Design of a cantilever wall

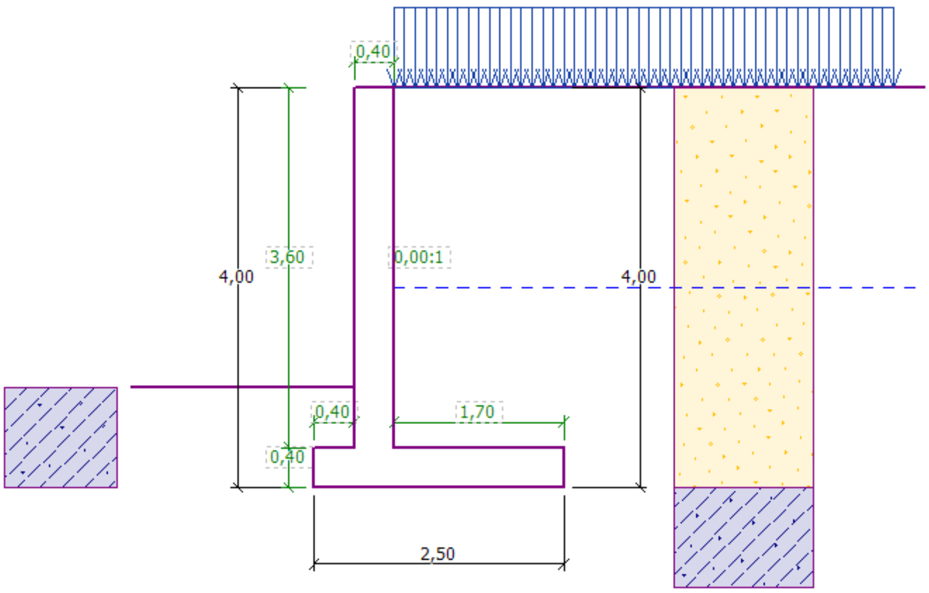
Program: Cantilever wall

File: Demo_manual_02.guz

This engineering manual describes how to design and analyze a cantilever wall.

Assignment:

Design a cantilever wall with a height of 4,0 m and analyze it according to EN 1997-1 (EC 7-1, Design approach 1). The terrain behind the structure is horizontal. The ground water table is 2,0 m deep under the surface. Behind the wall acts a strip surcharge with a length of 5,0 meters and a magnitude of 10 kN/m^2. The foundation soil consists of MS – Sandy silt, the allowable bearing capacity is 175 kPa. The soil behind the wall will consist of S-F – Sand with trace of fines. The cantilever wall will be made of reinforced concrete of class C 20/25.



Scheme of the cantilever wall – Assignment

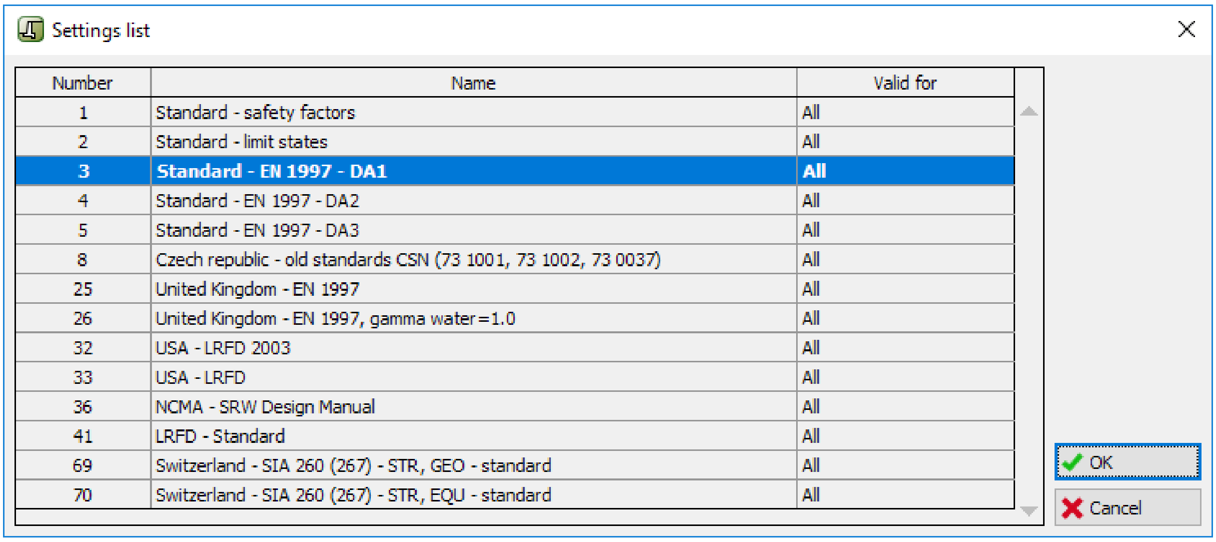
The parameters of the soils are defined as follows:

Soil	Profile $[m]$	Unit weight $\gamma\ [kN/m^3]$	Angle of internal friction $\varphi_{ef}\ [^\circ]$	Cohesion of soil $c_{ef}\ [kPa]$	Angle of friction structure – soil $\delta = [^\circ]$	Saturated unit weight $\gamma_{sat}\ [kN/m^3]$
S-F	0,0 – 4,0	17,5	28,0	0,0	18,5	18,0
MS	from 4,0	18,0	26,5	30,0	17,5	18,5

Solution

To solve this problem, we will use the GEO5 "Cantilever wall" program. In the following text, we will explain the solution step by step.

