Оглавление

INTRODUCTION

The main objective of the discipline “Foundation engineering” is to study the general provisions on the design of foundations and foundations; the basic principles on the design of foundations of shallow foundations and pile foundations; methods for calculating sediment (according to current regulatory and technical documents); principles of the design of pits and ensuring the stability of the walls of pits. Special attention is paid to the general principles of construction on structurally unstable soils and the examination of the actual condition of the foundations and foundations of buildings and structures.

The main characteristics of subsident soils are given, the procedure for designing foundations and foundations on subsident soils is indicated, and some technical and technological ways to improve the foundations are given.

Practical questions and examples of problem solving, considered in the teaching manual, will contribute to the mastering and consolidation of the material, help to organize the independent work of students in the course of practical classes.

PRACTICAL EXERCISES IN THE DISCIPLINE "FOUNDATION ENGINEERING"

Practical Lesson 1

1.1. Binding of the building to a specific engineering and geological section

The design of bases and foundations of buildings and structures is preceded by engineering-geological and engineering-hydrometeorological surveys. The scope and composition of the surveys depend on the structural and operational features of the facility to be constructed and the complexity of engineering and geological conditions on the construction site.

It is recommended to take a horizontal scale of 1 : 200 and a vertical scale of 1 : 100 for construction of the geotechnical cross-section. Marks corresponding to the same type of soil are connected by straight lines. Each soil layer is shaded in accordance with the accepted designations.

Example 1.1

The fragment shown in fig. 1.1 shows the outline of the building and 3 wells. Construct a geotechnical section between axes 1 and 2 along the A-axis. The lithological columns for the wells are given in table 1.1. The distances between borehols 10–15 and 15–20 are 24 and 34 m, respectively.

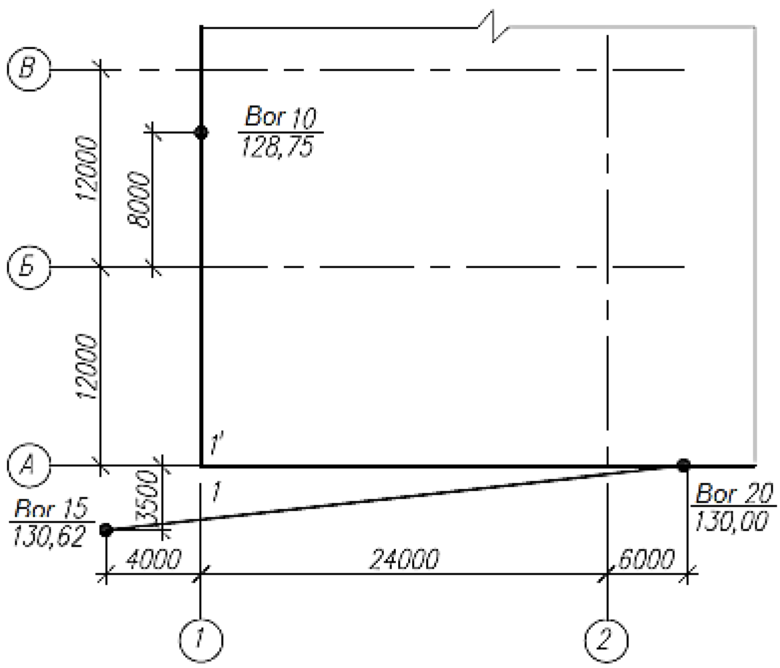


Fig. 1.1. Fragment of the site plan

Table 1.1

Lithological columns by borehols

Layer number	Soil name	Marks of the sole of the layers according to drilling data, m		
		Bor. $\frac{10}{128,75}$	Bor. $\frac{15}{130,62}$	Bor. $\frac{20}{130,00}$
1	Soil-vegetative	128,05	129,94	129,5
2	Loam	127,52	128,14	127,68
3	Sandy loam	126,52	127,34	125,85
4	Sand	115,62	118,15	116,5

Let's find the top marks of the layers at the reference point 1, which is located between boreholes 15 and 20 at distances of 4 and 30,0 m, respectively. Calculate the relative excess per meter of length. As the difference of the marks divided by the distance between the boreholes:

$$\Delta = \frac{NL_{15} - NL_{20}}{L} = \frac{130,62\ -\ 130,00}{34,0} = \frac{0,62}{34} = 0,0182.$$

The elevation of point 1 will then be calculated as the difference between the elevation of borehole 15 and the relative excess multiplied by the distance from borehole 15 to point 1.

$$130{,}62 – 0{,}0182 \cdot 4 = 130{,}55 \text{ m.}$$

Similarly, should find marks for all layers of soil on the considered vertical.

To build a geological section along the A-axis it is necessary to carry out interpolation between point 1 and well 10, that is to find marks for point 1, located at a distance of 3,5 m from point 1' and 20,5 m from borehole 10. The results of the calculations are shown in table 1.2.

Table 1.2

Results of calculations by boreholes

Layer number	Soil name	Layer sole marks		
		Point 1 / 130,54	Bor. 10 / 128,75	Point 1' / 130,28
1	Soil and vegetative	129,92	128,05	129,65
2	Loam	128,08	127,52	127,99
3	Sand loam	127,14	126,52	127,05
4	Sand	117,93	115,62	117,59

Based on these calculations, it is necessary to construct a geological section (fig. 1.2).

