Analysis of anti-slide pile

Input data

Settings

Slovenia - EN 1997 (43)

Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard
Steel structures : EN 1993-1-1 (EC3)
Partial factor on bearing capacity of steel cross section : γ_{M0} = 1,00

Pressure analysis

Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Caquot-Kerisel
Earthquake analysis : Mononobe-Okabe
Modulus of subsoil reaction : standard
Consider reduction of the modulus of subsoil reaction for a braced sheeting
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 earth resistance :	γ_{Re} =	1,40	[–]

Anchors

Verification methodology : Limit states (LSD)

Reduction coefficients			
Reduction. coeff of steel strength :	γ_s =	1,35	[–]
Reduction coefficient of pull out resistance (soil) :	γ_e =	1,35	[–]
Reduction coefficient of pull out resistance (grouting) :	γ_c =	1,35	[–]

Geometry of structure

Structure length = 4,60 m

Cross-section name : Pile curtain d = 0,50 m; a = 1,00 m
Material of pile : concrete
Computed coefficient of pressure reduction below the ditch = 1,00
Area of cross-section A = 1,96E-01 m^2/m
Moment of inertia I = 3,07E-03 m^4/m
Elastic modulus E = 33000,00 MPa
Shear modulus G = 13750,00 MPa

Forces above the slip surface

Depth of slip surface h_{s1} = 1,53 m

Input of active horizontal force : residual active force
Input of passive horizontal force : residual passive force

Active horizontal force T = 23,97 kN/m

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Passive horizontal force P = 23,97 kN/m

Distribution of active force : triangle
Distribution of passive force : triangle

Material of structure

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

Concrete : C 30/37

Cylinder compressive strength	f_{ck} =	30,00 MPa
Tensile strength	f_{ctm} =	2,90 MPa
Elasticity modulus	E_{cm} =	33000,00 MPa
Shear modulus	G =	13750,00 MPa

Longitudinal steel : B500

Yield strength f_{yk} = 500,00 MPa

Transverse steel: B500

Yield strength f_{yk} = 500,00 MPa

Modulus of reaction

Modulus of subsoil reaction is computed by method Schmitt.

Basic soil parameters

No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m^3]	γ_{su} [kN/m^3]	δ [°]
1	Glina		12,50	0,00	19,00	9,00	12,50
2	Preperina		30,00	10,00	21,00	11,00	30,00
3	Hribina		34,00	30,00	23,00	13,00	34,00
4	AB konzola		45,00	50,00	24,00	14,00	45,00

Soil parameters to compute pressure at rest

No.	Name	Pattern	Type calculation	φ_{ef} [°]	ν [–]	OCR [–]	K_r [–]
1	Glina		cohesive	-	0,40	-	-
2	Preperina		cohesive	-	0,30	-	-
3	Hribina		cohesive	-	0,20	-	-
4	AB konzola		cohesive	-	0,16	-	-

Parameters of soils to compute modulus of subsoil reaction (Schmitt)

No.	Name	Pattern	ν [–]	E_{oed} [MPa]	E_{def} [MPa]
1	Glina		0,40	2,00	-
2	Preperina		0,30	20,00	-

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No.	Name	Pattern	ν [–]	E_{oed} [MPa]	E_{def} [MPa]
3	Hribina		0,20	50,00	-
4	AB konzola		0,16	100,00	-

Soil parameters

Glina

Unit weight : γ = 19,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 12,50 °
Cohesion of soil : c_{ef} = 0,00 kPa
Angle of friction struc.-soil : δ = 12,50 °
Soil : cohesive
Poisson's ratio : ν = 0,40
Oedometric modulus : E_{oed} = 2,00 MPa
Saturated unit weight : γ_{sat} = 19,00 kN/m^3

Preperina

Unit weight : γ = 21,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 30,00 °
Cohesion of soil : c_{ef} = 10,00 kPa
Angle of friction struc.-soil : δ = 30,00 °
Soil : cohesive
Poisson's ratio : ν = 0,30
Oedometric modulus : E_{oed} = 20,00 MPa
Saturated unit weight : γ_{sat} = 21,00 kN/m^3

