

Calculation of subsidence

We perform the calculation in the following sequence:

1 We determine the thickness of the subsiding soil, in which it can be saturated with water to the degree of humidity

$$S_R = 0,9$$

We accept that the water can rise to the level of the foundation sole.

2 The entire layer is divided into calculated strips, preferably of the same thickness as during the settlement calculation

$h_i \leq 0,4b$, but not more than 2 m and not less than 2 pcs.

3 We calculate the values and build a graph of the stresses in the subsiding soil layer from its own weight when the layer above is saturated with water, taking into account possible cutting or backfilling when planning the territory:

$$\rho_{\text{sat}} = \frac{\rho}{1+W} \cdot \left(1 + \frac{S_{r,\text{sat}} \cdot e \cdot \rho_w}{\rho_s} \right) \quad \sigma_{g,\text{sat},i} = 10 \cdot \rho_{\text{sat}} \cdot h_i$$

4 We determine the total stresses in the middle of the height of the calculated strips from the soil's own weight and from the pressure transmitted by the foundation:

$$\sigma_{\Sigma,i} = \sigma_{g,\text{sat},i} + \sigma_{p,i}$$

5 Using a graph of the change in $\varepsilon_{\text{sl},i}$ from p_i , built earlier to determine the type of soil conditions relative to subsidence, we find the value of relative subsidence $\varepsilon_{\text{sl},i}$, corresponding to the total pressures $\sigma_{\Sigma,i}$

6 We calculate the subsidence of the base for each elementary layer of the subsiding soil, and then sum up the obtained values:

$$S_{sl} = \sum \varepsilon_{sl,i} \cdot h_i \cdot k_{sl,i}$$

$k_{sl,i} = 1$, if $b \geq 12$ м, if $b \leq 3$ м, according to the formula:

$$k_{sl,3} = 0,5 + 1,5 \cdot \frac{p_{cp} - p_{sl}}{p_0}, \text{ где } p_0 = 100 \text{ кПа.}$$

If $3 < b < 12$ м – by interpolation

$$k_{sl} = k_{sl,3} - \frac{k_{sl,3} - 1}{9} \cdot (b - 3)$$

Total deformation of the base $S' = S + S_{sl}$

Table - Coefficient α

ζ	Coefficient α for foundations							
	round	rectangular with the ratio of sides $\eta = l/b$,						strip ($\eta \geq 10$)
		1,0	1,4	1,8	2,4	3,2	5	
0	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
0,4	0,949	0,960	0,972	0,975	0,976	0,977	0,977	0,977
0,8	0,756	0,800	0,848	0,866	0,876	0,879	0,881	0,881
1,2	0,547	0,606	0,682	0,717	0,739	0,749	0,754	0,755
1,6	0,390	0,449	0,532	0,578	0,612	0,629	0,639	0,642
2,0	0,285	0,336	0,414	0,463	0,505	0,530	0,545	0,550
2,4	0,214	0,257	0,325	0,374	0,419	0,449	0,470	0,477
2,8	0,165	0,201	0,260	0,304	0,349	0,383	0,410	0,420
3,2	0,130	0,160	0,210	0,251	0,294	0,329	0,360	0,374
3,6	0,106	0,131	0,173	0,209	0,250	0,285	0,319	0,337
4,0	0,087	0,108	0,145	0,176	0,214	0,248	0,285	0,306
4,4	0,073	0,091	0,123	0,150	0,185	0,218	0,255	0,280
4,8	0,062	0,077	0,105	0,130	0,161	0,192	0,230	0,258
5,2	0,053	0,067	0,091	0,113	0,141	0,170	0,208	0,239
5,6	0,046	0,058	0,079	0,099	0,124	0,152	0,189	0,223
6,0	0,040	0,051	0,070	0,087	0,110	0,136	0,173	0,208
6,4	0,036	0,045	0,062	0,077	0,099	0,122	0,158	0,196
6,8	0,031	0,040	0,055	0,064	0,088	0,110	0,145	0,185
7,2	0,028	0,036	0,049	0,062	0,080	0,100	0,133	0,175
7,6	0,024	0,032	0,044	0,056	0,072	0,091	0,123	0,166
8,0	0,022	0,029	0,040	0,051	0,066	0,084	0,113	0,158
8,4	0,021	0,026	0,037	0,046	0,060	0,077	0,105	0,150
8,8	0,019	0,024	0,033	0,042	0,055	0,071	0,098	0,143
9,2	0,017	0,022	0,031	0,039	0,051	0,065	0,091	0,137
9,6	0,016	0,020	0,028	0,036	0,047	0,060	0,085	0,132
10,0	0,015	0,019	0,026	0,033	0,043	0,056	0,079	0,126
10,4	0,014	0,017	0,024	0,031	0,040	0,052	0,074	0,122
10,8	0,013	0,016	0,022	0,029	0,037	0,049	0,069	0,117
11,2	0,012	0,015	0,021	0,027	0,035	0,045	0,065	0,113
11,6	0,011	0,014	0,020	0,025	0,033	0,042	0,061	0,109
12,0	0,010	0,013	0,018	0,023	0,031	0,040	0,058	0,106

