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Results of field experiments on chemical grounting of less-like subsiding soil

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Abstract:*The method of strengthening the soil with a chemical (silicification and cementing) solution using equipment for injecting a solution with high pressures is used to strengthen the foundation soils of new buildings, during the construction of trunk network nodes and subway tunnels under the buildings of large cities, as well as to fix the foundation soils of structures above them, including including for the strengthening and stabilization of earthworks of large-scale reservoirs and wastewater disposal. The article considers the results of full-scale field experiments on the chemical fixation of loess-like subsiding soils in the territory of the city of Darkhan, Mongolia.*

Keywords:*cementation, silicification, mechanical parameters, deformation modulus, injector.*

I. INTRODUCTION

Soil strengthening is a method of artificially creating the physical and mechanical properties necessary for the construction of buildings using various physical and chemical methods. The purpose of artificial soil improvement is to increase its strength and stability, reduce deformations, water absorption and compression, and at the level of modern scientific developments, many problems in construction practice can be solved by choosing and applying effective physical and chemical methods of soil strengthening (B.A. Rjanitsyn [1], Abelev M.Yu., Averin I.V., Bahronov R.R. [2], Toms B.A. [3], D.Dashjamts D.[4], Karol R.H. [5], Magill, D. and R. Berry, [6], Makovetsky O.A.[7], US Army Corps of Engineers [8]). At the same time, especially in the conditions of Mongolia, the injection method is used to strengthen the under-compacted soil of the backfill of the foundation and under the floor of the building, as well as to strengthen the base and foundations of historical architectural monuments and modern buildings that have undergone subsidence deformation, as well as to eliminate horizontal and vertical displacements of the foundation soil and earthworks. Many researchers have found that the most appropriate and reliable technology for solving the above problems in a number of situations is the chemical method of silicization and cementation of soil by injection.

II. MATERIAL AND METHODS

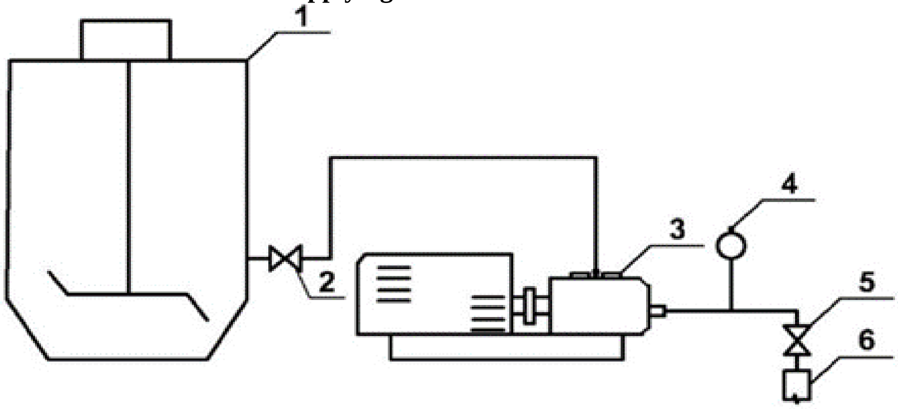
A. Engineering and geological conditions. As part of the development of technology for the installation of pile foundations, the territory of the city of Darkhan was chosen as a reference point and the characteristics of the physical and mechanical properties of the soil were determined. The next two soil layers lie in the experimental site, from which the sandy loam soil is separated: sandy loam with natural moisture for dynamic tests and with W_{sat} moisture for static tests.

EGE-1. Light yellow low-moisture dusty sandy loam lies to a depth of 4.5-5.5 m from the soil surface and belongs to type I in terms of subsidence. According to tables BNbD 50.01-16 [9] for the standard parameters of naturally wet soil: C_n=49 кПа, φ_n=34°, E=16,1MPa. And for soil at W_{sat} : C_n=12кПа, φ_n=27°, E=4,1Mpa.

EGE-2. Dense and semi-solid in consistency, reddish-brown gravel loam (dpQ(IV-III)) characteristics are given according to the results of laboratory tests of the soil: adhesion force C_n=76 kPa, internal friction angle φ=21°, deformation modulus E=32 MPa. When drilling to a depth of 18.0 m, no groundwater was found.