Hribina

Unit weight : γ = 23,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 34,00 °
Cohesion of soil : c_{ef} = 30,00 kPa
Angle of friction struc.-soil : δ = 34,00 °
Soil : cohesive
Poisson's ratio : ν = 0,20
Oedometric modulus : E_{oed} = 50,00 MPa
Saturated unit weight : γ_{sat} = 23,00 kN/m^3

AB konzola

Unit weight : γ = 24,00 kN/m^3
Stress-state : effective
Angle of internal friction : φ_{ef} = 45,00 °
Cohesion of soil : c_{ef} = 50,00 kPa
Angle of friction struc.-soil : δ = 45,00 °
Soil : cohesive
Poisson's ratio : ν = 0,16
Oedometric modulus : E_{oed} = 100,00 MPa
Saturated unit weight : γ_{sat} = 24,00 kN/m^3

Pile fixed into the rock

Length of wall in the rock l = 2,00 m

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Bearing capacity of rock R = 3000,00 kPa

Geological profile and assigned soils

Position information
Terrain elevation = 9,60 m

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Altitude [m]	Assigned soil	Pattern
1	0,60	0,00 .. 0,60	9,60 .. 9,00	AB konzola	
2	1,00	0,60 .. 1,60	9,00 .. 8,00	Glina	
3	1,32	1,60 .. 2,92	8,00 .. 6,68	Preperina	
4	-	2,92 .. ∞	6,68 .. -	Hribina	

Excavation

Soil in front of wall is excavated to a depth of 0,00 m.

Ditch bottom shape

No.	Coordinate x [m]	Depth z [m]
1	0,00	0,01
2	-0,25	0,01
3	-6,25	0,40
4	-10,75	2,30
5	-11,75	2,30

Origin [0,0] is located at the ditch bottom.
Positive coordinate +z has downward direction.

Terrain profile

No.	Coordinate x [m]	Depth z [m]
1	0,00	0,00
2	0,10	0,00
3	2,85	0,00
4	15,75	-0,40
5	18,05	-2,80
6	27,75	-3,90
7	28,75	-3,90

Origin [0,0] is located in upper right edge of construction.
Positive coordinate +z has downward direction.

Water influence

GWT behind the structure lies at a depth of 1,25 m
GWT in front of the structure lies at a depth of 1,30 m
Subgrade at the heel is not permeable.

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Input surface surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m²]	Mag.2 [kN/m²]	Ord.x x [m]	Length l [m]	Depth z [m]
1	Yes		permanent	250,00		2,25	13,00	on terrain

No.	Name
1	Hiša

Global settings

Number of FEs to discretize wall = 100
Analysis of depending pressures : reduce according to analysis settings
Minimum dimensioning pressure is considered as $\sigma_{a,min} = 0{,}20\sigma_z$

Settings of the stage of construction

Design situation : permanent

Analysis results

Pressure above the slip surface

Depth [m]	Passive pressure [kPa]	Active pressure [kPa]
0	0,00	0,00
0,00	0,00	0,00
0,00	0,00	0,00
1,53	31,39	31,39

Distribution of pressures acting on the structure (in front and behind the wall) - above slip surface

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.00	0.00	0.00
0.03	0.00	0.00	0.00	0.00	0.00	0.00
0.04	0.00	0.00	0.00	0.00	0.00	0.00
0.09	0.00	0.00	0.00	0.00	0.00	0.00
0.24	0.00	0.00	0.00	0.00	0.00	0.00
0.39	0.00	0.00	0.00	0.00	0.00	0.00
0.48	0.00	0.00	0.00	0.00	0.00	0.00
0.52	0.00	0.00	0.00	0.00	0.00	0.00
0.60	0.00	0.00	0.00	0.00	0.00	0.00
0.73	0.00	0.00	0.00	0.00	0.00	0.00
0.97	0.00	0.00	0.00	0.00	0.00	0.00
1.04	0.00	0.00	0.00	0.00	0.00	0.00
1.21	0.00	0.00	0.00	0.00	0.00	0.00
1.25	0.00	0.00	0.00	0.00	0.00	0.00
1.30	0.00	0.00	0.00	0.00	0.00	0.00
1.45	0.00	0.00	0.00	0.00	0.00	0.00
1.53	0.00	0.00	0.00	0.00	0.00	0.00

Distribution of pressures acting on the structure (in front and behind the wall) - below the slip surface

