

Sheeting structure verification

Input data (Stage of construction 1)

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 :	$\gamma_{M0} = 1,00$
Timber structures :	EN 1995-1-1 (EC5)
Partial factor for timber property :	$\gamma_M = 1,30$
Modif. factor of load duration and moisture content :	$k_{mod} = 0,50$
Coeff. of effective width for shear stress :	$k_{cr} = 0,67$

Pressure analysis

Verification methodology :	according to EN 1997
Active earth pressure calculation :	Coulomb
Passive earth pressure calculation :	Caquot-Kerisel
Analysis method :	dependent pressures
Earthquake analysis :	Mononobe-Okabe
Modulus of subsoil reaction :	standard
Consider reduction of the modulus of subsoil reaction for a braced sheeting	
Design approach :	2 - reduction of actions and resistances

Partial factors on actions (A)			
Permanent design situation			
		Unfavourable	Favourable
Permanent actions :	$\gamma_G =$	1,35 [-]	1,00 [-]
Variable actions :	$\gamma_Q =$	1,50 [-]	0,00 [-]
Water load :	$\gamma_w =$	1,35 [-]	

Partial factors for resistances (R)			
Permanent design situation			
Reduction coeff. of internal stability of anchors :	$\gamma_{Ris} =$	1,30 [-]	
Partial factor on earth resistance :	$\gamma_{Re} =$	1,40 [-]	

Partial factors for variable actions			
Permanent design situation			
Factor for combination value :	$\psi_0 =$	0,70 [-]	
Factor for frequent value :	$\psi_1 =$	0,50 [-]	
Factor for quasi-permanent value :	$\psi_2 =$	0,30 [-]	

Anchors

Verification methodology : Limit states (LSD)

Reduction coefficients			
Reduction. coeff of steel strength :	$\gamma_s =$	1,35 [-]	
Reduction coefficient of pull out resistance (soil) :	$\gamma_e =$	1,35 [-]	
Reduction coefficient of pull out resistance (grouting) :	$\gamma_c =$	1,35 [-]	

Geometry of structure

Structure length = 10,00 m

Cross-section name : Sheet pile : LARSEN 604 n

Area of cross-section $A = 1,57E-02 \text{ m}^2/\text{m}$

Moment of inertia $I = 3,04E-04 \text{ m}^4/\text{m}$

Sectional modulus $W = 1,600E-03 \text{ m}^3/\text{m}$

Plastic sectional modulus $W_{pl} = 1,862E-03 \text{ m}^3/\text{m}$

Material of structure

Structural steel: EN 10248-1 : S 240 GP

Yield strength $f_y = 240,00 \text{ MPa}$


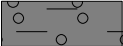

Elasticity modulus $E = 210000,00 \text{ MPa}$

Shear modulus $G = 81000,00 \text{ MPa}$


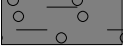
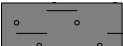
Modulus of reaction

Modulus of subsoil reaction is computed by method Schmitt.


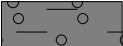

Basic soil parameters

No.	Name	Pattern	Φ_{ef} [°]	c_{ef} [kPa]	γ [kN/m ³]	γ_{su} [kN/m ³]	δ [°]
1	Glina		16,20	2,80	18,00	10,00	11,00
2	Zameljen prod		34,00	1,00	19,00	11,00	22,50
3	Siva zbita peščena		30,00	8,00	19,00	11,00	20,00

Soil parameters to compute pressure at rest

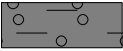

No.	Name	Pattern	Type calculation	Φ_{ef} [°]	ν [-]	OCR [-]	K_r [-]
1	Glina		cohesive	-	0,30	-	-
2	Zameljen prod		cohesionless	34,00	-	-	-
3	Siva zbita peščena		cohesive	-	0,30	-	-

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

No.	Name	Pattern	ν [-]	E_{oed} [MPa]	E_{def} [MPa]
1	Glina		0,30	-	5,00
2	Zameljen prod		0,30	-	15,00
3	Siva zbita peščena		0,30	-	18,00

