Analysis of anti-slide pile

Input data

Project

Task : Sanacija plazu pri hiši Straža 6
Description : Zagatna stena zgoraj
Customer : Občina Oplotnica
Author : GEOING d.o.o.
Date : 30/05/2025

Settings

Slovenia - EN 1997

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 = 5,00 m

Cross-section name : I-section : I(IPN) 200; a = 1,00 m
Computed coefficient of pressure reduction below the ditch = 0,64

Area of cross-section	A	=	3,34E-03	m^2/m
Moment of inertia	I	=	2,14E-05	m^4/m
Elastic modulus	E	=	210000,00	MPa
Shear modulus	G	=	81000,00	MPa
Sectional modulus	W	=	2,132E-04	m^3/m
Plastic sectional modulus	W_{pl}	=	2,481E-04	m^3/m

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Forces above the slip surface

Depth of slip surface h_{s1} = 2,50 m

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

Active horizontal force T = 0,00 kN/m
Passive horizontal force P = 0,00 kN/m

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

Material of structure

Structural steel: EN 10025 : Fe 360

Yield strength	f_y =	235,00 MPa
Elasticity modulus	E =	210000,00 MPa
Shear modulus	G =	81000,00 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		22,00	5,00	19,00	9,00	22,00
2	Preperina		30,00	10,00	21,00	11,00	30,00
3	Hribina		34,00	40,00	23,00	13,00	34,00

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	-	0,25	-	-
3	Hribina		cohesive	-	0,20	-	-

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

No.	Name	Pattern	ν [–]	E_{oed} [MPa]	E_{def} [MPa]
1	Glina		0,40	4,00	-
2	Preperina		0,25	20,00	-
3	Hribina		0,20	50,00	-

Soil parameters

Glina

Unit weight : γ = 19,00 kN/m^3

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Stress-state :	effective		
Angle of internal friction :	φ_{ef}	=	22,00 °
Cohesion of soil :	c_{ef}	=	5,00 kPa
Angle of friction struc.-soil :	δ	=	22,00 °
Soil :	cohesive		
Poisson's ratio :	ν	=	0,40
Oedometric modulus :	E_{oed}	=	4,00 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	=	0,25
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}	=	40,00 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

Pile fixed into the rock

Length of wall in the rock l = 1,00 m
Bearing capacity of rock R = 3000,00 kPa

Geological profile and assigned soils

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	4,50	0,00 .. 4,50	Glina	
2	0,50	4,50 .. 5,00	Preperina	
3	-	5,00 .. ∞	Hribina	

Excavation

Soil in front of wall is excavated to a depth of 2,00 m.

Terrain profile

Terrain behind construction has the slope 1: 1,96 (slope angle is 27,00 °).

Water influence

Ground water table is located below the structure.

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Input surface surcharges

No.	Surcharge new	Surcharge change	Action	Mag.1 [kN/m^2]	Mag.2 [kN/m^2]	Ord.x x [m]	Length l [m]	Depth z [m]
1	Yes		permanent	11,00		0,50	4,00	on terrain

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
2,00	0,00	0,00
2,00	0,00	0,00
2,50	0,00	0,00

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
0.00	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
0.22	0.00	0.00	0.00	0.00	0.00	0.00
0.28	0.00	0.00	0.00	0.00	0.00	0.00
0.43	0.00	0.00	0.00	0.00	0.00	0.00
0.65	0.00	0.00	0.00	0.00	0.00	0.00
0.87	0.00	0.00	0.00	0.00	0.00	0.00
1.09	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
1.52	0.00	0.00	0.00	0.00	0.00	0.00
1.74	0.00	0.00	0.00	0.00	0.00	0.00
1.96	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00
2.00	0.00	0.00	0.00	0.00	0.00	0.00
2.17	0.00	0.00	0.00	0.00	0.00	0.00
2.39	0.00	0.00	0.00	0.00	0.00	0.00
2.50	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]
2.50	0.00	-4.02	-21.97	42.95	42.95	105.80
2.61	0.00	-3.73	-25.02	39.84	41.67	110.00
2.73	0.00	-3.41	-28.35	36.45	43.33	114.56

