Verification of a gravity wall

Program: Gravity wall

File: Demo_manual_03.gtz

In this chapter an analysis of an existing gravity wall for permanent and accidental design situations is performed. The usage of construction stages is also explained.

Assignment

Using the EN 1997-1 (EC 7-1, DA2) standard, analyze an existing gravity wall for stability, overturning, and slip.

Road traffic acts on the wall with a magnitude of 10 kPa. Check if it is possible to install a barrier on top of the wall. An accidental load from a car crash is considered to be 50 kN/m and it acts horizontally at 1,0 m above the wall. The dimensions and the shape of the concrete wall can be seen in the picture below. The inclination of the terrain behind the construction is $\beta = 10°$, the foundation soil consists of silty sand. The friction angle between the soil and the wall is $\delta = 18°$.

We will not determine the bearing capacity and dimensionioning of the wall as a part of this task. In this analysis, we will consider effective parameters of the soil.
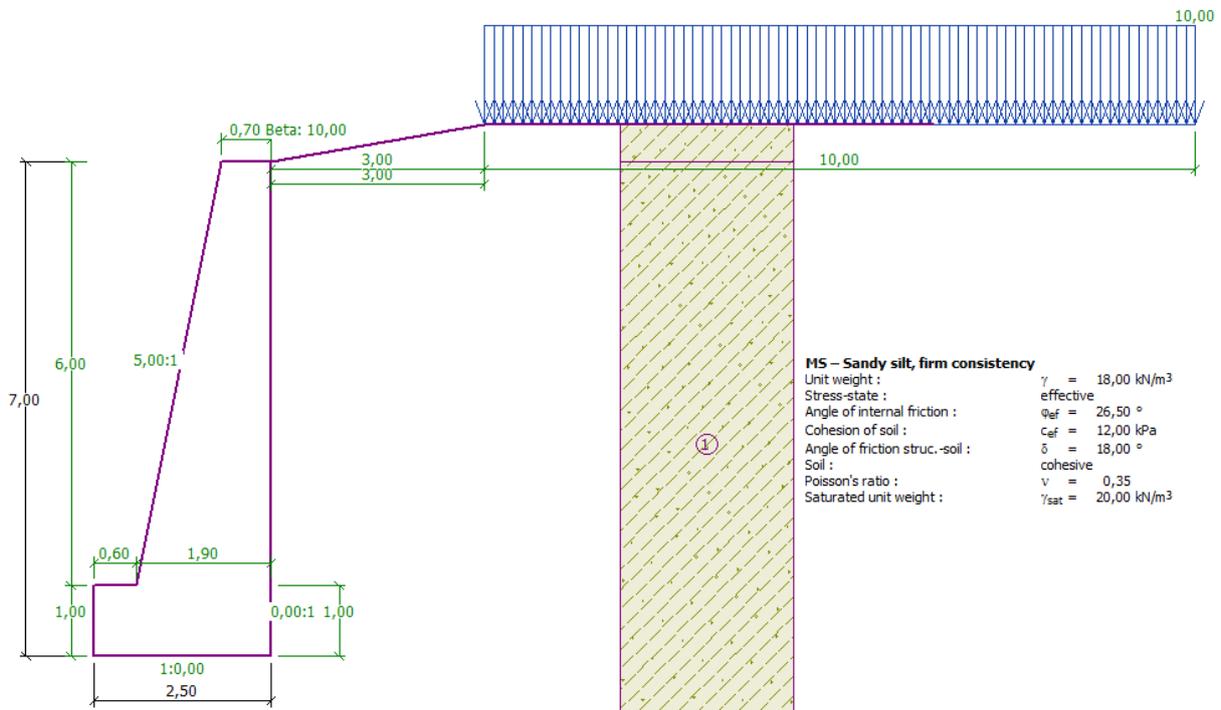
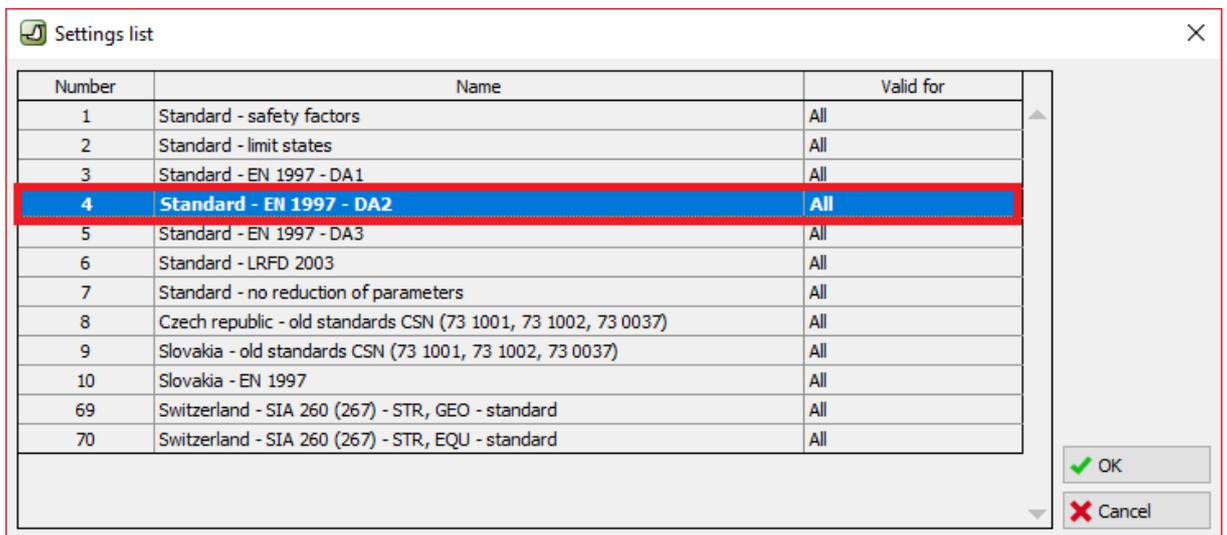*Scheme of the gravity wall – assignment*