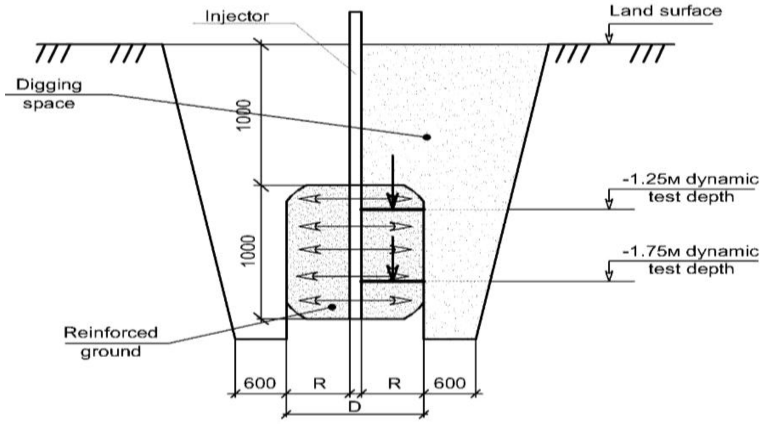
B. Field tests. Field tests for fixing subsiding sandy loamy soil were carried out according to the method described in MNS 2489:1986. The technological scheme of the experiment is shown in Fig. 1.

Fig1. Technological scheme for conducting an experiment on strengthening subsidence soil by the method of chemical injection: 1-a barrel for a solution; 2 and 5-valve; 3-pump; 4–manometer; 6-pipe for supplying the solution to the well.



The design scheme of the test and the location of sampling points for determining the mechanical parameters of the reinforced soil are shown in Fig 2.

Fig2. Calculation scheme and points for the selection of reinforced soils



III. RESULTS AND DISCUSSION

A. Mechanical characteristics. The design parameters of the strength of the reinforced soil are determined, among other things, by the ratio of the load and bearing capacity ***CBR***, the frontal resistance of the dynamic probe q_s, the adhesion force **c**, the angle of internal frictionφ, the density ρ, the humidity ***W*** and the degree of humidity ***Sr*** (B.Basbish [10]). Of these, the soil cohesion force c, the angle of internal friction φ and the density ρ are considered as the main mechanical indicators, which are compared in diagrams and are shown in Fig 3...8.