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
1.53	-4.80	-4.80	-4.80	200.59	200.59	200.59

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Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
1.60	-4.83	-4.83	-4.83	200.84	200.84	200.84
1.60	0.00	-12.63	-134.13	86.93	120.46	152.12
1.69	0.00	-13.06	-137.71	87.21	120.90	156.59
1.70	0.00	-13.07	-137.82	87.22	120.92	156.73
1.72	0.00	-13.18	-138.72	87.29	121.03	157.85
1.74	0.00	-13.26	-139.37	86.88	121.11	158.66
1.94	-0.72	-14.16	-146.86	66.88	122.05	168.01
2.18	-1.61	-15.26	-156.01	42.46	123.19	179.44
2.29	-2.01	-15.76	-160.21	31.26	123.71	184.68
2.30	-2.05	-15.81	-160.59	30.26	123.76	185.15
2.42	-1.22	-9.43	-165.16	18.05	124.33	190.86
2.60	0.00	0.00	-171.92	0.00	0.00	199.31
2.60	Rock	Rock	Rock	Rock	Rock	Rock
2.66	Rock	Rock	Rock	Rock	Rock	Rock
2.91	Rock	Rock	Rock	Rock	Rock	Rock
2.92	Rock	Rock	Rock	Rock	Rock	Rock
3.15	Rock	Rock	Rock	Rock	Rock	Rock
3.39	Rock	Rock	Rock	Rock	Rock	Rock
3.63	Rock	Rock	Rock	Rock	Rock	Rock
3.87	Rock	Rock	Rock	Rock	Rock	Rock
4.12	Rock	Rock	Rock	Rock	Rock	Rock
4.36	Rock	Rock	Rock	Rock	Rock	Rock
4.60	Rock	Rock	Rock	Rock	Rock	Rock

Distributions of the modulus of subsoil reaction and internal forces on the structure

Depth [m]	kh,p [MN/m3]	kh,z [MN/m3]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-4.73	0.00	0.00	0.00
0.01	0.00	0.00	-4.71	0.00	-0.00	0.00
0.23	0.00	0.00	-4.43	0.00	-0.00	0.00
0.46	0.00	0.00	-4.12	0.00	-0.00	0.00
0.69	0.00	0.00	-3.82	0.00	-0.00	0.00
0.92	0.00	0.00	-3.52	0.00	-0.00	0.00
1.15	0.00	0.00	-3.22	0.00	-0.00	0.00
1.38	0.00	0.00	-2.92	0.00	-0.00	0.00
1.52	0.00	0.00	-2.74	0.00	-0.00	0.00
1.53	0.00	0.00	-2.72	195.80	-0.78	0.00
1.61	24.46	0.00	-2.62	10.17	-11.91	0.60
1.84	24.46	0.00	-2.32	6.15	-14.45	3.65
2.07	24.46	24.46	-2.02	8.94	-15.33	7.04
2.30	24.46	24.46	-1.73	23.39	-19.06	10.93
2.53	24.46	24.46	-1.44	-25.48	-23.26	16.01
2.76	24.46	0.00	-1.16	-28.35	-16.25	20.56
2.99	83.00	0.00	-0.89	-73.82	-6.72	23.46
3.22	83.00	0.00	-0.63	-52.43	7.78	23.25
3.45	83.00	0.00	-0.39	-32.05	17.47	20.25
3.68	83.00	0.00	-0.15	-12.53	22.59	15.56
3.91	0.00	83.00	0.08	6.31	23.29	10.20

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Depth [m]	kh,p [MN/m3]	kh,z [MN/m3]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
4.14	0.00	83.00	0.30	24.71	19.72	5.17
4.37	0.00	83.00	0.52	42.88	11.94	1.45
4.60	0.00	83.00	0.73	60.97	-0.00	0.00

Maximum shear force = 23,82 kN/m
Maximum moment = 23,78 kNm/m
Maximum displacement = 4,7 mm
Displacement in the depth of slip surface = 2,7 mm

Verification of rock bearing capacity

Bearing capacity of rock R = 3000,00 kPa
Partial factor on rock bearing capacity γ_{Rr} = 1,40
Max. stress σ = 156,43 kPa
Design bearing capacity of rock R_d = 2142,86 kPa

