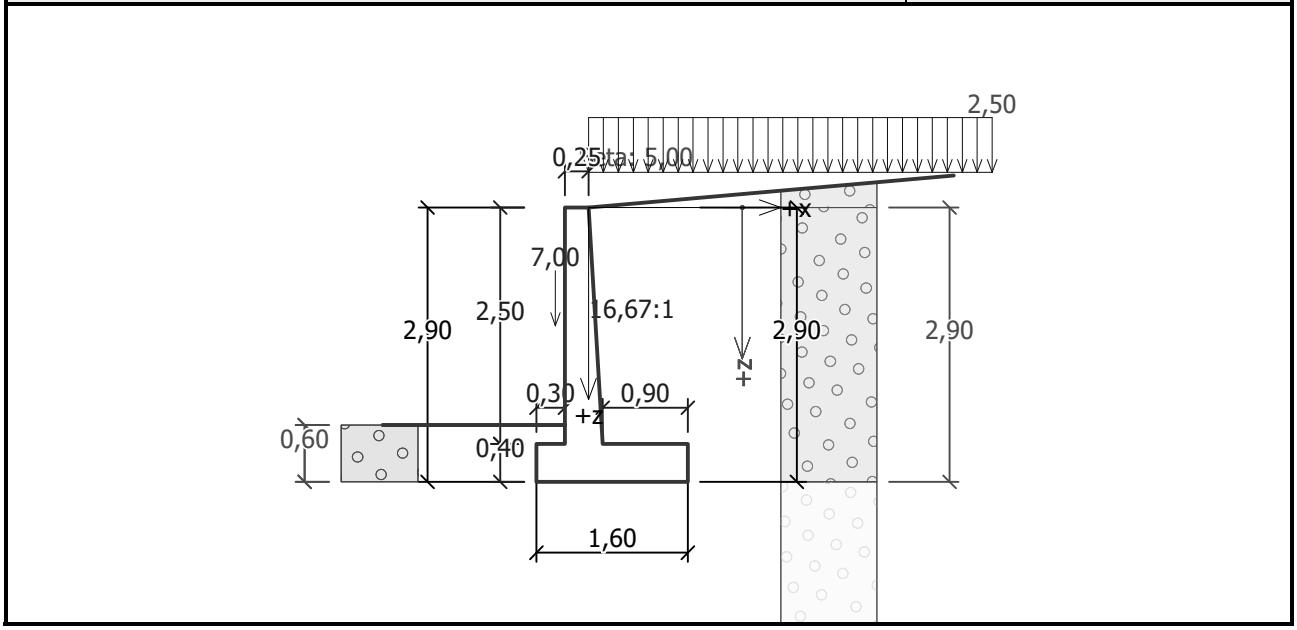
5.10 GEOSTATIČNI IZRAČUN OPORNEGA ZIDU

Cantilever wall analysis
Input data
Project

Task : Oporni zid levo - Hiša Č
Description : Geostatični izračun opornega zidu levo
Customer : Hiša Č
Author : IBG, projektiranje in svetovanje, Blaž Goljevšček s.p.
Date : 30.8.2017
Project number : PZI-3/2017

Name : Project	Stage - analysis : 1 - 0



Settings
Slovenia - EN 1997 (*IGIKON)
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_{Re} =	1,40	[–]
Partial factor on sliding resistance :	γ_{Rh} =	1,10	[–]
Partial factor on bearing capacity :	γ_{Rv} =	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	0,15	2,50
3	1,05	2,50
4	1,05	2,90
5	-0,55	2,90
6	-0,55	2,50
7	-0,25	2,50
8	-0,25	0,00

The origin [0,0] is located at the most upper right point of the wall.
Wall section area = 1,45 m^2.

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]	γ_{su} [kN/m^3]	δ [°]
1	Zasip zidu zadaj		30,00	0,00	21,00	11,00	15,00
2	Zasip zidu spredaj		30,00	0,00	21,00	11,00	15,00
3	Temeljna tla		30,00	0,00	21,00	11,00	15,00

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

Soil parameters

Zasip zidu zadaj
Unit weight : γ = 21,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 30,00 °
Cohesion of soil : c_{ef} = 0,00 kPa

Angle of friction struc.-soil : δ = 15,00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 21,00 kN/m3

Zasip zidu spredaj
Unit weight : γ = 21,00 kN/m3
Stress-state : effective
Angle of internal friction : φ_{ef} = 30,00 °
Cohesion of soil : c_{ef} = 0,00 kPa
Angle of friction struc.-soil : δ = 15,00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 21,00 kN/m3

Temeljna tla
Unit weight : γ = 21,00 kN/m3
Stress-state : effective
Angle of internal friction : φ_{ef} = 30,00 °
Cohesion of soil : c_{ef} = 0,00 kPa
Angle of friction struc.-soil : δ = 15,00 °
Soil : cohesionless
Saturated unit weight : γ_{sat} = 21,00 kN/m3

Geological profile and assigned soils

No.	Layer [m]	Assigned soil	Pattern
1	2,90	Zasip zidu zadaj	
2	-	Temeljna tla	

Foundation
Type of foundation : soil from geological profile

Terrain profile
Terrain behind construction has the slope 1: 11,43 (slope angle is 5,00 °).

