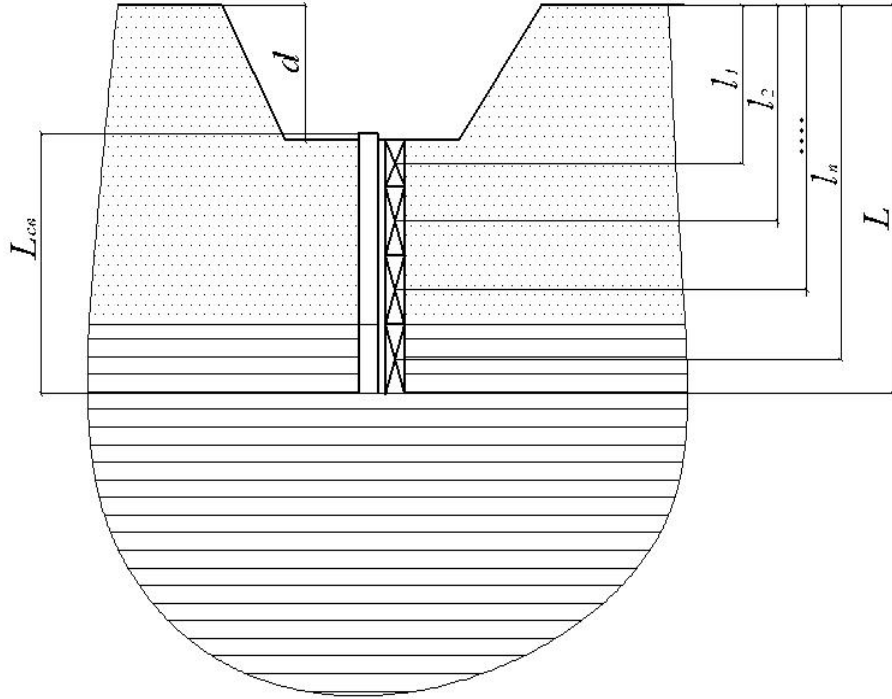


Calculation of pile foundations by bearing capacity



Pile length

$$L_p = (h_1 + h_2 + \dots + h_n) - d_p + 0,3 \text{ m} + 1 \text{ m}$$

Bearing capacity of a single friction pile

$$F_d = \gamma_c (\gamma_{cr} \cdot R \cdot A + u \cdot \sum \gamma_{cf} \cdot f_i \cdot h_i)$$

where γ_c is the coefficient of pile operating conditions in the soil, γ_c is taken=1;

R is the estimated resistance of the soil under the lower end of the pile, kPa, is accepted according to the table 10.1;

A – the area of the pile resting on the soil, m²;

u – the outer perimeter of the cross section of the pile, m;

$$f_i = \sigma_{zg,i} \frac{v_i}{1 - v_i} \operatorname{tg} \varphi_{II,i} + c_{II,i}$$

f_i and h_i are, respectively, the estimated resistance of the i-th layer of the foundation soil on the lateral surface of the pile, kPa, which is taken according to the table. 10.2, and the thickness of the ith soil layer, m;

γ_{cr} and γ_{cf} are the coefficients of soil conditions under the lower end and on the lateral surface of the pile, respectively, taking into account the influence of the method immersion of the pile to the estimated soil resistance are accepted in accordance with DBN B-2.1.-10 -2009 Change 1. For solid and hollow piles, driven with a closed lower end, $\gamma_{cr} = \gamma_{cf} = 1$.

The calculation is carried out in the following sequence:

1 When analyzing engineering and geological conditions, we select a layer of soil suitable for supporting piles. We choose the type, type and method of sinking piles (in this example, driven prismatic reinforced concrete piles are accepted, the method of sinking is driving).

2 The depth of laying the sole of the pile cap is below the depth of soil freezing.

3 We determine the length of the pile, which depends on the engineering and geological conditions, the method of connecting the pile with the pile cap and the depth of the pile in the bearing layer. In this case, we assume that the connection between the pile and the pile cap is rigid (300-350 mm), the depth of the pile into the bearing layer is at least 1 m. Then the required length of the pile can be determined according to the following relationship:

$$L_p = (h_1 + h_2 + \dots + h_n) - d_p + 0,3 \text{ m} + 1 \text{ m},$$

where h_1, h_2, h_n – the thickness of the layers passing through the pile;

d_p - the depth of laying the pile cap, m.

