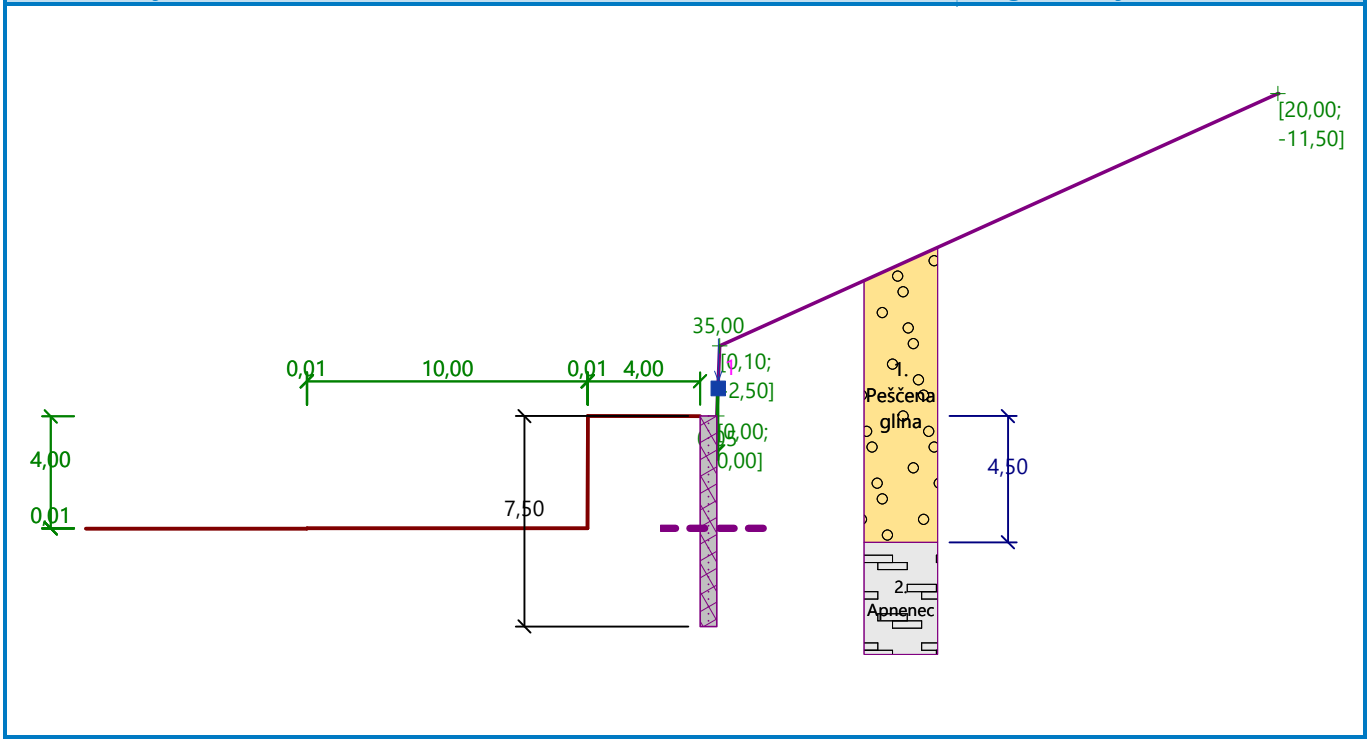
Analysis of anti-slide pile

Input data

Project : Plaz Gavce 26c
Part : Pilotna stena - pilot P1
Author : BLAN d.o.o.
Project number : GM - 212/2024

Name : Project	Stage - analysis : 1 - 0



Settings

Slovenia - EN 1997

Materials and standards

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

Pressure analysis

Verification methodology :	according to EN 1997
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

Pressures below the slip surface :	standard
Design approach :	2 - reduction of actions and resistances

Partial factors on actions (A)			
Permanent design situation			
		Unfavourable	Favourable

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Partial factors on actions (A)					
Permanent design situation					
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 = 7,50 m

Cross-section name : Pile curtain d = 0,60 m, a = 1,20 m
Material of pile : concrete
Input coefficient of pressure reduction below the ditch= 0,75
Area of cross-section A = 2,36E-01 m^2/m
Moment of inertia I = 5,30E-03 m^4/m

Forces above the slip surface

Depth of slip surface h_{s1} = 4,00 m
Input of active horizontal force : active pressure
Input of passive horizontal force : springs

Coeff. of increase of active pressure = 1,00

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

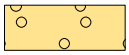
Longitudinal reinforcement: B500B
Yield strength f_{yk} = 500,00 MPa

Transverse reinforcement: B500B
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/m³]	γ_{su} [kN/m³]	δ [°]
1	Peščena glina		22,00	5,00	19,00	9,00	15,00