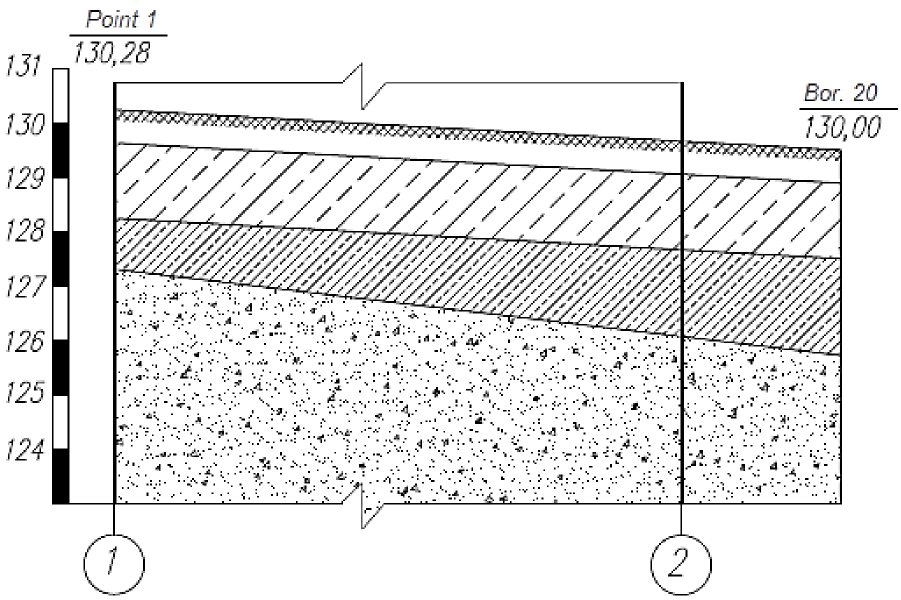


Fig. 1.2. Geological section

The next step after the construction of the engineering-geological section and the classification of the base soils (practical exercise 1) is a direct assessment of each of the soil layers with a prediction of possible changes in the properties of soils and the conclusion about the possibility of using them as a base.

Silts, peat, peaty soils, loose sands, clay soils in a fluid state and with porosity coefficients of sandy loam $e > 0{,}7$, loam $e > 1$ and clay $e > 1{,}1$ when erecting structures have a low bearing capacity or give large precipitation and cannot be used as natural bases of structures. Soils with $R_0 \leq 0{,}1$ MPa are also referred to as “weak” soils, which cannot be designated as foundations without structural measures or artificial improvement measures.

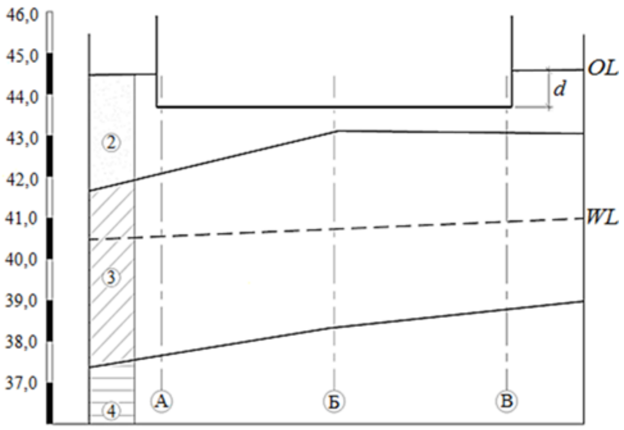


Fig. 1.3. Diagram of linking the building to the engineering-geological section

To determine the thickness of soil layers along the foundation axis, the building or structure is linking to the geological section (fig. 1.3).

The choice of the type of foundations and structural solutions of foundations is carried out according to the results of comparisons of technical and economic indicators. Obtained on the basis of variant design data.

1.2. Preliminary determination of the depth of shallow foundations and pile foundations

Assignment of the preliminary depth of shallow foundations.

The depth of the bottom foundation shall be appointed in accordance with the requirements of SP 22.13330.2016 "Foundations of Buildings and Structures" taking into account the structural features of the building, the relief of the site surface, the geological and hydrogeological conditions of the construction site, and the depth of seasonal freezing of soils. In all cases, the minimum depth of the foundation must be at least 0,5 m.

Taking into account the design features of the structure to be erected, the depth of the bottom foundation must be at least:

– for a columnar foundation for a reinforced concrete column (fig. 1.4, *a*):

$$d = h_f + h_4; \qquad h_f = h_1 + h_2 + h_3, \text{ m,}$$

where h_f — the height of the foundation;

h_1 — the thickness of the concrete slab under the foundation, taken at least 0,2 m;

h_2 — straightening gap under the column, taken as equal to 0,05 m;

h_3 — column embedding depth in the sleeve, taken at least on the larger side of the column cross-section, m;

h_4 — thickness of the floor structure, taken as equal to 0,15 m;

– for strip foundation with a basement (fig. 1.4, *b*):

$$d = d_b + h_{cf} + h_s,$$

where d_b — the distance from the level of planning to the basement floor, m;

h_{cf} — the thickness of the basement floor structure, m;

h_s — the thickness of the soil layer above of the bottom foundation from the basement floor side (in this case $h_{cf} + h_s \geq 0,5$ m).