Example

Geological structure and hydrogeological conditions of the construction site

№ layer	Soil	Well number and the depth of the sole of each soil layer from the surface of the earth, m				
		1	2	3	4	5
1.	plant layer	0,3	0,3	0,3	0,3	
2.	Subsidence soil	4,8	4,6	4,9	4,8	
3.	Sand medium-sized	3,4	3,6	3,5	3,3	
4.	sandy loam	3,5	3,6	3,7	3,6	
5.	Clay gray	8,7	8,9	8,8	8,7	
	The depth of underground water	8,2	8,0	8,3	8,1	
	Well mark, m					

Variant	Cross section of the column , mm	Combination			
		I		II	
		N,MN	M, MNm	N,MN	M,MNm
	600x400	2,1	0,26	1,2	0,41

Characteristics of soil properties

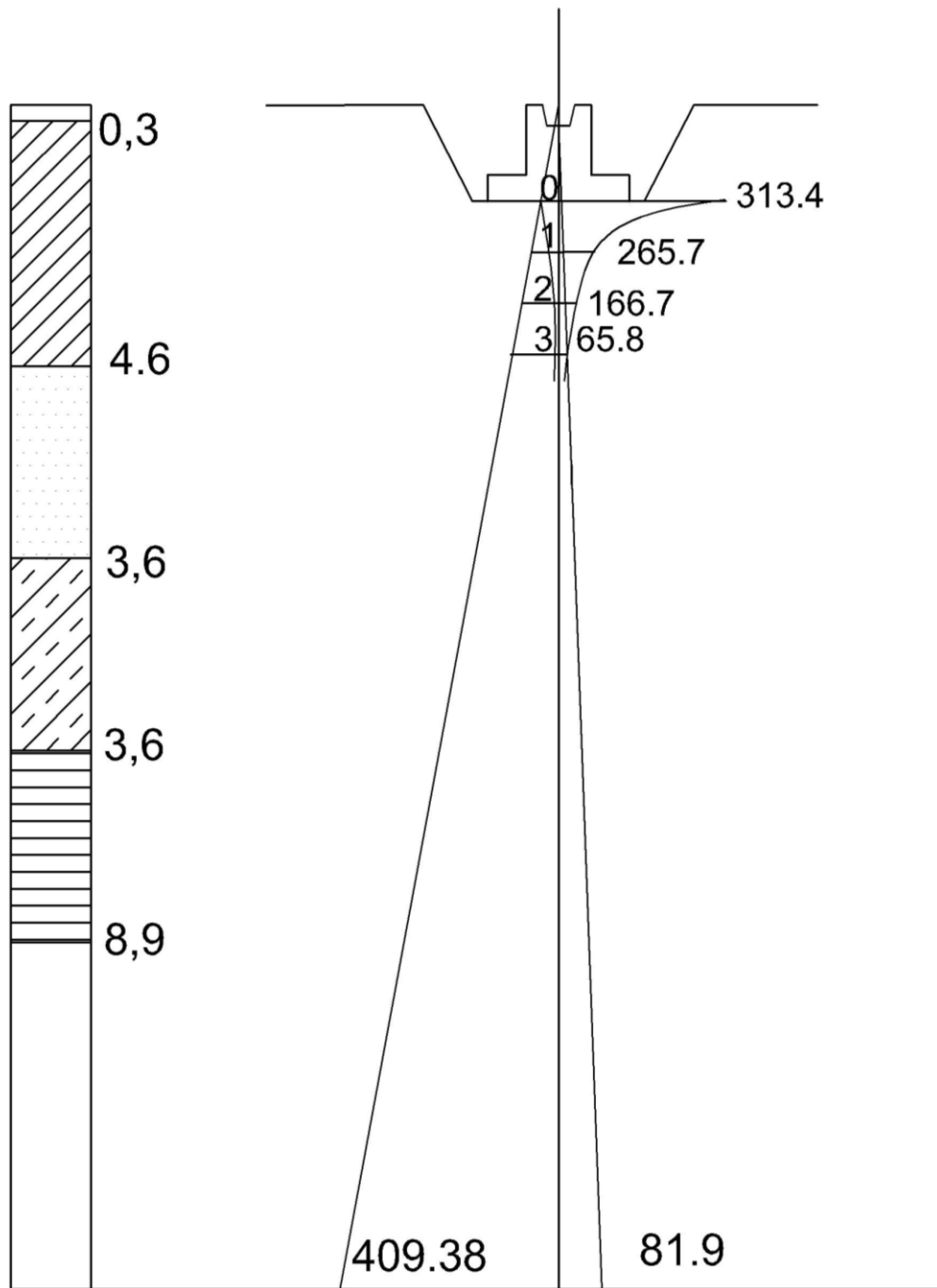
Name	Legend	Units of measurement	Layer number				
			1	2	3	4	5
Density	ρ_{II}	t/m ³	1,39	1,72	2,01	1,98	2,06
Solid Particle density	ρ_s	t/m ³		2,73	2,68	2,69	2,70
Water content	W			0,15	0,24	0,26	0,22
Liquid limit	W _L			0,35		0,28	0,40
Plastic limit	W _p			0,19		0,22	0,20
