



Slope stability analysis

Input data

Project

Date : 4.1.2013

Settings

(input for current task)

Stability analysis

Earthquake analysis : Standard

Verification methodology : Safety factors (ASD)

Safety factors

Permanent design situation

Safety factor : $SF_s = 1,50 [-]$

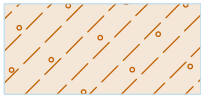
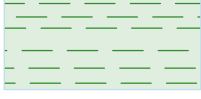
Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		-20,00	115,32	0,00	115,32	7,89	115,20
		11,54	116,85	17,20	117,99	17,25	118,00
		17,25	119,00	19,00	119,00	20,00	122,98
		21,50	122,98	26,50	122,98	29,80	124,92
		32,39	125,92	36,16	127,92	38,69	128,51
		41,22	128,69	50,00	128,75	70,00	128,75
2		17,20	117,99	21,50	117,90	21,50	120,02
		21,50	122,98				
3		21,50	120,02	36,18	120,75	53,99	121,70
		70,00	122,34				
4		-20,00	105,06	-3,99	104,21	24,73	103,26
		49,75	104,63	70,00	105,48		




Soil parameters - effective stress state

No.	Name	Pattern	Φ_{ef} [°]	C_{ef} [kPa]	γ [kN/m ³]
1	Soil No. 1		21,00	12,00	20,00



No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m ³]
2	Soil No. 2		26,50	16,00	18,00
3	Soil No. 3		40,00	50,00	19,00

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m ³]	γ_s [kN/m ³]	n [-]
1	Soil No. 1		22,00		
2	Soil No. 2		18,00		
3	Soil No. 3		22,00		

Soil parameters

Soil No. 1

Unit weight : $\gamma = 20,00 \text{ kN/m}^3$
 Stress-state : effective
 Angle of internal friction : $\varphi_{ef} = 21,00^\circ$
 Cohesion of soil : $c_{ef} = 12,00 \text{ kPa}$
 Saturated unit weight : $\gamma_{sat} = 22,00 \text{ kN/m}^3$


Soil No. 2

Unit weight : $\gamma = 18,00 \text{ kN/m}^3$
 Stress-state : effective
 Angle of internal friction : $\varphi_{ef} = 26,50^\circ$
 Cohesion of soil : $c_{ef} = 16,00 \text{ kPa}$
 Saturated unit weight : $\gamma_{sat} = 18,00 \text{ kN/m}^3$

Soil No. 3

Unit weight : $\gamma = 19,00 \text{ kN/m}^3$
 Stress-state : effective
 Angle of internal friction : $\varphi_{ef} = 40,00^\circ$
 Cohesion of soil : $c_{ef} = 50,00 \text{ kPa}$
 Saturated unit weight : $\gamma_{sat} = 22,00 \text{ kN/m}^3$

