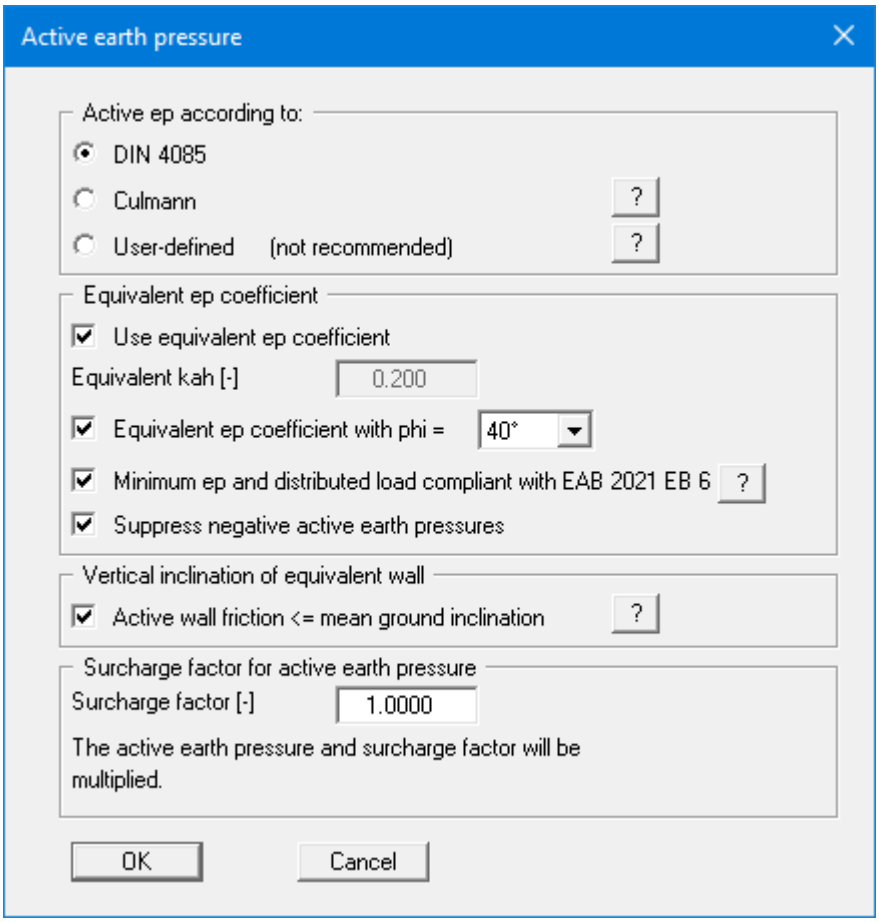
10.8 GGU-CANTILEVER: "Type of earth pressure" menu item

In this dialog box you define the type of earth pressure on which the analysis is to be based.



10.9 GGU-CANTILEVER: "Active earth pressure" menu item

You can specify active earth pressure preferences using this dialog box:



In the upper group box you specify the type of active earth pressure calculation. If the "**Culmann**" check box is activated the active earth pressure is calculated after Culmann using a slice method with straight slip surfaces.

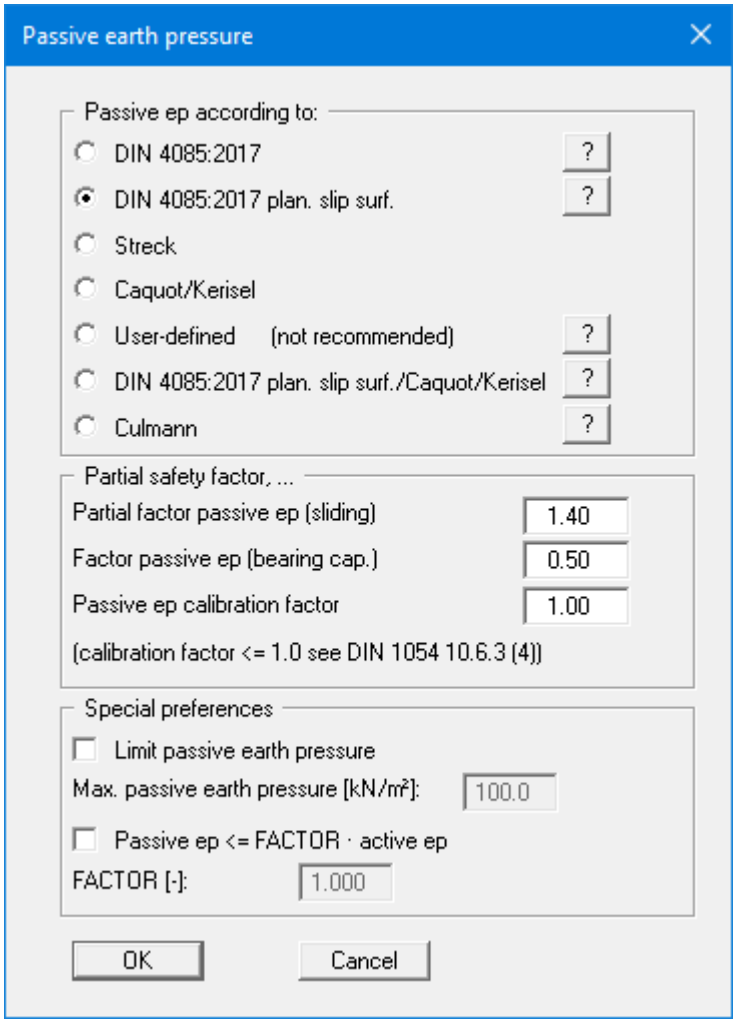
The "**Use equivalent ep coefficient**" check box should only be deactivated in exceptional circumstances (see EAB R 4). The equivalent earth pressure coefficient can only be smaller than 0.2 in special circumstances (see EAB R 4). It only makes sense to deactivate this check box when re-examining existing analyses (for instance, all the examples used in the Piling Handbook). Alternatively, the equivalent earth pressure coefficient can be defined by means of a friction angle phi = 40° or 45°. This procedure also takes the defined wall friction angle into consideration.

DIN 4085 states that for a vertical equivalent wall the active wall friction angle must equal the mean ground inclination. If the check box "**Active wall friction <= mean ground inclination**" is activated, the data entered in "**Editor 1/Soils**" are adopted.

A number of applications on the market also provide the option of a general increase in active earth pressure apart from certain forms or earth pressure redistribution. To be able to check calculations performed with such an application, **GGU-CANTILEVER** also offers this possibility.

10.10 GGU-CANTILEVER: "Passive earth pressure" menu item

You can specify passive earth pressure preferences using this dialog box:

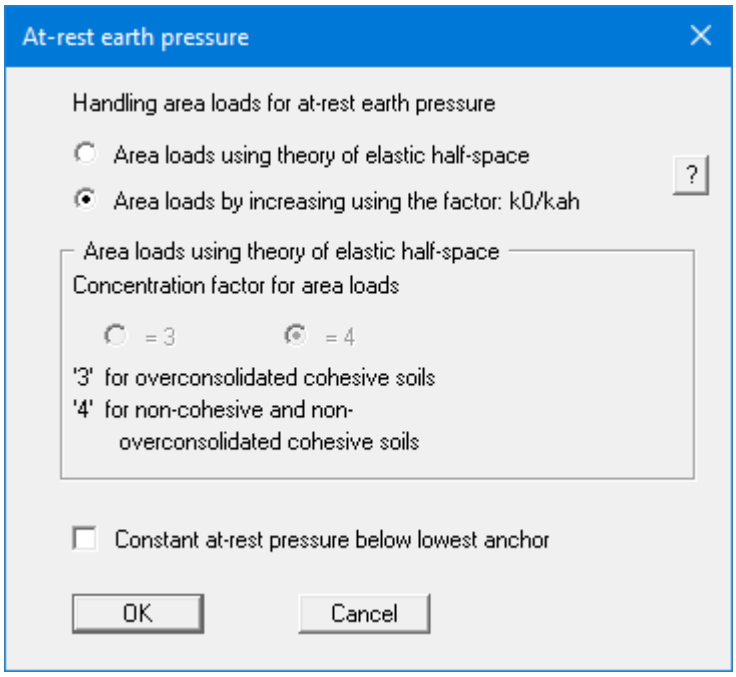


In the upper group box you specify the type of passive earth pressure calculation. If the "**Culmann**" check box is activated the passive earth pressure is calculated after Culmann using a slice method with straight slip surfaces.

10.11 GGU-CANTILEVER: "At-rest earth pressure" menu item

Using the at-rest earth pressure function, the area loads are calculated by increasing by the factor k0/kah in compliance with DIN 4085 Section 6.4.3.

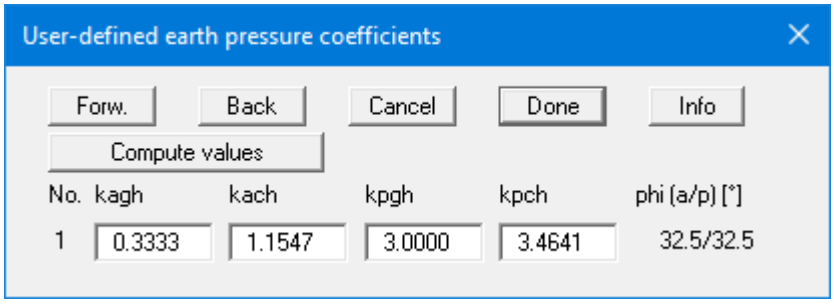
Alternatively, it is possible to determine the demands placed on the wall by area loads according to the theory of elastic half-space. The required concentration factor is specified in the following dialog box, if the upper check box is activated.



According to the EAB, R 23 (Paragraph 2), for systems with at least two rows of anchors or struts, at-rest earth pressure can be kept constant from the lowest support. To do this, activate the check box at the bottom of the dialog box.

10.12 GGU-CANTILEVER: "User-defined earth pressure coefficients" menu item

If you want to work with user-defined earth pressure coefficients instead of with those computed by the program you can enter them here. Enter the coefficients for horizontal ground. If necessary, the program will convert them for sloping ground using equation values for kah0 and kah (see "**Theoretical principles: Berms**").

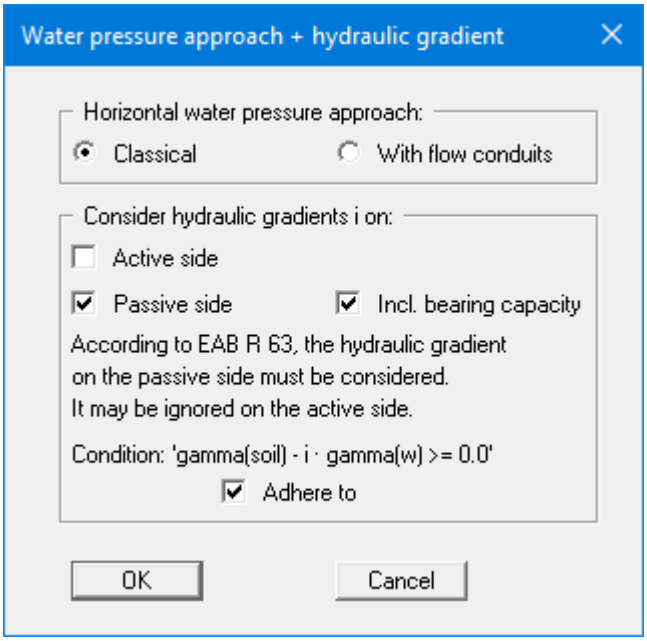


If the "**Compute values**" button is pressed the earth pressure coefficients can be calculated by the program in accordance with the required standard and slope angle.

The earth pressure coefficients entered here are only adopted if the "User-defined" check box is activated in "**Editor 1/Active earth pressure**" and/or in "**Editor 1/Passive earth pressure**" menu items.

10.13 GGU-CANTILEVER: "Groundwater" menu item

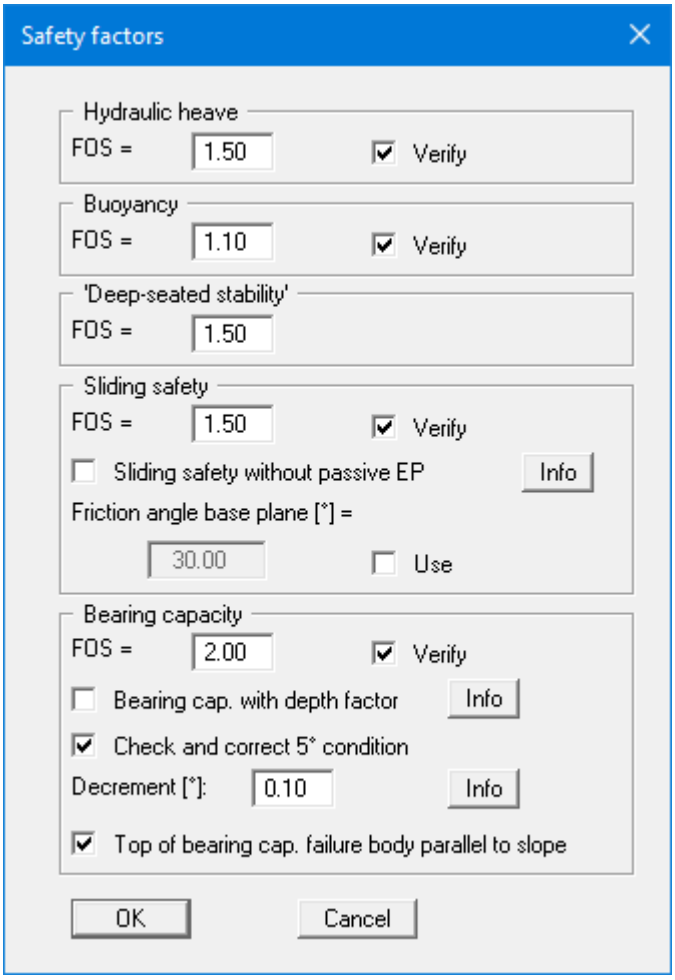
Regarding adopting horizontal water pressure you are referred to the explanations in **“Theoretical principles: Water pressure”.**



The cantilever walls of an excavation in flowing groundwater will experience increased earth pressure on the active side and decreased earth pressure on the passive side. In accordance with EAB R 63, the effect on the active side can generally be ignored, while the effect on the passive side must always be taken into consideration. You can make the appropriate selection in the bottom dialog group box.

