

## Verification of a gravity wall

Program: Gravity wall

File: Demo\_manual\_03.gtz

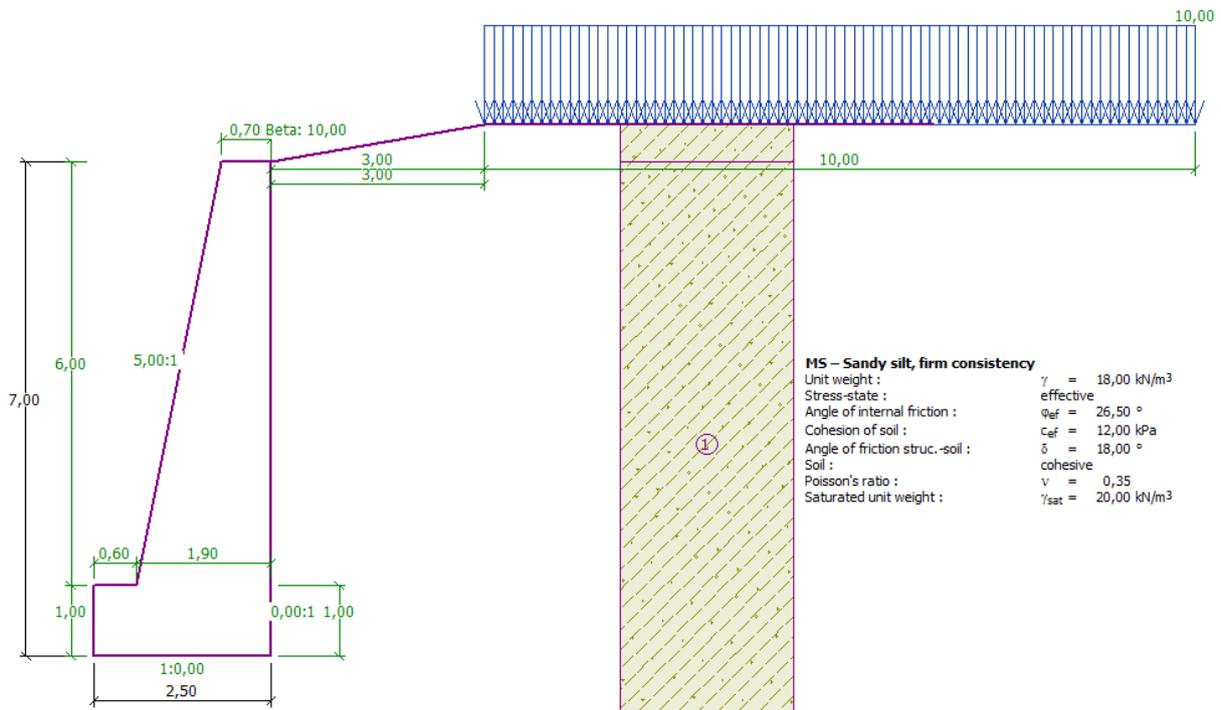
In this chapter we will perform an analysis of an existing gravity wall for permanent and accidental design situations and introduce the use of construction stages.

### 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 crash 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. We can see the dimensions and the shape of the concrete wall in the picture below. The inclination of the terrain behind the construction is  $\beta = 10^\circ$ , the foundation soil consists of silty sand. The friction angle between the soil and the wall is  $\delta = 18^\circ$ .

We will not determine the bearing capacity and dimensioning of the wall as a part of this task. In this analysis, we will consider the effective parameters of the soil.



