Analysis of nailed slope

Input data

Project

Date : 28.10.2015

Settings

(input for current task)

Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard

Wall analysis

Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Caquot-Kerisel
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0,333
Verification methodology : Safety factors (ASD)

Safety factors			
Permanent design situation			
Safety factor for overturning :	SF_o =	1,50	[–]
Safety factor for sliding resistance :	SF_s =	1,50	[–]
Safety factor for bearing capacity :	SF_b =	1,00	[–]

Stability analysis

Verification methodology : Safety factors (ASD)

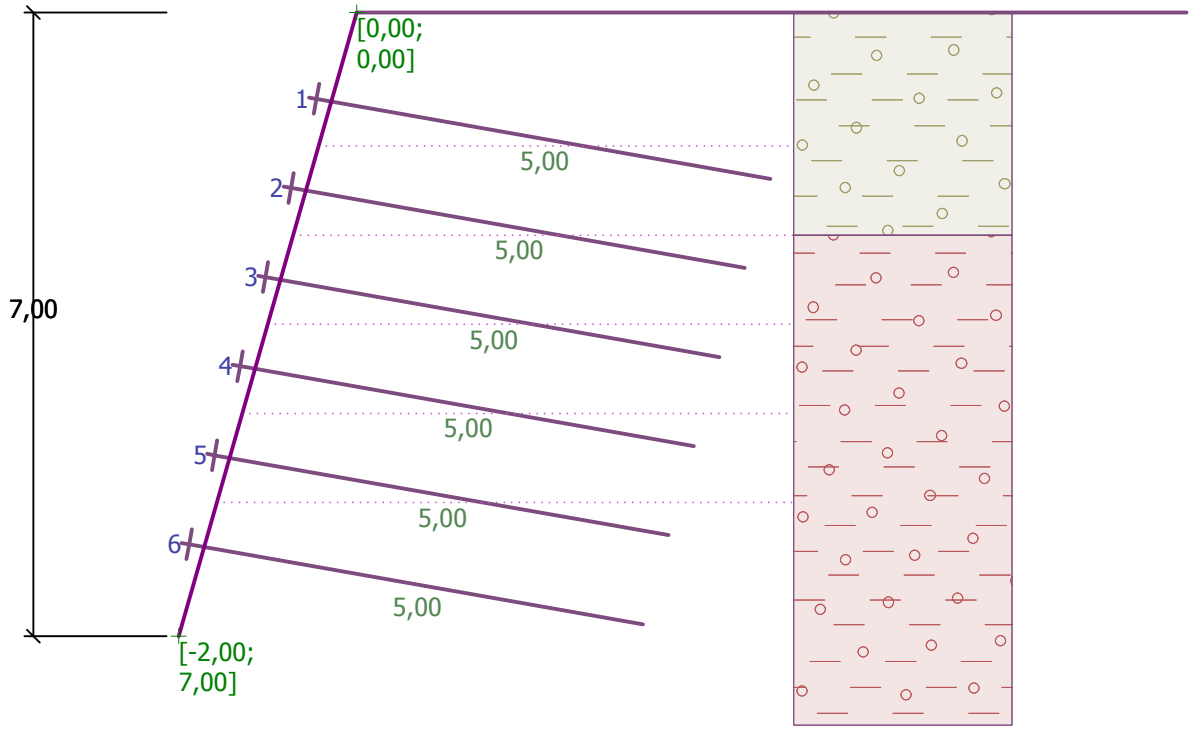
Safety factors			
Permanent design situation			
Safety factor for plane slip surface :	SF_{pl} =	1,20	[–]
Safety factor for broken slip surface :	SF_{br} =	1,30	[–]

Geometry of structure

Thickness of concrete cover = 0,20 m

No.	Depth z [m]	Coordinate x [m]
1	0,00	0,00
2	7,00	-2,00

Name : Geometry | **Stage - analysis : 1 - 0**



Type of nails

No.	Name	Tensile strength R_t [kN]	Pull out resistance T_p [kN/m]	Nail head strength R_f [kN]
1	Nail type No. 1	235,62	18,85	37,70