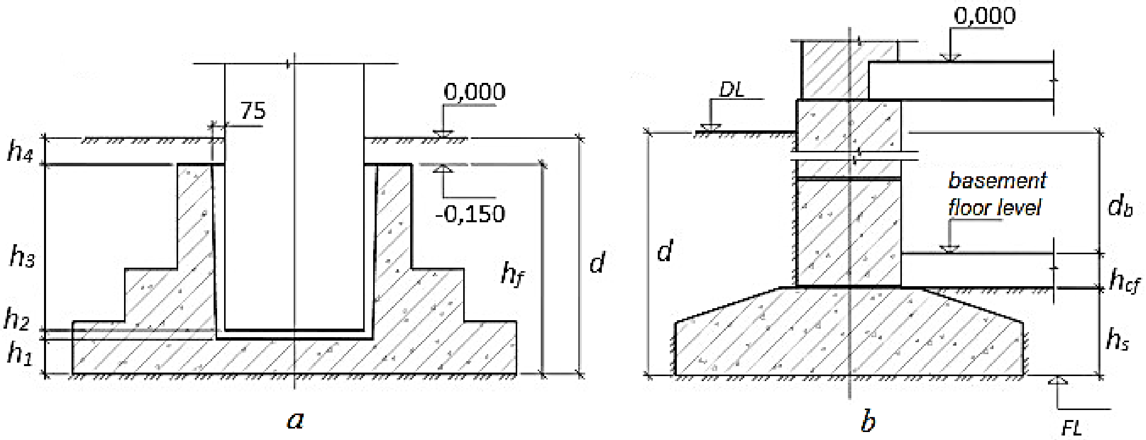


Fig. 1.4. Scheme for determining the depth of the foundation depending on the design features: *a* — for a columnar foundation without a basement; *b* — for a strip foundation with a basement

1.3. Influence of the depth of seasonal soil freezing

In accordance with the standards for design of foundations, the normative depth of soil freezing d_{fn} is determined in one of the following ways:

1) by observational data as the average of the annual (not less than 10 years) maximum seasonal freezing depths under the surface bare of snow at the groundwater level below the depth of seasonal ground freezing;

2) according to the map of normative depths of seasonal freezing of conditional ground, as which is taken the clay, with subsequent correction of this value by type of ground;

3) according to the formula for areas where the depth of soil freezing does not exceed 2,5 m:

$$d_{fn} = d_0\sqrt{M_t}, \quad (1.1)$$

where M_t — a dimensionless factor equal to the sum of absolute average monthly negative temperatures during the winter period in the construction region; d_0 is the freezing depth at $M_t = 1$, taken as 0,23 m for clays and loams; 0,28 m for sandy loam and fine sands; 0,3 m for sands of medium size, large and gravelly; 0,34 m for macrofragmental soils.

The calculated value of the frost penetration depth is determined by the formula:

$$d_f = k_h d_{fn}, \quad (1.2)$$

where k_h — the coefficient of influence of the temperature regime of the building on freezing of the ground near the exterior wall;

k_h — for the exterior and interior foundations of unheated buildings is equal to 1,1, except for areas with a negative average annual temperature, and for the exterior foundations of heated buildings — according to the table 5.2 of SP 22.13330.2016 Foundations of Buildings and Structures.

The final depth of the foundations is the greater of the values obtained in the analysis of the above factors.

Appointment of the preliminary depth of the grillage. The depth of the bottom foundation grillage is assigned taking into account the structural features of the underground part of the building (basement, technical basement, etc.), the height of the foundation and the depth of seasonal ground frost penetration.

The top of the foundation beams of non-basement buildings is taken 150 mm below the planning level. In residential and public buildings with a basement, the height of the basement footings for exterior walls is equal to the basement floor elevation, and for interior walls — the height of the top of the basement is equal to the basement floor elevation. In industrial buildings with a basement, the basement top mark is assumed to be equal to the basement floor mark.

Depending on the depth of seasonal freezing of soils, the depth of the bottom of the foundation footing is taken in accordance with the requirements for shallow foundations. The height of the foundation under the wall is taken for preliminary calculations equal to 300–500 mm, width not less than 400 mm. In the pile foundations of frame buildings a socket under the column is arranged, the height of the socket must be such that the layer of concrete below the bottom of the socket is not less than 500 mm.

1.4. Calculation methods for limit states, performing preliminary calculations

Base and foundations are calculated according to two groups of limit states. The first group of limit states is the calculation of bearing capacity. The purpose of calculations in Group I is to ensure the strength and stability of the foundation and to prevent the foundation from shifting on its underside and overturning.

