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CONSISTENT PATTERN OF CHANGE OF FILTER COEFFICIENTS OF IMPERVIOUS SCREEN

Petrovsky A.F.
Odessa State Academy of Construction and Architecture

The paper analyzes the research results of the anti-contagious shield created by injection. The regression models of the shield arrangement process, calculated by the «Compex» software, are used. Identified analytical and graphical dependence of filtration rate of these technological factors. The duration of the composition of feed injection, the concentration of bentonite powder per unit volume of solution hardening and discharge pressure (supply) of this solution into the screen. The conditions of protective shield production using horizontal directional drilling, by which the optimal soil filtration coefficient is achieved, are defined.
Keywords: anti-contagious protective shields, horizontal directional drilling, bentonite, soil filtration coefficient, experimental statistical modeling.

Formulation of the problem. 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 to 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. The problem of localization of toxic and radiation pollution as well as contaminated groundwater can be solved by various methods, among that there is technology unit of a closed vertical grouting (watertight) which is rather reliable. However, the effectiveness of such a vertical grouting is significantly reduced in the absence of practically attainable on the depth of waterproof layer of soil, in which the grouting shall be recessed. In the absence of aquiclude the problem can be solved by applying a new injection technology of installation of horizontal screen under the existing facilities. To create a new technology it is necessary to solve the problem of determining the influence of various structures of impervious screen on the index of coefficient of permeability.

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

An 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 determination of the optimum operating parameters of the anti-contagious shield arrangement by processing and analysis of experimental statistical dependency of soil filtration coefficient from the studied 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 technological parameters of anti-contagious shield arrangement in which an optimal value of soil filtration coefficient is obtained.

Algorithm of the study is shown on the Fig. 1.

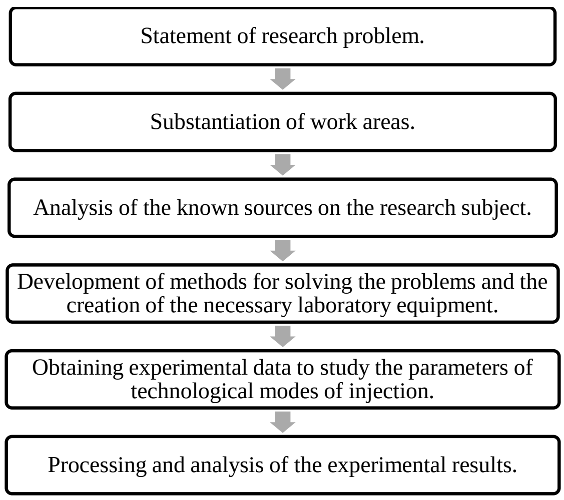

Fig. 1. Algorithm of research

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 promoted as the simulation of 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 parameter 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 dependence of filtration rate 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.

$$\text{SFC (m. per day)} = 0{,}105 \pm 0\ x_1 + 0{,}212x_1^2 + 0{,}123\ x_1x_2 - 0{,}064\ x_1x_3 - 0{,}087x_2 \pm 0\ x_2^2 \pm 0\ x_2x_3 \pm 0\ x_3 \pm 0x_3^2 \quad (1)$$

By depending on results of the analysis (the forms. 1) it can be concluded that the influence of the factor «time injection» is not essential in the engineering sense.

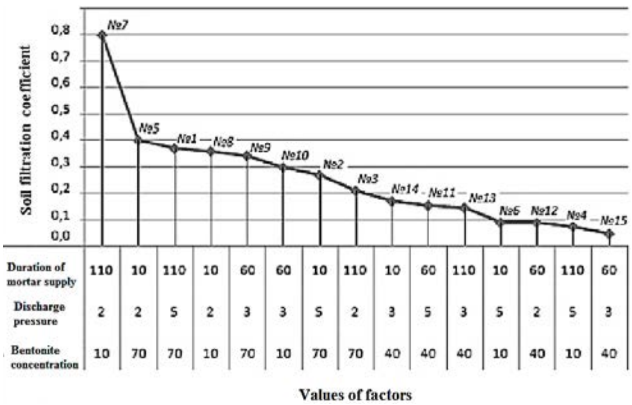

Fig. 2. Graph of soil filtration coefficient values (ranked in descending order)

Consider Fig. 2. It shows the descending ranking of soil filtration coefficient values obtained as a result of laboratory tests. By this ranking the conditions, which are the most suitable for low values of indicator, can be analyzed.

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	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

Five experiments were conducted according to an optimized plan, containing the value of bentonite concentrations in mortar at 40 grams per liter. The majority of them were carried out at the operating discharge pressure of X_2 = (-1, -0.33 (3)). These experiments showed the lowest filtration value. Also, low values of filtration coefficient are determined in the experiments, in which the combination of low concentrations of the bentonite (or the low viscosity of mortar) and relatively high discharge pressure were used. The experiments, in which a high viscosity and low discharge pressure of mortar were used, showed slightly higher values of soil filtration coefficient. Finally, the least favorable were the combination of high contents of bentonite in mortar and high discharge pressure; small saturation of bentonite powder and a low pressure of mortar. Inconsistencies of experiments ranking can be attributed to the account of the corrective the duration of mortar supply factor impact.

Fig. 3 shows the effect of the bentonite powder concentration and discharge pressure on the filtration rate of the protective shield while the duration of mortar supply is fixed on the level X_3 = 10 min. This level is selected to avoid errors in the construction of the dependency.