Angle of internal friction	φ_{II}	degree		21	33	20	15
Specific cohesion	C _{II}	kPa		25	1	12	80
Modulus of Deformation	E	MPa		20	30	15	50
Relative subsidence under pressure p, MПа	ϵ_{SL}	p=0,1		0,04			
		p=0,2		0,073			
		p=0,3		0,082			
Angle of internal friction water-saturated soil	$\varphi_{II,sat}$	degree		19			
Specific cohesion water-saturated soil	C _{II,sat}	kPa		5			
Modulus of Deformation water-saturated soil	E _{sat}	MPa		6			

Soil classification indicators

№ Layer	e	S_r	I_p	I_l	Soil properties
1					plant layer
2	0.825		0.16	-1.25	Subsidence soil loam solid
3	0.653	0.389			Sand medium-sized low moisture Medium density
4			0.06	0.667	sandy loam nplastic
5			0.2	0.1	Clay semi-solid

$$\rho_{sat} = \frac{\rho}{1+W} \cdot \left(1 + \frac{S_{r,sat} \cdot e \cdot \rho_w}{\rho_s} \right) = \frac{1,72}{1+0,15} \left(1 + \frac{0,9 \cdot 0,825 \cdot 1}{2,73} \right) = 1,93 \text{ t/m}^3$$

