Cantilever wall analysis

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
Base key : The base key is considered as inclined footing bottom
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	[–]

Material of structure

Unit weight γ = 23,00 kN/m^3
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

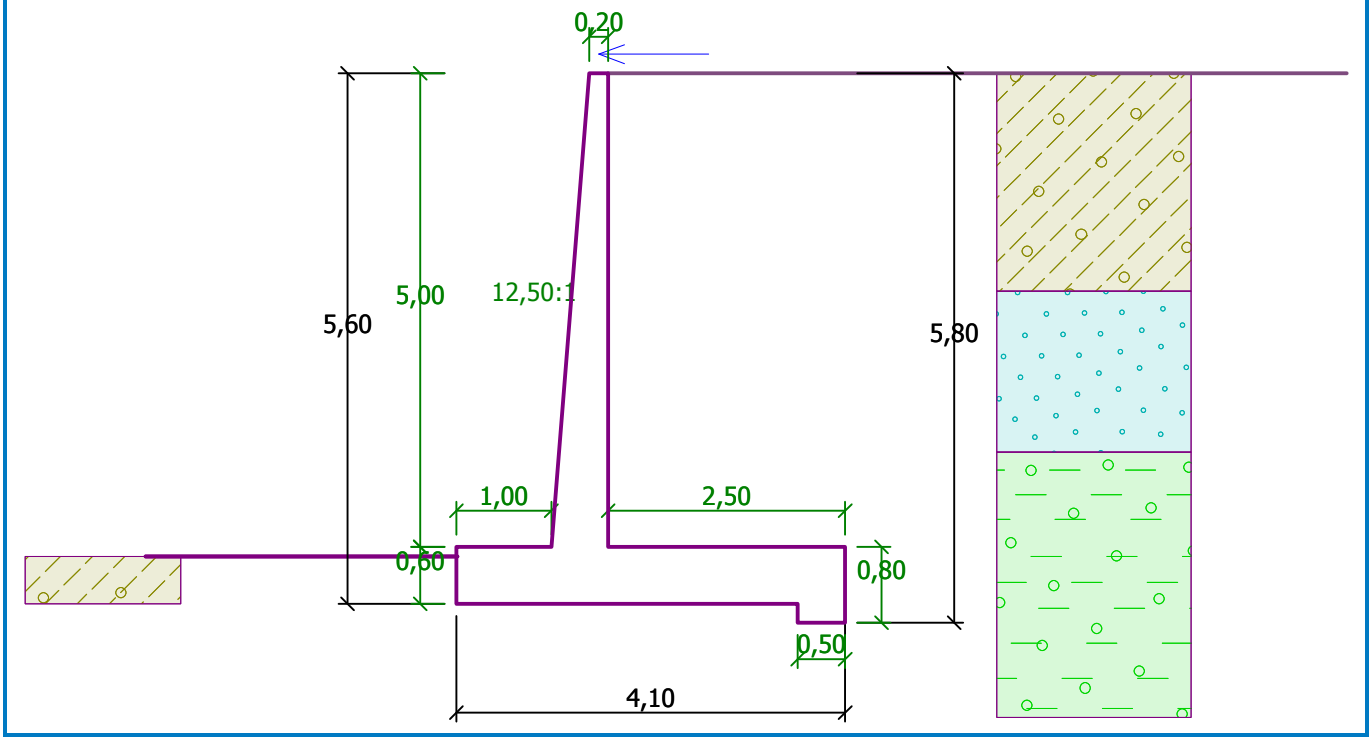
Longitudinal steel : B500
Yield strength f_{yk} = 500,00 MPa

