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EXPERIMENTAL RESEARCH OF SOIL STABILIZATION BY CEMENT PULSE INJECTION

The paper contains the results of experimental research dealing with the study of soil foundations carrying capacity stabilization using injection dynamic pressure. The results obtained proved the efficiency of pulse injection and showed that pulsing supply of the mortar provides 30% increase of its spreading, as compared with the usage of injection static pressure. The analysis of the study of mortars pulse injection in various soil structures has been performed, optimal parameters of the process are determined.

Key words: *pulse injection of the mortar, carrying capacity, foundation, spreading radius, depth of injection, dynamic pressure, pulsation frequency.*

Introduction

Numerous old buildings require constant monitoring of carrying capacity of main constructive elements of these buildings and their foundations. Practical experience shows that there exists the necessity to strengthen foundations and carrying basements of building and constructions. Recently, method of soil base strengthening and establishment of new foundations in condition of building density, providing the injection of high-pressure mortar in the depth of soil mass under certain static pressure has been widely used [1 – 3]. This method has a number of important advantages: it excludes dynamic loads on the foundation, emerging while driving piles; it can be used in any soil conditions and in conditions of dense building. Nowadays the problem of soil stabilization is actual and requires further research.

Analysis of the recent research and publications showed that the injection of foundations was carried out under the static (constant) pressure [2 – 4], it does not always provide high quality penetration and spreading of mortar in the depth of soil mass, and, as a result, does not ensure the necessary carrying capacity of the mass.

Main part

To improve the efficiency of injection method of soil foundations stabilization , the authors suggested the method of usage of additional pulsation of operation pressure, created by special generator of hydraulic pulses, on stationary flux of cement mortar delivery.

For carrying out experimental research experimental stand was developed (Fig. 1) [5, 6], it operates in the following way. When mortar pump 3 is switched on, injecting mortar under the preset pressure is fed across the pipeline and fills up the tank for injecting mortar supply 1. Under the action of working pressure, created by the compressor 10, the supply of injecting mortar across the check valve along the pipeline 2 in technological chamber 5 and further along the pipeline 12 to internal cavity of the injector 11 and pores of soil material, located in the tank 7 is performed.

When the pump of drive hydraulic system 8 working fluid under the preset pressure enters the cavity 4 of hydraulic cylinder 13. The pressure of the working fluid increases to certain boundary value, at which generator of hydraulic pulses 9 is adjusted. Under the action of working fluid pressure on the area of the plunger 6, it moves to the right and creates additional load on the closed volume of the injecting mortar, located in the chamber 5. As a result, additional portion of injecting mortar in the pipeline 12 is pushed across the injector 11 into the soil mass. When critical pressure of working fluid is achieved, the pulse valve 9 operates in the cavity 4. The pressure of working fluid in drive hydraulic system 8 drops and working fluid is removed to discharge. Further the process is repeated in automatic mode.

Experimental research were carried out at three types of soil foundations: sand, sand loam and loam. Soil foundations had the following physical-mechanical characteristics:

a) for sand: specific weight – 18.1 KN/m^3; filtration factor – 9.0 m/day; deformation modulus – 15.3 MPa; specific adhesion – 8.1 kPa; angle of internal friction – 27.8 degr;

b) for sand loam: specific weight – 18.6 KN/m^3; filtration factor – 0.48 m/day; deformation modulus – 12.5 MPa; specific adhesion – 19.2 kPa; angle of internal friction – 25.3 degr;

c) for loam: specific weight – 19.4 KN/m^3; filtration factor – 0.04 m/day; deformation modulus – 9.5 MPa; specific adhesion – 26.8 kPa; angle of internal friction – 18.2 degr.

As injecting mixture, cement mortar was used, ratio water/cement=1. While performing the experiments, working discharge pressure varied within the range 0.2 – 0.4 kgf/cm^2, frequency of pressure hydraulic pulses repetition varied from 5 to 10 Hz. Besides, the volume of injected mortar in soil mass also changed.

