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THE APPLICATION OF INJECTION - GROUTING FOR STRENGTHENING OF THE WEAK SUBGRADE FOUNDATIONS

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Introduction. The operating time of Ukrainian railway subgrades is over half a century, and reconstruction of such structures is not expected by the typical engineering processes and regulations. On the other hand there is a tendency of increasing in construction of new high-speed railway lines. Due to these facts, there is a necessity in guidelines for the construction of the high-speed railway lines on weak foundations.

Purpose. The purpose of this research is to evaluate the efficiency of using injection - grouting technology to consolidate the weak subgrade foundations and to proof the necessity and urgency of studying the parameters of the technology.

The main part.

Except the general quality control, the special deformations monitoring of the subgrade and its foundation is also required during the subgrade construction on weak soils. Most of structural solutions for subgrade construction include certain technological modes, which cannot be properly implemented without systematic visual and instrumental observations. Therefore, the monitoring of the subgrade deformations should be included in the construction estimate during the whole period of construction until the commissioning of the object.

Expansion and modernization of the railway transport requires using of previously unused lands which do not always have the physical and mechanical properties as well as lands that have lost essential characteristics during long-term operation. Due to this fact the engineering task is to strengthen weak bases becomes urgent. Analyzing of the design, construction and operation experience of the railway revealed that one of the most profitable and promising methods is injection - grouting strengthening, which is already widely used abroad. The main drawbacks of this technology are not sufficiently accurate predicting of results for a wide variety of soils and the lack of general calculation methods.

In the areas of weak soils the subgrade should be designed in the form of mounds. The necessity of raising the core area level over the calculated level of surface and ground water, the requirements for the soils that constitute the upper part of mound are determined by existing regulations according to the type of terrain, nature and humidity of soils.

For the subgrades, which are constructed using the weak soils at the basing of the mound, in addition to the general requirements of the existing regulations, an additional requirement comes – the stability of the basing must be provided, i.e. the possibility of residual extrusion of weak soils from under the mound during its

construction and operation must be excluded. Providing the strength of weak soils at the basing and general stability of the mound there is a subsidence which is caused by compression of the soil (static compaction).

The weak thicker subsidence is stretched in time, so the prediction of subsidence solves two problems:

- determination of the subsidence at the moment of achievement its acceptable intensity (the so-called final subsidence);
- determination of the intense subsidence expiration (or acquiring the necessary degree of consolidation by the soil).

Mechanical properties of weak soils for indicative forecasts of possible deformations can be determined by classification in Table 1.

Table 1.

Classification and estimated mechanical properties of the over humidified clay

Soil		The type by plasticity	Density, g/cm^3	Mechanical properties		
Type	The flow rate I_L			Soil coupling, C, MPa	Soil coupling, C, MPa	Модуль деформаціїЕ, МПа
Gently plastic	0,5 - 0,75	Sandy loam	1,90	0,005	20	38
		Loam	1,90	0,015	17	19
		Clay	1,95	0,020	14	2
Plastic fluid	0,75 - 1,0	Sandy loam	1,85	0,002	18	19
		Loam	1,85	0,010	13	12,5
		Clay	1,90	0,010	8	3
Fluid	> 1,0	Sandy loam	1,85	0,0	14	12,5
		Loam	1,80	0,005	10	6
		Clay	1,80	0,005	6	3

Currently, injection - grouting technology has been widely used in civil engineering. For constructing geotechnical structures the urgent issue is to get the real mechanical properties of fortified soils that can be obtained after using this technology. Expected mechanical properties obtained after fortifying the weak soil are shown in Table 2.

The construction of the reinforced with the injection - grouting technology basics should consider the design load for the two boundary conditions with the influence of reinforced soil on the surrounding loose one.

For the first group of boundary condition the strength of the piles material and bearing capacity of basing soil are checked. For the second group of boundary condition there is determination of the basing subsidence after the reinforcement.

For the stress boundary conditions Coulomb-Mohr criterion is taken.

Table 2.

Characteristics of inkjet cementation method

Strengthened soil	Characteristics of fortified soil	
	Compressive strength, MPa	Compressive strength, MPa
Clay	0,3…0,5	60…450
Loam	1,5…5,0	500…2000
Sandy loam, silty and shallow sand	5…10	2000…5000
Large and medium-sized sand	5…15	3000…10000
Gravel sand	5…20	4000…20000

Calculation of soils reinforced with injection - grouting technology can be done in two ways: discrete and composite. In the first case, the soil and reinforcing elements are taken as various finite elements that have been assigned to the soils or soil-cement characteristics. Otherwise, the array of reinforced soils is divided into elements that are characterized by composite properties, taking into account the properties of soils, reinforcing elements and links between them.

At this stage of research the strengthening of weak foundations is considered. During further research it is necessary to study the influence of heterogeneity deformation of the reinforced foundations on the stress-strain state of the mound body.

The main feature of the weak soils shearing at the base of mound is their long period work in terms of an incomplete consolidation.

For taking account of non-consolidated state during the calculations the existing shear test methods suggest that values of pore pressure are known.

Due to irregularity of weak soils consolidating rate and difficulties to determine and control the pore pressure in the weak thicker we can conclude that existing shear test methods make it impossible to predict the acceptable shear resistance in all areas of constructed subgrade during the design of railway subgrades on soft and weak soils.

Features of the weak thicker structure depend on its occurrence conditions, and affect the behavior of weak soil at the mound foundation.

The results of the analysis.

After analyzing the structural features of weak soils bases, there are some features that should be taken into account during the construction:

- the existence and nature of stratification weak thicker;

- the thickness of the weak layers, which determine the nature of the in depth stress, the final subsidence, duration and degree of basing stability;
- pursued water from the soil thicker the with its compression;
- the location of the weak thicker (presence of overlapping solid soils);
- the groundwater level.

Conclusions.

The results of current theoretical research show that using the weak soils in many cases significantly reduce the cost and complexity of work and increases the speed of construction, so the rejection of its application must be justified by technical and economic analysis with regard to the specific conditions.

Such analysis should be based on theoretical resistance, the ultimate value and duration of weak thicker subsidence during the construction the subgrade on it.

The analysis of patterns and experience of using soil-cement piles showed that this technology requires further research, and in-depth studying the limits of its usage for different geological conditions. In addition the issue of the stress-strain state of piles in the interaction with the surrounding soil is needed to be studied.

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