*Scheme of the gravity wall – assignment*

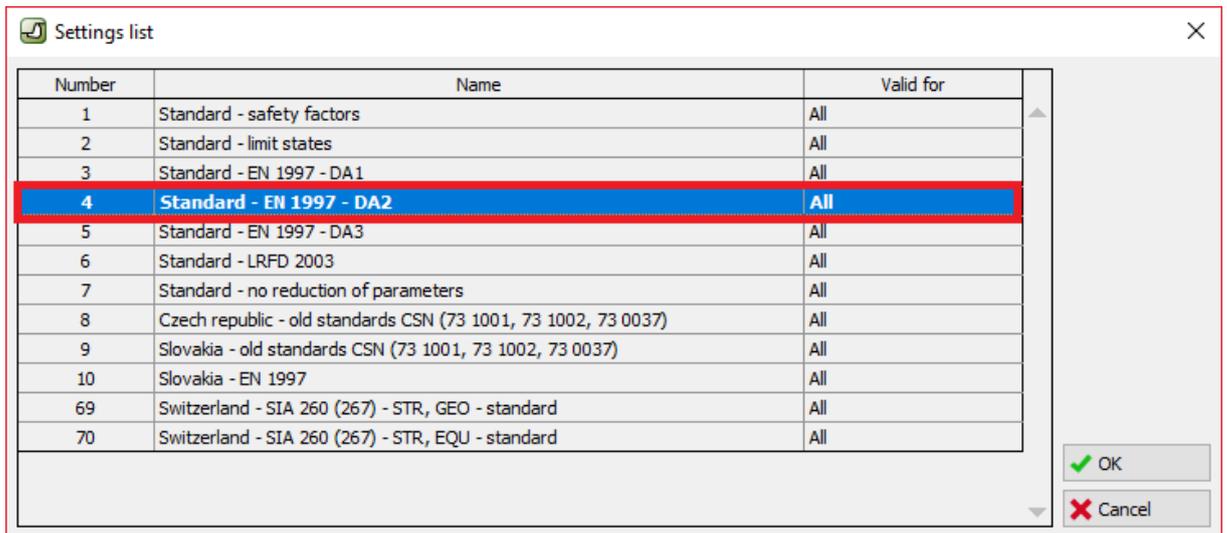
## Solution:

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

- 1<sup>st</sup> construction stage – analyzing the existing wall for road traffic.
- 2<sup>nd</sup> construction stage – analyzing the vehicle's impact on the crash barrier.

