

## Pile verification

### Input data

#### Project

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#### Settings

(input for current task)

#### Materials and standards

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 :  $k_{cr} = 0,67$

#### Pile






Analysis for drained conditions : CSN 73 1002  
 Load settlement curve : linear (Poulos)  
 Horizontal bearing capacity : Elastic subsoil (p-y method)  
 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 :	$\gamma_G =$	1,35 [-]	1,00 [-]






  

Partial factors for resistances (R)			
Permanent design situation			
Partial factor on shaft resistance :	$\gamma_s =$	1,40 [-]	
Partial factor on base resistance :	$\gamma_b =$	1,40 [-]	
Partial factor on resistance in tension :	$\gamma_{st} =$	1,54 [-]	






#### Basic soil parameters

No.	Name	Pattern	$\Phi_{ef}$ [°]	$C_{ef}$ [kPa]	$\gamma$ [kN/m <sup>3</sup> ]	$\nu$ [-]
1	16_2 - Puteklāins MĀLS, mīksts		15,00	21,00	18,25	0,42
2	18_2 - Morēnas MĀLSMILTS, mīksts līdz stingras konsistences, ar grants graudu un retu oļu ieslēgumiem		17,00	8,00	19,03	0,35
3	6_3 - Puteklaina SMILTS, vidēji blīva		32,00	0,00	19,33	0,30
4	14_3 - Putekļu grunts (MĀLSMILTS), stingras konsistences		32,00	23,00	20,30	0,35
5	6_5 - Puteklaina SMILTS, ļoti blīva		38,00	0,00	20,89	0,30

All soils are considered as cohesionless for at rest pressure analysis.

No.	Name	Pattern	$E_{oed}$ [MPa]	$E_{def}$ [MPa]	$\gamma_{sat}$ [kN/m <sup>3</sup> ]	$\gamma_s$ [kN/m <sup>3</sup> ]	n [-]
1	16_2 - Puteklains MĀLS, mīksts		-	5,00	18,29	-	-
2	18_2 - Morēnas MĀLSMILTS, mīksta līdz stingras konsistences, ar grants graudu un retu oļu ieslēgumiem		-	11,00	19,03	-	-
3	6_3 - Puteklaina SMILTS, vidēji blīva		-	20,00	20,49	-	-
4	14_3 - Putekļu grunts (MĀLSMILTS), stingras konsistences		-	17,00	20,30	-	-
5	6_5 - Puteklaina SMILTS, ļoti blīva		-	90,00	21,41	-	-

## Parameters of soils to compute modulus of subsoil reaction

No.	Name	Pattern	Type of soil	$n_h$ [MN/m <sup>3</sup> ]
1	16_2 - Puteklains MĀLS, mīksts		cohesive	-
2	18_2 - Morēnas MĀLSMILTS, mīksta līdz stingras konsistences, ar grants graudu un retu oļu ieslēgumiem		cohesive	-
3	6_3 - Puteklaina SMILTS, vidēji blīva		cohesionless	1,96
4	14_3 - Putekļu grunts (MĀLSMILTS), stingras konsistences		cohesive	-
5	6_5 - Puteklaina SMILTS, ļoti blīva		cohesionless	5,28

## Soil parameters

**16\_2 - Puteklains MĀLS, mīksts**

Unit weight :  $\gamma = 18,25 \text{ kN/m}^3$   
 Angle of internal friction :  $\phi_{ef} = 15,00^\circ$   
 Cohesion of soil :  $c_{ef} = 21,00 \text{ kPa}$   
 Poisson's ratio :  $\nu = 0,42$   
 Deformation modulus :  $E_{def} = 5,00 \text{ MPa}$   
 Saturated unit weight :  $\gamma_{sat} = 18,29 \text{ kN/m}^3$   
 Type of soil : cohesive

**18\_2 - Morēnas MĀLSMILTS, mīksta līdz stingras konsistences, ar grants graudu un retu oļu ieslēgumiem**

Unit weight :  $\gamma = 19,03 \text{ kN/m}^3$   
 Angle of internal friction :  $\phi_{ef} = 17,00^\circ$   
 Cohesion of soil :  $c_{ef} = 8,00 \text{ kPa}$   
 Poisson's ratio :  $\nu = 0,35$   
 Deformation modulus :  $E_{def} = 11,00 \text{ MPa}$   
 Saturated unit weight :  $\gamma_{sat} = 19,03 \text{ kN/m}^3$   
 Type of soil : cohesive