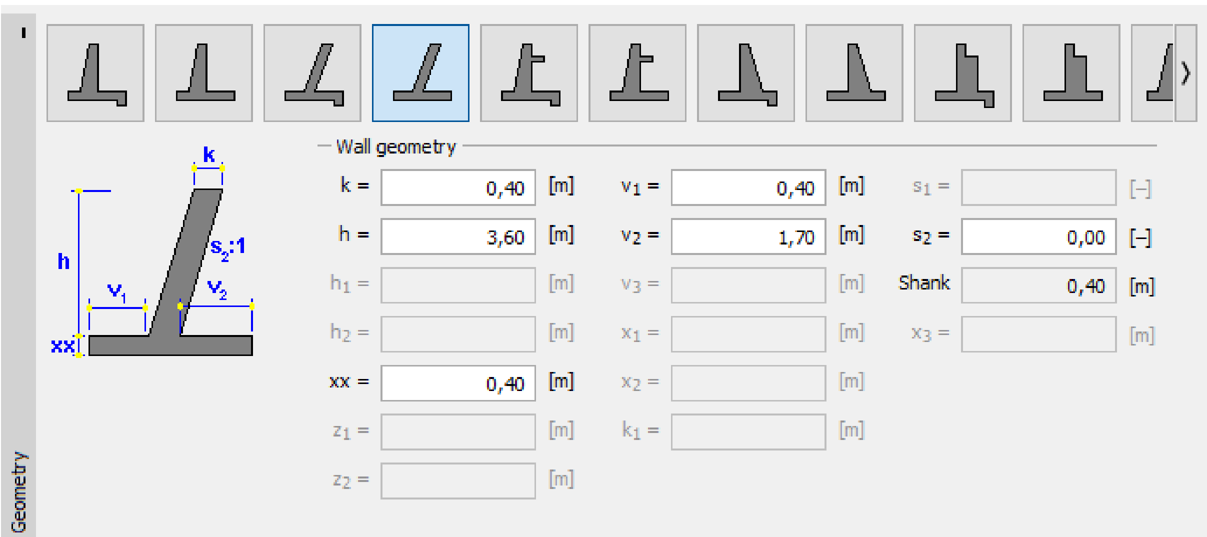
Firstly, in the frame "Settings" click on "Select settings" and choose analysis setting No. 3 – "Standard – EN 1997 – DA1".



Number	Name	Valid for
1	Standard - safety factors	All
2	Standard - limit states	All
3	Standard - EN 1997 - DA1	All
4	Standard - EN 1997 - DA2	All
5	Standard - EN 1997 - DA3	All
8	Czech republic - old standards CSN (73 1001, 73 1002, 73 0037)	All
25	United Kingdom - EN 1997	All
26	United Kingdom - EN 1997, gamma water=1.0	All
32	USA - LRFD 2003	All
33	USA - LRFD	All
36	NCMA - SRW Design Manual	All
41	LRFD - Standard	All
69	Switzerland - SIA 260 (267) - STR, GEO - standard	All
70	Switzerland - SIA 260 (267) - STR, EQU - standard	All

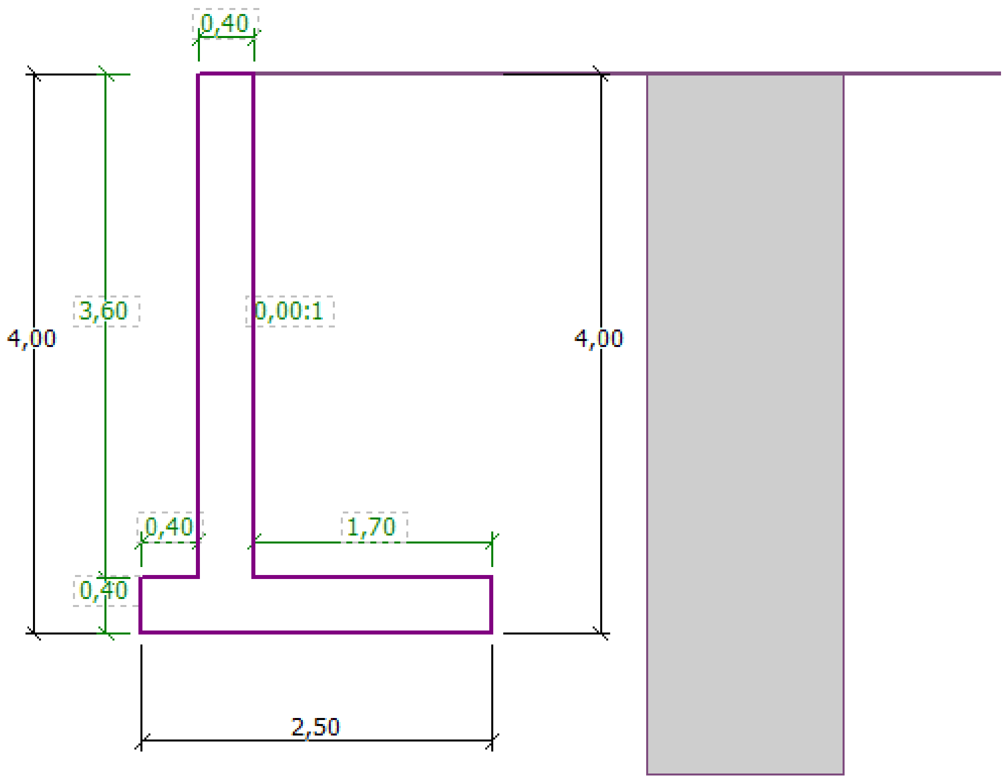
Dialog window "Settings list"

In the frame "Geometry" choose the 4th shape and enter its dimensions as shown in the picture.



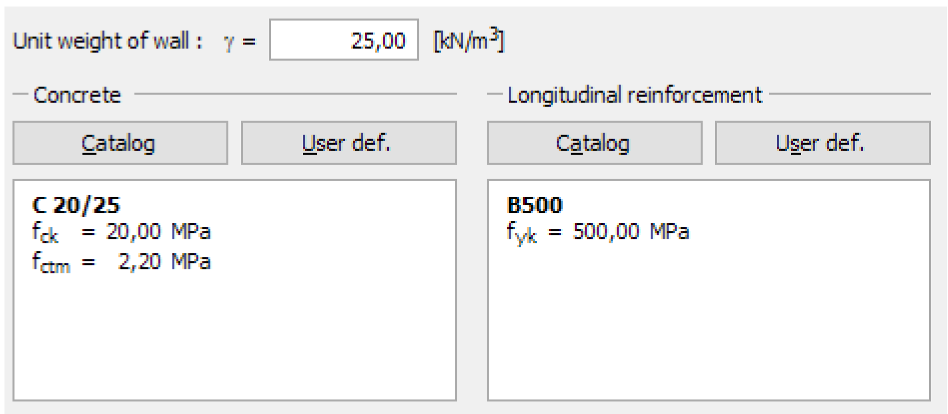
Frame "Geometry"

The structure now looks like this:



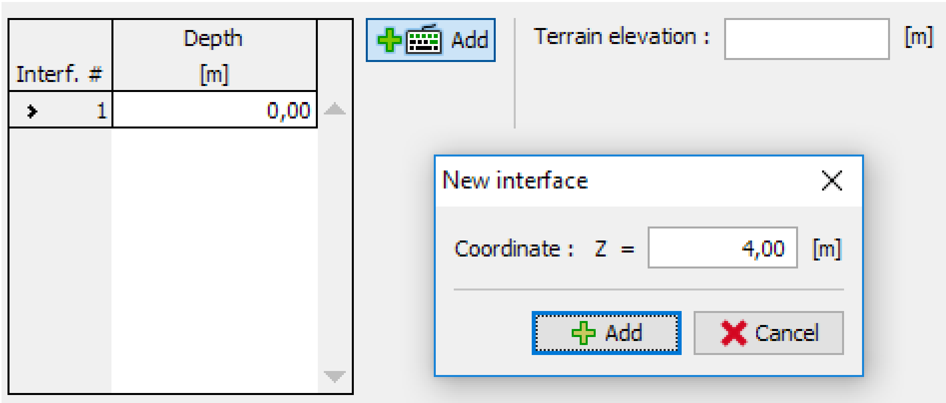
Frame "Geometry" – scheme of the cantilever wall

In the frame "Material" enter the material of the wall. The wall will have a unit weight of $\gamma = 25\ \mathrm{kN/m^3}$ and it will be made from concrete of class C 20/25 and steel of class B500.



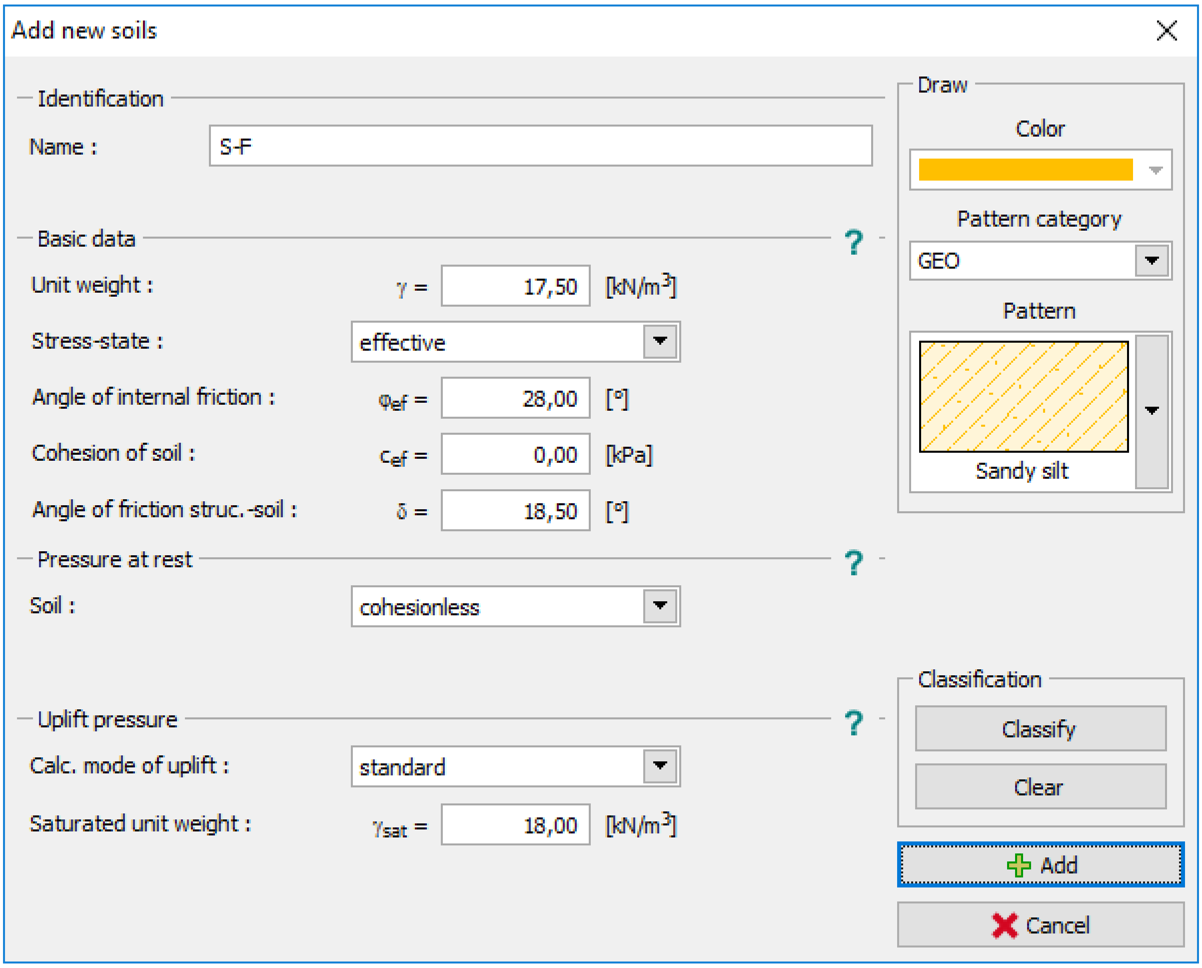
Frame "Material" – Input of material characteristics of the structure

In the frame "Profile", we define the soil interference at a depth of 4 m using the "Add" button.

