RESEARCH ARTICLE | MAY 31 2023

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AIP Conference Proceedings 2684, 030045 (2023)
https://doi.org/10.1063/5.0119941

Methods of Soils Cementation

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Abstract. The article describes modern methods of soil consolidation using physico-chemical processes, in particular, cementation. The use of cementation is an effective method in the construction of foundations. Soils under the building are used, so this reduces the cost of the construction process. Cementation improves the physical and mechanical properties of the soil base to those necessary to ensure the bearing capacity of the foundation. At the same time deformations of a basis at the expense of smaller compressibility considerably decrease. The structure of different methods of cementation is presented. The latest methods of cementation by injection are described. Technological schemes of performance of works on performance of jet-cementation are resulted. The application of deep soil mixing method for new construction and strengthening of existing foundations is described. Technological schemes of various methods of jet cementation are given. The main features of jet-mixing in comparison with similar technologies are described. Conclusions are made about the advantages and disadvantages of different methods of cementation.

INTRODUCTION

Problem Statement

Erection of foundations requires a significant part of the total construction costs. One of the effective ways to reduce the cost of foundation construction is to improve the characteristics of the soils that form the basis for the foundation. This can be achieved by impregnating the soil with cement slurry (grout) – cementation. As a result of the process of hydration of cement, a material of quite significant strength is obtained – soil-cement.

Analysis of Recent Sources and Publications

According to the general classification of foundations and artificial foundations proposed by Professor M. Zotsenko, cementation belongs to the group of artificial foundations and foundations, which are made using physic-chemical processes and subgroups, where fixing is carried out by injecting binders into the soil [1,2].

Purpose Setting

When installing artificial foundations, the method of cementation is the most accessible, while the bonding of soil particles and aggregates with cement is realized. Cement can be impregnated more or less evenly throughout the soil, and it is possible to fix in the mass of its individual volumes, which together with the loose soil will create a single structure of greater rigidity than the loose soil. At the present stage of construction, there are 4 main types of soil-cementations depending on the method of soil saturation with cement slurry (grout) [1,14].

Reliability and Durability of Railway Transport Engineering Structure and Buildings
AIP Conf. Proc. 2684, 030045-1–030045-8; https://doi.org/10.1063/5.0119941
Published by AIP Publishing. 978-0-7354-4501-7/$30.00

PRESENTING MAIN MATERIAL

The classification of cementation types with the selection of species according to the method of cement supply to the soil is proposed (Fig. 1).

The cementation of soils should include the actual cementation, when by injection of cement mortar, under a pressure of up to 0.4 MPa, fixed massifs of permeable soils (coarse sands, gravel, fractured rocks).

In recent years, the research and production center "Inject" is introducing a new technology that is patented in Ukraine. The innovativeness of the method is to inject the base with special solutions (gel composites) through wells of small diameters under pressure up to 0.8 MPa, resulting in the formation of an array in the soil, which ensures the stability of the structure and, as a result, it is removed from the emergency state new features.

The solution, the so-called HELECOMPOSIT, which includes: cement, liquid glass and, if necessary, chemical additives "Cerenol C" by German-Polish company Deiterman, "Water retainer - 01" (RHD, BC - 01) manufactured by LLC Monolith – polymer, Kyiv, etc., can be used for any dispersed soils of both natural origin (sand, loam, sand, clay) and man-made nature (bulk soils, construction debris, etc.).

