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SOIL-CEMENT PILES FIBER REINFORCED

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Problems and insufficient research of the issue of reinforcement of soil-cement piles are revealed. The use of fiber for reinforcing piles made by the deep soil mixing method is proposed. As a result, it is expected to increase the strength of soil-cement, which will positively affect the bearing capacity of soil-cement piles on the material. Given the advantages for applications in the studies adopted steel fiber. The program of tests with application of two factor matrices of planning of experiment is made. The obtained results showed the degree of influence of fiber reinforcement on the strength of soil-cement. Practical results have been obtained that can be used for implementation in the process of installation of soil-cement piles.

Key words: soil-cement, reinforced soil-cement piles, fiber reinforced, deep soil mixing, piles bearing capacity by material, laboratory tests, two factor matrix.

Introduction

The number of stores in a modern building increases, thus increasing the mass of the buildings themselves, and with it the load on the foundation and base, respectively. There is a tendency to the most efficient development of each land plot in the central parts of the cities of Ukraine and the world.

These factors lead to the fact that the centres of large cities are densely built up with high-rise buildings. Due to the fact that the load on the base is quite significant, it is almost always impossible to use the shallow foundations.

There is also a tendency to complete or renovate existing buildings and structures with a change in functional purpose. Accompanied by a change in loads and, often, a change in the structural scheme of the building.

A possible solution for the selected trends is the installation of pile foundations. Tight building conditions do not allow the hammering of reinforced concrete piles, due to the possible impact on neighboring buildings. The only rational solution is to use different types of drilling piles.

The stated requirements are met by the technologies of drilling injection piles and drilling piles, which are arranged according to the deep soil mixing technology – soil-cement piles.

It should be noted that the use of pile foundations in weak soils is not always economical, as in this case the bearing capacity of the pile by material is insufficiently used. Production of borehole injection, stuffing and driving of reinforced concrete piles of considerable length (more than 20 m) meets certain difficulties: for stuffed concrete piles – installation below the groundwater horizon, for prefabricated – joining piles and the possibility of breaking the pile joint during immersion.

In turn, soil-cement piles make it possible to install a pile foundation without the use of any methods of strengthening the walls of the well. Transportation of materials to the construction site is minimized due to the use as the main filler, for the material of the pile trunk, the soil that lies at the base of the building. (Zotsenko, Vynnykov & Zotsenko, 2016; Zotsenko, 2007; Zotsenko, Korshunov & Perederyy, 1987; Krysan, 2010; Lartseva & Petrash, 2006)

As noted earlier, deep soil mixing technology is the most suitable for use in the creation of soil-cement. The obtained soil-cement elements are reinforced and used as pile foundations for buildings and structures.

The purpose of the study

To reduce the cost of pile foundation construction, it is necessary to effectively use the soils that lie at the base of the building. In the study of world experience, we can identify the method of saturation of soils with cement, which results in a material of fairly high strength – soil-cement. Due to the use of deep soil mixing technology of soil saturation with cement, it becomes possible to install vertical cylindrical soil-cement piles of a given length and diameter.

Thus, the use of soil-cement piles is the most rational and economical method of laying foundations in the proposed conditions.

Among the disadvantages of soil-cement can be distinguished relatively lower bearing capacity of the pile material. Therefore, to increase the strength of soil-cement and, as a consequence, the bearing capacity of the pile on the material adopted to study the method of fiber reinforcement of the material. (Nesterenko, 2013; Petrash, 2013; Novyts′kyy, 2015; Bruce, 2000; Lambert, Rocher-Lacoste & Le Kouby, 2012)

The aim of the research is to study the influence of fiber reinforcement on the strength of soil-cement.

Materials and methods

The combination of increasing the strength of soil-cement and reinforcement of soil-cement piles can be considered the use of fibers (fibers), which serve both as aggregates and reinforcing particles for the material.

Fibers can be made of two types of material: steel fibers (shown in Fig. 1) and synthetic fibers (shown in Fig. 2).