Geometry of structure

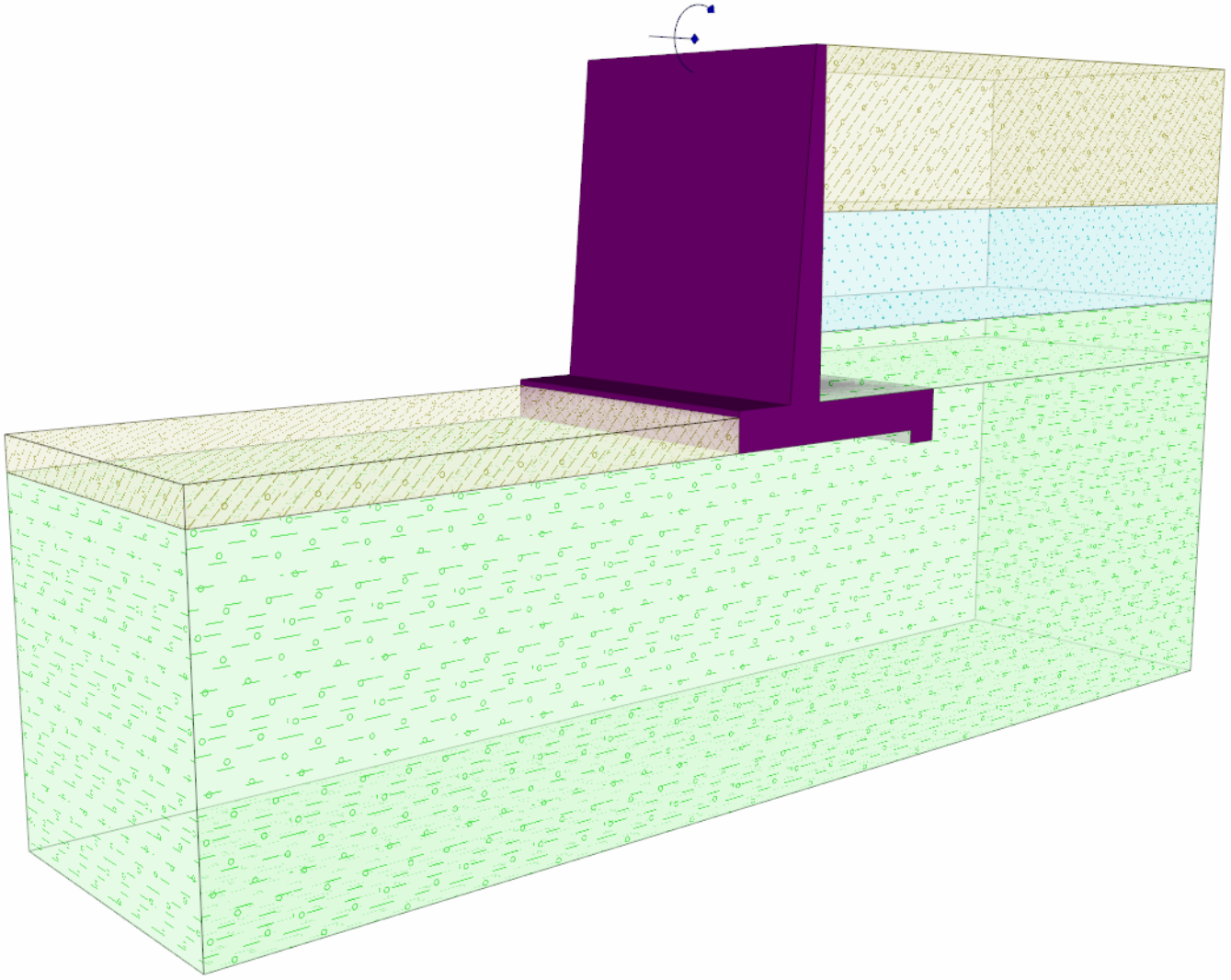
No.	Coordinate X [m]	Depth Z [m]
1	0,00	0,00
2	0,00	5,00
3	2,50	5,00
4	2,50	5,60
5	2,50	5,80
6	2,00	5,80
7	2,00	5,60
8	-1,60	5,60
9	-1,60	5,00
10	-0,60	5,00
11	-0,20	0,00

The origin [0,0] is located at the most upper right point of the wall.
Wall section area = 4,56 m^2.