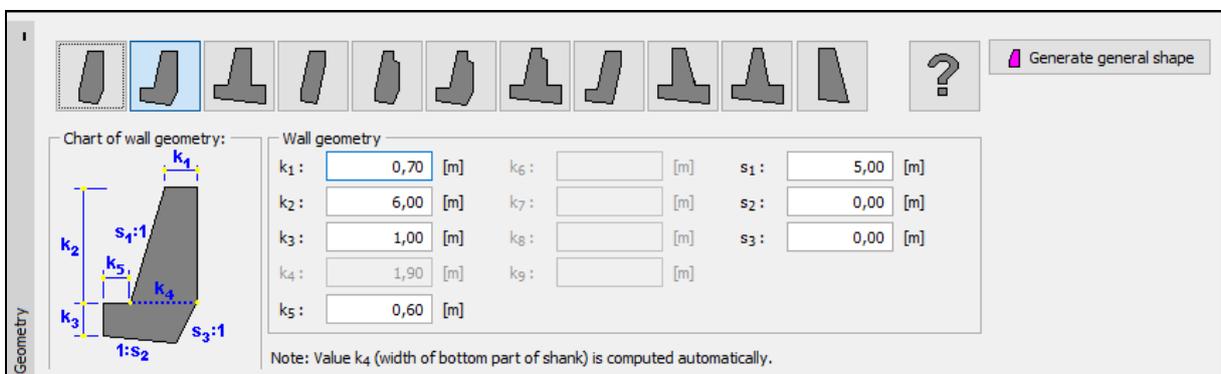
## Stage 1

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



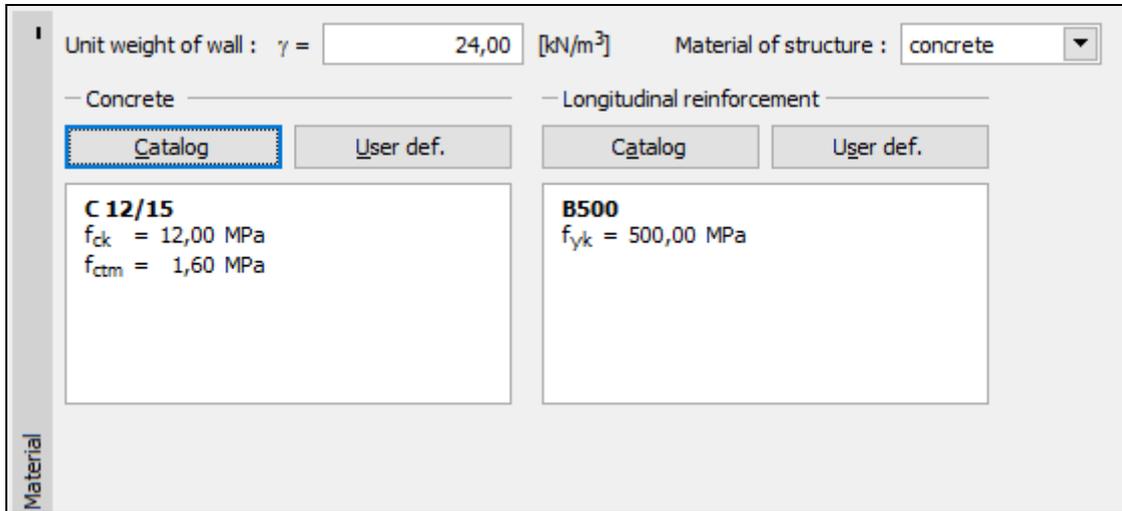
“Settings list” Dialog window

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



“Geometry” Frame

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



“Material” Frame – selecting the appropriate class of concrete

Then, move on to the “Soils” Frame. 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

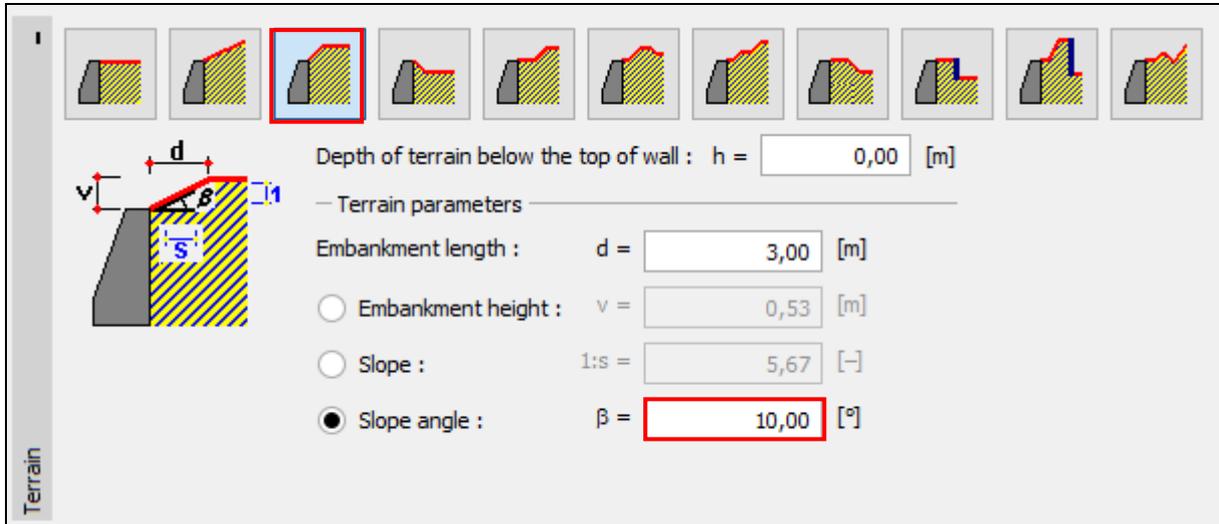
Soil (Soil classification)	Unit weight $\gamma \text{ [kN/m}^3\text{]}$	Angle of internal friction $\varphi_{ef} \text{ [}^\circ\text{]}$	Cohesion of soil $c_{ef} \text{ [kPa]}$	Angle of friction structure – soil $\delta = \text{[}^\circ\text{]}$
MS – Sandy silt, firm consistency	18,0	26,5	12,0	18,0