10.14 GGU-CANTILEVER: "Verifications/Safety factors" menu item

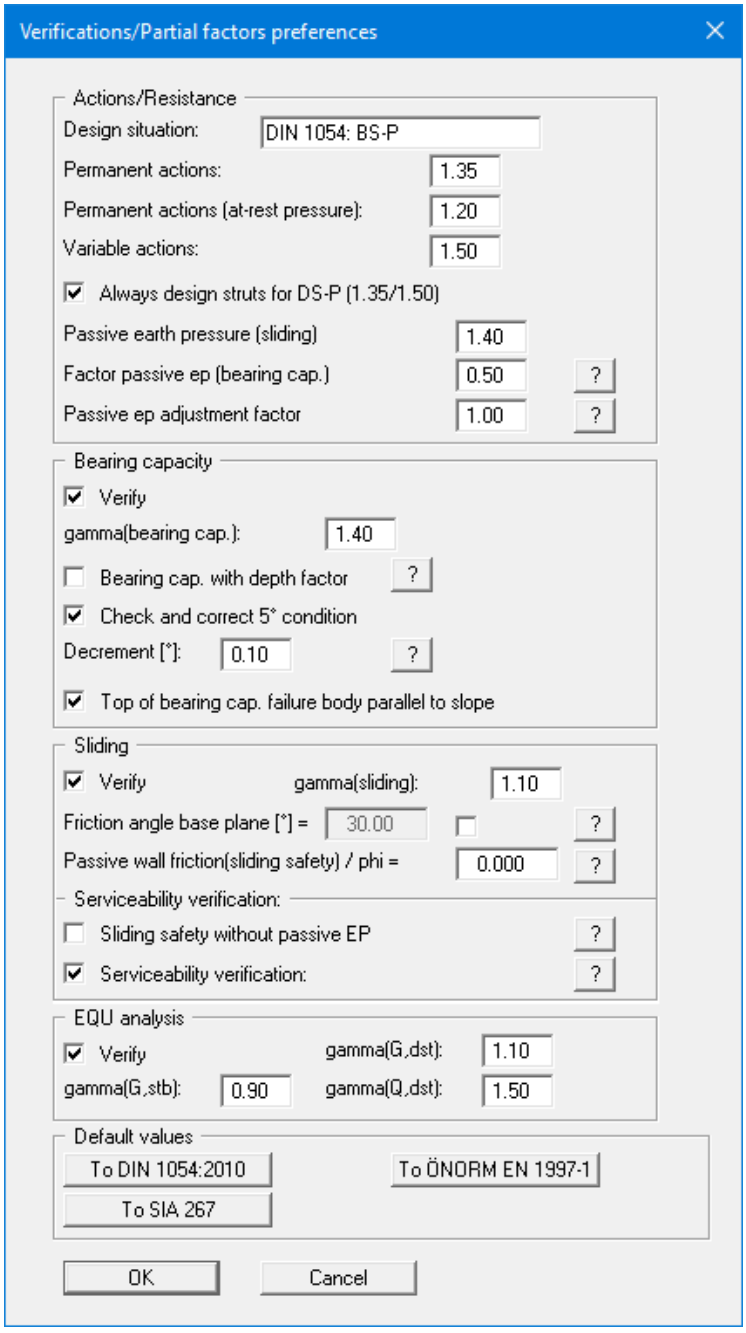
If you are analysing with ***global safety factors*** to DIN 1054 old, you can specify the verifications to be performed by the program by activating the corresponding check boxes in the dialog box shown below.



Then enter the safety factors for the individual verifications. The program's default values in the box are those required by the DIN 1054. If you do not want the program to perform the verifications, the corresponding check box must be deactivated. Pressing the two "**Info**" buttons, you will see further information.

10.15 GGU-CANTILEVER: "Verifications/Partial factors" menu item

If you are analysing with the ***partial safety factor concept***, you will see a dialog box for defining the partial factors.



The "**EQU analysis**" group box (limit state of loss of static equilibrium) is only available in EC 7.

In the "**Default values**" group box you can use the "**To DIN 1054:2010**" button to transfer the partial safety factors for the various load cases of DIN 1054:2010 or EC 7. The selected design situation is automatically entered at the top of the dialog box and can, if desired, be displayed in the ***General legend***. However, you can also use your own designations here.

In the partial safety concept according to EC 7, the designations of the load cases have been changed:

- Load Case 1 is now **DS-P**: Persistent Design Situation
- Load Case 2 is now **DS-T**: Transient Design Situation
- Load Case 3 is now **DS-A**: Accidental Design Situation

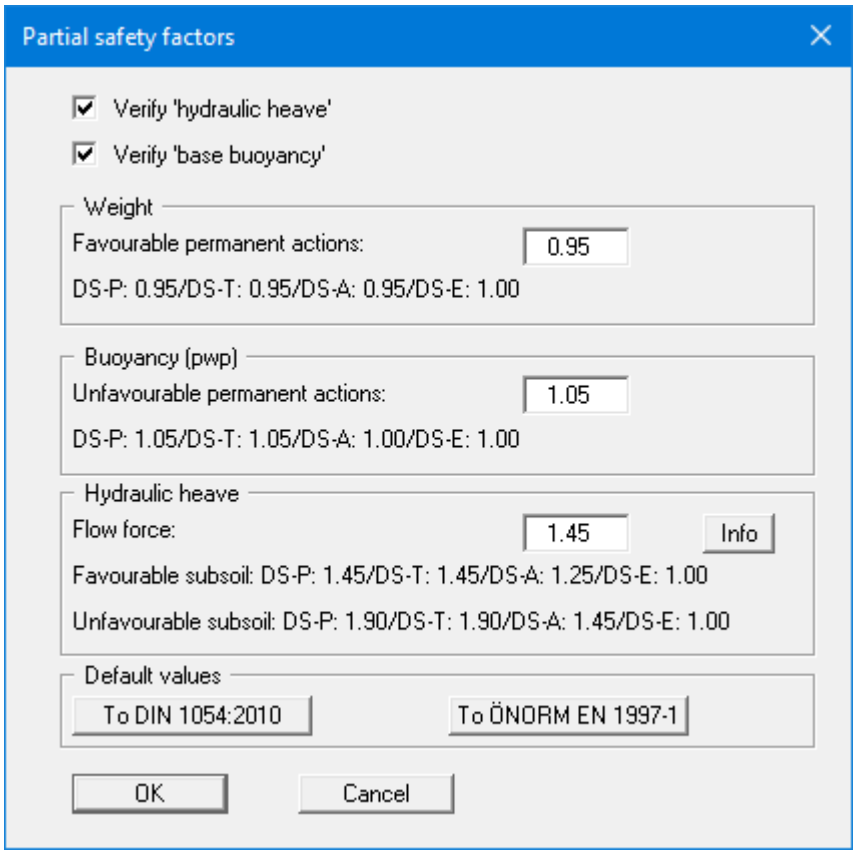
In addition, there is a seismic design situation: **DS-E**. In the DS-E design situation all partial factors = **1,0**.

It is also possible to select the partial safety factors compliant with Austrian standards using the "**To ÖNORM EN 1997-1**" button.

In **GGU-CANTILEVER** you can also select the partial safety factors according to Swiss standards using the "**to SIA 267**" button.

10.16 GGU-CANTILEVER: "Buoyancy + Hydraulic heave" menu item

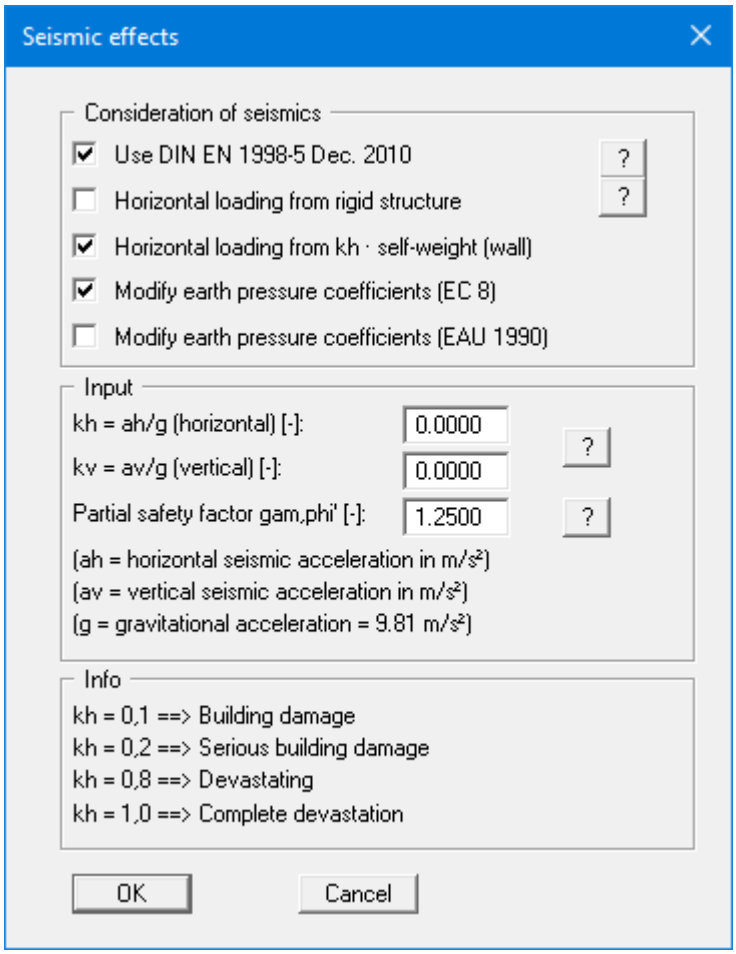
If you have selected the ***partial safety factor concept***, you will see a dialog box, using this menu item, in which you can activate the verifications for hydraulic heave and the buoyancy of the excavation base.



If you press the "**Info**" button, you will see further information on the subsoil situation (favourable/unfavourable). In the "**Default values**" group box the partial factors for the various load cases and subsoil conditions given in the DIN 1054:2010 and in the EC 7 can be selected by means of the dialog box reached by clicking the "**To DIN 1054:2010**" button. In addition, it is possible to select the partial safety factors compliant with Austrian standards using the "**To ÖNORM EN 1997-1**" button.

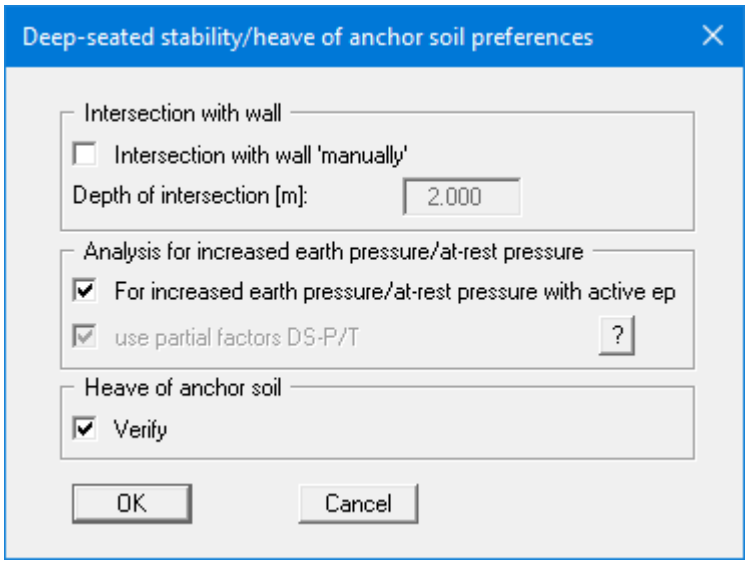
10.17 GGU-CANTILEVER: "Seismic effects" menu item

Seismic loads are taken into account according to EC 8. In addition to the modification of the earth pressure coefficients according to EC 8, a horizontal load from a rigid structure or from the dead weight of the wall can be considered. It is based on the equations from Annex E of DIN EN 1998-5, December 2010, p. 33 ff.



10.18 GGU-CANTILEVER: "Deep-seated stability/Heave of anchor soil" menu item

Using this menu item, you can select the intersection with the wall manually and enter an appropriate depth.



In the "**Analysis for increased earth pressure/at-rest pressure**" group box you can define whether the deep-seated stability analysis should be done with ***active earth pressure*** or alternatively, the ***partial factors DS-P/T*** should be used.

EAB R 44 stipulates that this must also be used for increased or at-rest earth pressure to analyse deep-seated stability. In addition, the partial factors for DS-P/T (LC1/2) must be adopted. In the DS-P/T load case the partial factor for passive earth pressure is 1.35. Only when the 'normal' partial factor for the passive earth pressure is greater than 1.35 DS-P/T is adopted.

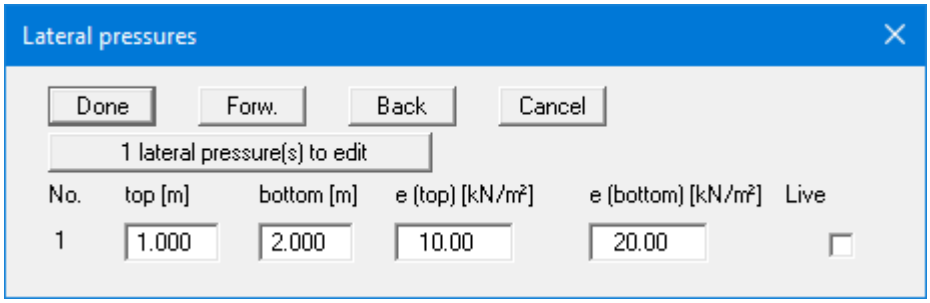
The partial factors for the actions to DS-P/T are around 5% greater than those to DS-T. Simplified, but conservatively, the anchor forces are multiplied by the factor '1.05'. R 44 does not always return higher utilisation factors.

Verification of ***heave of anchor soil*** can be activated in the lower group box of the dialog box. If a value unequal to "**0**" is entered for the height of the dead man when entering the anchors, and this check box is activated, verification is performed like the method described in Section 7.3.4 of the Piling Handbook 1977.

11 Editor 2 menu

11.1 GGU-CANTILEVER: "Lateral pressures" menu item

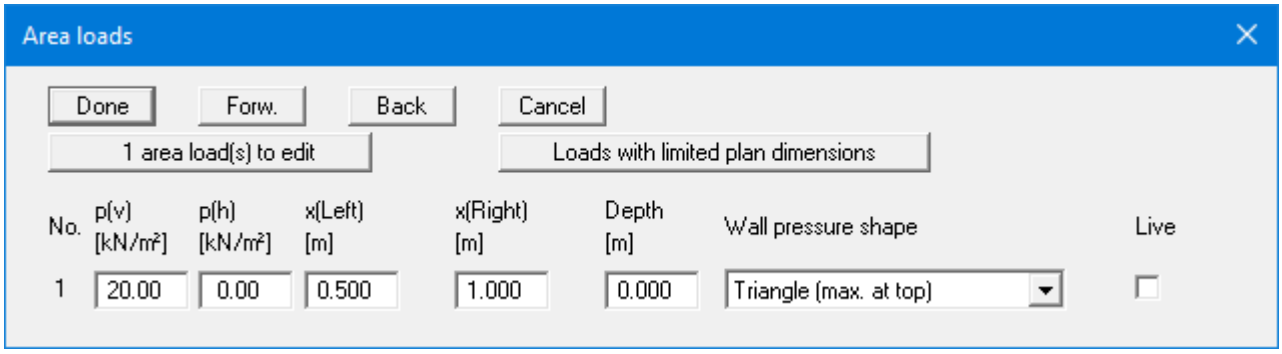
If, in addition to the diverse options for determining earth pressure on the wall, you also need to take surcharges on the active side into account, define them here.



The number of lateral pressures can be modified using the "**x lateral pressure(s) to edit**" button. Then enter the ordinates in metres from the top of the wall or as absolute heights, and the values for the lateral pressures. When analysing with the partial safety factors you will also see the "**Live**" check box because of the differentiation between permanent and changeable lateral pressures.

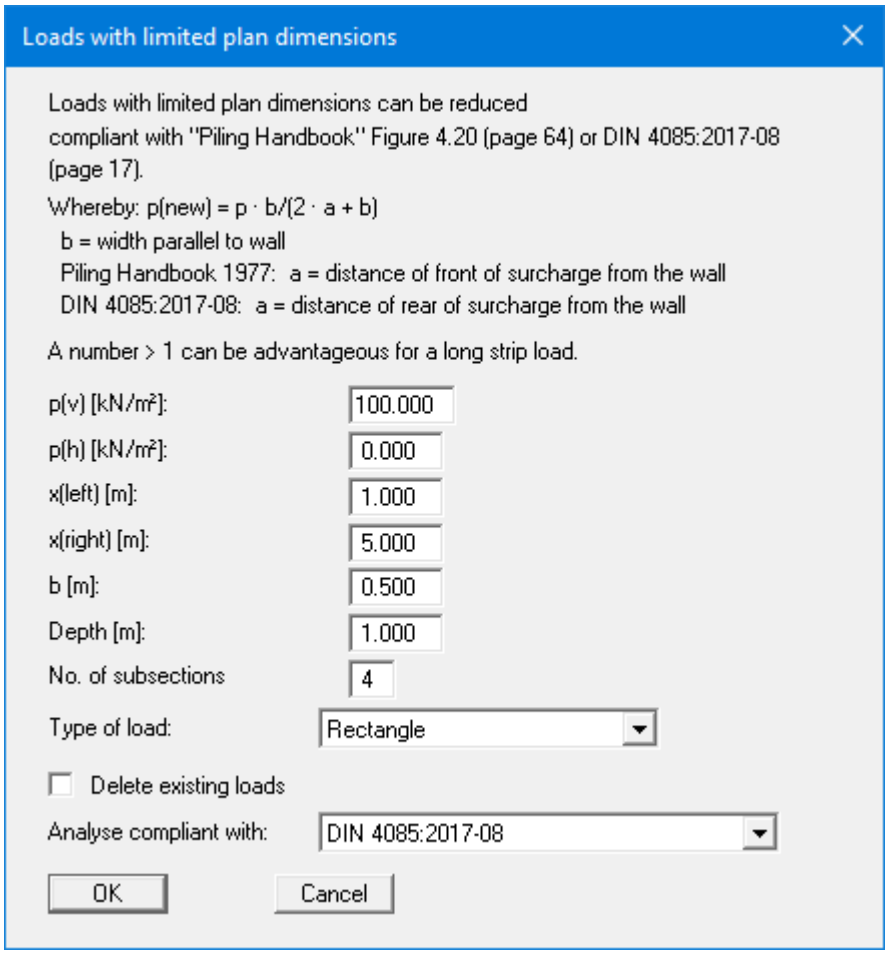
11.2 GGU-CANTILEVER: "Area loads" menu item

Using this menu item you define area loads and loads with limited plan dimensions.



