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Application of "Jet Grouting" for Installation of Substructures of Estates

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Abstract

The use of technology "soil jet grouting" for the device of vertical geotechnical barriers is now widespread. The arrangement of jet elements in the plan may be single - or multi-row, contiguous or split. The choice of the solution depends on specific geological conditions of the site. The design of the geotechnical barrier, made of jet elements, is reduced to the calculation of strength and reliability assessment of the structure. Principles of the purpose structural design are based on the theory of reinforced concrete and experimental data on testing of samples of materials. The purpose of this paper is the acquisition and analysis of the empirical data during the stabilization of foundation soil by applying the "jet grouting" method.

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Keywords: Jet grouting; Compressive strength of a soil-cement element.

1. Introduction

Jet geotechnology, known as «Jet-grouting method», is an advanced research field in modern geotechnics. Application of jet grouting enables to create homogeneous foundation soil with the pre-set physical and mechanical properties, and it provides a high serviceability [1]. Furthermore, in comparison with traditional design considerations, for example, application of bored piles, operation time and base preparation cost decrease. The construction method of jet grouting makes it possible to control compression zones of a base and modify its properties at best depth range [8,9].

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This technology has been applied in Russia and Europe during the construction of such large sports structures, as stadiums, which belong to the projects of enhanced responsibility [3].

2. Monitoring of formation conditions of the hard element

One of the examples is the construction of a new stadium of the football club «Krasnodar», the site of which is situated in the city of Kransodar, in Prikubansky interurban district. The terrain of the construction site is relatively flat. The absolute marks of the ground surface range from 27,2 till 28,4m.

Within the limits of the soil column, studied during soil investigation (to the depth of 40m), 7 engineering geological elements were separated: EGE-1 hard loam, collapsing (E=12.4MPa); EGE-2 semisolid loam (E=16.5MPa); EGE-3 silty sand, tight (E=28MPa); EGE-4 semisolid clay (E=14.9MPa); EGE-5 stiff loam (E=12MPa); EGE-6 medium sand, tight (E=34MPa); EGE-7 gravel sand, tight (E=41MPa).

The seismic activity at the construction site according to the map OCP-97B in terms of soil conditions is 8 points.

The analysis of engineering and geological conditions of the site with regard to its seismic activity showed that the main problems of the site are the possibility of vibroliquefaction and vibrocreep of the layer of tight silty sands EGE 3, and high porosity of the layer of brown clays EGE-4 at the earthquake intensity of 8 points [2,7].

At the stage of analyzing the stadium building-up documentation the following main peculiarities of its structural layout were found: the essential nonuniformity of loads on foundation and that the tolerances of settlement between the blocks of the stadium must be not more than 2.5cm.

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Therefore, the necessity of foundation grouting is determined by the objective to achieve stiff characteristics of the foundation, which comply with the requirements, imposed to the construction design of the stadium with regard to Relative differential settlement, and potential possibility of vibroliquefaction and vibrocreep of the layers EGE-3 and EGE-4.

Comparing two variants of securing serviceability of the foundation plate base under seismic forces: 1) installation of pile foundation consisting of bored elements, with the length of 15…20 meter and 2) solidification of layers EGE-3 (water-saturated sands) and EGE-4 (semisolid clays) by jet grouting, the second variant was chosen due to the cost and operation time criteria.

Measures for decreasing deformations of foundations and their influence on structures are regulated by the normative requirements. They specify that the design of soil solidification should make provision for the test and production work, moreover slurry compositions for soil solidification by injection method and physical and mechanical properties of soils should be specified according to the results of their solidification in laboratory or field conditions.

The quality control program was created for jet-elements during the process of foundation stabilization, which included: determination of the best process variables to secure the guaranteed diameter of a jet-element in all engineering and geological elements, and also determination of physical and mechanical properties of the obtained material (soil-cement) [4,5,6].

