

## 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 = 6,00 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  $f_y = 240,00 \text{ MPa}$


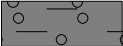

Elasticity modulus  $E = 210000,00 \text{ MPa}$

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


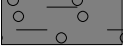
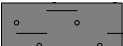
## Modulus of reaction

Modulus of subsoil reaction is computed by method Schmitt.


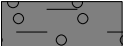

## Basic soil parameters

No.	Name	Pattern	$\Phi_{ef}$ [°]	$c_{ef}$ [kPa]	$\gamma$ [kN/m <sup>3</sup> ]	$\gamma_{su}$ [kN/m <sup>3</sup> ]	$\delta$ [°]
1	Glina		16,20	2,80	18,00	10,00	11,00
2	Zameljen prod		34,00	1,00	19,00	11,00	23,50
3	Siva zbita peščena		30,00	8,00	19,00	11,00	21,00

## Soil parameters to compute pressure at rest

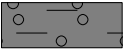

No.	Name	Pattern	Type calculation	$\Phi_{ef}$ [°]	$\nu$ [-]	OCR [-]	$K_r$ [-]
1	Glina		cohesive	-	0,30	-	-
2	Zameljen prod		cohesionless	34,00	-	-	-
3	Siva zbita peščena		cohesive	-	0,30	-	-

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

No.	Name	Pattern	$\nu$ [-]	$E_{oed}$ [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

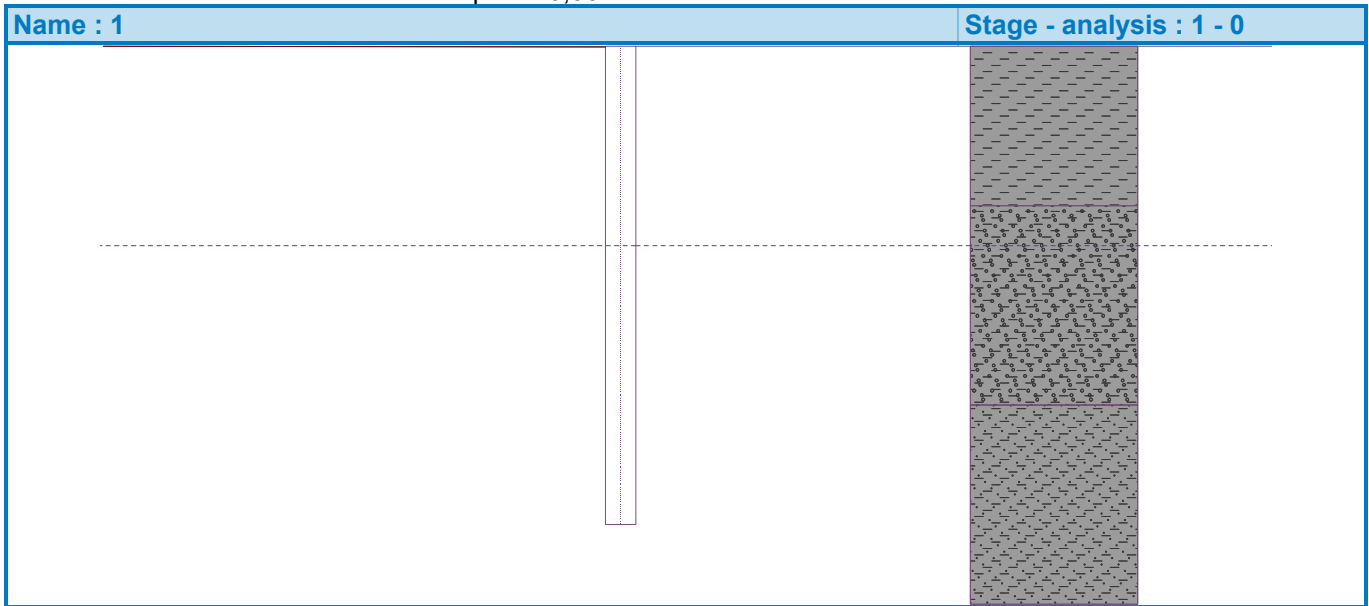
## Geological profile and assigned soils