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Solution:

To analyze this task, use the GEO5 "Gravity wall" program. In this text, we will describe how to analyze this example step by step in two construction stages.

− 1st construction stage – analyzing the existing wall for road traffic.

− 2nd construction stage – analyzing the impact of a vehicle on the barrier on the top of the wall.

Stage 1

In the frame "Settings" click on "Select settings" and choose No. 4 – "Standard – EN 1997 – DA2".

| 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
6	Standard - LRFD 2003	All
7	Standard - no reduction of parameters	All
8	Czech republic - old standards CSN (73 1001, 73 1002, 73 0037)	All
9	Slovakia - old standards CSN (73 1001, 73 1002, 73 0037)	All
10	Slovakia - EN 1997	All
69	Switzerland - SIA 260 (267) - STR, GEO - standard	All
70	Switzerland - SIA 260 (267) - STR, EQU - standard	All

Dialog window "Settings list"

Then, go to the frame "Geometry", select the shape of the gravity wall and define its parameters as shown in the picture below.

Frame "Geometry"

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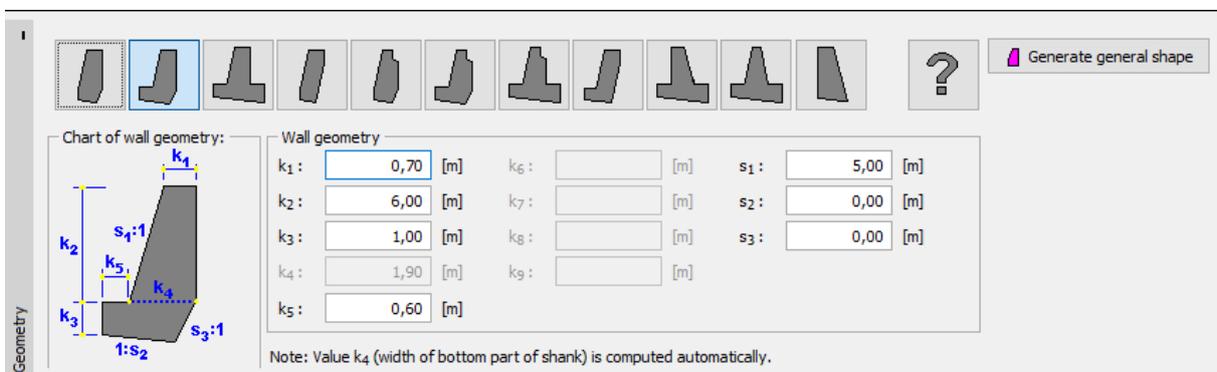
In the next step, input the material of the wall and the geological profile. Go to the frame "Material" and change the unit weight of the wall to $\gamma = 24 \; kN/m^3$. The wall is made from concrete of class C 12/15 and steel B500. Select the right class of concrete by clicking the button "Catalog".
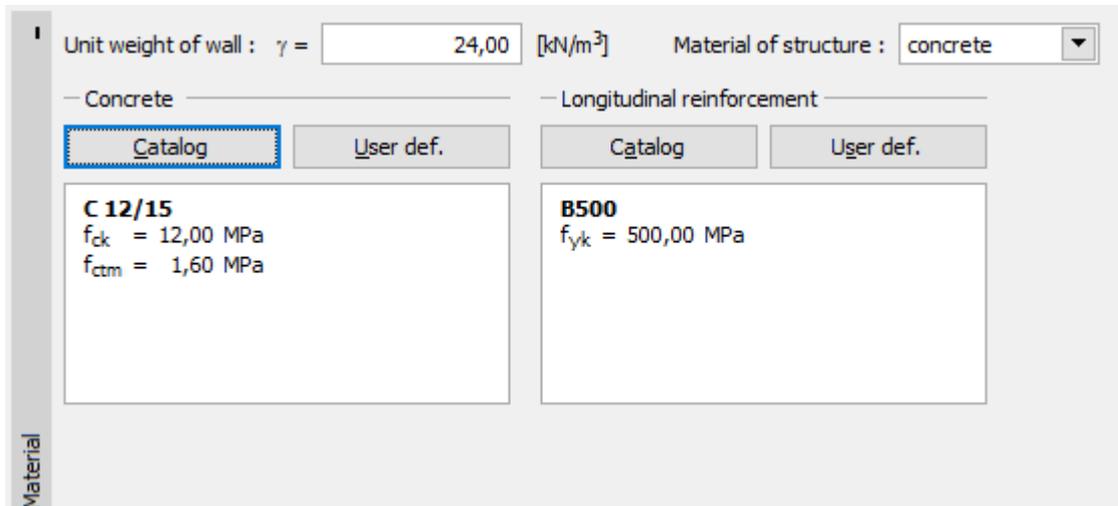
Frame "Material" – selecting the appropriate class of concrete

Then, move on to the frame "Soils". Here, we will define the parameters of the soil according to the table below and assign them to the profile.

Table with the soil parameters

Soil (Soil classification)	Unit weight $\gamma \; \left[kN/m^3 \right]$	Angle of internal friction $\varphi_{ef} \; [°]$	Cohesion of soil $c_{ef} \; [kPa]$	Angle of friction structure – soil $\delta = [°]$
MS – Sandy silt, firm consistency	18,0	26,5	12,0	18,0

In the frame "Soils", add a new soil by clicking the button "Add". Input the soil parameters shown in the picture below.


Dialog window "Add new soils"

Note: The magnitude of the active pressure also depends on the friction between the structure and the soil at angle $\delta \approx \left(\frac{1}{3} \div \frac{2}{3} \right) \cdot \varphi_{ef}$. In this case we consider the friction between the structure and the soil to have a value of $\frac{2}{3} \cdot \varphi_{ef}$ (δ=18°), when analyzing earth pressure. (More info can be found in HELP – F1).

In the frame "Terrain" select the shape of the terrain behind the wall. Define its parameters in terms of embankment length and slope angle as shown below.

Frame "Terrain"