After determining L_{CB} , the given number should be rounded to the nearest larger whole value.

The cross-section of the piles should be taken in the following dimensions: 250 x 250, 300 x 300 or 350 x 350 mm.

4. 4. We determine the bearing capacity of a single friction pile, having previously divided the soil stratum along the height of the piles into sections no longer than 2.0 m:

$$F_d = \gamma_c(\gamma_{cr} \cdot R \cdot A + u \cdot \sum \gamma_{cf} \cdot f_i \cdot h_i)$$

where γ_c is the coefficient of pile operating conditions in the soil, γ_c is taken=1;

R is the estimated resistance of the soil under the lower end of the pile, kPa,

is accepted according to the table 1;

A – the area of the pile resting on the soil, m²;

u – the outer perimeter of the cross section of the pile, m;

f_i and h_i are, respectively, the estimated resistance of the i-th layer of the foundation soil on the lateral surface of the pile, kPa, which is taken according to the table. 10.2, and the thickness of the ith soil layer, m;

γ_{cr} and γ_{cf} are the coefficients of soil conditions under the lower end and on the lateral surface of the pile, respectively, taking into account the influence of the method immersion of the pile to the estimated soil resistance are accepted in accordance with DBN B-2.1.-10 -2009 Change 1. For solid and hollow piles, driven with a closed lower end, $\gamma_{cr} = \gamma_{cf} = 1$.

$$f_i = \sigma_{zg,i} \frac{v_i}{1 - v_i} \operatorname{tg} \varphi_{II,i} + c_{II,i}$$

where σ_{zg} is the stress from the soil's own weight in the middle of the i-th calculated layer of the soil base;

v_i is the Poisson's ratio of the soil in the middle of the i-th calculated layer of the soil base, equal to 0.21 ... 0.29 - for sands, 0.3 ... 0.37 - for sandy loams and loams, and 0.4 - for clays.

5 . When the soil is completely saturated with water, the estimated characteristics of the soil should be taken at the liquidity index determined by the formula

$$I_L = \frac{0,9 \cdot e \cdot \frac{\gamma_w}{\gamma_s} - w_p}{w_L - w_p}$$

e – void ratio of the natural density soil,

γ_w – Total unit weight of water, $\gamma_w = 10 \text{ kN/m}^3$;

γ_s – Particle unit weight, kN/m^3 ;

w_L, w_p –Liquid limit and Plastic limit.

If $I_L < 0,4$ should be taken $I_L = 0,4$.

If $I_L > 1$ resistance on the side surface is not taken into account.

6. The calculation of piles based on the bearing capacity of the base soil in subsidence soils should be carried out with the condition :

$$N \leq \left(\frac{F_d}{\gamma_k} \right) - \gamma_c \cdot P_n$$

where N is the calculated load, kN , on one pile;

F_d - estimated bearing capacity of the soil of the base of a single pile,

γ_k - reliability coefficient (1.4 is assumed if the bearing capacity of the pile F_d is determined by calculation);

γ_c - coefficient of working conditions, which depends on the subsidence of the soil:

if $S_{sl} = 5 \text{ sm}$ - $\gamma_c = 0$, if $S_{sl} \geq 2 S_u$ - $\gamma_c = 0.8$ for intermediate values S_{sl} - γ_c determined by interpolation;

P_n - additional loading force of friction.

$$P_n = u \sum_0^{h_{sl}} \tau_i \cdot h_i$$

u - pile perimeter, m;

h_{sl} - calculated depth, m, within which summation of the forces of lateral friction of the subsiding soil layers is performed, which is equal to the depth of the sole of the subsiding layer of the soil under the action of its own weight;

τ_i - calculated soil resistance, kPa, which is determined up to a depth of 6 m by the formula:

$$\tau_i = \xi \sigma_{zg,i} \operatorname{tg} \varphi_i + c_i$$

ξ - side pressure coefficient, which is equal to 0,7;

φ_i, c_i - calculated values of the angle of internal friction and specific cohesion of the soil, averaged over depth h_i ;

σ_{zg} - vertical stress from self-weight of water-saturated soil, kPa :

h_i - thickness, m, of the soil layer that settles during soaking and is tangential to the lateral surface of the pile.