Geometry of nails

Overall number of nails - 6
Inclination of nails from horizontal dir. = 10,00 °

Nail	Depth [m]	Depth of joint [m]	Length [m]	Spacing [m]	Type of nail
1	1,00	0,50	5,00	1,00	Nail type No. 1
2	2,00	0,50	5,00	1,00	Nail type No. 1
3	3,00	0,50	5,00	1,00	Nail type No. 1
4	4,00	0,50	5,00	1,00	Nail type No. 1
5	5,00	0,50	5,00	1,00	Nail type No. 1
6	6,00	1,00	5,00	1,00	Nail type No. 1

Material of structure

Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete : C 20/25
Cylinder compressive strength f_{ck} = 20,00 MPa
Tensile strength f_{ctm} = 2,20 MPa

Longitudinal steel : B500
Yield strength f_{yk} = 500,00 MPa

Soil parameters

Soil No. 1
Unit weight : γ = 19,50 kN/m^3
Stress-state : effective

Angle of internal friction :	φ_{ef}	=	27,00 °
Cohesion of soil :	c_{ef}	=	12,00 kPa
Angle of friction struc.-soil :	δ	=	15,00 °
Soil :	cohesive		
Poisson's ratio :	ν	=	0,35
Saturated unit weight :	γ_{sat}	=	19,50 kN/m^3

Soil No. 2

Unit weight :	γ	=	21,00 kN/m^3
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	30,00 °
Cohesion of soil :	c_{ef}	=	15,00 kPa
Angle of friction struc.-soil :	δ	=	15,00 °
Soil :	cohesive		
Poisson's ratio :	ν	=	0,35
Saturated unit weight :	γ_{sat}	=	21,50 kN/m^3

Geological profile and assigned soils

No.	Layer [m]	Assigned soil	Pattern
1	2,50	Soil No. 1	
2	-	Soil No. 2	

Terrain profile

Terrain behind the structure is flat.

Water influence

Ground water table is located below the structure.

Settings of the stage of construction

Design situation : permanent

Verification No. 1

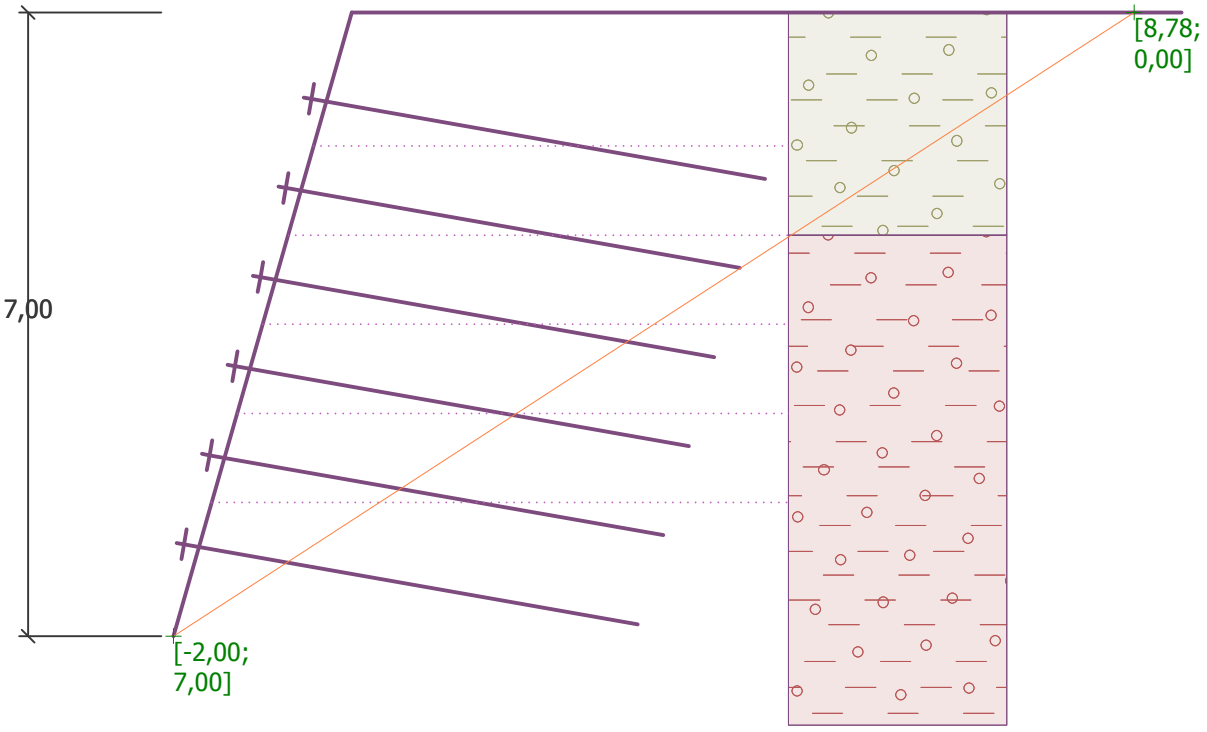
Plane slip surface after optimization :

