Cantilever wall analysis

Input data

Project

Task : OPORNI ZID ZA PARKIRIŠČE Z DOVOZNO CESTO POD POKOPALIŠČEM
Customer : OBČINA ROGATEC
Author : Vid Štukovni, dipl.inž.grad.
Date : 10. 05. 2019
Project ID : ZU 52/4/19
Project number : ZU 52/4/19

Settings

Slovenia - EN 1997

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 : 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 overturning :	γ_{Rv} =	1,40 [–]
Partial factor on sliding resistance :	γ_{Rh} =	1,10 [–]
Partial factor on bearing capacity :	γ_{Re} =	1,40 [–]

Partial factors for variable actions		
Permanent design situation		
Factor for combination value :	ψ_0 =	0,70 [–]
Factor for frequent value :	ψ_1 =	0,50 [–]
Factor for quasi-permanent value :	ψ_2 =	0,30 [–]

Material of structure

Unit weight γ = 25,00 kN/m^3
Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete : C 25/30
Cylinder compressive strength f_{ck} = 25,00 MPa
Tensile strength f_{ctm} = 2,60 MPa

Longitudinal steel : B500

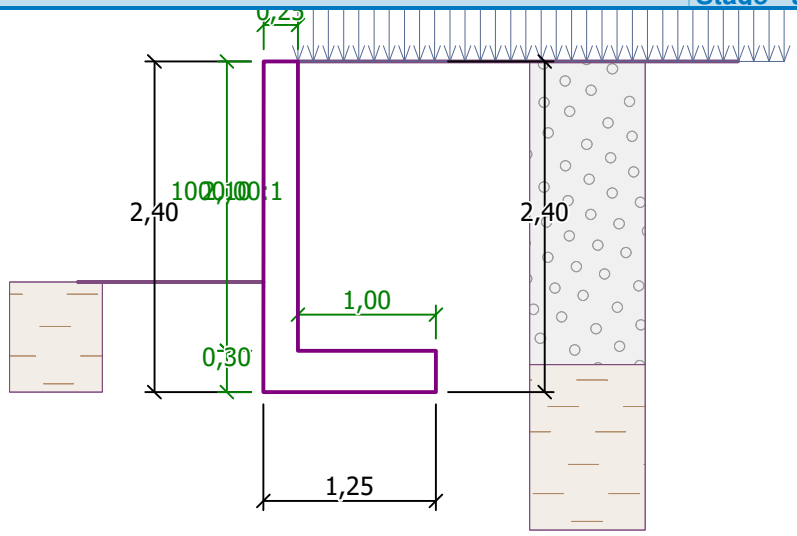
Yield strength f_{yk} = 500,00 MPa

Geometry of structure

No.	Coordinate X [m]	Depth Z [m]
1	0,00	0,00
2	0,00	2,10
3	1,00	2,10
4	1,00	2,40
5	-0,25	2,40
6	-0,25	2,10
7	-0,25	0,00

The origin [0,0] is located at the most upper right point of the wall.
Wall section area = 0,90 m^2.

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	glina		18,00	2,00	16,00	8,00	0,00
2	tampon		35,00	0,00	20,00	12,00	0,00

Soil parameters to compute pressure at rest

No.	Name	Pattern	Type calculation	φ_{ef} [°]	ν [–]	OCR [–]	K_r [–]
1	glina		cohesive	-	0,40	-	-
2	tampon		cohesionless	35,00	-	-	-

Soil parameters

glina

Unit weight :	γ =	16,00 kN/m^3
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	18,00 °
Cohesion of soil :	c_{ef} =	2,00 kPa
Angle of friction struc.-soil :	δ =	0,00 °
Soil :	cohesive	
Poisson's ratio :	ν =	0,40
Saturated unit weight :	γ_{sat} =	18,00 kN/m^3

tampon

Unit weight :	γ =	20,00 kN/m^3
Stress-state :	effective	
Angle of internal friction :	φ_{ef} =	35,00 °
Cohesion of soil :	c_{ef} =	0,00 kPa
Angle of friction struc.-soil :	δ =	0,00 °
Soil :	cohesionless	
Saturated unit weight :	γ_{sat} =	22,00 kN/m^3

Geological profile and assigned soils

No.	Layer [m]	Assigned soil	Pattern
1	2,20	tampon	
2	-	glina	

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.