At a depth of $6\text{ m} < h < h_{sl}$, the value of τ_i is assumed to be constant, equal to the value of τ_i at a depth of 6 m.

7. We determine the required number of piles in the pile cap :
$$n = \frac{F_v}{N}$$

We construct the pile cap, taking into account that the distance between the axes of the piles is taken as $(3...6)d$, and the distance from the edge of the pile cap to the axis of the extreme pile is d , where d is the side of the pile. We accept the height of the pile cap in the range of 500...600 mm.

8. Since not only the longitudinal force but also the bending moment acts on the pile foundation, it is necessary to check the amount of load on the extreme pile taking into account the action of the bending moment.

The magnitude of this load is determined by the formula

$$N_{\max \atop \min} = \frac{N_d}{n} \pm \frac{M_x y}{\sum y_i^2} \pm \frac{M_y x}{\sum x_i^2}$$

N_d – calculated compressive force, kN, which includes: vertical load from the upper structures, weight of the pile cap, weight of soil on its edges and weight of piles;

n – the number of piles in the foundation, units;

x_i, y_i – distance from the main axes to the axis of each pile, m;

$M_x; M_y$ – calculated bending moments, kNm, in relation to the main central axes x and y , the plan of the piles in the plane of the base of the foundation;

x, y – the distance from the main axes to the axis of each pile for which the design load is calculated, m.

Since the loads on the extreme pile are determined taking into account the action of the moment, the calculated load is taken as equal to 1.2 N (the short duration of the action of the moment is taken into account).

We check the condition:

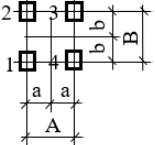
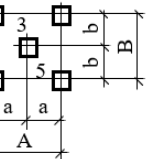
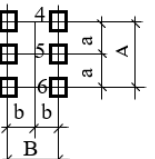
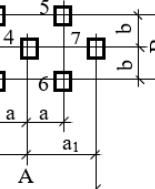
$$N_{\max} \leq \frac{1,2F_d}{\gamma_k}$$

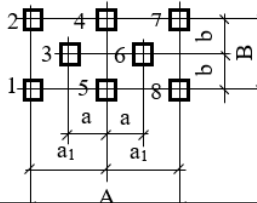
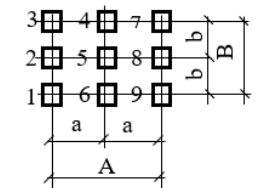
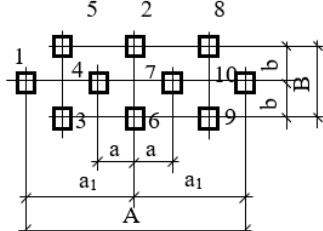
Table 1 – Values of estimated resistances under the lower end of driven piles and shell piles that are submerged without soil excavation

Immersion depth of the lower end of the pile, m	Estimated resistance under the lower end of driven piles and piles-shells, are immersed without soil excavation R, kPa						
	sandy soils of medium density						
	gravelly	large	-	Medium-sized	fine	dusty	-
	of clayey soils with a liquidity index of I_L						
	0	0,1	0,2	0,3	0,4	0,5	0,6
3	7500	6600 / 4000	3000	3100 / 2000	2000 / 1200	1100	600
4	8300	6800 / 5100	3800	3200 / 2500	2100 / 1600	1250	700
5	8800	7000 / 6200	4000	3400 / 2800	2200 / 2000	1300	800
7	9700	7300 / 6900	4300	3700 / 3300	2400 / 2200	1400	850
10	10500	7700 / 7300	5000	4000 / 3500	2600 / 2400	1500	900
15	11700	8200 / 7500	5600	4400 / 4000	2900	1650	100
20	12600	8500	6200	4800 / 4500	3200	1800	1100
25	13400	9000	6800	5200	3500	1950	1200
30	14200	9500	7400	5600	3800	2100	1300
35	15000	10000	8000	6000	4100	2250	1400