Slip surface angle = 33,00 °
Origin of slip surface at a depth of = 7,00 m

Gravity force	=	618,22	kN/m
Overall force carried by nails behind slip surf.	=	169,41	kN/m
Forces on slip surf. driving (grav.force)	=	336,71	kN/m
Forces on slip surf. driving (pressure)	=	0,00	kN/m
Forces on slip surf. resist. (soil)	=	529,71	kN/m
Forces on slip surf. resist. (nails)	=	123,90	kN/m

Factor of safety = 1,94 > 1,20
Stability of slip surface is SATISFACTORY

Name : Internal stability	Stage - analysis : 1 - 1



Verification No. 2

Broken slip surface after optimization :

Slip surface angle = 33,00 °
Origin of slip surface at a depth of = 7,00 m

Gravity force = 493,87 kN/m
Overall force carried by nails behind slip surf. = 169,41 kN/m
Forces on slip surf. driving (grav.force) = 268,98 kN/m
Forces on slip surf. driving (pressure) = 2,07 kN/m
Forces on slip surf. resist. (soil) = 419,42 kN/m
Forces on slip surf. resist. (nails) = 123,90 kN/m

Factor of safety = 2,00 > 1,30
Stability of slip surface is SATISFACTORY

Verification No. 3

Horizontal pressure on structure:

Point	Depth [m]	Pressure [kPa]
1	0,00	0,00
2	2,50	0,00
3	4,29	0,00
4	7,00	11,54

Verification of nails bearing capacity

Reduction coeff. of active earth pressure to check for nails bear. capacity k_n = 0,85.

Nail	h [m]	Nail bearing capacity [kN]	Nail force [kN]
1	1,00	94,25	0,00

Nail	h [m]	Nail bearing capacity [kN]	Nail force [kN]
2	2,00	94,25	0,00
3	3,00	94,25	0,00
4	4,00	94,25	0,08
5	5,00	94,25	2,62
6	6,00	94,25	10,81

Bearing capacity of nails is SATISFACTORY

Verification No. 1

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Gravity force	0,00	-3,40	731,18	3,53	1,000
Active pressure	17,42	-1,00	4,36	5,46	1,000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 2601,99 kNm/m
Overturning moment M_{ovr} = 17,41 kNm/m