**6\_3 - Puteklaina SMILTS, vidēji blīva**

Unit weight :  $\gamma = 19,33 \text{ kN/m}^3$   
 Angle of internal friction :  $\phi_{ef} = 32,00^\circ$

Cohesion of soil :  $c_{ef} = 0,00 \text{ kPa}$   
 Poisson's ratio :  $\nu = 0,30$   
 Deformation modulus :  $E_{def} = 20,00 \text{ MPa}$   
 Saturated unit weight :  $\gamma_{sat} = 20,49 \text{ kN/m}^3$   
 Type of soil : cohesionless  
 Modulus of  
 horiz.compressibility :  $n_h = 1,96 \text{ MN/m}^3$

#### 14\_3 - Putekļu grunts (MĀLSMILTS), stingras konsistences

Unit weight :  $\gamma = 20,30 \text{ kN/m}^3$   
 Angle of internal friction :  $\varphi_{ef} = 32,00^\circ$   
 Cohesion of soil :  $c_{ef} = 23,00 \text{ kPa}$   
 Poisson's ratio :  $\nu = 0,35$   
 Deformation modulus :  $E_{def} = 17,00 \text{ MPa}$   
 Saturated unit weight :  $\gamma_{sat} = 20,30 \text{ kN/m}^3$   
 Type of soil : cohesive

#### 6\_5 - Puteklaina SMILTS, ļoti blīva

Unit weight :  $\gamma = 20,89 \text{ kN/m}^3$   
 Angle of internal friction :  $\varphi_{ef} = 38,00^\circ$   
 Cohesion of soil :  $c_{ef} = 0,00 \text{ kPa}$   
 Poisson's ratio :  $\nu = 0,30$   
 Deformation modulus :  $E_{def} = 90,00 \text{ MPa}$   
 Saturated unit weight :  $\gamma_{sat} = 21,41 \text{ kN/m}^3$   
 Type of soil : cohesionless  
 Modulus of  
 horiz.compressibility :  $n_h = 5,28 \text{ MN/m}^3$

### Geometry

Pile profile: pipe pile

#### Dimensions

Diameter  $d = 1,02 \text{ m}$   
 Length  $l = 27,50 \text{ m}$   
 Thickness  $t = 20,0 \text{ mm}$   
 Coeff. of base reduction  $c = 0,70$

#### Calculated cross-sectional characteristics

Area  $A = 6,28\text{E-}02 \text{ m}^2$   
 Moment of inertia  $I = 7,86\text{E-}03 \text{ m}^4$

#### Location

Off ground height  $h = 15,00 \text{ m}$   
 Depth of finished grade  $h_z = 0,00 \text{ m}$

Technology: Driven piles

Modulus of subsoil reaction considered according to CSN 731004.

### Material of structure

Unit weight  $\gamma = 23,00 \text{ kN/m}^3$

#### Structural steel: EN 10210-1 : S 355

Yield strength  $f_y = 355,00 \text{ MPa}$   
 Ultimate tensile strength  $f_u = 510,00 \text{ MPa}$   
 Elasticity modulus  $E = 210000,00 \text{ MPa}$   
 Shear modulus  $G = 81000,00 \text{ MPa}$

**Geological profile and assigned soils**

No.	Thickness of layer t [m]	Depth z [m]	Assigned soil	Pattern
1	2,80	0,00 .. 2,80	16_2 - Puteklains MĀLS, mīksts	
2	2,70	2,80 .. 5,50	18_2 - Morēnas MĀLSMILTS, mīksts līdz stingras konsistences, ar grants graudu un retu oļu ieslēgumiem	
3	2,60	5,50 .. 8,10	6_3 - Puteklaina SMILTS, vidēji blīva	
4	1,10	8,10 .. 9,20	14_3 - Putekļu grunts (MĀLSMILTS), stingras konsistences	
5	4,30	9,20 .. 13,50	6_5 - Puteklaina SMILTS, ļoti blīva	
6	-	13,50 .. ∞	16_2 - Puteklains MĀLS, mīksts	