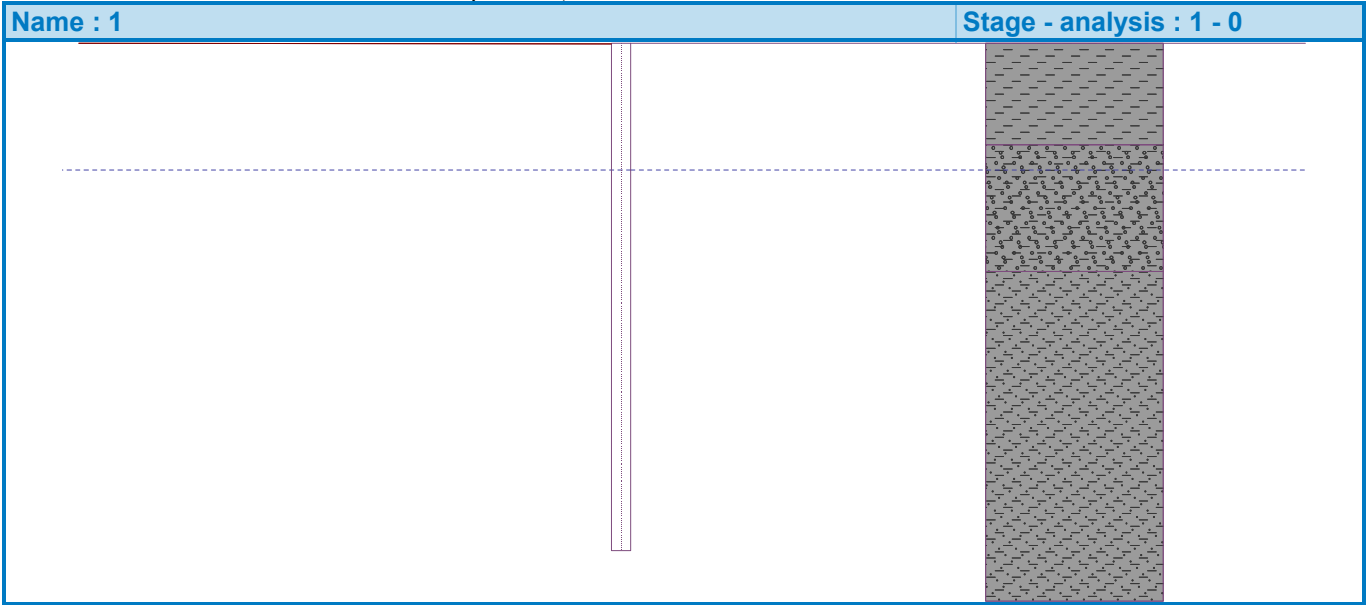
Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	2,00	0,00 .. 2,00	Glina	

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
2	2,50	2,00 .. 4,50	Zameljen prod	
3	-	4,50 .. ∞	Siva zbita peščena	

Excavation

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



Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 2,50 m

GWT in front of the structure lies at a depth of 2,50 m

Subgrade at the heel is permeable.

Hydraulic gradient = 0,00

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 (Stage of construction 1)

Distribution of pressures acting on the structure (in front and behind the wall)

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	-5.90	0.04	0.08	6.18
0.40	0.00	-3.04	-17.13	1.45	3.12	17.41
0.41	0.00	-3.12	-17.41	1.57	3.22	17.70
2.00	-15.35	-15.35	-62.61	19.32	19.32	62.89
2.00	-10.23	-15.79	-184.95	10.29	15.87	185.86
2.50	-13.25	-19.98	-233.03	13.30	20.06	233.94

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Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
4.50	-20.22	-29.68	-344.37	20.28	29.75	345.29
4.50	-15.44	-28.85	-272.58	15.51	28.93	273.24
10.00	-38.26	-54.78	-494.96	38.32	54.86	495.62