Water influence
Ground water table is located below the structure.

Input surface surcharges

No.	Surcharge		Action	Mag.1 [kN/m2]	Mag.2 [kN/m2]	Ord.x x [m]	Length l [m]	Depth z [m]
	new	change						
1	YES		variable	2,50				on terrain

No.	Name
1	UDL 2,5 kN/m2

Resistance on front face of the structure
Resistance on front face of the structure: not considered
Soil on front face of the structure - Zasip zidu spredaj
Angle of friction struc.-soil δ = 0,00 °
Soil thickness in front of structure h = 0,60 m

Terrain in front of structure is flat.

Applied forces acting on the structure

No.	Force new	Force modification	Name	Action	F_x [kN/m]	F_z [kN/m]	M [kNm/m]	x [m]	z [m]
1	YES		Kamnita obloga	permanent	0,00	7,00	0,00	-0,35	1,25

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]	Coeff. overtur.	Coeff. sliding	Coeff. stress
Weight - wall	0,00	-0,96	36,31	0,61	1,000	1,000	1,350
Weight - earth wedge	0,00	-1,05	18,48	0,96	1,000	1,000	1,350
Active pressure	30,99	-0,99	38,22	1,21	1,350	1,350	1,350
UDL 2,5 kN/m2	2,55	-1,45	3,05	1,08	1,500	1,500	1,500
Kamnita obloga	0,00	-1,65	7,00	0,20	1,000	1,000	1,350

Verification of complete wall
Check for overturning stability
Resisting moment M_{res} = 77,86 kNm/m
Overturning moment M_{ovr} = 47,13 kNm/m

Wall for overturning is SATISFACTORY

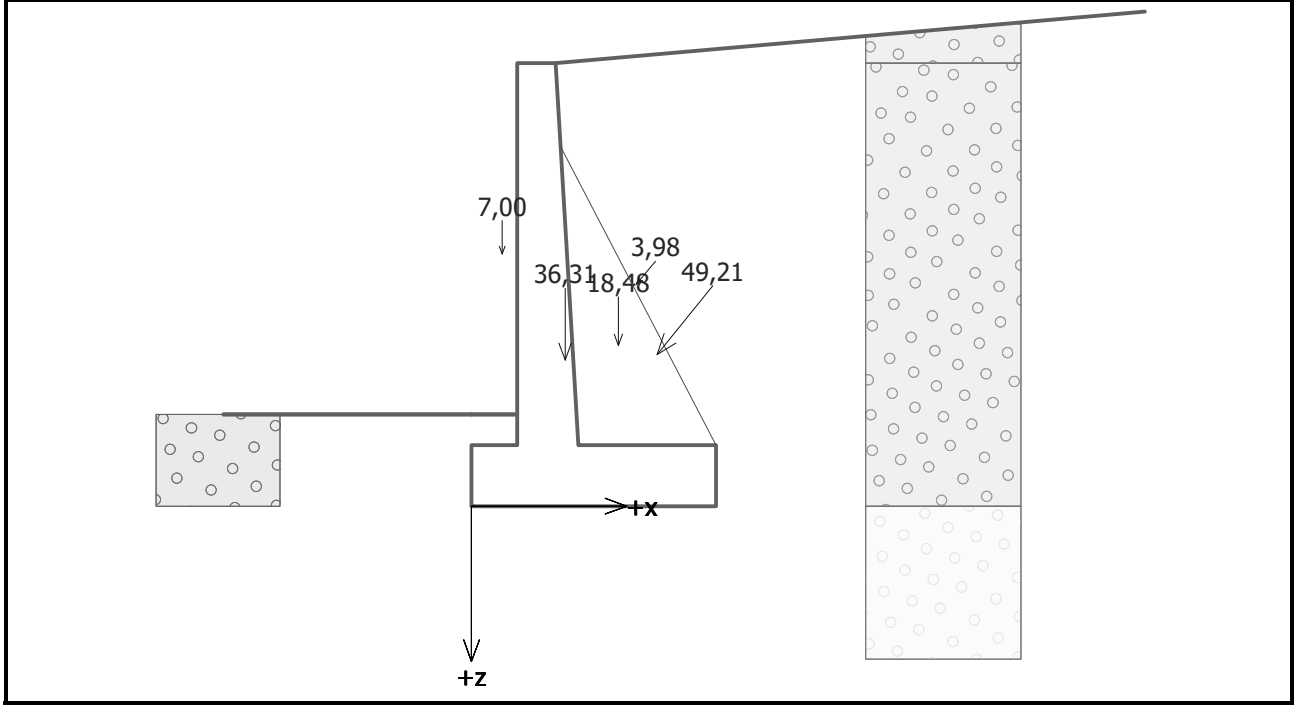
Check for slip
Resisting horizontal force H_{res} = 61,92 kN/m
Active horizontal force H_{act} = 45,67 kN/m