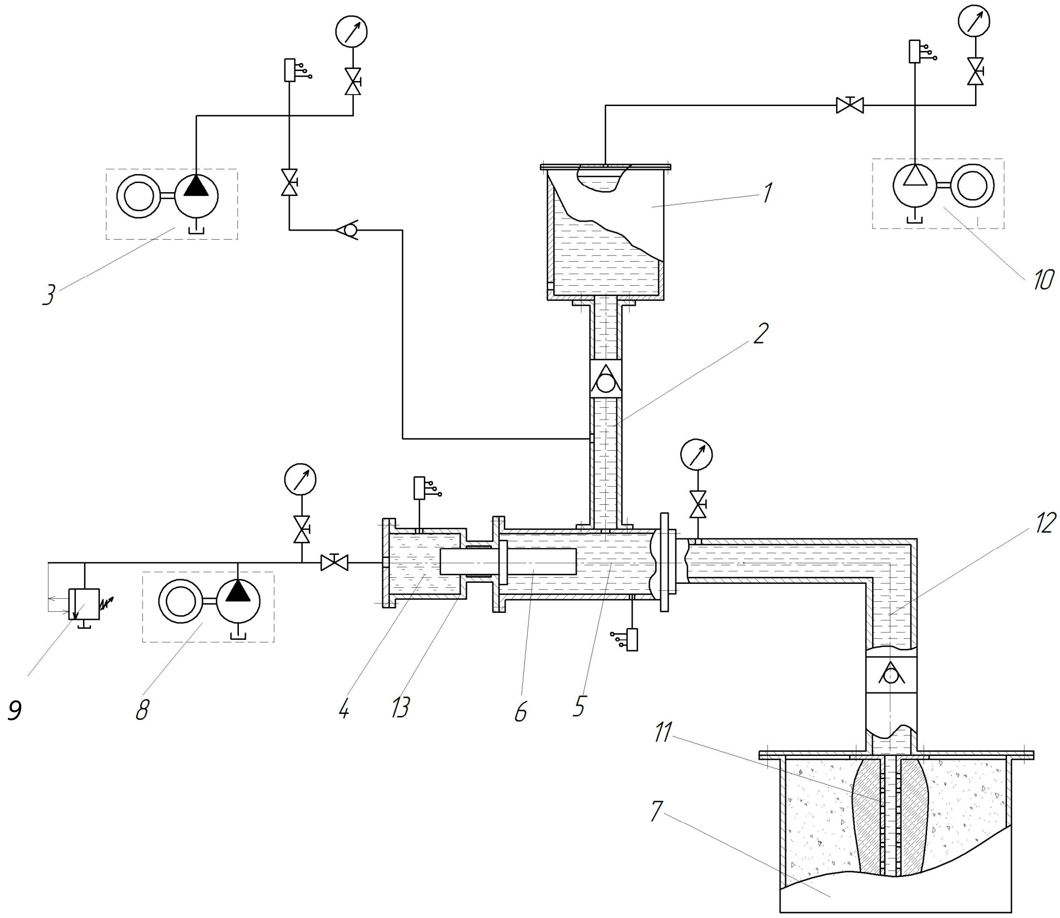

Fig. 1. General view of experimental stand and its components: 1 – vessel for injection mortar supply; 2, 12 – pipelines; 3 – mortar pump; 4 – working chamber; 5 – technological chamber; 6 – plunger; 7 – tank, filled with porous soil material; 8 – hydraulic-drive station; 9 – pulse valve; 10 – compressor; 11 – injector; 13 – hydraulic cylinder

Fig. 2. Determination of spreading radius of the mortar of obtained experimental sample under discharge pressure p = 0,3 kgfc/cm^2 with pulsation frequency10 Hz

Studies were performed in two stages [7]. At the first stage mortar injection was performed under constant (static) pressure. The obtained samples are shown in Fig. 3, c). At the second stage pulsation was imposed on stationary flux of mortar, supplied at the working pressure. The obtained samples are shown in Fig. 3 a), b), correspondingly. While performing the experiments all the obtained experimental samples had solid structure.

As it is seen from Fig. 3 permeability of the mortar was observed at pulsation frequency of 10 Hz. It can be explained by the fact, that as a result of hydraulic pulses application the forces of friction between soil foundation and injected mortar are reduced in the flux of cement mortar, that causes the increase of mortar spreading area and increase the radius of its spreading. As a result, carrying capacity of saturated soil increases. Pulse injection enables to discharge under pressure 1.8 – 2.2 times more cement mortar as compared with conventional static injection.