Name : Geometry	Stage - analysis : 1 - 0



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



Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]	γ_{su} [kN/m^3]	δ [°]
1	Soil No. 1		29,00	10,00	19,00	9,00	15,00
2	Soil No. 2		31,50	0,00	17,50	7,50	15,00
3	Soil No. 3		27,00	10,00	19,50	9,50	15,00

All soils are considered as cohesionless for at rest pressure analysis.

Soil parameters

Soil No. 1

Unit weight : γ = 19,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 29,00 °
Cohesion of soil : c_{ef} = 10,00 kPa
Angle of friction struc.-soil : δ = 15,00 °

Soil : cohesionless
Saturated unit weight : γ_{sat} = 19,00 kN/m^3

Soil No. 2
Unit weight : γ = 17,50 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 31,50 °
Cohesion of soil : c_{ef} = 0,00 kPa
Angle of friction struc.-soil : δ = 15,00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 17,50 kN/m^3

Soil No. 3
Unit weight : γ = 19,50 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 27,00 °
Cohesion of soil : c_{ef} = 10,00 kPa
Angle of friction struc.-soil : δ = 15,00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 19,50 kN/m^3

Geological profile and assigned soils

No.	Layer [m]	Assigned soil	Pattern
1	2,30	Soil No. 1	
2	1,70	Soil No. 2	
3	-	Soil No. 3	

Foundation

Type of foundation : soil from geological profile

Terrain profile

Terrain behind the structure is flat.

Water influence

Ground water table is located below the structure.

Resistance on front face of the structure

Resistance on front face of the structure: at rest
Soil on front face of the structure - Soil No. 1
Soil thickness in front of structure h = 0,50 m
Terrain in front of structure is flat.

Applied forces acting on the structure

No.	Force new	Force edit	Name	Action	F_x [kN/m]	F_z [kN/m]	M [kNm/m]	x [m]	z [m]
1	Yes		Force No. 1	permanent	-30,00	0,00	0,00	-0,10	-0,20

Settings of the stage of construction

Design situation : permanent
The wall is free to move. Active earth pressure is therefore assumed.

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
Weight - wall	0,00	-1,34	104,88	1,80	1,000
FF resistance	-1,22	-0,17	0,00	0,00	1,000
Weight - earth wedge	0,00	-2,00	99,17	2,44	1,000
Active pressure	84,30	-1,65	118,67	3,26	1,000
Force No. 1	30,00	-5,80	0,00	1,50	1,000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 817,56 kNm/m
Overturning moment M_{ovr} = 313,07 kNm/m