Rigid bodies

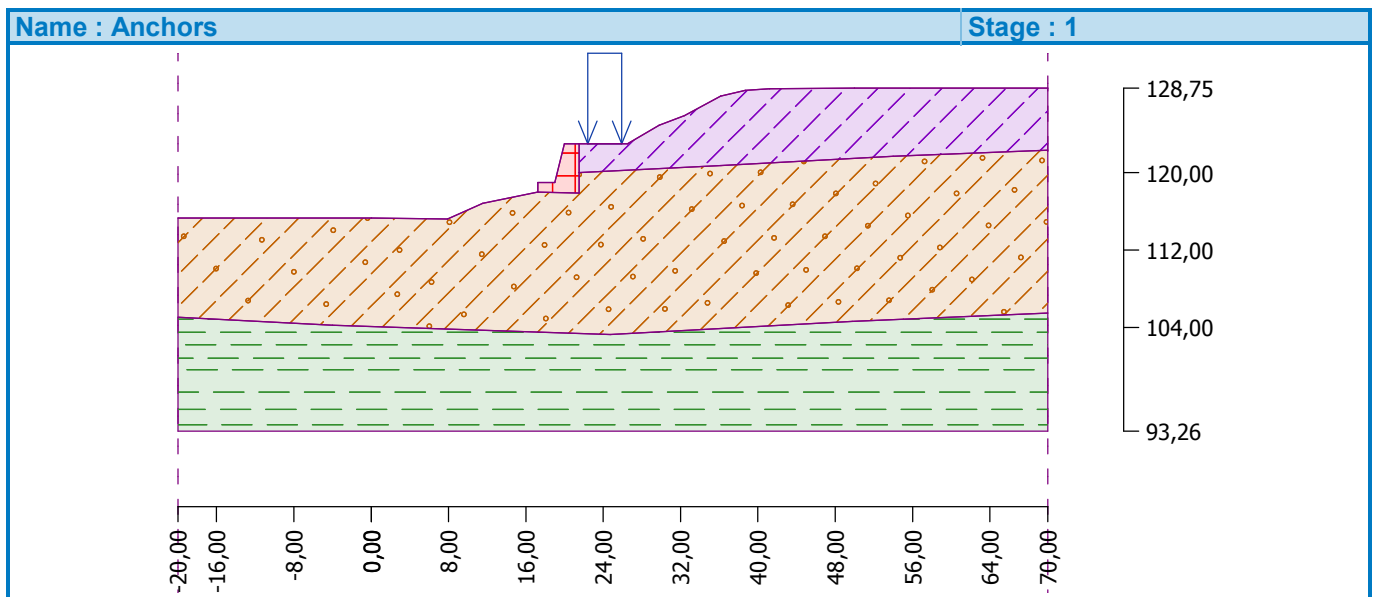
No.	Name	Sample	γ [kN/m ³]
1	Rigid body No. 1		25,00



Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		36,18	120,75	53,99	121,70	Soil No. 1
		70,00	122,34	70,00	128,75	
		50,00	128,75	41,22	128,69	
		38,69	128,51	36,16	127,92	
		32,39	125,92	29,80	124,92	
		26,50	122,98	21,50	122,98	
		21,50	120,02			
2		21,50	117,90	21,50	120,02	Rigid body No. 1
		21,50	122,98	20,00	122,98	
		19,00	119,00	17,25	119,00	
		17,25	118,00	17,20	117,99	
3		-3,99	104,21	24,73	103,26	Soil No. 2
		49,75	104,63	70,00	105,48	
		70,00	122,34	53,99	121,70	
		36,18	120,75	21,50	120,02	
		21,50	117,90	17,20	117,99	
		11,54	116,85	7,89	115,20	
		0,00	115,32	-20,00	115,32	
4		49,75	104,63	24,73	103,26	Soil No. 3
		-3,99	104,21	-20,00	105,06	
		-20,00	93,26	70,00	93,26	
		70,00	105,48			

Anchors





Surcharge

No.	Type	Type of action	Location z [m]	Origin x [m]	Length l [m]	Width b [m]	Slope α [°]	Magnitude	
								q, q ₁ , f, F	q ₂
1	strip	permanent	on terrain	x = 22,40	l = 3,50		0,00	12,00	kN/m ²

Surcharges

No.	Name
1	Surcharge No. 1

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 (stage 1)

Circular slip surface

Slip surface parameters						
Center :	x =	11,89	[m]	Angles :	$\alpha_1 =$	-5,91 [°]
	z =	153,34	[m]		$\alpha_2 =$	49,96 [°]
Radius :	R =	38,32	[m]			
The slip surface after optimization.						

Slope stability verification (Bishop)

Sum of active forces : $F_a = 945,71$ kN/m

Sum of passive forces : $F_p = 1703,57$ kN/m

Sliding moment : $M_a = 36239,76$ kNm/m

Resisting moment : $M_p = 65280,65$ kNm/m

Factor of safety = 1,80 > 1,50

Slope stability ACCEPTABLE

Analysis 2 (stage 1)

Circular slip surface

Slip surface parameters						
Center :	x =	11,89	[m]	Angles :	$\alpha_1 =$	-5,91 [°]
	z =	153,34	[m]		$\alpha_2 =$	49,96 [°]
Radius :	R =	38,32	[m]			
Analysis of the slip surface without optimization.						