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Depth [m]	Ta,p [kPa]	Tk,p [kPa]	Tp,p [kPa]	Ta,z [kPa]	Tk,z [kPa]	Tp,z [kPa]
2.83	0.00	-3.15	-31.14	33.61	44.73	118.40
3.04	0.00	-2.57	-37.26	27.39	47.81	126.79
3.26	0.00	-1.98	-43.38	21.16	50.91	135.19
3.48	0.00	-1.40	-49.49	14.94	54.02	143.58
3.70	0.00	-0.82	-55.61	8.71	57.15	151.98
3.91	0.00	-0.23	-61.73	2.49	60.29	160.38
4.00	0.00	0.00	-64.18	0.00	0.00	163.73
4.00	Rock	Rock	Rock	Rock	Rock	Rock
4.13	Rock	Rock	Rock	Rock	Rock	Rock
4.35	Rock	Rock	Rock	Rock	Rock	Rock
4.50	Rock	Rock	Rock	Rock	Rock	Rock
4.50	Rock	Rock	Rock	Rock	Rock	Rock
4.57	Rock	Rock	Rock	Rock	Rock	Rock
4.65	Rock	Rock	Rock	Rock	Rock	Rock
4.78	Rock	Rock	Rock	Rock	Rock	Rock
5.00	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	-21.84	0.00	-0.00	-0.00
0.25	0.00	0.00	-20.64	0.00	0.00	-0.00
0.50	0.00	0.00	-19.45	0.00	0.00	-0.00
0.75	0.00	0.00	-18.25	0.00	0.00	-0.00
1.00	0.00	0.00	-17.06	0.00	0.00	-0.00
1.25	0.00	0.00	-15.86	0.00	0.00	-0.00
1.50	0.00	0.00	-14.67	0.00	0.00	-0.00
1.75	0.00	0.00	-13.47	0.00	0.00	-0.00
2.00	0.00	0.00	-12.30	0.00	0.00	-0.00
2.00	0.00	0.00	-12.26	0.00	-0.00	-0.00
2.25	0.00	0.00	-11.09	0.00	-0.00	0.00
2.50	0.00	0.00	-9.91	0.00	-0.00	0.00
2.50	0.00	0.00	-9.87	20.76	-0.08	0.00
2.75	0.00	0.00	-8.70	6.79	-3.47	0.51
3.00	0.00	0.00	-7.51	-7.40	-3.40	1.44
3.25	5.13	0.00	-6.34	-13.09	-0.42	1.93
3.50	5.13	5.13	-5.20	-0.41	1.60	1.70
3.75	5.13	5.13	-4.09	15.32	-0.27	1.45
4.00	5.13	0.00	-2.99	-15.35	-3.59	2.08
4.25	5.13	0.00	-1.92	-9.87	-0.44	2.56
4.50	43.87	0.00	-0.89	-39.14	2.32	2.39
4.75	0.00	43.87	0.11	4.75	6.60	1.05
5.00	0.00	43.87	1.09	47.99	0.00	-0.00

Maximum shear force = 6,62 kN/m
Maximum moment = 2,57 kNm/m
Maximum displacement = 21,8 mm
Displacement in the depth of slip surface = 9,9 mm

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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	=	533,20	kPa
Design bearing capacity of rock	R_d	=	2142,86	kPa

Bearing capacity of rock is SATISFACTORY

Terrain settlement behind the structure

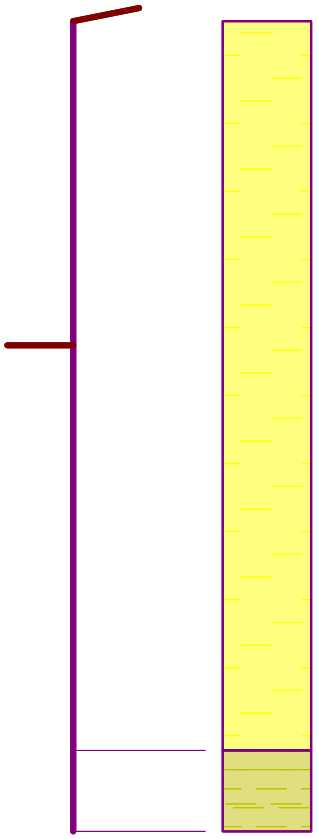
Terrain settlement δ_{max} = 13,8 mm

	Coordinate x [m]	Settlement z [mm]
1	0,00	10,4
2	0,47	14,3
3	0,95	17,1
4	1,42	18,8
5	1,90	19,5
6	2,37	19,0
7	2,85	17,4
8	3,32	14,7
9	3,80	10,9
10	4,27	6,0
11	4,74	0,0
12	4,74	0,0

