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Jet and jet-mixing grouting

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Analysis of ground cement elements production technologies by jet, jet mixing and mixing technologies with the consumption of various quantities of cement needed for their manufacture is carried out, their applicability is determined. It has been defined that design of bases and building bases grouted by ground-cement elements on weak and subsidence soils requires scientific approach. Mixing and jet-mixing technologies are more cost-effective ones and do not require pulp utilization; the material (ground cement) obtained during soils jet grouting for determining change in its characteristics in time and under the influence of various factors should be studied.

Keywords: ground cement, ground cement elements, cementation, fixing solutions, building bases, technologies

Струминне та струминно-змішувальне закріплення ґрунтів

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Приведено аналіз технологій виготовлення ґрунтоцементних елементів за струминною, струмино-змішувальною та змішувальною технологіями з витратою різної кількісті цементу на їх виготовлення, визначено їх можливості використання. Встановлено, що проектування основ і фундаментів підсилених ґрунтоцементними елементами на слабких и просадочних ґрунтах потребує наукового підходу. Основною відмінністю відомих технологій виготовлення ґрунтоцементу є спосіб змішування ґрунту з закріплює розчином і тиск подачі розчину. Спосіб струменевої цементації грунтів, що заснований на здатності високонапірного струменю руйнувати закріплювальним розчином ґрунти досить великий міцності, утворюючи при цьому пульпу, що складається з ґрунту геологічного розрізу і закріплювального розчину, який подається з сопла малого діаметру під тиском 45-60 МПа. Роботу з руйнування ґрунту і його перемішування виконує високонапірний струмінь. Дуже близькі за способом виготовлення ґрунтоцементу бурозмішувальна і струменева-змішувальна технології. Бурозмішувальна технологія передбачає руйнування ґрунту бурозмішувальним долотом і змішування зруйнованого ґрунту з закріплювальним розчином механічним способом, який є в'язким композитом. При струменево-змішувальній технології додатково до механічного перемішування, виконується гідравлічне перемішування вже зруйнованого механічно ґрунту струменем закріплювального розчину під тиском в 0,2-0,4 МПа. Змішувальна і струмино -змішувальна технології більш економічні за витратою матеріалів і не вимагають утилізації пульпи; потрібні дослідження матеріалу (ґрунтоцементу), одержуваного при струменевому закріпленні ґрунтів для визначення зміни його характеристик в часі і при впливі різних факторів

Ключові слова: ґрунтоцемент, ґрунтоцементні елементи, цементація, закріплюючі розчини, фундаменти, технології.

Introduction. The regulatory document «Change 2 to DBN B.2.1-10-2009 (base and building bases)» gives design wider opportunities, using efficient, reliable and economical technologies for foundations arrangement. Soil cement is increasingly used as the building basis and in some cases as a base, which gives significant economic effect to construction, and buildings long-term exploitation when at their construction soil cement was used, confirms this technology reliability. The analysis of recent research and publications, containing the solution of this problem is given in a number of works. The technology of soil cement manufacture for different technologies and its use are described in the works [2 – 6].

The main difference between the known technologies of soil cement manufacturing is the method of mixing the soil with fixing solution and the pressure of solution injection The method of soils ink cementation is based on the ability of high-pressure jet to destroy the soil fixing solution of quite high strength, while forming a pulp consists of geological section soil and fixing solution, which is injected from a small diameter nozzle under pressure of 45-60 MPa.

The work on the soil destruction and its mixing is performed with a high-pressure jet. Blasting and jet mixing technology are very similar to the method of soil cement manufacturing. Mixing technology involves soil destruction with a mixing bit and the mixing of damaged soil with a fixing solution by a mechanical method, which is a viscous composite. Under jet mixing technology, in addition to mechanical stirring, the hydraulic mixing of the mechanically ground with a jet of fixing solution under pressure at 0.2-0.4 MPa is carried out.

Actual scientific researches and issues analysis. Numerous studies of conducting the work on the soil cement manufacturing by various technologies and in various engineering-geological conditions enable determining their capabilities and explicabilities. The main parameters of construction work performing are the speed of their execution, quality, safety, reliability and cost. At the same time, the change in characteristics of soil cement strength, manufactured by different technologies, is studied insignificantly. In general these works are performed at Poltava Technical Yuri Kondratyuk University, under the supervision of ScD, Professor N.L. Zotsenko [7]. It is noted there, that soil cement, manufactured by mixing technology has a strength which increases with time. Information on the the material obtained during soil fixation flow is scarce.

Setting objectives. to analyze possibilities of ground cement elements manufacturing technology by different means are analysed, soil cement changes with time are evaluated, their applicability is determined.

