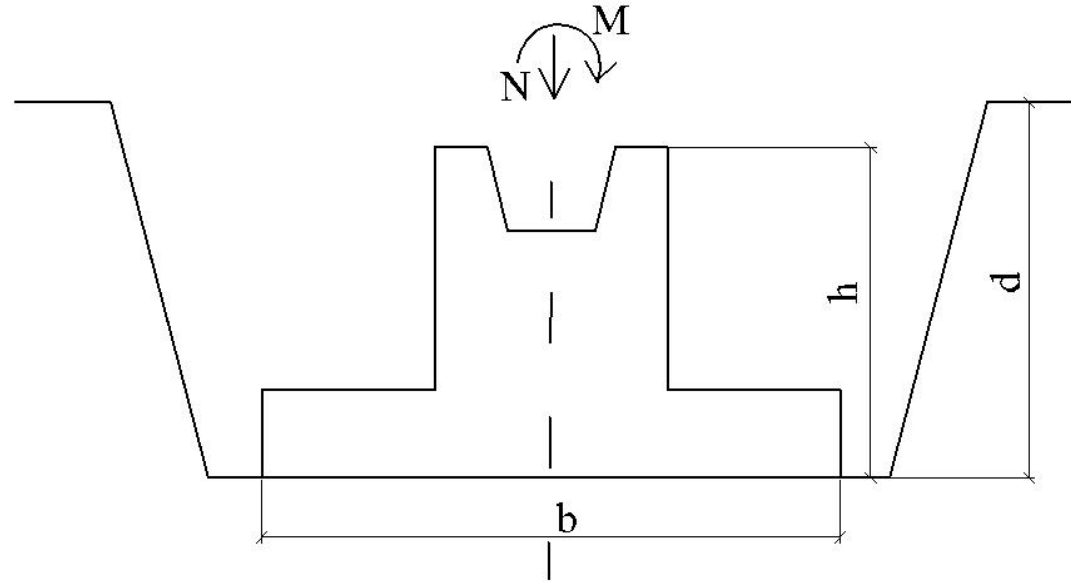


FOUNDATION ON NATURAL SUBSIDING SOIL



A building without a basement - the depth of laying the foundation is determined from the surface of the natural relief, which in this case coincides with the conditional mark of 0.000.

Since the building is heated, the depth of laying the foundation under the columns of the middle row does not depend on the depth of soil freezing, but under the columns of the outer row - it does.

Determining the dimensions of the foundation sole

We design a rigid reinforced concrete foundation.

We will accept the approximate ratio of the dimensions of the sole of the foundation $\eta = \frac{l}{b} = 1,4$
then the width of the foundation sole, m:

$$b = \sqrt{\frac{N \cdot 1000}{\eta \cdot (R - \gamma_{mt} \cdot d - q)}} \quad (1)$$

$$l = 1,4b$$

N – load, MH (we take the larger value of the two combinations)

γ_{mt} – the average calculated value of the specific weight of the soil and foundation material $= 20 \text{ кН/м}^3$,

d – foundation laying depth, counting from the planning mark;

b та l – width and length of the foundation sole;

q – load on the floor, for an industrial building $= 20 \text{ кН/м}^2$.

R – the estimated soil resistance, kPa.

Calculation algorithm

1. Determine R_0 according to the table. 1
2. Find b_0 according to formula (1) taking into account R_0

3. Determine R_1 by the formula:

$$R = \frac{\gamma_{c1} \cdot \gamma_{c2}}{k} \cdot [M_{\gamma} \cdot k_z \cdot b \cdot \gamma_{II} + M_q \cdot d_1 \cdot \gamma'_{II} + (M_q - 1) \cdot d_b \cdot \gamma'_{II} + M_c \cdot c_{II}]$$

γ_{c1} γ_{c2} – coefficients of working conditions, which take into account the type and condition of the base soil and the stiffness of the structural scheme of the structure

k - is a coefficient that takes into account the degree of reliability of determining the characteristics of the base soil;
 $k=1$, if the soil strength characteristics (φ_{II} and c) are determined experimentally; $k=1.1$, if the characteristics of soil strength (φ_{II} and c) are taken according to DBN

$k=1,1$

k_z – a coefficient that takes into account the features of the joint operation of a wide foundation with the base;

If $b < 10$ m **$k_z=1$** ; if $b > 10$ m $k_z = z_0/b + 0,2$ ($z_0=0,8$);

M_{γ} , M_q и M_c - coefficients that depend on the angle of internal friction φ_{II} of the soil and the shape of the foundation in plan;

c_{II} – specific cohesion of the bearing soil layer.