During in-situ production work the following compulsory controlled parameters were accepted: diameter of the elements - not less than 1200mm; compressive strength on the 28th day – not less than 4MPa.

In accordance with the program, on the construction site there were performed four soil-cement elements with «Jet-2» from the ground surface (absolute mark - 26,6m) at the depth of 13,0m (fig.1a). The drilling depth was determined on the basis of engineering and geological conditions of the construction site. The elements were performed with the cement consumption of 600, 650, 800 and 900 kg respectively, for one running meter of the stabilized soil. The layout of the elements is shown in fig. 1,b.

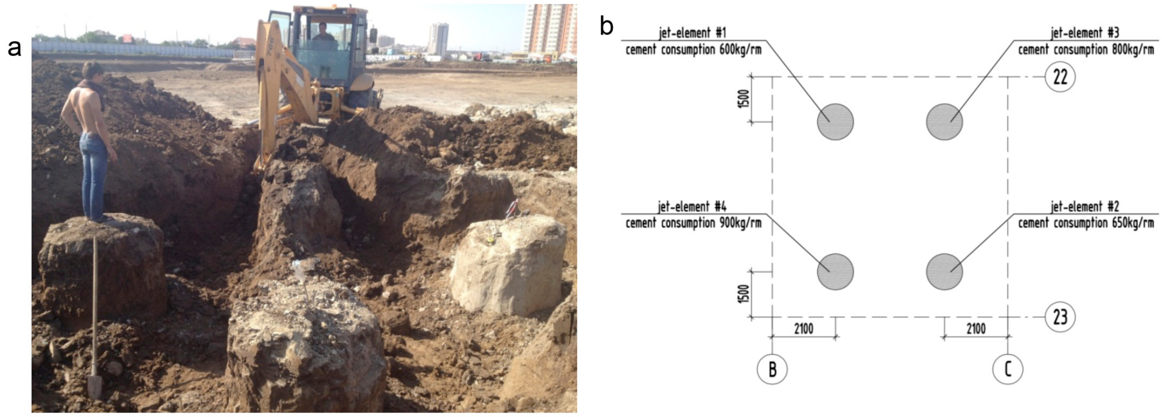

Fig.1. (a)Test site with excavated elements; (b) layout of jet-elements

3. Experimental determination of the mechanical properties

After the development of strength of soil-cement (aged 7 days) the performed elements were drilled around all over in order to determine their actual diameter. With the consumption 600 kg/m the diameter comprised 1000…1200mm that does not adequately provide for the parameters of an element required for the soil reinforcement. While performing the work with the cement consumption of 650, 800, 900kg/m the actual diameter of the elements in all engineering and geological elements is definitely higher than 1200mm.

Then check boring of the tested soil-cement elements with core sampling was performed for the following laboratory tests. Core sampling, transportation and storage were performed in accordance with GOST 12071-84. From each element there were taken 12 samples of soil-cement from the depths of 2,0; 3,0; 4,0; 6,0; 7,0; 8,0; 9,0; 10,5; 12,0 12,5m from the soil surface (fig. 2).