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No.	Name	Pattern	φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m³]	γ_{su} [kN/m³]	δ [°]
2	Pobočni grušč		33,00	0,00	21,00	11,00	22,00
3	Apnenec		0,00	500,00	23,00	13,00	0,00
4	Kamnito nasutje (cesta)		38,00	1,00	21,00	11,00	26,00

Soil parameters to compute pressure at rest

No.	Name	Pattern	Type calculation	φ_{ef} [°]	ν [–]	OCR [–]	K_r [–]
1	Peščena glina		cohesive	-	0,30	-	-
2	Pobočni grušč		cohesive	-	0,30	-	-
3	Apnenec		cohesive	-	0,10	-	-
4	Kamnito nasutje (cesta)		cohesive	-	0,30	-	-

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

No.	Name	Pattern	ν [–]	E_{oed} [MPa]	E_{def} [MPa]
1	Peščena glina		0,30	20,00	-
2	Pobočni grušč		0,30	40,00	-
3	Apnenec		0,10	100,00	-
4	Kamnito nasutje (cesta)		0,30	40,00	-

Soil parameters

Peščena glina

Unit weight : $\gamma = 19{,}00$ kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 22{,}00$ °
Cohesion of soil : $c_{ef} = 5{,}00$ kPa
Angle of friction struc.-soil : $\delta = 15{,}00$ °
Soil : cohesive
Poisson's ratio : $\nu = 0{,}30$
Oedometric modulus : $E_{oed} = 20{,}00$ MPa
Saturated unit weight : $\gamma_{sat} = 19{,}00$ kN/m³

Pobočni grušč

Unit weight : $\gamma = 21{,}00$ kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef} = 33{,}00$ °
Cohesion of soil : $c_{ef} = 0{,}00$ kPa
Angle of friction struc.-soil : $\delta = 22{,}00$ °

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Soil :	cohesive		
Poisson's ratio :	ν	=	0,30
Oedometric modulus :	E_{oed}	=	40,00 MPa
Saturated unit weight :	γ_{sat}	=	21,00 kN/m^3

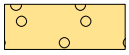
Apnenec

Unit weight :	γ	=	23,00 kN/m^3
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	0,00 °
Cohesion of soil :	c_{ef}	=	500,00 kPa
Angle of friction struc.-soil :	δ	=	0,00 °
Soil :	cohesive		
Poisson's ratio :	ν	=	0,10
Oedometric modulus :	E_{oed}	=	100,00 MPa
Saturated unit weight :	γ_{sat}	=	23,00 kN/m^3

Kamnito nasutje (cesta)

Unit weight :	γ	=	21,00 kN/m^3
Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	38,00 °
Cohesion of soil :	c_{ef}	=	1,00 kPa
Angle of friction struc.-soil :	δ	=	26,00 °
Soil :	cohesive		
Poisson's ratio :	ν	=	0,30
Oedometric modulus :	E_{oed}	=	40,00 MPa
Saturated unit weight :	γ_{sat}	=	21,00 kN/m^3

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	4,50	0,00 .. 4,50	Peščena glina	
2	-	4,50 .. ∞	Apnenec	

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	-4,00	0,00
3	-4,01	4,00
4	-14,01	4,00
5	-14,02	4,01
6	-15,02	4,01

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

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Terrain profile

No.	Coordinates x [m]	Depth z [m]
1	0,00	0,00
2	0,10	-2,50
3	20,00	-11,50
4	21,00	-11,50

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

Water influence

Ground water table is located below the structure.

Input line surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m]	Ord.x x [m]	Depth z [m]
1	Yes		permanent	35,00	0,05	on terrain

No.	Name
1	ZID

Global settings

Number of FEs to discretize wall = 100
Analysis of depending pressures : reduce according to analysis settings
Minimum 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	-
4,00	0,00	-

Active pressure - above slip surface

Depth [m]	Active pressure [kPa]
0.00	0.00
0.00	1138.63
0.00	1129.86
0.01	1013.87
0.01	1030.66
0.05	283.62
0.05	292.26
0.06	52.84
0.22	56.93
0.22	56.99
3.94	147.20
4.00	147.83

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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]
4.00	-7.98	-7.98	-9.30	110.88	110.88	185.10
4.00	-7.98	-7.98	-9.33	110.88	110.88	185.14
4.24	-7.98	-7.98	-16.88	112.67	112.67	195.51
4.50	-7.98	-7.98	-25.16	114.64	114.64	206.87
4.50	0.00	-0.99	-540.95	12.83	23.35	581.06
4.57	0.00	-0.99	-541.76	13.05	23.62	581.87
4.61	0.00	-0.99	-542.25	13.19	23.78	582.36
4.89	0.00	-1.54	-545.78	14.18	24.94	585.88
5.22	0.00	-2.17	-549.80	15.30	26.27	589.89
5.42	0.00	-2.56	-552.34	16.01	27.10	592.43
5.43	0.00	-2.57	-552.40	16.03	27.11	592.49
5.54	0.00	-2.79	-553.82	16.43	27.33	593.90
5.87	0.00	-3.42	-557.84	17.55	27.96	597.92
5.92	0.00	-3.52	-558.48	17.73	28.06	598.56
5.92	0.00	-3.52	-558.49	17.73	28.06	598.57
6.20	0.00	-4.04	-561.86	18.68	28.58	601.93
6.52	0.00	-4.67	-565.88	19.80	29.21	605.94
6.85	0.00	-5.29	-569.90	20.93	29.83	609.95
7.17	0.00	-5.92	-573.92	22.05	30.46	613.96
7.50	0.00	-6.54	-577.94	23.18	31.08	617.98