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	-0.09	0.00	-0.00	-0.00
0.01	6.68	0.00	-0.09	-0.56	0.00	-0.00
0.50	6.68	6.68	-0.08	-0.73	0.45	-0.11
1.00	6.68	6.68	-0.07	0.63	0.48	-0.37
1.50	6.68	6.68	-0.06	2.00	-0.18	-0.47
2.00	28.89	0.00	-0.04	2.74	-1.53	-0.07
2.50	28.89	28.89	-0.03	-1.61	-0.79	0.55
3.00	28.89	28.89	-0.02	-0.95	-0.16	0.77
3.50	28.89	28.89	-0.01	-0.46	0.19	0.75
4.00	28.89	28.89	-0.00	-0.14	0.33	0.62
4.50	36.84	36.84	-0.00	0.04	0.35	0.44
5.00	36.84	36.84	0.00	0.08	0.30	0.28
5.50	36.84	36.84	0.00	0.17	0.22	0.15
6.00	36.84	36.84	0.00	0.08	0.14	0.06
6.50	36.84	36.84	0.00	0.08	0.08	0.00
7.00	36.84	36.84	-0.00	0.07	0.03	-0.02
7.50	36.84	36.84	-0.00	0.04	0.00	-0.03
8.00	36.84	36.84	-0.00	0.02	-0.01	-0.03
8.50	36.84	36.84	-0.00	0.00	-0.02	-0.02
9.00	36.84	36.84	-0.00	-0.01	-0.02	-0.01
9.50	36.84	36.84	-0.00	-0.02	-0.01	-0.00
10.00	36.84	36.84	-0.00	-0.02	0.00	0.00

Maximum values of internal forces acting on the structure

Maximum shear force = 1,56 kN/m
Maximum moment = 0,79 kNm/m
Maximum displacement = 0,1 mm

Terrain settlement behind the structure

Terrain settlement δ_{\max} = 0,0 mm

	Coordinates x [m]	Settlement z [mm]
1	0,00	0,0
2	0,75	0,0
3	1,49	0,1
4	2,24	0,1
5	2,99	0,0
6	3,73	0,0
7	4,48	0,0
8	5,23	0,0
9	5,97	0,0
10	6,72	0,0

	Coordinates x [m]	Settlement z [mm]
11	7,47	0,0
12	7,47	0,0

Dimensioning No. 1 (Stage of construction 1)

Failure by heave

Favourable weight of soil $\sigma_{\text{stb}} = 169,20 \text{ kPa}$

Unfavourable water pressure $u_{\text{dst}} = 0,00 \text{ kPa}$

Verification of failure by heave is **SATISFACTORY**

Verification of failure by piping


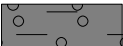

Critical hydraulic gradient $i_c = 0,67$

Hydraulic gradient $i = 0,00$

Verification of failure by piping is **SATISFACTORY**

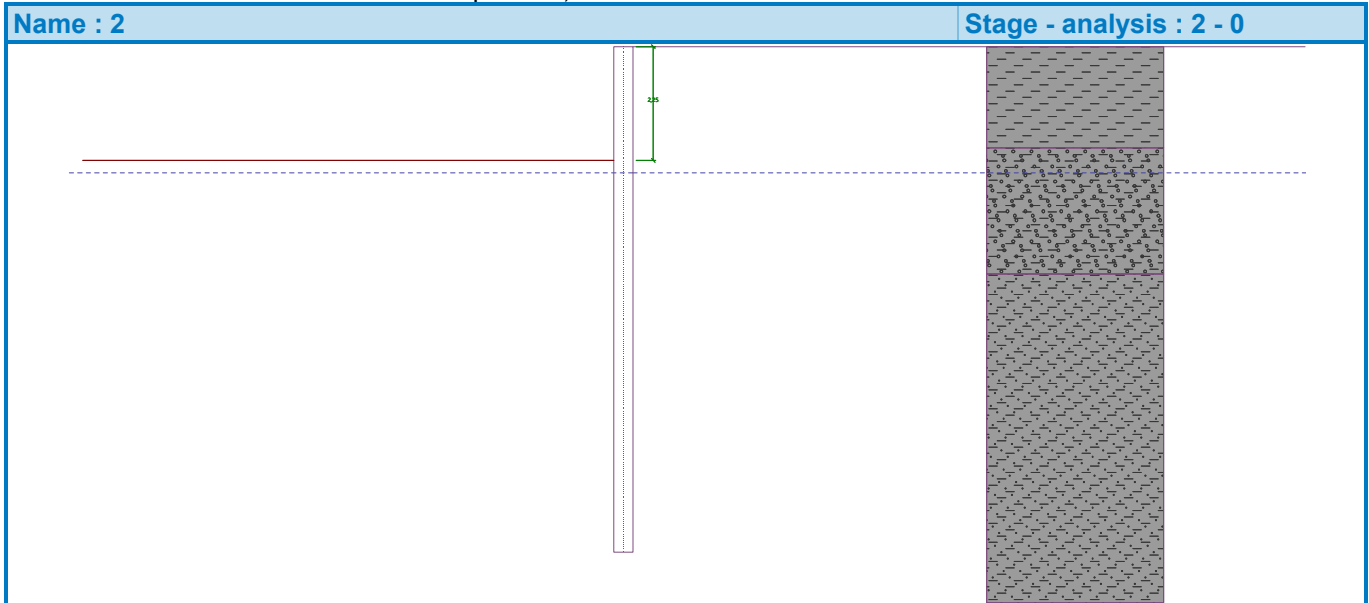
Input data (Stage of construction 2)