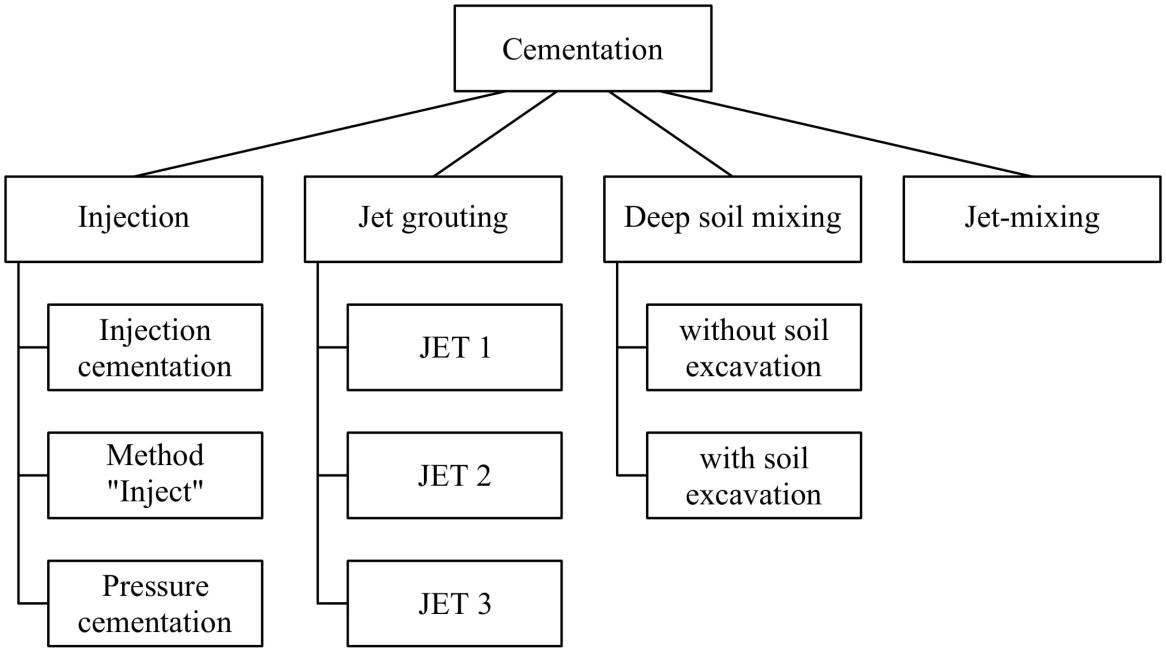

FIGURE 1. Types of cementations according to the method of cement supply to the soil.

The method of reinforcement of the soil mass, which is based on the controlled injection of volumes of hardening solutions, is carried out according to a specially calculated volume-planning scheme.

The inclusions formed in this case, within a radius of 0.5 - 1.5 m from the injector, expand during the pumping process and, due to the increase in the volume of the hardening solution, form a rigid reinforcing frame.

Fragments of the soil mass involved between the inclusions are compressed under the pressure of the injection solution and significantly improve their mechanical properties. The soil massif strengthened in this way is a new natural - technogenic formation.

Pressure cementation (hydraulic rupture of rocks) is when the cement slurry (grout) at high pressure ruptures impermeable soils, fills the gaps, thus forming a local network of cement fillings in the form of roots, which reinforces certain soil mass.

Jet Grouting

Jet cementation (JET GROUTING) is based on the use of high-pressure jet energy (30-90 MPa), which simultaneously destroys and mixes the soil with cement slurry (grout) in the mix-in-place mode, after hardening the

mixture forms a separate soil-cement column with sufficiently high mechanical properties relative to the soil. The scheme of jet cementation is shown in fig. 2 [12, 13, 14].

The process of manufacturing soil-cement column by Jet grouting technology:

1) drilling a leading well with a diameter of 112-132 mm (direct course);

2) lifting the drill string with rotation and simultaneous supply of a jet of cement slurry under pressure up to 700 atm (reverse stroke);

3) immersion in the formed soil-cement reinforcing element;

4) repeating for the next column.