Input surface surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m^2]	Mag.2 [kN/m^2]	Ord.x x [m]	Length l [m]	Depth z [m]
1	Yes		variable	9,00				on terrain

Resistance on front face of the structure

Resistance on front face of the structure: passive
Soil on front face of the structure - glina

Angle of friction struc.-soil	δ =	0,00 °
Soil thickness in front of structure	h =	0,80 m

Terrain in front of structure is flat.

Settings of the stage of construction

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

Verification No. 1 (Stage of construction 1)

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	-0,85	22,57	0,33	1,000	1,000	1,350
FF resistance	-14,28	-0,31	0,01	0,00	1,000	1,000	1,350
Weight - earth wedge	0,00	-0,94	19,21	0,59	1,000	1,000	1,350
Active pressure	17,35	-0,73	22,79	0,89	1,350	1,350	1,350
Surch.1 - surface	6,32	-1,12	9,00	0,75	1,500	1,500	1,500

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 40,29 kNm/m

Overturning moment M_{ovr} = 23,30 kNm/m

Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 26,82 kN/m

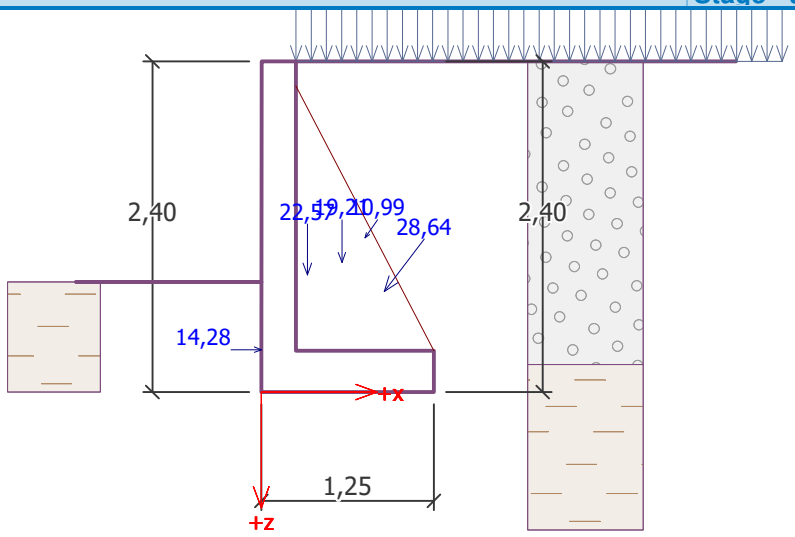
Active horizontal force H_{act} = 18,62 kN/m