Fig. 1. Steel fibers

Fig. 2. Synthetic fibers

The adhesion of the fiber to the cement stone is due to the curvature of the fiber itself, as well as notches that may be on the surface of the fibers. The disadvantage of synthetic fiber is the high smoothness of the surface, which has a lower level of adhesion to cement stone than steel. The disadvantages of synthetic fiber also include almost 50 times less modulus of elasticity and half the strength. (Denies & Van Lysebetten, 2012; Kyiashko, 2013; Doroshenko, 2014; Fatahi, 2012; Sadek, 2013)

Steel fiber was adopted for experimental studies of its effect on the strength of soil-cement, given its advantages and relatively lower cost. Fibers are made from used ropes and cables.

Fiber-reinforced soil-cement is a type of dispersed reinforced concrete.

Comparisons of technical characteristics of synthetic and steel fibers used for construction are shown in table 1.

Table 1

Technical characteristics of synthetic and steel fibers.

Fiber's type	Synthetic fibers	Metal fibers
Length, mm	40 ± 2	20; 35; 50
Thickness, mm/Wide, mm	0.6/1.2	1.00 mm ± 0. 03
High / step wave, mm	1.5/7.0	2.0 / 8.0
Relative elongation at break, %	10.0	–
Tensile strength. N/mm^2	600	1150
The amount of fiber in 1 kg, not less, pcs	52 000	3 240
Modulus of elasticity, MPa	4 000	190 000

Fiber-reinforced structures are divided into:

– with evenly distributed fiber throughout the volume of the material, without the use of reinforcement;

– with even distribution of fiber throughout the volume and reinforcement with steel reinforcement;

– with the distribution of fiber only in the areas of tension.

For soil-cement piles that work mainly on compression, it is rational to use a method of using fiber for which the distribution occurs throughout the structure. In this case, taking into account the technological features of drilling technology without soil removal, there is a need to introduce fiber into the water-cement solution in the process of mixing and feeding with subsequent distribution on the body of the pile and mixing in the soil. At the same time, the uniformity of fiber distribution and the quality of soil-cement mixing remain an unsolved problem.

When using fiber reinforcement of soil-cement piles, it becomes almost impossible to reinforce piles with reinforcing frames due to the impossibility of pressing them into the pile material.

Plastic loam with a flow rate of 0.4 was used for the production of soil cement. The dosage of CEM I R42.5 cement was 250 kg/m^3, with a water-cement ratio of 1.0.

To test the effect of the use of fiber for soil reinforcement, a series of samples of cubes, size 150×150×150 mm, according to a two-factor matrix, the structure of the matrix is shown in Table 2.

Table 2

The structure of the two factor matrices of the experimental plan

X1	"+1"	"+1"	"-1"	"-1"	"+1"	"-1"	"0"	"0"	"0"	"0"	"0"
X2	"+1"	"-1"	"+1"	"-1"	"0"	"0"	"+1"	"-1"	"0"	"0"	"0"

The first factor (X1) was the consumption of fiber by weight, with (-1) = 20 grams per cube, (0) = 60 grams and (+1) = 100 grams. The cost of fiber per cube was calculated according to the recommendations and was 20-100 kg / m3.

The second factor was the length of the fiber, with (-1) = 20 mm, (0) = 35 mm and (+1) = 50 mm. Accepted lengths correspond to those provided by the manufacturers.

Results. The tests were performed on a PSU-10 press during the curing period of 28 days, the samples were stored in moist soil.

It should be noted that the destruction of soil-cement not reinforced with fiber is more fragile and chips appear immediately. The destruction of fiber-reinforced soil-cement samples is less fragile and the sample retains its shape and integrity after destruction. The destruction of the samples is shown in Fig. 3 and Fig. 4.

Fig. 3. No fiber soil-cement

Fig. 4. Fiber-reinforced soil-cement

Results and discussion

Selection of the optimal ratio of length and amount of fiber is performed according to the obtained graphs. (Fig. 5–7)