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

“Add new soils” dialog window

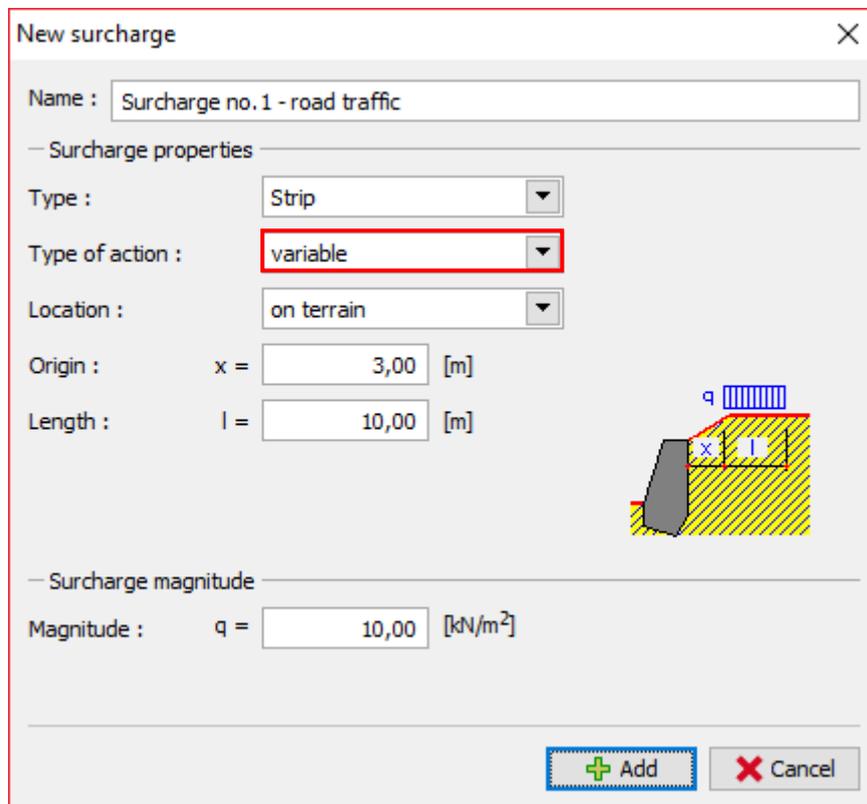
Note: The magnitude of the active pressure also depends on the friction between the structure and the soil at an angle  $\delta \approx \left(\frac{1}{3} \div \frac{2}{3}\right) \cdot \varphi_{ef}$ . In this case we consider the friction between the structure and the soil to have a value of  $\frac{2}{3}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

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



"Terrain" Frame

Now we will 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".



"New surcharge" Dialog window

We will skip the “FF resistance” frame, because the terrain shape 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 passive pressure if the displacement of the structure is allowed. (More info can be found in HELP – F1).*

In the “Stage settings” frame 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)

“Stage settings” Frame

Now open the “Verification” frame, 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 [m]		Minor load
				x	z	
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 Results:

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

“Verification Frame – 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.

**Forces acting on construction**

Name	F <sub>hor</sub> [kN/m]	App.Pt. z [m]	F <sub>vert</sub> [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	1,350
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**