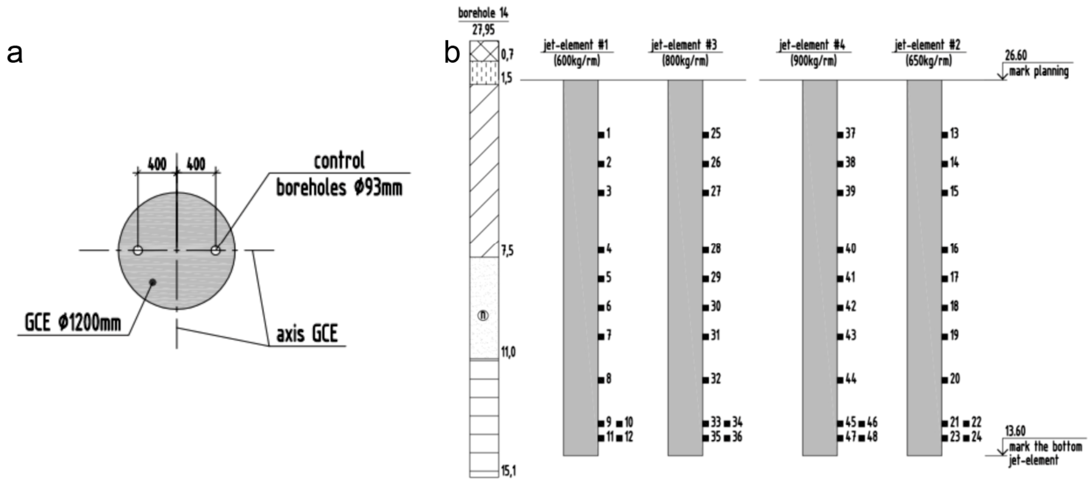

Fig.2. (a) layout of core sampling during check boring of boreholes; (b) layout of core sampling in depth of a borehole

The selected samples of the stabilized soil (soil-cement) were tested at the hardening age of 7 days and 14 days. Determination of compressive strength (Rcompr.) and stress-strain modulus (E) was performed on the universal testing machine Zwick2-250, in accordance with GOST 21153.2-84 and GOST 28985-91. Statistical processing of the test results enabled to define the mean values of the soil-cement compressive strength and stress-strain modulus, materialized in each engineering and geological element with different cement consumption values for one running meter. The soil-cement compressive strength (Rcompr.) is within the range: 3,2…5,3 MPa for EGE-2 (loam); 8,0…9,0 MPa for EGE-3 (sand); 3,4…3,8 MPa for EGE-4 (clay). The soil-cement stress-strain modulus (E) is within the range: 1,5…2,0 HPa for EGE-2 (loam); 4,0…4,4 HPa for EGE-3 (sand); 1,5…2,0 НПa for EGE-4 (clay).

The characteristics of soil, obtained in the course of investigation on the test site, were used for development of the project design for the new stadium construction. They made it possible to control compression zones of a base and modify its properties at best depth range.

The improvement of physical and mechanical properties of the foundation soil was achieved by installation of “geomass” in the base of the plate - soil-cement reinforcing elements with the diameter of 1,3…1,5 m, with the spacing between the axes of 2,5…2,8 m. In this case, soil-cement elements work in a unified mass with the surrounding soil under the whole surface of the plate, and are not considered as a pile element, delivering the load on the underlying layers with its tip.

The physical and mechanical properties of a separate soil-cement element were determined: density of the material γ = 23…25 kN/m3; design compressive strength – R= 3,5…4,0 MPa; stress-strain modulus – E = 350…400 MPa.

The represented strain characteristics of such geomass considerably increased. Specifically, the total strain modulus increased by the values E = 60,0…80,0 MPa as compared to the values of the strain modulus of natural soil E = 15,0…25,0 MPa.

Installation of the base reinforcement, according to the standard calculation, leads to decreasing of the effect of seismic forces on the structure. The presence of the regular grid of reinforced elements with the higher speed of S - wave transmission, as compared to the natural soil, leads to considerable energy dispersion in them (elements), and the wave impact on the soil, protected by the elements, is minimal.

At the same time, installation of such vertical reinforcing elements brings about the effect of soil squeeze reduction and possibility limitation and the absolute value of its volume strains under the influence of the seismic wave. Under the circumstances there are no such phenomena as «vibroliquefaction» and «vibrocreep».

After completing the work on soil stabilization at the eight construction sites, the geometric properties of the reinforcing elements and coring of more than 90 samples of the material (soil-cement) were subjected to control.

The results of the analysis proved the design consideration to be correct.

To sum up, installation of soil-cement reinforcing elements considerably increase the serviceability of the foundation by means of increasing its strain characteristics and active protection of soils from the influence of the seismic vibrations, providing for the safe operation of the sports structure.

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