Slope stability verification (all methods)

Bishop : FS = 1,80 > 1,50 **ACCEPTABLE**

Fellenius / Petterson : FS = 1,74 > 1,50 **ACCEPTABLE**

Spencer : FS = 1,81 > 1,50 **ACCEPTABLE**

Janbu : FS = 1,81 > 1,50 **ACCEPTABLE**

Morgenstern-Price : FS = 1,81 > 1,50 **ACCEPTABLE**

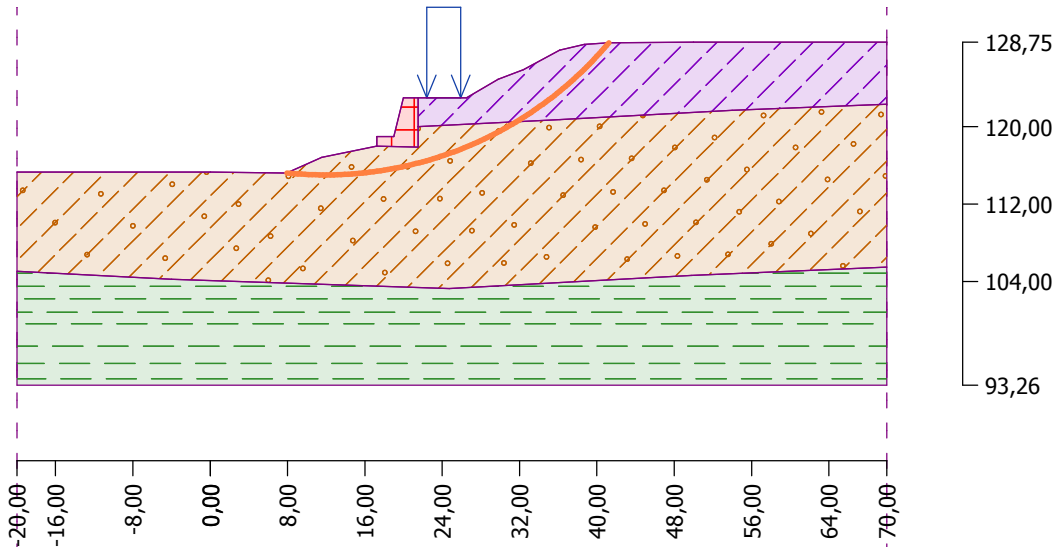
Shachunyan : FS = 1,74 > 1,50 **ACCEPTABLE**

ITFM : FS = 1,82 > 1,50 **ACCEPTABLE**

ITFM explicit solution : FS = 1,88 > 1,50 **ACCEPTABLE**

Name : Analysis

Stage - analysis : 1 - 2



Input data (Stage of construction 2)

Earth cut

No.	Cut location	Coordinates of cut points [m]					
		x	z	x	z	x	z
1		41,00	128,67	41,50	127,50	53,00	127,50
		54,00	128,75				

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		36,18	120,75	53,99	121,70	Soil No. 1
		70,00	122,34	70,00	128,75	
		54,00	128,75	53,00	127,50	
		41,50	127,50	41,00	128,67	
		38,69	128,51	36,16	127,92	
		32,39	125,92	29,80	124,92	
		26,50	122,98	21,50	122,98	
2		21,50	117,90	21,50	120,02	Rigid body No. 1
		21,50	122,98	20,00	122,98	
		19,00	119,00	17,25	119,00	
		17,25	118,00	17,20	117,99	