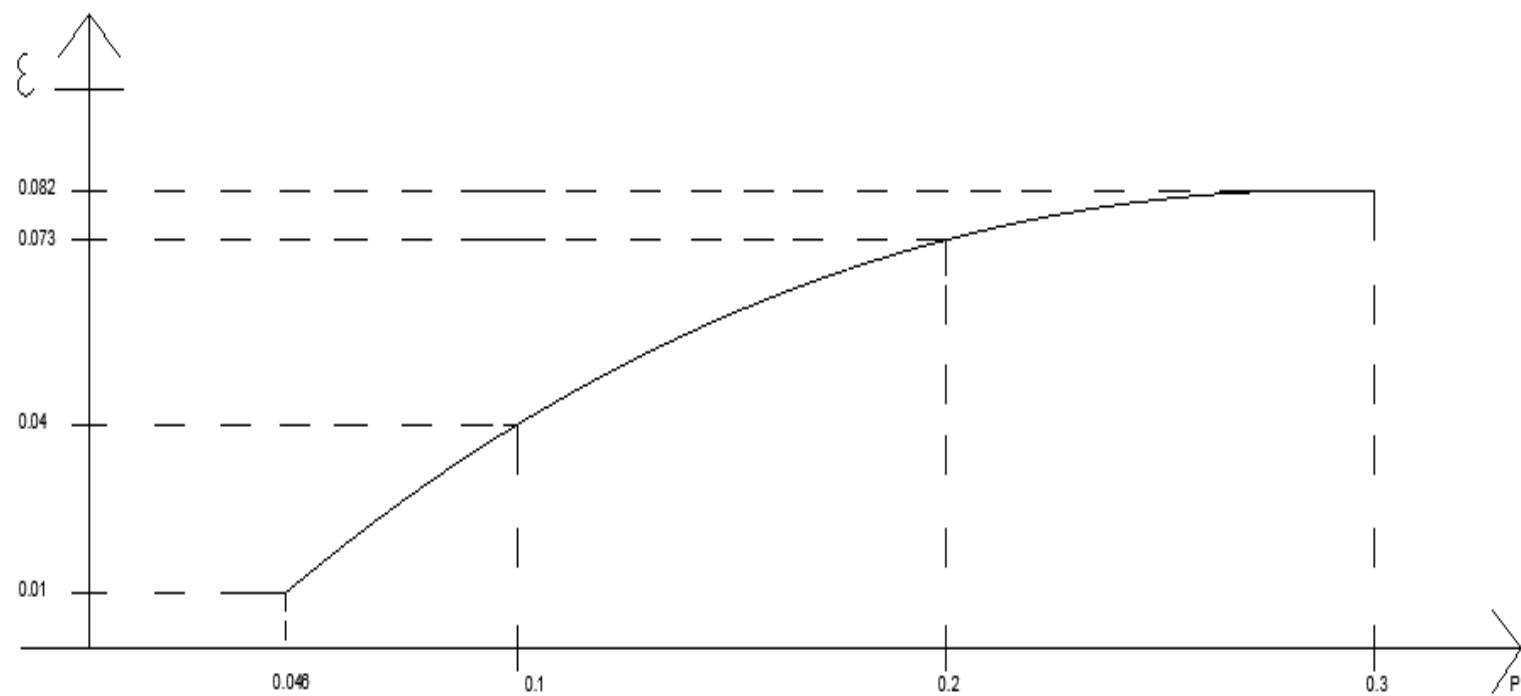
Psl=46 kPa



$$b=2,4 \text{ m}, l=3,4 \text{ m}, d=1,8 \text{ m}$$

$$\rho_{sat} = \frac{\rho}{1+W} \cdot \left(1 + \frac{S_{r,sat} \cdot e \cdot \rho_w}{\rho_s} \right) = 1.93 \text{ t/m}^3$$

$$P_{cp} = \frac{2100}{2.4 \cdot 3.4} + 20 \cdot 1.8 + 20 = 313.4 \text{ kPa} < 330.4 \text{ kPa}$$



