

Efficiency of using construction machines when strengthening foundation soils

**Vadim Turchin¹, Ludmila Yudina¹, Tatyana Ivanova², Tatyana Zhilkina³,
Stanislav Sychugov⁴, Rimantas Mackevicius⁵ and Slizyte Danutė⁵**

¹Izhevsk State Technical University named after M.T. Kalashnikov, Studencheskaya str. 77, Izhevsk, Russia, 426069

²Izhevsk State Technical University named after M.T. Kalashnikov, Studencheskaya str. 7, Izhevsk, Russia, 426069

³Moscow State University of Civil Engineering, Yaroslavskoye Sh. 26, Moscow, Russia, 129337

⁴Izhevsk State Technical University named after M.T. Kalashnikov, Studencheskaya str. 7, Izhevsk, Russia, 426069

⁵Vilnius Gediminas Technical University, Saulėtekio str. 11, Vilnius, Lithuania, LT-10223

e-mail: vadimturchinn@mail.ru

Abstract. The article describes the efficiency of using construction machines when strengthening foundation base soils, as one of the ways to solve the problem of reducing and optimizing costs during construction. The analysis is presented in regard to inspection results of the soil bodies in the pile foundation base of “School of general education No. 5 in the town of Malgobek” of the republic of Ingushetia. Economical efficiency through reducing the duration of construction due to the automation of production is calculated.

1. Introduction

The problem of constructing on collapsible loessial soils and in other special circumstances routinely confronts designers with the need for qualified solutions to ensure stability and reliability of buildings and structures with high technical and economical indicators, and the builders - with the need for the implementation of these solutions with high quality and at low cost. Costs, expenses, prime cost are the most important economic categories. Their level largely determines the amount of profit and cost effectiveness of construction companies, the efficiency of its business activities. Reduction and optimization of costs during construction is one of the main ways to improve the economic performance of every construction company.

In Russia, the main areas (more than 80%) of occurrence of loessial soils are located on the territory of Central Chernozem Region, Eastern and Western Siberia, Povolzhye, Stavropol Region, Trans-Caucasian Region and in the North Caucasus. The loessial soils in certain regions of the North Caucasus region occupy up to 85% of the area and are the main type of soil foundations [1]. The total damage in the country caused by collapsible processes is approximately estimated at 600-800 million dollars a year. [2] Therefore, the problem of constructing on collapsible soils, as well as the reduction and optimization of costs during construction in the context of complex geotechnical conditions, are relevant both for investors and for design and survey organizations.



At the moment, there is a tendency to reduce costs for works by reducing the number of equipment involved during work, as well as by improving its reliability and performance.

In this article we estimate the economical efficiency through reducing the duration of construction due to the automation of construction processes.

2. Materials and methods

Due to the flooding of soils occurring within the compressed thickness of the foundation bases, there is watering of the soil body, causing a sharp reduction of its load-bearing capacity, which leads to the relative settlement of superstructures. The building settlement process can be disastrous, so it is necessary to provide for measures to strengthen the soil foundation.

Injectible strengthening of soils and materials is the most effective technological method of strengthening the bases and foundations of buildings and structures. When constructing on collapsible loessial soils, loams and clays they use methods of silicatization and cementation. In the process of strengthening various reagents injected into the soil begin to harden, forming strong structural links between the soil particles, thereby providing increased strength, reduced soil compressibility, as well as decreasing soil water permeability and sensitivity to environmental changes [3, 4].

For the conditions of construction on collapsible soils be obvious for the investor, it is necessary to solve a number of problems of effective project management of construction on collapsible soils, which include the development and implementation of sound investment projects for new construction and reconstruction, the assessment of the effectiveness of investment planning and budgeting necessary for the successful implementation of the project, the formation of the model of "life cycle" of the construction project, and a number of other issues to be solved within the construction company.

When constructing in difficult engineering and geological conditions, material-technical supply in preparation for production has an important place in the strategic management of the company costs. To minimize costs the construction companies need to create the most low-cost supply schemes. The applied transportation model should distribute resources in such a way as to minimize the costs for supply, storage, movement.

3. Results

One of the buildings affected by watering and frequent earthquakes in the submontane regions of the Greater Caucasus is the building of "School of general education No. 5 in the town of Malgobek" of the republic of Ingushetia, figure 1.



Figure 1. The School of general education No. 5 in the town of Malgobek of the republic of Ingushetia

A three-story H-shaped building under reconstruction, with basement. Structural diagram of a building – reinforced concrete frame. The frame spatial rigidity is ensured by combined action of monolithic reinforced concrete columns, diaphragm plates and horizontal floor discs. Building foundations - bored piles with strip grill design.