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	-10.16	-15.79	-188.73	10.22	15.87	189.66
2.50	-13.15	-19.98	-237.81	13.20	20.06	238.74

--

Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
4.50	-20.07	-29.68	-351.46	20.13	29.75	352.39
4.50	-15.36	-28.85	-277.17	15.42	28.93	277.84
6.00	-21.53	-35.92	-338.90	21.60	36.00	339.58

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

Depth [m]	kh,p [MN/m <sup>3</sup> ]	kh,z [MN/m <sup>3</sup> ]	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	-0.55	0.00	-0.00
0.30	6.68	6.68	-0.08	-0.99	0.26	-0.04
0.60	6.68	6.68	-0.07	-0.43	0.50	-0.15
0.90	6.68	6.68	-0.07	0.38	0.51	-0.31
1.20	6.68	6.68	-0.06	1.20	0.27	-0.43
1.50	6.68	6.68	-0.05	2.03	-0.21	-0.45
1.80	6.68	0.00	-0.05	2.96	-0.95	-0.28
2.10	28.89	28.89	-0.04	-2.16	-1.45	0.13
2.40	28.89	28.89	-0.03	-1.70	-0.87	0.47
2.70	28.89	28.89	-0.02	-1.28	-0.43	0.67
3.00	28.89	28.89	-0.02	-0.92	-0.10	0.74
3.30	28.89	28.89	-0.01	-0.62	0.13	0.74
3.60	28.89	28.89	-0.01	-0.37	0.28	0.67
3.90	28.89	28.89	-0.00	-0.18	0.36	0.58
4.20	28.89	28.89	-0.00	-0.04	0.39	0.46
4.50	36.84	36.84	-0.00	0.07	0.38	0.35
4.80	36.84	36.84	0.00	0.16	0.35	0.24
5.10	36.84	36.84	0.00	0.24	0.29	0.14
5.40	36.84	36.84	0.00	0.30	0.21	0.07
5.70	36.84	36.84	0.00	0.35	0.11	0.02
6.00	36.84	36.84	0.00	0.40	-0.00	0.00

**Maximum values of internal forces acting on the structure**

Maximum shear force = 1,58 kN/m  
Maximum moment = 0,75 kNm/m  
Maximum displacement = 0,1 mm

**Terrain settlement behind the structure**

Terrain settlement  $\delta_{\max}$  = 0,0 mm

	Coordinates x [m]	Settlement z [mm]
1	0,00	0,0
2	0,53	0,1
3	1,05	0,1
4	1,58	0,1
5	2,10	0,1
6	2,63	0,1
7	3,16	0,1
8	3,68	0,0
9	4,21	0,0
10	4,74	0,0

	Coordinates x [m]	Settlement z [mm]
11	5,26	0,0
12	5,26	0,0

Dimensioning No. 1 (Stage of construction 1)

Failure by heave

Favourable weight of soil  $\sigma_{\text{stb}} = 100,80 \text{ kPa}$   
Unfavourable water pressure  $u_{\text{dst}} = 0,00 \text{ kPa}$