$P_{sl} = 0.046 \text{ MPa} = 46 \text{ kPa}$

2. Determine the stress from the soil's own weight

$$\sigma_{zg,1} = \gamma_1 \cdot h_1 = 1.39 \cdot 10 \cdot 0.3 = 4 \text{ kN/m}^2$$

$$\sigma_{zg,2} = \gamma_1 \cdot h_1 + \gamma_2 \cdot h_2 = 0.4 + 1.72 \cdot 10 \cdot 4.6 = 83.12 \text{ kN/m}^2$$

$$\sigma_{zg,3} = \sigma_{zg,2} + \gamma_3 \cdot h_3 = 83.12 + 2.01 \cdot 10 \cdot 3.6 = 155.48 \text{ kN/m}^2$$

$$\sigma_{zg,4} = \sigma_{zg,3} + \gamma_4 \cdot h_4 = 155.48 + 1.96 \cdot 10 \cdot 3.6 = 226.04 \text{ kN/m}^2$$

$$\sigma_{zg,5} = \sigma_{zg,4} + \gamma_5 \cdot h_5 = 226.04 + 2.06 \cdot 10 \cdot 8.9 = 409.38 \text{ kN/m}^2$$

We determine the stress from the soil's own weight at the level of the foundation sole

$$\sigma_{zg,0} = \sigma_{zg,1} + \gamma_2 \cdot h_d = 4 + 1.72 \cdot 10 \cdot 1.5 = 29.8 \text{ kN/m}^2$$

3. The soil layer under the foundation is divided into elementary layers with a thickness of h , but no more than 1 m:

$$h \leq 0.4b$$

$$h = 0.4 \cdot 2.4 = 0.96 \text{ m}$$

Table - Settlement calculation

Layer №	№	soil	h, m	Z, M	$\zeta = \frac{2 \cdot z}{b}$	α	kPa $\sigma_{zp} = \alpha \cdot p$	$\sigma_{zp, cp}$	$\zeta_k = \frac{2 \cdot z}{B_k}$	α_k	kPa $\sigma_{z\gamma} = \alpha_k \cdot \sigma'_{zg, 0}$	$\sigma_{z\gamma, cp}$	E _i , kPa	$0,8 \cdot \frac{(\sigma_{zp, i, cp} - \sigma_{z\gamma, i}) \cdot h_i}{E_i}$	S _i , M
	0		0	0	0	1	313,4		0	1	29,8				
	1		0,96	0,96	0,8	0,848	265,76	289,58	0,564	0,848	25,27	27,54	20000	0,01006	
	2		0,96	1,92	1,6	0,532	166,73	216,25	1,129	0,532	15,85	20,56	20000	0,00751	
	3		0,96	2,88	2,4	0,325	101,86	134,29	1,6941	0,325	9,69	12,77	20000	0,00467	
	4		0,96	3,84	3,2	0,21	65,81	83,83	2,258	0,21	6,26	7,97	20000	0,00291	

S=2,8 cm4 < 10 cm

Calculation of subsidence

$$S_{sl} = \sum \varepsilon_{sl,i} \cdot h_i \cdot k_{sl,i}$$

$$k_{sl,3} = 0,5 + 1,5 \cdot \frac{p_{cp} - p_{sl}}{p_0} = 0,5 + 1,5 \frac{313,4 - 46}{100} = 4,511$$

h, m	$\sigma_{zp} = \alpha \cdot p$ MPa	$\sigma_{g.sat,i}$ kPa	$\sigma_{p,i} + \sigma_{g.sat,i}$ MPa	σ_{Σ}^{cp} MPa	ε_{sl}	h_i m	k_{sl}	$S_{sl,i}$ m
0	313,4	33,12	346,52					
0,96	265,763	51,65	317,411	331,965	0,078	0,96	4,511	0,0338
0,96	166,728	70,18	236,905	277,158	0,068	0,96	4,511	0,0294
0,96	101,86	88,70	190,559	213,732	0,05	0,96	4,511	0,0217
0,22	65,81	92,95	158,764	174,662	0,0425	0,22	4,511	0,0042

$$S' = S + S_{sl} = 1,85 + 13,9 = 15,75 \text{ cm} > 10 \text{ cm}$$

$$\sum S_{sl} = 0,139 \text{ m}$$