ЗАКОНОМЕРНОСТИ ИЗМЕНЕНИЯ КОЭФФИЦИЕНТА ФИЛЬТРАЦИИ ГРУНТА С ПРИМЕНЕНИЕМ ИНЪЕКЦИОННОЙ ТЕХНОЛОГИИ

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REGULARITIES OF SOIL FILTRATION COEFFICIENT CHANGES ON THE APPLICATION OF GROUND INJECTION TECHNOLOGY

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Аннотация

В работе проведен анализ результатов рабочих исследований процесса создания противофильтрационных экранов с использованием регрессионных моделей, реализованных в программном продукте «Compex». Определены аналитические и графические зависимости коэффициента фильтрации от следующих исследуемых факторов: длительности подачи состава, образующего противофильтрационную завесу, концентрации бентонитового порошка в единице объёма твердеющего раствора, создающего экран, и давления нагнетания (подачи) данного раствора в экран.

Ключевые слова: противофильтрационные защитные экраны, горизонтально направленное бурение, бентонит, коэффициент фильтрации, экспериментально-статистическое моделирование.

ABSTRACT

The paper analyzes the anti-contagious shield research results provided by regression models, implemented in the «Compex» software. The analytical and graphical dependences of soil filtration coefficient from the following factors are identified: the duration of mortar supply, by which a shield is formed, bentonite powder concentration per unit of volume of hardening mortar and the discharge pressure (supply) of this mortar in the base soil.

KEYWORDS: anti-contagious protective shields, horizontal directional drilling, bentonite, soil filtration coefficient, experimental statistical modeling.

Introduction. Analysis of the problems arising from the disposal of the consequences of the Chernobyl accident showed that the scale of the impact and the necessary of financial and technical resources are playing a dominant role in the localization of pollution and in the reduction of emission of radioactive substances into the environment. The arrangement of anti-contagious protective shields by horizontal directional drilling method can be used for protection of groundwater from migration of contaminants. Numerous methods help to build the impervious underground shields, but their analysis showed low economic and environmental performance.

According to these criteria, the use of horizontal directional drilling is preferred. The present study has a social significance, as it will allow protecting the population from the consequences of contamination by radionuclide contaminated water.

The analysis of the literature. As a result of the analysis of known sources on the subject it is concluded that the existing methods of the anti-contagious shields arrangement are not effective for the localization of radioactive waste [1, 2]. In recent years, several attempts were made to develop an efficient technology for such works [3], but the use of horizontal directional drilling for groundwater protection shields can be more promising from an economic or technological perspective.

The purpose and objectives of the study. The aim of the study is to construct experimental and statistical dependencies of soil filtration coefficient of the shield, formed by horizontal directional drilling, from technological factors. In accordance with the purpose of the following research several objectives were formulated:

1. To carry out the laboratory research of arrangement of protective shield by horizontal directional drilling with varying technological parameters of mortar injection.
2. To build the experimental statistical dependencies of shield filtration coefficient from technological factors by regression analysis of laboratory results with the help of «Compex» software.
3. To determine the nature and extent of the influence of technological factors on the filtration rate of shield made by injection.

Algorithm of the study is shown below:

1. Statement of research problem.
2. Substantiation of work areas.
3. Analysis of the known sources on the research subject.
4. Development of methods for solving the problems and the creation of the necessary laboratory equipment.
5. Obtaining experimental data to study the parameters of technological modes of injection.
6. Processing and analysis of the experimental results.

Main part. Since the main feature of impervious screen is its hydrophobicity, which is ability not to let through the groundwater, it was decided to use such a key indicator of physical characteristic of soil as a filtration coefficient.

The modern technology of horizontal directional drilling was combined with injection process, which allows forming impervious horizontal shields for contaminated sites. To simulate this, the laboratory bench was produced which shows section perpendicular to the drill axis, wherein an injection mortar is distributed at different distance away from the input under the influence of the operating parameters. Singling out the middle part of the section, you can get an idea about the nature of soil filtration coefficient change.

The factors that have the greatest impact on the indicator have been identified:

X_1 - bentonite powder concentration per unit of volume of hardening mortar, which changes a sandy soil filtration property. This factor is important because the bentonite-containing mortar prevents the penetration of contaminated water through injected ground. Considering this, the concentration of the bentonite should be sufficient to form the shield, which has a maximum capacity of hydrophobicity. However, there is a limiting factor - viscosity of the injection mortar, which affects the penetration of material into the gaps between the fine particles of a sandy ground. According to sources considered, the permissible viscosity for clay and cement mortars is between 26 and 43 sec. The viscosity was determined by viscometer "Marsh Funnel" with volume of 1000 ml.

X_2 - discharge pressure (supply) of injection mortar in the base soil. Discharge pressure affects the range of injection mortar spread in soil. This factor is very important in economic terms, as modern industrial pumps can achieve more than 100 bar pressures, at the same time allowing you to increase the distance between the horizontally drilled wells, which reduces the cost of the project.

X_3 - the duration of mortar supply, by which a shield is formed. Time factor could allow establishing a direct proportional relationship between the injection time and the concentration of active substances which affects the properties of impervious soil shield.