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

Depth [m]	kh,p [MN/m^3]	kh,z [MN/m^3]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-66.37	0.00	-0.00	-0.00
0.01	0.00	0.00	-66.18	874.66	-10.67	0.06
0.38	0.00	0.00	-61.30	32.73	-49.14	15.01
0.75	0.00	0.00	-56.23	25.90	-60.13	35.58
1.13	0.00	0.00	-51.19	19.07	-68.57	59.79
1.50	0.00	0.00	-46.20	12.25	-74.44	86.68
1.88	0.00	0.00	-41.28	5.42	-77.75	115.30
2.25	0.00	0.00	-36.46	-1.40	-78.50	144.67
2.63	0.00	0.00	-31.75	-8.23	-76.70	173.85
3.00	0.00	0.00	-27.18	112.05	-112.84	208.61
3.38	0.00	0.00	-22.78	121.16	-156.56	259.01
3.75	0.00	0.00	-18.58	130.27	-203.71	326.46
3.98	0.00	0.00	-16.19	135.19	-233.61	375.64
4.00	0.00	0.00	-15.97	135.40	-236.45	380.57
4.00	0.00	0.00	-15.89	101.48	-237.40	382.47
4.13	0.00	0.00	-14.65	98.55	-249.50	411.93
4.50	0.00	0.00	-11.06	89.47	-284.76	512.21
4.88	0.00	0.00	-7.87	-531.46	-109.25	589.89
5.25	0.00	0.00	-5.16	-534.79	90.68	593.41
5.63	130.71	0.00	-2.91	-366.71	273.28	522.52
6.00	130.71	0.00	-1.08	-127.17	364.36	400.16

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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]
6.38	0.00	130.71	0.43	84.51	372.33	259.51
6.75	0.00	130.71	1.72	254.95	308.05	129.94
7.13	0.00	130.71	2.92	411.41	182.85	36.07
7.50	0.00	130.71	4.07	563.59	0.00	0.00

Maximum values of internal forces acting on the structure

Maximum shear force = 378,92 kN/m
Maximum moment = 601,00 kNm/m
Maximum displacement = 66,4 mm
Displacement in the depth of slip surface = 15,9 mm

Maximum internal forces on cross-section

Maximum shear force = 454,70 kN
Maximum moment = 721,20 kNm

Terrain settlement behind the structure

Terrain settlement δ_{max} = 27,6 mm

	Coordinates x [m]	Settlement z [mm]
1	0,00	31,1
2	0,75	38,0
3	1,50	42,6
4	2,25	45,0
5	3,00	45,2
6	3,75	43,1
7	4,50	38,9
8	5,25	32,5
9	6,00	23,9
10	6,75	13,0
11	7,50	0,0

Utilization of passive pressure

Maximum passive pressure R_{max} = 1888,95 kN/m
Mobilized passive pressure R_{mob} = 902,24 kN/m

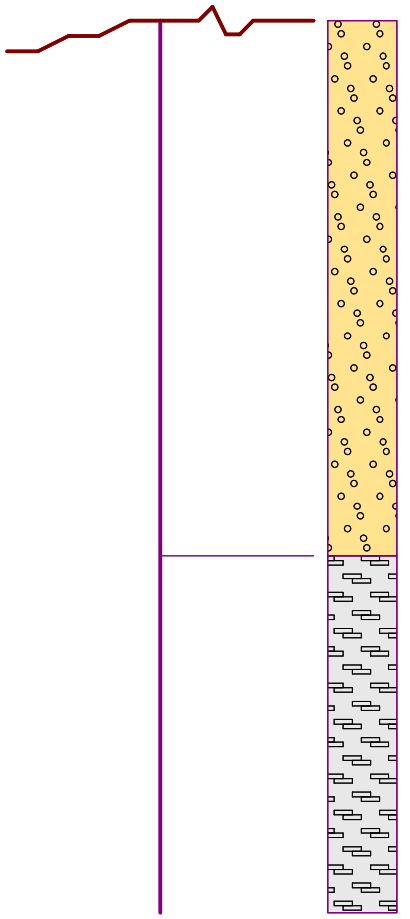
Requested safety factor SF_p = 1,50 < 2,09