Bearing capacity of rock is SATISFACTORY

Terrain settlement behind the structure

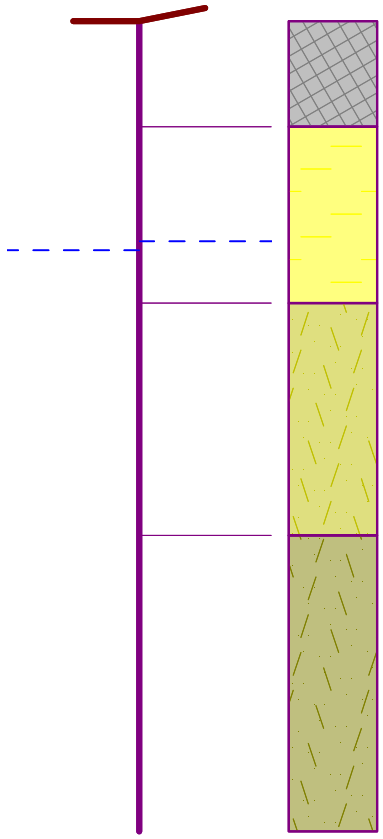
Terrain settlement δ_{max} = 3,0 mm

	Coordinate x [m]	Settlement z [mm]
1	0,00	2,0
2	0,37	2,9
3	0,74	3,5
4	1,11	3,9
5	1,48	4,1
6	1,85	4,0
7	2,22	3,7
8	2,59	3,1
9	2,96	2,3
10	3,33	1,3
11	3,70	0,0
12	3,70	0,0

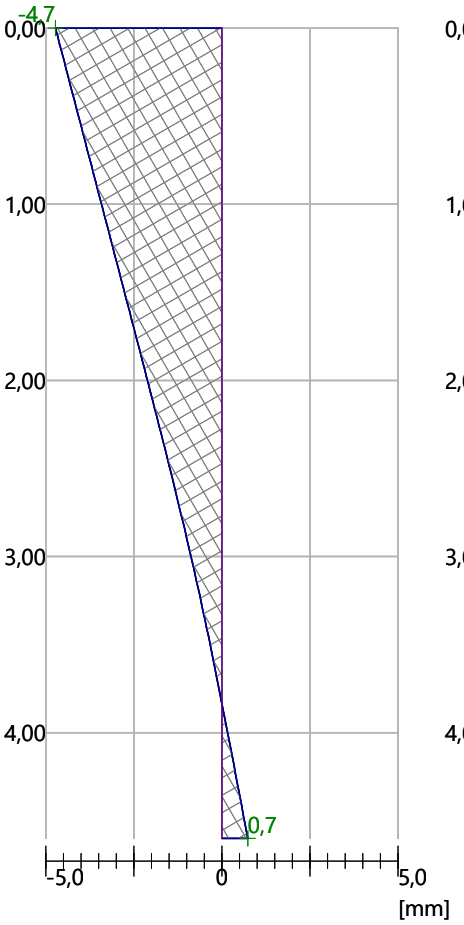
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Name : Analysis	Stage - analysis : 1 - -1

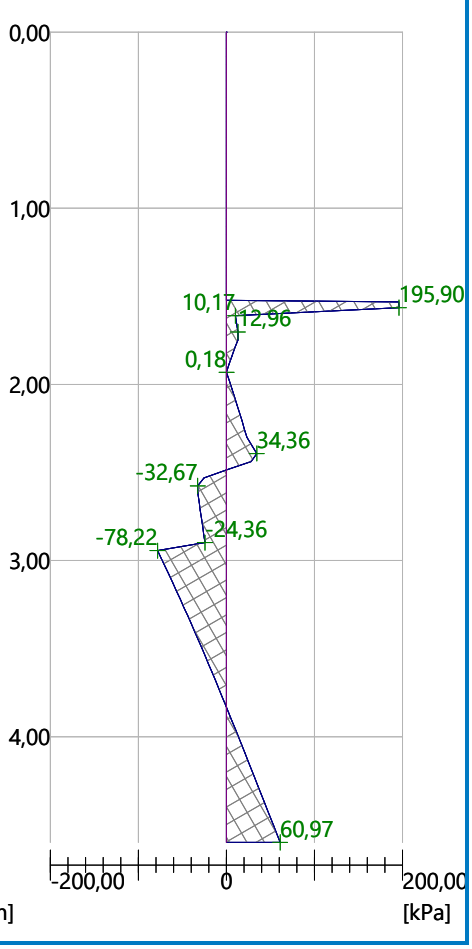
Geometry of structure
Length of structure = 4,60m