Laboratory bench, which simulates the spread of an injection mortar in the injected soil area, has been used in experimental studies. Under the influence of variable combinations of technological parameters the injection mortar forms a model of the protective shield with the different let-through ability.

Measuring the value of soil filtration coefficient in a certain section of the laboratory bench helps to determine dependency of the impervious properties of the shield from the factor combination used.

The processing of the received experimental results (table 1) is performed by regression analysis method using «Compex» software [4, 5]. As a result of this analysis the experimental statistical model of filtration rate dependence from technological parameters of shield arrangement was built (form. 1). The factor impact estimations, deemed indistinguishable from zero, are marked by points in this formula.

Table 1.

The plan and the results of experimental laboratory studies

№	Full-scale variables			Coded variables			Soil filtration coefficient (SFC), meter per day
	X_1	X_2	X_3	X_1	X_2	X_3	
	Bentonite powder concentration, grams per liter.	Discharge pressure of mortar, atm.	Duration of mortar supply, min.	Bentonite powder concentration, grams.	Discharge pressure of mortar, atm.	Duration of mortar supply, min.	
1	2	3	4	5	6	7	8
1	70	5	110	1	1	1	0,37114
2	70	5	10	1	1	-1	0,26929
3	70	2	110	1	-1	1	0,21114
4	10	5	110	-1	1	1	0,07526
5	70	2	10	1	-1	-1	0,40124
6	10	5	10	-1	1	-1	0,08985
7	10	2	110	-1	-1	1	0,80065
8	10	2	10	-1	-1	-1	0,36041
9	70	3	60	1	-0,33	0	0,34387
10	10	3	60	-1	-0,33	0	0,29899
11	40	5	60	0	1	0	0,15554
12	40	2	60	0	-1	0	0,08977
13	40	3	110	0	-0,33	1	0,14669
14	40	3	10	0	-0,33	-1	0,17049
15	40	3	60	0	-0,33	0	0,04775

$$\text{SFC (m. per day)} = 0.105 \bullet + 0.212 X_1^2 + 0.123 X_1X_2 - 0.064 X_1X_3 - 0.087 X_2 + \bullet + \bullet + \bullet + \bullet \quad (1)$$

Fig. 1 shows the ranking of the degree of influence of variable factors on the indicator.

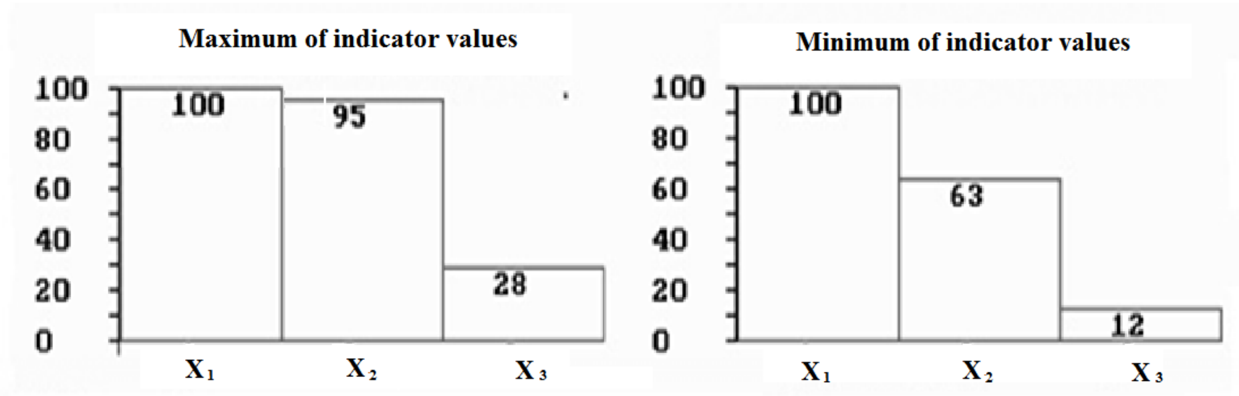

Fig.1 Ranking the impact of variable factors on the indicator (soil filtration coefficient)

The greatest influence on the filtration coefficient in the area of maximum indicator values has two factors in approximately the same degree: the concentration of bentonite powder and discharge pressure of mortar. At the same time, the duration of mortar supply does not play such a significant role in the change of the indicator. In the area minimum indicator values, where the dependencies are the most significant, the degree of influence of the discharge pressure decreased slightly. The degree of the time factor influence in the considered factor space has decreased to the limits that are not significant from an engineering point of view.

These rankings can be interpreted as follows:

— Bentonite concentration in the mortar plays a most important role for the following reasons: the conditions of the experiments carried out have enabled the most complete way to explore this relationship in the framework of selected factor space, which is confirmed by the nature of the graph shown in Fig. 2;

composition of the mortar does play a major role in the arrangement of protective shields.

— From a physical point of view, the degree of influence of pressure on impervious properties is quite high, as the supply pressure of the mortar directly affects the amount of bentonite injected into the soil.