Foundations shall be calculated with regard to the bearing capacity in cases stipulated below:

a) large horizontal loads are transferred to the foundation (retaining walls, struts);

b) the structure is located on a slope or near a slope;

c) the foundation is composed of slowly compacted water-saturated dusty-clayey or biogenic soils (with a consolidation coefficient of $Cv \leq 107$ cm^2/year, water saturation coefficient $Sr \geq 0{,}85$; fluidity index $I_L > 0{,}5$);

d) the foundation is subjected to a pulling load;

e) there is a layer of steeply falling plastic clayey soils in the foundation.

Calculation of foundations and bases according to the first group of limit states is performed on the basis of the condition:

$$F \leq \frac{\gamma_c F_u}{\gamma_n},$$

where F — the design load on the foundation;

F_u — the ultimate strength of the foundation;

γ_c — the coefficient of working conditions, taken in the range of 0,8–1,0, depending on the type of soil;

γ_n — the factor of reliability for the purpose of construction, taken equal to 1,2; 1,15; 1,10 respectively for buildings and structures of I, II, III classes.

The second group of limit states — the calculation of deformations.

The goal of calculations in the second group of limit states is to restrict the absolute and relative movements of foundations to certain conditions that guarantee the normal operation of the building or structure during its entire service life.

For the majority of industrial and civil buildings and structures, as a rule, the calculation of foundations by deformations is the main one, since they are established exclusively from the conditions of normal operation of the structures themselves.

1.5. Calculation of foundations on deformations is carried out from the condition:

$$s \leq s_u,$$

where s — the joint deformation of the foundation and the structure, determined by calculation;

s_u — the limit value of the joint deformation of the foundation and the structure, recommended in SP 22.13330.2016.

The uneven settlement of the structure is checked on the basis of the condition:

$$(\Delta s / L) \leq (\Delta s / L)_u,$$

where Δs — the difference between the settlements of neighboring foundations determined by calculation;

L — the distance between the axes of the adjacent foundations in question;

$\Delta s/L$ — the relative difference in settlement;

$(\Delta s/L)_u$ — the maximum allowable value of the relative difference in settlement, recommended in SP 22.13330.2016.

The roll of the building or structure is checked on the basis of the condition:

$$i \leq i_u,$$

where i — the roll of the structure according to the calculation;

i_u — the maximum allowable roll of the structure recommended in SP 22.13330.2016.

The foundations must be designed so that neither the first nor the second limit state can occur

Performing preliminary calculations

Design of foundations and bases is performed in the following sequence:

1. Assessment of the results of engineering-geological, engineering-geodesic and engineering-hydrometeorological surveys for construction.

2. Analysis of the designed building and structure. In accordance with the design assignment the planned dimensions of the structure, its design and calculation schemes, materials of structural elements, methods of transfer of loads on the ground are determined. Based on the structural, operational and technological requirements, the sensitivity of the structure or its individual parts to uneven settlements is determined, the limit values of deformations of the foundation are assigned.

An important step is to determine the loads acting on the structure (wind loads, light loads, special loads, etc.), as well as loads from the bearing structures of the structure, floors, various types of equipment and operating conditions, transmitted to the foundations.

3. Selection of the type of base and foundation structures. With the information listed above, the projected structure is tied up to the construction site, i.e. the alignment of the structure axes with the engineering geological cross sections and the selection depth of the bottom foundation. This is where the process of designing footings and foundations actually begins.

4. Calculation of foundations according to the limit states, technical and economic analysis of the options and making of the final decision.

Example 1.2

Determine the preliminary width of the strip foundation footing with the embedment depth of d = 2,1 m. The design load of the second group of limiting conditions at the edge of the foundation N_{II} = 450 kN/m. The mark *DL* coincides with the mark *NL*.

EGE-1: (layer thickness is 1,0 m). Embankment is not compacted, R_0 not standardized.

EGE-3: (layer thickness is 3,5 m). Medium-grained, dense sand with low water content R_0 = 400 kPa (table B.2, SP 22.13330.2016).

Let's determine the area of the foundation's footing $A = bl$. For a strip foundation, l = 1 m.

$$A = \frac{N_{\text{II}}}{R_0 - \gamma_{cp}\, d}, \tag{1.3}$$

where γ_{cp} — the average value of the specific weight of the foundation material and the ground support, taken as 20 kN/m^3.

$$A = \frac{450}{400 - 20 \cdot 2{,}1} = 1{,}26 \text{ m}^2.$$

Since for the strip foundation l = 1 m, the width depth of the bottom of the strip foundation b = 1,26 m. We take, according to GOST 13580-85, the nearest value to the larger side of the foundation plate width of 1,4 m.

Example 1.3

To determine the preliminary width of the footing base with a columnar foundation with a footing depth of d = 2,7 m. The design load of the second group of limiting conditions at the foundation's edge N_{II} = 500 kN. The *DL* mark coincides with the *NL* mark.

Soil conditions are similar to Example 1.1.

Using formula (1.1), let us determine the area of the columnar foundation's underside.

$$A = \frac{500}{400 - 20 \cdot 2{,}1} = 1{,}397 \text{ m}^2.$$

Since for the columnar foundation $A = bl$, where b and l are the width and length of the foundation. In accordance with GOST 24476-80*, let's assume that the foundation has a square shape in the plan. Then

$$b = \sqrt{\frac{500}{400 - 20 \cdot 2{,}1}} = 1{,}18 \text{ m}.$$

Finally accept b = 1,2 м m according to GOST 24476-80*.