**Load**

No.	Load new	Load change	Name	Type	N [kN]	M <sub>x</sub> [kNm]	M <sub>y</sub> [kNm]	H <sub>x</sub> [kN]	H <sub>y</sub> [kN]
1	Yes		Load No. 1	Design	-1271,00	0,00	0,00	0,00	0,00
2	Yes		Load No. 2	Design	2965,00	0,00	0,00	0,00	0,00

**Ground water table**

The ground water table is at a depth of -14,00 m from the original terrain.

**Global settings**

Analysis of vertical bearing capacity : analytical solution

Analysis type : analysis for drained conditions

**Settings of the stage of construction**

Design situation : permanent

Verification methodology : without reduction of soil parameters

**Verification No. 1****Verification of pile bearing capacity according to theory of LS - partial results**

Pile base bearing capacity:

Coefficient of bearing capacity  $N_c = 61,35$

Coefficient of bearing capacity  $N_d = 48,93$

Coefficient of bearing capacity  $N_b = 56,17$

Coefficient of bearing capacity  $K_1 = 1,00$

Design pile base bearing capacity  $R_{bd} = 10020,35 \text{ kPa}$

Area of pile transverse cross-section  $A_p = 8,17E-01 \text{ m}^2$

Pile shaft resistance:

Reduction of effective pile length  $L_p = 3,41 \text{ m}$

Depth [m]	Thickness [m]	$\Phi_d$ [°]	$c_{ud}$ [kPa]	$\gamma$ [kN/m <sup>3</sup> ]	$\gamma_{R2}$ [-]	$f_s$ [kPa]	$R_{si}$ [kN]
2,80	2,80	15,00	21,00	8,29	1,00	24,11	154,52
5,50	2,70	17,00	8,00	9,03	1,00	18,82	116,33
8,10	2,60	32,00	0,00	10,49	1,00	38,26	227,69

Depth [m]	Thickness [m]	$\Phi_d$ [°]	$c_{ud}$ [kPa]	$\gamma$ [kN/m <sup>3</sup> ]	$\gamma_{R2}$ [-]	$f_s$ [kPa]	$R_{si}$ [kN]
9,09	0,99	32,00	23,00	10,30	1,00	72,96	165,09

Bearing capacity of tensile pile:

Depth [m]	Thickness [m]	$\Phi_d$ [°]	$c_{ud}$ [kPa]	$\gamma$ [kN/m <sup>3</sup> ]	$\gamma_{R2}$ [-]	$f_s$ [kPa]	$R_{si}$ [kN]
2,80	2,80	15,00	21,00	8,29	1,00	24,11	216,32
5,50	2,70	17,00	8,00	9,03	1,00	18,82	162,86
8,10	2,60	32,00	0,00	10,49	1,00	38,26	318,77
9,20	1,10	32,00	23,00	10,30	1,00	73,32	258,45
12,50	3,30	38,00	0,00	11,41	1,00	82,05	867,68

#### Verification of pile vertical bearing capacity according to the theory of LS - results

Analysis carried out with automatic selection of the most unfavourable load cases.

Verification of compressive pile:

Most unfavorable load case No. 2. (Load No. 2)

Pile skin bearing capacity  $R_s = 663,62$  kN

Pile base bearing capacity  $R_b = 4093,95$  kN

Pile bearing capacity  $R_c = 4757,58$  kN

Ultimate vertical force  $V_d = 2965,00$  kN

$$R_c = 4757,58 \text{ kN} > 2965,00 \text{ kN} = V_d$$

**Pile compressive resistance is SATISFACTORY**

Verification of tensile pile:

Most unfavorable load case No. 1. (Load No. 1)