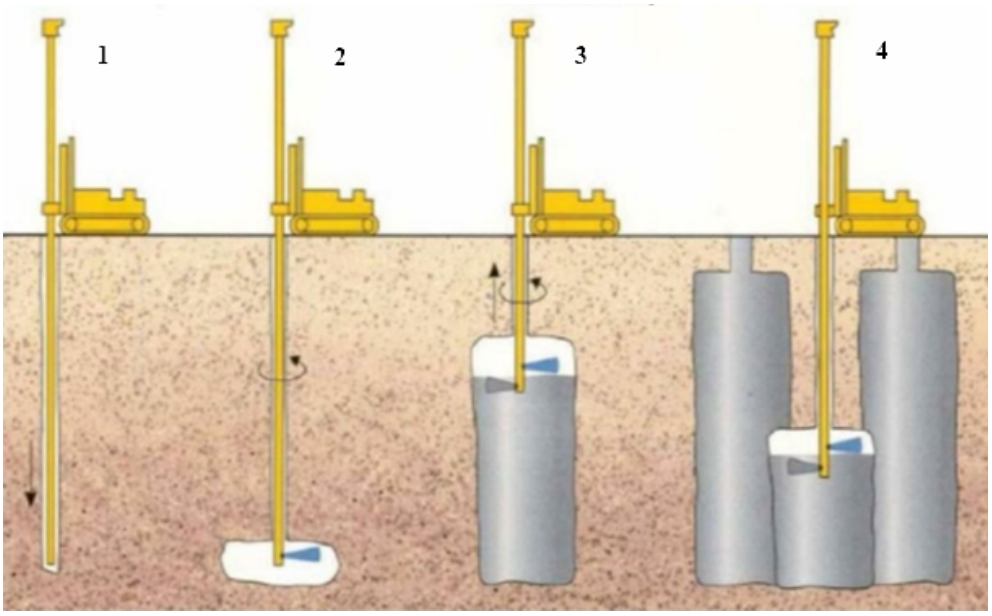

FIGURE 2. Scheme of jet cementation of soils.

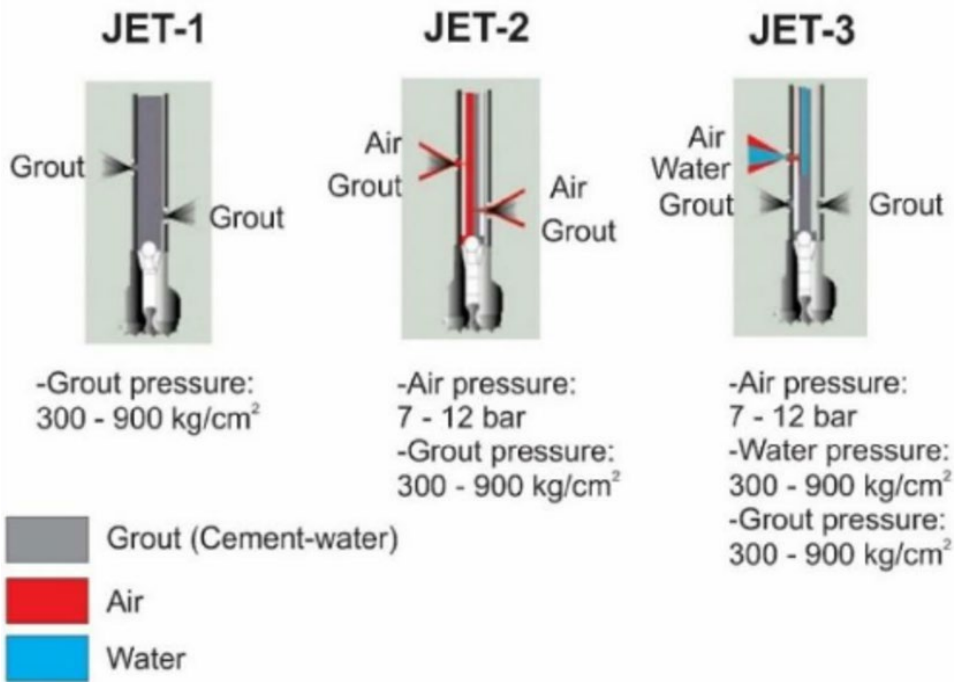

FIGURE 3. Methods of JET GROUTING technology.

There are 3 methods of column production by JET GROUTING technology (Fig. 3) [12].