Practical Lesson 2

2.1. Fundamentals of shallow foundations design, peculiarities of calculation the limit states

According to the regulations in force of SP 22.13330.2016, the design the bases and foundations grounded on the limit states, taking into account the joint operation of the system of base, foundations, and above-ground structures is provided.

In all cases, the foundations are calculated according to the second group of limit states.

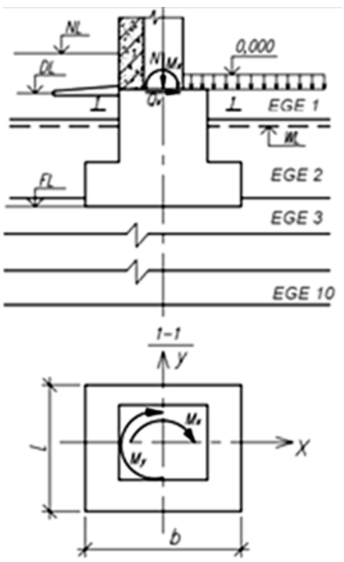


Fig. 2.1. Calculation scheme

Fig. 2.1 shows the design diagram of a single columnar foundation in the stratum of a multilayer soil foundation. The foundation and base operate jointly under the action of loads N_{II}, M_{IIx}, Q_{IIx}, M_{IIy}, Q_{IIy}, indicated in the diagram, to which the above-ground part of the building is exposed.

Average pressure under the foundation's underside P should not exceed the design resistance of foundation soil R:

$$P \le R. \tag{2.1}$$

The pressure on the ground at the edges of the footing P_{max}, P_{min} and at the corner points of the foundation P^{c}_{max} , P^{c}_{min} must satisfy the relations

$$\begin{aligned} P_{max} &\le 1{,}2R; \\ P_{min} &> 0; \\ P^{c}_{max} &\le 1{,}5R; \\ P^{c}_{min} &> 0. \end{aligned} \tag{2.2}$$

To determine the size of the bottom foundation, it is necessary to fulfill the conditions (2.1), (2.2). According to § 5.7 SP 22.13330.2016, the design resistance R can be determined by the formula:

$$R = \frac{\gamma_{c1}\,\gamma_{c2}}{k}\left[M_\gamma\, k_z\, b\,\gamma_{II} + M_q\, d_1\,\gamma'_{II} + (M_q - 1)\, d_b\,\gamma'_{II} + M_c\, c_{II}\right]. \tag{2.3}$$

The average pressure under the bottom of the foundation can be determined by the formula:

$$P = \frac{N_{II}}{A} + \gamma_{cp} d, \tag{2.4}$$

where N_{II} — the vertical load at the top edge of the foundation, kN;

d — the difference between the planning elevation and the foundation's bottom elevation, m;

A — the area of the foundation's underside, m^2 (where l is the foundation's length), $A = bl$;

γ_{cp} — the average value of the specific weight of the soil of the backfill and the foundation structure, which is taken equal to 20 kN/m^3.

The maximum and minimum pressures under the edges of the foundation under the action of the moment of forces with respect to one of the main axes of inertia of the foundation area are determined by the formula:

$$\begin{aligned} P_{max} &= \frac{N^{c}_{II}}{A} + \frac{M^{c}_{II}}{W}; \\ P_{min} &= \frac{N^{c}_{II}}{A} - \frac{M^{c}_{II}}{W}, \end{aligned} \tag{2.5}$$

where N^{c}_{II} — the total vertical load at the level of the foundation's underside, kN;

M^{c}_{II} — the total moment of forces relative to the center of the bottom foundation, kNm;

W — the resistance moment of the foundation's underside, m^3, equal to

$$W = \frac{bl^2}{6}, \tag{2.6}$$

where l — the size of the foundation in the direction of the moment, m.

The maximum and minimum pressures at the corner points of the foundation under the action of the moments of forces in two directions are determined by the formula:

$$P^c_{\max} = \frac{N^c_{\mathrm{II}}}{A} + \frac{M^c_{\mathrm{II}x}}{W_x} + \frac{M^c_{\mathrm{II}y}}{W_y};$$
$$P_{\min} = \frac{N^c_{\mathrm{II}}}{A} + \frac{M^c_{\mathrm{II}x}}{W_x} + \frac{M^c_{\mathrm{II}y}}{W_y}, \tag{2.7}$$

where $M^c_{\mathrm{II}x}$, $M^c_{\mathrm{II}y}$, W_x, W_y — the total moments of forces and moments of resistance of the bottom foundation in the direction of x- and y-axes.

As can be seen from formulas (2.1)–(2.2), the required dimensions of the foundation base can be found from their joint solution, since $R = f(b)$ и $P = f(b, l)$.

Usually, the unknown dimensions of the foundation b and l are determined either by the method of successive approximations or by the graphoanalytic method.

Approximation method. As a first approximation, the value $R = R_0$ is specified (see examples 1.1 and 1.2 of practical exercises 1). After that, we specify the design loads on the foundation and the values of its design resistance by using the formula (2.3) for the obtained width of the foundation. The width of the foundation is determined again for the obtained value of R. Approximations are made as long as the difference between the pressure under the foundation's underside and the design resistance is insignificant.