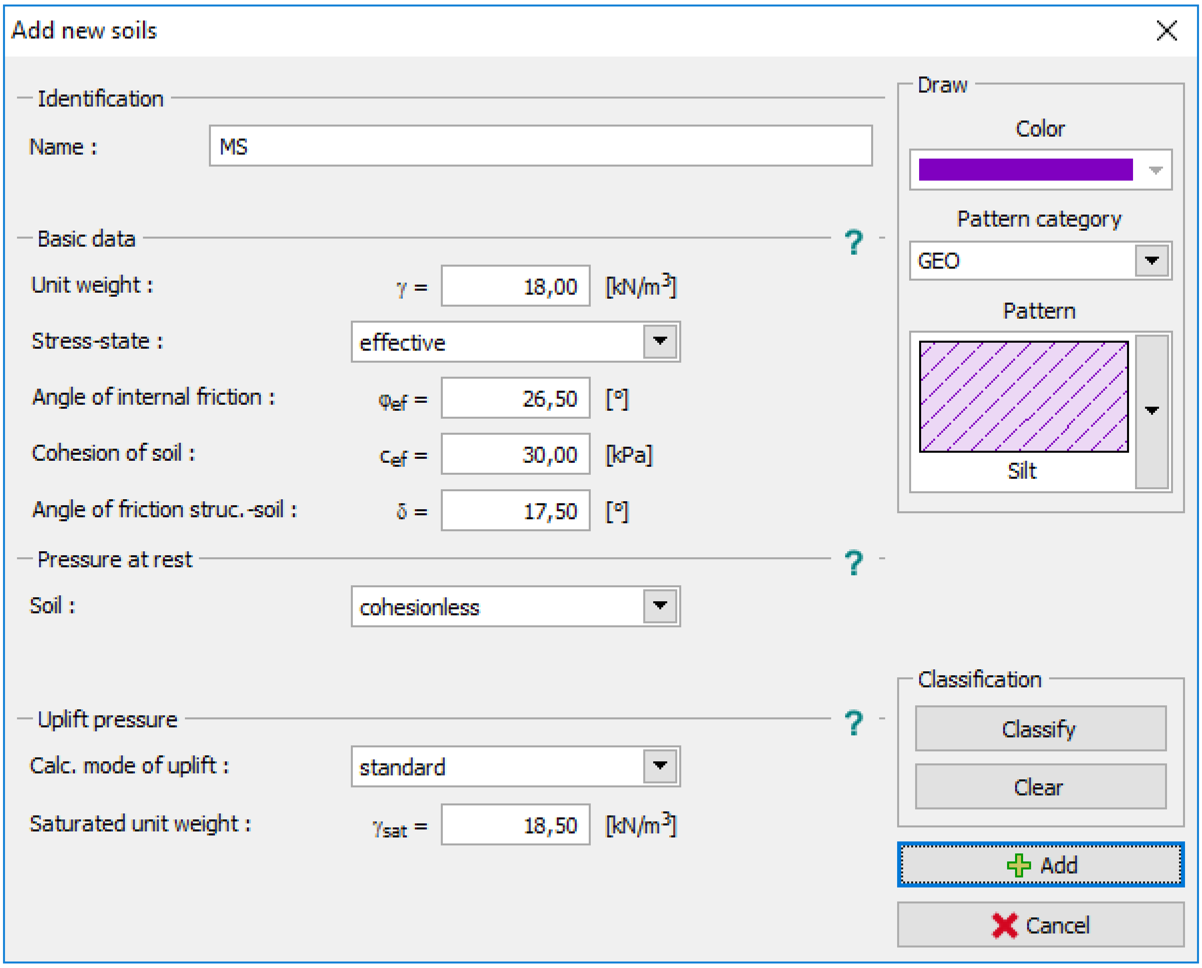


Frame "Profile"

Then, we will move to the frame "Soils". Here, we will define the parameters of the soils, as shown in the following pictures, by clicking the button "Add". Firstly, we will add the S-F soil, which will be behind the wall. Next, we will add the MS soil, which will form the foundation.



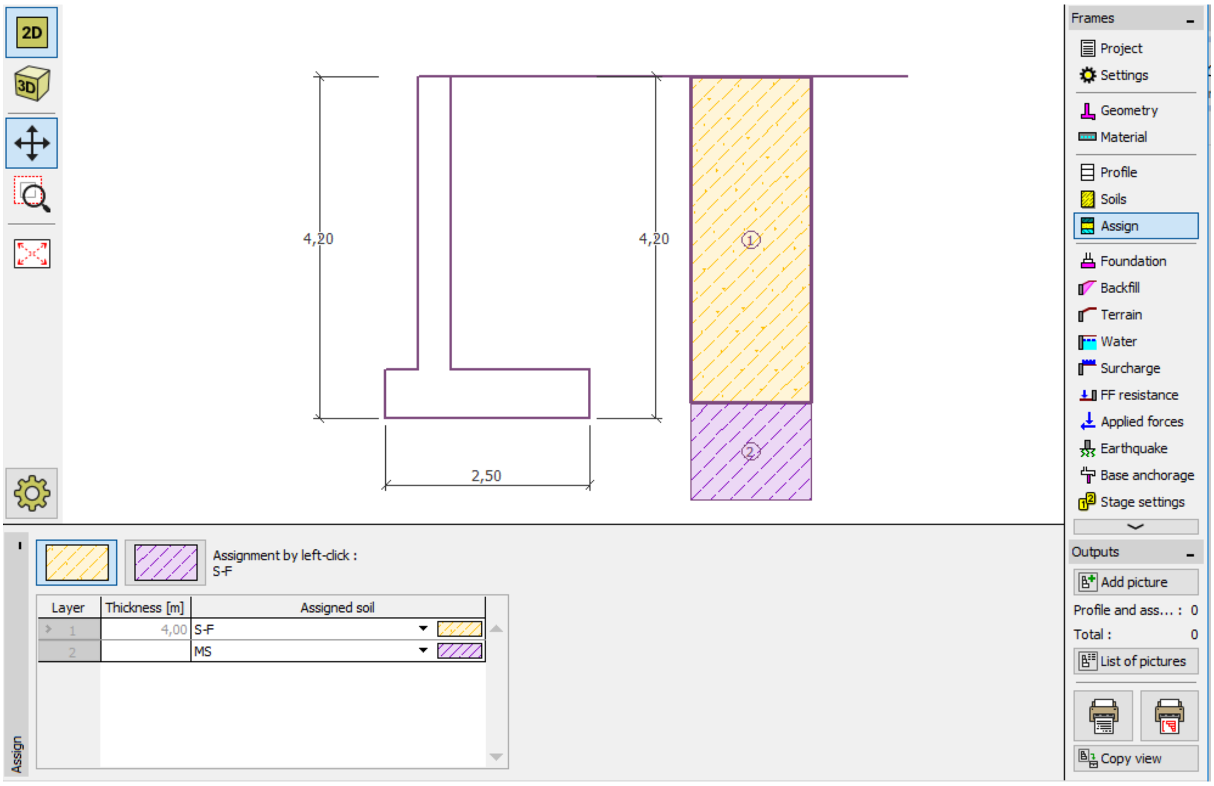
Dialog window "Add new soils" – adding soil S-F