Safety factor = 149,48 > 1,50
Wall for overturning is SATISFACTORY

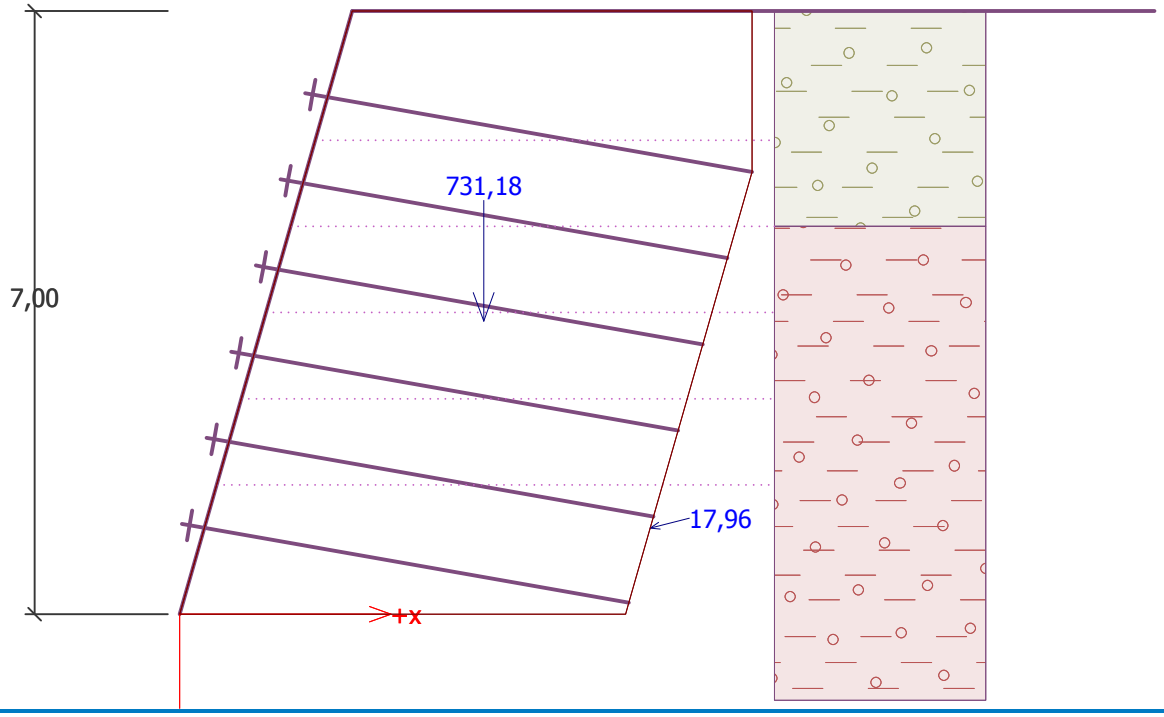
Check for slip

Resisting horizontal force H_{res} = 502,25 kN/m
Active horizontal force H_{act} = 17,42 kN/m

Safety factor = 28,83 > 1,50
Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Name : Verification	Stage - analysis : 1 - 1



Bearing capacity of foundation soil

Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	-682,43	735,54	17,42	0,000	142,21

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	-682,43	735,54	17,42

Verification of foundation soil

Eccentricity verification

Max. eccentricity of normal force $e = 0,000$
Maximum allowable eccentricity $e_{alw} = 0,333$