Safety factor = 2,61 > 1,50
Wall for overturning is SATISFACTORY

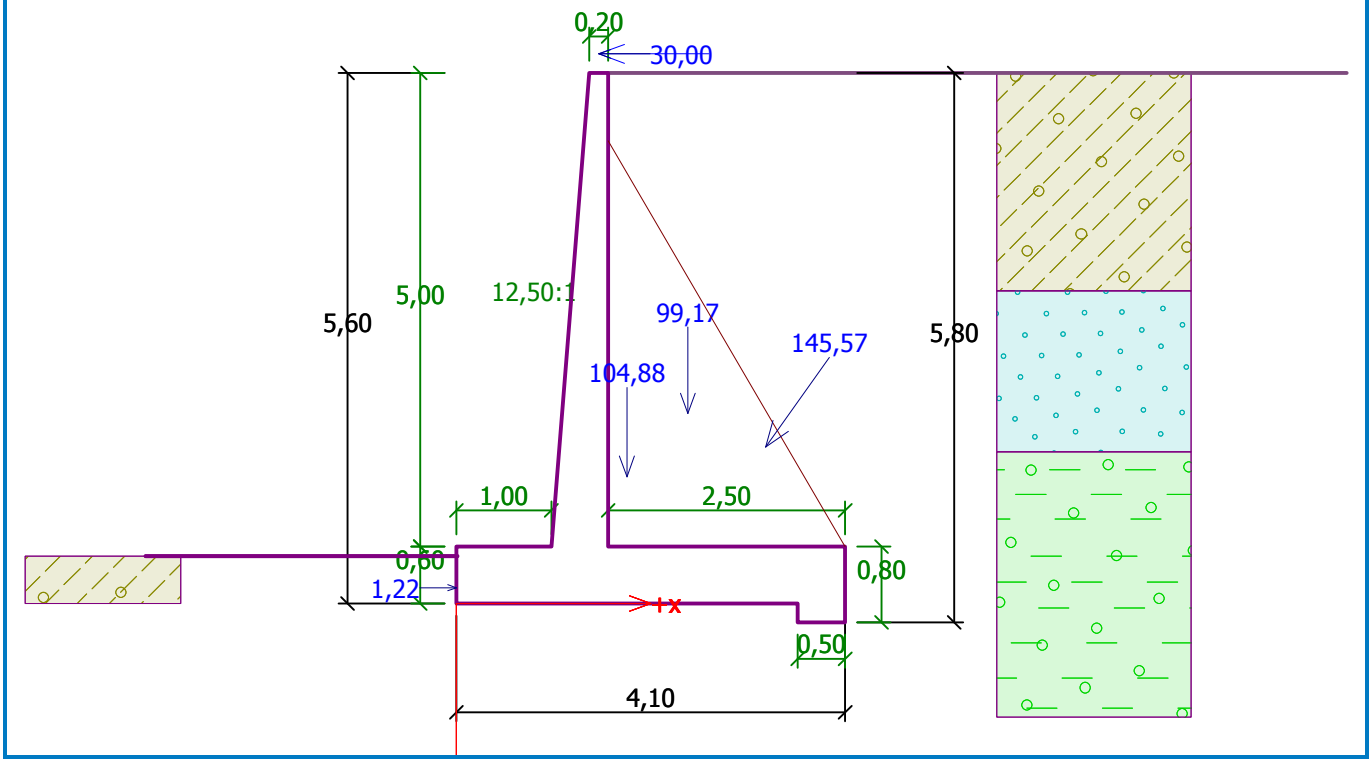
Check for slip

Resisting horizontal force H_{res} = 197,82 kN/m
Active horizontal force H_{act} = 97,21 kN/m

Safety factor = 2,03 > 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	168,39	327,85	96,96	0,125	106,53

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	168,39	327,85	96,96

Verification of foundation soil

Eccentricity verification

Max. eccentricity of normal force $e = 0,125$
Maximum allowable eccentricity $e_{alw} = 0,333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

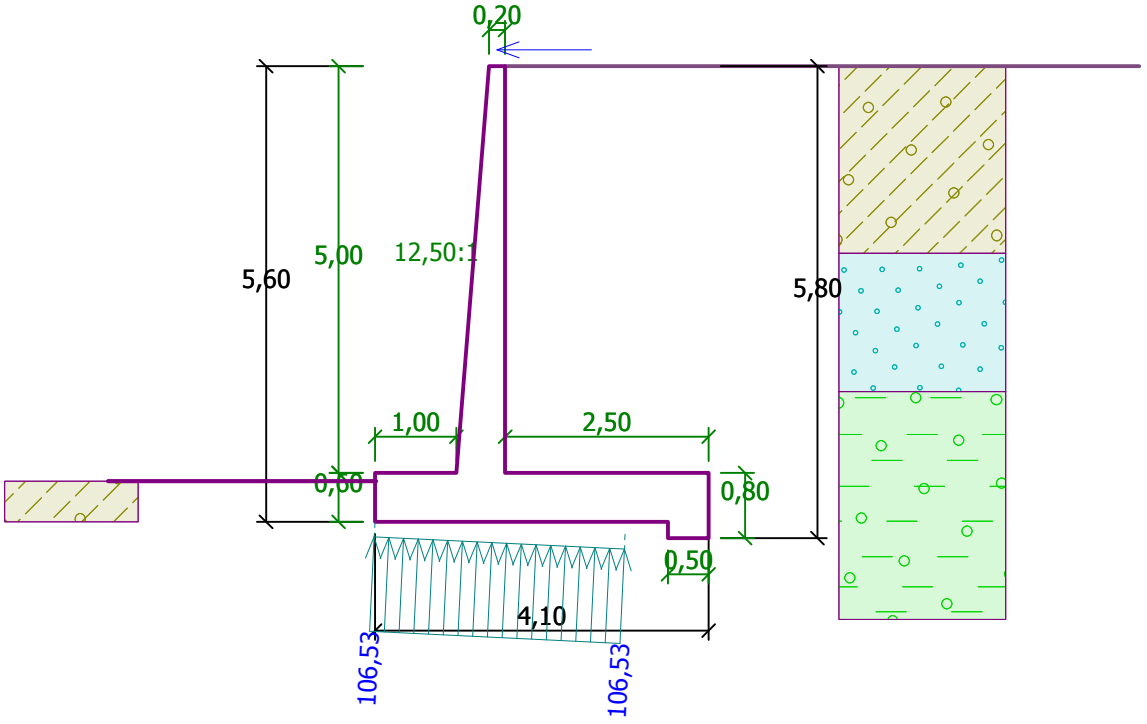
Max. stress at footing bottom $\sigma = 106,53$ kPa
Bearing capacity of foundation soil $R_d = 180,00$ kPa