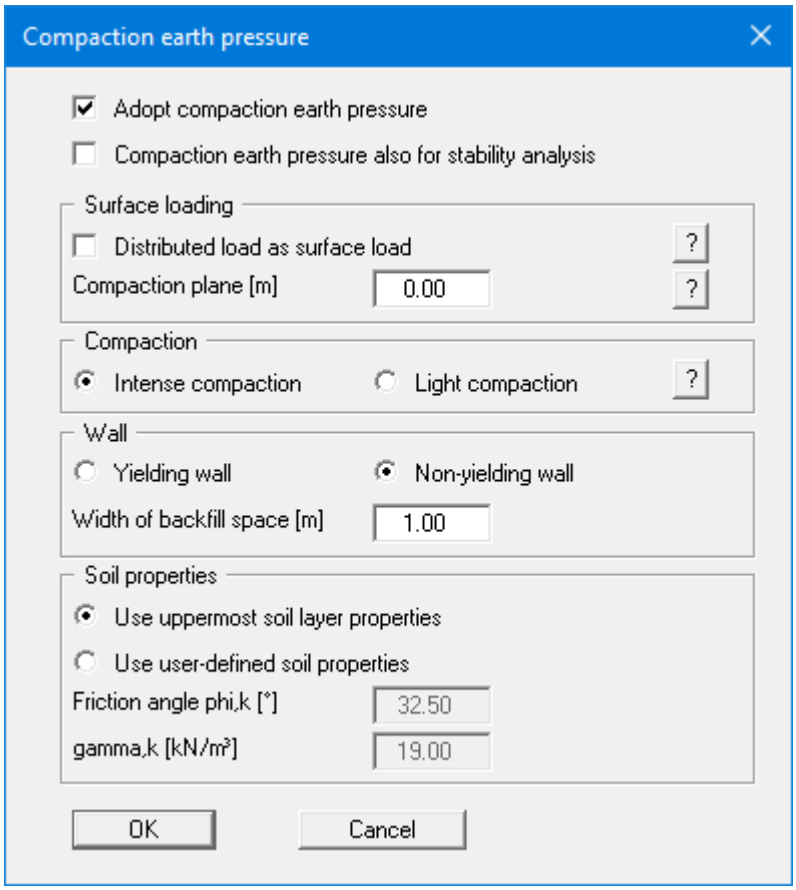
The "**x area load(s) to edit**" button allows you to determine the number of area loads to be considered. Subsequently you can enter the sizes "**p(v)**" (= vertical) and "**p(h)**" (= horizontal), the ordinates and the "**Depth**" of the area loads. You must also enter the "**Wall pressure shape**" of the resultant horizontal forces on the wall (see also "**Theoretical principles: Area loads**"). To define an area load as a live load, activate the corresponding "**Live**" check box on the right.

Use the "**Loads with limited plan dimensions**" button, to define such loads (see also "**Theoretical principles: Loads with limited plan dimensions**"):



11.3 GGU-CANTILEVER: "Compaction earth pressure" menu item

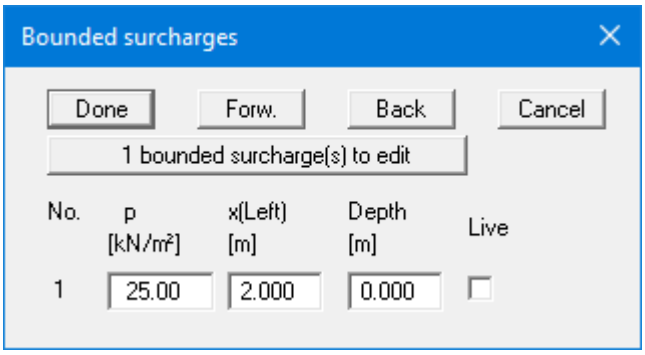
The compaction earth pressure to DIN 4085:2017 can be analysed using this menu item. The data required are described in the DIN and can be entered into the dialog box shown below. Pressing the "**?**" buttons, you will see further information.



Two files containing analyses taken from *Geotechnische Nachweise nach EC 7 und DIN 1054* (Geotechnical analyses to EC7 and DIN 1054), 3rd edition 2012, by Martin Ziegler, can be found in the program's example folder. The analyses refer to pages 70 and 72 of the literature references.

11.4 GGU-CANTILEVER: "Bounded surcharges" menu item

Bounded surcharges are defined in the following dialog box. You are first queried whether the surcharges are entered to be on the active or the passive side. The following dialog box opens for ***active side*** input:

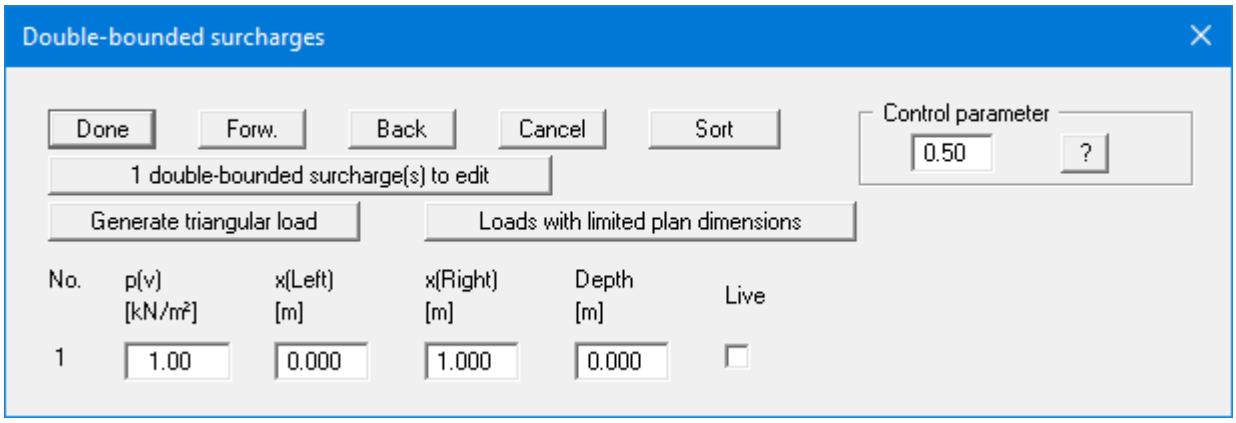


Using "**x bounded surcharge(s) to edit**" you can determine the number of bounded surcharges. You can then enter the size of the surcharges, the ordinates and the depth in metres from the top of the wall or as absolute heights.

Input of bounded surcharges on the ***passive side*** is analogous, but without the "**Live**" check box.

11.5 GGU-CANTILEVER: "Double-bounded surcharges" menu item

Double-bounded surcharges are defined using this menu item. You are first queried whether the surcharges are entered to be on the active or the passive side. The following dialog box opens for ***active side*** input:



The number of surcharges can be edited using the "**x double-bounded surcharge(s) to edit**" button. Then enter the size of the surcharges, the ordinates and the depth in metres from the top of the wall or as absolute heights.

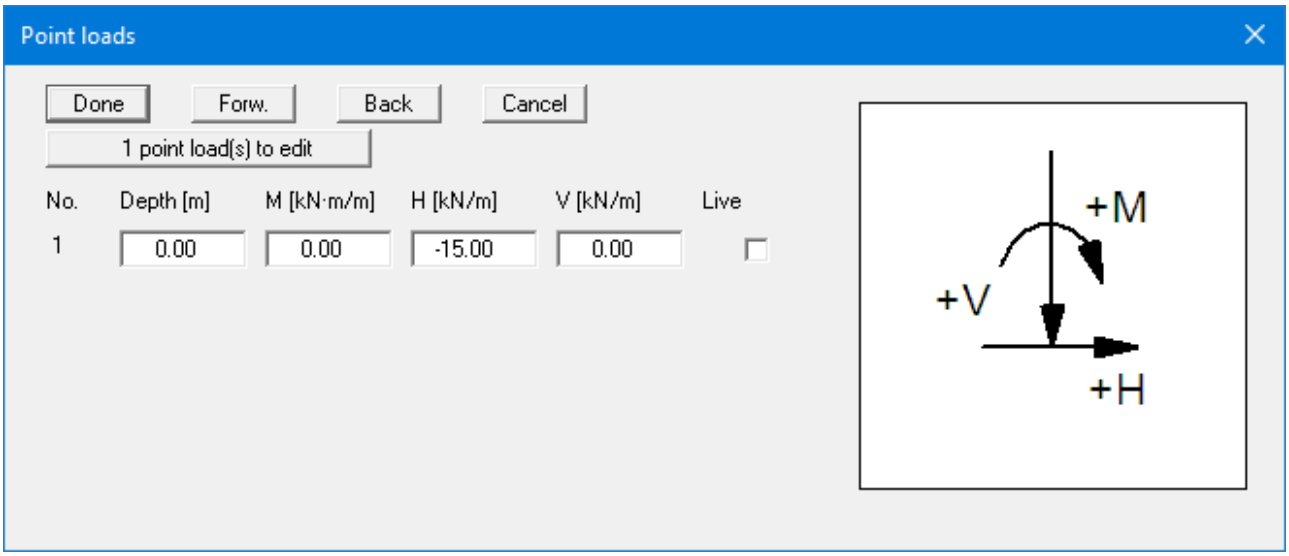
Double-bounded surcharges consist of 2 bounded surcharges with opposing signs. Whether or not the linear component of the resulting earth pressure (see Figure in "**Theoretical principles: Double-bounded surcharges (active side)**") may be adopted at its full value for the bounded surcharge with the negative sign has not yet been conclusively clarified. This can be influenced using the control parameter:

- Control parameter = 0.0 no linear component
- Control parameter = 1.0 linear component at full value

Input of double-bounded surcharges on the ***passive side*** is analogous, but without the "**Live**" check box. There is no linear component for bounded surcharges on the passive side, meaning that a control parameter is not necessary.

11.6 GGU-CANTILEVER: "Action boundary conditions" menu item

You can introduce additional action boundary conditions anywhere along the wall.

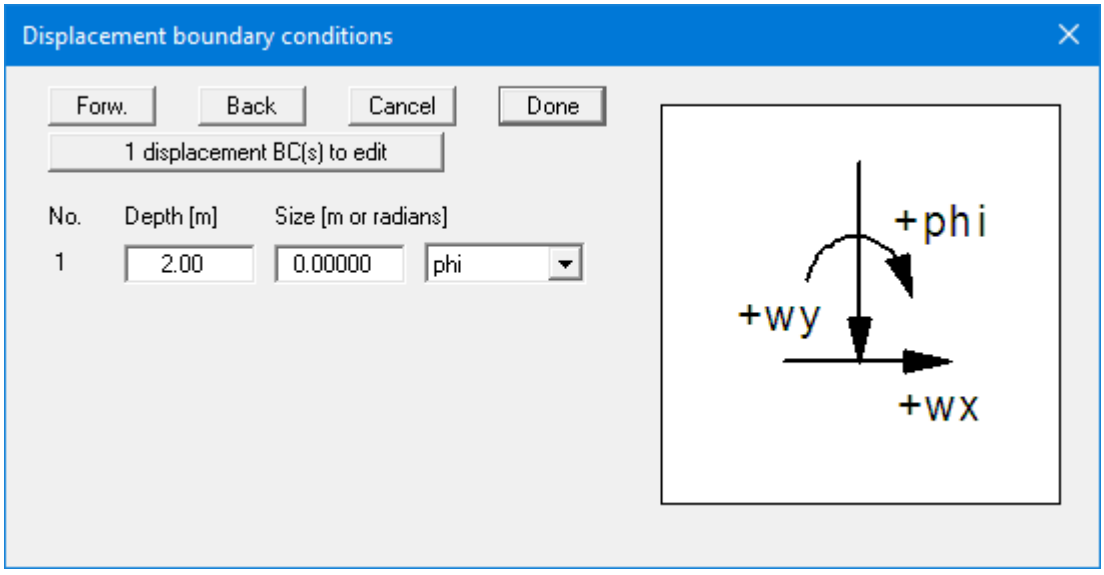


The direction of the forces is defined by means of the sign. In the example above a horizontal force of 15 kN/m has been entered at the top of the wall, acting towards the left.

When analysing with the ***partial safety factors*** you will also see the "**Live**" check box because of the differentiation between permanent and changeable loads.

11.7 GGU-CANTILEVER: "Displacement boundary conditions" menu item

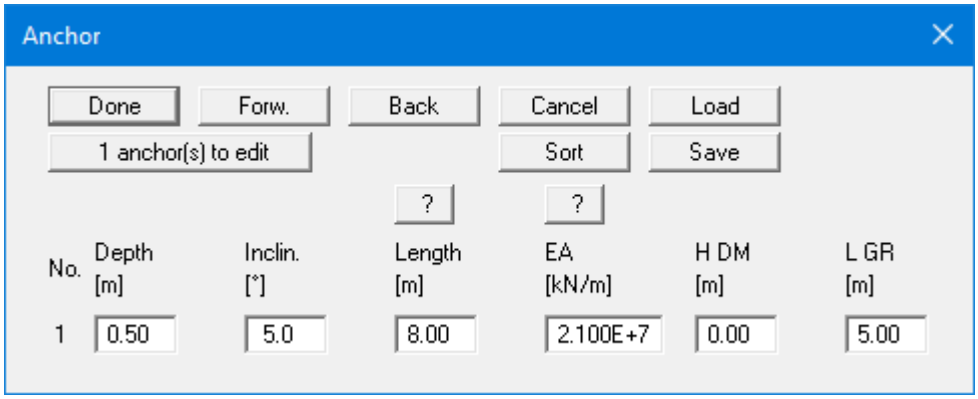
You can introduce additional displacement boundary conditions anywhere along the wall.



In the example above a **rotation** "**phi**" of the wall of **0.0** has been entered 2.0 m below the top of the wall. "**wx**" and "**wy**" in the pull-down menu stand for the horizontal and vertical displacements; the direction is defined by means of the sign.

11.8 GGU-CANTILEVER: "Anchors" menu item

Anchors are defined in the dialog box of this menu item.

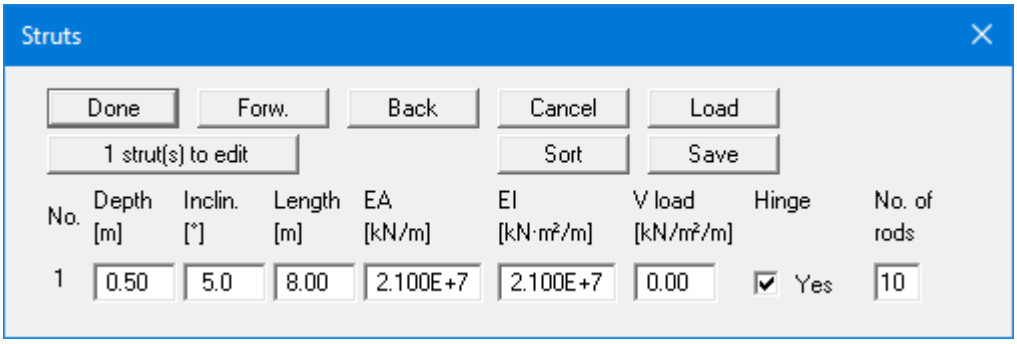


It is necessary to enter the following information:

- Depth [m] = position of anchor head
- Inclination [°] of anchor
- Length [m] of anchor = starting point of deep-seated stability
- EA [kN/m] = axial stiffness of the anchor steel
- H DM [m] = height of deadman (if present)
  This value is only necessary for analysis of deep-seated stability.
- L GR [m] = length of grouted section
  This value is of no importance for the analysis itself, but for the graphical visualisation. The length labelling of the anchor includes half the length of the grouted section.