Wall for slip is SATISFACTORY

Overall check - WALL is SATISFACTORY

Maximum stress in footing bottom : 127,58 kPa

Name : Verification	Stage - analysis : 1 - 1



Bearing capacity of foundation soil

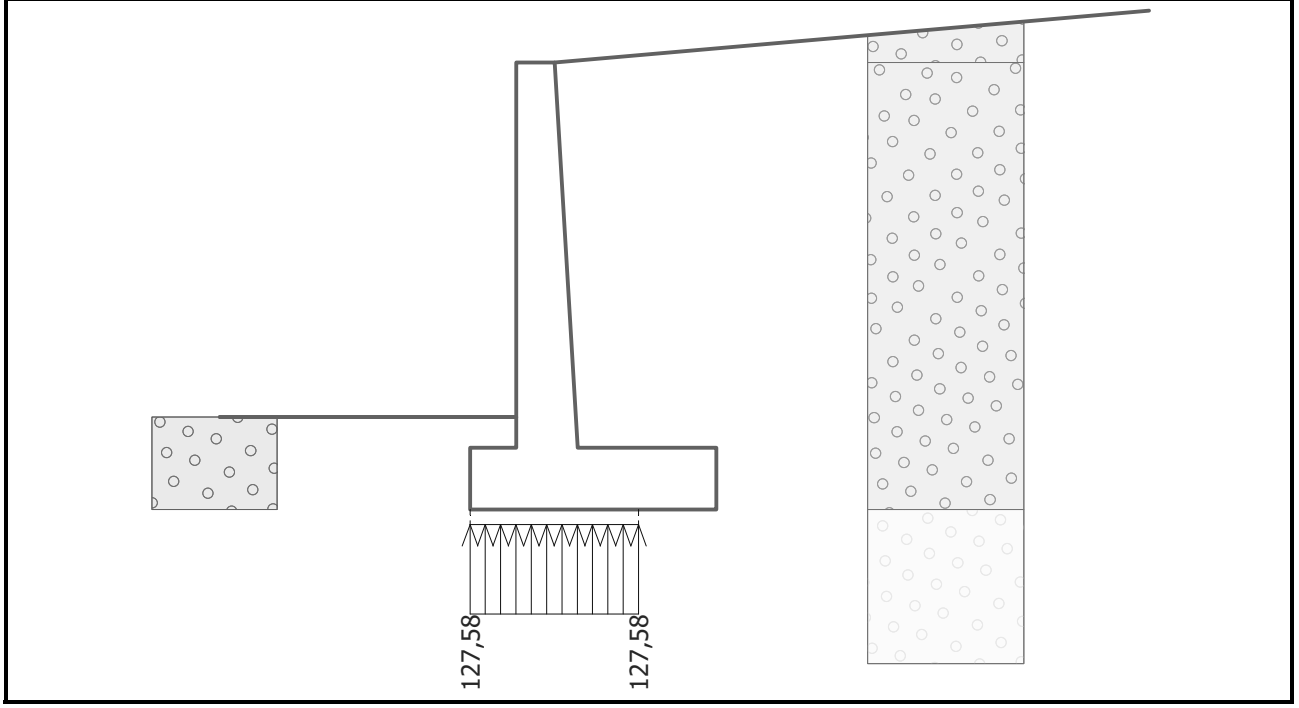
Design load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]	Eccentricity [–]	Stress [kPa]
1	35,31	139,60	45,67	0,158	127,58
2	32,50	117,97	45,67	0,172	112,46

Service load acting at the center of footing bottom

No.	Moment [kNm/m]	Norm. force [kN/m]	Shear Force [kN/m]
1	25,83	103,07	33,54

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]	Coeff. moment	Coeff. norm.force	Coeff. shear for.
Weight - wall	0,00	-1,15	20,30	0,17	1,350	1,350	1,000
Pressure at rest	33,10	-0,83	3,93	0,35	1,350	1,350	1,350
UDL 2,5 kN/m2	3,14	-1,25	0,74	0,32	1,500	1,500	1,500
Kamnita obloga	0,00	-1,25	7,00	-0,10	1,350	1,350	1,000