Overall verification of passive pressure utilization is SATISFACTORY

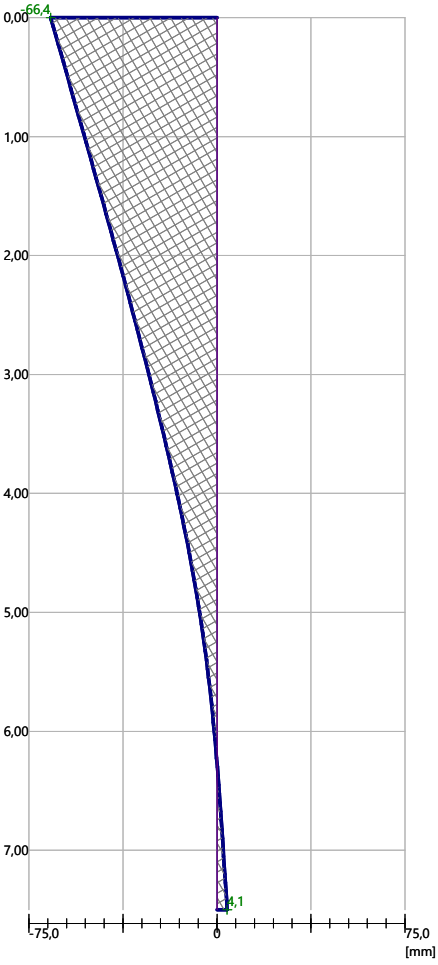
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Name : Analysis Deformations+stresses | Stage - analysis : 1 - -1

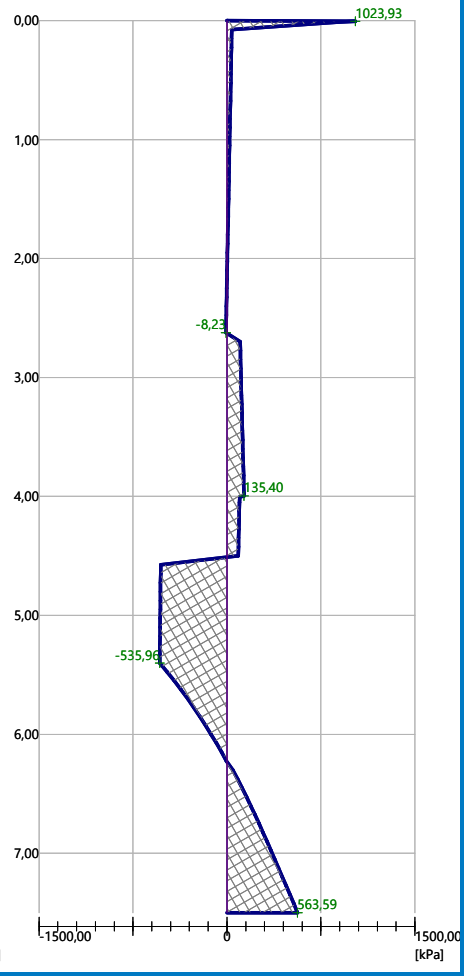
Geometry of structure
Length of structure = 7,50m



Displacement of structure
Max. disp. = 66,4 mm



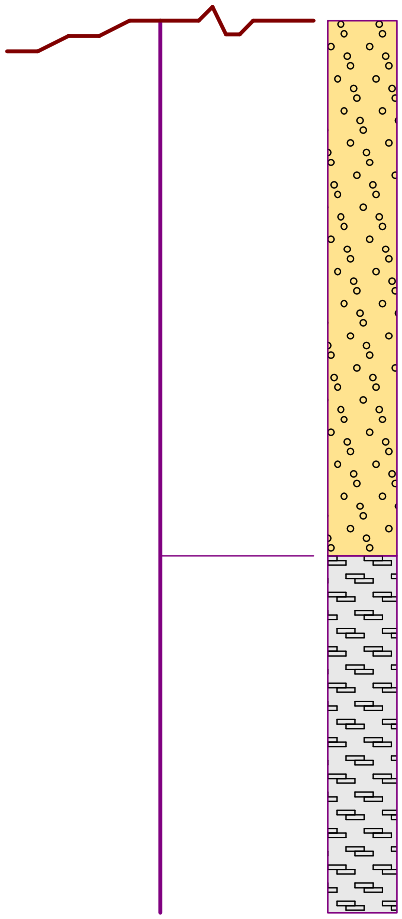
Pressure acting on structure
Max. pressure = 1023,93 kPa