The school is located within the Alhanchurtskaya valley formed by continuous cover of loessial collapsible rocks whose thickness reaches several tens of meters. The soils are characterised by layer-

like structure, the bedding direction coinciding with the inclination of ground surface; a thin vertical fissuring is observed.

As per results of geological engineering surveys it is established that the following EGEs (engineering geological elements) rest from the top downward:

- EGE1: slightly humic dark-brown loam with rootstocks of grassed vegetation, sometimes with by-product waste;
- EGE2: light, pulverous, greyish-yellow, macroporous, loessial, slightly wet, hard texture loam with carbonaceous contractions, manganese and ferrum oxides.
- EGE3: light, pulverous, ochre-yellow, macroporous, loessial, wet, plastic texture loam with carbonaceous contractions, manganese and ferrum oxides.
- EGE4: light, pulverous, macroporous, loessial, wet, plastic texture loam with colour from ochre-yellow to ochre-brown.

According to physical and mechanical characteristics the base soil of pile foundations is weak. Calculated soil characteristics for each of the resting layers are shown in Table 1.

Table 1. Summary table of standard and calculated characteristics of soils.

No. of EGE	Geological index	Lamellosity indicator	Porosity factor	Density, t/m ³	Angle of internal friction, deg	Specific cohesion, kPa	Deformation modulus, MPa	Degree of humidity
1	2	4	5	0.85/0.95	0.85/0.95	0.85/0.95	9	10
				6	7	8		
1	aQ _{III}	-	-	-	-	-	-	-
2	vdQ _{III-IV}	11	0.77	1.77/1.52	15	23	16.38/8.19	0.56
3	eQ _{III-IV}	11.3	0.67	1.96/1.62	16	19	16.65/18.45	0.77
4	N ₂	17.1	0.69	1.99/1.63	20	11	24.6/13.8	0.89

Upon visual inspection of school building structures, it was found that as a result of watering of the base soil the supporting structures received excess loads initiating their destruction, numerous fractures in the exterior and interior structures are detected.

The destructions of structures are caused by uneven deformations of the bases under foundations due to soil watering [5].

To increase the bearing capacity of pile foundation base soils the authors suggested that a complex compression of the base soils is performed. Along the side surface in the top section of the collapsible thickness of loessial soils they used the method of one-solution silicatization in order to increase the bearing capacity of pile foundations due to elimination of the negative friction of collapsible loessial soils being watered.

After the silicatization of the upper layer, in order to increase the calculated resistance of the soils under the lower end of the piles resting in this zone of loams and clays, it was decided to establish an integral, man-induced, fixed soil body in the water-saturated, plastic clays EGE4, by injecting cement grouting based on hydrofracturing technology, according to [3]. The applicability of this method is due to the filtration factor of EGE2 soils that is equal to 2 m/day.

To eliminate further watering of the base soils around the perimeter one should make an impervious barrier on the three sides of the building, figure 2, from the side of the active movement of ground and surface waters [6-15].



Figure 2. Impervious barrier



Figure 3. Drilling machine UNB-125x50

The cementation based on the traditional technology, with the preparation of the cement grouting in the tanks, is characterized by plenty of equipment and personnel, so in order to reduce work costs and the number of equipment involved during work, the injection was performed with the use of the pumping unit UNB-125x50 SO (hereinafter - the unit), figure 3, developed in 2012 by scientists of the Izhevsk State University named after M. T. Kalashnikov.

The pumping unit UNB-125x50 SO is designed for transporting powder materials (cement, grouting mixtures), for mechanically regulating the supply of these materials with screw conveyors (augers) during the preparation of grouting mixtures, for their accumulation and mixing, and for pumping various liquid fluids during well cementing when drilling.

The unit can perform all the works regarding the tempering of grouting mixture and the implementation of technological operations during wall cementing, both independently and in combination with other units.

The unit is a set of equipment mounted on the frame and installed on the chassis of a cross-country KamAZ 63501 vehicle. The pump is driven by the traction motor of the vehicle [16].

The general view of the unit is shown in Figure 4.