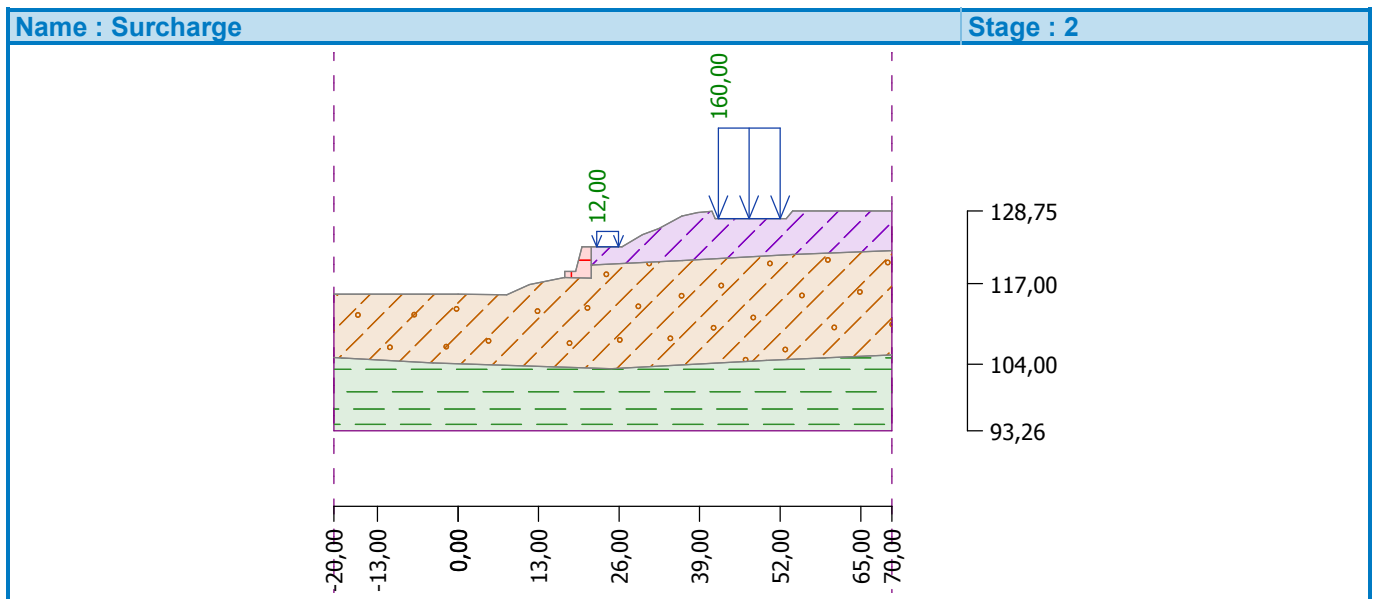
No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
3		-3,99	104,21	24,73	103,26	Soil No. 2
		49,75	104,63	70,00	105,48	
		70,00	122,34	53,99	121,70	
		36,18	120,75	21,50	120,02	
		21,50	117,90	17,20	117,99	
		11,54	116,85	7,89	115,20	
		0,00	115,32	-20,00	115,32	
4		49,75	104,63	24,73	103,26	Soil No. 3
		-3,99	104,21	-20,00	105,06	
		-20,00	93,26	70,00	93,26	
		70,00	105,48			

Surcharge

No.	Surcharge		Type	Type of action	Location	Origin	Length	Width	Slope	Magnitude		
	new	change								z [m]	x [m]	l [m]
1	No	No	strip	permanent	on terrain	x = 22,40	l = 3,50		0,00	12,00		kN/m ²
2	Yes		strip	permanent	on terrain	x = 42,00	l = 10,00		0,00	160,00		kN/m ²

Surcharges

No.	Name
1	Surcharge No. 1
2	Surcharge No. 2



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 2)

Analysis 1 (stage 2)

Circular slip surface

Slip surface parameters						
Center :	x =	14,56	[m]	Angles :	$\alpha_1 =$	-7,57 [°]
	z =	166,63	[m]		$\alpha_2 =$	41,04 [°]
Radius :	R =	51,88	[m]			
Analysis of the slip surface without optimization.						

Slope stability verification (all methods)

Bishop : FS = 1,61 > 1,50 **ACCEPTABLE**
 Fellenius / Petterson : FS = 1,55 > 1,50 **ACCEPTABLE**
 Spencer : FS = 1,62 > 1,50 **ACCEPTABLE**
 Janbu : FS = 1,62 > 1,50 **ACCEPTABLE**
 Morgenstern-Price : FS = 1,62 > 1,50 **ACCEPTABLE**
 Shachunyanc : FS = 1,55 > 1,50 **ACCEPTABLE**
 ITFM : FS = 1,63 > 1,50 **ACCEPTABLE**
 ITFM explicit solution : FS = 1,68 > 1,50 **ACCEPTABLE**

Analysis 2 (stage 2)

Circular slip surface

Slip surface parameters						
Center :	x =	16,90	[m]	Angles :	$\alpha_1 =$	-4,33 [°]
	z =	165,22	[m]		$\alpha_2 =$	38,44 [°]
Radius :	R =	48,16	[m]			
Analysis of the slip surface without optimization.						