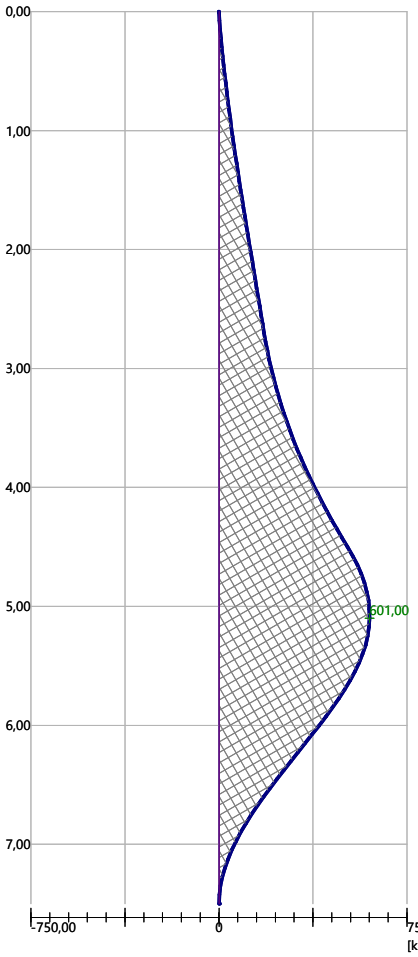
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Name : Analysis Internal forces | Stage - analysis : 1 - -1

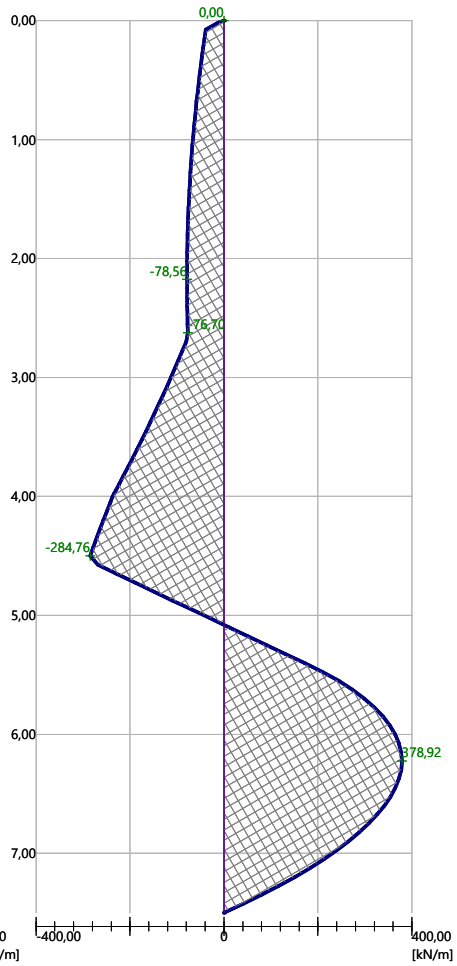
Geometry of structure
Length of structure = 7,50m