A significant disadvantage of jet technology is that when destroying soils, especially clay, part of the cement slurry remains outside the body of the column. This part of the grout comes to the surface in the form of soil-cement pulp. Only about half of the total cement costs are used to make the column. 250 kg of Portland cement M500 requires the installation of one m^3 of soil-cement column with a strength of 7-8 MPa according to the deep soil mixing technology. Under similar conditions, 500 kg of cement per 1 m^3 of columns is required by jet technology. The positive quality of jet technology is its high productivity, because with its help it is possible to make up to 100 m columns in one shift in loam. According to the brown mixing technology of columns with the specified characteristics it is possible to make only 50 m. The introduction of jet technology for the production of soil-cement columns is further complicated by the fact that such equipment is not manufactured in Ukraine at all. It is quite complex, has special conditions of use due to the need to achieve high pressures (up to 90 MPa).

Deep Soil Mixing

For the above reasons, deep soil mixing technology for pile foundations, developed in the early twentieth century, is now gaining ground in Ukraine [3, 4, 6-11].

Deep soil mixing technology with partial soil extraction (Fig. 4). The essence of drilling technology is that with the help of drilling rigs, which provide drilling in compressed conditions at any angle, drill a leading well. When the well reaches the design mark, the reverse rotation of the auger puts forward additional knives of larger diameter and loosens the soil. In the zone of destruction through the swivel, which is equipped with a drilling machine, the slurry pump injects water-cement slurry (grout), which is thoroughly mixed with a loose mixer with loose soil. Loosening the soil, supplying cement slurry, and mixing it with the soil is performed over the entire thickness of the fixed base. After hardening of the mixture, a strong soil-cement element (column) with a diameter equal to the diameter of the knives is formed, which does not soak in the aqueous medium.