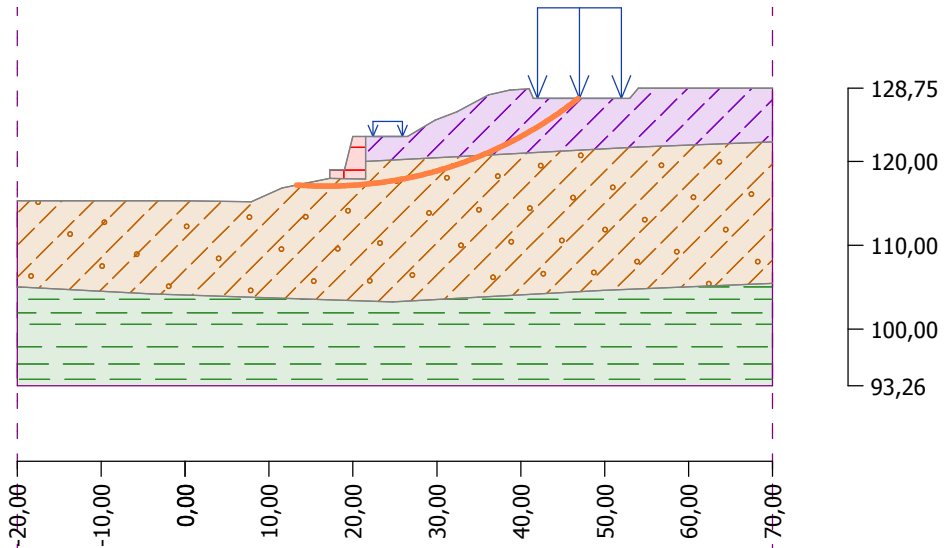
Slope stability verification (Bishop)

Sum of active forces : $F_a = 1301,81$ kN/m
 Sum of passive forces : $F_p = 2135,11$ kN/m
 Sliding moment : $M_a = 62695,01$ kNm/m
 Resisting moment : $M_p = 102826,95$ kNm/m
 Factor of safety = 1,64 > 1,50

Slope stability ACCEPTABLE

Name : Analysis

Stage - analysis : 2 - 2



Input data (Stage of construction 3)