Wall stem check

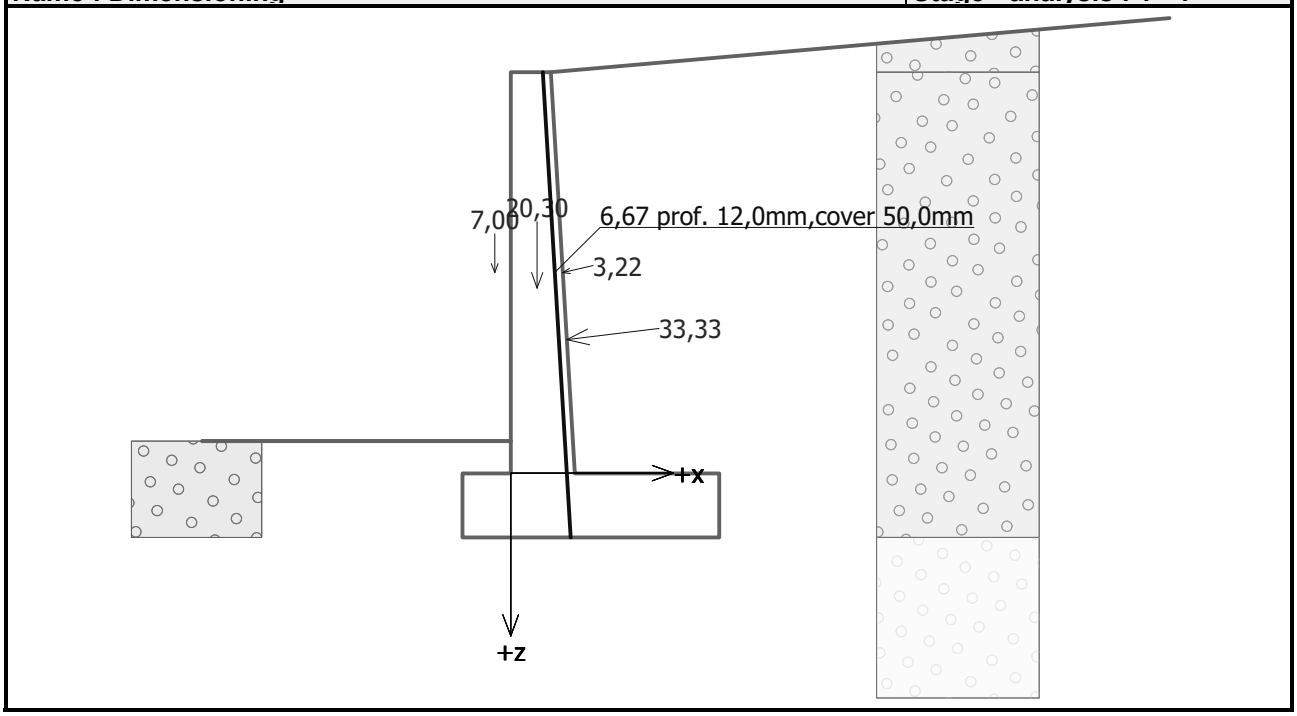
Reinforcement and dimensions of the cross-section

Bar diameter = 12,0 mm
Number of bars = 6,67
Reinforcement cover = 50,0 mm
Cross-section width = 1,00 m
Cross-section depth = 0,40 m

Reinforcement ratio	ρ	=	0,22	%	>	0,14	%	= ρ_{min}
Position of neutral axis	x	=	0,02	m	<	0,21	m	= x_{max}
Ultimate shear force	V_{Rd}	=	140,83	kN	>	49,39	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	109,56	kNm	>	45,95	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	-0,96	36,31	0,61	1,350
Weight - earth wedge	0,00	-1,05	18,48	0,96	1,350
Active pressure	30,99	-0,99	38,22	1,21	1,350
UDL 2,5 kN/m2	2,55	-1,45	3,05	1,08	1,500
Kamnita obloga	0,00	-1,65	7,00	0,20	1,350