Dialog window "Add new soils" – adding soil MS

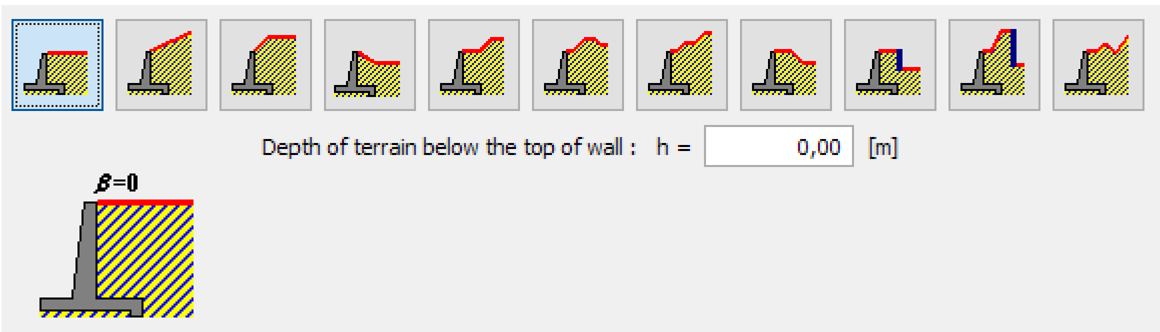
Note: The magnitude of the active pressure also depends on the friction between the structure and the soil. The friction angle depends on the material of the structure and the angle of internal soil friction – normally entered in the interval $\delta \approx \left(\frac{1}{3} \div \frac{2}{3} \right) \cdot \varphi_{ef}$

We assign the soils to the geological layers in the frame “Assignment”.



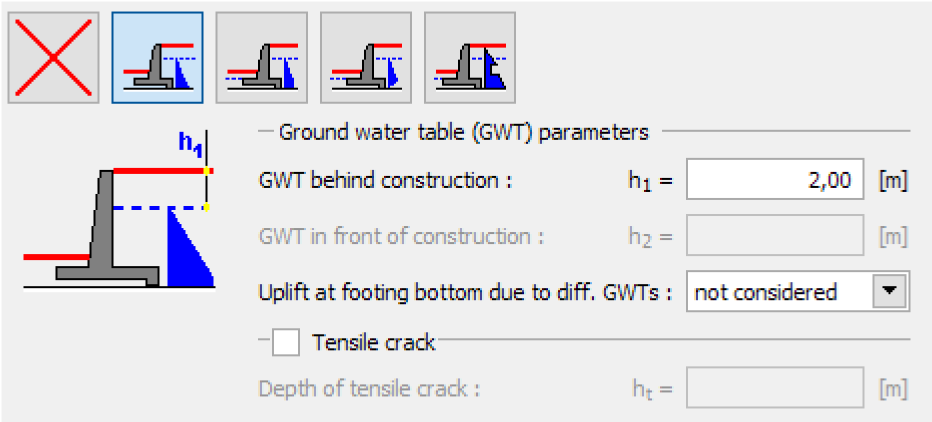
Frame “Assignment”

In the frame “Terrain” choose the horizontal terrain shape.



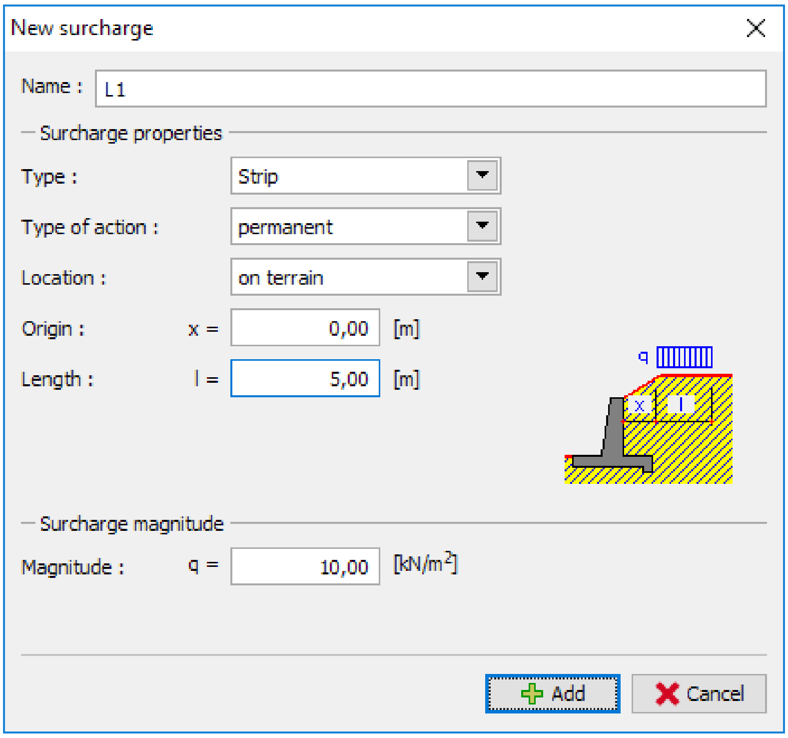
Frame “Terrain”

The ground water table is in a depth of 2,0 meters. Therefore, we will move on to the frame “Water” and select the type of water close to the structure and its parameters, as shown in the picture below.



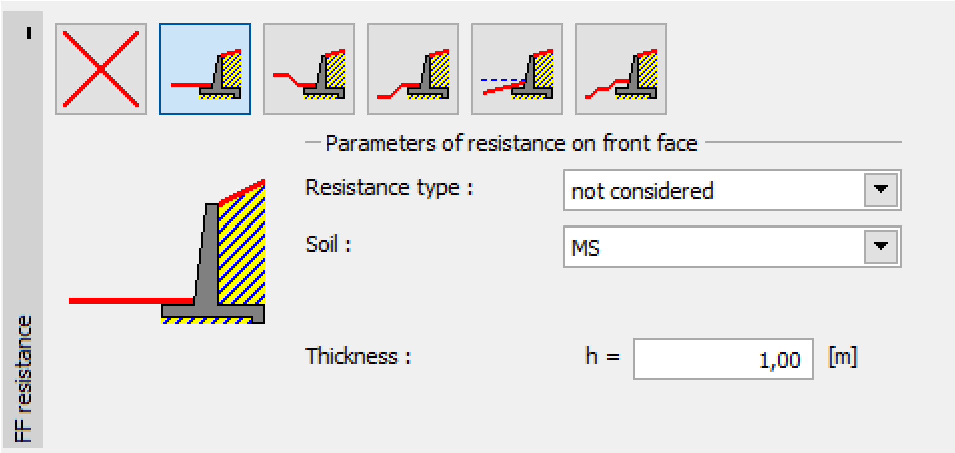
Frame "Water"

Then, move on to the frame "Surcharge". Here, select permanent strip surcharge with a magnitude of 10 kN/m^3 acting as a dead load on the terrain.