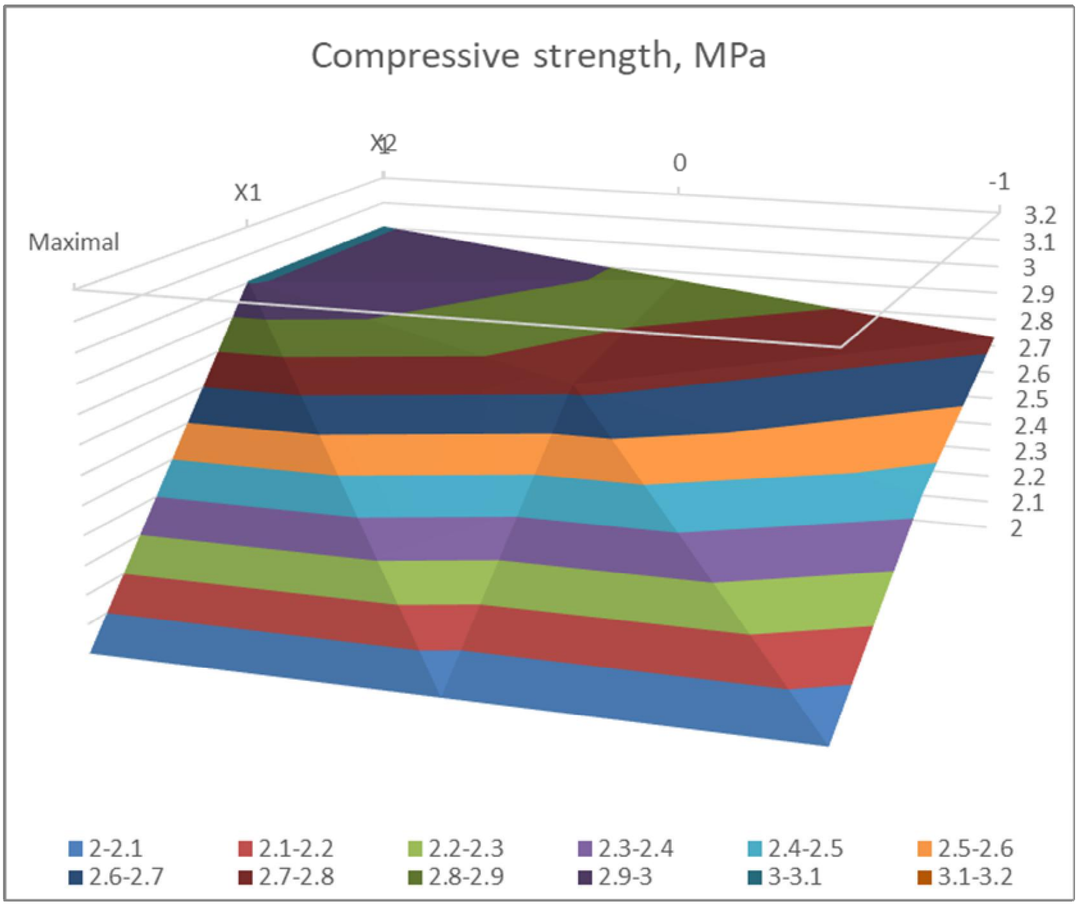

Fig. 5. Graph of the maximum level matrix

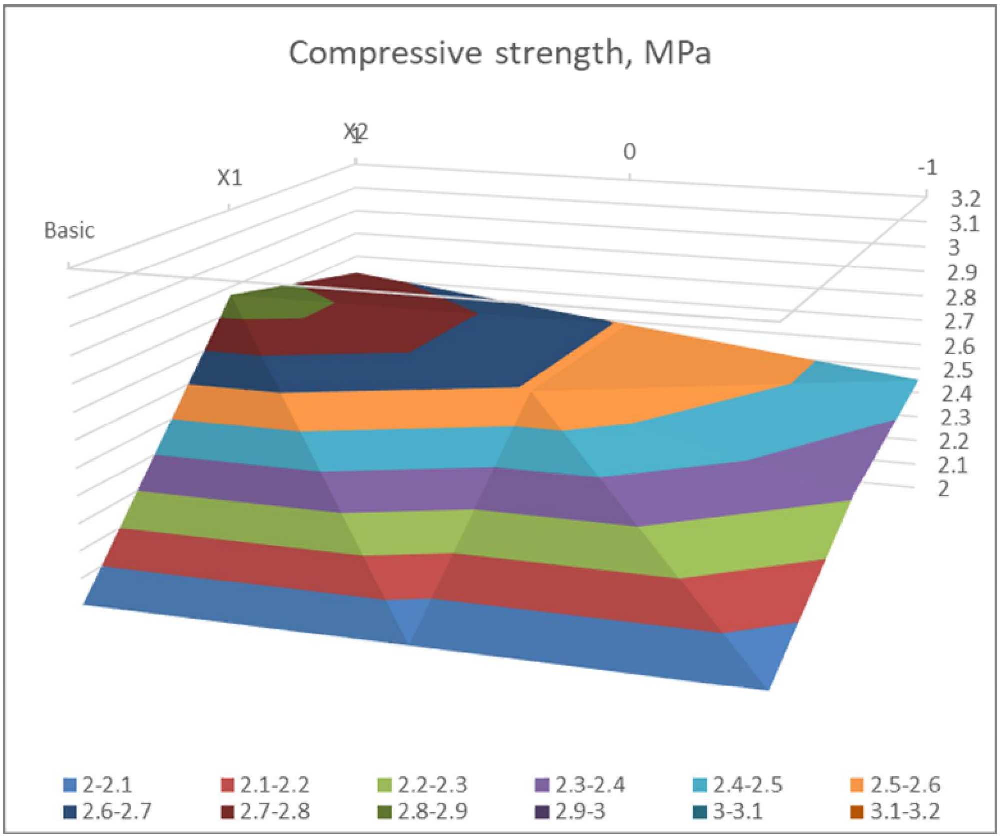

Fig. 6. Graph of the basic level matrix

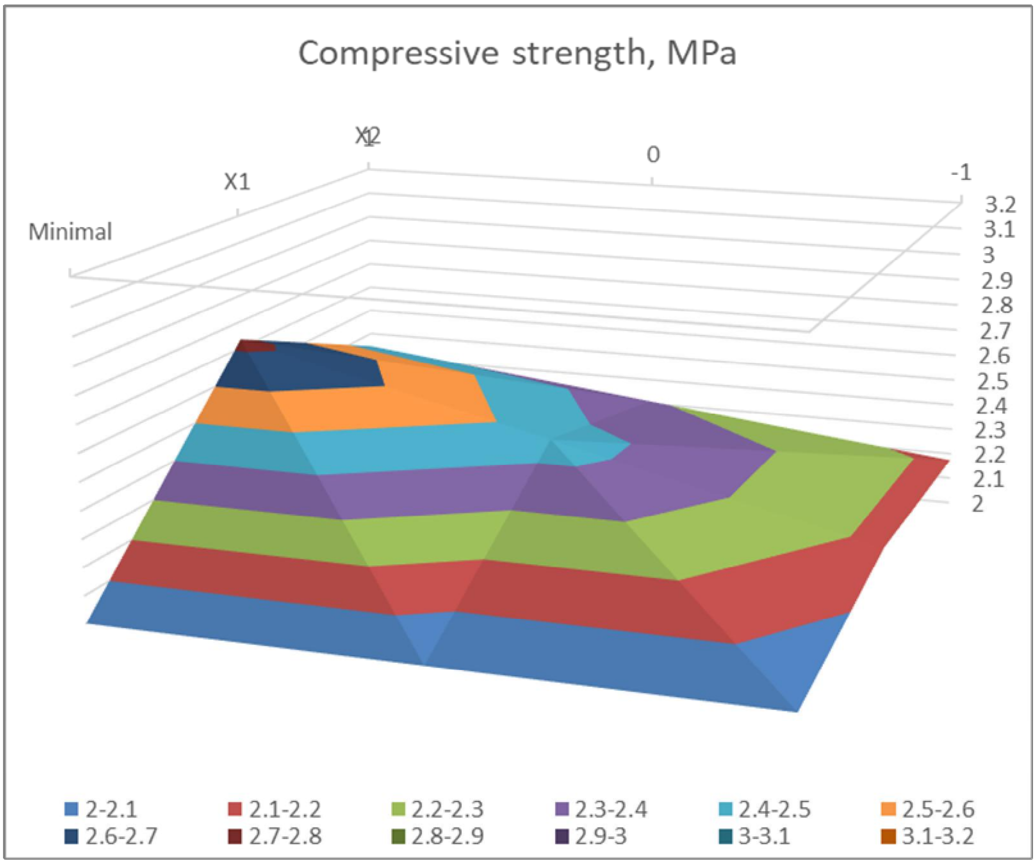

Fig. 7. Graph of the minimum level matrix

The results of the strength control are shown in Table 3

Table 3

Strength of soil-cement samples with steel fiber

Mass of fiber (X1), g	100	100	20	20	100	20	60	60	60	60	60
Length of fiber (X2), mm	50	20	50	20	35	35	50	20	35	35	35
Strength, MPa	**2.99**	2.78	**2.39**	2.15	2.78	2.33	**2.79**	2.42	2.59	2.66	2.52