11.9 GGU-CANTILEVER: "Struts" menu item

Struts are defined in this dialog box.



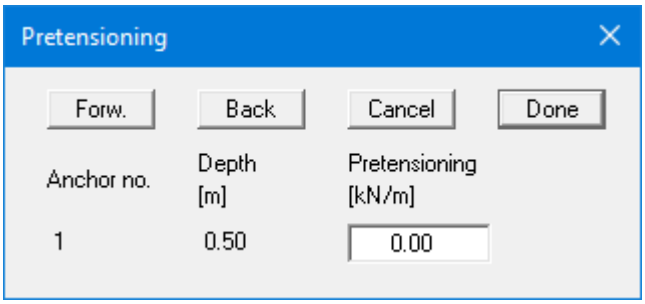
It is necessary to enter the following information:

- Depth [m] = position of the strut head
- Inclination [°] of the strut

- Length [m] of the strut
- EA [kN/m] = Axial stiffness of the strut [kN/m]
- EI [kN·m²/m] = Bending stiffness of the strut [kN·m²/m]
- V load [kN/m²/m] = Vertical load on the strut [kN/m²/m]
- Hinge
  Here you specify whether the strut is hinged or rigidly fixed to the wall.
- No. of rods
  If you have defined a vertical load on the strut, you will also get its distribution of moments. Of course, this only works if the strut is divided into several rods (finite elements, see "**Theoretical principles: Structural system**"). The maximum number of rods that can be specified is 20.

11.10 GGU-CANTILEVER: "Pretensioning" menu item

Personal experience has shown that discussions surrounding the necessity for considering pretensioning are never-ending. Independently, the program enables pretensioning for anchors/struts to be taken into consideration



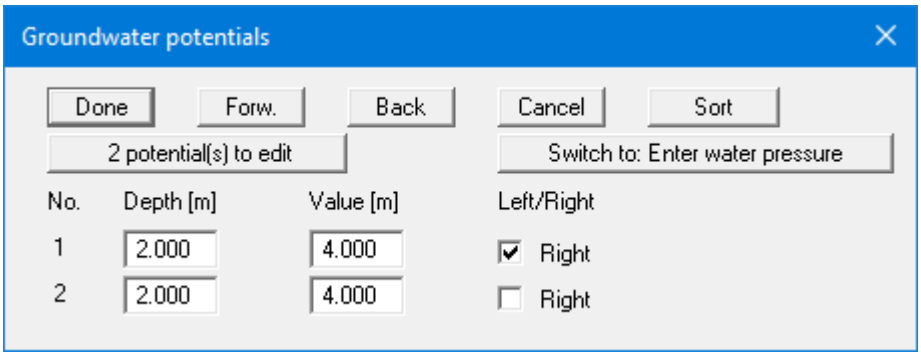
For anchors, pretensioning must be entered as positive. Faulty input is pointed out before analysis begins. From a structural perspective, the program inserts an action boundary condition equivalent in size and direction to the pretensioning force into the system at the appropriate depth.

Anchors are generally pretensioned at 80% and more of the resulting anchor force. This can be modelled with sufficient accuracy using a high axial rigidity EA without pretensioning. If you wish to analyse more precisely, specify the axial rigidity EA according to the selected anchor and define a pretensioning force. Following analysis, the selected pretensioning force must be examined against the results. This generally requires an iteration process by the user.

The same applies to struts.

11.11 GGU-CANTILEVER: "Groundwater potentials" menu item

You can define additional potentials anywhere along the wall (see "**Theoretical principles: Water pressure approch using flow conduits**").

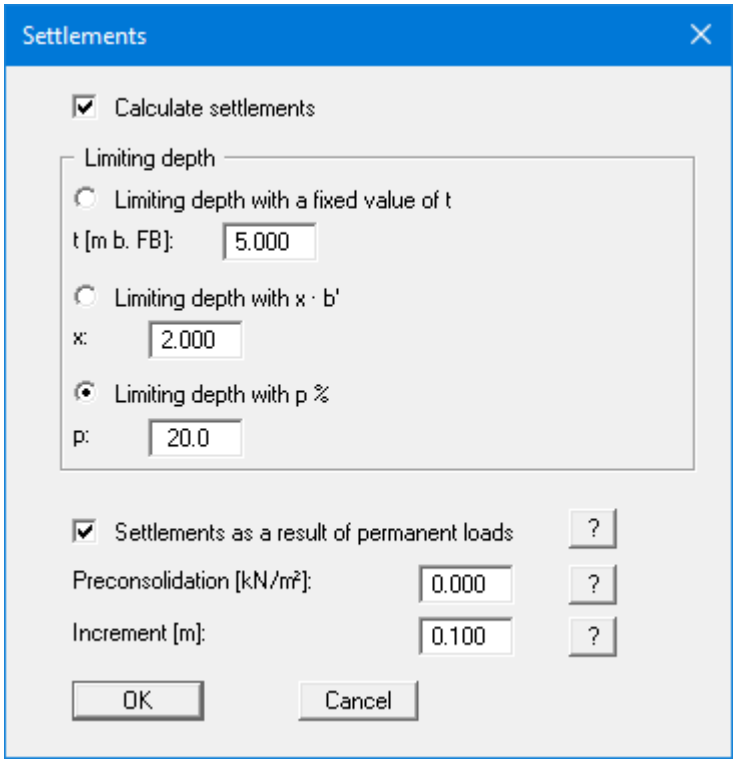


In the above example a potential of 4.0 m below the top of wall at the left and right of the cantilever wall has been entered at a depth of 2.0 m below the top of wall. Additional potentials will only be considered if the water pressure approach using ***flow conduits*** has been selected (see menu item "**Editor 1/Groundwater**").

Instead of the potential values in [m], you can enter the values as water pressures in [kN/m²] to the left and right of the cantilever wall. To do this, click on the "**Switch to: Enter water pressure**" button.

11.12 GGU-CANTILEVER: "Settlements" menu item

The form of limiting depth calculation can be specified in three different ways using this menu item. In some GGU programs you first activate the "**Calculate settlements**" check box (see dialog box shown).



According to DIN 4019, settlement analysis can be terminated at a depth (limiting depth) in which the stress from soil self-weight and ground surcharges (overburden stress) is greater than 20% of the stresses caused by the wall. The stress analysis for determining the limiting depth is performed for the mean soil pressure in the characteristic point. The lateral stresses on the active side of the wall are adopted for this limiting depth calculation. If the limiting depth lies below the depth of the lowest soil layer for this type of calculation, the values of this lowest layer are adopted for the settlement analysis.

In addition, a "**Preconsolidation**" can be defined. This preconsolidation in kN/m² is subtracted from the existing soil pressure. Settlement analysis will then be performed with the reduced values. The overburden stress is also reduced by this amount when calculating the limiting depth.

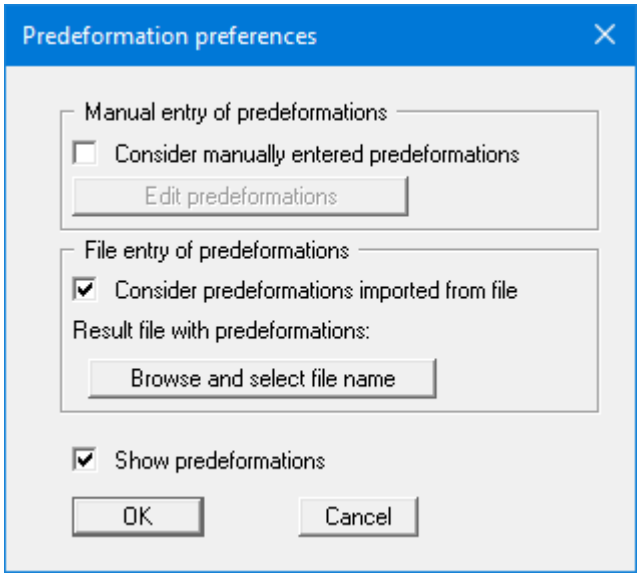
The "**Increments**" are only important for the graphical visualisation of the stress diagram.

11.13 GGU-CANTILEVER: "Predeformation info" menu item

You will see information on predeformations.

11.14 GGU-CANTILEVER: "Predeformation preferences" menu item

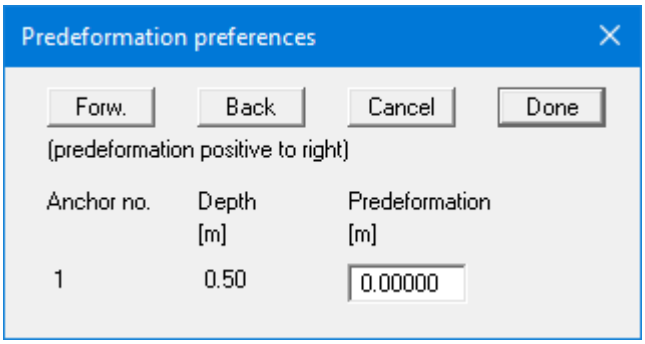
If predeformations from previous construction phases must be taken into consideration as boundary conditions (see also “**Theoretical principles: Predeformation**”), the necessary settings are made here.



In the bottom section of the dialog box, you can choose whether or not to have the loaded predeformation data shown on screen. If you choose to have it shown, the system graphics show the system's bending line with predeformations.

Predeformations can be defined in two different ways:

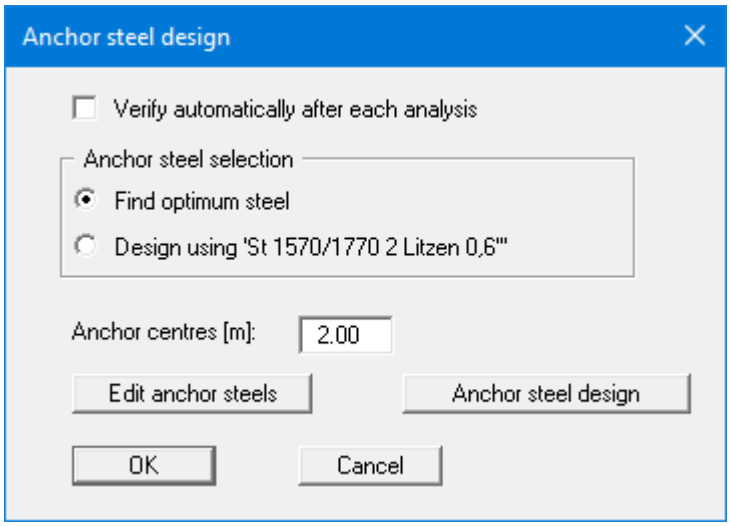
- **Manual entry of predeformations**
  If you know the size of the predeformations, select "**Consider manually entered predeformations**", and then click the "**Edit predeformations**" button. In the dialog box that appears you can enter a predeformation for every currently defined anchor.



- **File entry of predeformations**
  Alternatively, predeformation data can be automatically imported from an existing file. Select "**Consider predeformations imported from file**" and "**Browse and select file name**". A dialog box will open for selecting the appropriate file, which must have been saved with the results of the analysis; otherwise, you will receive an error message. The program imports the appropriate data from this file. The file name is then shown on the button and below this the project identification of the imported file.
  You can view the loaded values by clicking "**Edit predeformations**". If you need to alter the height of the anchors during further processing, these values will be automatically adjusted. This means that whenever you begin an analysis, the selected file will be loaded, and the values recomputed. You may also want to recompute the current system during a later session, although the file with the predeformation data has altered in the meantime. In this case, the new predeformation data will be loaded automatically.

11.15 GGU-CANTILEVER: "Anchor steel design" menu item

Using this menu item, you can specify preferences for designing the anchor steel and carry out the design for an analysed system by means of the "**Anchor steel design**" button.



If you activate the "**Verify automatically after each analysis**" check box, you will be automatically presented with a query for anchor steel design when analysis is complete.

You can choose to design with a specified anchor steel or to search for the optimum steel from a list of existing steels.

For an analysis using ***global safety factors*** you must then enter the factor for the anchor steels which for active earth pressure = 0.0 and for loading solely by at-rest pressure = 1.0. Intermediate values can be linearly interpolated. FOS equals 1.0 for pretensioned anchors.

When using the **partial safety factors** only the anchor centres still need to be defined, as the other data is taken into consideration via the partial factor for permanent actions resulting from at-rest earth pressure.

Using the "**Edit anchor steels**" button you arrive at a dialog box listing the existing anchor steels with their names and the allowable anchor forces for active and at-rest earth pressures. By marking the selection check box in front of the desired anchor steel and clicking the "**Selected steel as design steel**" button, it can be transferred to the above dialog box. New anchor steels can be added to the list after clicking "**x anchor steel(s) to edit**".

The "**Anchor steel design**" button only appears if the system is already analysed!

12 System menu

12.1 GGU-CANTILEVER: "Info" menu item

You will see information on the current system in a message box.

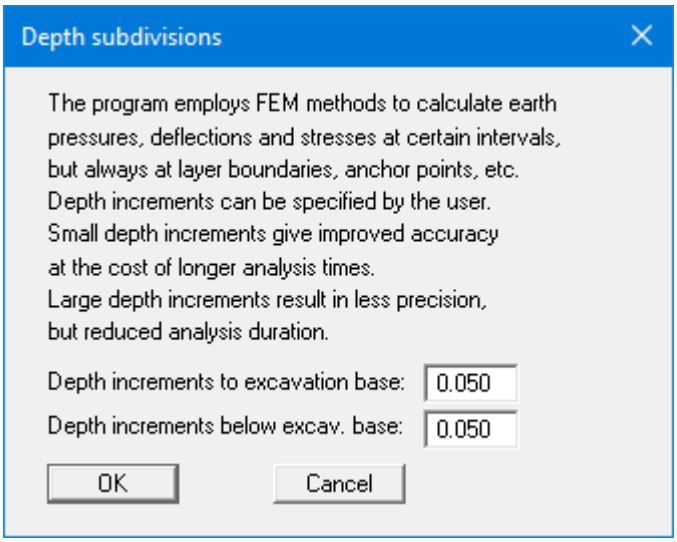
12.2 GGU-CANTILEVER: "Special preferences" menu item

The program performs a multitude of plausibility checks. After starting the analysis, the preferences specified by the user are displayed in a message box; for problematical preferences separate information or warning are displayed. It is therefore recommended to leave the "**Show warnings in future**" check box activated.

If you do not want to see the automatic display when the analysis starts, deactivate the check box. You can subsequently view your special preferences using this menu item.

12.3 GGU-CANTILEVER: "Depth subdivisions" menu item

The program uses the finite element method, which requires the system to be divided into a number of finite elements (rods, see “**Theoretical principles: Structural system**”). You can specify the size of these depth increments for the region above and below the excavation base.