Wall for slip is SATISFACTORY

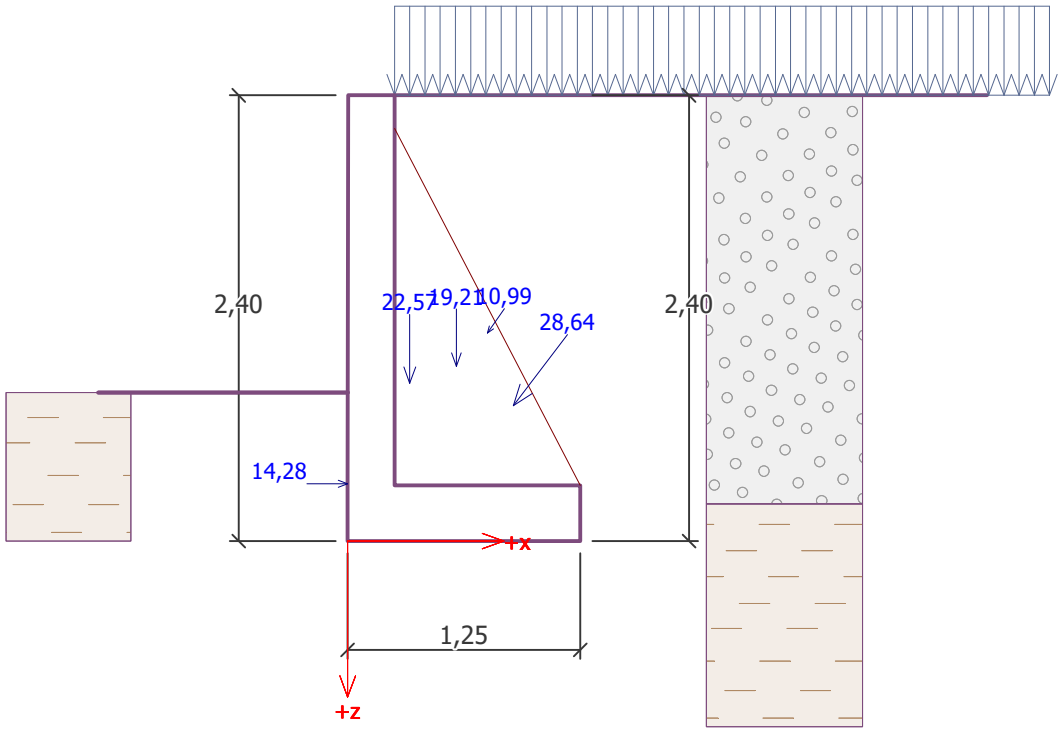
Overall check - WALL is SATISFACTORY

Maximum stress in footing bottom : 122,93 kPa

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



Name : Verification	Stage - analysis : 1 - 1



Bearing capacity of foundation soil (Stage of construction 1)

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	21,80	100,68	13,62	0,173	122,93
2	20,76	86,05	18,62	0,193	111,82

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	15,49	73,58	9,39

Dimensioning No. 1 (Stage of construction 1)

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. moment	Coeff. norm.force	Coeff. shear for.
Weight - wall	0,00	-1,05	13,17	0,13	1,000	1,350	1,000
FF resistance	-6,59	-0,20	0,01	0,00	1,000	1,350	1,000
Pressure at rest	18,78	-0,70	0,00	0,25	1,350	1,000	1,350
Surch.1 - surface	8,05	-1,05	0,00	0,25	1,500	0,000	1,500

Wall stem check

Reinforcement and dimensions of the cross-section
5 prof. 10,0 mm, cover 50,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,25 m

Reinforcement ratio ρ = 0,20 % > 0,14 % = ρ_{min}
Position of neutral axis x = 0,01 m < 0,12 m = x_{max}

Ultimate shear force V_{Rd} = 97,56 kN > 30,85 kN = V_{Ed}
Ultimate moment M_{Rd} = 32,78 kNm > 29,09 kNm = M_{Ed}

Cross-section is SATISFACTORY.

Dimensioning No. 2 (Stage of construction 1)

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. moment	Coeff. norm.force	Coeff. shear for.
Weight - wall	0,00	-1,05	13,17	0,13	1,000	1,350	1,000
FF resistance	-6,59	-0,20	0,01	0,00	1,000	1,350	1,000
Pressure at rest	18,78	-0,70	0,00	0,25	1,350	1,000	1,350
Surch.1 - surface	8,05	-1,05	0,00	0,25	1,500	0,000	1,500

Wall check at the construction joint 2,10 m from the wall crest

Reinforcement and dimensions of the cross-section
5 prof. 10,0 mm, cover 50,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,25 m

Reinforcement ratio ρ = 0,20 % > 0,14 % = ρ_{min}
Position of neutral axis x = 0,01 m < 0,12 m = x_{max}
Ultimate shear force V_{Rd} = 97,56 kN > 30,85 kN = V_{Ed}
Ultimate moment M_{Rd} = 32,78 kNm > 29,09 kNm = M_{Ed}

Cross-section is SATISFACTORY.