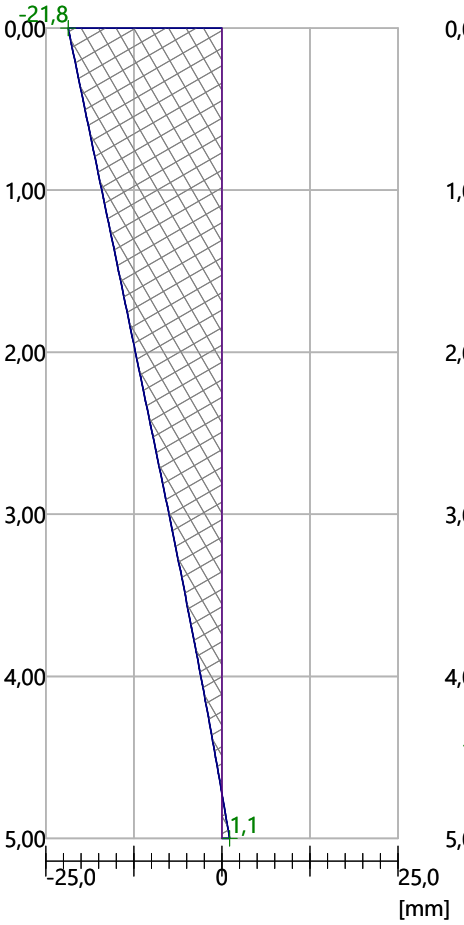
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Name : Analysis	Stage - analysis : 1 - -1

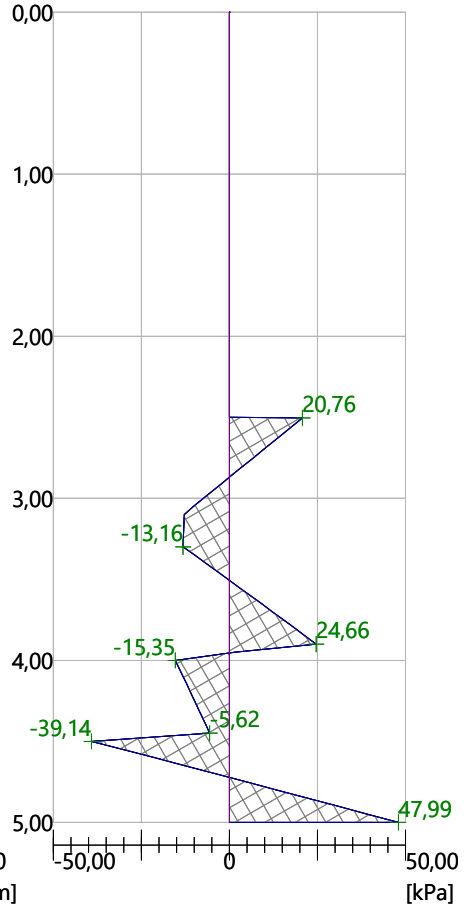
Geometry of structure
Length of structure = 5,00m