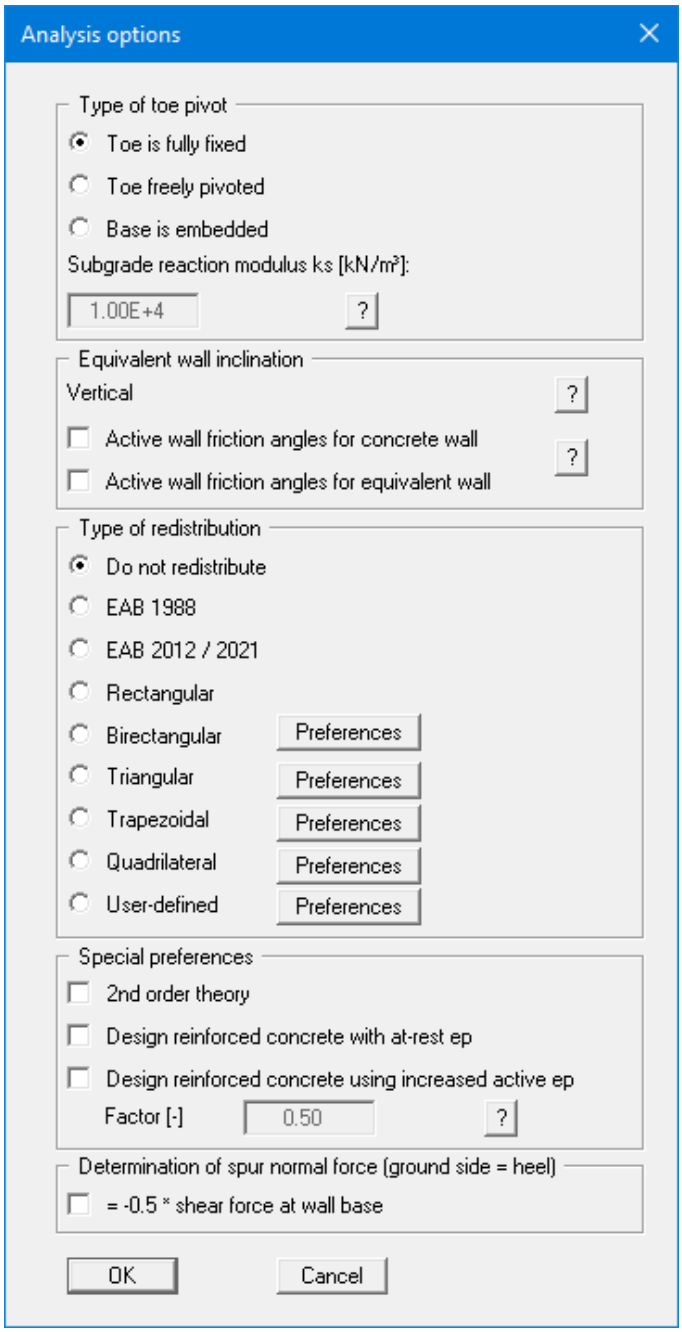
12.4 "Analyse" menu item

12.4.1 GGU-CANTILEVER: Start dialog box (Analyse)

Once you have entered all data required to fully describe the system it can be analysed. After selecting the "**System/Analyse**" menu item, a start dialog box appears with three group boxes, which are explained in the following sections.

You can also start the analysis by pressing the [**F5**] function key or the calculator symbol

and you will then see the same start dialog box. The selection options and check boxes vary according to the analysis principles adopted, shown here for a system with an anchor.



After confirming your preferences start the analysis by clicking "**OK**". The program first performs comprehensive plausibility checks on your input and notifies you of any inconsistencies and special preferences you made.

Once analysis is complete the design dialog box immediately opens. Explanations of design aspects can be found in the "**System/Design defaults**" menu item. The analysis and design results are first displayed in info boxes and then visualised graphically on the screen. The system data can be saved in a file, together with the results (menu item "**File/Save as**").

12.4.2 GGU-CANTILEVER: "Type of toe pivot" group box (Analyse)

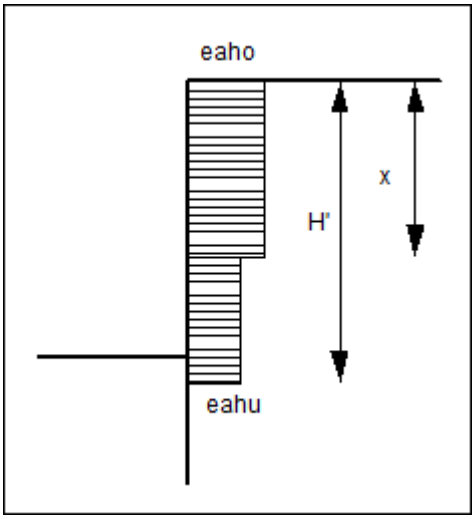
In the first group box of the start dialog box of the "**System/Analyse**" menu item you can specify the toe pivot. This is, of course, not possible in systems without anchors or struts. In such cases, the toe is always ***fully fixed***.

In systems with anchors or struts, a subgrade modulus for the base can be entered in place of "**Toe is fully fixed**" or "**Toe freely pivoted**". Activate the "**Base is embedded**" check box and enter a subgrade reaction. This creates a torsion spring at the base of the wall.

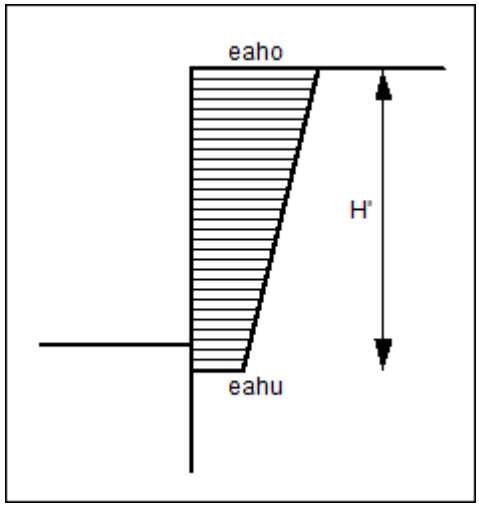
12.4.3 GGU-CANTILEVER: "Type of redistribution" group box (Analyse)

The following options are offered in the "**Type of redistribution**" group box in the start dialog box of the "**System/Analyse**" menu item:

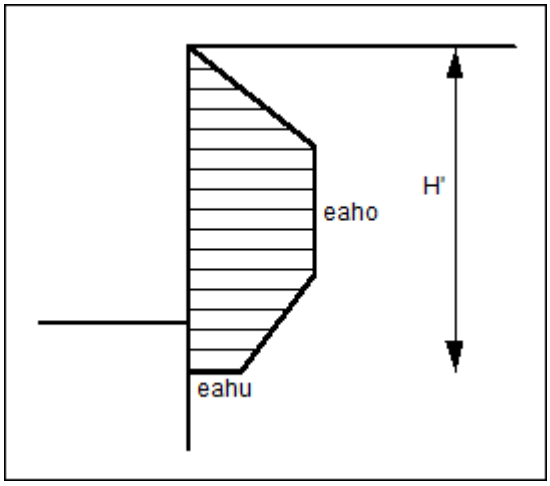
- "**Do not redistribute**"
  The analysis is performed using classical earth pressure redistribution.
- "**EAB 1988**" and "**EAB 2012 / 2021**"
  Redistribution diagrams are given as a function of anchor positioning in EAB 1988 and EAB 2012 or 2021. The program selects the appropriate redistribution from these diagrams. If no agreement is found an appropriate error message is shown.
- "**Rectangular**"
  Earth pressure is redistributed in the form of a rectangle.
- "**Birectangular**"
  Earth pressure is redistributed in birectangular form. The relationship between the top and bottom earth pressure ordinates (eaho/eahu), as well as depth of the subdivision x, can be specified.



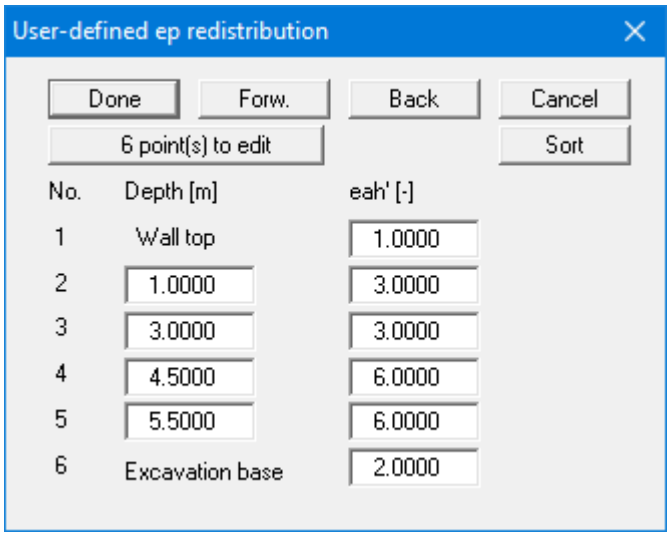
- "**Triangular**"
  Earth pressure is redistributed in the form of a triangle. The associated "**Preferences**" button enables you to determine the position of the maximum (top, central, bottom).
- "**Trapezoidal**"
  Earth pressure is redistributed in the form of a trapezoidal. The associated "**Preferences**" button enables you to determine the eahu/eaho ratio.

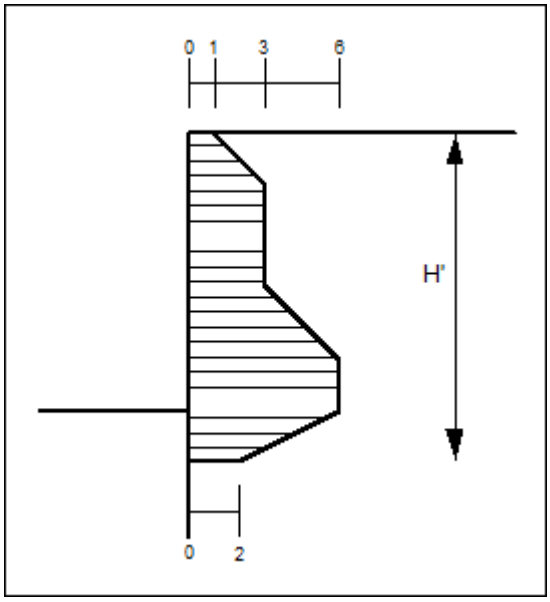


- "**Quadrilateral**"
  The earth pressure is redistributed in a quadrilateral. After clicking the "**Preferences**" button you can select the ordinates at which the maximum should occur, either by entering the depth or, alternatively, the anchor positions. Activate the appropriate check boxes at the left of the dialog box. The ordinate at the base of the wall is defined by the ratio eaho/eahu.



- "**User-defined**"
  If all the earth pressure redistributions offered so far do not meet your requirements, you can also carry out any earth pressure redistribution by defining a polygon course using the "**Preferences**" button.
  You can define several depths between the top of the wall and the base of the excavation and assign specific, freely definable earth pressure coordinates to these depths. This creates a polygonal composite surface. The calculated earth pressure is redistributed to precisely this area during subsequent analysis. For the example in the following dialog box, the following image is shown:





12.4.4 GGU-CANTILEVER: "Special preferences" group box (Analyse)

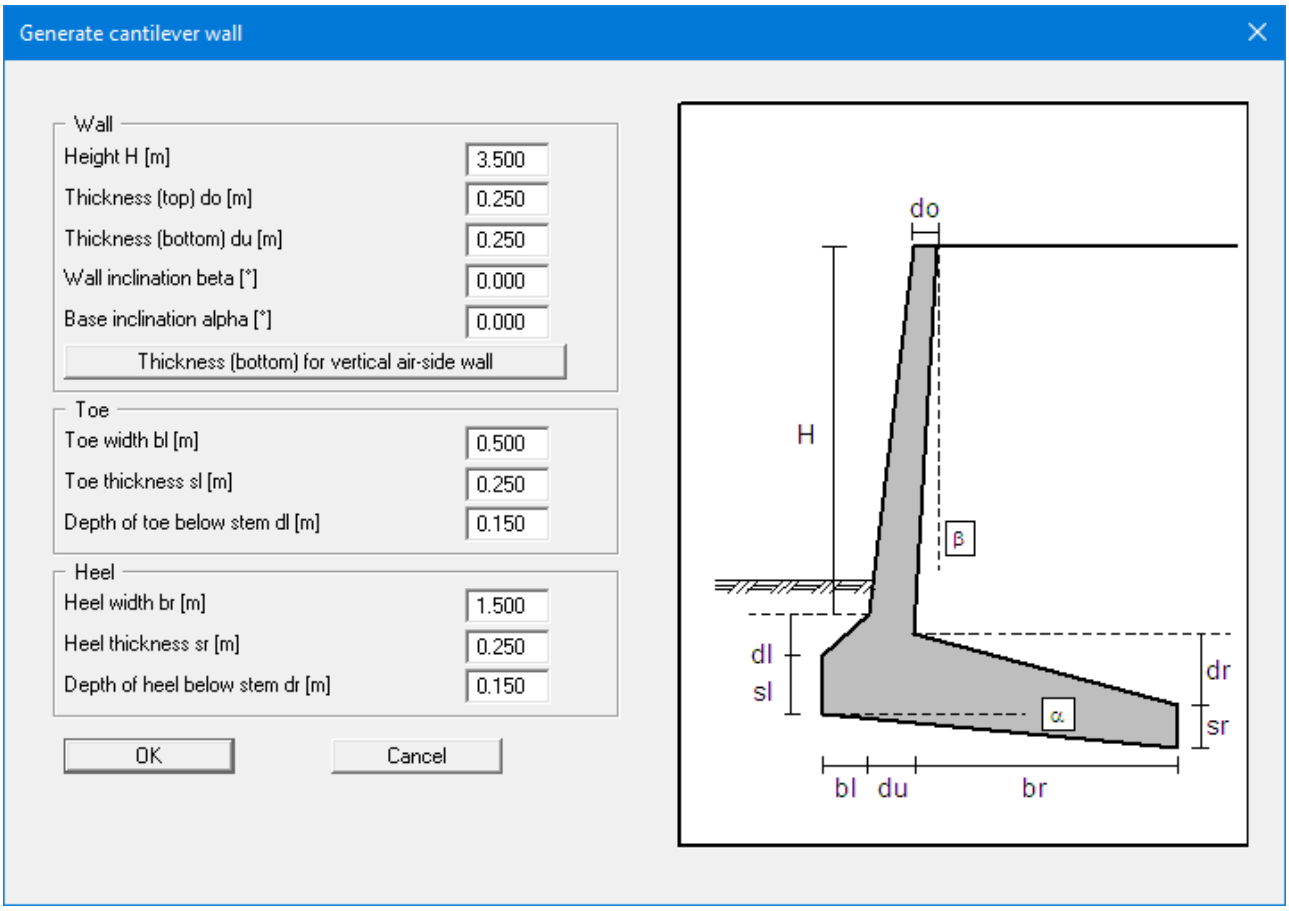
In the "**Special preferences**" group box it is possible to specify that analysis be performed using "**2nd order theory**". To do this, the program must perform an iteration process, which prolongs analysis.

It is usual to design the reinforced concrete using the at-rest earth pressure. In addition, you can design the reinforced concrete using increased active earth pressure. Wall stability analyses (bearing capacity, sliding, ...), in contrast, are generally performed using the active earth pressure.

12.5 GGU-CANTILEVER: "Optimise" menu item

The geometry of the cantilever wall can be optimised via this menu item or by pressing [**F8**].