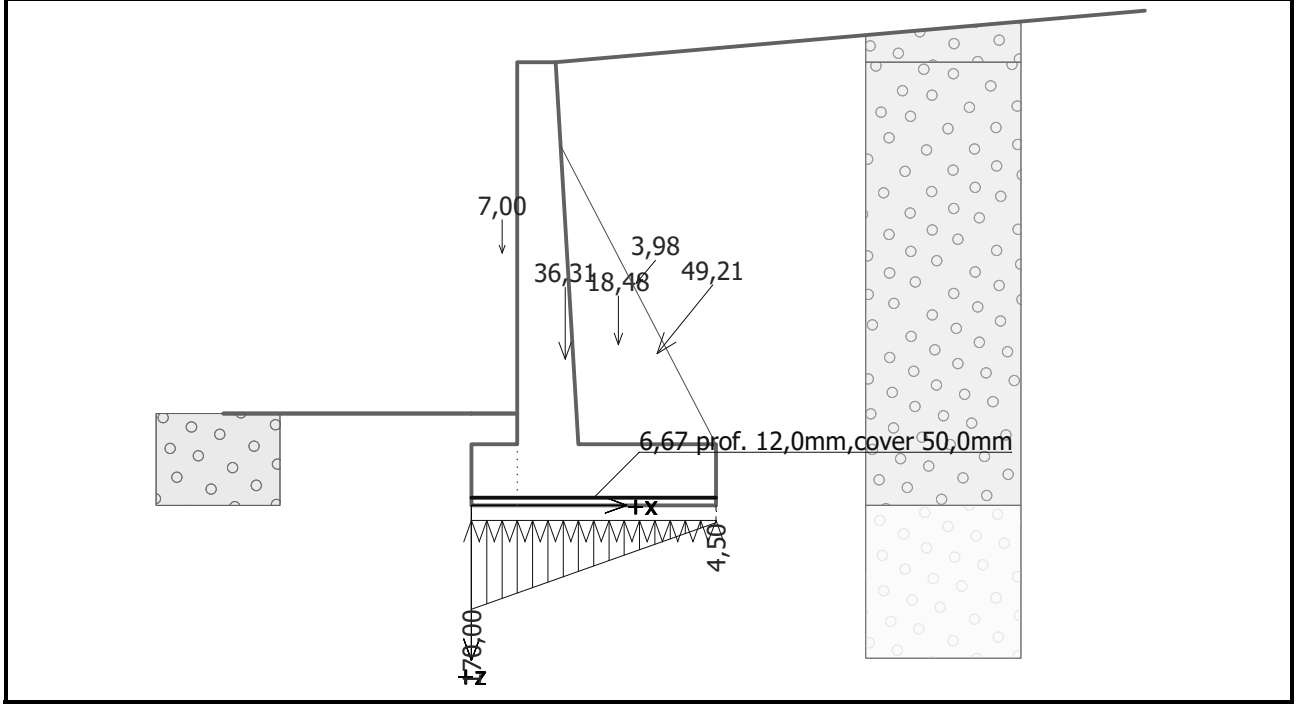
Front wall jump check

Reinforcement and dimensions of the cross-section

Bar diameter		=	12,0	mm				
Number of bars		=	6,67					
Reinforcement cover		=	50,0	mm				
Cross-section width		=	1,00	m				
Cross-section depth		=	0,40	m				
Reinforcement ratio	ρ	=	0,22	%	>	0,14	%	= ρ_{min}
Position of neutral axis	x	=	0,02	m	<	0,21	m	= x_{max}
Ultimate shear force	V_{Rd}	=	140,86	kN	>	46,35	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	109,60	kNm	>	7,18	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Name : Dimensioning	Stage - analysis : 1 - 2



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	-0,20	9,00	1,15	1,350
Weight - earth wedge	0,00	-1,05	18,48	0,96	1,350
Active pressure	30,99	-0,99	38,22	1,21	1,350
UDL 2,5 kN/m2	2,55	-1,45	3,05	1,08	1,500
Contact stress	0,00	0,00	-45,94	1,01	1,000
Gravity surch. 1	0,00	-2,90	0,08	0,72	1,500

Back wall jump check

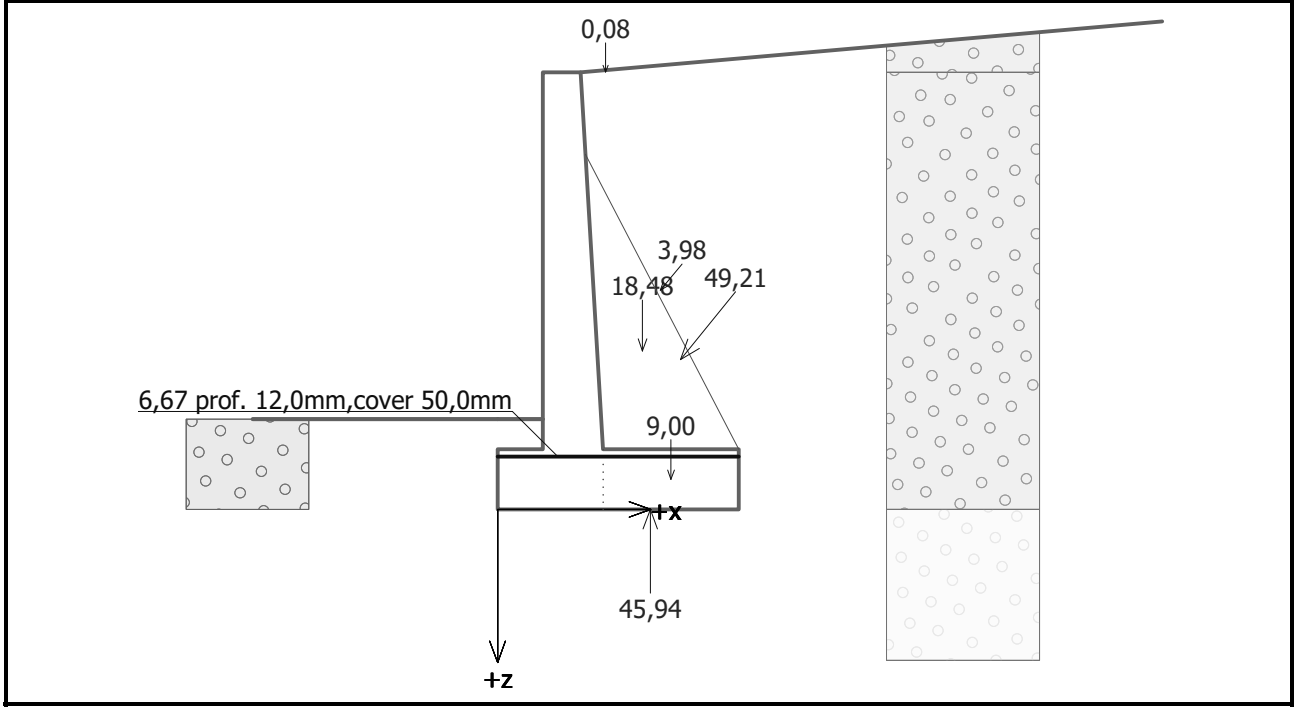
Reinforcement and dimensions of the cross-section

Bar diameter		=	12,0	mm				
Number of bars		=	6,67					
Reinforcement cover		=	50,0	mm				
Cross-section width		=	1,00	m				
Cross-section depth		=	0,40	m				
Reinforcement ratio	ρ	=	0,22	%	>	0,14	%	= ρ_{min}
Position of neutral axis	x	=	0,02	m	<	0,21	m	= x_{max}

Ultimate shear force	V_{Rd}	=	140,86	kN	>	47,46	kN	= V_{Ed}
Ultimate moment	M_{Rd}	=	109,60	kNm	>	25,86	kNm	= M_{Ed}

Cross-section is SATISFACTORY.