In the next frame, define the "Surcharge". Input the surcharge from the road traffic as a strip, with its location on the terrain, and as a type of action select "variable".
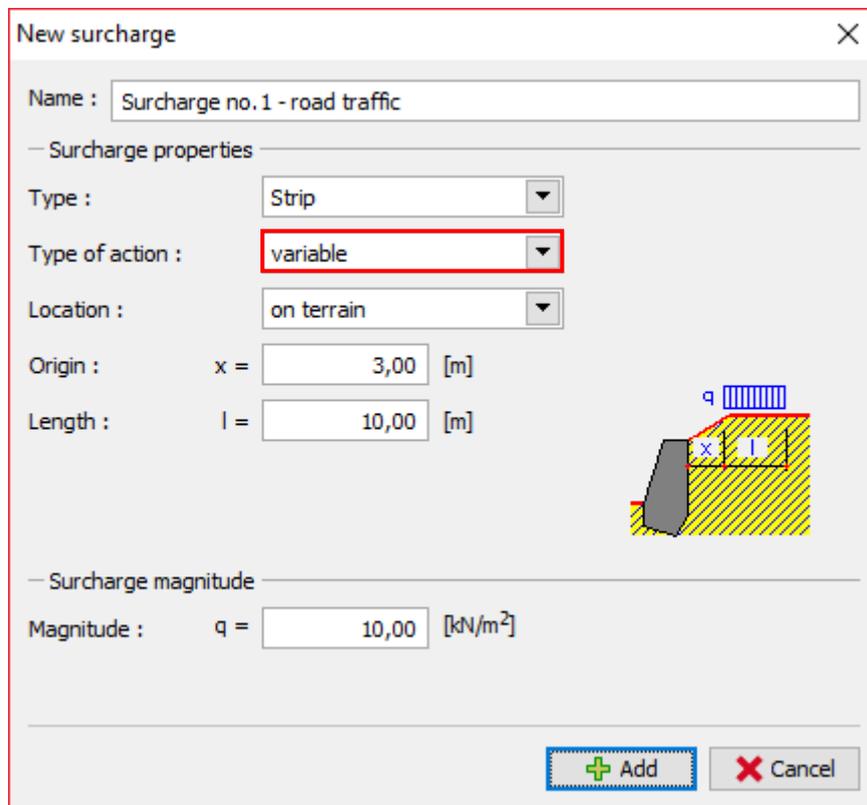
Dialog window "New surcharge"

We will skip the frame "FF resistance", because the shape of the terrain in front of the wall is horizontal.

Note: In this case, we do not consider 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 pressure at rest for the original soil or a well compacted soil. It is only possible to consider the passive pressure if displacement of the structure is allowed. (More info can be found in HELP – F1).

In the frame "Stage settings" select the type of the design situation. In the first construction stage, consider the *"permanent"* design situation.

Design situation :	permanent	▼
Pressure acting on the wall :	the wall can deflect (active pressure)	▼

Frame "Stage settings"

Now open the frame "Verification", where we will analyze the gravity wall for overturning and slip.

No. of force	Force	F_x [kN/m]	F_z [kN/m]	Application point x [m]	z [m]	Minor load
1	Weight - wall	0,00	247,20	1,67	-2,80	
2	Active pressure	-84,17	27,35	2,50	-1,73	
3	Surcharge no. 1 - road traffic	-16,36	6,05	2,50	-2,72	

Verification
OVERTURNING : SATISFACTORY (70,0%)
SLIP : SATISFACTORY (90,6%)

Frame "Verification – stage 1"

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

Verification

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0,00	-2,80	247,20	1,67	1,000	1,000	1,350
Active pressure	84,17	-1,73	27,35	2,50	1,350	1,350	1,000
Surcharge No. 1 - Road traffic	16,36	-2,72	6,05	2,50	1,500	1,500	1,500

Verification of complete wall

Check for overturning stability
Resisting moment M_{res} = 376,91 kNm/m
Overturning moment M_{ovr} = 263,73 kNm/m
Wall for overturning is SATISFACTORY

Check for slip
Resisting horizontal force H_{res} = 152,53 kN/m
Active horizontal force H_{act} = 138,17 kN/m
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Maximum stress in footing bottom : 162,84 kPa

Dialog window "Verification (in detail)"

Note: For analyses based on EN-1997, the program determines if the force acts favorably or unfavorably. Then each force is multiplied by the corresponding partial factor which is then shown in the report.

