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DETERMINATION OF THE MAIN DESIGN PARAMETERS FOR SOIL CHEMICAL STABILIZATION

When designing or reconstructing buildings and structures on the swelling soils, it is necessary to be particularly concerned about the pattern of these soils behavior in order to subsequently be able to predict the behavior of the 'basement – foundation – building' system. The most effective way to stabilize soil behavior of the basement contaminated with industrial effluents is injection methods used for stabilization. The main task of soil chemical stabilization is to strengthen the bonds between soil particles with the help of chemical reagents. As a result of the research, the design parameters for foundations stabilization of soils composed contaminated with peroxy acid were determined. Depending on the concentration of peroxy acid in the soil and the density of the used sodium silicate solution, the limiting values initial components volume ratios were determined to carry out qualitative and reliable soil stabilization for the basements.
***Keywords:** silication, chemical swelling, peroxy acid.*

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ВИЗНАЧЕННЯ ОСНОВНИХ РОЗРАХУНКОВИХ ПАРАМЕТРІВ ХІМІЧНОГО ЗАКРІПЛЕННЯ ҐРУНТІВ

Обґрунтовано можливість прогнозування поведінки системи «основа – фундамент – споруда» при проектуванні чи реконструкції будівель і споруд на ґрунтах, що набухають. Визначено, що найбільш дієвим способом стабілізації поведінки ґрунтів основ, забруднених промисловими стоками, є ін'єкційні методи із закріплення. Основне завдання хімічного закріплення ґрунтів полягало в посиленні зв'язків між частинками ґрунту за допомогою хімічних реагентів.

У результаті досліджень були визначено розрахункові параметри закріплення основ фундаментів, складених ґрунтами, забрудненими пероцтовою кислотою. Залежно від концентрації пероцтової кислоти, яка знаходиться в ґрунті, та щільності застосовуваного розчину силікату натрію визначено граничні величини об'ємних співвідношень вихідних компонентів, що дозволяють здійснити якісне і надійне закріплення ґрунтів основ.
***Ключові слова:** силікатизація, хімічне набрякання, пероцтова кислота.*

Introduction. The operating experience of many enterprises has shown that due to the soaking of soils with industrial effluents in case of emergency the chemically active solutions of various concentrations enter the basement of buildings and significantly influence the properties of soils. Thus, upon the interaction of soil minerals with the solutions of acids and alkalis the physical and chemical processes and exchange reactions result in the increase of soil volume. This phenomenon was called the «chemical swelling». [1, 2]. The process has complex physical-and-chemical character and can lead to extremely negative consequences for both foundations and the «basement–foundation–building» system as a whole.

The main task of the soil chemical stabilization is to strengthen the bonds between soil particles using chemical reagents. There is a number of different ways of soil chemical stabilization. Some of them are very common and often used in construction, while others are used in rare, exceptional cases.

The Analysis of Recent Research and Publications. The problems of chemical swelling have been studied by many authors [3 – 5]. Previous studies have been aimed at studying the effect of chemical solutions, basement soil physical and chemical state, as well as latter structural properties [5, 6]. Chemical swelling in most cases leads to unacceptable deformations of foundations and supra fundamental structures of various industrial buildings and structures.

At the current stage of construction, various technology-related problems should be solved with due regard to the influence of the accepted decisions on the ecological state of environment. This issue is particular relevance to areas with a large share of chemical and food industries.

In the course of intensive economic development of territory areas the soils are exposed to various contaminants, both organic and inorganic. The impact of the former affects the composition, structure and properties of the soils. Different soils react differently to contaminants; some of them are more «sensitive» to them, while others are less sensitive. The most significant structural changes during contamination are typical of clay, loam, and partly – of sandy loam [5]. To a lesser extent the contaminants affect the structure of sandy soils and soils with coarse waste. The structure of rocky soils that is of magmatic, metamorphic and sedimentary cemented is the least subjected to the influence of contaminants.

The properties of contaminated soils are very different from those of the original soils. Various contaminants can affect physical properties of soils, changing the density, porosity, filtration properties, physical-and-chemical or physical-and-mechanical properties, etc.

At present in the food industry it is widely used the detergent and disinfectant Oxonia Active-150 based on the 25% peroxy acid. Due to dribbles and because of the sewage effluents this substance reacts with the chemically active substances of the soil when occurring in the basement resulting in the basement swelling.