Fig 3. Comparison of average values C of soil reinforced with liquid glass

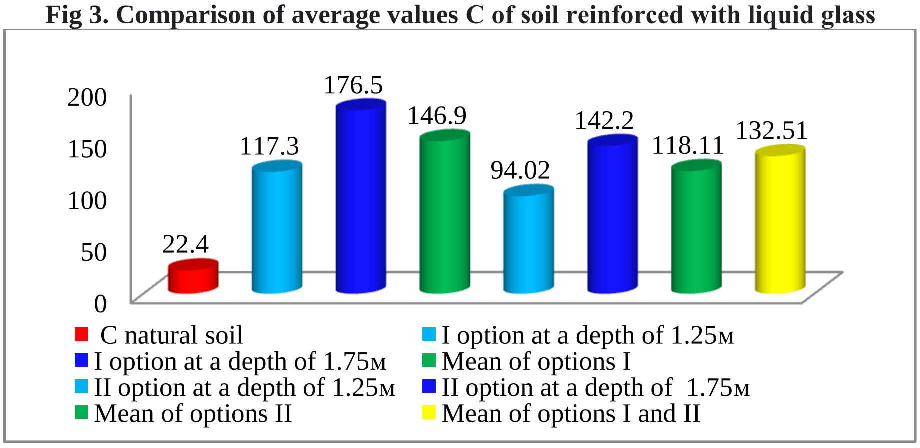


Fig 4. Comparison of average C values of cement-reinforced soil

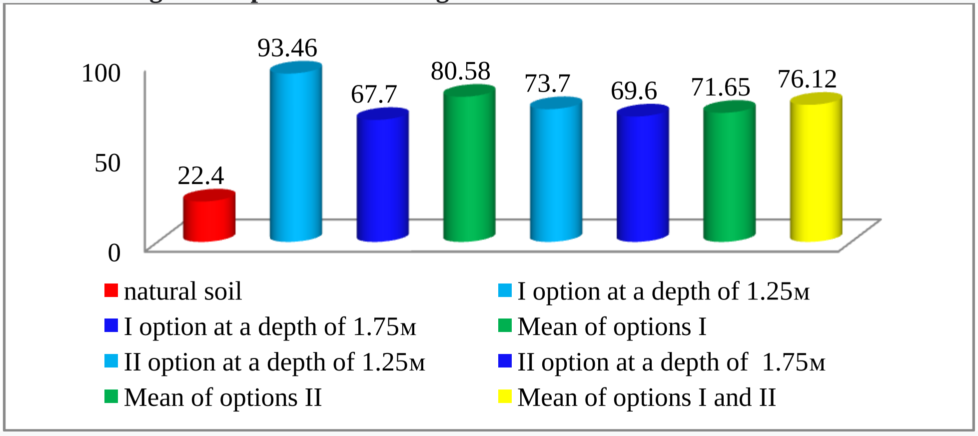


Fig 5. Comparison of the average values of φ of the soil reinforced with liquid glass

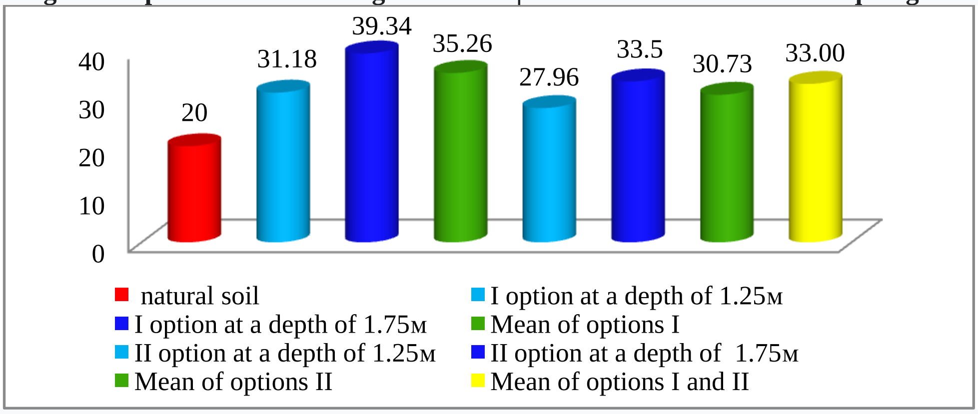


Fig 6. Comparison of the average values of φ of soil reinforced with cement mortar

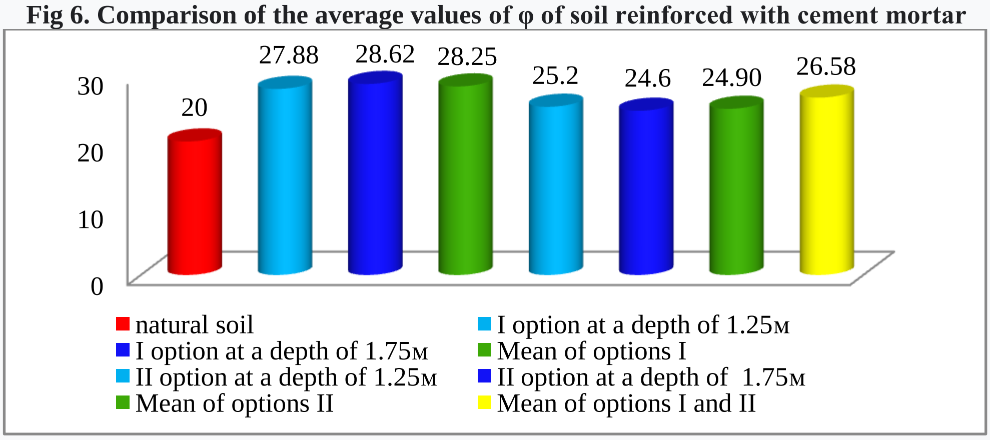


Fig 7. Comparison of the average values of ρ density of soil reinforced with cement mortar