γ_{II} γ'_{II} – average values of specific unit weight of soils above and below the base of the foundation

d_b – basement depth – the distance from the planning level to the basement floor

(for buildings with a basement width $B \leq 20$ m and a depth of more than 2 m, $d_b=2$ is accepted, for a basement width $B > 20$ m, $d_b=0$ is accepted).

$$\gamma' = \frac{\sum \gamma_i h_i}{\sum h_i}$$

$$\gamma'_{II} = 10 \cdot \frac{\rho_1 \cdot h_1 + \rho_2 (d - h_1)}{d}$$

4. We specify the value of b_1 at R_1

5. We find b_2 at R_2

6. The difference between b_2 and b_1 , R_2 and R_1 is less than 10%, then we accept: b_2

$$l_2 = 1,4b_2$$

Table 1 – Estimated resistances R_0 of subsiding soils

Soils	R_0 , kPa (kg/cm ²), soils			
	natural composition with density in the dry state p_d , t/m ³		compacted with density in the dry state p_d , t/m ³	
	1,35	1,55	1,60	1,70
Sandy loams	$\frac{300(3)}{150(1,5)}$	$\frac{350(3,5)}{180(1,8)}$	200(2)	250(2,5)
Loams	$\frac{350(3,5)}{180(1,8)}$	$\frac{400(4)}{200(2)}$	250(2,5)	300(3)
Note: the numerator shows the values of R_0 , which refer to non-soaked loamy soils with a degree of moisture $S_r \leq 0.5$; in the denominator - R_0 values, which refer to the same soils with $S_r \geq 0.8$, as well as to soaked silty soils.				

Table 1– Coefficients of working conditions γ_{c2} , γ_{c2}

soils	Coefficient γ_{c1}	Coefficient for structures with a rigid structural scheme when the ratio of the length of the structure or its section to the height L/H is equal to	
		4 and more	1,5 and less
Large-clastic with sandy aggregate and sand, except small and dusty	1,4	1,2	1,4
The sands are fine	1,3	1,1	1,3
Dusty sands:			
- low moisture and wet,	1,25	1,0	1,2
- saturated with water	1,1	1,0	1,2
Clay, as well as large-fragmented with clay aggregate with a Liquidity index of the soil or aggregate $I_L \leq 0,25$	1,25	1,0	1,1
The same with $0,25 < I_L \leq 0,5$	1,2	1,0	1,1
The same with $I_L > 0,5$	1,0	1,0	1,0

Notes:

1 Buildings with a rigid structural scheme include buildings whose structures are specially adapted to absorb forces from deformation of the foundations, including due to the measures specified in Appendix K [1].

2 For buildings with a flexible structural scheme, the value of the coefficient γ_{c2} is assumed to be equal to one.

3 At intermediate L/H values, the γ_{c2} coefficient is determined by interpolation.

4 For loose sands γ_{c1} and γ_{c2} taken equal to 1.

Table 2 - Coefficients M_γ, M_q, M_c

Angle of internal friction , deg. φ_{II}	Coefficients			Angle of internal friction φ_{II} , deg.	Coefficients		
	M_γ	M_q	M_c		M_γ	M_q	M_c
0	0	1,00	3,14	23	0,69	3,65	6,24
1	0,01	1,06	3,23	24	0,72	3,87	6,45
2	0,03	1,12	3,32	25	0,78	4,11	6,67
3	0,04	1,18	3,41	26	0,84	4,37	6,90
4	0,06	1,25	3,51	27	0,91	4,64	7,14
5	0,08	1,32	3,61	28	0,98	4,93	7,40
6	0,10	1,39	3,71	29	1,06	5,25	7,67
7	0,12	1,47	3,82	30	1,15	5,59	7,95
8	0,14	1,55	3,93	31	1,24	5,95	8,24
9	0,16	1,64	4,05	32	1,34	6,34	8,55
10	0,18	1,73	4,17	33	1,44	6,76	8,88
11	0,21	1,83	4,29	34	1,55	7,22	9,22
12	0,23	1,94	4,42	35	1,68	7,71	9,58
13	0,26	2,05	4,55	36	1,81	8,24	9,97
14	0,29	2,17	4,69	37	1,95	8,81	10,37
15	0,32	2,30	4,84	38	2,11	9,44	10,80
16	0,36	2,43	4,99	39	2,28	10,11	11,25
17	0,39	2,57	5,15	40	2,46	10,85	11,73
18	0,43	2,73	5,31	41	2,66	11,64	12,24
19	0,47	2,89	5,48	42	2,88	12,51	12,79
20	0,51	3,06	5,66	43	3,12	13,46	13,37
21	0,56	3,24	5,84	44	3,38	14,50	13,98
22	0,61	3,44	6,04	45	3,66	15,64	14,64

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

1. First, let's accept R_0 for table 1.

$$\rho_d = \frac{\rho}{(1+W)} = \frac{1,72}{(1+0,15)} = 1,496 \text{ t/m}^3.$$

$$\rho_d = 1.35 \text{ т/м}^3 \quad R_0 = 350 \text{ kPa}$$

$$\rho_d = 1.55 \text{ т/м}^3 \quad R_0 = 400 \text{ kPa}$$

$$\rho_d = 1.496 \text{ т/м}^3 \quad R_0 = 350 + \frac{400-350}{1,55-1,35} (1,496 - 1,35) = 387 \text{ kPa}$$