Displacement of structure
Max. disp. = 4,7 mm



Pressure acting on structure
Max. pressure = 195,90 kPa



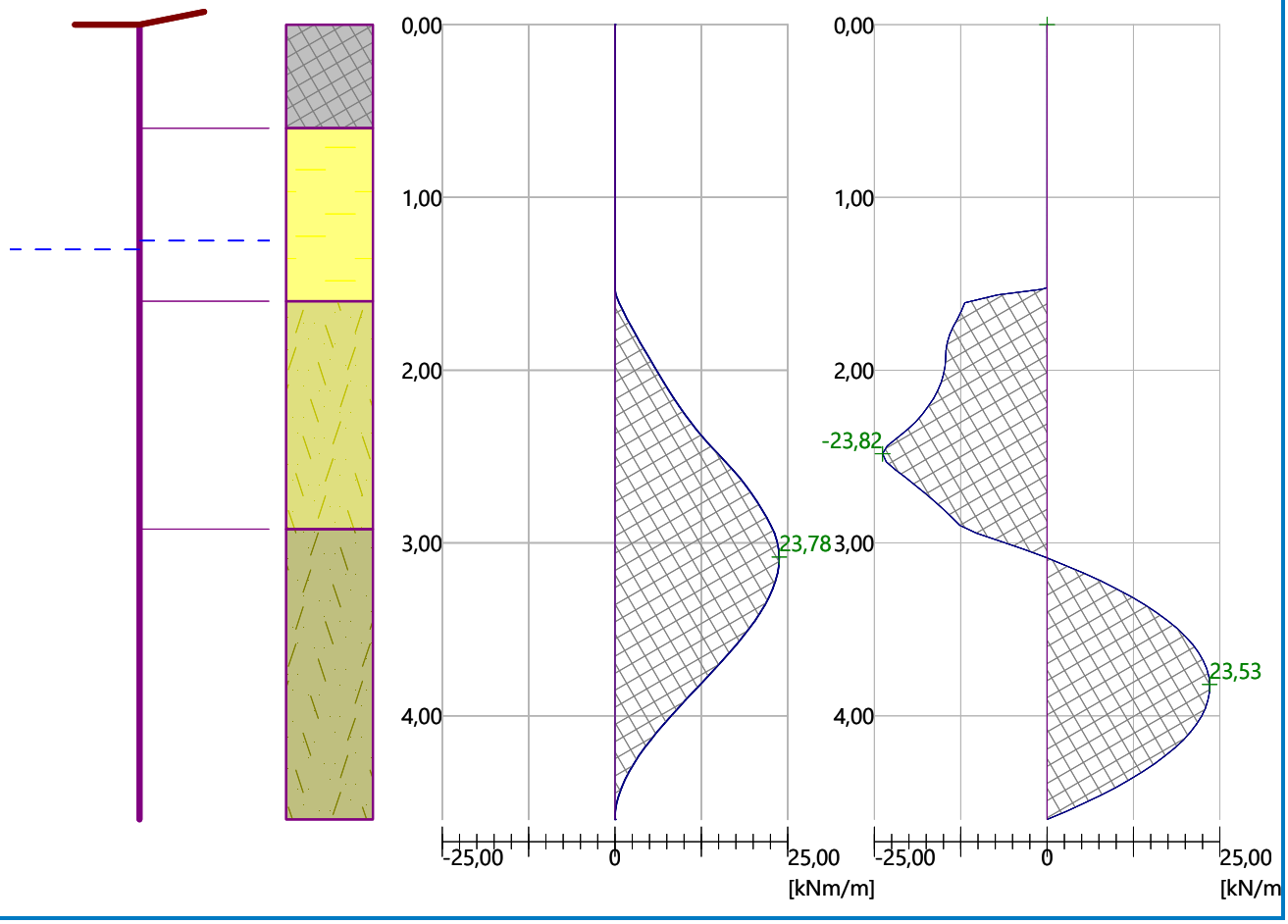
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Name : Analysis	Stage - analysis : 1 - -1