Verification of failure by heave is **SATISFACTORY**


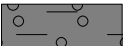

Verification of failure by piping

Critical hydraulic gradient  $i_c = 0,67$   
Hydraulic gradient  $i = 0,00$

Verification of failure by piping is **SATISFACTORY**

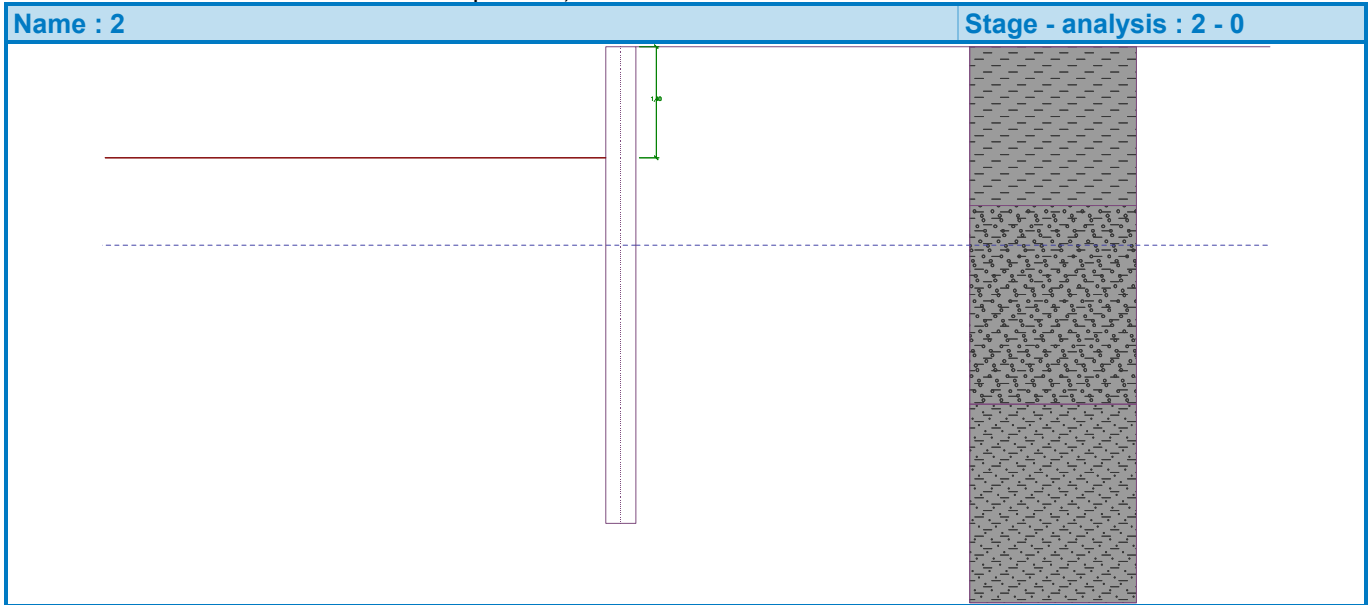
Input data (Stage of construction 2)

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 1,40 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
1.40	0.00	0.00	0.00	12.06	12.06	45.79
1.40	0.00	-0.00	-5.90	12.06	12.06	45.80
1.80	0.00	-3.12	-17.41	16.95	16.95	57.30
2.00	-2.37	-4.63	-23.00	19.32	19.32	62.89
2.00	-2.29	-4.76	-59.47	10.22	15.87	189.66
2.50	-5.27	-8.95	-108.55	13.20	20.06	238.74
4.50	-12.20	-18.65	-222.21	20.13	29.75	352.39
4.50	-6.00	-18.13	-183.55	15.42	28.93	277.84
6.00	-12.17	-25.20	-245.29	21.60	36.00	339.58

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

Depth [m]	kh,p [MN/m <sup>3</sup> ]	kh,z [MN/m <sup>3</sup> ]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-1.88	0.00	-0.00	-0.00
0.30	0.00	0.00	-1.72	1.08	-0.16	0.02
0.60	0.00	0.00	-1.55	3.54	-0.79	0.14
0.90	0.00	0.00	-1.39	6.74	-2.33	0.58
1.20	0.00	0.00	-1.23	9.93	-4.83	1.63
1.38	0.00	0.00	-1.13	11.85	-6.79	2.67
1.40	0.00	0.00	-1.12	6.09	-7.05	2.84
1.50	6.68	0.00	-1.07	5.38	-7.58	3.54
1.80	6.68	0.00	-0.91	7.74	-9.55	6.09
2.10	28.89	0.00	-0.76	-16.86	-9.78	9.22
2.40	28.89	0.00	-0.63	-13.72	-5.20	11.44
2.70	28.89	0.00	-0.51	-10.84	-1.52	12.43
3.00	28.89	0.00	-0.41	-8.37	1.35	12.43
3.30	28.89	0.00	-0.33	-6.40	3.55	11.68
3.60	28.89	28.89	-0.26	-4.15	5.20	10.35
3.90	28.89	28.89	-0.21	-1.16	5.98	8.65
4.20	28.89	28.89	-0.17	1.13	5.97	6.84
4.50	36.84	36.84	-0.14	0.58	5.43	5.13
4.80	36.84	36.84	-0.12	1.94	5.07	3.54
5.10	36.84	36.84	-0.10	3.23	4.29	2.13
5.40	36.84	36.84	-0.09	4.30	3.16	1.00
5.70	36.84	36.84	-0.08	5.27	1.72	0.27
6.00	36.84	36.84	-0.06	6.20	-0.00	-0.00