The main material and results. It is important for a designer to determine possibility of applying a certain technology to prepare basis of a specific section at a particular engineering geological structure. It is known that under complicated engineering and geological conditions, the value of the buildings foundations may amount to 25% or more of all construction.

The given article is not aimed at analyzing of what is better – the piles, which will cut the weak part of the base, or reinforcing this part of the base with a ground cement; we suggest leaving it for further objective research, and in turn we will perform a comparison of technologies for soil cement production. Thus, according to the reports and publications, we will analyze consumption of cement as the main component of fixing solution.

It is noted in [3] that consumption of cement is equal to the amount from 200 to 270 kg per 1 m^3 of soil cement while manufacturing soil cement by jet mixing technology. In such a case, the excess of soil cement pulp is from 0.1% to 0.5%, depending on the length of the cement element and the geological structure.

Under mixing technology [7] cement consumption is from 170 to 200 kg per 1 m^3 of soil cement, with an excess of pulp from 0.1% to 0.5%. As can be seen, these technologies are very close to materials cost. The consumption of cement under the jet technology is equal to the amount [8] from 800 to 1000 kg per 1 m^3 of soil cement. The excess of technological slurry is from 30 to 70%.

While performing works on soil cement elements manufacturing in sections made of subsidence soils, and especially in the built-up areas, it is necessary to exclude the possibility of such soils soaking. Soaking of these soils will have a negative impact on the adjacent building, and in some cases, catastrophic effects.

A series of experiments [3] was carried out to determine the influence distance of the cement element manufacturing by jet-mixing technology on adjacent soils, the purpose of which included determining the radius of forest soils humidification while manufacturing soil cement elements by the given technology. To perform this, the pit was carried out, the walls of which were secured by the jet mixing technology, and soil samples were taken from the walls to determine the change in the soil humidity for laboratory studies. It is known that forest soil, due to its structure, is better for pure water filtering, and impurities that are there in aqueous solution are delayed. In this case, it can be said that the distribution of water occurs at a greater distance than the solution. According to these data, it is established that increasing in humidity of cement element adjacent to the soil at a distance of 10 cm is nowhere in evidence.

Carrying out that and other field number and laboratory studies enable to arrange disconnecting screens from ground-cement elements in various engineering-geological conditions Fig. 1.

Figure 1 – Protective screen from ground cement elements

Such screens are used to exclude the influence of the building base in the newly erected building on the nearby shallow laying building bases in existing buildings.

Very close data are also obtained in the manufacture of soil cement elements by mixing technology. It indicates soil cement elements safe placement possibility on the above-mentioned technologies in forest soils.

In the paper [4] it is noted that when arranging the cement constructions in their manufacture by the jet technology in conditions of heterogeneous layering weak water-saturated dust-clay soils, strength soil cement strength value on compression practically does not depend on the type of soil, since most of the soil is placed on the surface in the composition of the pulp; the aggregates of the soil lower layer, when exiting the surface, together with the pulp, are mixed with the working balls set up above, and thus the body of the pile turns out to be practically homogeneous in composition of the height of the palm), which at one time was marked by A.G. Malinin [6]. In fact, the strength of the soil cement turns out to be approximately equal to the strength of the cement stone for a given water-cement ratio.

In addition, the results determining the change in the specific resistance to immersion of the cone probe at different distances from the manufactured cement-based element are given here. The criterion for assessing the changes in soil properties was ground soils static sounding results, performed before the work start on the fence installation and building base excavation pit.

According the paper, the resistance of the cone immersion varies greatly, and at the distance of 2.5D from the edge of the soil cement element strength adjoining soil increases by an average of 20-30%, which is a sign of the penetration solution at a considerable distance. In general, the diameter of the cement-based elements, which are made by the jet technology, is about 1000 mm. If the strength of the adjoining soils increases at a distance of 2500 mm, then the soaking occurs at a much greater distance. In forest soils, soaking up entails sedimentation. It must necessarily be taken into account when designing grouting base. Avoid it, due to manufacturing technology peculiarities of ground cement elements by the jet technology, it is impossible.

In addition, as noted above, there is a significant removal of the pulp, consisting of soil and cement mortar, and requires utilization. The amount of pulp, depending on the type of soil, is from 30 to 70% cement element amount.

As for all fixing solutions preparation using cement, it is necessary to understand the basic processes occurring in solutions preparation and solidification processes.

In the research course, which determined the optimal composition of the cement amount in the soil cement, samples were made, where the cement was 90-95%. The samples were exposed to weather conditions. When viewed, they were once again discovered that their destruction was occurring, as can be seen in Fig. 2, 3.