Geometry of structure
Length of structure = 4,60m

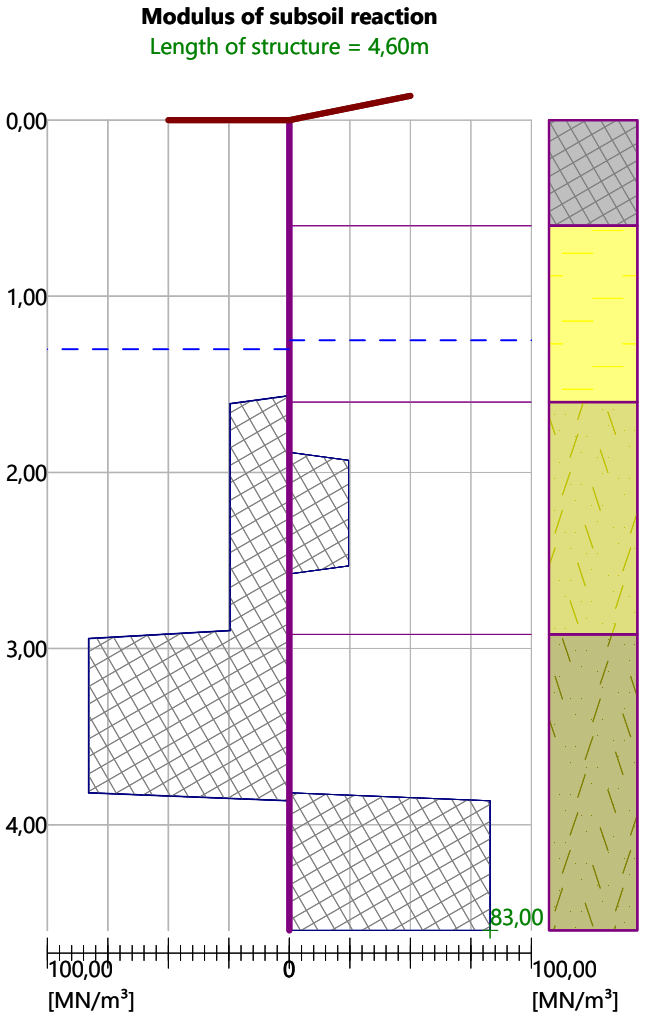
Bending moment
Max. M = 23,78 kNm/m

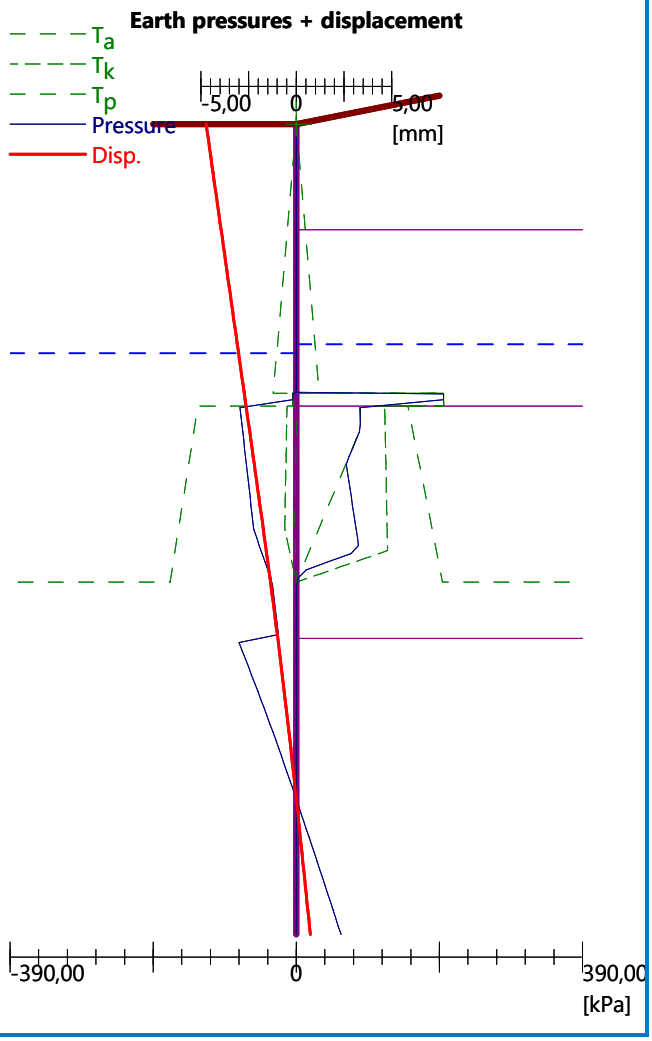
Shear force
Max. Q = 23,82 kN/m



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Name : Analysis	Stage - analysis : 1 - -1