Pile tensile resistance  $R_{sdt} = 1184,47$  kN

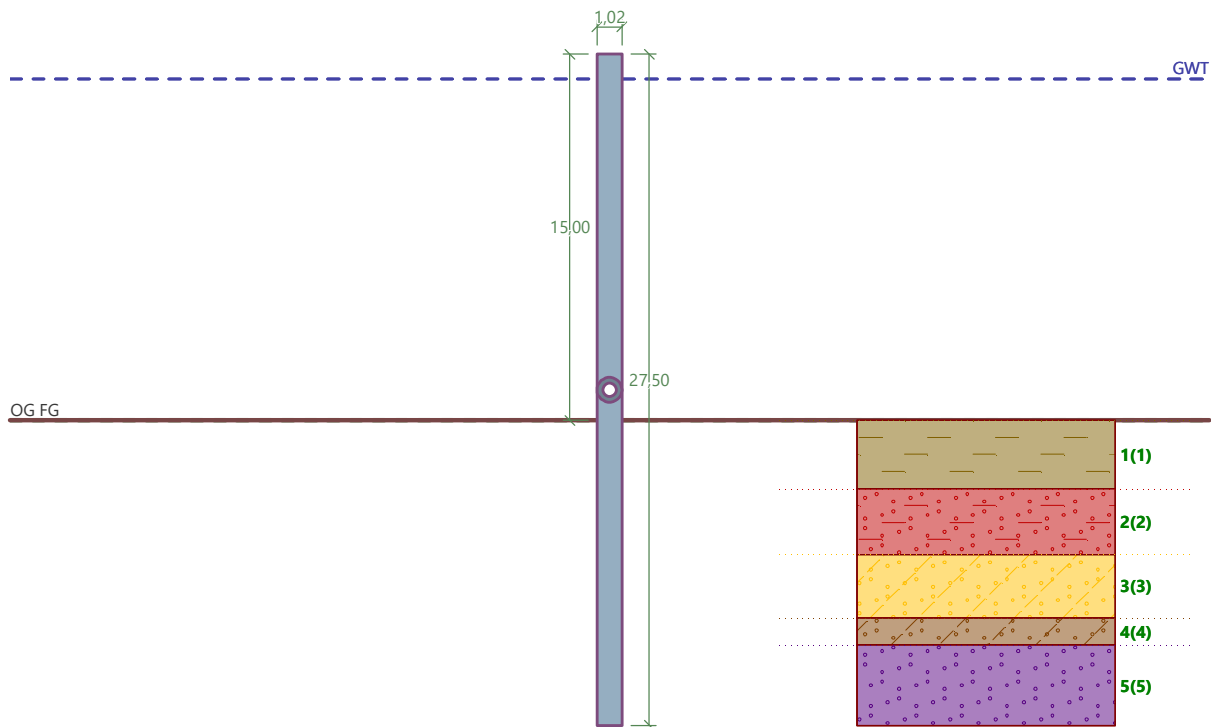
Pile self-weight  $w_p = 300,29$  kN

Maximum tensile load  $V_d = 970,71$  kN

$$R_c = 1184,47 \text{ kN} > 970,71 \text{ kN} = V_d$$

**Pile tensile resistance is SATISFACTORY**

**Pile bearing capacity is SATISFACTORY**



## Verification No. 1

### Analysis of load settlement curve - input data

Layer No.	$E_s$ [MPa]
1	4,00
2	27,00
3	30,00
4	23,00
5	80,00

Maximum pile settlement  $s_{lim} = 50,0$  mm

### Analysis of load settlement curve - partial results

Correction factor for pile compressibility	$C_k = 0,93$
Correction factor for Poisson's ratio of soil	$C_v = 0,83$
Correction factor for stiffness of bearing stratum	$C_b = 3,57$
Base-load proportion for incompressible pile	$\beta_0 = 0,09$
Proportion of applied load transferred to pile base	$\beta = 0,26$

Influence coefficients of settlement :

Basic - dependent on ratio $l/d$	$l_0 = 0,13$
Correction factor for pile compressibility	$R_k = 1,11$
Correction factor for finite depth of layer on a rigid base	$R_h = 1,00$
Correction factor for Poisson's ratio of soil	$R_v = 0,93$

### Analysis of load settlement curve - results

Load at the onset of mobilization of skin friction	$R_{yu} = 1247,10$ kN
The settlement for the force $R_{yu}$	$s_y = 4,4$ mm
Total resistance	$R_c = 4230,68$ kN

Maximum settlement  $s_{lim} =$  50,0 mm