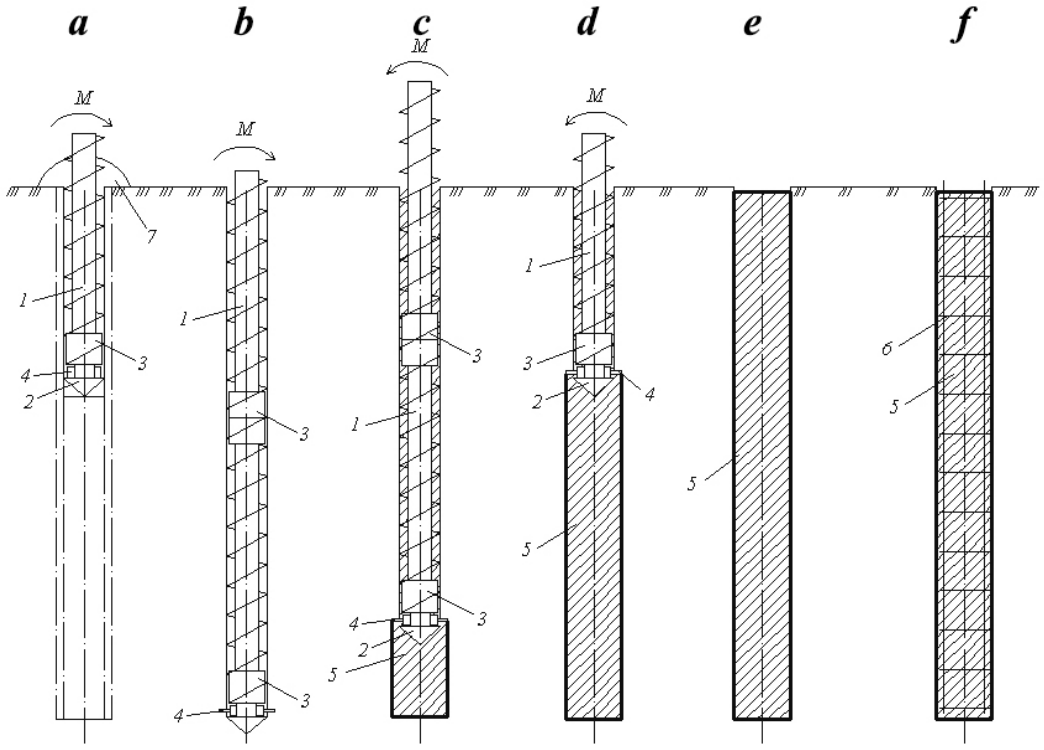

FIGURE 4. Technological scheme of arrangement of soil-cement element with partial excavation of soil:
a) drilling a well with the first auger; b) drilling with augers; c) the first passage of the auger with the solution; d) mixing of soil-cement on the site; e) elements with mixed soil-cement; f) immersion of a reinforcing framework in soil-cement:
1 - screws; 2 - tip; 3 - coupling; 4 - folding knives; 5 – soil-cement; 6 - reinforcing frame; 7 – soil.

The process of manufacturing soil-cement elements (columns) by this technology is shown in Fig. 4.

Drilling of the well begins with the first auger, which is equipped with a tip for soil destruction and folding knives for expanding the well and mixing the soil-cement. It also has holes for supplying mortar to the well (Fig. 4, a). The design depth of the well is achieved by gradually increasing the augers, which are connected by special couplings. In the process of drilling, a certain part of the soil is fed to the surface by augers and removed from the well (Fig. 4, b). When the design depth of the well is reached, the auger begins to rotate in the opposite direction, and the folding knives are opened. When lifting the augers, the knives begin to cut the soil in an area with a diameter of 200 mm. At this time, cement mortar begins to flow through the swivel from the mortar pump, which mixes with the soil (Fig. 4, c). At the height of one auger, mixing can be performed several times to achieve greater homogeneity of the soil-cement. After that, the upper auger is removed and the previous operations are repeated on the next section. Thus, the gradual removal of augers achieves the filling of the entire well with soil-cement (Fig. 4, d). In fig. 4, d shows the finished soil-cement element of soil reinforcement. If necessary, the reinforcing frame is inserted into the fresh soil-cement by means of hydraulics or vibration (Fig. 4, e).