Dimensioning No. 1

	Disp. min [mm]	Disp. max [mm]	Shear force min. [kN/m]	Shear force max [kN/m]	Moment min. [kNm/m]	Moment max. [kNm/m]
0.00	-4.73	-4.73	0.00	0.00	0.00	0.00
0.01	-4.72	-4.72	0.00	0.00	-0.00	-0.00
0.01	-4.72	-4.72	-0.00	-0.00	-0.00	-0.00
0.01	-4.71	-4.71	-0.00	-0.00	0.00	0.00
0.23	-4.43	-4.43	-0.00	-0.00	0.00	0.00
0.46	-4.12	-4.12	-0.00	-0.00	0.00	0.00
0.69	-3.82	-3.82	-0.00	-0.00	0.00	0.00
0.92	-3.52	-3.52	-0.00	-0.00	0.00	0.00
1.15	-3.22	-3.22	-0.00	-0.00	0.00	0.00
1.38	-2.92	-2.92	-0.00	-0.00	0.00	0.00
1.52	-2.74	-2.74	-0.00	-0.00	0.00	0.00
1.52	-2.74	-2.74	-0.00	-0.00	0.00	0.00
1.52	-2.73	-2.73	-0.00	-0.00	0.00	0.00
1.52	-2.73	-2.73	-0.00	-0.00	0.00	0.00
1.53	-2.72	-2.72	-0.78	-0.78	0.00	0.00
1.53	-2.72	-2.72	-0.78	-0.78	0.00	0.00

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	Disp. min [mm]	Disp. max [mm]	Shear force min. [kN/m]	Shear force max [kN/m]	Moment min. [kNm/m]	Moment max. [kNm/m]
1.61	-2.62	-2.62	-11.91	-11.91	0.60	0.60
1.84	-2.32	-2.32	-14.45	-14.45	3.65	3.65
2.07	-2.02	-2.02	-15.33	-15.33	7.04	7.04
2.30	-1.73	-1.73	-19.06	-19.06	10.93	10.93
2.53	-1.44	-1.44	-23.26	-23.26	16.01	16.01
2.76	-1.16	-1.16	-16.25	-16.25	20.56	20.56
2.99	-0.89	-0.89	-6.72	-6.72	23.46	23.46
3.22	-0.63	-0.63	7.78	7.78	23.25	23.25
3.45	-0.39	-0.39	17.47	17.47	20.25	20.25
3.68	-0.15	-0.15	22.59	22.59	15.56	15.56
3.91	0.08	0.08	23.29	23.29	10.20	10.20
4.14	0.30	0.30	19.72	19.72	5.17	5.17
4.37	0.52	0.52	11.94	11.94	1.45	1.45
4.60	0.73	0.73	-0.00	-0.00	0.00	0.00

Maximum values of internal forces

Maximum displacement = -4,7 mm
Minimum displacement = 0,7 mm
Maximum bending moment = 23,78 kNm/m
Minimum bending moment = 0,00 kNm/m
Maximum shear force = 23,82 kN/m

Verification of RC cross section (Pile curtain d = 0,50 m; a = 1,00 m)

All construction stages are taken into the analysis.
Reduct. coefficient of bearing capacity = 1,00

Verification of cross section in bending:

Reinforcement - 6 pc bars 16,0 mm; cover 40,0 mm
Type of structure (reinforcement ratio) : beam
Reinforcement ratio ρ = 0,307 % > 0,151 % = ρ_{min}
Load : M_{Ed} = 23,78 kNm
Bearing capacity : M_{Rd} = 102,83 kNm
Designed pile reinforcement is SATISFACTORY