Dimensioning No. 3 (Stage of construction 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	-0,15	7,50	0,75	1,350
Weight - earth wedge	0,00	-0,94	19,21	0,59	1,350
Active pressure	17,35	-0,73	22,79	0,89	1,350
Surch.1 - surface	6,32	-1,12	9,00	0,75	1,500
Contact stress	0,00	0,00	-63,60	0,58	1,000

Back wall jump check

Reinforcement and dimensions of the cross-section
5 prof. 10,0 mm, cover 30,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,30 m

Reinforcement ratio ρ = 0,15 % > 0,14 % = ρ_{min}
Position of neutral axis x = 0,01 m < 0,16 m = x_{max}
Ultimate shear force V_{Rd} = 118,47 kN > 16,73 kN = V_{Ed}
Ultimate moment M_{Rd} = 44,37 kNm > 19,46 kNm = M_{Ed}

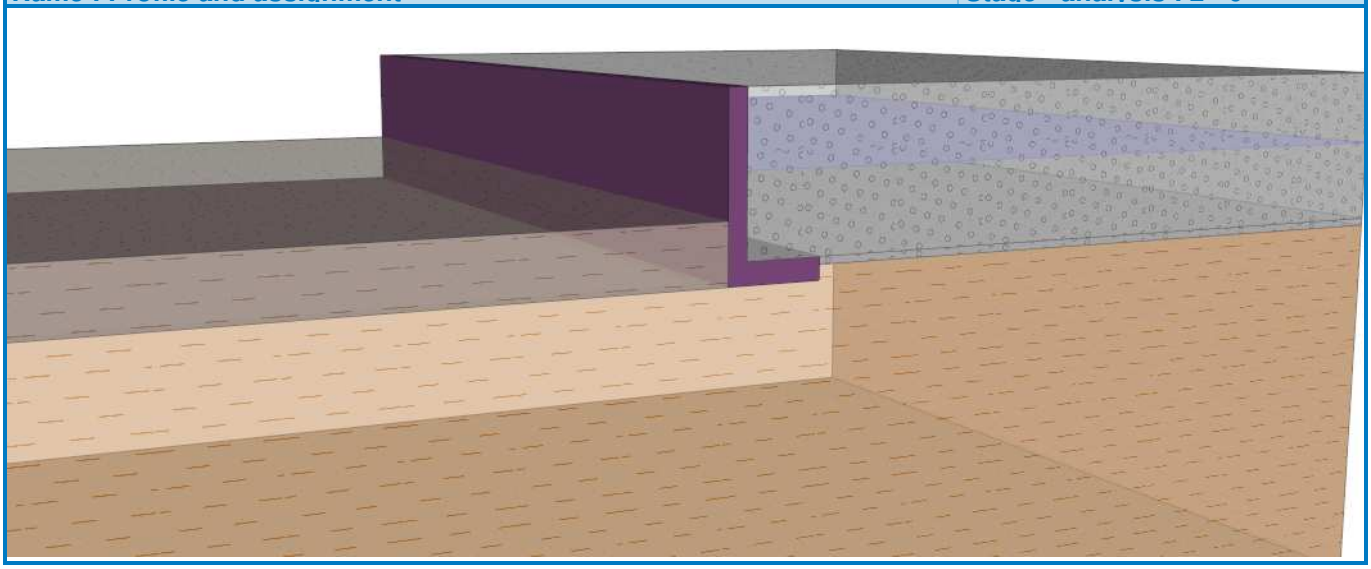
Cross-section is SATISFACTORY.

Input data (Stage of construction 2)

Geological profile and assigned soils

No.	Layer [m]	Assigned soil	Pattern
1	2,20	tampon	
2	-	glina	

Name : Profile and assignment **Stage - analysis : 2 - 0**



Foundation

Type of foundation : soil from geological profile

Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 1,00 m
Uplift in foot. bottom due to different pressures is not considered.

Resistance on front face of the structure

Resistance on front face of the structure: passive
Soil on front face of the structure - glina
Angle of friction struc.-soil $\delta = 0,00$ °
Soil thickness in front of structure $h = 0,80$ m

Terrain in front of structure is flat.