Table 2 – Coefficients of working conditions Methods of immersion driven piles and shell piles that are sunk without excavation, and types of soils	Coefficients of soil conditions for calculating the bearing capacity of piles	
	under the lower end γ_{cR}	on the lateral surface γ_{cf}
1 Immersion of solid and hollow piles with a closed lower end by mechanical (suspended), steam-air and diesel hammers	1,0	1,0
2 Immersion by hammering and pressing into pre-drilled pilot wells with the pile ends being buried at least 1 m below the wellhead at its diameter:		
a) is equal to the side of a square pile;	1,0	0,5
b) 0.05 m less than the side of the square pile;	1,0	0,6
c) 0.15 m less than the side of a square or the diameter of a pile of round cross-section (for power transmission line supports).	1,0	1,0
3 Immersion with washing in sandy soils, provided that the piles are finished at the last stage of immersion without using washing for 1 m or more	1,0	0,9
4 vibration immersion of shell piles, vibration immersion and vibration pressing of piles into the soil:		
a) sands of medium density:		
- large and medium-sized;	1,2	1,0
- small;	1,1	1,0
- dusty;	1,0	1,0
b) dusty-clay with a liquidity index $I_L = 0.5$:		
- sandy loam;	0,9	0,9
- loam;	0,8	0,9
- clay;	0,7	0,9
c) dusty-clay with a liquidity index $I_L \leq 0$.	1,0	1,0
5 Hammer sinking of any structure of hollow reinforced concrete piles with an open lower end:		
a) when the diameter of the pile cavity is 0.4 m or less;	1,0	1,0
b) the same from 0.4 to 0.8 m.	0,7	1,0
6 Immersion by any method of hollow piles of round cross-section with a closed lower end to a depth of 10 m or more with subsequent installation at the lower end of piles of camouflaged expansion in sandy soils of medium density and in silty-clay soils with a liquidity index $I_L \leq 0.5$ with a diameter expansion equal to:		
a) 1.0 m regardless of the specified types of soil;	0,9	1,0
b) 1.5 m in sand and sandy loam;	0,8	1,0
c) 1.5 m in loams and clays;	0,7	1,0
7 Immersion by driving piles:		
a) sands of medium density, large, medium-sized and small;	1,1	1,0
b) in dusty sands;	1,1	0,8
c) in dusty-clay soils with a liquidity index $I_L < 0.5$;	1,1	1,0
d) the same, $I_L > 0.5$.	1,0	1,0

Parameters of typical pile groups (pile caps) from driven piles for industrial buildings

A typical diagram of a pile cap	The size of the cross section of the pile, mm	Dimensions, mm				
		a	a ₁	A	b	B
1	2	3	4	5	6	7
4 piles 	300x300	450		900	450	900
		600		1200		
		650		1300		
		800		1600		
	350x350	600		1200	450	900
		750		1500		
		1050		2100		
		600		1200		
5 piles 	300x300	650		1300	450	900
		800		1600		
		950		1900		
		1100		2200		
	350x350	1075		2150	625	1250
		1255		2450		
		900		1800		
6 piles 	300x300	900		1800	450	900
		1100		2200		
		1250		2500		
	350x350	1050		2100	600	1200
		1200		2400		
7 piles 	300x300	475	950	1900	800	1600
		625	1250	2500	650	1300
		525	1050	2100	900	1800
	350x350	675	1350	2700		

A typical diagram of a pile cap	The size of the cross section of the pile, mm	Dimensions, mm				
		a	a ₁	A	b	B
1	2	3	4	5	6	7
8 piles 	300x300	475	950	1900	800	1600
		625	1250	2500	650	1300
	350x350	525	1050	2100	900	1800
		675	1350	2700		
9 piles 	300x300	900		1800	900	1800
		1100		2200		
		1400		2800		
		1550		3100		
	350x350	1050		2100	1050	2100
		1225		2450		
		1375		2750		
		1650		3300		
10 piles 	300x300	450	1350	2700	900	1800
		500	1500	3000		
	350x350	550	1650	3300	900	1800
		600	1800	3600		