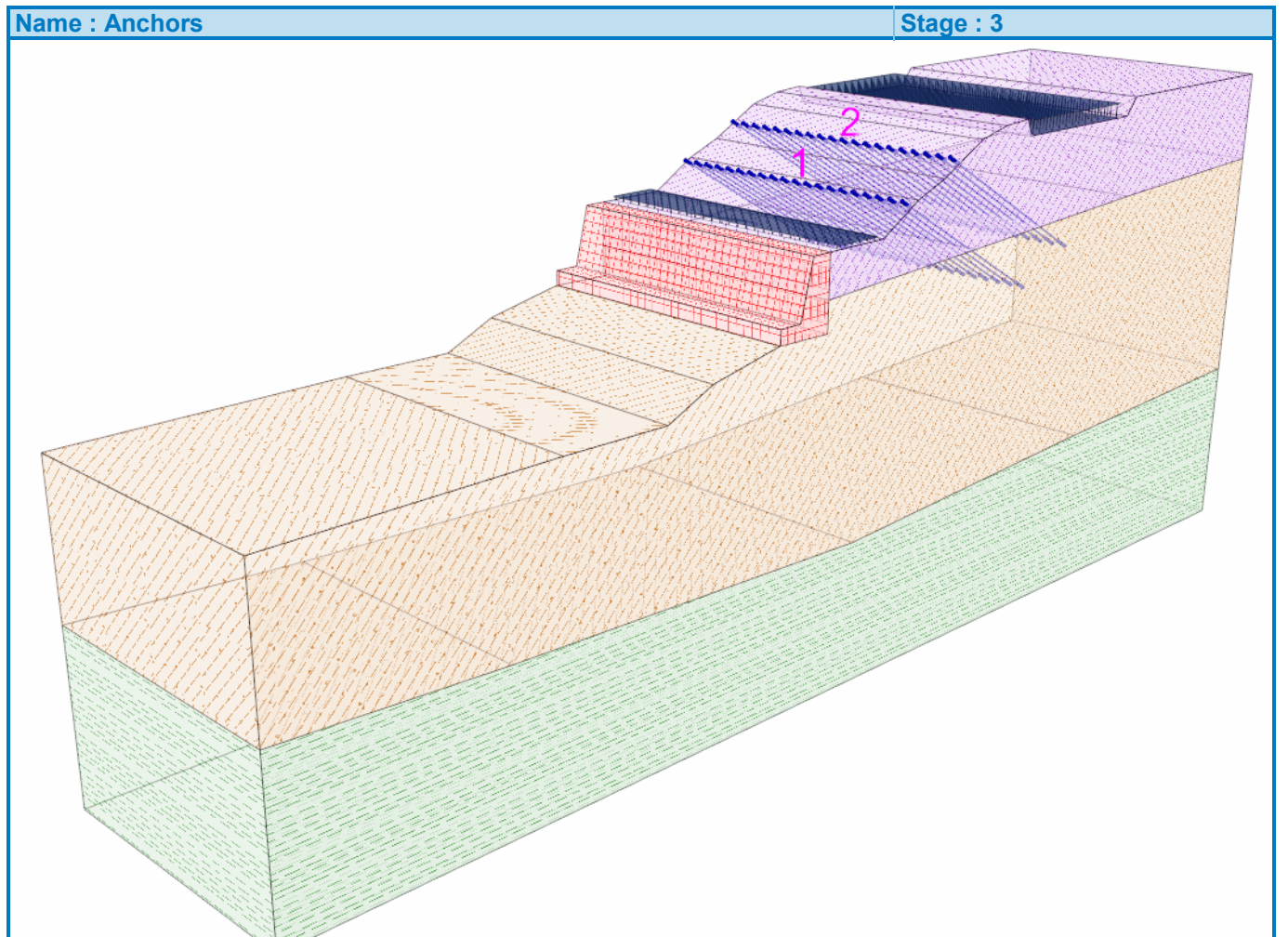
Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil			
		x	z	x	z				
1		36,18	120,75	53,99	121,70	Soil No. 1 			
		70,00	122,34	70,00	128,75				
		54,00	128,75	53,00	127,50				
		41,50	127,50	41,00	128,67				
		38,69	128,51	36,16	127,92				
		32,39	125,92	29,80	124,92				
		26,50	122,98	21,50	122,98				
2		21,50	117,90	21,50	120,02	Rigid body No. 1 			
		21,50	122,98	20,00	122,98				
		19,00	119,00	17,25	119,00				
		17,25	118,00	17,20	117,99				
3		-3,99	104,21	24,73	103,26	Soil No. 2 			
		49,75	104,63	70,00	105,48				
		70,00	122,34	53,99	121,70				
		36,18	120,75	21,50	120,02				
		21,50	117,90	17,20	117,99				
		11,54	116,85	7,89	115,20				
4		0,00	115,32	-20,00	115,32	Soil No. 3 			
		-20,00	105,06						
		49,75	104,63	24,73	103,26				
		-3,99	104,21	-20,00	105,06				
				70,00	93,26	70,00	93,26		
				70,00	105,48				