The analysis dialog box opens first, allowing the required earth pressure redistribution to be selected (see "**System/Analyse**" menu item). The following dialog box then opens:

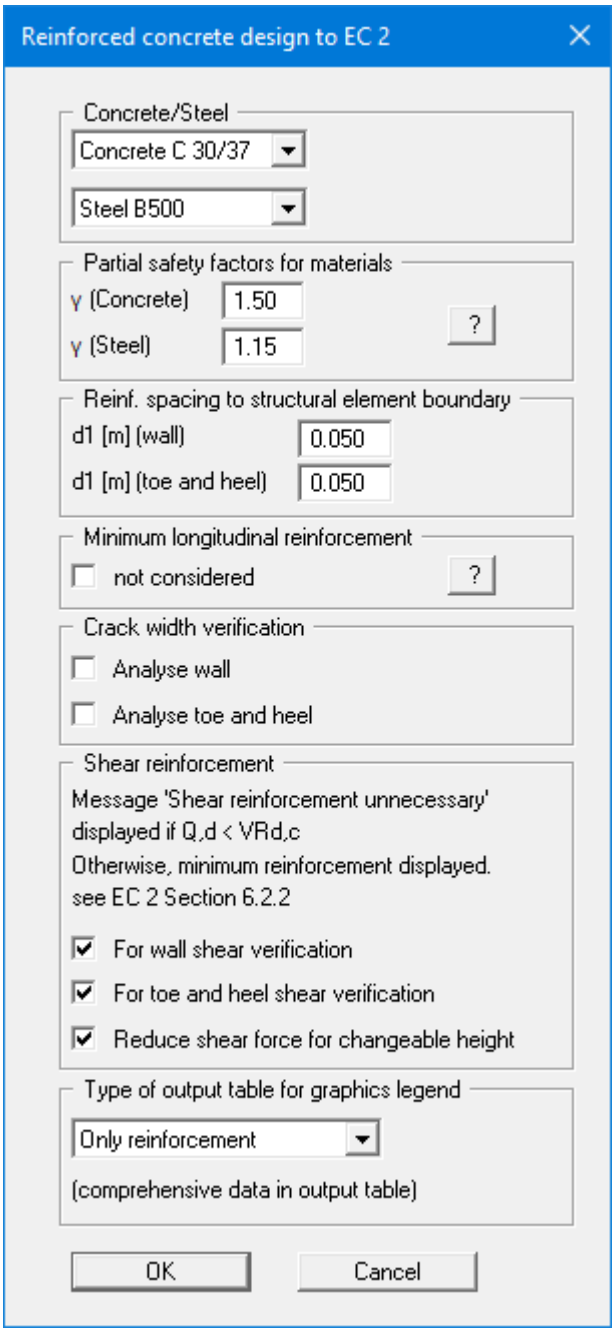


The existing cantilever wall geometry can be viewed and edited by entering data directly into the input boxes. Specify whether the toe or heel (left and right spurs) are to be optimised in the upper group box. Enter an appropriate interval.

Once optimisation is complete the optimum value is shown in a message box and can be selected for further use or rejected. If this value is accepted the program continues the analysis and a further dialog box opens for reinforced concrete design (see menu item “**System/Design defaults**”).

12.6 GGU-CANTILEVER: "Design defaults" menu item

This menu item can be used for reinforced concrete design using different settings for a previously analysed system. The following dialog box opens:

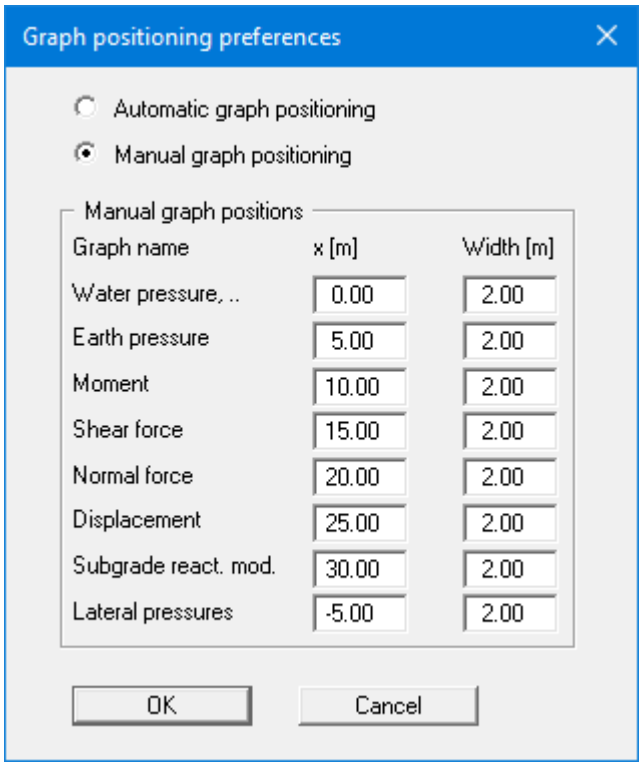


The spacing of the reinforcement for the wall, toe and heel is defined, besides the concrete and steel qualities. By activating the appropriate check boxes, it is possible to perform crack width verification and define preferences for shear reinforcement output for the stem, toe and heel.

"**Only reinforcement**" is the default setting to stop the design legend from appearing too large in the system visualisation. However, all results are shown in the output table (see menu item "**File/Print output table**").

12.7 GGU-CANTILEVER: "Graph positioning preferences" menu item

If you are not happy with the automatic graph arrangement, you can use this menu item to create an arbitrary arrangement. The dialog box of the **GGU-RETAIN** program is shown here as an example. Other graphs may be listed in other GGU programs.

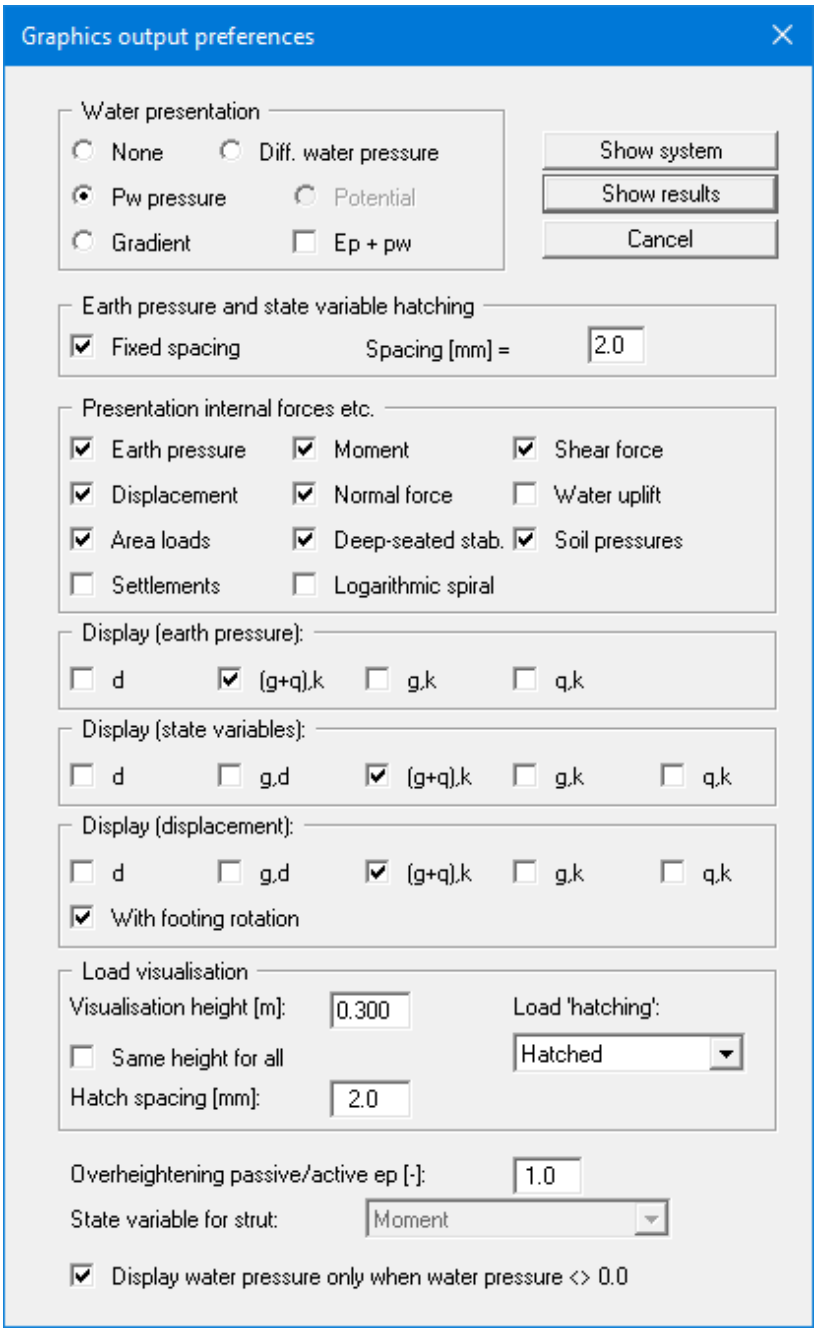


For a customised graph arrangement, activate the "**Manual graph positioning**" check box. The graphs are then displayed centred at the sheet position "**x**" with the specified "**Width**".

The fastest way to modify the position of a graph is to press the [**F11**] function key and then to pull the diagram to the new position holding the left mouse button pressed.

12.8 GGU-CANTILEVER: "Graphics output preferences" menu item

Among other things, the screen graphics consist of several graphs, presenting depth-oriented results. This menu item opens a dialog box which allows you to visualise the selected state variables on the screen by activating the corresponding check boxes.



On the whole, the dialog box is self-explanatory. For example, if the "**Settlements**" check box is activated, the stresses below the footing for the characteristic point are visualised. When "**Ep + pw**" is selected, the sum of earth pressure and water pressure (pw) is displayed in the diagram for earth pressure.

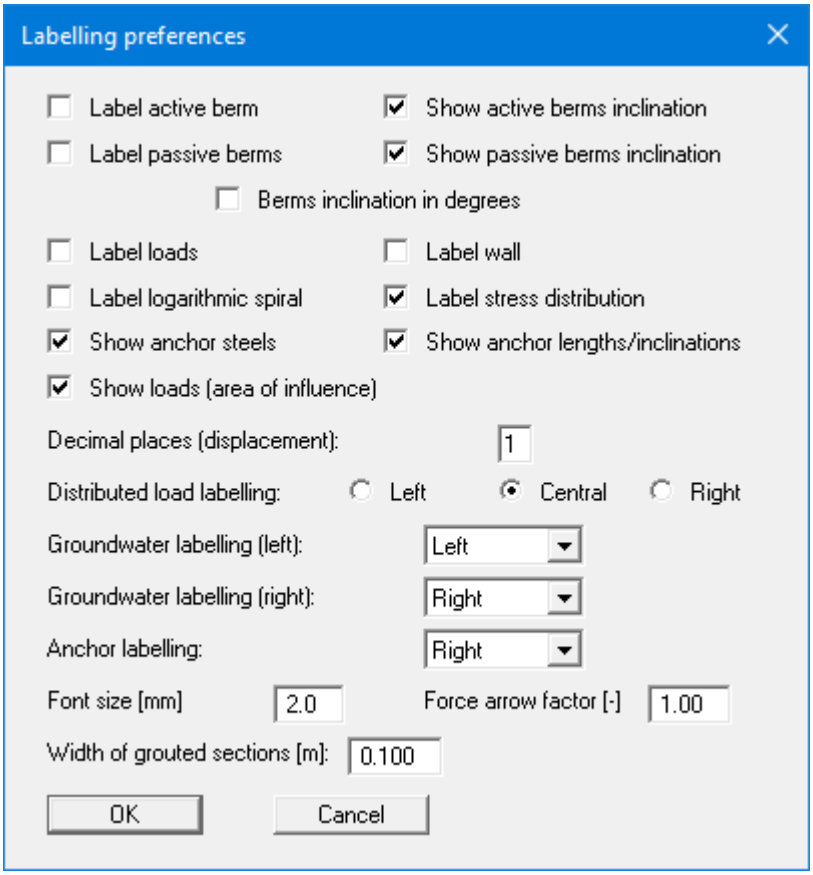
When analysing using ***partial safety factors*** you will also see the group boxes "**Display (earth pressure):**", "**Display (state variables):**" and "**Display (displacement):**", in which you can activate display of the permanent (g) and/or live loads (q). In addition, the design values (d) can be displayed.

You can also specify hatching and the presentation height of loads. If the "**Same height for all**" check box is not selected, load visualisation is based on load size, the height of the presentation indicating the maximum load.

Leave the dialog box by pressing "**Show system**". If the system has already been analysed, you can leave the box by pressing "**Show results**" and then view the result graphics on the screen.

12.9 GGU-CANTILEVER: "Labelling preferences" menu item

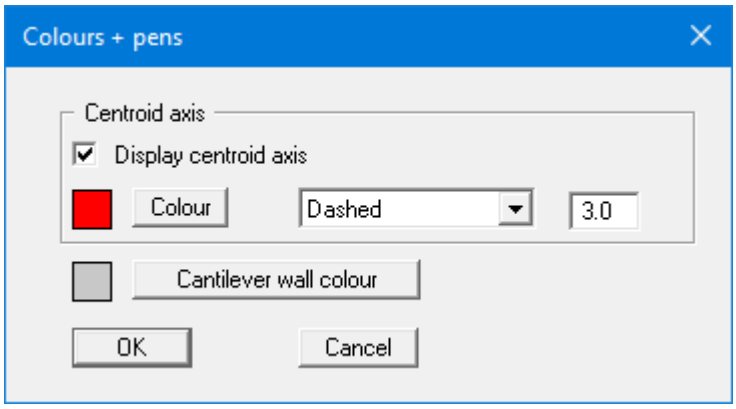
This menu item allows you to specify labelling preferences for the system visualisation and the result graphics.



In the dialog box, you activate the required check boxes and select the preferences for alignment or font sizes. In addition, groundwater labelling and the width of the graphical visualisation of any grouted section can be edited.

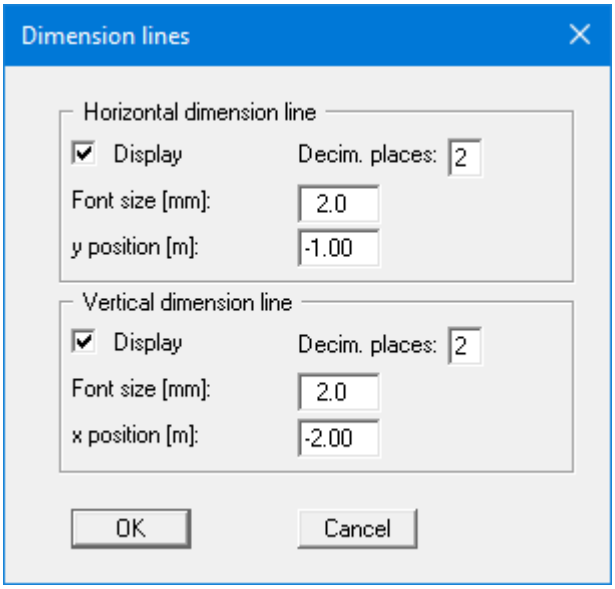
12.10 GGU-CANTILEVER: "Wall pens + colours" menu item

The cantilever wall can be visualised together with the centroid axis. The colour and line type of the centroid axis can be defined if the check box is activated. The cantilever wall colour can be altered to suit requirements using the "**Cantilever wall colour**" button.



12.11 GGU-CANTILEVER: "Dimension lines" menu item

You can include a vertical and/or horizontal dimension line in the graphic to illustrate the system dimensions. If the dimension lines are displayed on the screen, you can also open the following dialog box directly by double-clicking the left mouse button over a dimension line.



The distance to the wall or pile is defined by means of the "**y position**" for the horizontal dimension line and "**x position**" for the vertical dimension line. Negative values define a position above or to the left of the wall or pile. All values are in metres in the scale selected (see the menu item "**Page size + margins/Manual resize (editor)**").

The fastest way to modify the position of the dimension lines is to press the [**F11**] function key and then to pull the legend to the new position with the left mouse button pressed.

12.12 GGU-CANTILEVER: "Display system" menu item

Once a system has been analysed, all the state variables are automatically shown on screen. So as not to overburden the screen, certain elements of the system (for example, surcharges) are no longer shown. If you want to view all the system data without state variables, clicking this menu item will enable you to do so.

12.13 GGU-CANTILEVER: "Display results" menu item

After a system has been analysed, all state variables are automatically presented on the screen. If you used the menu item "**System/Display system**" to return to the system visualisation, you can go to this menu item to return to the result presentation without renewed analysis. Of course, this only works if the system has already been analysed.

13 Evaluation menu

13.1 GGU-CANTILEVER: General notes on evaluation

All the following information regarding the analysis results can be sent to the printer or to a file by going to the menu items "**File/Print and export**" or "**File/Print output table**". However, it is always more desirable to be able to check over the analysis results without wasting a lot of paper. The following menu items were included in the program for just this reason.