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			

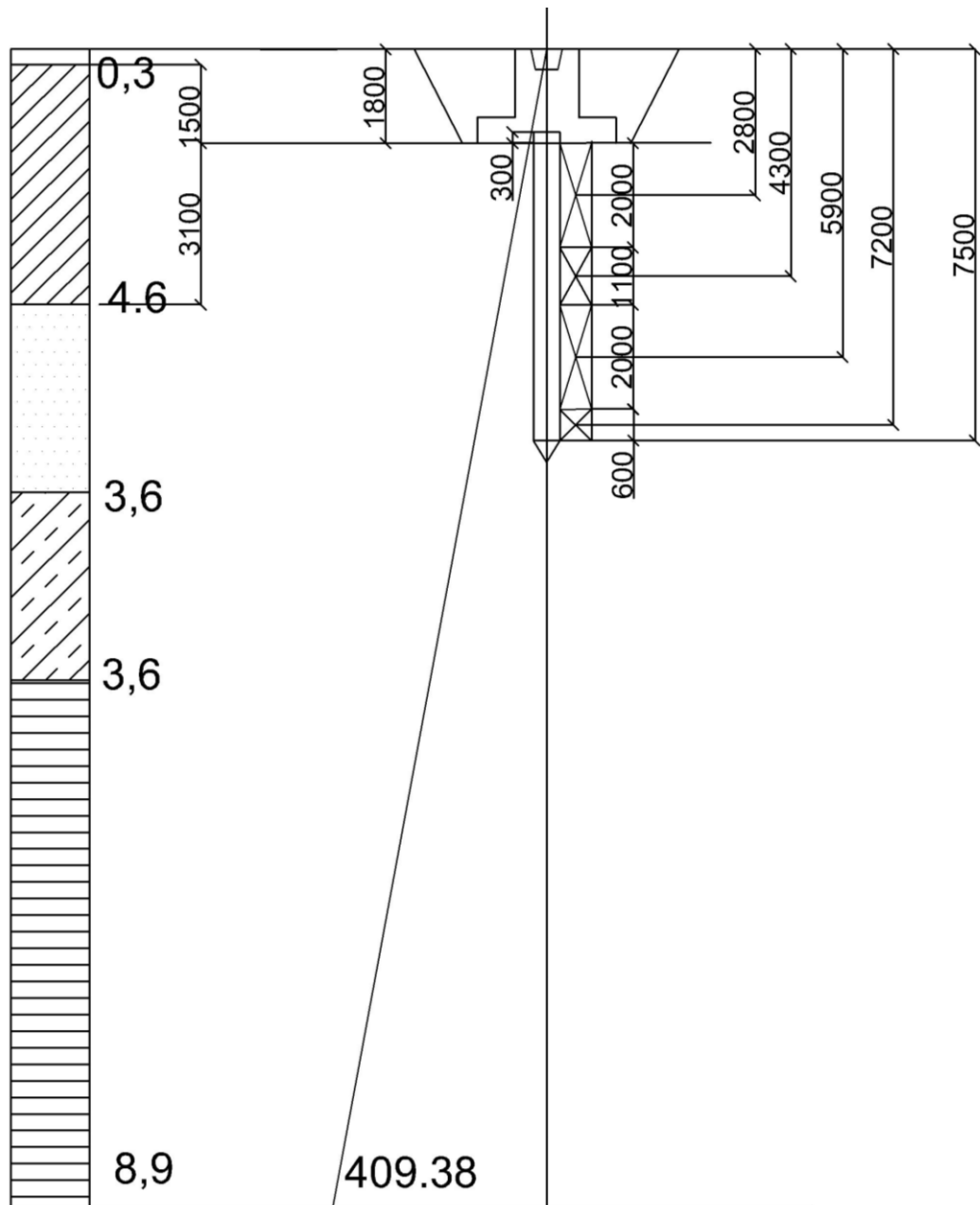
Soil classification indicators

№ 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

Розрахунок і проектування пальових фундаментів



Pile length

$$L_{CB} = 3,1 + 2,6 + 0,3 = 6 \text{ m}$$

We find the calculated characteristics of the soil at full water saturation

$$I_L = \frac{0,9 \cdot e \cdot \frac{\gamma_w}{\gamma_s} - w_p}{w_L - w_p} = \frac{0,9 \cdot 0,825 \cdot \frac{1}{2,73} - 0,19}{0,35 - 0,19} = 0,5$$

The main depth parameters are the depth of laying the sole of the pile cap and the length of the piles.

We will accept the sole of the pile cap for constructive reasons at a depth of 1.8 m.

The pile goes into the pile cap at the anchoring depth of 300 mm.