Next, go to the frame "Stability" and analyze the overall stability of the wall. The "Slope Stability" program will open. Go to the frame "Analysis" and choose the "Bishop" method of the analysis. Perform an analysis with **optimization of circular slip surface** by clicking the "Analyze" button. When the analysis is done, click on "Exit and save" on the right side of the screen. The results or pictures will be shown in the analysis report in the "Gravity wall" program.
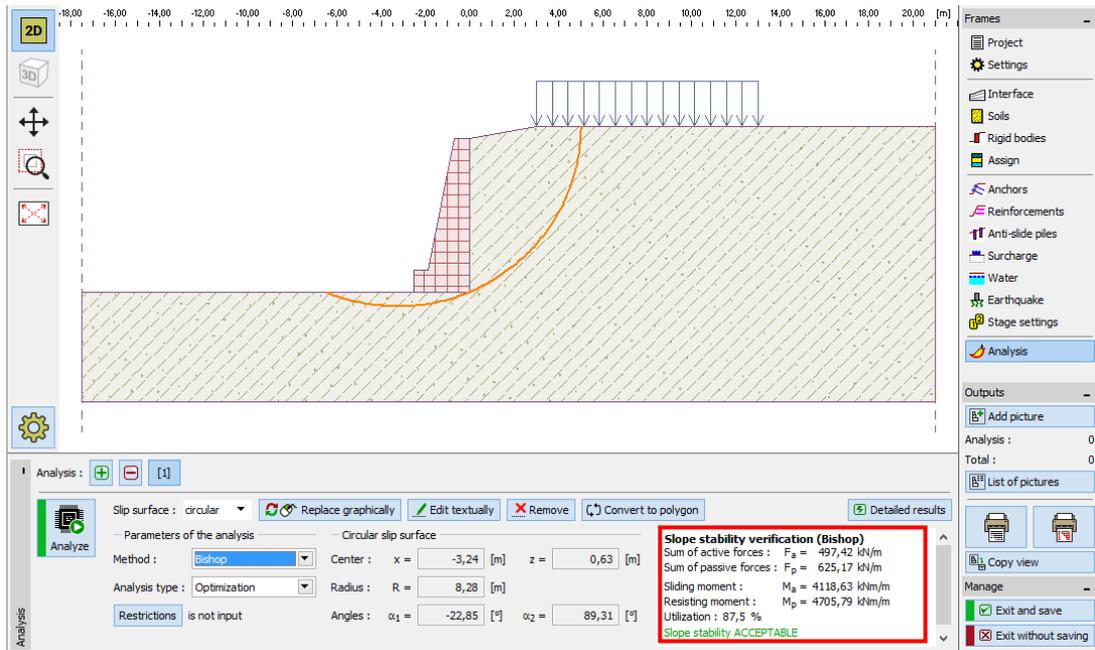
*Program "Slope stability" – stage 1*

Analysis results: Stage 1

When analyzing bearing capacity, we are looking for values of overturning and slip of the wall on the footing bottom. Then we need to know its overall stability. In our case, the utilization of the wall is:

- Overturning: 70,0 % $M_{res} = 376,91 > M_{ovr} = 263,73$ [kNm/m]   SATISFACTORY

- Slip: 90,6 % $H_{res} = 152,53 > H_{act} = 138,17$ [kN/m]   SATISFACTORY

- Overall stability: 87,5 % Method – Bishop (optimalization)   SATISFACTORY

Stage 2

Now, add construction stage 2 using the tool bar in the upper left corner of the screen.
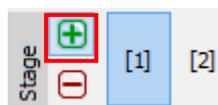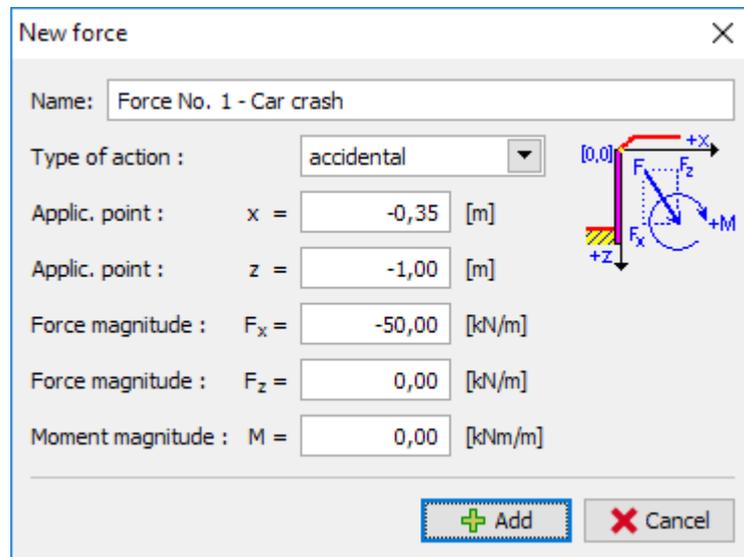

"Construction stage" toolbar

In this stage, we will define the load from the impact of a vehicle on the barrier, using the frame "Applied forces". The load will be accidental. We will add a new force by clicking the button "Add" and specifying the parameters as shown below.