#### Maximum values of internal forces acting on the structure

Maximum shear force = 11,07 kN/m

Maximum moment = 12,54 kNm/m

Maximum displacement = 1,9 mm


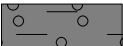
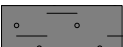
Terrain settlement behind the structure

Terrain settlement  $\delta_{\max} = 0,9 \text{ mm}$

	Coordinates x [m]	Settlement z [mm]
1	0,00	1,0
2	0,53	1,2
3	1,05	1,3
4	1,58	1,4
5	2,10	1,4
6	2,63	1,3
7	3,16	1,2
8	3,68	1,0
9	4,21	0,7
10	4,74	0,4
11	5,26	0,0
12	5,26	0,0

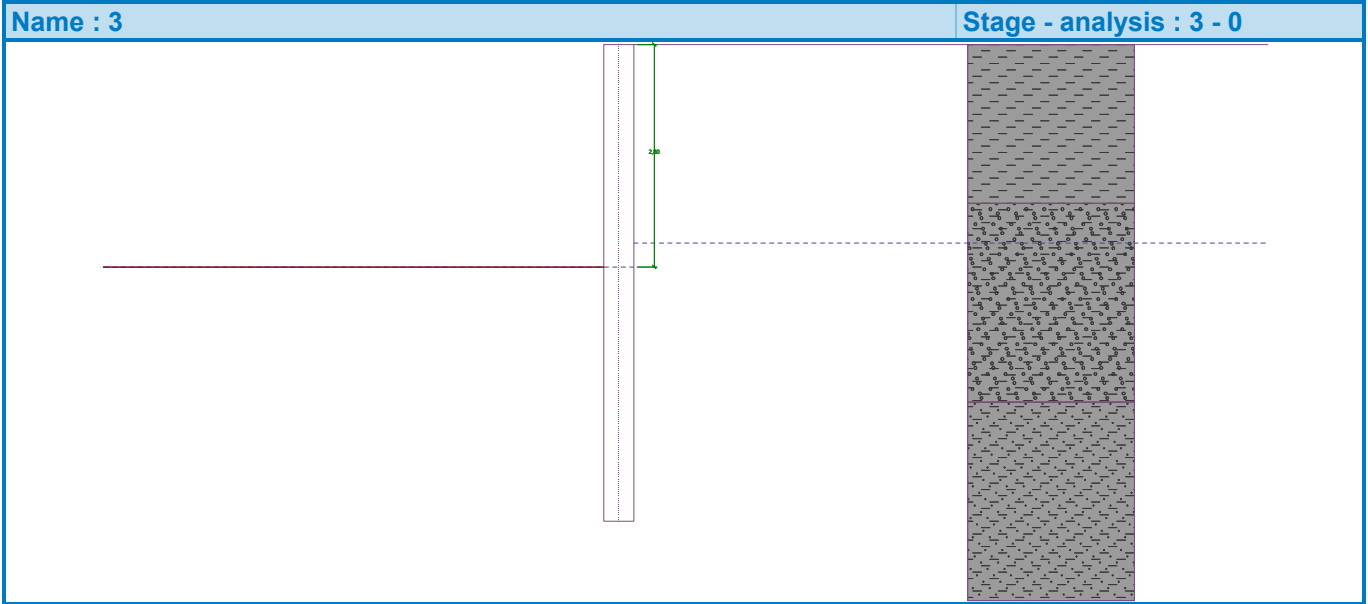
Input data (Stage of construction 3)

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 2,80 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 2,80 m  
Subgrade at the heel is permeable.  
Hydraulic gradient = 0,04