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	2,00	0,00 .. 2,00	Glina	
2	2,50	2,00 .. 4,50	Zameljen prod	
3	-	4,50 .. ∞	Siva zbita peščena	

Excavation

Soil in front of wall is excavated to a depth of 2,25 m.



Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 2,50 m

GWT in front of the structure lies at a depth of 2,50 m

Subgrade at the heel is permeable.

Hydraulic gradient = 0,00

Settings of the stage of construction

Design situation : permanent

Analysis results (Stage of construction 2)

Distribution of pressures acting on the structure (in front and behind the wall)

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	5.90
0.40	0.00	0.00	0.00	1.45	3.12	17.41
2.00	0.00	0.00	0.00	19.32	19.32	62.89
2.00	0.00	0.00	0.00	10.29	15.87	185.86
2.25	0.00	0.00	0.00	11.80	17.96	209.90
2.25	0.00	-0.00	-3.66	11.80	17.96	209.91
2.44	0.00	-1.57	-21.65	12.92	19.53	227.89
2.50	-0.38	-2.09	-27.70	13.30	20.06	233.94
4.50	-7.36	-11.79	-139.04	20.28	29.75	345.29
4.50	-0.14	-11.46	-123.46	15.51	28.93	273.24
10.00	-22.95	-37.39	-345.84	38.32	54.86	495.62

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	-4.80	0.00	-0.00	-0.00
0.50	0.00	0.00	-4.17	2.53	-0.49	0.08
1.00	0.00	0.00	-3.53	8.13	-3.15	0.87
1.50	0.00	0.00	-2.91	13.73	-8.61	3.69
2.00	0.00	0.00	-2.29	19.32	-16.88	9.95
2.25	0.00	0.00	-2.00	11.77	-20.04	14.52
2.25	0.00	0.00	-1.99	7.78	-20.12	14.68
2.50	0.00	0.00	-1.72	-14.39	-19.31	19.65
3.00	28.89	0.00	-1.22	-24.83	-7.10	26.45
3.50	28.89	0.00	-0.83	-14.10	2.50	27.38
4.00	28.89	0.00	-0.54	-6.44	7.51	24.72
4.50	36.84	0.00	-0.35	-4.32	9.55	20.38
5.00	36.84	36.84	-0.23	0.18	11.17	15.05
5.50	36.84	36.84	-0.18	4.16	9.93	9.69
6.00	36.84	36.84	-0.16	5.32	7.47	5.31
6.50	36.84	36.84	-0.17	4.91	4.87	2.24
7.00	36.84	36.84	-0.19	3.82	2.68	0.37
7.50	36.84	36.84	-0.20	2.59	1.08	-0.54
8.00	36.84	36.84	-0.22	1.51	0.06	-0.80
8.50	36.84	36.84	-0.23	0.64	-0.47	-0.68
9.00	36.84	36.84	-0.24	-0.04	-0.61	-0.40
9.50	36.84	36.84	-0.25	-0.62	-0.44	-0.12
10.00	36.84	36.84	-0.25	-1.15	-0.00	0.00