Name : Dimensioning	Stage - analysis : 1 - 3

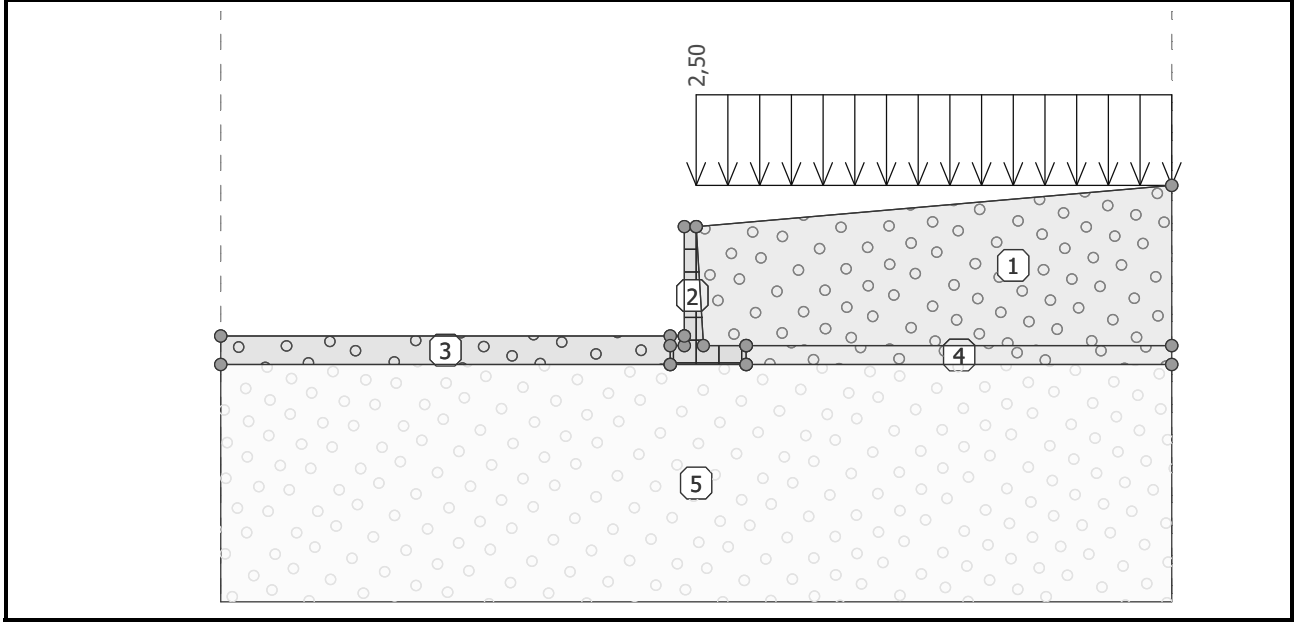


Slope stability analysis

Input data

Project

Name : Project	Stage : 1



Settings

Slovenia - EN 1997 (*IGIKON)

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 =	1,35	[–]	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	[–]

Soil parameters - effective stress state

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]
1	Zasip zidu zadaj		30,00	0,00	21,00
2	Zasip zidu spredaj		30,00	0,00	21,00
3	Temeljna tla		30,00	0,00	21,00

Soil parameters - uplift

No.	Name	Pattern	γ_{sat} [kN/m³]	γ_s [kN/m³]	n [–]
1	Zasip zidu zadaj		21,00		
2	Zasip zidu spredaj		21,00		
3	Temeljna tla		21,00		

Soil parameters

Zasip zidu zadaj

Unit weight : γ = 21,00 kN/m³
Stress-state : effective
Angle of internal friction : φ_{ef} = 30,00 °
Cohesion of soil : c_{ef} = 0,00 kPa
Saturated unit weight : γ_{sat} = 21,00 kN/m³

Zasip zidu spredaj

Unit weight : γ = 21,00 kN/m³
Stress-state : effective
Angle of internal friction : φ_{ef} = 30,00 °

Cohesion of soil : c_{ef} = 0,00 kPa
Saturated unit weight : γ_{sat} = 21,00 kN/m^3

Temeljna tla
Unit weight : γ = 21,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 30,00 °
Cohesion of soil : c_{ef} = 0,00 kPa
Saturated unit weight : γ_{sat} = 21,00 kN/m^3

Rigid bodies

No.	Name	Sample	γ [kN/m³]
1	Wall material		25,00

Surcharge

No.	Type	Type of action	Location z [m]	Origin x [m]	Length l [m]	Width b [m]	Slope α [°]	Magnitude q, q1, f, F	Magnitude q2	Magnitude unit
1	strip	variable	on terrain	x = 0,00	l = 10,00		0,00	2,50		kN/m2

Surcharges

No.	Name
1	UDL 2,5 kN/m2

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 =	-0,91	[m]	Angles :	α_1 =	-41,21	[°]
	z =	0,95	[m]		α_2 =	81,24	[°]
Radius :	R =	4,32	[m]				
The slip surface after optimization.							