Safety factor = 1,69 > 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

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0,00	-2,08	45,98	0,38	1,000
Pressure at rest	118,80	-1,65	0,00	0,60	1,000
Force No. 1	30,00	-5,20	0,00	0,50	1,000

Wall stem check

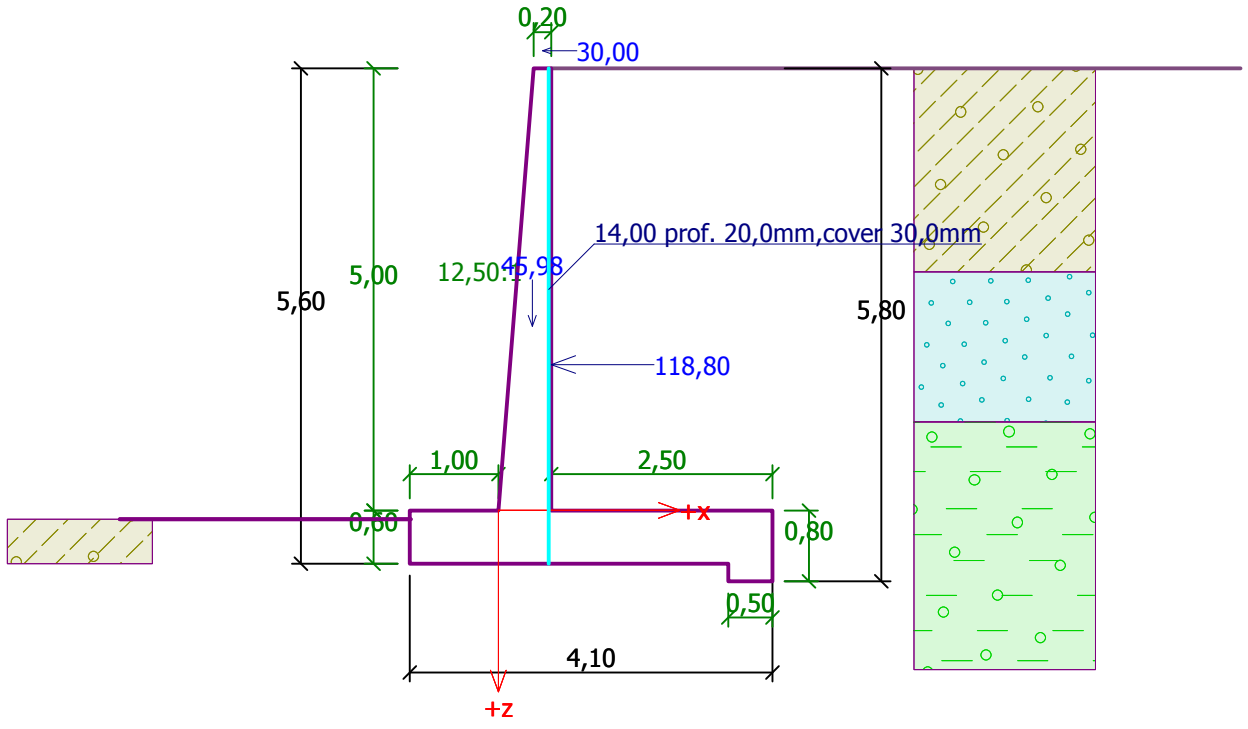
Reinforcement and dimensions of the cross-section