Displacement of structure
Max. disp. = 21,8 mm



Pressure acting on structure
Max. pressure = 47,99 kPa



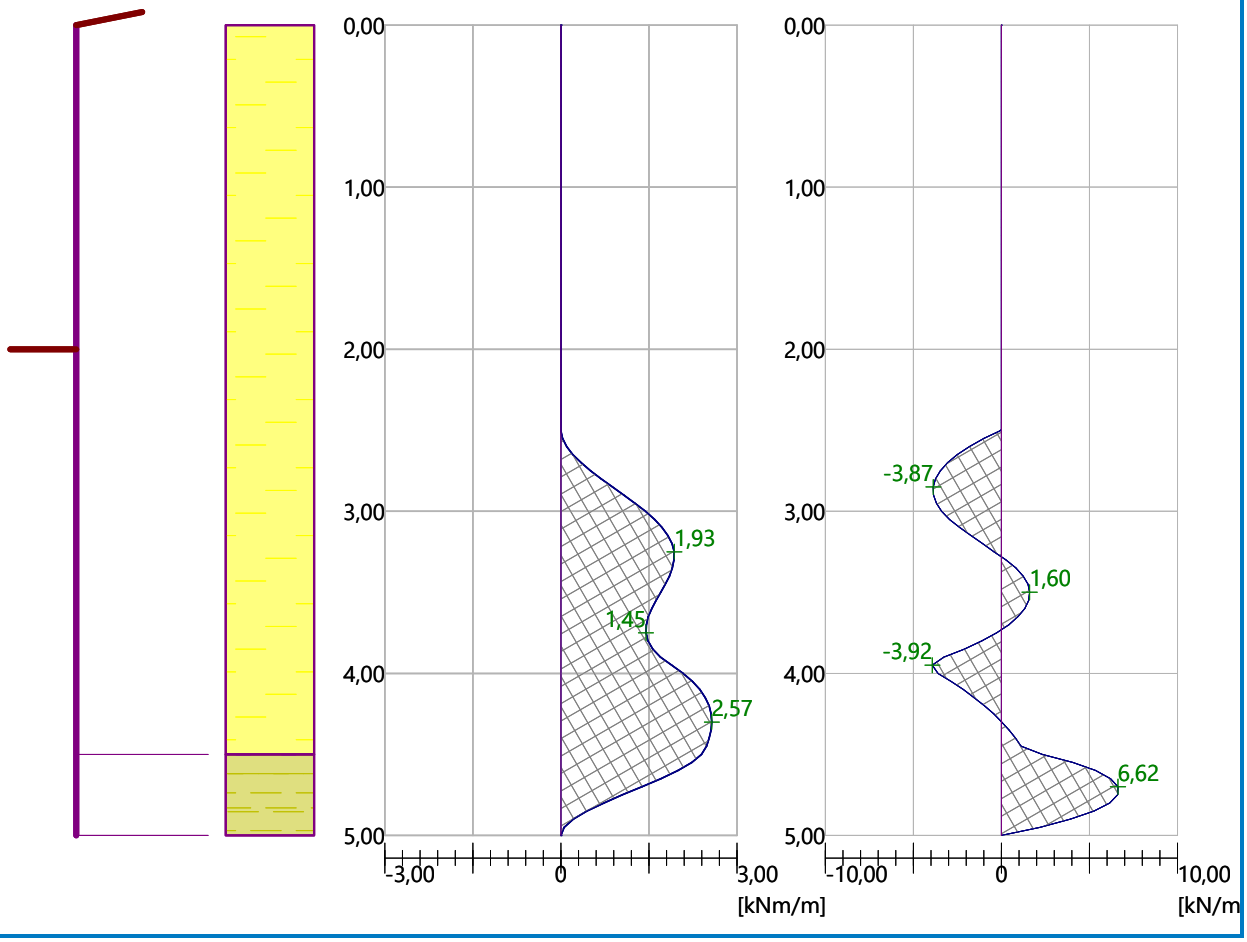
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Name : Analysis	Stage - analysis : 1 - -1