Dialog window "New surcharge"

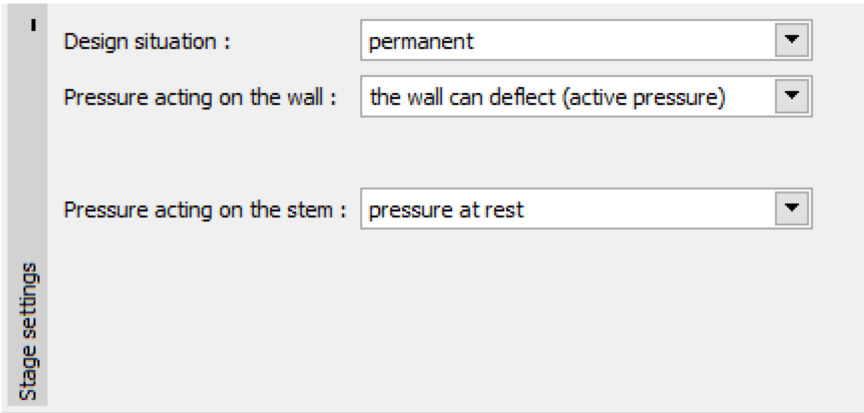
In the frame "FF resistance" select the terrain shape in front of the wall and then define other parameters of the resistance on the front face.



Frame "FF resistance"

Note: In this case, we do not consider the resistance on the front face, so the results will be conservative. The FF resistance depends on the quality of the soil and the allowable displacement of the structure. We can consider the pressure at rest for the original soil, or well compacted soil. It is only possible to consider passive pressure if displacement of the structure is allowed. (for more information, see HELP – F1)

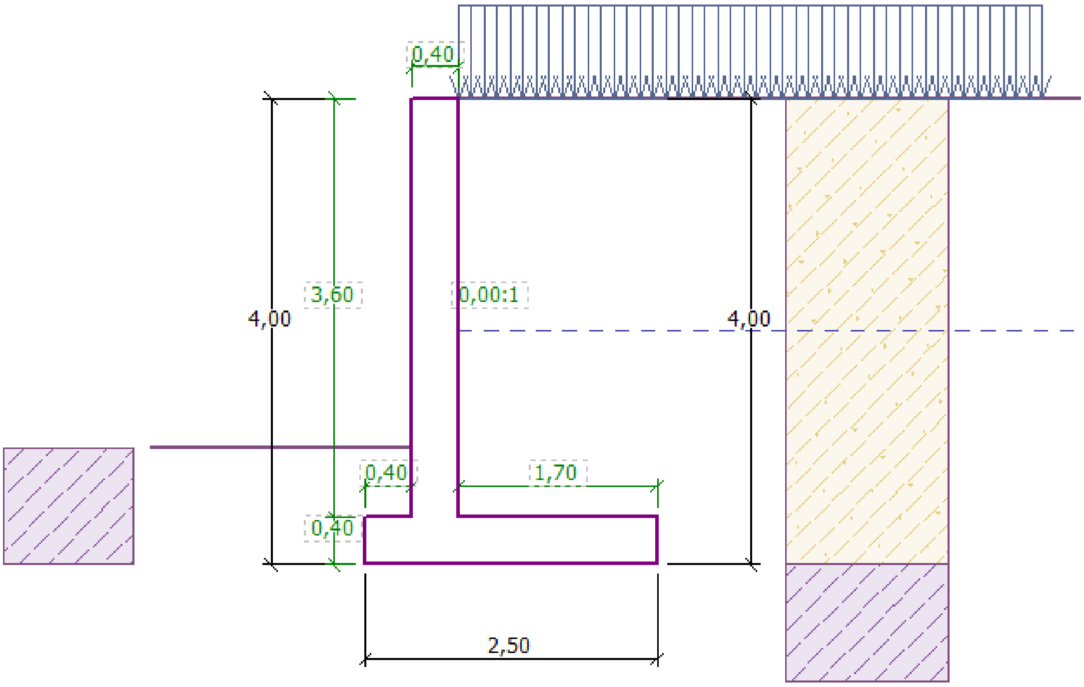
Then, in the frame "Stage settings" choose the type of the design situation. In this case, it will be permanent. Also choose the pressure acting on the wall. In our case, we will choose active pressure because the wall can move.



Frame "Stage settings"

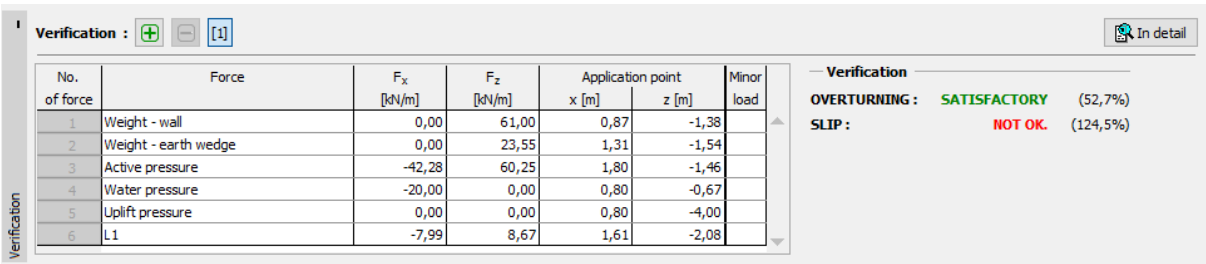
Note: A wall stem is usually dimensioned on earth pressure at rest, i.e., the wall can´t be moved. The possibility of evaluating the stem and the wall for active pressure is considered only in exceptional circumstances - such as the effects of an earthquake (seismic design situation with partial coefficient equal to 1.0).

Now our task looks as follows:



Analyzed structure

Now, open the frame "Verification", where you can analyze the results for overturning and slip of the cantilever wall.



No. of force	Force	F_x [kN/m]	F_z [kN/m]	Application point x [m]	Application point z [m]	Minor load
1	Weight - wall	0,00	61,00	0,87	-1,38	
2	Weight - earth wedge	0,00	23,55	1,31	-1,54	
3	Active pressure	-42,28	60,25	1,80	-1,46	
4	Water pressure	-20,00	0,00	0,80	-0,67	
5	Uplift pressure	0,00	0,00	0,80	-4,00	
6	L1	-7,99	8,67	1,61	-2,08	

Frame "Verification"

Note: The "In detail" button in the right section of the screen opens a dialog window with detailed information about the analysis results.