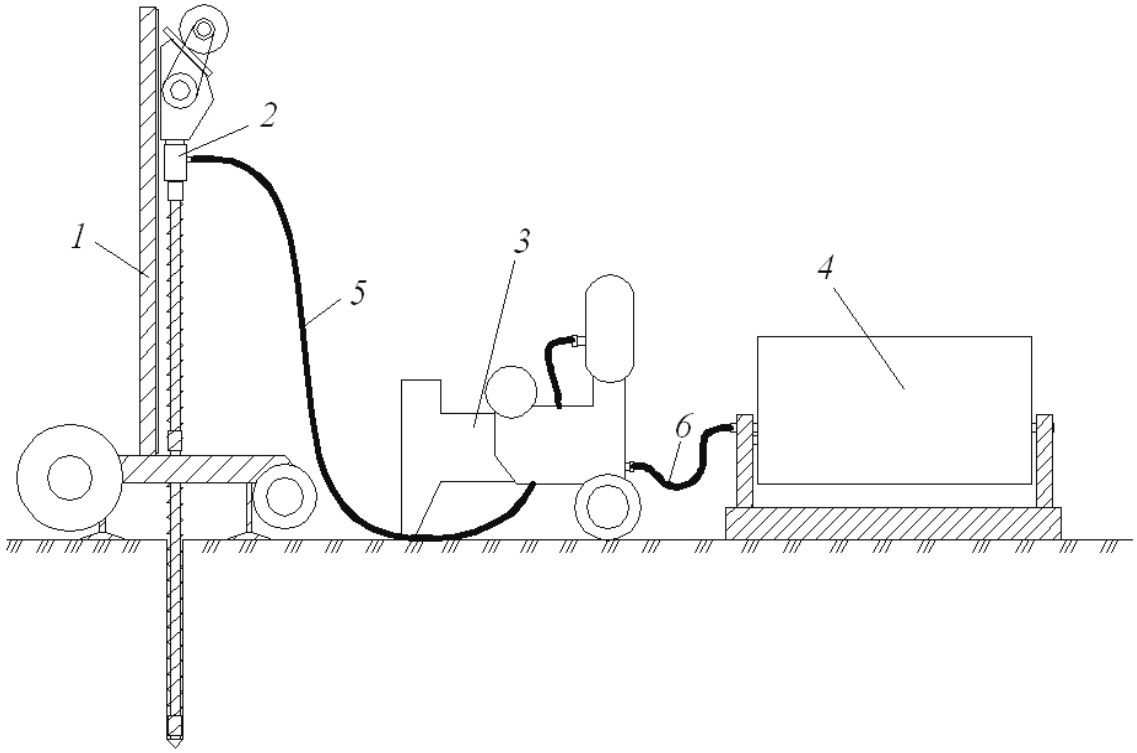

FIGURE 5. Set of equipment for the installation of soil-cement elements:
1 - drilling machine; 2 - swivel; 3 - slurry pump; 4 - slurry mixer; 5 - hose for feeding the solution through the swivel to the well; 6 - hose for supplying solution from the mixer to the pump.

The manufacture of soil-cement elements (columns) with partial excavation was carried out using a set of equipment (Fig. 5), which included:

- drilling machine UZB-12, modernized by the fact that instead of an internal combustion engine, an electric motor is installed; screws with a diameter of 80 mm are made with channels and openings for giving of solution; pressure hoses and swivels are provided to connect the augers to the mortar pump;
- slurry mixer for solution preparation, brand RN-90, volume 90;
- slurry pump for injection of solution into the well, brand CO-49, pump pressure 1.5 MPa.

The essence of drilling technology without soil extraction is that in the process of drilling a well with a special drill bit loosens the natural soil without removing it from the well. A water-cement slurry is pumped into the fracture zone through the swivel, which is equipped with the drilling machine, which is thoroughly mixed with loose soil by the working body. Loosening the soil, supplying cement mortar and mixing it with the soil is performed along the

entire length of the soil-cement element. After hardening of the mixture, a strong soil-cement element is formed, which does not soak in the aqueous medium.

Drilling mixing technology without soil extraction (Fig. 6).