The procedure for calculating the width of the foundation's underside using the graph-analytical method:

1. A rectangular coordinate system is specified. The values of the bottom foundation width b are plotted along the x-axis. The y-axis is used to plot the values of pressures and design resistance, kPa.
2. Graphs of the equations are plotted $R = f(b)$, $1{,}2R = f(b)$, $P_{cp} = f(b)$, $P_{\max} = f(b)$.
3. In order to plot the dependence $R = f(b)$ it is necessary to determine the value of design resistance at two values of b (for example, at $b = 0$ and at $b = 3$ m).
4. In order to build graphs of dependence $P_{cp} = f(b)$, $P_{\max} = f(b)$ it is necessary to determine their values at several (at least three) values of b.
5. The intersections of plots $P_{cp} = f(b)$ with $R = f(b)$ and $P_{\max} = f(b)$ with $1{,}2R = f(b)$ will give two values of b, at which conditions $P_{cp} \le R$ and $P_{\max} \le 1{,}2R$ will be satisfied (fig. 2.2).
6. The larger value rounded off to the nearest tenth is taken as the final width of the bottom foundation. At the same time, taking into account the plotting errors, it is necessary to check the conditions $P_{\mathrm{cp}} \le R$ and $P_{\max} \le 1{,}2\,R$ with the accepted value of the foundation's base width. If these conditions are not met by more than 5 %, it is necessary to adjust the foundation dimensions towards their increase.

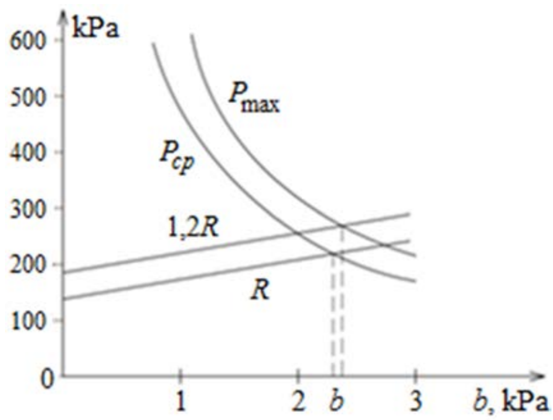


Fig. 2.2. Graphic method for determining the width of the bottom foundation

To calculate the finite (stabilized) settlement of shallow foundations, the method of layer-by-layer summation is most widely used.

The values of the maximum allowable deformations of buildings and structures, as well as the determination of the values of loads on the foundation should be determined by the joint calculation of the system "base — foundation — upper structure", taking into account the requirements from the technical specifications. The terms of reference must clearly reflect all the requirements for the normal operation of the building.

The method of layer-by-layer summation. The method of layer-by-layer summation makes it possible to take into account the heterogeneity of the soil mass in depth.

The calculation formula of the method of layer-by-layer summation (5.16) according to SP 22.13330.2016:

$$s = \beta \sum_{i=1}^{n} \frac{\left(\sigma_{zp,i} - \sigma_{z\gamma,i}\right) h_i}{E_i} + \beta \sum_{i=1}^{n} \frac{\sigma_{z\gamma,i}\, h_i}{E_{e,i}}. \tag{2.8}$$

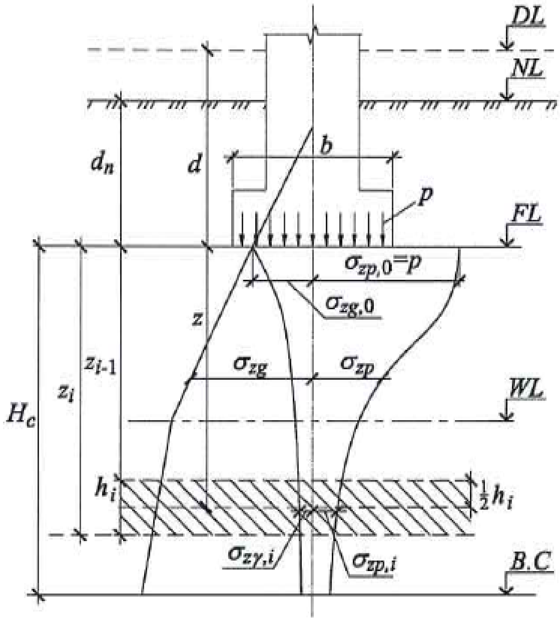


Fig. 2.3. Scheme of vertical stress distribution in a linearly deformed half-space

The diagram 2.3 shows: *DL* — layout mark; *NL* — mark of the surface of the natural relief; *FL* — mark of the foundation's base; *WL* — groundwater level; *B.C* — the lower boundary of the compressible strata; d and d_n — the depth of the foundation, respectively, from the level of planning and the surface of the natural relief; b — the width of the foundation; p — the average pressure under the base of the foundation; σ_{zg} and $\sigma_{zg,0}$ — the vertical stresses from the soil's own weight at the depth z from the foundation's underside and at the underside level; $\sigma_{z\gamma,i}$ — the vertical stress from the own weight of the excavated soil in the middle of the i-th layer at the depth z from the bottom of the foundation; N_c — the depth of the compressible stratum.