Settings of the stage of construction

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

Verification No. 1 (Stage of construction 2)

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	-0,85	22,57	0,33	1,000	1,000	1,350
FF resistance	-14,28	-0,31	0,01	0,00	1,000	1,000	1,350
Weight - earth wedge	0,00	-1,02	12,93	0,56	1,000	1,000	1,350
Active pressure	14,69	-0,79	20,27	0,87	1,350	1,350	1,350
Water pressure	9,80	-0,47	0,00	0,25	1,350	1,350	1,000
Uplift pressure	0,00	-2,40	0,00	0,25	1,000	1,000	1,000

Verification of complete wall

Check for overturning stability

Resisting moment M_{res} = 27,64 kNm/m

Overturning moment M_{ovr} = 17,46 kNm/m

Wall for overturning is SATISFACTORY

Check for slip

Resisting horizontal force H_{res} = 19,80 kN/m

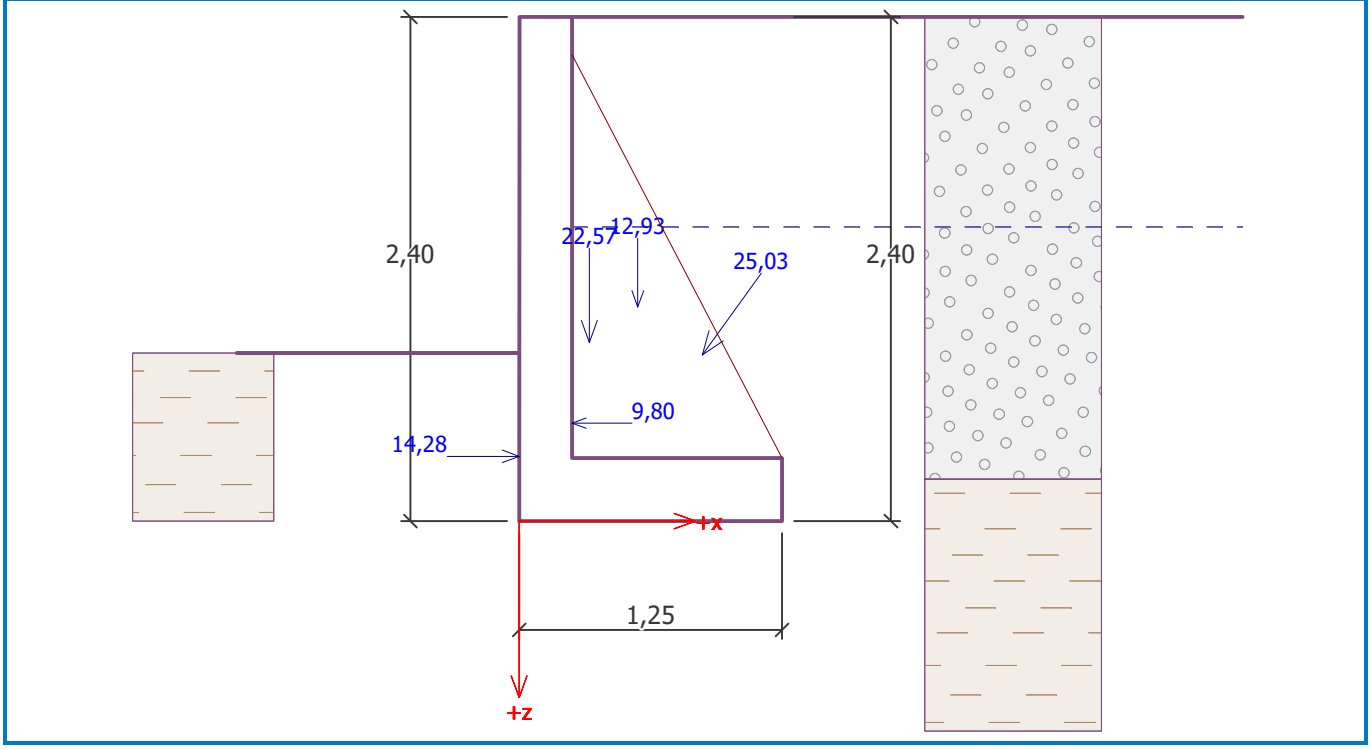
Active horizontal force H_{act} = 18,78 kN/m

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Maximum stress in footing bottom : 95,84 kPa

Name : Verification	Stage - analysis : 2 - 1



Bearing capacity of foundation soil (Stage of construction 2)