Bar diameter = 20,0 mm
Number of bars = 14
Reinforcement cover = 30,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,60 m

Reinforcement ratio	ρ	=	0,79	%	>	0,13	%	= ρ_{min}
Position of neutral axis	x	=	0,18	m	<	0,35	m	= x_{max}
Ultimate shear force	V_{Rd}	=	268,85	kN	>	148,80	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	933,56	kNm	>	348,11	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Name : Dimensioning	Stage - analysis : 1 - 1



Dimensioning No. 2

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0,00	-1,34	104,88	1,80	1,000
FF resistance	-1,22	-0,17	0,00	0,00	1,000

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - earth wedge	0,00	-2,00	99,17	2,44	1,000
Active pressure	84,30	-1,65	118,67	3,26	1,000
Force No. 1	30,00	-5,80	0,00	1,50	1,000

Front wall jump check

Reinforcement and dimensions of the cross-section
Bar diameter = 16,0 mm
Number of bars = 6
Reinforcement cover = 30,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,60 m

Reinforcement ratio	ρ	=	0,21	%	>	0,13	%	= ρ_{min}
Position of neutral axis	x	=	0,05	m	<	0,35	m	= x_{max}
Ultimate shear force	V_{Rd}	=	177,46	kN	>	111,61	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	284,46	kNm	>	58,25	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Dimensioning No. 3

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0,00	-0,30	34,50	2,85	1,000
Weight - earth wedge	0,00	-2,00	99,17	2,44	1,000
Active pressure	84,30	-1,65	118,67	3,26	1,000
Contact stress	0,00	0,00	-141,27	2,58	1,000

Back wall jump check

Reinforcement and dimensions of the cross-section
Bar diameter = 16,0 mm
Number of bars = 6
Reinforcement cover = 30,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,60 m

Reinforcement ratio	ρ	=	0,21	%	>	0,13	%	= ρ_{min}
Position of neutral axis	x	=	0,05	m	<	0,35	m	= x_{max}
Ultimate shear force	V_{Rd}	=	177,46	kN	>	111,07	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	284,46	kNm	>	185,25	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Dimensioning No. 4

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Design coefficient
Weight - wall	0,00	-0,05	0,47	0,11	1,000
Pressure at rest	0,05	-0,03	0,00	0,21	1,000
Force No. 1	30,00	-0,30	0,00	0,11	1,000

Wall check at the construction joint 0,10 m from the wall crest

Reinforcement and dimensions of the cross-section

Bar diameter		=	16,0	mm				
Number of bars		=	6					
Reinforcement cover		=	30,0	mm				
Cross-section width		=	1,00	m				
Cross-section depth		=	0,21	m				
Reinforcement ratio	ρ	=	0,71	%	>	0,13	%	= ρ_{min}
Position of neutral axis	x	=	0,05	m	<	0,10	m	= x_{max}
Ultimate shear force	V_{Rd}	=	98,78	kN	>	30,05	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	78,85	kNm	>	9,00	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Slope stability analysis

Input data

Project

Settings

(input for current task)

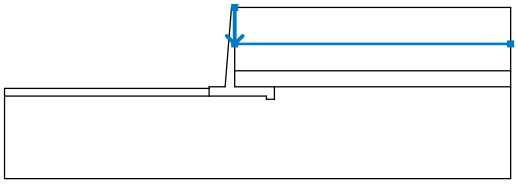
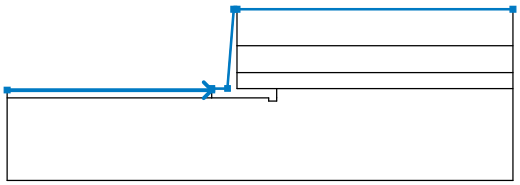
Stability analysis