Analysis of the graph shows that the dependence of the indicator from the concentration of bentonite is close to parabolic. The effect of the discharge pressure of mortar supply is inversely proportional: minimum zone of soil filtration coefficient is formed at the highest pressures, highs zone – at the least. The area of the curve extremum is observed when the value of the concentration of bentonite is X_1 = (-0.5, -0.4), in the zone of highs – when X_1 = (0.1; 0.2). Thus, in the case of short-term injection, the maximum pressure should be followed with the optimal concentration of bentonite in mortar for about 22-25 grams per liter, with the least – 43-46 grams per liter, and less viscous mortar is more effective. The soil filtration coefficient is equal to 0.023 meters per day and 0.194 meters per day respectively to parameters indicated.

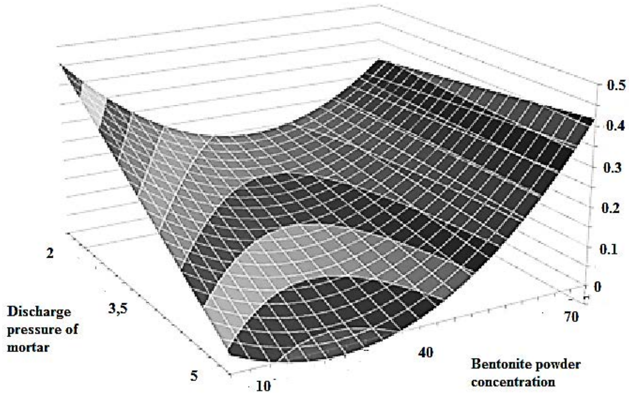

Fig. 3. Change of the soil filtration coefficient of the protective shield under the influence of the bentonite powder concentration and discharge pressure when fixing the duration of mortar supply at X_3 = 10 min.

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.

3. The optimum soil filtration coefficient value is equal to 0.023 meters per day, and is achieved at a bentonite powder concentration equal to 22-25 grams per liter and the discharge pressure of mortar – to 5 atm.

References:

1. Chernobylskaya katastrofa / NAN Ukraine: gol. red. Barjahtar V.G. – Kiev: Nauk. dumka, 1995. – 560 p.
2. Bojko G. A. Primenenie tonkih protivo-fil'tracionnyh diafragm v uslovijah Belorussii. Stroitel'stvo i arhitektura Belorussii / G. A. Bojko, G. G. Azbel', G. N. Nikol'skaja. – 1980. – № 4. – P. 31.
3. Pat. 2015248 S1 Rossijskaja Federacija, MPK5 E 02 D 3/12. Sposob sozdanija protivofil'tracionnoj zavesy v lessovom grunte / V. I. Osipov, S. D. Filimonov, B. N. Mel'nikov, E. V. Kajl'; zajavl. 27.12.91; opubl. 30.06.94.
4. Voznesenskij V. A. Statisticheskie metody planirovanija jeksperimenta v tehniko-jekonomicheskih issledovanijah / V. A. Voznesenskij. – 2-oe izd. – M.: Finansy i statistika, 1981. – 263 p.
5. Voznesenskij V. A. Chislennye metody reshenija stroitel'no-tehnologicheskih zadach na JeVM / V. A. Voznesenskij, T. V. Ljashenko, B. L. Ogarkov. – K.: Vishha shkola, 1989. – 327 p.

Петровський А.Ф.
Одеська державна академія будівництва та архітектури

ЗАКОНОМІРНІСТЬ ЗМІНИ КОЕФІЦІЄНТА ФІЛЬТРАЦІЇ ПРОТИФІЛЬТРАЦІЙНОГО ЕКРАНА

Анотація
У роботі проведено аналіз результатів досліджень процесу створення протифільтраційних екранів по ін'єкційної технології. Використано регресивні моделі, реалізовані в програмному продукті «Compex». Визначено аналітичні і графічні залежності коефіцієнта фільтрації від наступних технологічних факторів. Тривалість подачі ін'єкційного складу, концентрація бентонітової порошку в одиниці об'єму твердіє розчину і тиску нагнітання (подачі) даного розчину в екран. Виявлено технологічні режими ін'єктування при влаштуванні захисних екранів за допомогою горизонтально направленого буріння, при яких досягається оптимум коефіцієнта фільтрації.
Ключові слова: горизонтально направлене буріння, протифільтраційний екран, розрив пластів, дренаж, ін'єкція.

Петровский А.Ф.
Одесская государственная академия строительства и архитектуры

ЗАКОНОМЕРНОСТЬ ИЗМЕНЕНИЯ КОЭФФИЦИЕНТА ФИЛЬТРАЦИИ ПРОТИВОФИЛЬТРАЦИОННОГО ЭКРАНА

Аннотация
В работе проведен анализ результатов исследований процесса создания противофильтрационных экранов по инъекционной технологии. Использованы регрессионные модели, реализованные в программном продукте «Compex». Определены аналитические и графические зависимости коэффициента фильтрации от следующих технологических факторов. Длительность подачи инъекционного состава, концентрация бентонитового порошка в единице объёма твердеющего раствора и давления нагнетания (подачи) данного раствора в экран. Выявлены технологические режимы инъецирования при устройстве защитных экранов с помощью горизонтально направленного бурения, при которых достигается оптимум коэффициента фильтрации.
Ключевые слова: горизонтально направленное бурение, противофильтрационный экран, разрыв пластов, дренаж, инъекция.