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	17,56	75,30	10,36	0,186	95,84
2	18,12	62,87	18,78	0,230	93,03

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	14,19	55,78	10,21

Verification of foundation soil

Stress in the footing bottom : rectangle

Eccentricity verification

Max. eccentricity of normal force $e = 0,230$
Maximum allowable eccentricity $e_{alw} = 0,333$

Eccentricity of the normal force is SATISFACTORY

Verification of bearing capacity

Bearing capacity of foundation soil $R = 200,00$ kPa
Partial factor on bearing capacity $\gamma_{Rv} = 1,40$
Max. stress at footing bottom $\sigma = 95,84$ kPa
Bearing capacity of foundation soil $R_d = 142,86$ kPa

Bearing capacity of foundation soil is SATISFACTORY

Overall verification - bearing capacity of found. soil is SATISFACTORY

Dimensioning No. 1 (Stage of construction 2)

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. moment	Coeff. norm.force	Coeff. shear for.
Weight - wall	0,00	-1,05	13,17	0,13	1,000	1,350	1,000
FF resistance	-6,59	-0,20	0,01	0,00	1,000	1,350	1,000
Pressure at rest	16,72	-0,74	0,00	0,25	1,350	1,000	1,350
Water pressure	6,04	-0,37	0,00	0,25	1,350	1,000	1,350
Uplift pressure	0,00	-2,10	0,00	0,25	1,000	1,000	1,000

Wall stem check

Reinforcement and dimensions of the cross-section
5 prof. 10,0 mm, cover 50,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,25 m

Reinforcement ratio $\rho = 0,20$ % $> 0,14$ % $= \rho_{min}$
Position of neutral axis $x = 0,01$ m $< 0,12$ m $= x_{max}$
Ultimate shear force $V_{Rd} = 97,56$ kN $> 24,14$ kN $= V_{Ed}$
Ultimate moment $M_{Rd} = 32,78$ kNm $> 18,38$ kNm $= M_{Ed}$

Cross-section is SATISFACTORY.

Dimensioning No. 2 (Stage of construction 2)

Forces acting on construction

Name	F_{hor} [kN/m]	App.Pt. z [m]	F_{vert} [kN/m]	App.Pt. x [m]	Coeff. moment	Coeff. norm.force	Coeff. shear for.
Weight - wall	0,00	-1,05	13,17	0,13	1,000	1,350	1,000
FF resistance	-6,59	-0,20	0,01	0,00	1,000	1,350	1,000
Pressure at rest	16,72	-0,74	0,00	0,25	1,350	1,000	1,350
Water pressure	6,04	-0,37	0,00	0,25	1,350	1,000	1,350
Uplift pressure	0,00	-2,10	0,00	0,25	1,000	1,000	1,000

Wall check at the construction joint 2,10 m from the wall crest

Reinforcement and dimensions of the cross-section
5 prof. 10,0 mm, cover 50,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,25 m

Reinforcement ratio	ρ	=	0,20	%	>	0,14	%	= ρ_{min}
Position of neutral axis	x	=	0,01	m	<	0,12	m	= x_{max}
Ultimate shear force	V_{Rd}	=	97,56	kN	>	24,14	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	32,78	kNm	>	18,38	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Dimensioning No. 3 (Stage of construction 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	-0,15	7,50	0,75	1,350
Weight - earth wedge	0,00	-1,02	12,93	0,56	1,350
Active pressure	14,69	-0,79	20,27	0,87	1,350
Contact stress	0,00	0,00	-46,53	0,56	1,000

Back wall jump check

Reinforcement and dimensions of the cross-section
5 prof. 10,0 mm, cover 50,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,30 m

Reinforcement ratio	ρ	=	0,16	%	>	0,14	%	= ρ_{min}
Position of neutral axis	x	=	0,01	m	<	0,15	m	= x_{max}
Ultimate shear force	V_{Rd}	=	112,60	kN	>	8,41	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	40,96	kNm	>	13,10	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Slope stability analysis