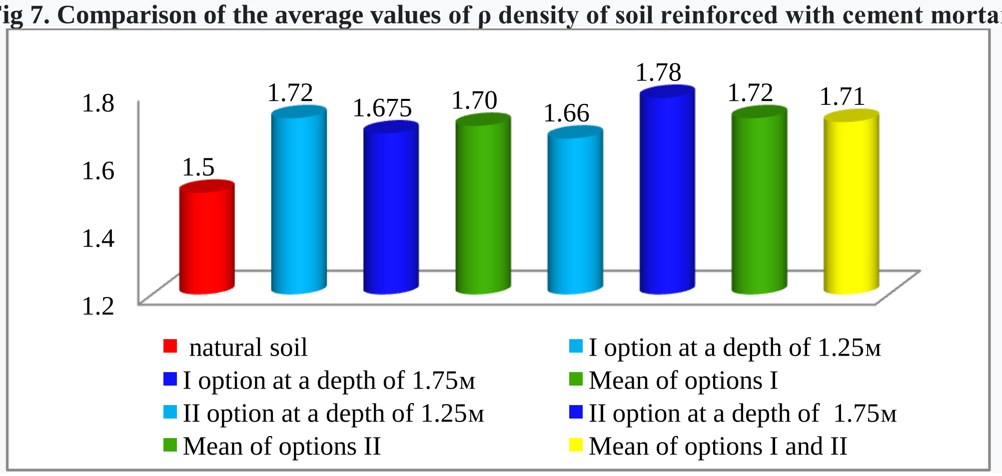
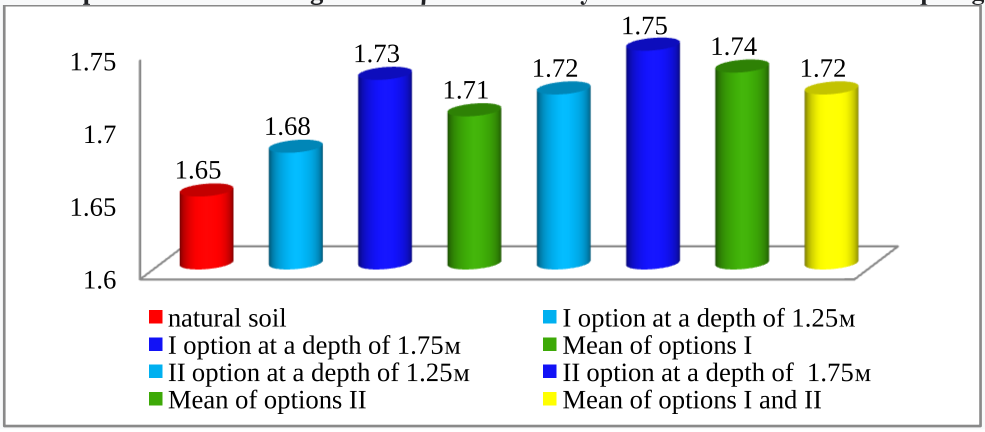


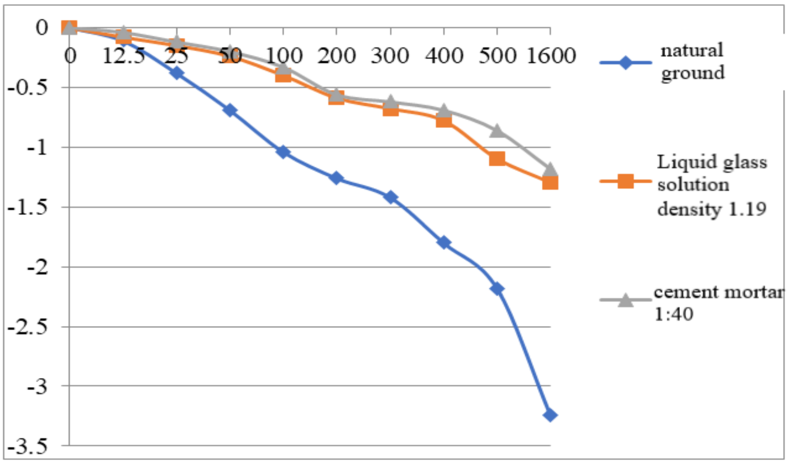
Fig 8. Comparison of the average values ρ of the density of the soil reinforced with liquid glass



According to the results of the analysis of the compared strength indicators, i.e. adhesion force C of chemically fixed sandy loamy soil, it was found that it increased 6 times compared to loose soil, and φ of loose soil decreased by 10 ° compared to φ of fixed soil, natural density ρ increased from 1.5 t/m3 to 1 .75 t/m3 after fixing.

B. Settlement of fixed ground. 6 soil samples with undisturbed structure (3 pcs × 2) were tested in the laboratory under a pressure of 12.5-1500 kPa and precipitation was determined according to the standard method. According to the results of the experiments, a graph of the dependence S=f(P) was plotted, shown in Fig. 9.