2. Find b_0 using the formula

$$b_0 = \sqrt{\frac{2100}{\mathbf{1,4} (387 - 20 \times \mathbf{1.8} - \mathbf{20})}} = 2.31 \text{ м}$$

3. Determine R1 by the formula:

$$R = \frac{\gamma_{c1} \cdot \gamma_{c2}}{k} \cdot (M_{\gamma} \cdot k_z \cdot b \cdot \gamma_{II} + M_q \cdot d_1 \cdot \gamma'_{II} + (M_q - 1) \cdot d_b \cdot \gamma'_{II} + M_c \cdot c)$$

$$\gamma_{c2} = k = k_z = 1 \quad d_b = 0 \quad \gamma_{c1} = 1,25 \quad c = 25 \text{ кПа}$$

$$\text{For } \varphi_2 = 21 \quad M_{\gamma} = 0,56 \quad M_q = 3,24 \quad M_c = 5,84$$

$$\gamma_{II} = 10 \cdot \rho_2 = 17,2 \text{ (кН/м}^3\text{)}$$

$$\gamma'_{II} = 10 \cdot \frac{\rho_1 \cdot h_1 + \rho_2 (d - h_1)}{d} = 10 \frac{1,39 \cdot 0,3 + 1,72 \cdot (1,8 - 0,3)}{1,8} = 16,7 \text{ (кН/м}^3\text{)}$$

$$R_1 = \frac{1,25 \cdot 1}{1} (0,56 \cdot 1 \cdot 2,31 \cdot 17,2 + 3,24 \cdot 1,8 \cdot 16,7 + 5,84 \cdot 25) = 327,1 \text{ кПа}$$

4. We specify the value of b1 at R1

$$b_1 = \sqrt{\frac{2100}{1,4 (327,1 - 20 \times 1,8 - 20)}} = 2,35 \text{ м}$$

5. We specify R2 according to the formula:

$$R_2 = \frac{1.25 \cdot 1}{1} (0.56 \cdot 1 \cdot 2.35 \cdot 17.2 + 3.24 \cdot 1.8 \cdot 16.7 + 5.84 \cdot 25) = 329,8 \text{ kPa}$$

6. We specify the value of b2 at R2

$$b_2 = \sqrt{\frac{2100}{1,4 (329,8 - 20 \times 1.8 - 20)}} = 2.34 \text{ m}$$

7. Find the difference between b2 and b1

$$\frac{2,35 - 2,34}{2,35} 100\% = 0,4\% < 10\%$$

Since the difference is less than 10%, we accept:

b= 2.4 m, **l**= 3.4 m, **d**=1.8 m, **R**=330.4 kPa, **1.2R**=396.5 kPa

8. We perform checks of the ultimate stresses, kPa:

$$P_{\max} = \frac{N}{b \cdot l} + \gamma_{mf} \cdot d + q + \frac{M}{W} \leq 1.2R$$

$$P_{\min} = \frac{N}{b \cdot l} + \gamma_{mf} \cdot d + q - \frac{M}{W} > 0$$

$$P_{cp} = \frac{N}{b \cdot l} + \gamma_{mf} \cdot d + q \leq R$$

$$W = \frac{b \cdot l^2}{6} = \frac{2,4 \cdot 3,4^2}{6} = 4,624 \text{ m}^3$$

1. $N=2100 \text{ kN}$ $M=260 \text{ kNm}$

$$P_{\max} = \frac{2100}{2,4 \cdot 3,4} + 20 \cdot 1,8 + 20 + \frac{260}{4,624} = 369,6 \text{ kPa} < 396,5 \text{ kPa}$$

$$P_{\min} = \frac{2100}{2,4 \cdot 3,4} + 20 \cdot 1,8 + 20 - \frac{260}{4,624} = 257,1 \text{ kPa} > 0 \text{ kPa}$$

$$P_{cp} = \frac{2100}{2,4 \cdot 3,4} + 20 \cdot 1,8 + 20 = 313,4 \text{ kPa} < 330,4 \text{ kPa}$$

2. $N=1200 \text{ kN}$ $M=410 \text{ kNm}$

$$P_{\max} = \frac{1200}{2,4 \cdot 3,4} + 20 \cdot 1,8 + 20 + \frac{410}{4,624} = 291,7 \text{ kPa} < 396,5 \text{ kPa}$$

$$P_{\min} = \frac{1200}{2,4 \cdot 3,4} + 20 \cdot 1,8 + 20 - \frac{410}{4,624} = 114,4 \text{ kPa} > 0 \text{ kPa}$$

$$P_{cp} = \frac{1200}{2,4 \cdot 3,4} + 20 \cdot 1,8 + 20 = 203,1 \text{ kPa} < 330,4 \text{ kPa}$$

Conditions are met.