Maximum values of internal forces acting on the structure

Maximum shear force = 20,38 kN/m

Maximum moment = 27,57 kNm/m

Maximum displacement = 4,8 mm



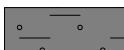
Terrain settlement behind the structure

Terrain settlement $\delta_{\max} = 1,6 \text{ mm}$

	Coordinates x [m]	Settlement z [mm]
1	0,00	2,5
2	0,75	2,9
3	1,49	3,1
4	2,24	3,1
5	2,99	3,1
6	3,73	2,9
7	4,48	2,6
8	5,23	2,1
9	5,97	1,5
10	6,72	0,8
11	7,47	0,0
12	7,47	0,0

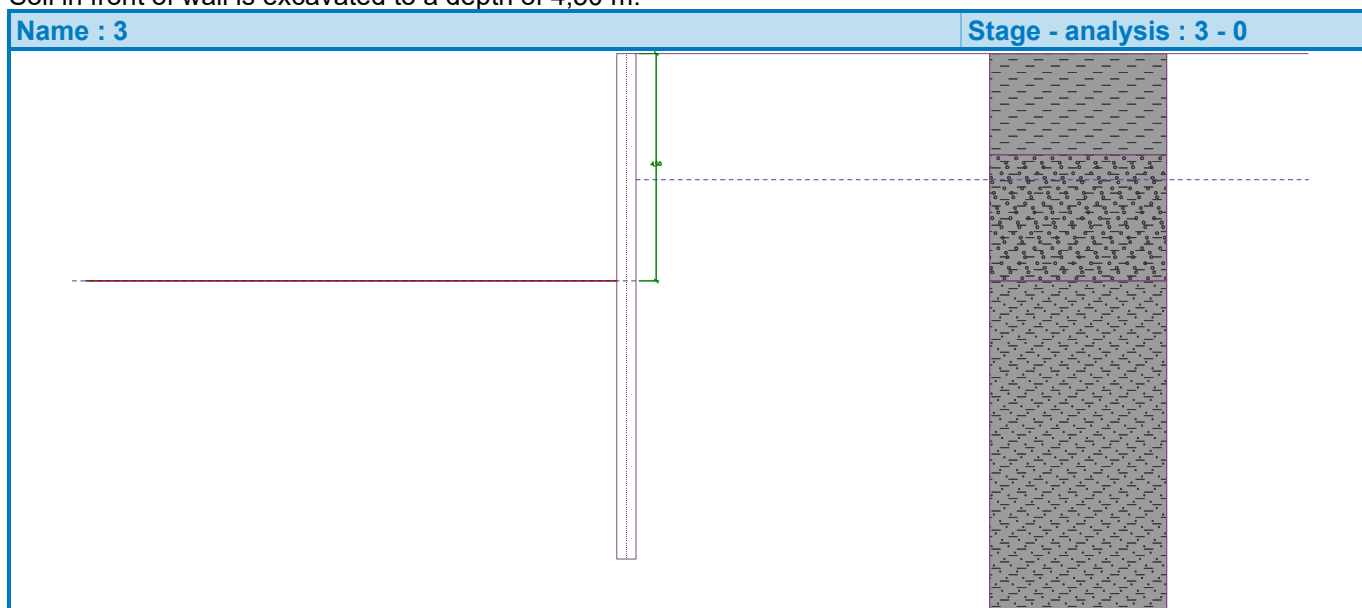
Input data (Stage of construction 3)

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	2,00	0,00 .. 2,00	Glina	
2	2,50	2,00 .. 4,50	Zameljen prod	
3	-	4,50 .. ∞	Siva zbita peščena	

Excavation

Soil in front of wall is excavated to a depth of 4,50 m.



Terrain profile

Terrain behind the structure is flat.