Eccentricity of the normal force is SATISFACTORY

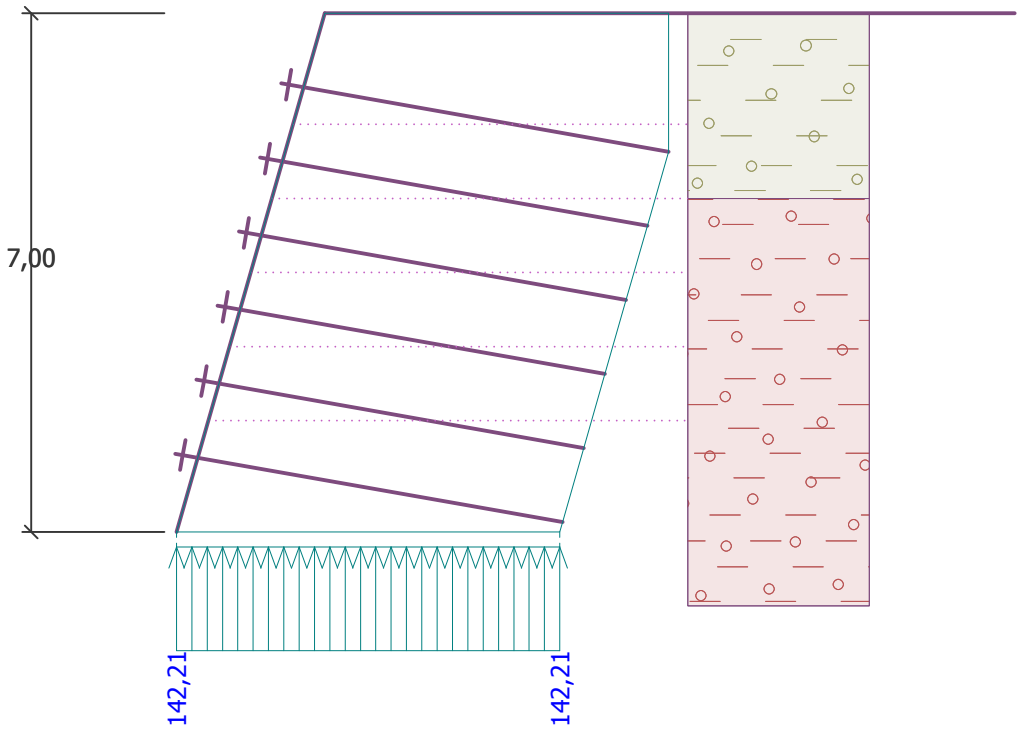
Verification of bearing capacity

Max. stress at footing bottom $\sigma = 142,21$ kPa
Bearing capacity of foundation soil $R_d = 160,00$ kPa

Safety factor = 1,13 > 1,00
Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Name : Bearing cap. | **Stage - analysis : 1 - -1**



Dimensioning No. 1

Depth [m]	Horiz.pres. [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	2.01	-0.00
0.33	0.00	2.01	-0.67
0.67	0.00	2.01	-1.34
1.00	0.00	2.01	-2.01
1.00	0.00	-4.02	-2.01
1.50	0.00	-4.02	0.00
2.00	0.00	-4.02	2.01
2.00	0.00	4.02	2.01
2.50	0.00	4.02	0.00
3.00	0.00	4.02	-2.01
3.00	0.00	-4.02	-2.01
3.50	0.00	-4.02	0.00
4.00	0.00	-4.02	2.01
4.00	0.00	4.03	2.01
4.29	0.00	4.03	0.85
4.50	0.91	3.93	0.00
5.00	3.03	2.95	-1.76
5.00	3.03	-2.59	-1.76
5.50	5.16	-4.64	0.00
6.00	7.29	-7.76	3.06
6.00	7.29	7.41	3.06
6.33	8.71	4.74	1.02
6.67	10.13	1.60	-0.05
7.00	11.54	-2.01	0.00

Dimensioning of concrete cover in section 6,00 m. (max.moment)