Analysis results:

The verification of the slip is not satisfactory. The utilization of the structure is:

- Overturning: 52,7 % $M_{res} = 208{,}17 > M_{ovr} = 109{,}75$ [kNm/m] SATISFACTORY
- Slip: 124,5 % $H_{res} = 65{,}74 < H_{act} = 81{,}83$ [kN/m] NOT OK

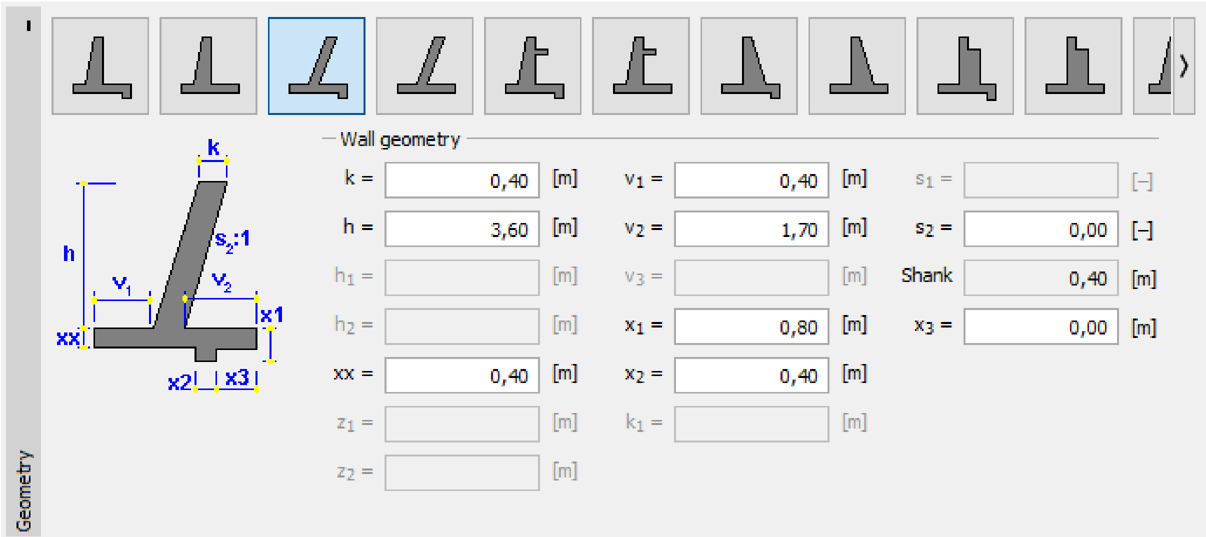
Now we have several possibilities how to improve the design. For example, we can:

- Use a soil with better characteristics behind the wall
- Anchor the base
- Increase the friction by bowing the footing bottom
- Anchor the stem

These changes would be economically and technologically demanding, so we will instead choose the easiest alternative. The most efficient way to deal with this in the design phase is to change the shape of the wall and introduce a wall jump.

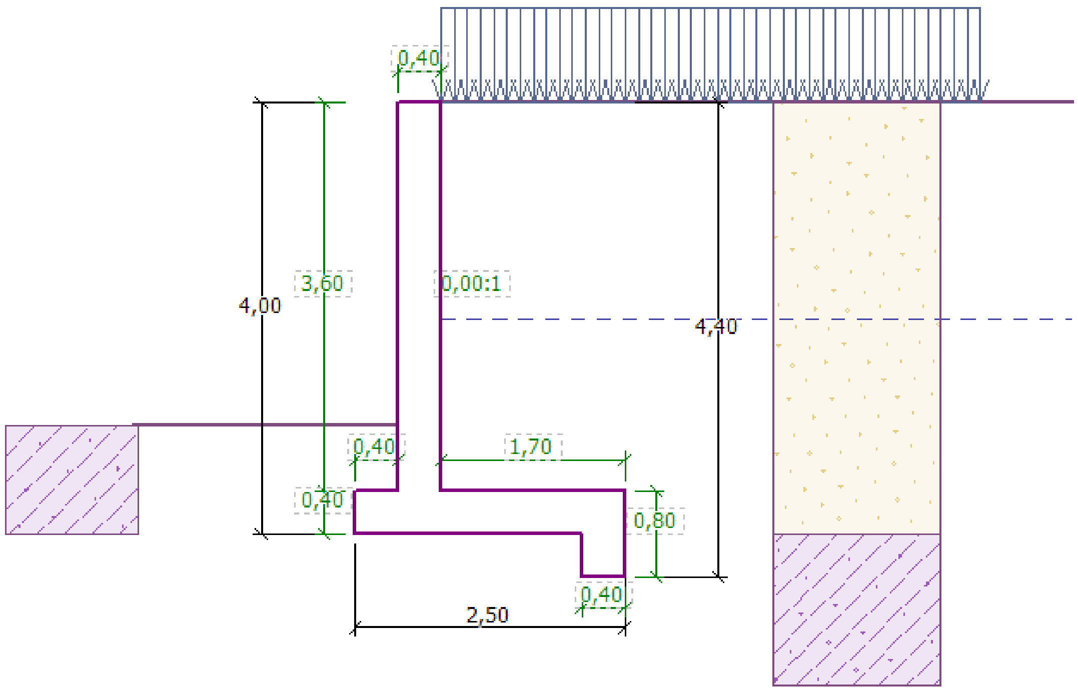
Changing the design: change the shape and the geometry of the wall

Return to the frame "Geometry" and change the shape of the cantilever wall. To increase the resistance against a slip, we will introduce a base jump. Change the shape of the wall and the values of x_1 and x_2 as shown in the picture.



Frame "Geometry" (Changing the dimensions of the cantilever wall)

Note: A base jump is usually analyzed as an inclined footing bottom. If the influence of the base jump is evaluated as front face resistance, the program analyzes it with a straight footing bottom, but FF resistance of the construction is analyzed to the depth of the bottom part of the base jump (More info in HELP – F1)



New shape of the structure

Then analyze the newly designed structure for overturning and slip.