The average strength of control soil-cement samples produced without fiber reinforcement was 2.07 MPa.

Comparing the strength results of samples without fiber reinforcement and samples with the maximum value of strength, a significant increase to 44 % of the compressive strength of soil-cement is observed.

Analyzing the obtained graphs (Fig. 5–7), it should be noted that the further increase in the length and number of steel fibers will lead to an increase in the compressive strength of soil-cement.

Experimental studies of the effect of soil-cement fiber reinforcement on its strength have been carried out. According to the two-factor matrix experiment, the relationships between the strength of the material, the amount of fiber and the length of the fiber fibers were obtained.

According to the results obtained from research, the positive effect of fiber reinforcement on the strength of soil-cement is clearly traced, which in turn will increase the bearing capacity of the soil-cement pile on the material. The introduction of fiber along the entire length of the pile in the process of drilling without removing the soil requires additional technological refinement. But in the most loaded heads of soil-cement piles it is possible to use fiber reinforcement.

Conclusions

The use of fiber reinforcement soil-cement has a positive effect on the strength of the material. The use of steel fiber with a length of 60 mm in the amount of 100 kg / m^3 leads to an increase in strength compared to non-reinforced soil-cement up to 44 %. According to the results of the obtained graphs, it is clear that the indicator can be improved by further increasing the length and number of steel fibers. At the same time, the technological issue of installation of fiber reinforced soil-cement piles on deep soil mixing technology without soil extraction needs additional refinement to solve it.

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ФІБРОАРМУВАННЯ ҐРУНТОЦЕМЕНТНИХ ПАЛЬ

Виділено тенденції в будівництві, для яких застосування ґрунтоцементних паль, встановлених за бурозмішувальним методом, є оптимальним геотехнічним рішенням. Виявлено проблематику та недостатнє дослідження питання армування ґрунтоцементних паль. Запропоновано використання фіброволокна для армування паль, виготовлених за бурозмішувальним методом без виймання ґрунту. Як результат очікується підвищення міцності ґрунтоцементу як матеріалу, що, своєю чергою, позитивно вплине на несучу здатність ґрунтоцементних паль за матеріалом. Виділені основні характеристики металевих та синтетичних фіброволокон, що можуть бути застосовані для паль. Враховуючи переваги для застосування, в дослідженнях використано металеві фіброволокна, які мають вищу міцність, модуль пружності та доступнніші. Складено програму випробувань із застосуванням двофакторної матриці планування експерименту для проведення випробувань міцності фіброармованого ґрунтоцементу. Першим змінним фактором прийнято кількість фіброволокон, що вводяться для армування в ґрунтоцемент під час змішування. Другим змінним фактором прийнято довжину металевих фіброволокон. Виготовлено ґрунтоцемент, в котрий додано фіброволокна та сформовано випробувальні зразки. Проведено серію лабораторних випробувань зразків кубів. Виконано аналіз отриманих результатів випробувань міцності на стиск. Складені графіки відображають залежність міцності фіброармованого ґрунтоцементу від заданих змінних факторів кількості та дожини фіброволокон. Одержані результати показали ступінь впливу фіброармування на міцність ґрунтоцементу. Отримано практичні результати випробувань, котрі можуть бути застосовані для впровадження під час влаштування ґрунтоцементних паль. Із висновків зрозуміло, що поставленої мети досліджень досягнуто і виявлений напрям потребує подальших досліджень в процесі впровадження в будівництво.

Ключові слова: ґрунтоцемент, армовані ґрунтоцементні палі, фіброармування, бурозмішувальний метод, несуча здатність паль за матеріалом, лабораторні випробування, двофакторна матриця.