When designing or reconstructing buildings and structures on the swelling soils, it is necessary to be particularly concerned about the pattern of these soils behavior in order to subsequently be able to predict behavior of the «basement–foundation–building» system.

The most effective way to stabilize the soil behavior of basement contaminated with industrial effluents are the injection methods used for soil stabilization [2, 7 – 9].

Stabilization of soils that are prone to contamination with industrial sewage is a complex of various measures that consider both technical and environmental issues. When carrying out work on stabilization of soils contaminated with industrial wastewater, the following requirements must be considered:

1) when carrying out work on stabilization of the contaminated soil mass it must be considered stabilization of section ecological condition, to minimize the introduction of chemicals necessary while work performing;

2) proposed method is supposed to ensure deformations stabilization in the «basement–foundation–building» system;

3) after the performance of work, that is after stabilization, the mechanical parameters and the parameters of deformation of the soil mass are supposed to be improved;

4) it is absolutely necessary to ensure the continuity of the contaminated soil mass stabilization process throughout its volume.

The prerequisite for choosing one or the other stabilization technologies is the observation of all the above requirements simultaneously. Is is the most optimal method for searching and selecting the best method of chemical stabilization of soil mass contaminated with industrial wastewater.

The Identification of Previously Unresolved Parts of the Problem. Most of the recent performed [1, 2, 5, 9] was devoted to the study of regularities of single swelling, i.e. swelling in a single humidification cycle. Regularities of cyclic swelling are studied considerably less, i.e. the behavior of soils with repeated moistening and drying. Meanwhile, basements soils of the industrial buildings where wet processes has variable regime of moistening.

The behavior of soils under these conditions is determined by the regularities of the cyclic swelling, but not of the single swelling. Cyclic moistening and drying lead to significant increase in the rates of swelling compared to single swelling.

Statement of the Task. The purpose of the study is to determine basic design parameters for the stabilization of foundations composed basements of soils contaminated with peroxy acid.

The Major Material and Results. The use of silicate and peracetic components for chemical stabilization of sandy and silt-and-clayey soils contaminated with industrial effluents of peroxy acid reduces to the injection of a mono-solution of sodium silicate into the soil.

The author studied the parameters influencing the swelling properties of soils from the action of organic acid. Dependences were found between the concentration of infiltrated acid and the amount of free swelling. However, the question of the effect of organic acids on the mechanical properties of both sandy and silty-clay soils remained unresolved.

From the results of the work performed, it can be seen that with an increase in the acid concentration from 0% (water) to 3%, the strain modulus decreases by 15% -40%, from the value in the natural state. Specific adhesion decreases by 25% - 60%, and the angle of internal friction decreases by 11% - 19%.

As for sandy soils, when soaking with acid solutions, a swelling pressure is observed. With an increase in the concentration of the infiltrated acid to 3%, 0.022 MPa increases. While with soaking water in sandy soils, swelling does not occur at all. For clay soils, swelling appears even at 0.5% acid and with an increase to 3%, the swelling pressure reaches 0.175 MPa.

After the research by the author on fixing contaminated soils, they acquire significant strength, mechanical characteristics are significantly improved. In some cases, the mechanical characteristics of the anchored soil exceed their values in the natural state.

R increases by 1.81 to 3.01 times, the specific cohesion C increases by 9.6 times, the strain modulus E increases by a factor of 2.48, the angle of internal friction increases by 1.56 times.

The parameters include:

– the concentration of peroxy acid in soil pores $\mu_к$,%;

– the design time interval for gelling $t_г$, min;

– the proportion of volumes of the original components Ω;

– the required volume of sodium silicate solution per 1 m^3 of the stabilized soil V_c;

– the coefficient of volume filling.

The soil mass with the raised acid content level is divided into separate sections which are stabilized according to individually calculated parameters. The lines of these sections are determined by the concentration of peroxy acid in the pores of the soil $\mu_к$. The calculations are carried out on the basis of the physical-and-chemical characteristics of soil with raised acid content level determined in laboratory conditions:

– $m_к$ is the mass of peroxy acid in 1 cm^3, in grams (determined by titration);

– m_W is water mass in 1 cm^3 of the soil with the raised acid content level, in grams (determined by the weighting method);

– n – porosity, %.