## 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	10.22	15.87	189.66
2.50	0.00	0.00	0.00	13.20	20.06	238.74
2.80	0.00	0.00	0.00	18.34	24.57	258.62
2.80	0.00	-0.00	-3.68	18.34	24.57	258.63
3.14	0.00	-1.56	-21.96	19.12	25.95	278.23
4.50	-4.53	-7.91	-96.35	22.31	31.56	358.02
4.50	0.00	-7.69	-92.40	17.66	30.72	282.19
5.29	0.00	-11.26	-123.56	20.04	33.85	315.48
6.00	-2.81	-14.47	-151.62	22.18	36.67	345.44

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

Depth [m]	kh,p [MN/m <sup>3</sup> ]	kh,z [MN/m <sup>3</sup> ]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
0.00	0.00	0.00	-22.36	0.00	0.00	0.00
0.30	0.00	0.00	-20.92	1.08	-0.16	0.02
0.60	0.00	0.00	-19.48	3.65	-0.80	0.14
0.90	0.00	0.00	-18.05	7.01	-2.40	0.59
1.20	0.00	0.00	-16.61	10.37	-5.00	1.68
1.50	0.00	0.00	-15.17	13.73	-8.62	3.70
1.80	0.00	0.00	-13.74	17.09	-13.24	6.95
2.10	0.00	0.00	-12.32	10.81	-18.02	11.70
2.40	0.00	0.00	-10.91	12.61	-21.53	17.62
2.70	0.00	0.00	-9.53	16.63	-25.81	24.69
2.80	0.00	0.00	-9.10	18.27	-27.48	27.24
2.80	0.00	0.00	-9.10	18.27	-27.48	27.24
2.82	0.00	0.00	-8.99	13.61	-27.84	27.91
3.00	0.00	0.00	-8.19	4.22	-29.44	33.09
3.30	0.00	0.00	-6.89	-11.43	-28.36	41.88
3.60	0.00	0.00	-5.65	-27.09	-22.59	49.64
3.90	0.00	0.00	-4.48	-42.74	-12.11	54.96
4.20	0.00	0.00	-3.39	-58.39	3.06	56.44
4.50	36.84	0.00	-2.38	-73.25	22.21	52.66
4.80	36.84	0.00	-1.44	-43.51	40.19	43.06
5.10	36.84	0.00	-0.56	-11.57	48.41	29.53
5.40	36.84	36.84	0.28	43.00	44.53	15.14
5.70	0.00	36.84	1.09	74.16	26.72	4.23



Depth [m]	kh,p [MN/m <sup>3</sup> ]	kh,z [MN/m <sup>3</sup> ]	Displacement [mm]	Pressure [kPa]	Shear Force [kN/m]	Moment [kNm/m]
6.00	0.00	36.84	1.90	103.98	-0.00	0.00

Maximum values of internal forces acting on the structure

Maximum shear force = 48,98 kN/m  
Maximum moment = 56,52 kNm/m  
Maximum displacement = 22,4 mm