Water influence

GWT behind the structure lies at a depth of 2,50 m
GWT in front of the structure lies at a depth of 4,50 m
Subgrade at the heel is permeable.
Hydraulic gradient = 0,15

Settings of the stage of construction

Design situation : permanent

Analysis results (Stage of construction 3)

Distribution of pressures acting on the structure (in front and behind the wall)

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	5.90
0.40	0.00	0.00	0.00	1.45	3.12	17.41
2.00	0.00	0.00	0.00	19.32	19.32	62.89
2.00	0.00	0.00	0.00	10.29	15.87	185.86
2.50	0.00	0.00	0.00	13.30	20.06	233.94
4.50	0.00	0.00	0.00	48.26	51.11	375.14
4.50	0.00	-0.00	-25.14	43.67	50.25	298.84
7.29	0.00	-11.31	-122.13	43.16	55.09	420.14
10.00	-9.67	-22.30	-216.41	42.68	59.80	538.04

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	-3626.85	0.00	-0.00	-0.00
0.50	0.00	0.00	-3429.01	2.53	-0.49	0.08
1.00	0.00	0.00	-3231.17	8.13	-3.15	0.87
1.50	0.00	0.00	-3033.33	13.73	-8.61	3.69
2.00	0.00	0.00	-2835.52	19.32	-16.88	9.95
2.50	0.00	0.00	-2637.74	13.30	-23.23	20.01
3.00	0.00	0.00	-2440.04	22.04	-32.06	33.65
3.50	0.00	0.00	-2242.47	30.78	-45.27	52.80
4.00	0.00	0.00	-2045.12	39.52	-62.84	79.65
4.50	0.00	0.00	-1849.65	48.19	-84.59	116.03
4.50	0.00	0.00	-1846.50	18.39	-84.86	116.71
5.00	0.00	0.00	-1651.49	1.06	-89.68	160.35
5.50	0.00	0.00	-1455.54	-16.42	-85.84	204.60
6.00	0.00	0.00	-1260.38	-33.90	-73.26	244.74
6.50	0.00	0.00	-1066.18	-51.38	-51.94	276.40
7.00	0.00	0.00	-873.06	-68.86	-21.88	295.22
7.50	0.00	0.00	-681.09	-86.34	16.92	296.82
8.00	0.00	0.00	-490.28	-103.82	64.46	276.84
8.50	0.00	0.00	-300.54	-121.30	120.74	230.90
9.00	0.00	0.00	-111.69	-138.78	185.76	154.64
9.50	0.00	1.84	76.56	192.07	183.67	53.94
10.00	0.00	0.00	264.58	528.36	0.00	-0.00