Having designated the weight of the peroxy acid solution in the pores of the soil m_r, it is possible to determine the concentration of peroxy acid in the pore solution μ_k from the proportion:

$$\mu_к = \frac{100 \cdot m_k}{m_r}, \% , \tag{1}$$

where m_r is the mass of the stabilizing solution;

considering that

$$m_r = m_k + m_w \ , \tag{2}$$

t is find

$$\mu_к = \frac{100 \cdot m_k}{m_k + m_r}, \% \ . \tag{3}$$

On the basis of the design parameter Ω_i, the formation of silicate peracetic gels with the formation time from 1 to 60 minutes, with the concentration of pore solutions of μ_k, is possible. Depending on the value of μ_k, separate sections for stabilization are identified.

The possibility of obtaining positive result when stabilizing the soils with raised acid content levels, the strength, density, continuity, the degree of ecological purity of the stabilized mass, as well as the cost and laboriousness of work performed depending on the chosen design time interval for gelling $t_г$. Depending on $t_г$, the number of sections with individual parameters, stabilization is determined, where the entire area with the raised acid content level is divided.

The required volume of sodium silicate solution V_c is calculated from the ratio:

$$\Omega = \frac{V_к}{V_c} \ . \tag{4}$$

To clarify the value of the required volume of sodium silicate solution in a liter per 1 m^3 of soil, the known function [5] is used which, considering the obtained dependences, becomes:

$$V_c = \frac{10^3 (m_k + m_w)^2}{\sqrt[b]{\frac{t_г}{a}}(1.58 m_k + m_w)}, \tag{5}$$

In Figure 1 the graphical scheme for determining the limiting acid concentrations of the pore solutions at individual sections of the stabilized soil mass $\mu_к$ and the volumetric ratios of the initial components involved in the gelling reaction Ω is given.

It has been established that with the increase in the concentration of peroxy acid in pore solutions the required density of sodium silicate solutions increases.

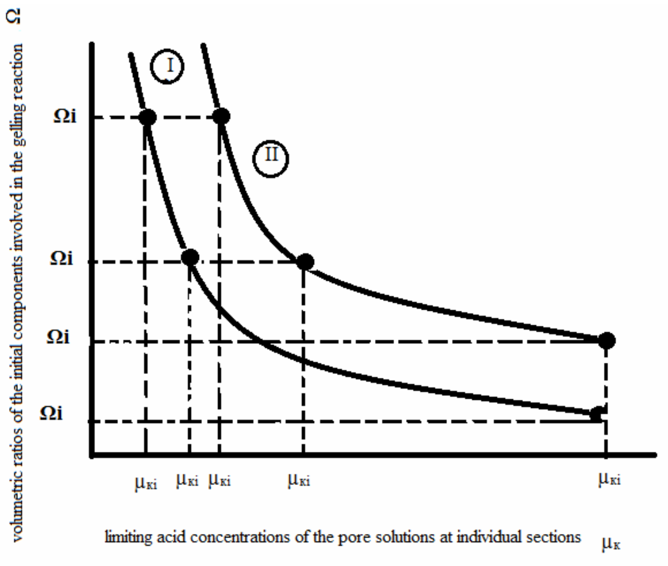

Figure 1 – Determination of the stabilized sections and the parameter *Ω* lines:
I – for gels with $t_г$ <10 min, II – for gels with $t_г$ > 10 min

Table 1 – The recommended values of volumes ratios of the initial components for the intervals of peroxy acid concentration in the individual stabilized sections are shown

The stabilized section number	The concentration of peroxy acid in pore solutions, μ_K, %	The density of sodium silicate, ρ_c	The design of the initial components ratios value, Ω
1	1,0	1,10	3,89 – 8,5
2		1,15	4,25 – 9,76
3		1,20	7,5 – 13,5
4		1,25	10,6 – 17,5
5	2,0	1,10	3,5 – 8,92
6		1,15	5,02 – 10,6
7		1,20	7,96 – 14,49
8		1,25	10,57 – 17,93
9	3,0	1,10	4,36 – 9,02
10		1,15	5,69 – 11,37
11		1,20	8,5 – 16,52
12		1,25	12,63 – 18,34

Considering required volume of sodium silicate and its density are different for different sections of stabilization and for different types of soils when stabilizing the sections of soils with the raised acid content levels according to the method it is recommended to use drilling-and-mixing or jetting technologies for delivering soil stabilizing solutions [4, 6].

Conclusions. As a result of the research, the design parameters for stabilization of soil foundations composed contaminated with peroxy acid were determined. Depending on the concentration of peroxy acid in the soil and the density of the used sodium silicate solution, of volumes limiting values ratios of the initial components were determined allowing to carry out qualitative and reliable soils stabilization for the basements.

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