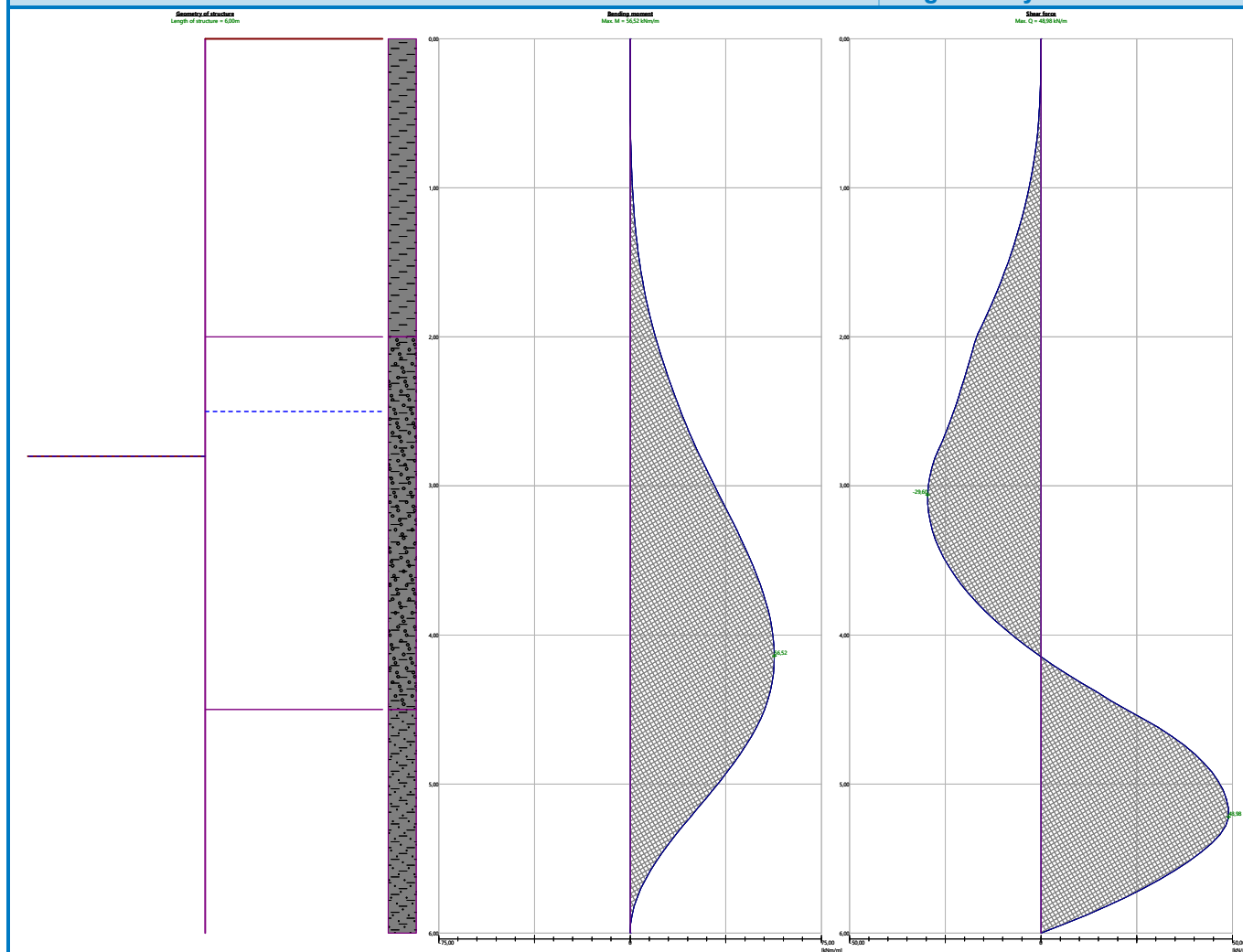
Terrain settlement behind the structure

Terrain settlement  $\delta_{max}$  = 13,2 mm

	Coordinates x [m]	Settlement z [mm]
1	0,00	10,2
2	0,53	14,0
3	1,05	16,6
4	1,58	18,3
5	2,10	18,8
6	2,63	18,3
7	3,16	16,8
8	3,68	14,2
9	4,21	10,5
10	4,74	5,8
11	5,26	0,0
12	5,26	0,0

Name : NSK

Stage - analysis : 3 - -1



### Dimensioning No. 1 (Stage of construction 3)

#### Failure by heave

Favourable weight of soil  $\sigma_{stb} = 54,72$  kPa

Unfavourable water pressure  $u_{dst} = 4,05$  kPa

Verification of failure by heave is **SATISFACTORY**

#### Verification of failure by piping

Critical hydraulic gradient  $i_c = 0,73$

Hydraulic gradient  $i = 0,04$

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	-22.36	-0.09	-0.00	0.00	-0.00	0.00
0.01	-22.34	-0.09	-0.00	-0.00	0.00	0.00
0.01	-22.30	-0.09	-0.00	0.00	-0.00	0.00
0.30	-20.92	-0.08	-0.16	0.26	-0.04	0.02
0.60	-19.48	-0.07	-0.80	0.50	-0.15	0.14