Fig. 3. Obtained experimental specimen: a) at injection frequency 10 Hz; b) at injection frequency 5 Hz; c) at constant injection pressure

Table 1

Comparative table of mortar spreading radius change at various injection modes

Injection pressure	Static pressure	Pulse injection ω=5 *Hz*	Pulse injection ω=10 *Hz*
		sand	
p =0,2 kgf/cm^2	64 *mm*	84 *mm*	108 *mm*
p =0,3 kgf/cm^2	78 *mm*	96 *mm*	118 *mm*
p =0,4 kgf/cm^2	86 *mm*	106 *mm*	124 *mm*
		sand loam	
p =0,2 kgf/cm^2	53 *mm*	74 *mm*	92 *mm*
p =0,3 kgf/cm^2	62 *mm*	88 *mm*	102 *mm*
p =0,4 kgf/cm^2	70 *mm*	93 *mm*	110 *mm*
		loam	
p =0,2 kgf/cm^2	29 *mm*	40 *mm*	56 *mm*
p =0,3 kgf/cm^2	34 *mm*	46 *mm*	64 *mm*
p =0,4 kgf/cm^2	38 *mm*	53 *mm*	74 *mm*

After carrying out experimental research determination of mortar spreading radius at various injection modes was performed (Fig. 3). The results of spreading radius change are shown in Table 1. As it is seen from the Table, while using pulse injection at pulsation frequency 5 Hz, it is possible to increase the radius of mortar spreading on average 25 – 30%, and if pulsation frequency is 10 Hz, then the radius increases on average 35 – 40%. Varying the pulsation frequency of cement mortar we can forecast the necessary radius of its spreading in soil foundation.

On the basis of experimental research, carried out, graphs of the radius of mortar spreading change, depending on injection pressure (Fig. 4 – 6) were constructed. As it is seen from the given graphs, maximal radius of mortar spreading is observed at pulsation frequency of 10 Hz at all values of pressure change Proceeding from the results obtained, the conclusion can be drown that the permeability of mortars and the area of their spreading increases with the increase of pulsation frequency. For practical application of pulse injection it should be noted that pulsation frequency of the mortar can be increased only till certain limiting value, at which further hydraulic break of porous medium occurs.

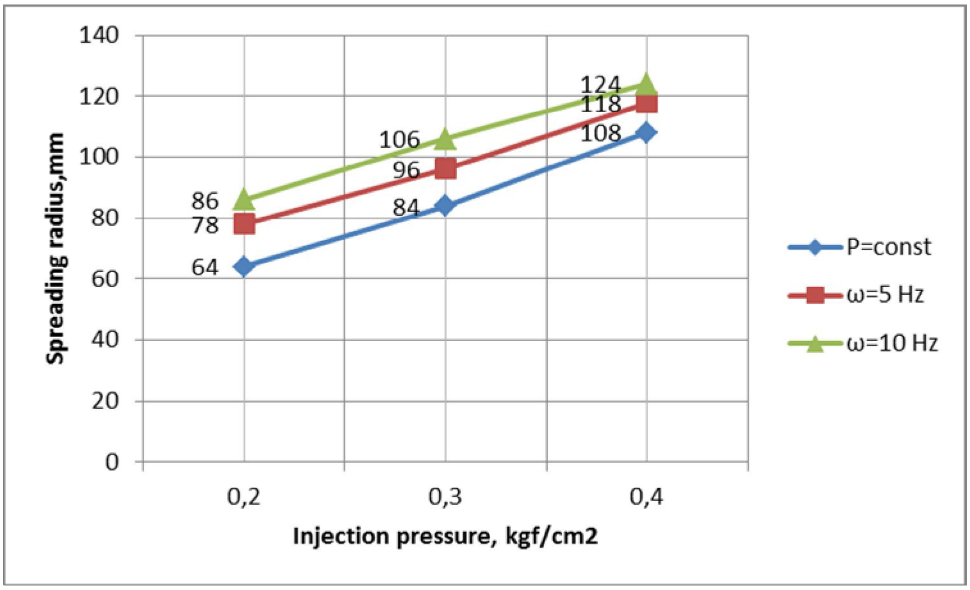

Fig. 4. Graph of mortar spreading radius change dependence on injection dynamic pressure for sand