Geometry of structure
Length of structure = 5,00m

Bending moment
Max. M = 2,57 kNm/m

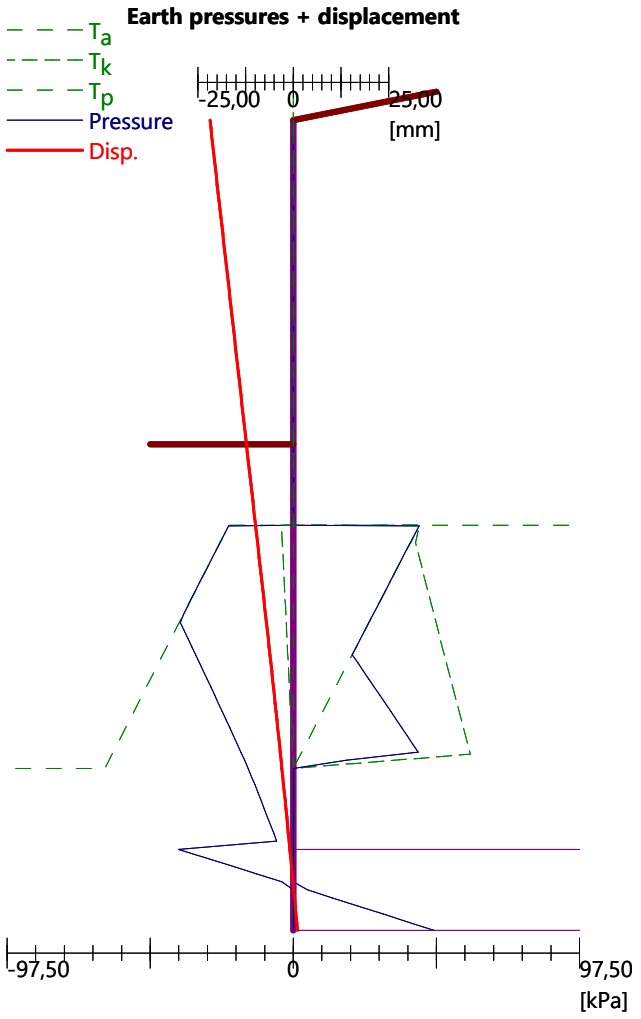
Shear force
Max. Q = 6,62 kN/m



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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	-21.84	-21.84	-0.00	-0.00	-0.00	-0.00
0.25	-20.64	-20.64	0.00	0.00	-0.00	-0.00
0.50	-19.45	-19.45	0.00	0.00	-0.00	-0.00
0.75	-18.25	-18.25	0.00	0.00	-0.00	-0.00
1.00	-17.06	-17.06	0.00	0.00	-0.00	-0.00
1.25	-15.86	-15.86	0.00	0.00	-0.00	-0.00
1.50	-14.67	-14.67	0.00	0.00	-0.00	-0.00
1.75	-13.47	-13.47	0.00	0.00	-0.00	-0.00
2.00	-12.30	-12.30	0.00	0.00	-0.00	-0.00
2.00	-12.26	-12.26	-0.00	-0.00	-0.00	-0.00
2.25	-11.09	-11.09	-0.00	-0.00	0.00	0.00
2.50	-9.91	-9.91	-0.00	-0.00	0.00	0.00
2.50	-9.87	-9.87	-0.08	-0.08	0.00	0.00
2.75	-8.70	-8.70	-3.47	-3.47	0.51	0.51
3.00	-7.51	-7.51	-3.40	-3.40	1.44	1.44
3.25	-6.34	-6.34	-0.42	-0.42	1.93	1.93

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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]
3.50	-5.20	-5.20	1.60	1.60	1.70	1.70
3.75	-4.09	-4.09	-0.27	-0.27	1.45	1.45
4.00	-2.99	-2.99	-3.59	-3.59	2.08	2.08
4.25	-1.92	-1.92	-0.44	-0.44	2.56	2.56
4.50	-0.89	-0.89	2.32	2.32	2.39	2.39
4.75	0.11	0.11	6.60	6.60	1.05	1.05
5.00	1.09	1.09	0.00	0.00	-0.00	-0.00

Maximum values of internal forces

Maximum displacement = -21,8 mm
Minimum displacement = 1,1 mm
Maximum bending moment = 2,57 kNm/m
Minimum bending moment = 0,00 kNm/m
Maximum shear force = 6,62 kN/m

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

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

Internal forces per 1 I-section

M_{max} = 2,57 kNm; Q = 0,02 kN
Q_{max} = 6,62 kN; M = 1,38 kNm

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

Verification of bending:

$M_{max}/M_{c,Rd} = 0,051 \leq 1$ **Is satisfactory**

Verification of shear:

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

Verification of plane state of stress:

Normal stress $\sigma_{x,Ed}$ = 10,65 MPa
Shear stress τ_{Ed} = 0,01 MPa

Verification: $(\sigma_{x,Ed}/(f_y/\gamma_{M0}))^2 + 3*(\tau_{Ed}/(f_y/\gamma_{M0}))^2 = 0,002 \leq 1$ **Is satisfactory**

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

Verification of bending:

$M/M_{c,Rd} = 0,028 \leq 1$ **Is satisfactory**

Verification of shear:

$Q_{max}/V_{c,Rd} = 0,038 \leq 1$ **Is satisfactory**

Verification of plane state of stress:

Normal stress $\sigma_{x,Ed}$ = 5,73 MPa
Shear stress τ_{Ed} = 3,96 MPa

Verification: $(\sigma_{x,Ed}/(f_y/\gamma_{M0}))^2 + 3*(\tau_{Ed}/(f_y/\gamma_{M0}))^2 = 0,001 \leq 1$ **Is satisfactory**

