The dynamics of changes in the physical and mechanical characteristics of the base soil

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Abstract. This article discusses the change in the physical and mechanical characteristics of the foundation soil during the operation of construction projects and the possibility of taking these changes into account when designing shallow foundations. Methods Based on the assumption that the weight of the engineering and geological elements of the base remains constant regardless of the level of existing additional vertical stresses, an expression is obtained for determining the coefficient \( k_γ \), taking into account changes in the density and specific gravity of the soil during the operation of buildings and structures. Moreover, based on the assumption that the plot of the additional vertical stresses is triangular, an equation for calculating the coefficient \( k_c \) is determined, which allows determining the change in soil adhesion during the operation of construction projects. Using the coefficients \( k_γ \) and \( k_c \), an expression is obtained to determine the change in the calculated resistance of the soil of the base during the operation of construction projects. Taking into account the coefficient \( k_γ \) with the width of the projected foundation more than two meters with a ratio of settlement of the base to the depth of the compressible thickness equal to 0.3 leads to an increase in the design resistance of the operated base by 5%; by 3% and 1% with \( S/H_c = 0.2 \) and with \( S/H_c = 0.1 \), respectively. In this case, depending on the width of the designed foundation, taking into account the coefficient \( k_c \) allows you to exceed \( R \) by 25%. Joint accounting of the considered coefficients leads to an increase in the calculated resistance of the soil of the base by an average of 27%. Conclusion The obtained coefficients, taking into account changes in the specific gravity and soil adhesion during the operation of the base, make it easy to estimate the growth of the design resistance during the compression process, which in turn makes it possible to save an average of 10% of the material when designing shallow foundations.

1. Introduction
It is known that in the process of buildings and structures operation there is a change in the physical mechanical characteristics of the soil base. In particular, there is an increase in the specific weight, the angle of internal friction, grip.

Changes in these characteristics lead to a change in the calculated resistance of the base soil [1-21]. Therefore, it is necessary to develop methods of analyzing the dynamics of changing the physical mechanical characteristics of the ground to assess the residual resource of the base during the reconstruction of buildings and structures, as well as to take into account the width of the foundation sole at the design stage [11, 12].
2. Method for assessing changes in the specific gravity of soil

One of the main conditions of the base’s strength according to the 2 group of limit states: the average pressure under the sole of the foundation should not exceed the calculated resistance of the base soil \[ P_{cp} \leq R \]. Calculated resistance \((R)\) according to current regulatory documents is determined by the known formula (1):

\[
R = \frac{\gamma_{v1} \gamma_{v2}}{k} \left[ M_y \cdot k_z \cdot b \cdot \gamma_{H1} + M_q \cdot d_1 \cdot \gamma_{H1} + (M_q - 1) \cdot d_2 \cdot \gamma_{H1} \right] + M_c \cdot c_2
\]

The change of soil specific weight is connected with joint deformation of the "building- basis" system \([9, 17, 18]\):

\[
\gamma_{H2} = \frac{\gamma}{\gamma_v} \cdot \frac{1}{1 + \frac{M_c}{M_q} \cdot \gamma v1} \cdot \gamma_{H1},
\]

i.e. change of this physical characteristic can be defined as the soil weight ratio to a difference between compressed thickness depth and draft. To study the dynamics of the change in the calculated resistance when increasing the specific weight, we will determine the \(k_y\) coefficient, taking into account the change in the specific weight of the soil during operation:

\[
k_y = H_c / (H_c - S) = 1 / (1 - S / H_c).
\]

3. The results of the assessment of changes in the specific gravity of the soil

The impact analysis of change in the specific weight on the value of calculated resistance is made with application of the offered coefficient and presented graphically (figure 1).

![Figure 1](image)

Figure 1. Ratio of calculated soil resistance of the base after \(R\) and before \(R\) operation in various draft ratio to the depth of the compressed thickness of the \(S/H_c\)

From figure 1 it is visible that with an average draft of 4 cm calculated resistance will increase by 4.5%. 

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4. Method for assessing changes in specific soil adhesion

The change in the specific clutch is connected with soil compaction in the course of joint deformation of the “building base” system. Similarly with $k_Y$ coefficient we will define $k_c$ coefficient which consider these changes (2), where $s/H_c$ is the ratios of the draft to the depth of the compressed thickness:

$$
k_Y = \frac{H_c}{H_c - S} = \frac{1}{1 - \frac{s}{H_c}}
$$

(2)

The analysis of the effect of the clutch on calculated resistance has been fulfilled by means of the offered coefficient and presented graphically in (figure 2). Taking into account the given coefficients, the formula for determining the calculated resistance considering the change in physical and mechanical characteristics of the soil base will take a form, where $C$ is specific adhesion of soil:

$$
k_c = 1 + \frac{R \cdot t \cdot \varphi}{2 \cdot C}.
$$

(3)

5. The results of the assessment of changes in specific adhesion

Calculated resistance of soil base before $R$ and after $Re$ operation is presented graphically (figure 2).

![Figure 2](image)

Figure 2. Calculated resistance of soil base before $R$ and after $Re$ operation at various ratios of the draft to the depth of the compressed thickness $S/H_c$

6. Experimental studies of changes in the physical and mechanical characteristics of soil

From figure 2 it is visible that at the average draft of 6 cm the calculated resistance increases by 35%. In order to check the settlement device for apparatus to assess the dynamics of the change in the calculated soil resistance of the base is developed, the priority of which is protected by the patent for useful model. An experiment essence is the following: the fixed vertical tension is transferred to the soil sample placed in shift the device; further through a polyspast steps put the loading creating
horizontal tension, the moment of shift of a sample is registered. Further, according to the well-known formula of Coulomb-Mora, the angle of internal friction and specific coupling of the soil is determined [13-15].

*Figure 3. Scheme (a) and general view (b) of the test unit: 1 – mobile part of the device; 2 - motionless part of the device; 3 - soil sample; 4 - cut and shift line; 5 – freight; 6 – press; 7, 8 – indicators; 9 - steel rope*

The model of the operated basis was created in a tray. The foundation is simulated as a rigid square stamp a concentrated load application. During the experiment base draft was fixed until it stabilized. Further soil was withdrawn, and re-testing on shear was carried out.

*Figure 4. Scheme (a) and a general view of model of the exploited basis.*
7. The results of experimental studies of changes in the physical and mechanical characteristics of the soil

By results of pilot studies specific weight increased by 10%, coupling for 24%, the angle of internal friction for 17%. The matched analysis of experimental and analytical data is presented in Table 1.

Table 1. Results of changes in physical and mechanical characteristics of soil base before and after soil compaction.

| №  | Before soil compaction | After soil compaction |
|----|----------------------|-----------------------|
| 1  | Angle of internal friction 15,64° | 18,8° |
|    | Specific cohesion 28 kPa     | 37 kPa |

For further research, the authors plan to obtain additional data that must be collected to refine (confirm) the results.

8. Conclusion

Difference between theoretical values and results of an experiment is an average 10%. As a result of a research it is defined that changes in calculated resistance of soil in operation of buildings and structures process is in direct proportion to the base draft ratio to the depth of the compressed thickness, width of a foundation sole and an average pressure under his soil.

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