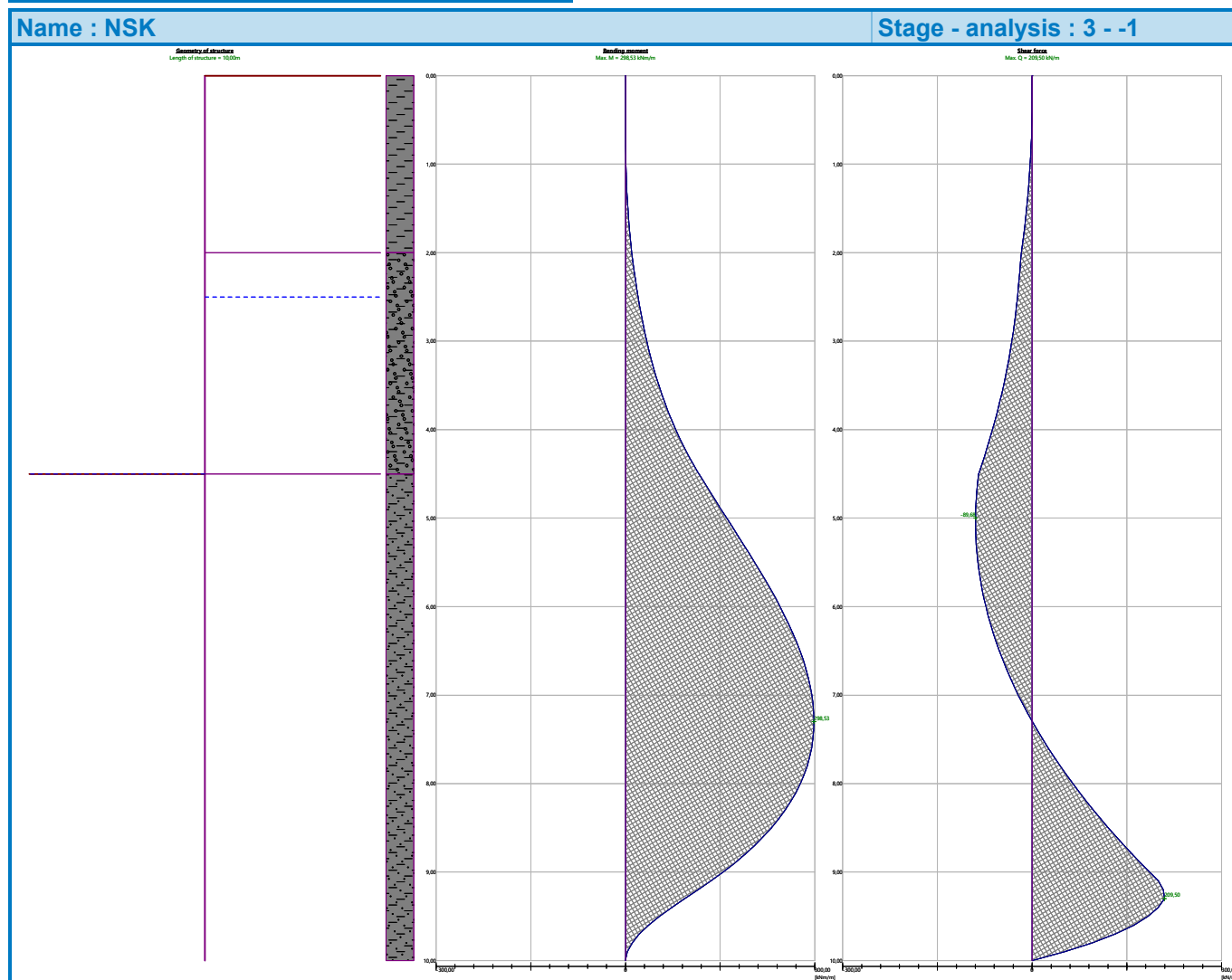
Maximum values of internal forces acting on the structure

Maximum shear force = 209,50 kN/m
Maximum moment = 298,53 kNm/m
Maximum displacement = 3626,8 mm

Terrain settlement behind the structure

Terrain settlement $\delta_{\max} = 3056,4 \text{ mm}$

	Coordinates x [m]	Settlement z [mm]
1	0,00	1681,1
2	0,75	2613,3
3	1,49	3301,0
4	2,24	3744,2
5	2,99	3942,8
6	3,73	3897,0
7	4,48	3606,6
8	5,23	3071,7
9	5,97	2292,3
10	6,72	1268,4
11	7,47	0,0
12	7,47	0,0



Dimensioning No. 1 (Stage of construction 3)