Bending moment
Max. M = 601,00 kNm/m

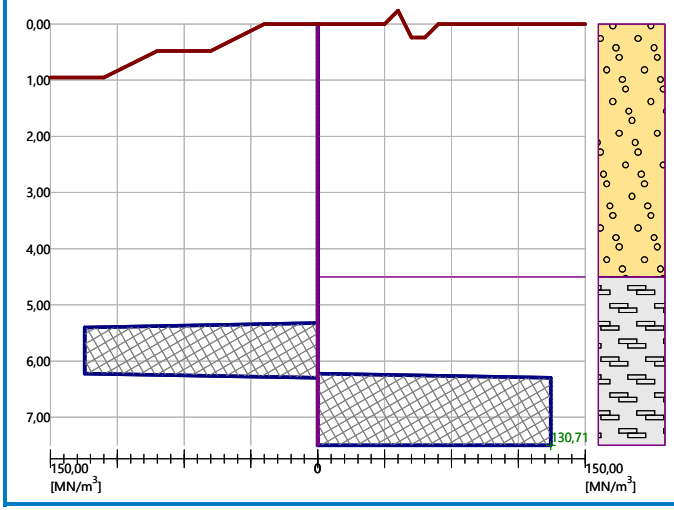


Shear force
Max. Q = 378,92 kN/m

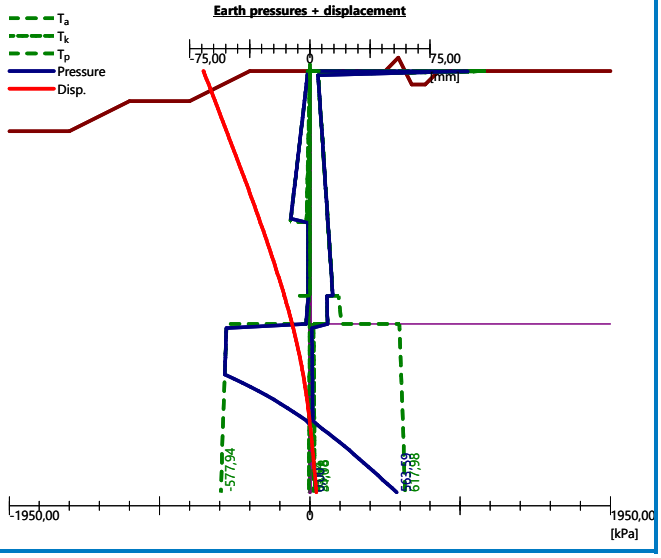


Name : Analysis Kh+Pressures | Stage - analysis : 1 - -1

Modulus of subsoil reaction
Length of structure = 7,50m

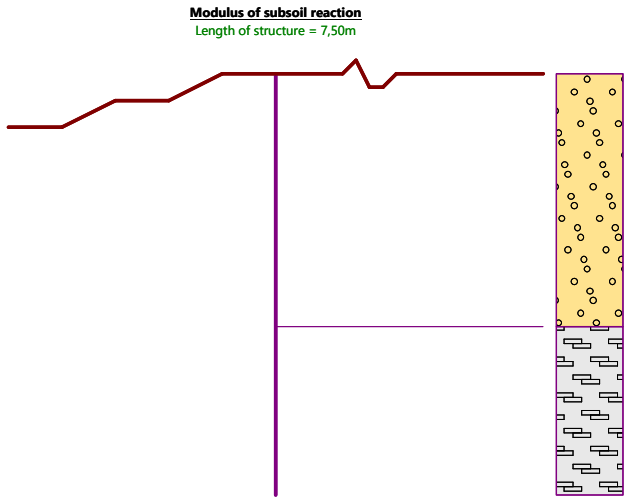


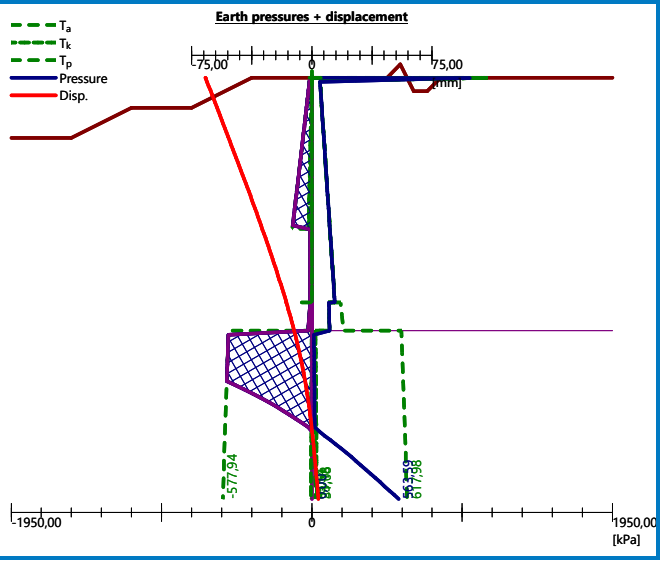
Earth pressures + displacement



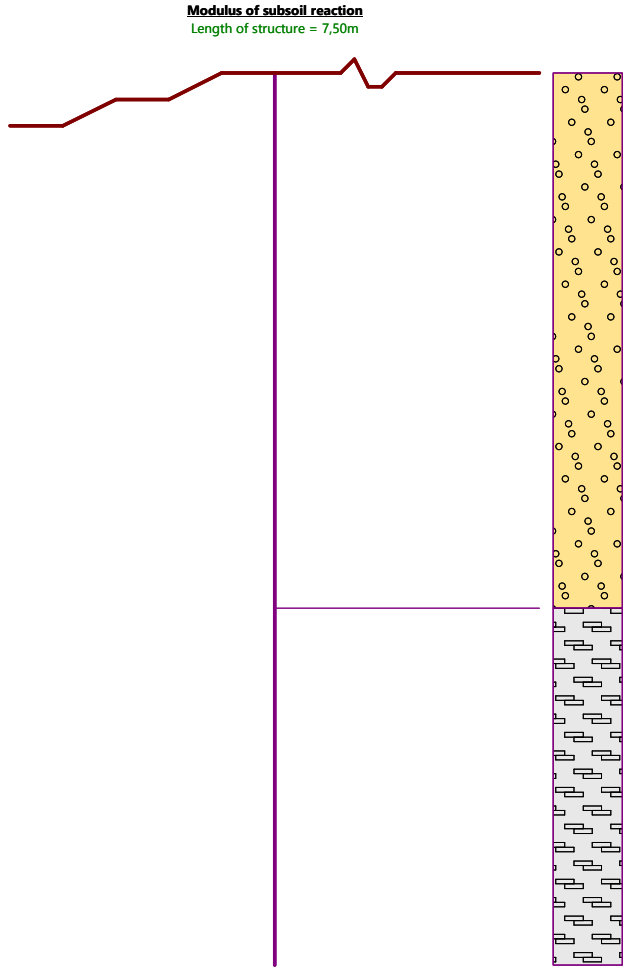
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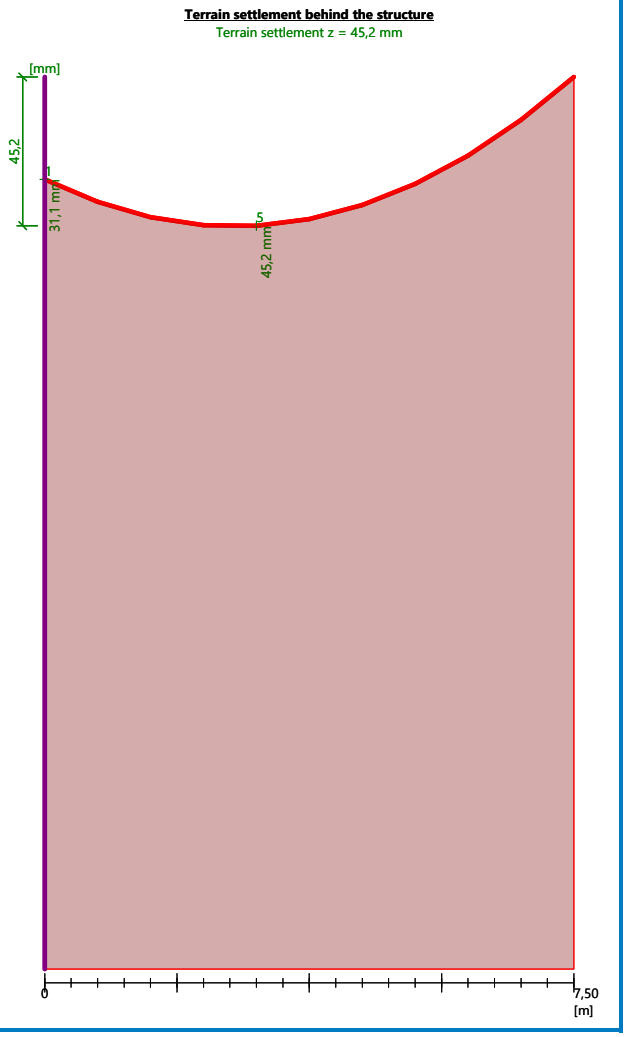
Name : Analysis Passive pressure utilization | Stage - analysis : 1 - -1