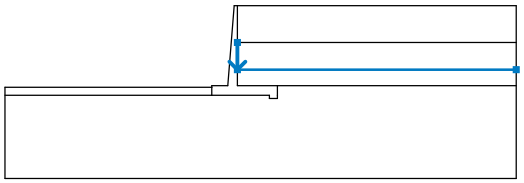
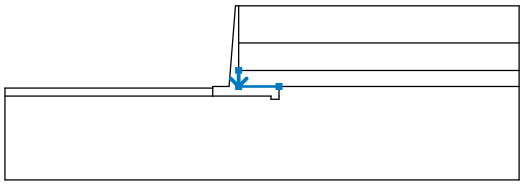
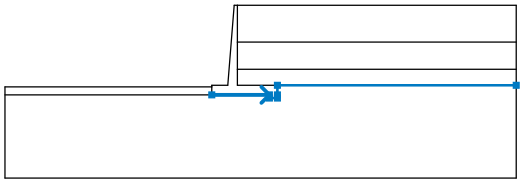
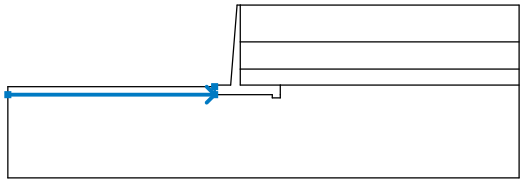
Earthquake analysis : Standard
Verification methodology : according to EN 1997
Design approach : 2 - reduction of actions and resistances

Partial factors on actions (A)					
Permanent design situation					
		Unfavourable		Favourable	
Permanent actions :	γ_G =	1,35	[–]	1,00	[–]
Variable actions :	γ_Q =	1,50	[–]	0,00	[–]
Water load :	γ_w =	1,35	[–]		

Partial factors for resistances (R)			
Permanent design situation			
Partial factor on sliding resistance (on slip surface) :	γ_{Rs} =	1,10	[–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		0,00	100,00	0,00	97,70	17,40	97,70
2		-14,50	94,90	-1,60	94,90	-1,60	95,00
		-0,60	95,00	-0,20	100,00	0,00	100,00
		17,40	100,00				

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
3		0,00	97,70	0,00	96,00	17,40	96,00
4		0,00	96,00	0,00	95,00	2,50	95,00
5		-1,60	94,40	2,00	94,40	2,00	94,20
		2,50	94,20	2,50	94,40	2,50	95,00
		17,40	95,00				
6		-14,50	94,40	-1,60	94,40	-1,60	94,90

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]
1	Soil No. 1		29,00	10,00	19,00
2	Soil No. 2		31,50	0,00	17,50
3	Soil No. 3		27,00	10,00	19,50

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m^3]	γ_s [kN/m^3]	n [–]
1	Soil No. 1		19,00		
2	Soil No. 2		17,50		
3	Soil No. 3		19,50		

Soil parameters

Soil No. 1

Unit weight :	γ =	19,00 kN/m^3
Stress-state :		effective
Angle of internal friction :	φ_{ef} =	29,00 °
Cohesion of soil :	c_{ef} =	10,00 kPa
Saturated unit weight :	γ_{sat} =	19,00 kN/m^3

Soil No. 2

Unit weight :	γ =	17,50 kN/m^3
Stress-state :		effective
Angle of internal friction :	φ_{ef} =	31,50 °
Cohesion of soil :	c_{ef} =	0,00 kPa
Saturated unit weight :	γ_{sat} =	17,50 kN/m^3