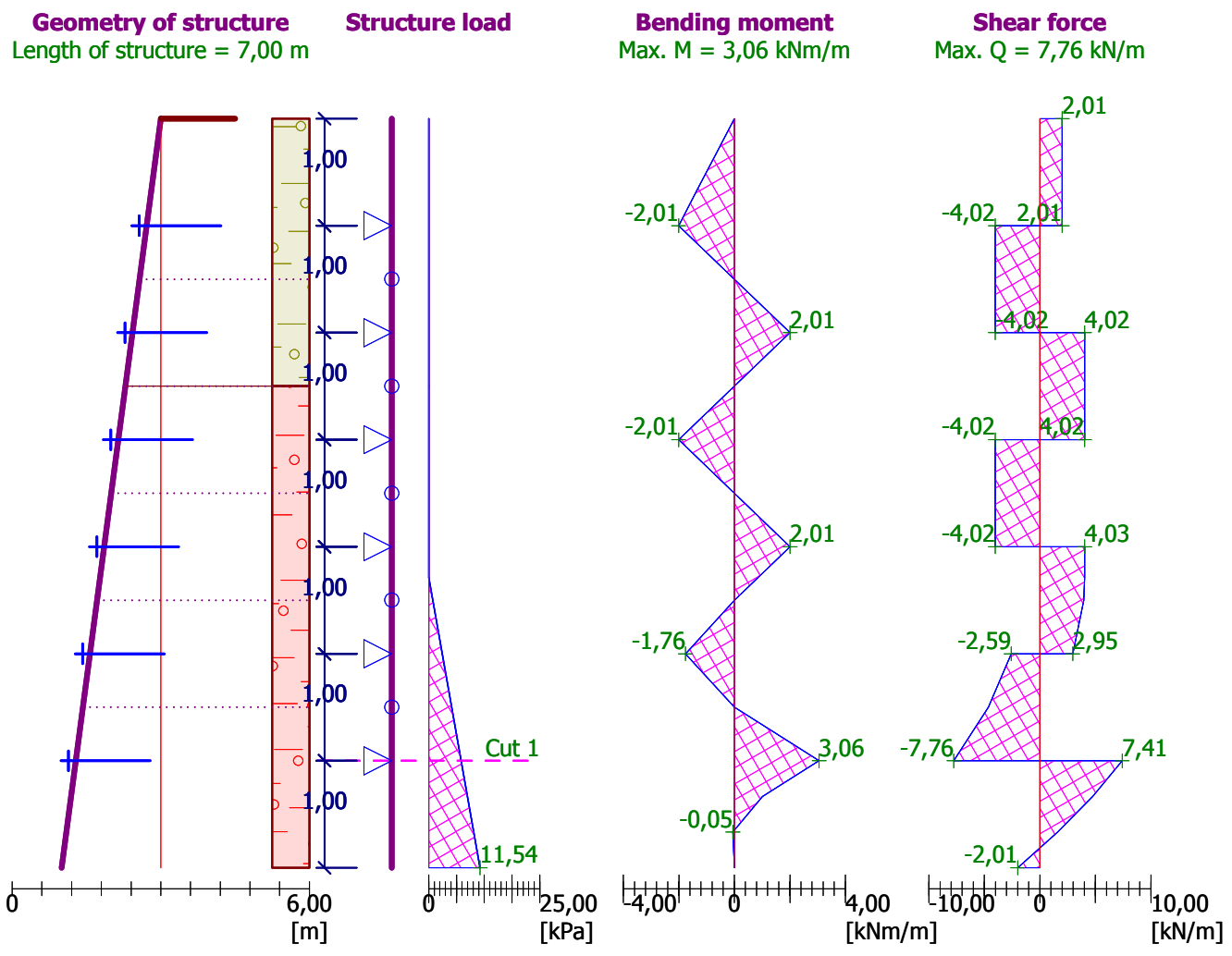
Analysis performed for vertical reinforcement
Reinforcement and dimensions of the cross-section:

Bar diameter	=	12,0	mm
Number of bars	=	5	
Reinforcement cover	=	20,0	mm
Cross-section width	=	1,00	m
Cross-section depth	=	0,20	m

Reinforcement ratio	ρ	=	0,32	%	> 0,13	%	=	ρ_{min}
Position of neutral axis	x	=	0,02	m	< 0,11	m	=	x_{max}
Ultimate shear force	V_{Rd}	=	77,93	kN/m	> 7,76	kN/m	=	V_{Ed}
Ultimate moment	M_{Rd}	=	40,51	kNm/m	> 3,06	kNm/m	=	M_{Ed}

Cross-section is SATISFACTORY.

Name : Dimensioning | **Stage - analysis : 1 - 1**



Slope stability analysis

Input data

Project

Settings

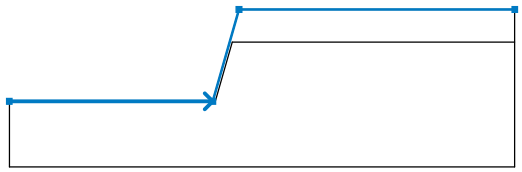
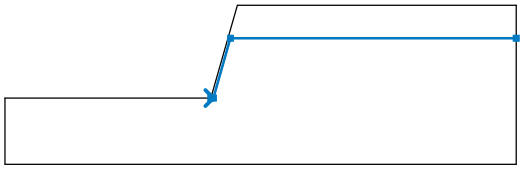
(input for current task)

Stability analysis

Earthquake analysis : Standard
Verification methodology : Safety factors (ASD)

Safety factors			
Permanent design situation			
Safety factor :	SF_s =	1,50	[–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		-17,50	-7,00	-2,00	-7,00	0,00	0,00
		21,00	0,00				
2		-2,00	-7,00	-1,81	-7,00	-0,52	-2,50
		21,00	-2,50				