Name : Analysis Settlement | Stage - analysis : 1 - -1





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Dimensioning No. 1

Distribution of forces on construction

	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	-66.37	-66.37	-0.00	-0.00	-0.00	-0.00
0.01	-66.29	-66.29	-3.07	-3.07	0.01	0.01
0.01	-66.29	-66.29	-3.07	-3.07	0.01	0.01
0.01	-66.18	-66.18	-10.67	-10.67	0.06	0.06
0.01	-66.18	-66.18	-10.67	-10.67	0.06	0.06
0.38	-61.30	-61.30	-49.14	-49.14	15.01	15.01
0.75	-56.23	-56.23	-60.13	-60.13	35.58	35.58
1.13	-51.19	-51.19	-68.57	-68.57	59.79	59.79
1.50	-46.20	-46.20	-74.44	-74.44	86.68	86.68
1.88	-41.28	-41.28	-77.75	-77.75	115.30	115.30
2.25	-36.46	-36.46	-78.50	-78.50	144.67	144.67
2.63	-31.75	-31.75	-76.70	-76.70	173.85	173.85
3.00	-27.18	-27.18	-112.84	-112.84	208.61	208.61
3.38	-22.78	-22.78	-156.56	-156.56	259.01	259.01
3.75	-18.58	-18.58	-203.71	-203.71	326.46	326.46
3.98	-16.19	-16.19	-233.61	-233.61	375.64	375.64
4.00	-15.97	-15.97	-236.45	-236.45	380.57	380.57
4.00	-15.97	-15.97	-236.45	-236.45	380.57	380.57
4.00	-15.89	-15.89	-237.40	-237.40	382.47	382.47
4.00	-15.89	-15.89	-237.40	-237.40	382.47	382.47
4.13	-14.65	-14.65	-249.50	-249.50	411.93	411.93
4.50	-11.06	-11.06	-284.76	-284.76	512.21	512.21
4.88	-7.87	-7.87	-109.25	-109.25	589.89	589.89
5.25	-5.16	-5.16	90.68	90.68	593.41	593.41
5.63	-2.91	-2.91	273.28	273.28	522.52	522.52
6.00	-1.08	-1.08	364.36	364.36	400.16	400.16
6.38	0.43	0.43	372.33	372.33	259.51	259.51
6.75	1.72	1.72	308.05	308.05	129.94	129.94
7.13	2.92	2.92	182.85	182.85	36.07	36.07
7.50	4.07	4.07	0.00	0.00	0.00	0.00

Maximum values of internal forces

Maximum displacement = -66,4 mm
Minimum displacement = 4,1 mm
Maximum bending moment = 601,00 kNm/m
Minimum bending moment = 0,00 kNm/m
Maximum shear force = 378,92 kN/m

Verification of RC cross section (Pile curtain d = 0,60 m, a = 1,20 m)