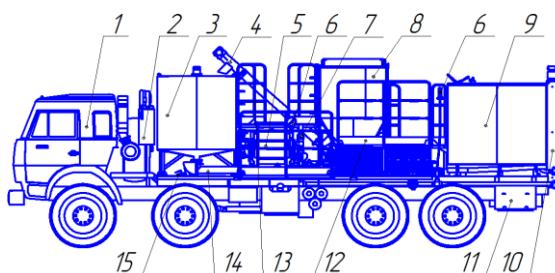


Figure 4. The pumping unit UNB-125x50 SO:

- 1 - KamAZ vehicle chassis, 2 - hydraulic tank, 3 - mixing container, 4 - feeding screw, 5 - pump NTP-175x40, 6 - pressure gauge, 7 - safety valve, 8 - storage bin, 9 - measuring tank with bottom valves, 10 - exhaust, purge and heat system 11 - rack stack, 12 - tiltable platforms, 13 - operator platforms, 14 - manifold of the unit, 15 - sample taker

The process of well cementing combined several functions at once - dry mixture supply, liquid supply, preparation of the grouting mixture of the given density and its subsequent injection into the well. Because of this we achieved the reduction of the construction period. The application of the unit made possible to reduce the process of strengthening the soil of the foundation base by 10 work days (2 weeks). Below is a calculation of the economic effects resulted by reducing construction time.

The effect produced by reducing the construction period is determined from the formula (1) [17].

$$Eff. = 0.5 \frac{Q_{CIW} BC'}{EC_{local\ cost\ estimate}} \left(1 - \frac{T_p}{T_s} \right), \quad (1)$$

where Q_{CIW} – estimate cost of construction installation works, RUB '000; BC' – burden cost amount, RUB '000; $EC_{local\ cost\ estimate}$ – estimate cost of general construction work, RUB '000; T_p , T_s – project, standard duration, days.

The initial data for calculation is based on local and facility dependent cost estimates provided by the construction company.

$$Eff. = 0.5 \frac{Q_{CIW} BC'}{EC_{local\ cost\ estimate}} \left(1 - \frac{T_p}{T_s} \right) = 0.5 \frac{24000000 \cdot 2160000}{27120000} \left(1 - \frac{12}{22} \right) = 434433 \text{ RUB'000},$$

4. Conclusion

Thus, the use of construction machines for strengthening the foundation base soils is one of the ways to solve the problem of reducing and optimizing costs during construction. The automation of production processes can reduce the duration of the construction works by 1.5-2 times. The use of the pumping unit UNB-125x50 SO allowed to reduce the construction period by 10 work days, resulting in 434433 rubles saved. In addition to the above, the increase of the bearing capacity of the pile foundations was achieved, and a geotechnological body of the fixed soil was created under the bottom of foundation.

The adequate organization of the project management system provides for the adequate execution of all works in time and within the projected budget.

References

- [1] Vidyapin V I, Stepanov M V, Rylskii VA, Vidyapin V I and others 2009 *Economic geography of Russia* (Moscow: INFRA-M) 566 pp
- [2] URL: <http://biofile.ru/geo/yy> (12.04.2017)
- [3] Panchenko A I, Harchenko I Ya 2005 *Constructional materials* **10** pp 76-78
- [4] Kambefor A 1971 *Injection of soils. Principles and methods: translation from French* (Moscow: Energiya) 332 pp
- [5] OOO “ElektroIndustriya”. Technical report. Structural assessment of bearing and enclosing structures of the building of State-owned educational establishment “Secondary school of general education No. 5 in the town of Malgobek” of the republic of Ingushetia
- [6] Gilkina T A 2007 *Selected papers of the 9th international conference Modern Building Materials, Structures and Techniques I* pp 18-20
- [7] Zhilkina T 2010 *The 10th International Conference Modern Building Materials, Structures and Techniques* pp 1186-1190
- [8] Guidelines 22.13330 on SnIP 2.02.01: 2011 Building footing and constructions.
- [9] Turchin V V, Ivanova T N et al 2016 *Privolzhsky scientific reporter* **2(54)** pp 117-121
- [10] Sokolovich V E 1980 *Chemical injection of soils* (Moscow: Stroiizdat) 119 pp
- [11] Yudina L V, Turchin V V and Baburin Y G 2010 *10th International Conference Modern Building Materials, Structures and Techniques* pp 1116-1120
- [12] Turchin V V, Yudina L V et al 2013 *Procedia Engineering of the 11th International Conference on Modern Building Materials, Structures and Techniques* pp 1166-1172
- [13] Runova R, Rudenko I and Konstantynovskiy O 2012 *18 Internationale Baustofftagung IBAUSIL H 1 S 1-1087-1-1094*
- [14] Isozaki K, Iwamoto S 1986 *Cement Association of Japan General Meeting 40 05XX* pp 120-123
- [15] Tatiana I, Turchin V, Ludmila Y, Krutikov V et.al. 2017 *Procedia Engineering* pp 393-400
- [16] Operation manual 72UNB.00.00.000 RE. – Izhevsk: Rimera Izhneftemash, 2010
- [17] Asaul A N, Starovoytov M K, Faltinsky R A 2009 *Management of expenses in construction* (SPb: IPEV) 392 pp