Consider the processes that occur when preparing a cement solution.

After adding to the water cement, a solution is formed which is supersaturated with respect to calcium hydroxide and contains ions:

$$Ca2 +, SO42-, OH-, Na +, K + \quad (1)$$

From the solution, hydrosulfate acuminate and calcium hydroxide are precipitated as primary tumors. At this stage, the system is not strengthened; the hydration of minerals is like a hidden nature. The second period of hydration (tussing) begins in about an hour with the formation of initially very thin crystals of calcium hydro silicates.

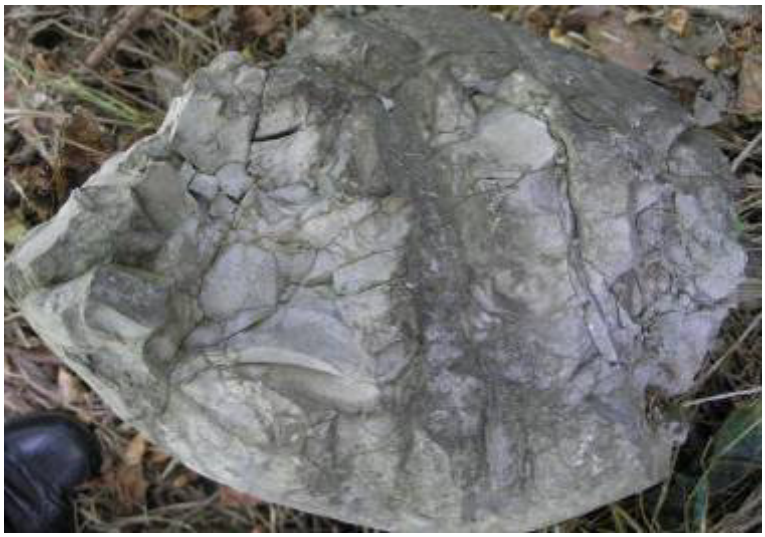

Figure 2 – Material sample fragment made by jet technology

Figure 3 – Material bundle under weather conditions influence

Hydro silicates and calcium hydrosulfate aluminates grow in long fibers form that penetrates the liquid phase in the form of bridges that fill the pores. A porous matrix is formed, which is gradually strengthened and filled with products of hydration. As a result, the mobility of solid particles is reduced and the cement paste is gripped. It is the first high-porosity low-strength structure that determines the tensile strength, consisting mainly of products interacting with water and gypsum. During the third period (hardening) pores are gradually filled with clinker minerals hydration products, there is a consolidation and strengthening of cement stone structure, as calcium hydro silicates increasing quantity formation result.

In the final form, the cement stone is an inhomogeneous system a complex conglomerate of crystalline and colloidal hydrates of formations, not activated residues of cement grains, finely divided water and air. It is sometimes called micro concrete.

The structural and mechanical properties of the cement dough increase as hydration of cement. For example, the maximum stress of the shift of the cement dough, according to E.E. Segalov. Measured after its manufacture, amounted to 0.01 MPa; before the beginning of the seizure, it increased to 0.15 MPa (i.e., 15 times), and by the end of the decade it reached 0.5 MPa (increased 50 times). Consequently, the cement paste differs with the ability to change quickly the rheological properties within 1 - 2 hours.

Portland cement hardening process is very complicated and is not yet fully understood at the same time. There are two main hypotheses that explain the transition of liquid cement mortar into a solid state. The crystallization hypothesis, initiated by Le Chatelier, explains the ability of the liquid cement mortar to

solidify and solidify by the fact that Portland cement clinker source minerals have significantly higher solubility than their connection with water.

In the final form, the cement stone represents an inhomogeneous system - a complex conglomerate of crystalline and colloidal hydrates of formations, cement grains non-activated residues, finely divided water and air. It is sometimes called micro concrete.

As can be seen from the samples, their cracking occurs due to the presence of non-activated cement grains, which, after the end of the solidification time, are reacting and the stresses that arise at the same time, lead to the bundle of the material.

From all of the above, the following **conclusions** are drawn:

– The design of building base and building base with soil cement elements on weak and subsidence soils requires a scientific approach;

– Strengthening of weak and subsidence soils by ground-cement elements by mixing and jet mixing technologies can be used to create bases for slab and separately located building base;

– Mixing and jet mixing technologies are applicable for strengthening the existing base and buildings base and eliminating dissolution occurrence;

– Mixing and jet mixing technologies are more cost-effective materials and do not require pulp use;

– Material (ground cement) study obtained during the jet grouting to determine the change in its characteristics in time and under the influence of various factors should be conducted.

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