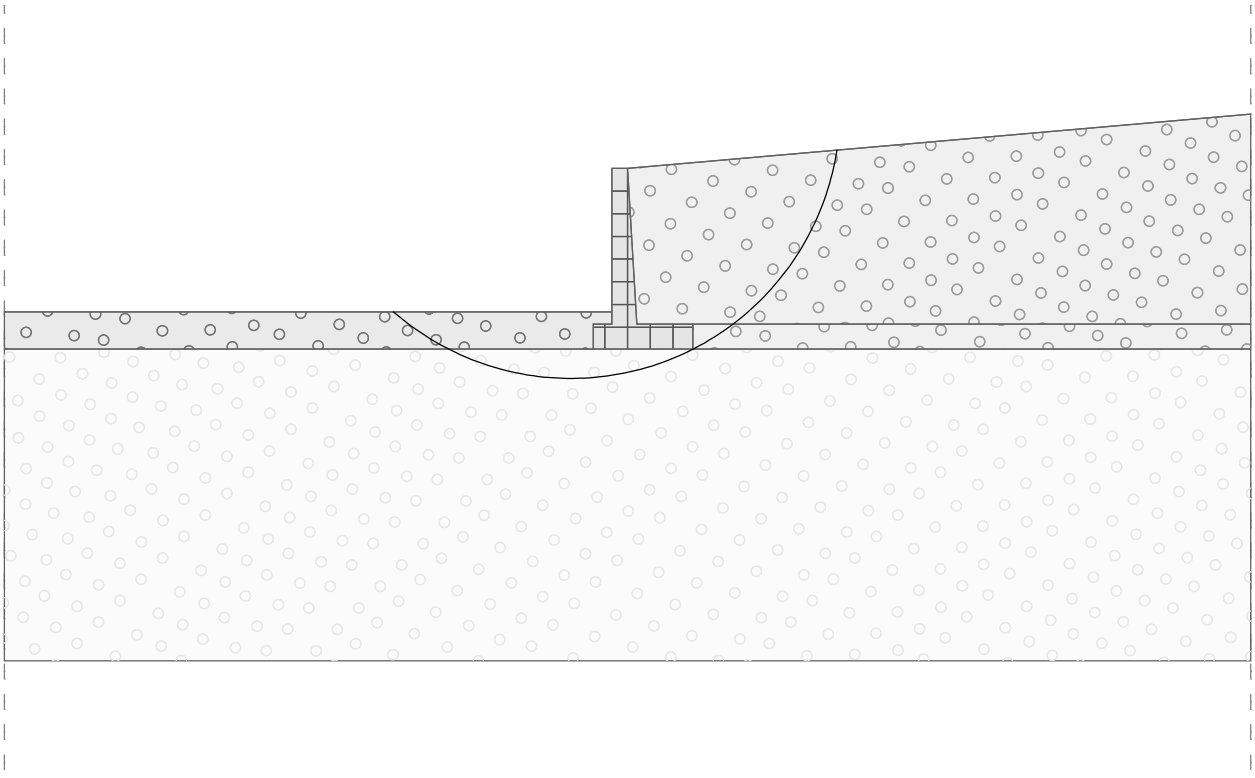
Slope stability verification (Bishop)

Sum of active forces : F_a = 89,93 kN/m
Sum of passive forces : F_p = 125,92 kN/m

Sliding moment : M_a = 388,52 kNm/m
Resisting moment : M_p = 543,95 kNm/m
Utilization : 71,4 %

Slope stability ACCEPTABLE

Name : Analysis	Stage - analysis : 1 - 1



Bearing resistance calculation according to Eurocode 7, Annex D

Project: Kontrola nosilnosti temeljnih tal opornega zidu levo

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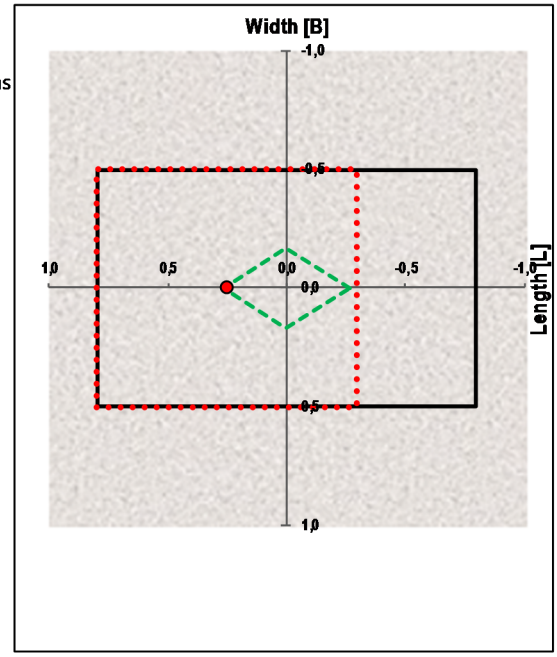


Conditions: ☑ Drained conditions ☐ Undrained conditions

Foundation dimensions:

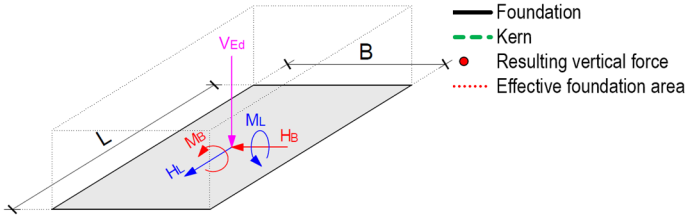
B =	1,60	m	...foundation width
L =	1,00	m	...foundation length
α =	0,00	°	...inclination of foundation base