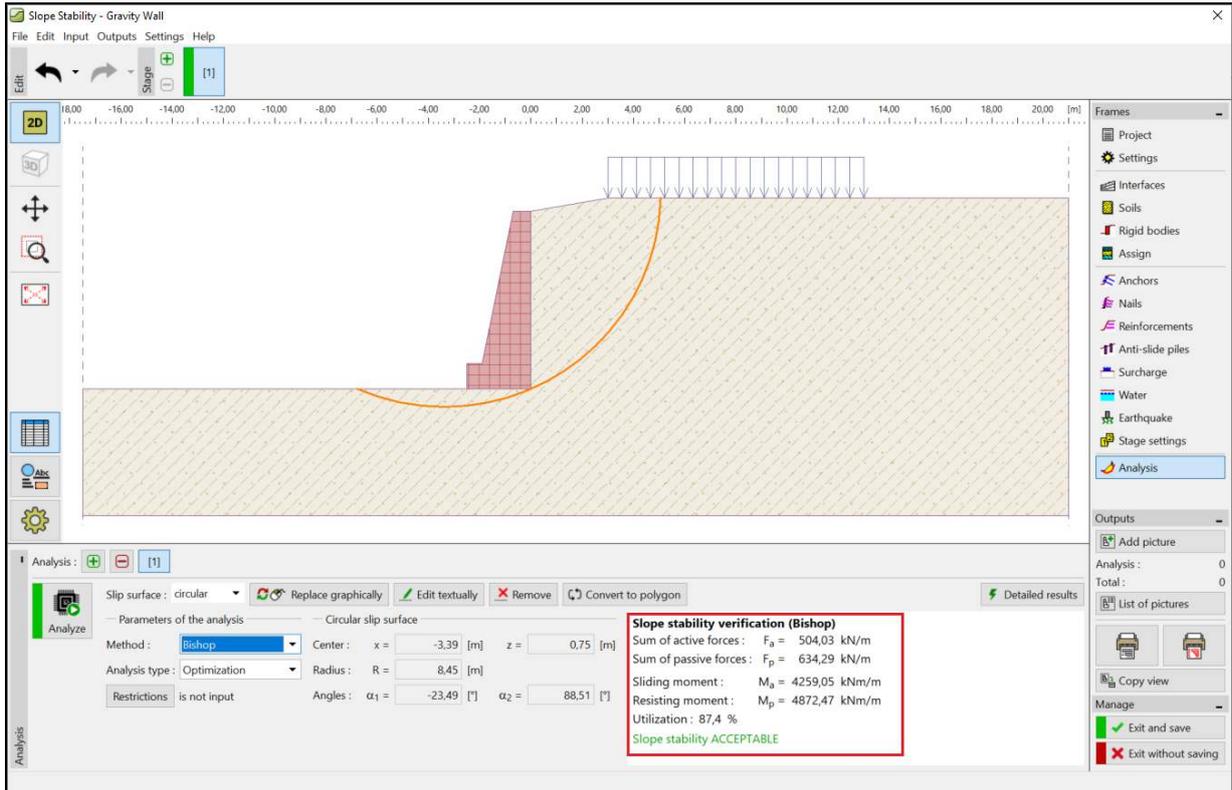
**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 176,53 kPa

“Verification (in detail)” Dialog window

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 “Stability” frame and analyze the overall stability of the wall. The “Slope Stability” program will open. Go to the “Analysis” frame and choose the “Bishop” method of analysis. Perform the analysis with **optimization of circular slip surface** by clicking the “Analyze” button. When the analysis is completed, click on “Exit and save” on the right side of the screen. The results will be shown in the analysis report in the “Gravity wall” program.



“Slope stability” Program – stage 1

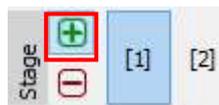
## Analysis results: Stage 1

When analyzing the bearing capacity, we are looking for values of overturning and the 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:     87,4 % Method – Bishop (optimization)     **SATISFACTORY**