Verification : [1]

No. of force	Force	F_x [kN/m]	F_z [kN/m]	Application point x [m]	Application point z [m]	Minor load
1	Weight - wall	0,00	65,00	0,95	-1,28	
2	Weight - earth wedge	0,00	23,55	1,31	-1,54	
3	Active pressure	-42,28	60,25	1,80	-1,46	
4	Water pressure	-28,80	0,00	0,80	-0,40	
5	Uplift pressure	0,00	0,00	0,80	-4,00	
6	L1	-7,99	9,06	1,65	-2,08	

Verification

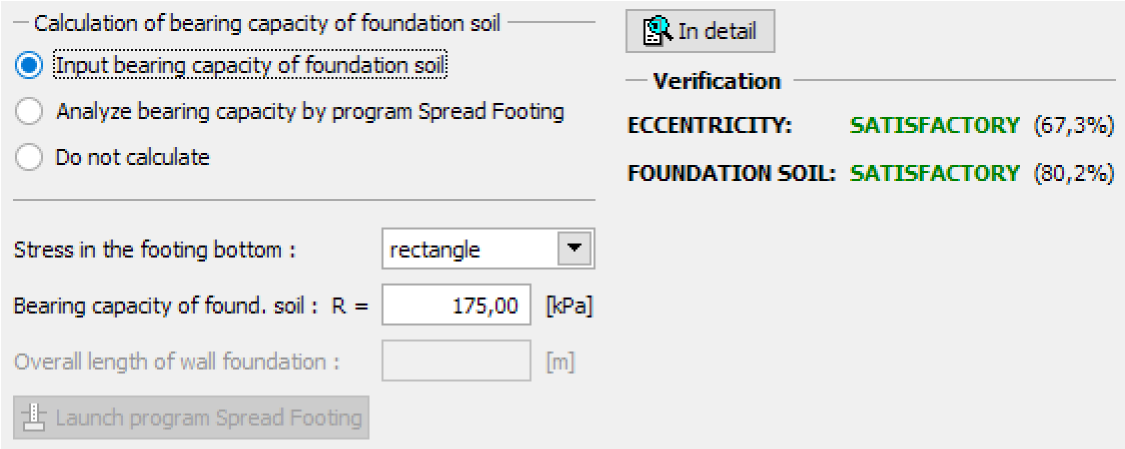
OVERTURNING : SATISFACTORY (49,4%)

SLIP : SATISFACTORY (64,9%)

Frame "Verification"

Now, the overturning and slip of the wall are both satisfactory (Utilization: 49.4 % and 64.9%)

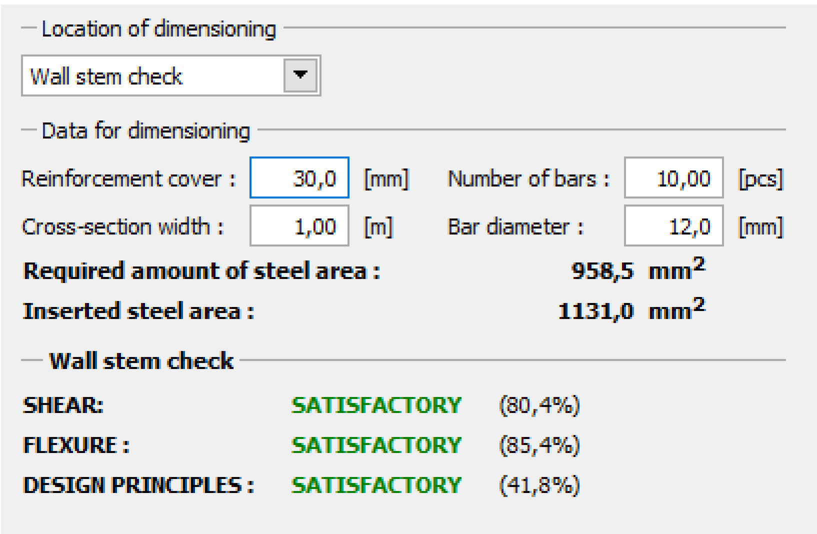
Then, in the frame "Bearing capacity", perform an analysis for design bearing capacity of the foundation soil - 175 kPa.



Frame "Bearing capacity"

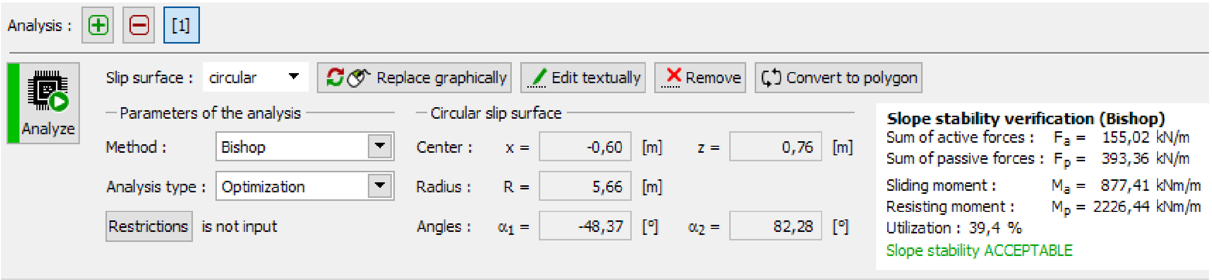
Note: In this case, we analyze the bearing capacity of the foundation soil as an input value, which we can get from a geological survey, or from some standards. These values are usually highly conservative, so it is generally better to analyze the bearing capacity of the foundation soil in the "Spread footing" program, which takes other influences such as the inclination of the load, the depth of the foundation etc. into account.

Next, in the frame "Dimensioning", we will do a wall stem check. Design the main reinforcement into the stem – *10 pcs. Ø 12 mm*, which satisfies all the design principles.



Frame "Dimensioning"

Then, go to frame “Stability”, where we will analyze the overall stability of the wall. This will open the “Slope stability” program, where we will move on to frame “Analysis”. In our case, we will use the “*Bishop”* method, which has conservative results. Perform the analysis with **optimization of circular slip surface**, click “Analyze” to perform the calculations and when the calculation is complete, leave the program by clicking “Exit and save”. The results will be imported to the analysis report in the “Cantilever wall” program.



“Slope stability” program – frame “Analysis”

Conclusion:

Result of the analysis:

- Overturning: 49,4 % $M_{res} = 218{,}35 > M_{ovr} = 107{,}94$ [kNm/m] SATISFACTORY
- Slip: 64,9 % $H_{res} = 99{,}26 > H_{act} = 64{,}38$ [kN/m] SATISFACTORY
- Bearing capacity: 80,2 % $R_d = 175 > \sigma = 140{,}31$ [kPa] SATISFACTORY
- Wall stem check: 85,4 % $M_{Rd} = 169{,}92 > M_{Ed} = 145{,}18$ [kNm] SATISFACTORY
- Overall stability: 39,4 % Method – Bishop (optimization) SATISFACTORY

This cantilever wall is SATISFACTORY.