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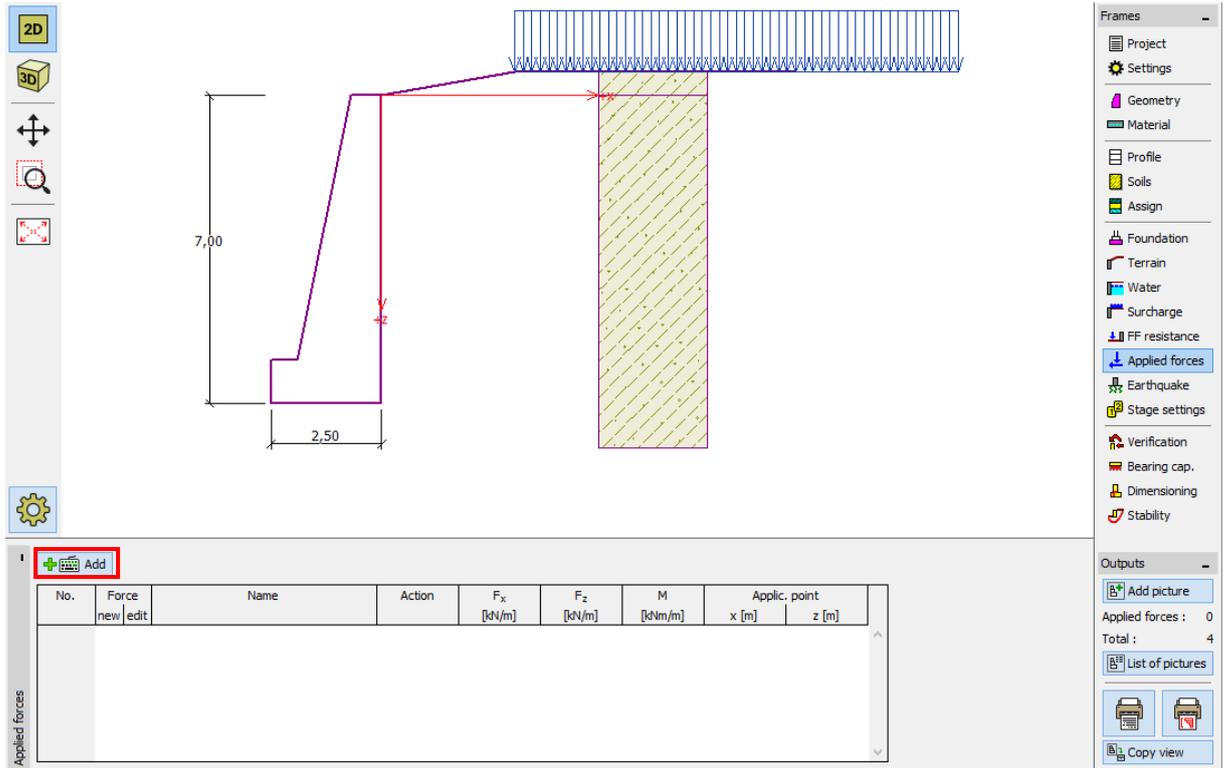
Frame "Applied forces" – adding a new force

Dialog window "Edit force" – construction stage 2 (accidental design situation)

Then in the frame "Stage settings" change the design situation to "accidental". The program will use partial factors for an accidental situation.

The data that we entered in stage 1 has not changed, so we don't have to open these frames again. Go to the frame "Verification" to perform a verification of overturning and slip again.

Frame "Verification – stage 2"

Analysis results: Stage 2

From the results we see that the existing wall is not satisfactory in case a car crashes into the barrier. In this case, the utilization of the wall is:

- − Overturning: 116,3 % $M_{res} = 488,62 < M_{ovr} = 568,13$ [kNm/m]   NOT OK.

- − Slip: 102,9 % $H_{res} = 138,39 < H_{act} = 142,35$ [kN/m]   NOT OK.

Conclusion

The analysis of the existing gravity wall shows that the bearing capacity is only satisfactory in the first construction stage, where just the road traffic acts. In the second construction stage, which

simulates the accidental impact of a crashing vehicle on the barrier on the top of the wall, the wall is not satisfactory.

A solution to this would be to increase the bearing capacity for overturning and slip. It is also possible to introduce soil anchors. Alternatively, we could place a barrier on the edge of the road, so that the wall is not impacted by the force of a crashing car.