Fig 9. Dependence curve S=f(P) based on the results of tests of fixed subsidence soil



Analysis of the S=f(P) dependence graph, carried out on the basis of the results of laboratory odometric tests of unreinforced and chemically reinforced sandy loamy soil, revealed the following dependencies: in comparison of the test results of reinforced soil with a solution of liquid glass, the amount of settlement corresponding to a pressure of 50 kPa, 1.3 times, and the magnitude of the settlement corresponding to the same pressure of the settlement of the soil reinforced with a cement mortar 2.1 times greater than that of the unreinforced soil.

C. Deformation modulus of reinforced subsidence soil. A field test procedure for determining the modulus of compacted soil is described in MNS 2489:1986. 28 days after the strengthening of the soil, digging with a measurement at a depth of 1.25 m, a reinforced monolith with a diameter of 0.95 m was formed, and at a depth of 1.75 m with a diameter of 1.20 m, with a length (height) of 1.1 -1.2 m (Fig. 10).

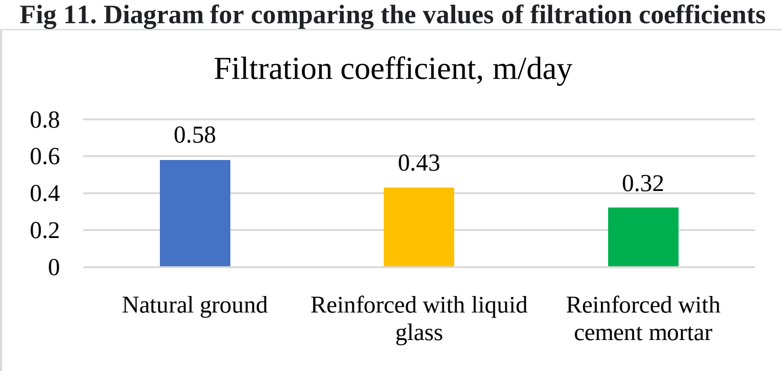
Fig 10. Photo of measuring the geometric dimensions of the fortified subsidence soil.

D. The filtration capacity was determined on the KF-00 device, the values of the filtration coefficient are given in Tab 1 and are shown by a digaramma (Fig. 11).

Table 1 Comparison of average values of filtration coefficients for reinforced soils

Type of reinforced soi	Filtration coefficient, m/day
Soil with a natural structure	0.60
Soil with a strength of 1.19 g/cm^3, enlarged with liquid glass	0.43
Soil coarsened with cement mortar 1:40	0.32

Fig 11. Diagram for comparing the values of filtration coefficients



From the diagram, it can be concluded that after strengthening with a chemical solution, the filtration capacity of the soil decreases by 17-28%, and it can be seen that the injected solutions filled the pores between the solid particles of the subsiding soil.

IV. CONCLUSION

1.The numerical value of the deformation modulus is determined by formula (3.12) from SP 22.13330.2016 based on the (q_s) results of a dynamic probe test carried out with a proative device, and is given in table 7.14 of the dissertation. When comparing the results of field and laboratory tests and analytical calculations, it was found that the average modulus of deformation of soil reinforced with a solution of liquid glass with a density of 1.19 g/cm3 is E = 7.80 MPa, and soil reinforced with cement solution E = 11.52 MPa , the difference is 33.0%.
2. Settlement of soil reinforced with a solution of liquid glass, corresponding to a pressure of 100 kPa, is 1.76 times less, sediment of soil reinforced with a solution of cement is 2.0 times less. The sediment of soil reinforced with a solution of liquid glass, corresponding to a pressure of 500 kPa, is 2.15 times less, the sediment of soil reinforced with a solution of cement is 2.45 times less. The sediment, corresponding to a pressure of 1600 kPa, in soil reinforced with a solution of liquid glass is 2.5 times lower, and fortified with cement mortar, 2.75 times lower than in loose soil.

3. Based on the results of experimental and theoretical studies, an effective method for strengthening subsidence soil, taking into account the regional characteristics of Mongolia, is cementation using a cement slurry prepared with a composition of 1:40 and grade 450, can be combined with various additives, such as silicate mortars, bentonite clay and sand quartzite (Nyamdorj S.[11]).

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