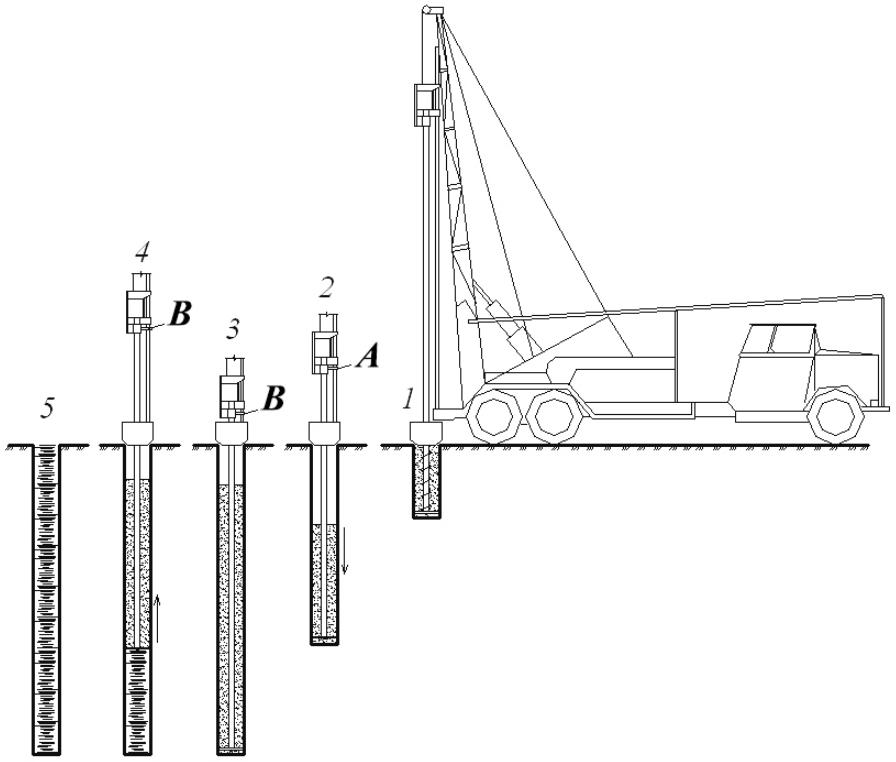

FIGURE 6. Technological scheme of arrangement of soil-cement elements in loess soils:
1 - arrangement of a pit; 2 - deepening of the drill mixer, and transfer of soil to a fluid state; 3 - the cavity is filled with soil of fluid consistency; 4- lifting the drill mixer and supplying water-cement slurry; 5 – ready element:
A – water; B – cement slurry.

Jet-Mixing

In Ukraine, the technology of the device of soil-cement elements using jet-mixing technology has been developed. The technology is taken as an analogue of drilling-mixing sludge consolidation, improved by the inclusion of elements of jet technology. It has been improved in application to rocks of different fractional composition, as a result of which good results have been obtained when performing work [5].

According to this technology, the soil is simultaneously destroyed and mixed by a stream of fixing solution, as well as mechanical mixing of natural soil with the supplied fixing solution.

Implementation of jet-mixing soil consolidation, depending on the required density of the massif, can be performed using the method of the leader well device or without it. The lead well is drilled with a screw. Auger drilling is called rotary drilling, in which the rock destroyed at the bottomhole is delivered to the surface by a screw conveyor - a string of augers. The auger is a hollow or massive shaft, on the surface of which a steel tape (flange) is welded along a helical line, which, when rotating, raises the destroyed soil to the surface. At the lower end of the auger string, a rock cutting tool is fixed. Under the action of an axial load, a rotating rock cutting tool separates rock particles from the bottom. They fall on the flange and are transported to the surface. In this case, part of the soil is removed, which ensures the supply of a larger amount of the fixing composition into the body of the reinforcing element. As it sinks into the ground, the drill string is built up with additional augers. This drilling is called flow drilling. In-line auger drilling is used for drilling sandy and clayey rocks that do not contain large inclusions. This method provides high drilling performance.

There are two types of auger drilling - continuous and annular face. Full face drilling is carried out with a continuous run (flow drilling), trip runs (trip drilling) and screw-in.

During in-line drilling, the rock to be drilled is continuously carried out of the borehole to the surface by a screw string, which is used to drill homogeneous layers of sand and loam that do not contain interlayers of silts and other soft soils, to determine the depth of hard rocks. The rotational speed of the drill string is set in the range of 50 - 150 rpm.

Route drilling consists of successive cycles (runs), including the immersion of the auger with a bit into the ground and its subsequent extraction from the well. It is used for drilling clay plastic and tough-plastic rocks. The size of the voyage deepening is set from 0.8 to 1.0 m, the rotational speed of the screw string is from 50 to 150 rpm, and the axial load is up to 500 N.

Rotary auger drilling allows you to determine the boundaries between soil layers with an error ranging from 0.5 to 0.75 m.

When installing soil-cement elements, the use of auger drilling allows you to adjust the amount of the supplied fixing agent per unit volume of soil. Drilling can be carried out with augers of various diameters, and, therefore, we can extract the required volume of soil from the well, which we subsequently replace with a fixing solution. Accordingly, it is possible, when mixing the soil per unit of its volume, to supply a larger amount of the fixing solution and significantly reduce the loss of the fixing solution when working in soils capable of holding the walls of the well.

CONCLUSIONS

Cementation technologies significantly affect the improvement of the mechanical characteristics of the base soil. To date, there are 4 main cementation technologies. Given their features, disadvantages and advantages, it can be stated that there is a need for economic justification for the use of certain technologies for specific geological conditions of the construction site. Injection methods have a disadvantage due to the low predictability of the spread of the solution in the soil. Jet cementation is the most productive production technology, but the equipment has a high cost and the technology itself is the most expensive. Optimal for application is brown mixing technology, which can be used in new construction and in strengthening the foundations of existing buildings.

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