Cross section is SATISFACTORY

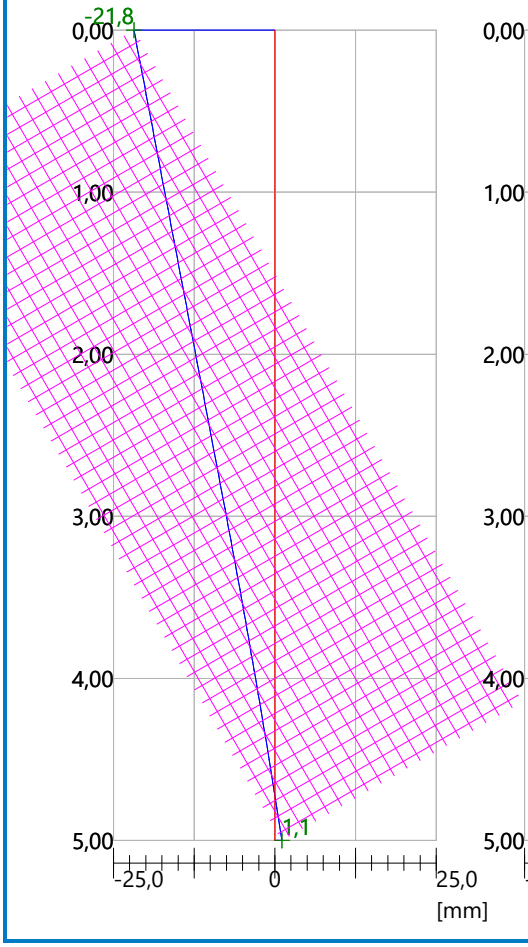
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Name : Dimensioning	Stage - analysis : 1 - 1

Displacement

Min1 = 1,1; Min2 = -21,8mm

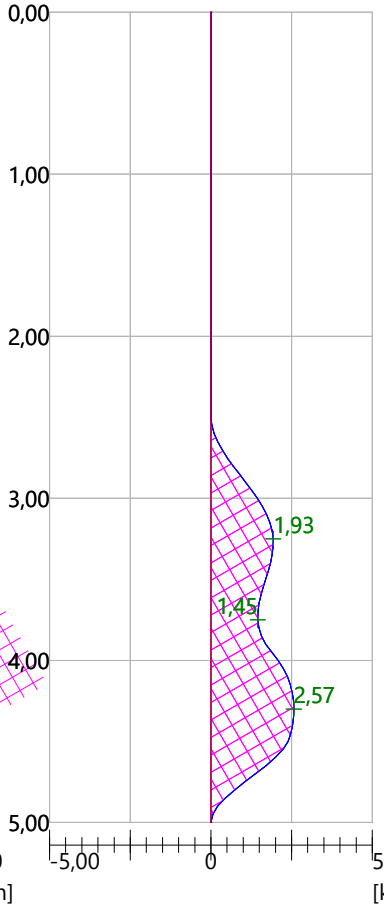
Max1 = 1,1; Max2 = -21,8mm



Bending moment

Min1 = 2,57; Min2 = 0,00kNm/m

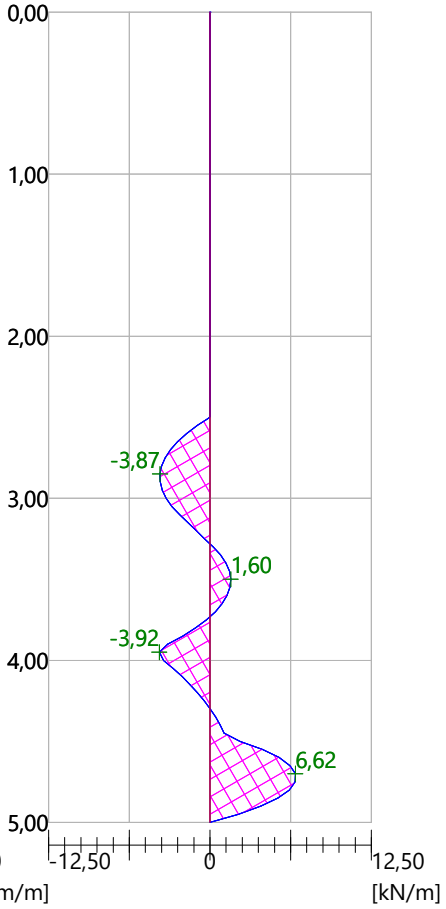
Max1 = 2,57; Max2 = 0,00kNm/m



Shear force

Min1 = 6,62; Min2 = -3,92kN/m

Max1 = 6,62; Max2 = -3,92kN/m



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