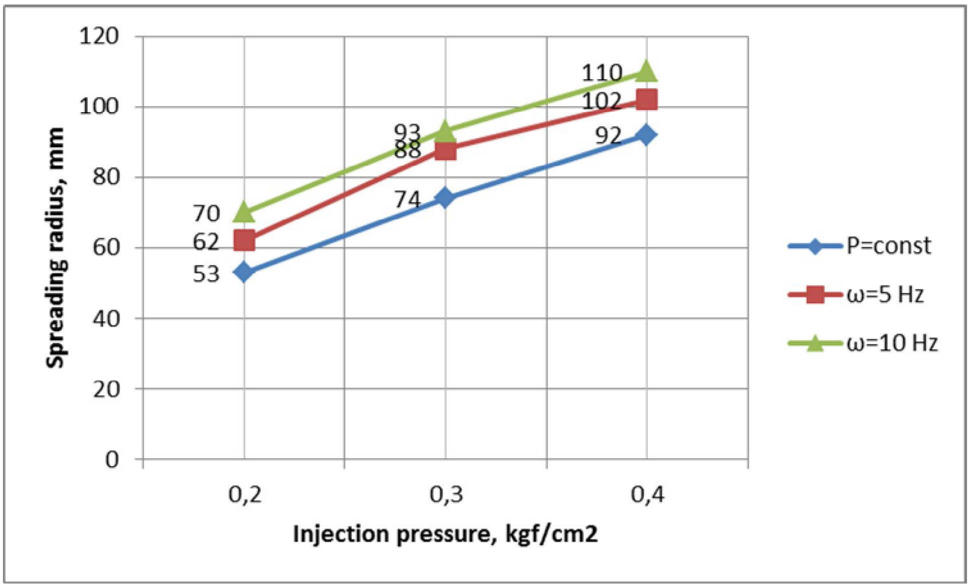

Fig. 5. Graph of mortar spreading radius change dependence on injection dynamic pressure for sand loam

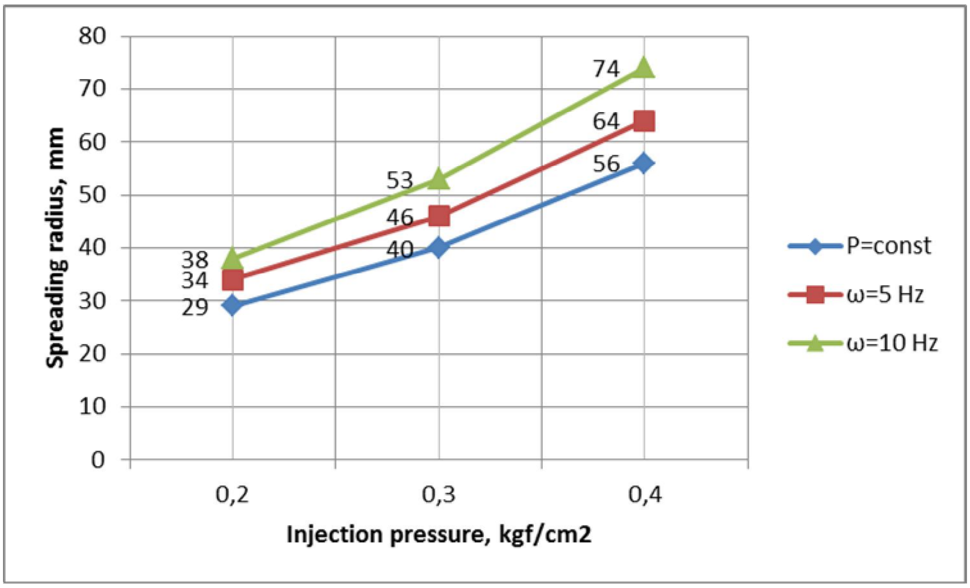

Fig. 6. Graph of mortar spreading radius change dependence on injection dynamic pressure for loam

Conclusion

1. Experimental verification of the suggested hydraulic pulse equipment has been carried out, quantitative and qualitative evaluation of parameters and characteristics of technological mortars discharge under pressure into soil mass has been performed, the verification, carried out proved the efficiency of the equipment.

2. Comparison of research results, carried out in accordance with the analysis of formed filling bodies (Fig. 2, 3) showed that pulse discharge of injecting mortars in the mass is more efficient as compared with static one, at the increase of pulsation frequency of the mortar , its spreading in the depth of soil mass also increases. Finally, in practical application this may ensure high strength of reinforced soil mass and greater carrying capacity of bases and foundations.

3. Experimental research showed that pulse injection enables to discharge under pressure 1.8 – 2.2 times more cement mortar as compared with the static injection. The increase of mortar spreading radius on average by 30 – 40% as compared with conventional static injection is observed, that considerably influences the stability and carrying capacity of stabilized soil mass.

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