Soil parameters:

c_u =	0,00	kPa	...undrained shear strength
q =	0,00	kPa	...soil pressure and surcharge at found. level
γ_s' =	21,00	kN/m^3	...effective weight density below found. base
φ' =	30,00	°	...effective angle of inner friction
c' =	0,00	kPa	...effective cohesion
q' =	12,00	kPa	...effective compression at foundation level

Design load:

V_{Ed} =	139,60	kN	...axial force (compression is positive)
M_B =	35,31	kNm	...bending moment in B direction
M_L =	0,00	kNm	...bending moment in L direction
H_B =	45,67	kN	...horizontal force in B direction
H_L =	0,00	kN	...horizontal force in L direction



Eccentricities:

$$e_B = \frac{M_B}{V_{Ed}}$$ e_B = 0,25 m ...eccentricity of axial force in B direction

$$e_L = \frac{M_L}{V_{Ed}}$$ e_L = 0,00 m ...eccentricity of axial force in L direction

Effective foundation dimensions:

$B' = B - 2 \cdot e_B$ B' = 1,09 m ...effective foundation width

$L' = L - 2 \cdot e_L$ L' = 1,00 m ...effective foundation length

$A' = B' \cdot L'$ A' = 1,09 m^2 ...effective foundation area

DRAINED CONDITIONS:

Factors for the bearing resistance:

$$N_q = e^{\pi \cdot \tan\varphi'} \cdot \tan^2\left(45 + \frac{\varphi'}{2}\right)$$ N_q = 18,40 ...dimensionless factor for loading

$$N_c = \left(N_q - 1\right) \cdot \cot\varphi'$$ N_c = 30,14 ...dimensionless factor for cohesion

$$N_\gamma = 2 \cdot \left(N_q - 1\right) \cdot \tan\varphi'$$ N_γ = 20,09 ...dimensionless factor for soil density

Factors for the inclination of foundation base:

$$b_c = b_q - \frac{1 - b_q}{N_c \cdot \tan\varphi'}$$ b_c = 1,00 ...dimensionless factor for cohesion

$$b_q = (1 - \alpha \cdot \tan\varphi')^2$$ b_q = 1,00 ...dimensionless factor for loading

$$b_\gamma = (1 - \alpha \cdot \tan\varphi')^2$$ b_γ = 1,00 ...dimensionless factor for soil density

Factors for the shape of foundation:

$$s_q = 1 + \left(\frac{B'}{L'}\right) \cdot \sin\varphi'$$ s_q = 1,55 ...dimensionless factor for loading

$$s_\gamma = 1 - 0.3 \cdot \frac{B'}{L'}$$ s_γ = 0,67 ...dimensionless factor for soil density

$$s_c = \frac{s_q \cdot N_q - 1}{N_q - 1}$$ s_c = 1,58 ...dimensionless factor for cohesion

Factors for the inclination of the load, caused by a horizontal load H:

$$H = \sqrt{(H_B{}^2 + H_L{}^2)}$$ H = 45,67 kN ...total horizontal force

$$i_c = i_q - \frac{1 - i_q}{N_c \cdot \tan\varphi'}$$ i_c = 0,53 ...dimensionless factor for cohesion

$$i_q = \left[1 - \frac{H}{V + A' \cdot c' \cdot \cot\varphi'}\right]^m$$ i_q = 0,56 ...dimensionless factor for loading

$$i_\gamma = \left[1 - \frac{H}{V + A' \cdot c' \cdot \cot\varphi'}\right]^{m+1}$$ i_γ = 0,37 ...dimensionless factor for soil density

$$m_B = \frac{2 + \frac{B'}{L'}}{1 + \frac{B'}{L'}}$$ m_B = 1,48 ...exponent in forumlas for the inclination factor i

$$m_L = \frac{2 + \frac{L'}{B'}}{1 + \frac{L'}{B'}}$$ m_L = 1,52 ...exponent in forumlas for the inclination factor i

$$m = m_L \cdot \cos^2\theta + m_B \cdot \sin^2\theta$$ m = 1,48 ...exponent in forumlas for the inclination factor i

$$\tan\theta = \frac{H_B}{H_L}$$ θ = 90,00 ° ...inclination of horizontal force forming an angle with L' direction

Design vertical load and design vertical bearing resistance:

$$V_d = \frac{V_{Ed}}{A'}$$ V_{Ed}/A' = 127,59 kPa ...design vertical load of foundation base

$$\frac{R}{A'} = c' \cdot N_c \cdot b_c \cdot s_c \cdot i_c + q' \cdot N_q \cdot b_q \cdot s_q \cdot i_q + 0.5 \cdot \gamma' \cdot B' \cdot N_\gamma \cdot b_\gamma \cdot s_\gamma \cdot i_\gamma$$

R_d/A' = 177,38 kPa ...design vertical bearing resistance of foundation base

Bearing resistance utilization:

$$U = \frac{V_{Ed}/A'}{R_d/A'} = \frac{V_{Ed}}{R_d}$$ U = 71,93 % BEARING RESISTANCE IS SUFFICIENT!