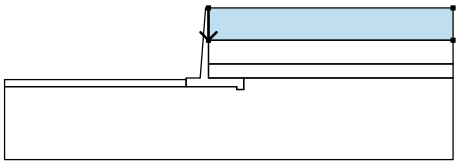
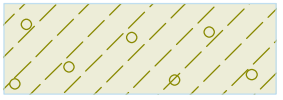
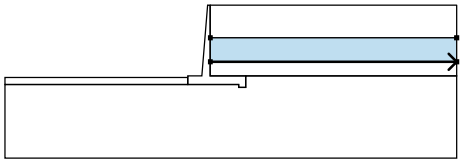
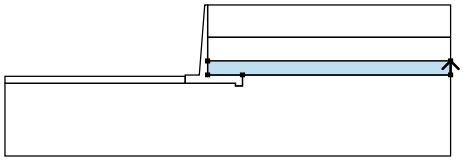
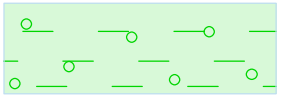
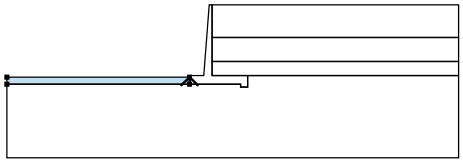
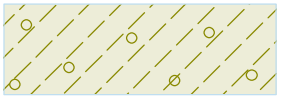
Soil No. 3

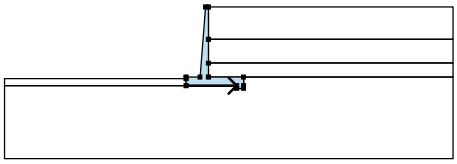
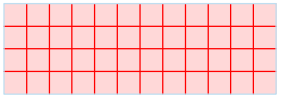
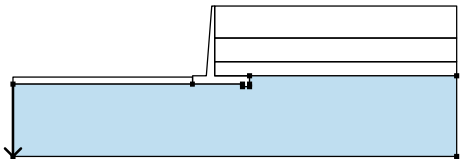
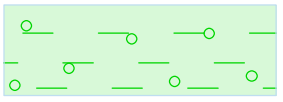
Unit weight :	γ =	19,50 kN/m^3
Stress-state :		effective
Angle of internal friction :	φ_{ef} =	27,00 °
Cohesion of soil :	c_{ef} =	10,00 kPa
Saturated unit weight :	γ_{sat} =	19,50 kN/m^3

Rigid bodies

No.	Name	Sample	γ [kN/m^3]
1	Wall material		23,00

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		0,00	100,00	0,00	97,70	Soil No. 1
		17,40	97,70	17,40	100,00	
2		0,00	96,00	17,40	96,00	Soil No. 2
		17,40	97,70	0,00	97,70	
3		17,40	95,00	17,40	96,00	Soil No. 3
		0,00	96,00	0,00	95,00	
		2,50	95,00			
4		-1,60	94,40	-1,60	94,90	Soil No. 1
		-14,50	94,90	-14,50	94,40	

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
5		-1,60	94,40	2,00	94,40	Wall material
		2,00	94,20	2,50	94,20	
		2,50	94,40	2,50	95,00	
		0,00	95,00	0,00	96,00	
		0,00	97,70	0,00	100,00	
		-0,20	100,00	-0,60	95,00	
		-1,60	95,00	-1,60	94,90	
6		-14,50	94,40	-14,50	89,20	Soil No. 3
		17,40	89,20	17,40	95,00	
		2,50	95,00	2,50	94,40	
		2,50	94,20	2,00	94,20	
		2,00	94,40	-1,60	94,40	

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 =	-1,46	[m]	Angles :	α_1 =	-38,83	[°]
	z =	101,07	[m]		α_2 =	82,24	[°]
Radius :	R =	7,92	[m]				
Analysis of the slip surface without optimization.							

Slope stability verification (all methods)

Bishop : Utilization = 61,5 % **ACCEPTABLE**
Fellenius / Petterson : Utilization = 71,7 % **ACCEPTABLE**
Spencer : Utilization = 61,6 % **ACCEPTABLE**
Janbu : Utilization = 61,6 % **ACCEPTABLE**
Morgenstern-Price : Utilization = 61,6 % **ACCEPTABLE**