13.2 GGU-CANTILEVER: "Earth pressure redistribution" menu item

Here you are provided with information relating to earth pressure redistribution. This can be particularly interesting if you have calculated according to the EAB, in which case it is probably a good idea to have a copy of the EAB at hand.

13.3 GGU-CANTILEVER: "Main output summary" menu item

A message box appears containing the main system analysis parameters. This function can also be initialized pressing the [**F4**] function key.

You are also informed that double-clicking the left mouse button (after you have closed the message box) on any part of the graphics will cause the corresponding state variables to be shown on screen.

13.4 GGU-CANTILEVER: "Interim results" menu item

A message box containing the results described in "**Theoretical principles: Cantilever wall**" is displayed. This function can also be accessed by pressing [**F6**].

13.5 GGU-CANTILEVER: "Bearing capacity" menu item

Here you will obtain information in a message box related to the analysis. This function can also be initialized pressing the [**F7**] function key.

13.6 GGU-CANTILEVER: "Sliding safety" menu item

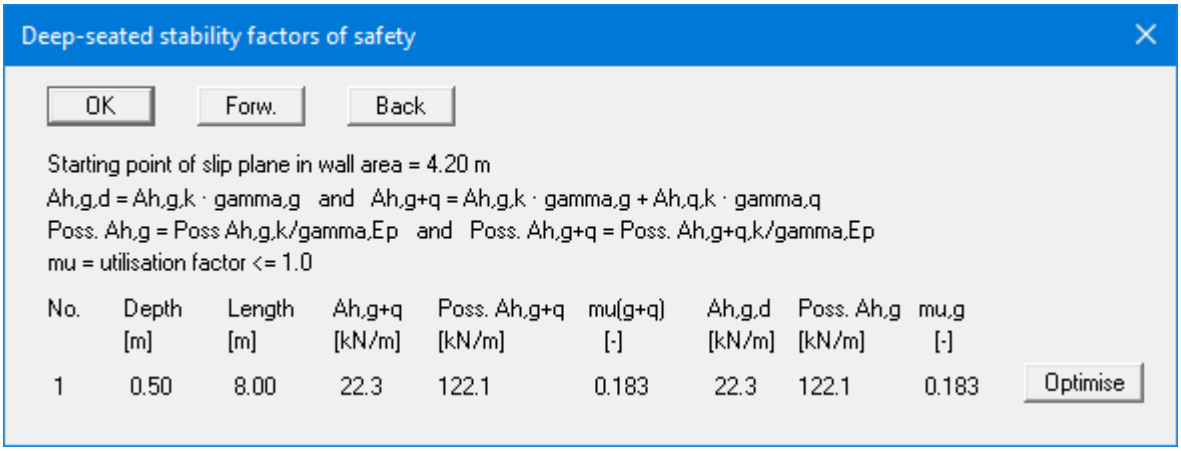
The calculated sliding safety is displayed in a message box.

13.7 GGU-CANTILEVER: "Settlements (evaluation)" menu item

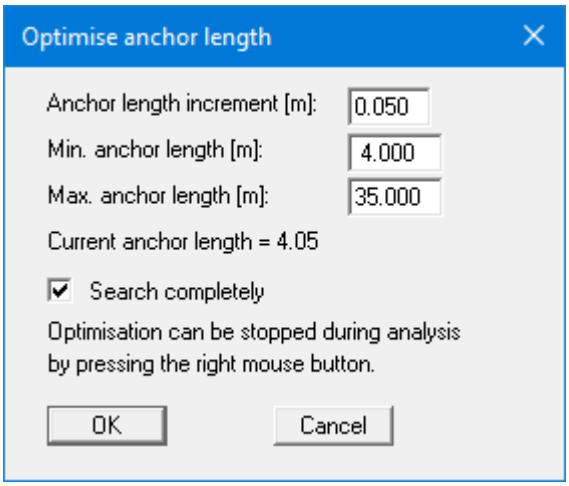
Here you will obtain the results of the settlement analysis displayed in a message box. CP means that the settlements are calculated for the characteristic points. This function can also be initialized pressing the [**F8**] function key.

13.8 GGU-CANTILEVER: "Deep-seated stability summary" menu item

After the state variables have been calculated by the program, and depending on the safety factors selected, the deep-seated stability safety factor or the utilisation factor of any anchor is automatically determined.



In addition to the information with regard to the anchors, the critical utilisation factor for deep-seated stability for each anchor is given. In the example shown here, the anchor has an utilisation factor 0.183 which is below the required value of 1.0. Select the "**Optimise**" button to optimise the length of the anchor.



By activating the "**Search completely**" button the optimum is searched for between the minimum and the maximum anchor length (***recommended setting!***). Otherwise, an optimum is searched for based on the current neighbouring anchor lengths. Because interaction occurs between anchors if more than one anchor is involved, it is possible for other anchors to fall below the required safety factor during the optimisation. These anchors must then be ***subsequently optimised***.

13.9 GGU-CANTILEVER: "Hydraulic heave FOS summary" menu item

You obtain all data relating to verification of hydraulic heave safety displayed in a message box (see "**Theoretical principles: Hydraulic heave**").

13.10 GGU-CANTILEVER: "Buoyancy FOS summary" menu item

You obtain all data relating to verification of buoyancy safety displayed in a message box (see "**Theoretical principles: Buoyancy**").

13.11 GGU-CANTILEVER: "Anchor and strut summary" menu item

Here the design values for all the system's anchors and struts are shown in a message box.

13.12 GGU-CANTILEVER: "Heave of anchor soil" menu item

This menu item displays the results in a message box. Verification must be activated, of course, (see menu item "**Editor 1/Deep-seated stability/Heave of anchor soil**").

13.13 GGU-CANTILEVER: "EQU analysis" menu item

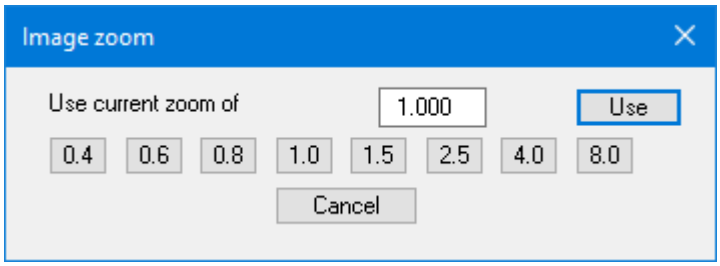
All the necessary data on the analysis of the static equilibrium limit state are displayed in a message box.

14 Graphics preferences menu

14.1 GGU-CANTILEVER: "Refresh and zoom" menu item

The program works on the principle of ***What you see is what you get***. This means that the screen presentation represents, overall, what you will see on your printer. In the last consequence, this would mean that the screen presentation would have to be refreshed after every alteration you make. For reasons of efficiency and as this can take several seconds for complex screen contents, the screen is not refreshed after every alteration.

If, e.g., after using the zoom function (see below), only part of the image is visible, you can achieve a complete view using this menu item.

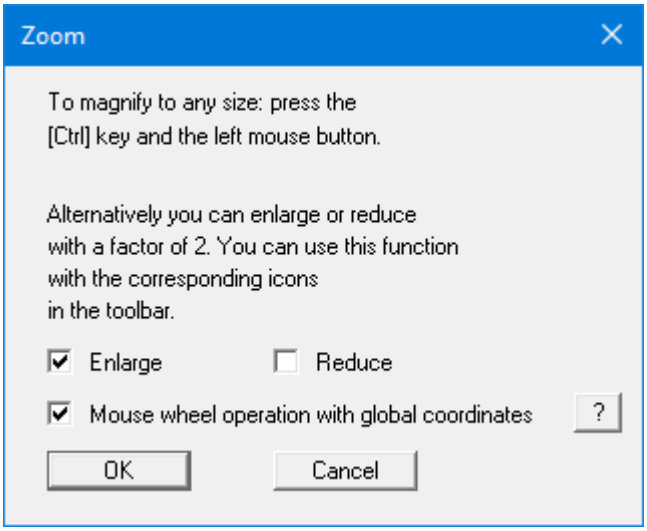


A zoom factor between 0.4 and 8.0 can be entered in the input box. By then clicking on "**Use**" to exit the box the current factor is accepted. By clicking on the "0.4", "0.6", etc. buttons, the selected factor is used directly, and the dialog box closed.

It is much simpler, however, to get a complete overview using [**Esc**]. Pressing [**Esc**] allows a complete screen presentation using the zoom factor specified in this menu item. The [**F2**] key allows screen refreshing without altering the coordinates and zoom factor.

14.2 GGU-CANTILEVER: "Zoom info" menu item

An info box informs you about the activation and possibilities of the zoom functions.



A quick way to enlarge a specific section of the screen is to open a magnifying glass window by holding down the [**Ctrl**] key and the mouse button.

A quicker way to zoom in and out of the system graphics is to use the mouse wheel. When the program is started for the first time, the default setting for mouse wheel operation is activated according to Windows conventions.

If you want to change the system coordinates and the scale of your system using the mouse wheel, activate the "**Mouse wheel operation with global coordinates**" check box. If you close the program with this setting, the setting is still activated the next time you start it.

The functions via the mouse wheel can be found in the chapter "**Tips and Tricks: Keyboard and Mouse**".

14.3 GGU-CANTILEVER: "Legend font selection" menu item

With this menu item you can switch to a different true-type font. All available true-type fonts are displayed in the dialog box.

14.4 GGU-CANTILEVER: "Pen colour and width" menu item

In order to enhance the clarity of the graphics you can preset the pen settings for various graphic elements in the GGU programs.

You can change the pen widths for the elements listed in the dialog box and adjust the pen and/or fill colours by clicking on the button with the element name. In some GGU programs you can also define a line colour for selected elements.

For the graphic output of colours on ***monochrome printers*** (e.g. laser printers), colours are replaced by an equivalent shade of grey. In the case of very light colours, the corresponding graphic elements are then barely visible on the printer. In such cases, it makes sense to change the colour setting to darker colours.

14.5 GGU-CANTILEVER: "Mini-CAD toolbar" and "Header toolbar" menu items

Using this menu item you can add free text, lines, circles, polygons and images (e.g. files in formats BMP, JPG, PSP, TIF, etc.) to the main program graphics. PDF files can also be imported as images. A pop-up menu opens, the icons and functions used are described in more detail in the **Mini-CAD manual**.

The differences between the Mini-CAD and Header CAD are as follows:

- Drawing objects created with **Mini-CAD** refer to the coordinate system (generally in [m]) in which the drawing is created and are displayed accordingly. You should therefore select this menu item if you wish to enter additional information on the system. These objects can be saved in a "**.mcd**" file using the

  icon in the pop-up menu and loaded as such in other GGU programs using the

  icon in the pop-up menu.
- Drawing objects created with the **Header CAD** refer to the sheet format (in [mm]). They therefore always remain at the same sheet position, regardless of the coordinate system of the measuring points. You should select this menu item if you want to enter general information on the drawing (e.g. company logo, report number, system number, stamp). If you save this so-called header data in a "**.kpf**" file using the icon

  in the pop-up menu, you can reload this header data for a completely different system (with different system coordinates) and also in other GGU programs using the icon

  in the pop-up menu. The saved header data can then be found in the same position. This considerably simplifies the creation of general sheet information.

14.6 GGU-CANTILEVER: "Toolbar preferences" menu item

After starting the program, a horizontal toolbar for menu items appears below the program menu bar. If you would rather work with a popup window with several columns, you can specify your preferences using this menu item. The smart icons can also be switched off.

At the bottom of the program window, you find a status bar with further information.
You can also activate or switch off the status bar here. The preferences will be saved in the "**GGU-CANTILEVER.alg_wst**" file (see menu item "**Graphics preferences/Save graphics preferences**") and will be active at the next time the program is started.

By clicking on the tools (smart icons) for the menu items you can directly reach most of the program functions. The meaning of the smart icons appears as a text box if you hover with the mouse pointer over the tools. Some of the tool functions cannot be called up via normal menu titles and menu entries.

Not all of the icons described below are available in all GGU programs.

"**Next page**"/"**Previous page**"
You can use these icons to scroll forwards and backwards between individual pages. In many GGU programs, you can use this in the ***output table representation***.

"**Select page**" or "**Diagram/Output table**"
If you are in the ***output table representation***, you can use this symbol to jump to a specific page or switch back to the normal display, i.e. your graphic display.

"**Zoom out**"
If you have previously zoomed in, this tool returns to a full screen display.

"**Zoom (-)**"/"**Zoom (+)**"
With the zoom functions you can zoom in or out of parts of the image, by clicking the left mouse button.

"**Copy/print area**"
Use this tool to copy only parts of the graphics in order to paste them, e.g. to a report. You will see information on this function and can then mark an area, which is copied to the clipboard or can be saved in a file. Alternatively, you can send the marked area directly to your printer (see "**Tips and tricks**").

"**Colour on/off**" or "**Colour/hatching**"
If you want to remove the colour from the system display, e.g. to create a black and white printout, you can do this using this on/off switch.
In several GGU programs, 4 colour and hatching settings are possible via this icon, which you can click through in sequence. A colour filled representation is the default setting, the next click shows the hatching, then coloured and hatched. The fourth click shows a representation with neither colour nor hatching. The next click starts again.

"**Move object**"
Use this icon to position legends and diagrams at the desired position on the output sheet.

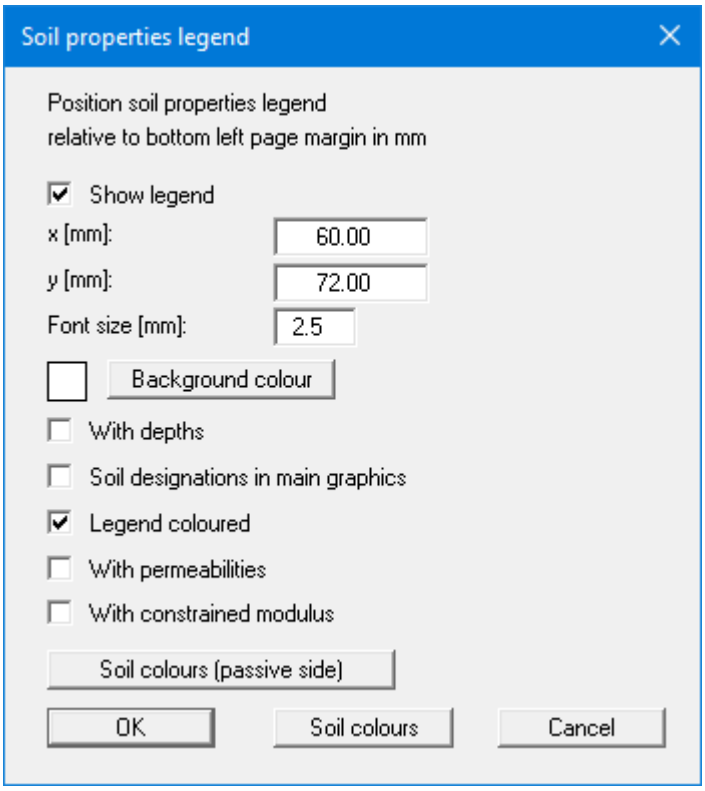
"**Undo move object**"
By clicking this icon the last performed movement of graphical elements made using the [F11] function key or the menu item "**Output preferences/Move objects**" can be undone.

"**Restore move object**"
By clicking this symbol, the last object movement undo carried out using "Undo move object" can be restored.

“**Construction phase back**”/”**Construction phase forward**”
If you are in the display of construction phases, you can use these icons to scroll back and forth between the individual construction phases.

14.7 GGU-CANTILEVER: "Soil properties legend" menu item

A legend with the soil properties of the individual layers will be displayed on your output sheet. If you have activated the "**Show legend**" check box, you can alter the type of visualisation using the dialog box of this menu item.



You can define and edit the position of the legend using the values "**x**" and "**y**". You can control the size of the legend via the "**Font size**" and "**Max. no. of lines**"; if necessary, the legend is displayed in several columns. You can also define a background colour in some legends.