— Duration of mortar supply factor is not significant from an engineering point of view on the role of the monitoring indicator within the selected experimental conditions.

Fig. 2 shows graphs of the indicator from each of variable factors.

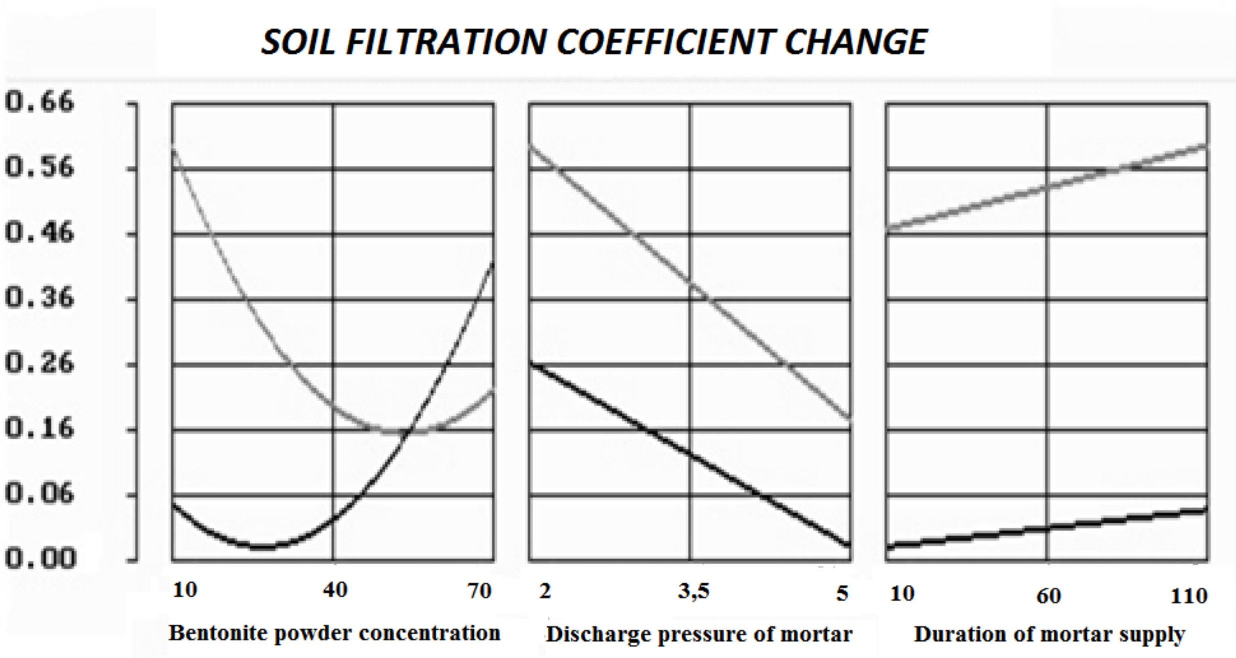

Fig. 2 Curves of the indicator dependences from the factors

The nature of the graph of the soil filtration coefficient from bentonite concentration can be called close to parabolic. In this case, the extremum of this curve is vividly shown and is within X_1 = (0.4, -0.5) in minimum indicator area, whereas it is within X_1 = (0.6, 0.7) in maxima zone. It can be said that for the conditions studied in the experiments, it was possible to identify the optimal conditions for bentonite powder concentration. When translating into full-scale parameters, the most effective mortar in the minima zone would contain the amount of bentonite within 22-25 grams per liter, in the area of the maxima – 58-61 grams per liter.

The dependence of soil filtration coefficient from the discharge pressure of mortar is inversely proportional. The angle of the line to the horizontal is sufficiently sharp, therefore we can assume that the data points belong to the parabolic nature of the curve with a peak, not included in considered factor space. In this case, used pressure values are not the highest possible from a technical point of view and may be adjusted upward during the further study.

The effect of duration of mortar supply on the indicator value is directly proportional. Limits of soil filtration coefficient changes are quite small for time variation, so you can conclude that the dependency, which follows from the obtained data, is not enough meaningful from an engineering point of view. However, under natural conditions, long duration of injection will undoubtedly affect the soil filtration coefficient of the protective shield to the reduction. The reason for this discrepancy may be due to imperfect experimental conditions.

Nature of the dependence obtained in the zone of high and low values of indicator are close. It should be noted that dependences obtained in the zone of the low values of indicator must be taken as highly significant. This is due to the ultimate goal of the experiments which is to determine the conditions under which the soil filtration coefficient of the anti-contagious shield will meet the specified conditions for water-proof resistance.

Conclusions:

1. Conducted laboratory tests allowed determination of the soil filtration values at different levels of technological factors values.
2. Experimental statistical dependency built by regression analysis has allowed determination the nature and extent of the influence of technological factors on the filtration rate of protective shield.

The biggest impact on the index has bentonite concentration in the injection mortar and the discharge pressure of mortar. Thus the optimum amount of bentonite is at the level of 22 - 25 grams per liter and the maximum allowed pressure of the discharge. Duration of mortar supply does not noticeably affect the indicator for the chosen experimental conditions.

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