Input data

Project

Settings

Slovenia - EN 1997

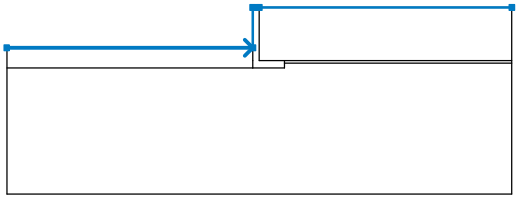
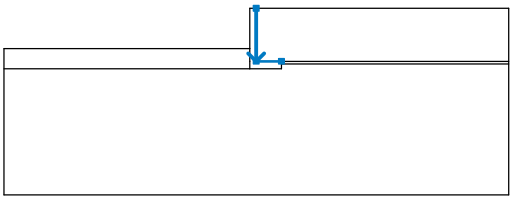
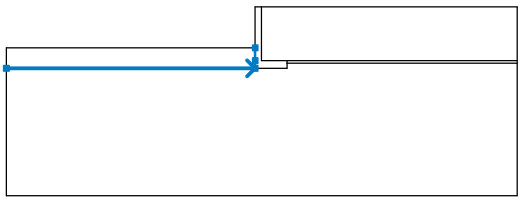
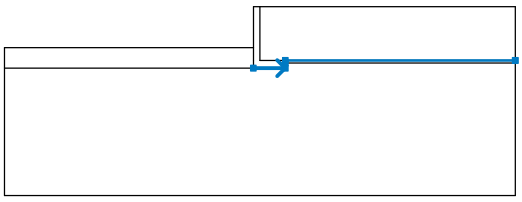
Stability analysis

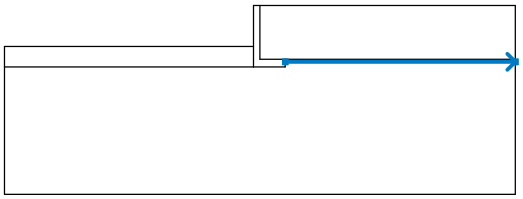
Earthquake analysis : Standard
Verification methodology : according to EN 1997
Design approach : 3 - reduction of actions (GEO, STR) and soil parameters

Partial factors on actions (A)								
Permanent design situation								
		State STR				State GEO		
		Unfavourable		Favourable		Unfavourable		Favourable	
Permanent actions :	γ_G =	1,00	[–]	1,00	[–]	1,00	[–]	1,00	[–]
Variable actions :	γ_Q =	1,50	[–]	0,00	[–]	1,30	[–]	0,00	[–]
Water load :	γ_w =					1,00	[–]		

Partial factors for soil parameters (M)			
Permanent design situation			
Partial factor on internal friction :	γ_ϕ =	1,25	[–]
Partial factor on effective cohesion :	γ_c =	1,25	[–]
Partial factor on undrained shear strength :	γ_{cu} =	1,40	[–]

Interface

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
1		-10,00	0,60	-0,25	0,60	-0,25	2,20
		0,00	2,20	10,00	2,20		
2		0,00	2,20	0,00	0,10	1,00	0,10
3		-10,00	-0,20	-0,25	-0,20	-0,25	0,10
		-0,25	0,60				
4		-0,25	-0,20	1,00	-0,20	1,00	0,00
		1,00	0,10	10,00	0,10		

No.	Interface location	Coordinates of interface points [m]					
		x	z	x	z	x	z
5		1,00	0,00	10,00	0,00		

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]
1	glina		18,00	2,00	16,00
2	tampon		35,00	0,00	20,00

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m^3]	γ_s [kN/m^3]	n [–]
1	glina		18,00		
2	tampon		22,00		

Soil parameters

glina

Unit weight : γ = 16,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 18,00 °
Cohesion of soil : c_{ef} = 2,00 kPa
Saturated unit weight : γ_{sat} = 18,00 kN/m^3