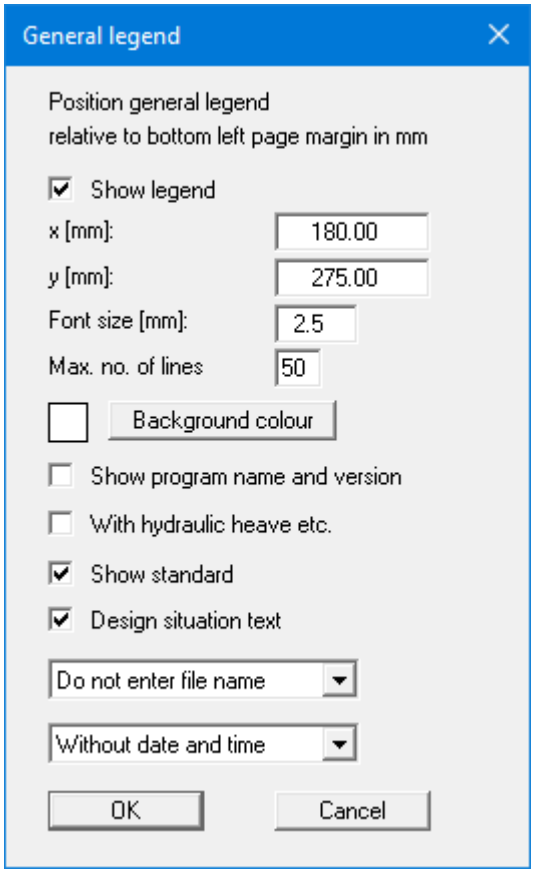
The fastest way to modify the position or size of the legend is to press the [**F11**] function key and then to either pull the legend to the new position or to move the sides of the legend to their new size with the left mouse button pressed.

- "**Background colour**"
  Using this button you can define the background colour for the legend.
- "**With depths**"
  The depths of the individual soil layers will be shown in the soil properties legend.
- "**Soil designations in main graphics**"
  The designations entered for the individual ground layers are displayed in the system graphics adjacent to the layer depths.
- "**Legend coloured**"
  The soil colours are displayed in the legend. Otherwise, they will be numbered.
- "**With permeabilities**"
  The k-values of the individual soil layers will be shown in the soil properties legend.
- "**With constrained modulus**"
  The constrained modulus of the individual soil layers will be shown in the soil properties legend.

- "**Soil colours**"/"**Soil colours (passive side)**"
  You will see a dialog box, in which you can define your preferences. After clicking the button with the desired number, you can assign each soil layer a new number or reorganise using the "**Soil colours/Reorganise**" command button. You can save your colour preferences to a file with "**Soil colours/Save**" and use them for different systems by means of the "**Soil colours/Load**" command button. In the lower group box, you can also transfer the colour preferences to the Windows colour management dialog box, or vice versa, as user-defined colour preferences for example. You can read a further description by pressing the "**Info**" button.

14.8 GGU-CANTILEVER: "General legend" menu item

A legend with general properties will be displayed on your output sheet, if the "**Show legend**" check box is activated. You can alter the type of visualisation using the dialog box of this menu item.



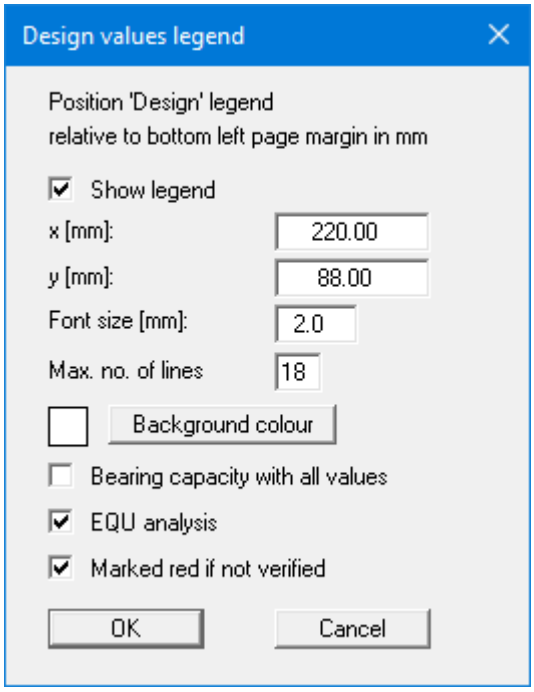
You can define and edit the position of the legend using the values "**x**" and "**y**". You can control the size of the legend via the "**Font size**" and "**Max. no. of lines**"; if necessary, the legend is displayed in several columns. You can also define a background colour in some legends.

The fastest way to modify the position or size of the legend is to press the [**F11**] function key and then to either pull the legend to the new position or to move the sides of the legend to their new size with the left mouse button pressed.

In the ***General legend*** you can, if wished, display information on the program (name and version), on the adopted standard and on the current file (name, path, time info). Any project identification entered in the "**File/New**" or "**Editor 1/Analysis options**" dialog box will also be shown in the General legend , as well as the hydraulic heave if the appropriate check box is activated.

14.9 GGU-CANTILEVER: "Design legend" menu item

Following analysis and design a legend containing the principal system design results is displayed on the screen. Using this menu item, you can alter the type of presentation if the "**Show legend**" check box is activated.



You can define and edit the position of the legend using the values "**x**" and "**y**". You can control the size of the legend via the "**Font size**" and "**Max. no. of lines**"; if necessary, the legend is displayed in several columns. You can also define a background colour in some legends.

The fastest way to modify the position or size of the legend is to press the [**F11**] function key and then to either pull the legend to the new position or to move the sides of the legend to their new size with the left mouse button pressed.

The number of values displayed in the graphical design legend can be influenced using the lower check boxes. These values are automatically contained in the output table that can be opened using the "**File/Print output table**" menu item.

14.10 GGU-CANTILEVER: "Settlement legend" menu item

Following analysis and design a legend containing the principal results of the settlement analysis is displayed on the screen. Amongst other things, the share of the settlement for each individual layer can be taken from this legend. Using this menu item, you can alter the type of presentation if the "**Show legend**" check box is activated. You can also display the footing rotation.

You can define and edit the position of the legend using the values "**x**" and "**y**". You can control the size of the legend via the "**Font size**" and "**Max. no. of lines**"; if necessary, the legend is displayed in several columns. You can also define a background colour in some legends.

The fastest way to modify the position or size of the legend is to press the [**F11**] function key and then to either pull the legend to the new position or to move the sides of the legend to their new size with the left mouse button pressed.

14.11 GGU-CANTILEVER: "Move objects" menu item

If you select this entry, you can then use the mouse to move the various objects and legends. Move the mouse over the object of your choice. If you are over a movable object, the mouse pointer will take on the shape of a cross. Now press the left mouse button and drag the object to the desired position while holding down the button.

After going to this menu item **only one object** at a time can be moved using the mouse or its size be altered.

If you want to edit several objects, you can also activate the function more quickly by pressing the [**F11**] key or the symbol

. An info box will then no longer appear.

In many GGU programs you can also alter the size of an object using this menu item or the [**F11**] function key. If you are positioned over the frame of a resizable object after activating the function, the mouse takes on the shape of a double arrow. Hold down the left mouse button and drag the frame until the object has reached the desired size. Drag a corner to maintain the aspect ratio of the sides. If you drag on one side, the object becomes taller or wider.

Using the [**Back**] key or by clicking on the icon

you can undo the last change to the position or size of an object.

In programs in which you can position the diagrams yourself (menu item "**System/Graph positioning preferences**"), the result diagrams can also be moved using this function if you have switched to "**Manual graph positioning**".

If "**Manual graph positioning**" has been selected in the "**System/Graph positioning preferences**" menu item, the result graphs can also be repositioned using this function.

14.12 GGU-CANTILEVER: "Save graphics preferences" menu item

Some of the preferences you made with the menu items of the "**Graphics preferences**" menu can be saved to a file. If you select "**GGU-CANTILEVER.alg_wst**" as file name and save the file on the same level as the program, the data will be automatically loaded the next time the program is started and need not be entered again.

If you do not go to "**File/New**" upon starting the program, but open a previously saved file instead, the preferences used at the time of saving are shown. If subsequent changes in the general preferences are to be used for existing files, these preferences must be imported using the menu item "**Graphics preferences/Load graphics preferences**".

14.13 GGU-CANTILEVER: "Load graphics preferences" menu item

You can reload a graphics preferences file into the program, which was saved using the "**Graphics preferences/Save graphics preferences**" menu item. Only the corresponding data will be refreshed.

15 Page size + margins menu

15.1 GGU-CANTILEVER: "Auto-resize" menu item

This menu item provides a to-scale visualisation, in both x and y coordinates, of the system and result graphics. If you have previously altered the image coordinates graphically or via editor, you can quickly achieve a complete view using this menu item.

This function can also be accessed using the [**F9**] function key.

15.2 GGU-CANTILEVER: "Manual resize (mouse)" menu item

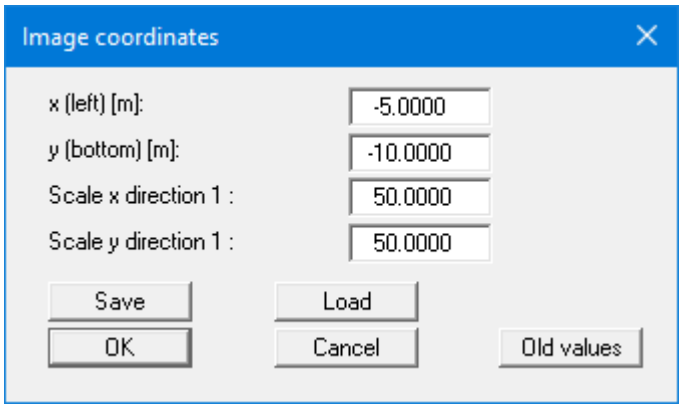
You can transfer the coordinates of a section of your previous graphic display as new image coordinates by holding down the [**Ctrl**] and [**Shift**] keys and marking the desired area with the left mouse button. The scales of the x-direction and y-direction are adjusted accordingly.

In the default setting, the "**Proportional section**" check box is activated. This retains the previous proportions (scale x-direction/scale y-direction).

If you activate the "**Redefine origin**" check box, you can adjust the image coordinates without changing the scale. In this way, you can quickly achieve the desired visualisation without having to try out the x/y coordinates if the scale is set appropriately.

15.3 GGU-CANTILEVER: "Manual resize (editor)" menu item

You can alter the current image coordinates by direct numerical input in a dialog box. This allows precise scale input. The coordinates refer to the drawing area. This can be defined in the "**Page size + margins/Page size and margins**" menu item by means of the plot margins.



The image coordinates entered here can be saved in a file with the extension "**.bxy**" and be reloaded later for the same file or for different files.

If you want to recover the previous values during input or use the menu item again after editing the coordinates, you can do this by pressing the "**Old values**" button.

15.4 GGU-CANTILEVER: "Zoom" menu item

You can enlarge or reduce the graphical representation by a fixed value by entering the required factor in the dialog box.

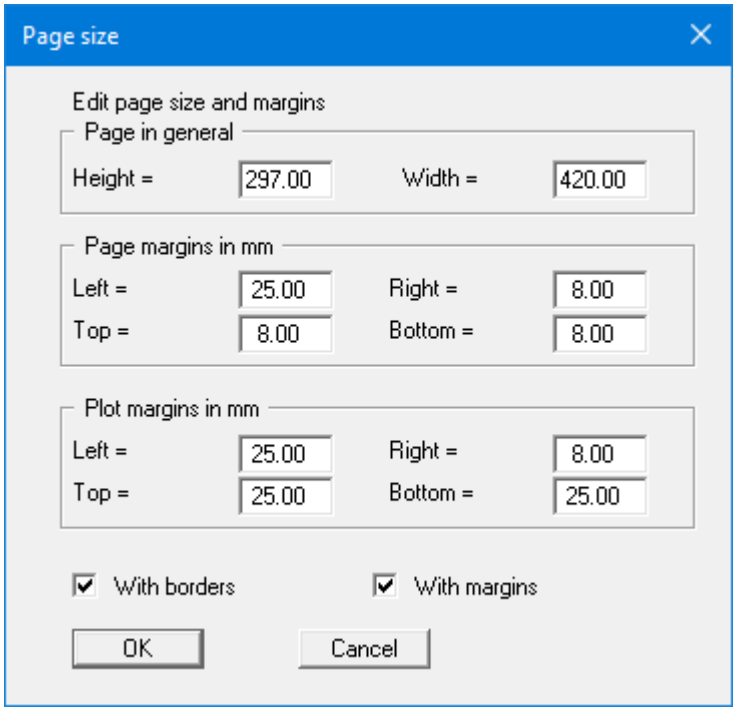
15.5 GGU-CANTILEVER: "Font size selection" menu item

You can edit font sizes for labelling the various drawing elements.

The font sizes of text within legends are edited in the respective legend editor. Just double-click in a legend to do this.

15.6 GGU-CANTILEVER: "Page size and margins" menu item

The default page set-up is A3 when the program is started. You can edit the page format in the following dialog box.



- "**Page in general**" defines the size of the output sheet. The A3 format is set as default. The program automatically draws thin cutting borders around the page, which are required when using a plotter on paper rolls. The borders can be switched off deactivating the "**With borders**" check box.
- "**Page margins**" define the position of a frame as a distance to the margins. This frame encloses the subsequent diagram. You can switch off the frame deactivating the "**With margins**" check box.
- The "**Plot margins**" define a set distance between the page margin and the actual ***drawing area*** in which the graphical evaluation of your input is presented.

15.7 GGU-CANTILEVER: "Undo" menu item

If you have carried out any changes to dialog boxes or moved objects to a different position on the screen after selecting the "**Graphics preferences/Move objects**" menu item or using the [**F11**] function key, this menu item will allow you to undo the movements.

This function can also be reached by using the key combination [**Alt**] + [**Back**] or the icon

in the toolbar.

15.8 GGU-CANTILEVER: "Restore" menu item

When this menu item is selected the last change made in a dialog box or the last change in the position of objects, which you undid using the menu item "**Page size + margins/Undo**" will be restored.

This function can also be reached by using the key combination [**Ctrl**] + [**Back**] or the icon

in the toolbar.

15.9 GGU-CANTILEVER: "Preferences" menu item

You can activate or deactivate the undo functions.

16 Info menu

16.1 GGU-CANTILEVER: "Copyright" menu item

You will see a copyright message and information on the program version number.

The "**System**" button shows information on your computer configuration and the folders used by the GGU program.

16.2 GGU-CANTILEVER: "Maxima" menu item

Here you can check the defaults for maximum values.

16.3 GGU-CANTILEVER: "Compare earth pressure coefficients" menu item

Here you can calculate the earth pressure coefficients for given values of phi, delta and beta.

16.4 GGU-CANTILEVER: "Help" menu item

You will be directed to the homepage of the online manual for the GGU program. The help function can also be accessed using the [**F1**] function key.

16.5 GGU-CANTILEVER: "GGU on the web" menu item

Using this menu item, you can access the **GGU Software website**.

Check the page of your program module at regular intervals for information about updates and changes. On the "**Changelogs**" subpage, you can also subscribe to an e-mail notification that informs you of all changes on a monthly basis.

16.6 GGU-CANTILEVER: "GGU support" menu item

This menu takes you directly to the **GGU Software Support Portal**.

Here you can enter your support request directly and upload your edited GGU program file.

16.7 GGU-CANTILEVER: "What's new?" menu item

You will see information on program improvements in comparison to older versions.

16.8 GGU-CANTILEVER: "Language preferences" menu item

This menu item allows you to switch the menus and the graphics from German to English and vice versa. To work in German, deactivate the two check boxes "**Dialoge + Menüs übersetzen (translate dialogues, menus)**" und "**Graphiktexte übersetzen (translate graphics)**".

Alternatively, you can work bilingually, e.g. with German dialog boxes but with graphic output in English. The program always starts with the language setting applicable when it was last ended.