Anchors

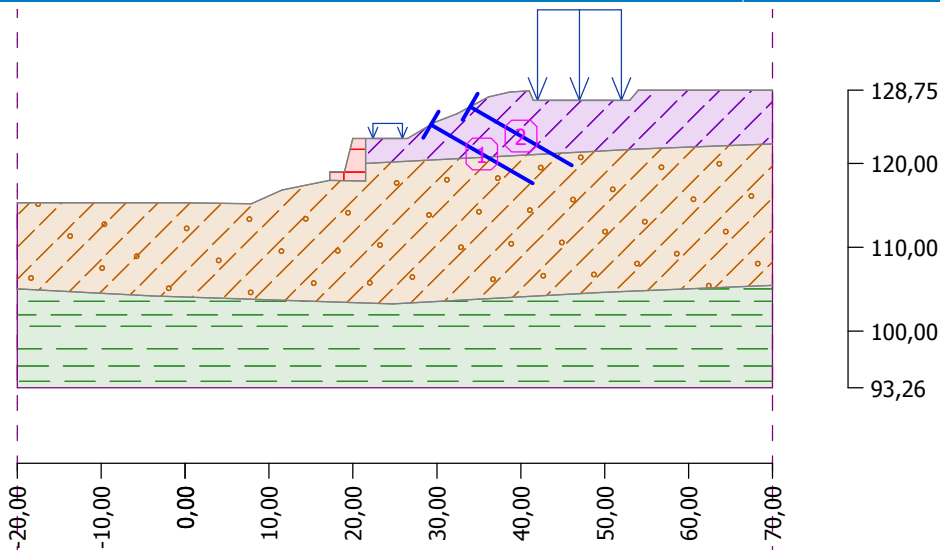
No.	Anchor		Origin		Length and slope / coordinates		Anchor spacing b [m]	Diameter / area d [mm] / A [mm ²]	Elastic modulus E [MPa]	Tensile strength F _c [kN]	Active in compress.	Force F [kN]
	new	post-stress	x [m]	z [m]	l [m] / x [m]	α [°] / z [m]						
1	Yes		29,29	124,62	l = 14,00	α = 30,00	1,00	d =			No	200,00
2	Yes		33,97	126,76	l = 14,00	α = 30,00	1,00	d =			No	200,00





Name : Anchors

Stage : 3



Surcharge

No.	Surcharge		Type	Type of action	Location z [m]	Origin x [m]	Length l [m]	Width b [m]	Slope α [°]	Magnitude		
	new	change								q, q ₁ , f, F	q ₂	unit
1	No	Yes	strip	permanent	on terrain	x = 22,40	l = 3,50		0,00	22,00		kN/m ²
2	No	No	strip	permanent	on terrain	x = 42,00	l = 10,00		0,00	160,00		kN/m ²

Surcharges

No.	Name
1	Surcharge No. 1
2	Surcharge No. 2

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 3)

Analysis 1 (stage 3)

Circular slip surface

Slip surface parameters							
Center :	x =	14,56	[m]	Angles :	$\alpha_1 =$	-7,57	[°]
	z =	166,63	[m]		$\alpha_2 =$	41,04	[°]
Radius :	R =	51,88	[m]				
Analysis of the slip surface without optimization.							

Slope stability verification (all methods)

Bishop : FS = 1,79 > 1,50 **ACCEPTABLE**

Fellenius / Petterson : FS = 1,74 > 1,50 **ACCEPTABLE**

Spencer : FS = 1,90 > 1,50 **ACCEPTABLE**



Janbu : FS = 1,90 > 1,50 **ACCEPTABLE**
 Morgenstern-Price : FS = 1,90 > 1,50 **ACCEPTABLE**
 Shachunyanc : FS = 1,85 > 1,50 **ACCEPTABLE**
 ITFM : FS = 1,99 > 1,50 **ACCEPTABLE**
 ITFM explicit solution : FS = 1,92 > 1,50 **ACCEPTABLE**

Analysis 2 (stage 3)

Polygonal slip surface

Coordinates of slip surface points [m]									
x	z	x	z	x	z	x	z	x	z
13,25	117,19	17,12	116,28	22,53	117,39	28,39	118,29	32,99	120,29
36,90	121,86	42,30	123,65	46,85	127,50				

Analysis of the slip surface without optimization.

Slope stability verification (all methods)

Sarma : FS = 1,94 > 1,50 **ACCEPTABLE** One of the dividing planes cuts through the rigid body. The results can be overestimated.

Spencer : FS = 1,94 > 1,50 **ACCEPTABLE**

Janbu : FS = 1,96 > 1,50 **ACCEPTABLE**

Morgenstern-Price : FS = 1,91 > 1,50 **ACCEPTABLE**

Shachunyanc : FS = 1,91 > 1,50 **ACCEPTABLE**

ITFM : FS = 2,12 > 1,50 **ACCEPTABLE** The increments of slip segment obliqueness is higher than 10 degrees. The results can be overestimated.

ITFM explicit solution : FS = 1,98 > 1,50 **ACCEPTABLE** The increments of slip segment obliqueness is higher than 10 degrees. The results can be overestimated.