Failure by heave

Favourable weight of soil $\sigma_{\text{stb}} = 94,05 \text{ kPa}$

Unfavourable water pressure $u_{\text{dst}} = 27,00 \text{ kPa}$

Verification of failure by heave is **SATISFACTORY**

Verification of failure by piping

Critical hydraulic gradient $i_c = 0,73$

Hydraulic gradient $i = 0,15$

Verification of failure by piping is **SATISFACTORY**

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	-3626.85	-0.09	-0.00	-0.00	-0.00	-0.00
0.01	-3624.47	-0.09	-0.00	-0.00	0.00	0.00
0.01	-3621.31	-0.09	-0.00	0.00	-0.00	0.00
0.50	-3429.01	-0.08	-0.49	0.45	-0.11	0.08
1.00	-3231.17	-0.07	-3.15	0.48	-0.37	0.87
1.50	-3033.33	-0.06	-8.61	-0.18	-0.47	3.69
2.00	-2835.52	-0.04	-16.88	-1.53	-0.07	9.95
2.25	-2738.20	-0.04	-20.05	-1.25	0.29	14.54
2.25	-2735.04	-0.04	-20.14	-1.23	0.30	14.70
2.50	-2637.74	-0.03	-23.23	-0.79	0.55	20.01
3.00	-2440.04	-0.02	-32.06	-0.16	0.77	33.65
3.50	-2242.47	-0.01	-45.27	2.50	0.75	52.80
4.00	-2045.12	-0.00	-62.84	7.51	0.62	79.65
4.50	-1849.65	-0.00	-84.59	9.54	0.44	116.03
4.50	-1849.65	-0.00	-84.59	9.54	0.44	116.03
4.50	-1848.08	-0.00	-84.73	9.55	0.44	116.37
4.50	-1846.50	-0.00	-84.86	9.57	0.44	116.71
4.50	-1846.50	-0.00	-84.86	9.57	0.44	116.71
5.00	-1651.49	0.00	-89.68	11.17	0.28	160.35
5.50	-1455.54	0.00	-85.84	9.93	0.15	204.60
6.00	-1260.38	0.00	-73.26	7.47	0.06	244.74
6.50	-1066.18	0.00	-51.94	4.87	0.00	276.40
7.00	-873.06	-0.00	-21.88	2.68	-0.02	295.22
7.50	-681.09	-0.00	0.00	16.92	-0.54	296.82
8.00	-490.28	-0.00	-0.01	64.46	-0.80	276.84
8.50	-300.54	-0.00	-0.47	120.74	-0.68	230.90
9.00	-111.69	-0.00	-0.61	185.76	-0.40	154.64
9.50	-0.25	76.56	-0.44	183.67	-0.12	53.94
10.00	-0.25	264.58	-0.00	0.00	-0.00	0.00

Maximum values of internal forces

Maximum displacement = -3626,8 mm

Minimum displacement = 264,6 mm

Maximum bending moment = 298,53 kNm/m

Minimum bending moment = -0,80 kNm/m

Maximum shear force = 209,50 kN/m

Verification of steel section according to EN 1993-1-1

All construction stages are taken into the analysis.

Partial factor on load = 1,00

Internal forces per 1 m of wall

$M_{\max} = 298,53 \text{ kNm/m}; \quad Q = 0,35 \text{ kN/m}$

$Q_{\max} = 209,50 \text{ kN/m}; \quad M = 93,70 \text{ kNm/m}$

Verification of max. moment $M_{\max} + Q$:

Verification of bending:

$M_{\max}/M_{c,Rd} = 0,777 \leq 1 \quad \text{Is satisfactory}$

Verification of shear:

$Q/V_{c,Rd} = 0,000 \leq 1 \quad \text{Is satisfactory}$

Verification of plane state of stress:

Normal stress $\sigma_{x,Ed} = 176,76 \text{ MPa}$

Shear stress $\tau_{Ed} = 0,05 \text{ MPa}$

Verification: $(\sigma_{x,Ed}/(f_y/\gamma_{M0}))^2 + 3*(\tau_{Ed}/(f_y/\gamma_{M0}))^2 = 0,542 \leq 1 \quad \text{Is satisfactory}$

Verification of max. shear force $Q_{\max} + M$:

Verification of bending:

$M/M_{c,Rd} = 0,244 \leq 1 \quad \text{Is satisfactory}$

Verification of shear:

$Q_{\max}/V_{c,Rd} = 0,282 \leq 1 \quad \text{Is satisfactory}$

Verification of plane state of stress:

Normal stress $\sigma_{x,Ed} = 55,48 \text{ MPa}$

Shear stress $\tau_{Ed} = 27,29 \text{ MPa}$

Verification: $(\sigma_{x,Ed}/(f_y/\gamma_{M0}))^2 + 3*(\tau_{Ed}/(f_y/\gamma_{M0}))^2 = 0,092 \leq 1 \quad \text{Is satisfactory}$

Cross section is SATISFACTORY