	Disp. min [mm]	Disp. max [mm]	Shear force min. [kN/m]	Shear force max [kN/m]	Moment min. [kNm/m]	Moment max. [kNm/m]
0.90	-18.05	-0.07	-2.40	0.51	-0.31	0.59
1.20	-16.61	-0.06	-5.00	0.27	-0.43	1.68
1.38	-15.74	-0.06	-7.05	0.01	-0.46	2.76
1.40	-15.67	-0.06	-7.25	-0.02	-0.46	2.88
1.40	-15.63	-0.06	-7.35	-0.03	-0.46	2.94
1.50	-15.17	-0.05	-8.62	-0.21	-0.45	3.70
1.80	-13.74	-0.05	-13.24	-0.95	-0.28	6.95
2.10	-12.32	-0.04	-18.02	-1.45	0.13	11.70
2.40	-10.91	-0.03	-21.53	-0.87	0.47	17.62
2.70	-9.53	-0.02	-25.81	-0.43	0.67	24.69
2.80	-9.10	-0.02	-27.48	-0.31	0.70	27.24
2.80	-9.10	-0.02	-27.48	-0.31	0.70	27.24
2.80	-9.06	-0.02	-27.62	-0.30	0.70	27.46
2.82	-8.99	-0.02	-27.84	-0.28	0.71	27.91
3.00	-8.19	-0.02	-29.44	1.35	0.74	33.09
3.30	-6.89	-0.01	-28.36	3.55	0.74	41.88
3.60	-5.65	-0.01	-22.59	5.20	0.67	49.64
3.90	-4.48	-0.00	-12.11	5.98	0.58	54.96
4.20	-3.39	-0.00	0.39	5.97	0.46	56.44
4.50	-2.38	-0.00	0.38	22.21	0.35	52.66
4.80	-1.44	0.00	0.35	40.19	0.24	43.06
5.10	-0.56	0.00	0.29	48.41	0.14	29.53
5.40	-0.09	0.28	0.21	44.53	0.07	15.14
5.70	-0.08	1.09	0.11	26.72	0.02	4.23
6.00	-0.06	1.90	-0.00	-0.00	-0.00	0.00

#### Maximum values of internal forces

Maximum displacement = -22,4 mm  
 Minimum displacement = 1,9 mm  
 Maximum bending moment = 56,52 kNm/m  
 Minimum bending moment = -0,46 kNm/m  
 Maximum shear force = 48,98 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

$M_{\max} = 56,52 \text{ kNm/m}; \quad Q = 0,35 \text{ kN/m}$   
 $Q_{\max} = 48,98 \text{ kN/m}; \quad M = 23,66 \text{ kNm/m}$

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

##### Verification of bending:

$M_{\max}/M_{c,Rd} = 0,147 \leq 1$  **Is satisfactory**

##### Verification of shear:

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

##### Verification of plane state of stress:

Normal stress  $\sigma_{x,Ed} = 33,46 \text{ MPa}$

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

Verification:  $(\sigma_{x,Ed}/(f_y/Y_{M0}))^2 + 3*(\tau_{Ed}/(f_y/Y_{M0}))^2 = 0,019 \leq 1$  **Is satisfactory**

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

**Verification of bending:**

$$M/M_{c,Rd} = 0,062 \leq 1 \quad \text{Is satisfactory}$$

**Verification of shear:**

$$Q_{max}/V_{c,Rd} = 0,066 \leq 1 \quad \text{Is satisfactory}$$

**Verification of plane state of stress:**

$$\text{Normal stress } \sigma_{x,Ed} = 14,01 \text{ MPa}$$

$$\text{Shear stress } \tau_{Ed} = 6,38 \text{ MPa}$$

$$\text{Verification: } (\sigma_{x,Ed}/(f_y/\gamma_{M0}))^2 + 3*(\tau_{Ed}/(f_y/\gamma_{M0}))^2 = 0,006 \leq 1 \quad \text{Is satisfactory}$$

**Cross section is SATISFACTORY**