For rectangular, circular and strip foundations, the values of σ_{zp}, kPa, at the depth z from the base of the foundation along the vertical line passing through the center of the base, are calculated by the formula:

$\sigma_{zp} = \alpha\, p$,

where α — the coefficient taken according to table 5.8 of SP 22.13330.2016 depending on the relative depth ζ, equal to $2z/b$;

p — the average pressure under the foundation's underside, kPa.

The vertical stress from the soil's own weight at the foundation's footing level $\sigma_{z\gamma} = \sigma_{zg} - \sigma_{zu}$, kPa, at the depth z from the footing of rectangular, circular and strip foundations values are calculated by the formula:

$$\sigma_{z\gamma} = \alpha\, \sigma_{zg,0},$$

where α — the coefficient taken according to table 5.8 of SP 22.13330.2016 depending on the relative depth ζ, equal to $2z/b$;

$\sigma_{zg,0}$ — the vertical stress from the soil's own weight at the foundation's underside mark, kPa (when planning by cutting $\sigma_{zg,0} = \gamma' d$, in the absence of leveling and leveling by backfill $\sigma_{zg,0} = \gamma' d_n$, where γ' — specific gravity of soil kN/m^3 located above the bottom (fig. 2.3).

In this calculation, $\sigma_{z\gamma}$ uses the dimensions in the plan, not the foundation, but the excavation.

2.2. Ensuring stability of excavation walls

Sheet pile fences enclosures are thin retaining walls whose stability is ensured by deep embedding in the ground. In relatively shallow pits (up to 4 m) the stability of the sheet piling is ensured by its embedding below the bottom of the excavation. In deep excavations, the retaining wall must be secured with anchors, struts or other methods.

Sheet piles can be made of:

– wood;
– steel;
– reinforced concrete;
– plastic elements.

Wooden sheet piles (fig. 2.4) are used to secure small pits or trenches up to 2...3 m deep. Wooden sheet piles are made from bars or boards, by selecting the groove and ridge. Less often they are made of composite boards connected with nails.

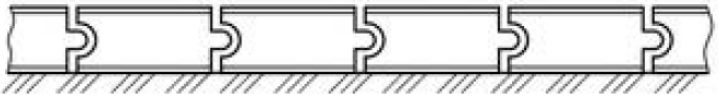


Fig. 2.4. Sheet pile row with wooden boards

Metal sheet pile made of steel sheet pile profiles (fig. 2.5) can be hammered in and out of the ground many times. It is easy to transport and more cost-effective than wooden sheet piles. An important advantage of steel sheet piles is not only the ability to absorb lateral earth pressure, but also to be a watertight structure that prevents water from seeping through the section of the fence. Properly made locking joints of the sheet pile profiles and the plugging effect make the sheet piling fences practically watertight when erected. In difficult hydro-geological conditions or in ponds, the locks of the sheet piling profiles are treated with a special sealant to make the fences watertight.

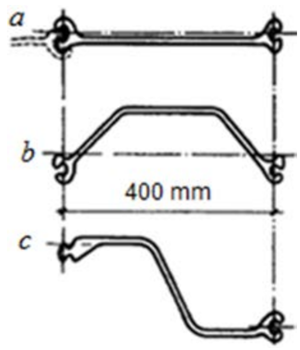


Fig. 2.5. Profiles of a rolled steel sheet pile:
a — flat; *b* — trough; *c* — Z-shaped

Reinforced concrete sheet piles are used in the construction of hydraulic structures and structures to strengthen the banks of ponds, or in cases where the sheet pile is further used as part of the construction of a building or structure. Reinforced concrete sheet piles are rectangular in shape, with a trapezoidal slot and a crest. The length of such piles does not exceed 15 m. If they are longer, cracks can form during transport and installation.

The sheet piles are sunk into the ground by various methods: vibro-diving, impact method, indentation method or screwing.

Sheet piling must be designed on the basis of:

– available data and the results of engineering and geological and hydrogeological surveys performed at the time of new construction;

– data obtained as a result of the survey and characterizing the design features and condition of existing buildings and structures as well as the stabilization of deformations in the foundations of structures during their operation based on the results of observations or calculations;

– data on the parameters of oscillations of soils, buildings and structures caused by pile driving or vibro-loading of piles and sheet piles;

– technical and economic comparison of possible variants of design solutions.

2.3. Calculation methods for excavation enclosures and protection against waterlogging

Determination of active and passive ground pressure on the excavation enclosures is similar to the determination of active and passive ground pressure on retaining walls. These issues have already been discussed in detail in the Geotechnical Engineering course.