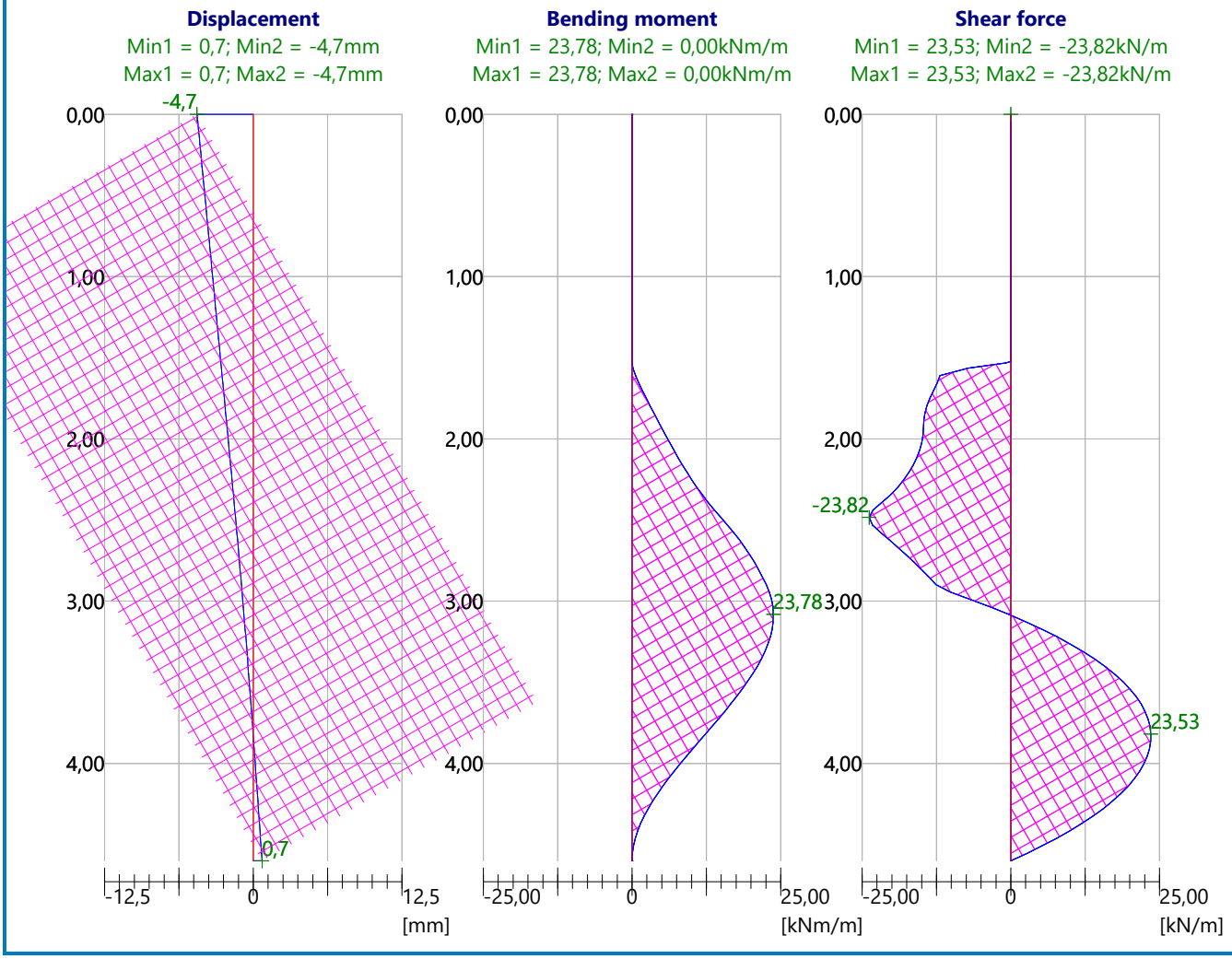
Verification of cross section in shear:

Shear reinf. - 2 profile 10,0 mm; distance 250,0 mm
A_{sw} = 628,3 mm^2
Ultimate shear force: V_{Rd} = 245,86 kN > 23,82 kN = V_{Ed}
Cross-section is SATISFACTORY.
only minimal shear reinforcement

Overall verification: Cross-section is SATISFACTORY

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Name : Dimensioning	Stage - analysis : 1 - 1



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