All construction stages are taken into the analysis.
Partial factor on load = 1,00

Verification of cross section in bending:

Reinforcement - 12 pc bars 36,0 mm; cover 80,0 mm
Type of structure (reinforcement ratio) : beam
Reinforcement ratio $\rho = 2,160\ \% > 0,151\ \% = \rho_{min}$
Load : $M_{Ed} = 721,20$ kNm

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Bearing capacity : M_{Rd} = 813,48 kNm

Designed pile reinforcement is SATISFACTORY

Verification of cross section in shear:

Shear reinf. - profile 20,0 mm; spacing 500,0 mm

A_{sw} = 2 x 628,3 = 1256,6 mm^2

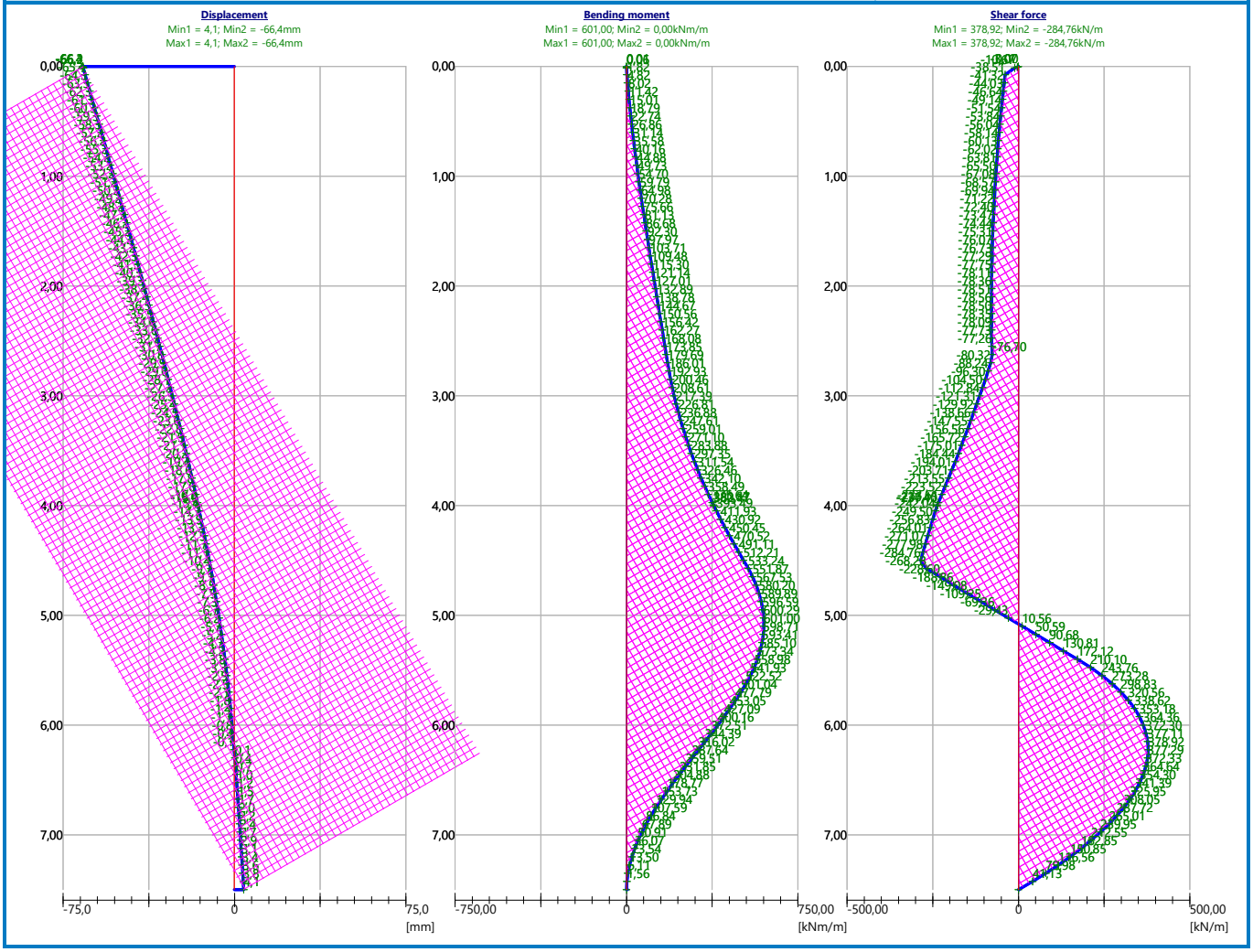
b_w = 0,53 m; d = 0,48 m

Ultimate shear force: V_{Rd} = 590,07 kN > 454,70 kN = V_{Ed}

Cross-section is SATISFACTORY.

Overall verification: Cross-section is SATISFACTORY

Name : Dimensioning	Stage - analysis : 1 - 1



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