Approximate method for calculating the stability of fences. This method consists in the fact that the length of the fence must be such that the condition is observed:

$$\frac{M_p}{M_a} \geq 1{,}1. \tag{2.9}$$

The calculation is carried out in the following order. Active and passive ground pressures are plotted. In the expressions for determining the active and passive pressures we substitute the weighted average values of the specific gravity γ_{cp}, the angle of internal friction φ_{cp} and the specific cohesion of soils c_{cp}, lying in the limit of thickness ($H + t$):

$$\begin{aligned} \gamma_{cp} &= \sum \gamma_i h_i / \sum h_i; \\ \varphi_{cp} &= \sum \varphi_i h_i / \sum h_i; \\ c_{cp} &= \sum c_i h_i / \sum h_i. \end{aligned} \tag{2.10}$$

The active pressure force is equal to the area of the active ground pressure diagram and is calculated:

– as the area of a rectangular triangle in the absence of a payload along the excavation edge (fig. 2.6, *a*):

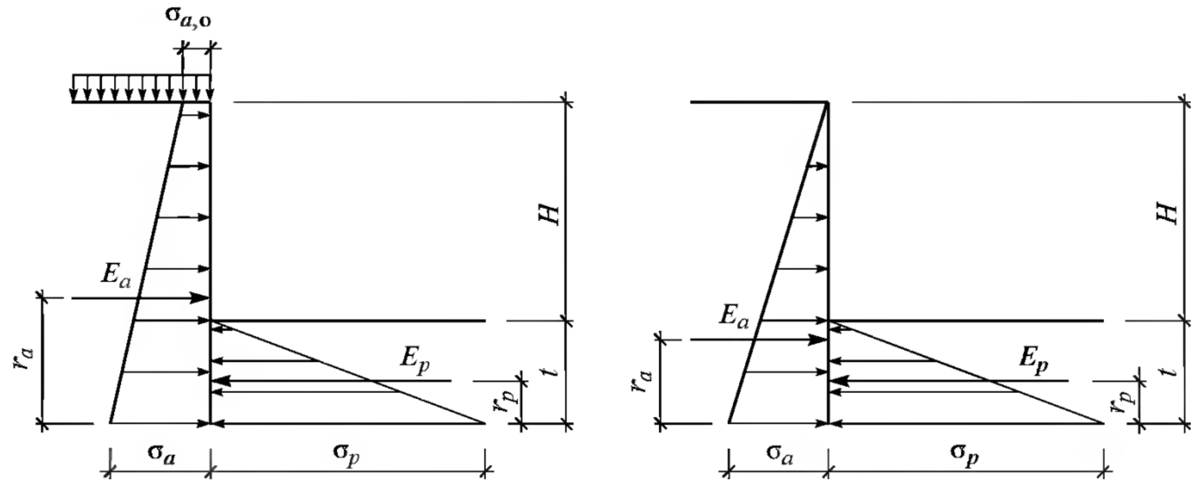
$$E_a = 0{,}5\sigma_a (H + t); \tag{2.11}$$

– as the area of a rectangular trapezoid in the presence of a payload on the pit's edge:

$$E_a = 0{,}5(\sigma_a + \sigma_{a,0})\ (H + t). \tag{2.12}$$

The passive pressure force is calculated according to a similar principle (fig. 2.6, *b*):

$$E_p = 0{,}5\, \sigma_p^t. \tag{2.13}$$



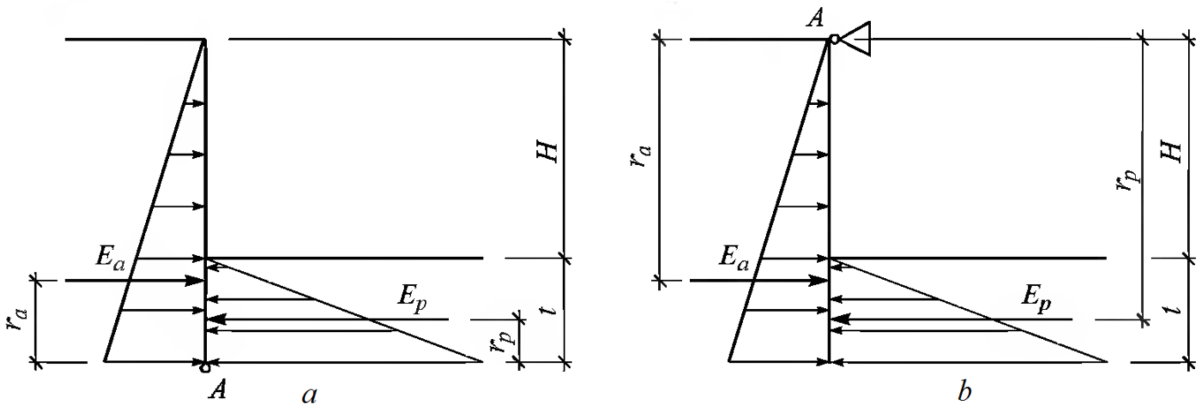
a *b*

Fig. 2.6. Calculation scheme: *a* — the case with the load on the pit's edge; *b* — without it

Moment of tilting force and its shoulder (the force at the level of the center of gravity of the section of the epyure) for the case of the cantilever wall shown in fig. 2.7, *a*:

$$M_a = E_a r_a; \tag{2.14}$$

$$r_a = (H + t) / 3. \tag{2.15}$$



a *b*

Fig. 2.7. Calculation scheme for determining r_a and r_p for the cantilevered (*a*) and braced (*b*) walls