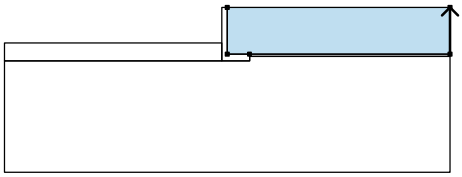
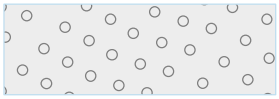
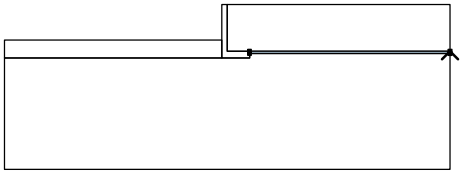
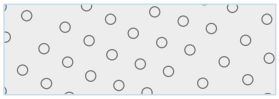
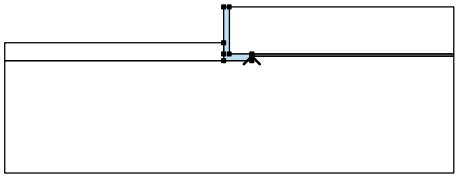
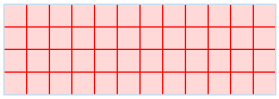
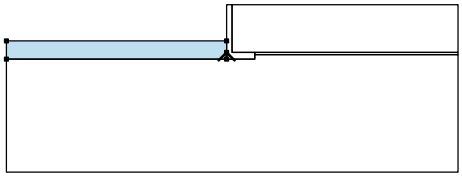
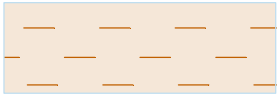
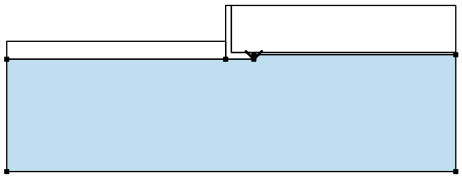
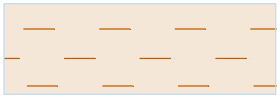
tampon

Unit weight : γ = 20,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 35,00 °
Cohesion of soil : c_{ef} = 0,00 kPa
Saturated unit weight : γ_{sat} = 22,00 kN/m^3

Rigid bodies

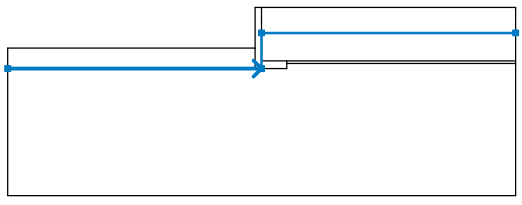
No.	Name	Sample	γ [kN/m^3]
1	Wall material		25,00

Assigning and surfaces

No.	Surface position	Coordinates of surface points [m]				Assigned soil
		x	z	x	z	
1		10,00	0,10	10,00	2,20	tampon
		0,00	2,20	0,00	0,10	
		1,00	0,10			
2		10,00	0,00	10,00	0,10	tampon
		1,00	0,10	1,00	0,00	
						
3		1,00	-0,20	1,00	0,00	Wall material
		1,00	0,10	0,00	0,10	
		0,00	2,20	-0,25	2,20	
		-0,25	0,60	-0,25	0,10	
		-0,25	-0,20			
4		-0,25	-0,20	-0,25	0,10	glina
		-0,25	0,60	-10,00	0,60	
		-10,00	-0,20			
5		1,00	0,00	1,00	-0,20	glina
		-0,25	-0,20	-10,00	-0,20	
		-10,00	-5,20	10,00	-5,20	
		10,00	0,00			

Water

Water type : GWT

No.	GWT location	Coordinates of GWT points [m]					
		x	z	x	z	x	z
1		-10,00	-0,20	0,00	-0,20	0,00	1,20
		10,00	1,20				

Tensile crack

Tensile crack not input.

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 =	-0,44	[m]	Angles :	α_1 =	-55,19	[°]
	z =	2,21	[m]		α_2 =	89,80	[°]
Radius :	R =	2,82	[m]				
The slip surface after optimization.							

Slope stability verification (Bishop)

Sum of active forces : F_a = 46,30 kN/m
Sum of passive forces : F_p = 50,25 kN/m

Sliding moment : M_a = 130,57 kNm/m
Resisting moment : M_p = 141,72 kNm/m
Utilization : 92,1 %

Slope stability ACCEPTABLE

Name : Analysis	Stage - analysis : 1 - 1