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m3]
1	Soil No. 1		27,00	12,00	19,50
2	Soil No. 2		30,00	15,00	21,00

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m3]	γ_s [kN/m3]	n [–]
1	Soil No. 1		19,50		
2	Soil No. 2		21,50		

Soil parameters

Soil No. 1

Unit weight : γ = 19,50 kN/m3
Stress-state : effective
Angle of internal friction : φ_{ef} = 27,00 °
Cohesion of soil : c_{ef} = 12,00 kPa
Saturated unit weight : γ_{sat} = 19,50 kN/m3

Soil No. 2

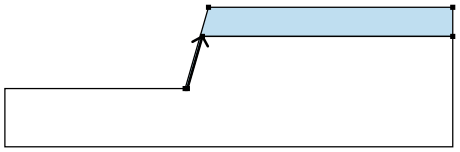
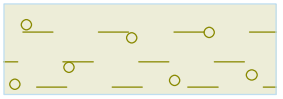
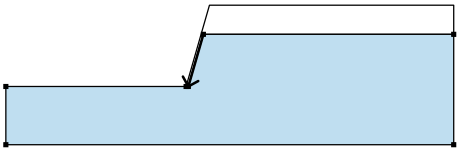
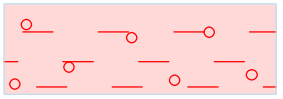
Unit weight : γ = 21,00 kN/m3
Stress-state : effective

Angle of internal friction : φ_{ef} = 30,00 °
Cohesion of soil : c_{ef} = 15,00 kPa
Saturated unit weight : γ_{sat} = 21,50 kN/m^3

Rigid bodies

No.	Name	Sample	γ [kN/m3]
1	Wall material		23,00

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m] x	z	x	z	Assigned soil
1		-1,81	-7,00	-0,52	-2,50	Soil No. 1
		21,00	-2,50	21,00	0,00	
		0,00	0,00	-2,00	-7,00	
2		-0,52	-2,50	-1,81	-7,00	Soil No. 2
		-2,00	-7,00	-17,50	-7,00	
		-17,50	-12,00	21,00	-12,00	
		21,00	-2,50			

Reinforcements

No.	Point to the left x [m]	z [m]	Point to the right x [m]	z [m]	Length L [m]	Strength R_t [kN/m]	Pull out resist.	End of reinf.
1	-0,29	-1,00	4,64	-1,87	5,01	235,62	T_p = 18,85 kN/m^2	Fixed
2	-0,57	-2,00	4,35	-2,87	5,00	235,62	T_p = 18,85 kN/m^2	Fixed
3	-0,86	-3,00	4,07	-3,87	5,01	235,62	T_p = 18,85 kN/m^2	Fixed
4	-1,14	-4,00	3,78	-4,87	5,00	235,62	T_p = 18,85 kN/m^2	Fixed
5	-1,43	-5,00	3,50	-5,87	5,01	235,62	T_p = 18,85 kN/m^2	Fixed
6	-1,71	-6,00	3,21	-6,87	5,00	235,62	T_p = 18,85 kN/m^2	Fixed

Water

Water type : No water

Tensile crack

Tensile crack not inputted.

Earthquake

Earthquake not included.

Settings of the stage of construction

Design situation : permanent

Results (Stage of construction 1)

Analysis 1

Circular slip surface

Slip surface parameters							
Center :	x =	-3,85	[m]	Angles :	α_1 =	10,08	[°]
	z =	3,42	[m]		α_2 =	71,14	[°]
Radius :	R =	10,58	[m]				
The slip surface after optimization.							

Reinforcement forces

Reinforcement	Force [kN/m]
1	0,00
2	0,00
3	4,23
4	16,62
5	33,65
6	57,17

Slope stability verification (Bishop)

Sum of active forces : F_a = 343,23 kN/m
Sum of passive forces : F_p = 600,09 kN/m

Sliding moment : M_a = 3631,40 kNm/m
Resisting moment : M_p = 6348,96 kNm/m
Factor of safety = 1,75 > 1,50
Slope stability ACCEPTABLE