We will accept driven piles with a section of 300x300 mm, 6 m long.

The heel of the pile is at a depth of 7.5 m.

Bearing capacity of a single friction pile

$$F_d = \gamma_c(\gamma_c \cdot R \cdot A + u \cdot \sum \gamma_{cf} \cdot f_i \cdot h_i),$$

A - the area of the pile resting on the soil : $A=0,09 \text{ m}^2$,

u - the outer perimeter of the cross section of the pile, $u=1,2 \text{ m}$;

$$\gamma_c = 1 \quad \gamma_{cR} = 1 \quad \gamma_{cf} = 1$$

R - estimated soil resistance under the lower end of the pile, kPa,

For the soil, medium-sized sand at depth $Z = 7.5 \text{ m}$

$$z=7 \text{ m} \quad R=3700 \text{ kPa}$$

$$z=10 \text{ m} \quad R=4000 \text{ kPa}$$

$$z=7.5 \text{ m} \quad R = 3700 + \frac{(4000-3700)}{10-7} (7,5 - 7) = 3750 \text{ kPa}$$

$$f_i = \sigma_{zg,i} \frac{v_i}{1 - v_i} \operatorname{tg} \varphi_{II,i} + c_{II,i}$$

v_i - is the Poisson's ratio of the soil in the middle of the i-th calculated layer of the soil base, equal to 0.21 ... 0.29 - for sands, 0.3 ... 0.37 - for sandy loams and loams, and 0.4 - for clays.

We determine the stress from the soil's own weight

$$\sigma_{zg,1} = \gamma_1 \cdot h_1 = 1.39 \cdot 10 \cdot 0.3 = 4.17 \text{ kN/m}^2$$

$$\sigma_{zg,2} = \gamma_1 \cdot h_1 + \gamma_2 \cdot h_2 = 4.17 + 1.72 \cdot 10 \cdot 4.6 = 83.12 \text{ kN/m}^2$$

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

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

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

We determine the stress from the soil's own weight

$$\sigma_{zg,T.1} = \gamma_1 \cdot h_1 + \gamma_2 \cdot h_{T.1} = 4,17 + 1,72 \cdot 10 \cdot 2,5 = 47 \text{ kN/m}^2$$

$$\sigma_{zg,T.2} = \gamma_1 \cdot h_1 + \gamma_2 \cdot h_{T.2} = 4,17 + 1,72 \cdot 10 \cdot 4,05 = 73,63 \text{ kN/m}^2$$

$$\sigma_{zg,T.3} = \sigma_{zg,2} + \gamma_3 \cdot h_{T.3} = 83,12 + 2,01 \cdot 10 \cdot 2 = 103,22 \text{ kN/m}^2$$

$$\sigma_{zg,T.4} = \sigma_{zg,2} + \gamma_3 \cdot h_{T.4} = 83,12 + 2,01 \cdot 10 \cdot 2,3 = 129,39 \text{ kN/m}^2$$

hi	σ_{zg}	v	φ	$\text{tg}\varphi$	c	fi	γ_{cf}	$\Sigma \gamma_{cf} \cdot f_i \cdot h_i$
2	47	0.3	21	0.38	25	32.65	1	65.3
1.1	73.66	0.3	21	0.38	25	37	1	40.7
2	103.22	0.21	33	0.65	1	18.83	1	37.66
0.6	129.39	0.21	33	0.65	1	23.4	1	14.04
							Σ	157.7

$$F_d = \gamma_c (\gamma_{cR} \cdot R \cdot A + u \cdot \Sigma \gamma_{cf} \cdot f_i \cdot h_i) = 1 (1 \cdot 3750 \cdot 0,09 + 1,2 \cdot 157,7) = 522,247 \text{ kN}$$

Piles based on the bearing capacity of the base soil in the soil should be calculated from the condition:

$$N \leq \left(\frac{F_d}{\gamma_k} \right) - \gamma_c \cdot P_n,$$

N – calculated load, kN, for one pile;

F_d – estimated bearing capacity of the soil of the foundation of a single pile,

γ_k - reliability factor (1.4 is accepted if the load-bearing capacity of the pile F_d is determined by calculation);

γ_c – coefficient of working conditions, which depends on the subsidence of the soil:

If $S_{sl} = 5 \text{ sm} - \gamma_c = 0$, if $S_{sl} \geq 2 S_u - \gamma_c = 0.8$ for intermediate values $S_{sl} - \gamma_c$ determined by interpolation;

$$\text{if } \sum S_{sl} = 0,318 \text{ m} \quad \gamma_c = 0.8$$

$$P_n = u \sum_0^{h_{sl}} \tau_i \cdot h_i$$

τ_i - calculated soil resistance, kPa, which is determined up to a depth of 6 m by the formula:

$$\tau_i = \xi \sigma_{zg,i} \operatorname{tg} \varphi_i + c_i$$

ξ - side pressure coefficient, which is equal to 0,7;

φ_i, c_i - calculated values of the angle of internal friction and specific cohesion of the soil, averaged over depth h_i ;

σ_{zg} - vertical stress from self-weight of water-saturated soil, kPa :

h_i - thickness, m, of the soil layer that settles during soaking and is tangential to the lateral surface of the pile.

At a depth of $6\text{ m} < h < h_{sl}$, the value of τ_i is assumed to be constant, equal to the value of τ_i at a depth of 6 m.

$$\tau_i = \xi \sigma_{zg,i} \operatorname{tg} \varphi_i + c_i$$

$$\sigma_{zg,T.1} = \gamma_1 \cdot h_1 + \gamma_{sat} \cdot h_{T.1} = 4 + 1,93 \cdot 10 \cdot 2,5 = 52,25 \text{ kN/m}^2$$

$$\sigma_{zg,T.2} = \gamma_1 \cdot h_1 + \gamma_{sat} \cdot h_{T.2} = 4 + 1,93 \cdot 10 \cdot 4,05 = 82,165 \text{ kN/m}^2$$

$$\tau_1 = \xi \sigma_{zg,i} \operatorname{tg} \varphi_i + c_i = 0,7 \cdot 52,25 \cdot 0,38 + 25 = 38,9 \text{ kPa},$$

$$\tau_2 = \xi \sigma_{zg,i} \operatorname{tg} \varphi_i + c_i = 0,7 \cdot 82,165 \cdot 0,38 + 25 = 46,86 \text{ kPa},$$

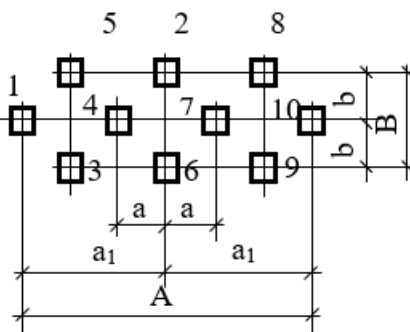
$$P_n = u \sum_0^{h_{sl}} \tau_i \cdot h_i = 1,2 \cdot (38,9 \cdot 2 + 46,86 \cdot 1,1) = 155,22 \text{ kN},$$

$$N \leq \left(\frac{F_d}{\gamma_k} \right) - \gamma_c \cdot P_n = \left(\frac{522,247}{1,4} \right) - 0,8 \cdot 155,22 = 249 \text{ кН}$$

The required number of piles for longitudinal force is determined by the formula:

$$n = \frac{F_v}{N} = \frac{2520}{249} = 10 \text{ шт}$$

Where is the calculated load $F_v = N \cdot 1,2 = 2100 \cdot 1,2 = 2520 \text{ кН}$

A typical diagram of a pile cap	The size of the cross section of the pile, mm	<u>Dimensions, mm</u>				
		a	a ₁	A	b	B
10 piles 	300x300	450	1350	2700	900	1800
		500	1500	3000		
	350x350	550	1650	3300	900	1800
		600	1800	3600		

Checking the amount of load on the extreme pile taking into account the action of the bending moment

$$N_{\max} = \frac{N_d}{n} \pm \frac{M_x y}{\sum y_i^2} \pm \frac{M_y x}{\sum x_i^2} = \frac{2520}{10} + \frac{312 \cdot 1,35}{2 \cdot 0,45^2 + 4 \cdot 0,9^2 + 2 \cdot 1,35^2} = 375,1 \text{ кН}$$

Checking the conditions:

$$N_{\max} = 375,1 \text{ кН} \leq \frac{1,2 \cdot 522,247}{1,4} = 447,6 \text{ кН}$$