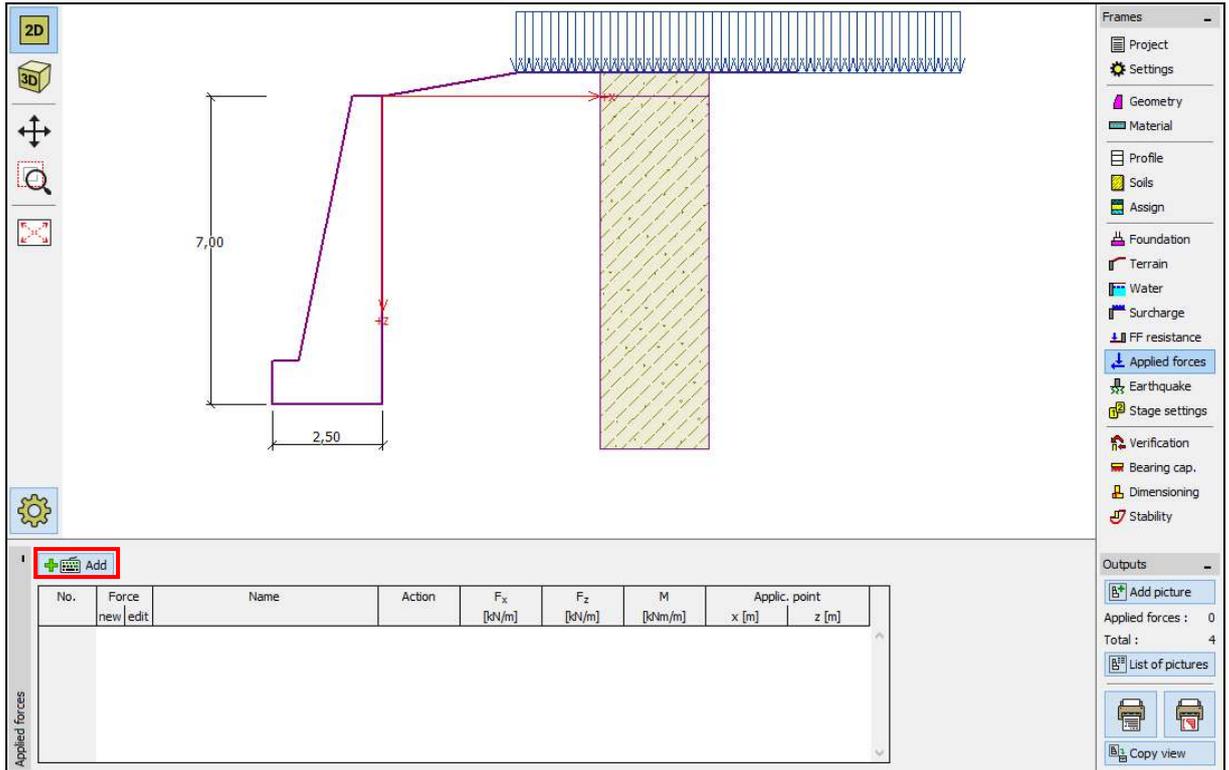
## Stage 2

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

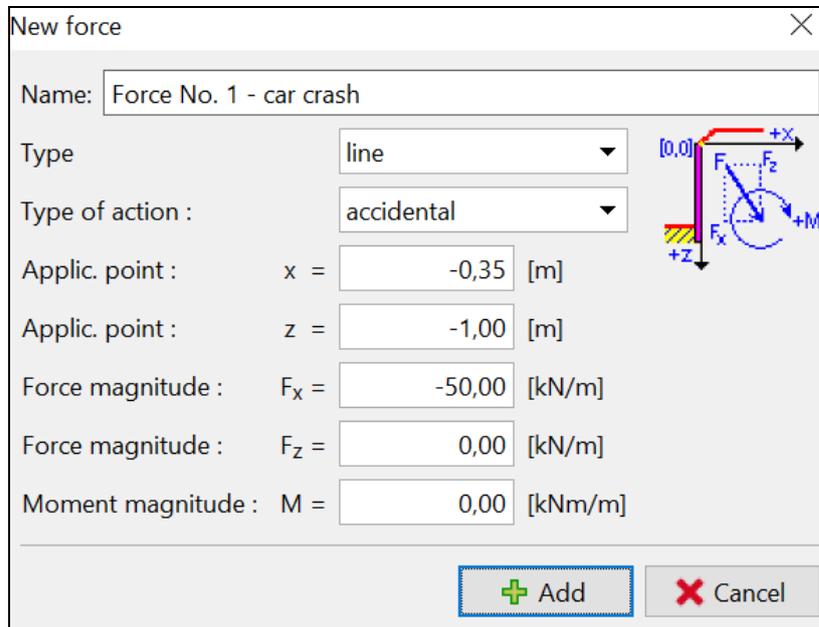


“Construction stage” toolbar

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



*“Applied forces” frame – adding a new force*



*“Edit force” dialog window – construction stage 2 (accidental design situation)*

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

Design situation : accidental

Pressure acting on the wall : the wall can deflect (active pressure)

“Stage settings” Frame

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

No. of force	Force	F <sub>x</sub> [kN/m]	F <sub>z</sub> [kN/m]	Application point		Minor load
				x [m]	z [m]	
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	
4	Force No. 1 - Car crash	-50,00	0,00	2,15	-8,00	

Verification		
OVERTURNING :	NOT OK.	(116,3%)
SLIP :	NOT OK.	(102,9%)

“Verification” frame – stage 2”

## Analysis results: Stage 2

From the results we can see that the existing wall is not satisfactory in case of a car crash. 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 only the road traffic acts. In the second construction stage, which simulates the impact of a vehicle crash on the crash barrier, 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 the crashing car.