Study of retaining structures made of composite materials

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ABSTRACT

The modern sustainable development of territories, taking into account the peculiarities of natural and climatic conditions, shall consider the ecological balance of architectural, natural, environmental, engineering, infrastructural and legal methods for their development. At the same time, special attention should be paid to protective structures, including retaining structures, bank protection structures, etc., which ensure the reliability and safety of the functioning of urban development and the population residing there.

The issues of experimental and theoretical studies of ground-reinforced and soil-filled technical solutions for the retaining structures using composite nanomaterials are discussed in the article, as well as the results of the studies are presented.

Keywords: retaining structures, composite nanomaterials, reliability, technical solutions, studies.

1 INTRODUCTION

The modern methods of using composite nanomaterials in engineering solutions for various fields of science, engineering and technology allow creating structures and their elements with sufficient strength, stability, durability, operational reliability and safety in various climatic conditions, including the Arctic zone, recreational facilities of southern Russia and other regions of the country.

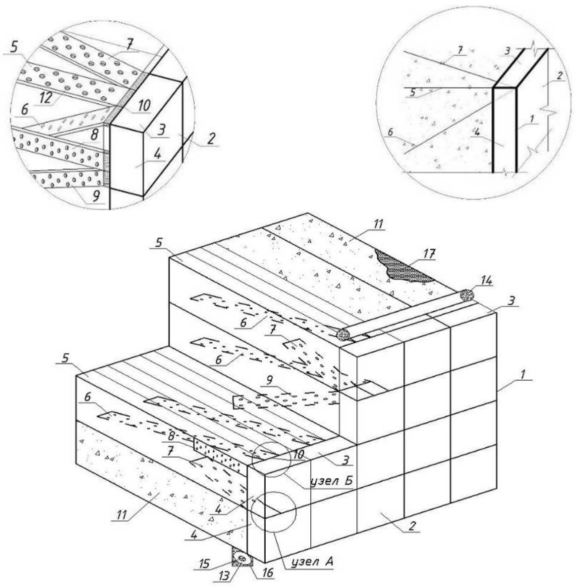
2 EXPERIMENTAL SUBSTANTIATION OF TECHNICAL SOLUTIONS OF GROUND-REINFORCED STRUCTURES

2.1 Technical solutions

The soil-filled and ground-reinforced structures developed earlier and practically applied at the end of the last century showed good performance data for 3–8 years, however, the insufficient quality of composite materials did not contribute to their further operational condition. The emergence of new composite nanomaterials in the world and Russian construction practices made it possible to create new technical and technological solutions, which allows their use in various structural elements of retaining structures, including ground-reinforced and soil-filled ones, ensuring the environmental safety of urban areas, recreational zones, creating quality living environment of the population, and using them as engineering protection complexes.

The main elements of the current ground-reinforced construction are as follows: front wall with front wing walls (elements), horizontal, inclined and lateral reinforcing tapes, soil body (Fig. 1).

Fig. 1. Ground-reinforced structure with a front wall consisting of individual front elements: 1 - front wall; 2 - front elements (wing walls); 3 - horizontal, inclined and side reinforcing tapes; 4 - sections of the front element; 5 - horizontal reinforcing tapes;



6 - bottom reinforcing tapes; 7 - top reinforcing tapes; 8 - side straight reinforcing tapes; 9 - inclined reinforcing tapes; 10 - flexible connections; 11 - soil body; 12 - perforated reinforcing tapes; 13 - top multi-shell anchors; 14 - bottom multi-shell anchors; 15 - groundwater; 16 - pit, 17 - coating of polymer material with seeds.

Table 1. Parameters of tested modules of the front elements and reinforcing tapes

$l_a = H$ m	b_a, mm	$l_{л.э}$, mm	$b_{л.э}$, mm	$S_л = S_h$, mm	Material
300	10	100	100	100	Unisol 630

$$\frac{H_н}{H_м} = \frac{a_{лэ,н}}{a_{лэ,м}} = \frac{h_{лэ,н}}{h_{лэ,м}} = \frac{b_{лэ,н}}{b_{лэ,м}} = \frac{l_{а,м}}{l_{а,м}} = \frac{b_{а,м}}{b_{а,м}} = \frac{S_{v,н}}{S_{v,н}} = \frac{S_{h,м}}{S_{h,м}} = \alpha_L,$$

2.2 Experimental studies

Experimental studies of ground-reinforced structures, taking into account patent No.2444589, were conducted under the supervision of the author by graduate students Prikhodko A.P. and Kundupyan K.S. at the Faculty of Industrial and Civil Engineering, Geotechnical Engineering and Foundation Engineering, Platov South-Russian State Polytechnic University (NPI) in a flat deformation tray made of organic glass with a working space of 0.8 * 0.1 * 0.6 m, while dry sand was used as a backfill and ground-reinforced foundation. Its physical and mechanical characteristics are as follows: $\varphi = 40^\circ$ is the angle of internal friction; $c = 0{,}005$ MPa is the adhesion; $E = 31{,}4$ MPa is the deformation modulus; $\gamma = 17{,}4$ kN/m^3 is the specific weight; $e = 0{,}53$ is the porosity ratio.

In the course of the experiments, the sizes of the front wall (150, 100, 50 mm) and the front element (50, 30, 10 mm), the length of reinforcing tapes -$e = 0{,}7H,\ 0{,}5H,\ 1H$, where H is the total height of the moving wall, were changed. As a result of the study, it was found that the most optimal solution provides for the following sizes: the front wall 50 * 50 mm, the front element 30 * 30 mm, and the length of the horizontal tapes from 40 mm to 75 mm depending on the angle of internal friction of the filler φ - with a layer thickness of 50 mm depending on the structure production technology.

In the process of loading, horizontal deformations of each front element are recorded with watch-type indicators ICH-10 with an accuracy of 0.015 mm, and the degree of sand compaction is measured by a densitometer designed by Yu.I. Murzenko.

The entire study process is recorded by photometry. The ground foundation and backfill of the ground-reinforced body was performed using dry sand with the following physical and mechanical characteristics: $\varphi = 40^\circ$ is the angle of internal friction; $c = 0{,}005$ MPa is the adhesion; $E = 31{,}4$ MPa is the deformation modulus; $\gamma = 17{,}4$ kN/m^3 is the specific weight; $e = 0{,}53$ is the porosity ratio.

Table 1. Parameters of tested modules

where H_n; H_m *is* the total height of the supporting structure, respectively, for nature and model; α geometric scale.

As a result of the photometry carried out, the deflections of the reinforcing tapes due to the load (64–200 kPa) were clearly revealed (Fig. 2).

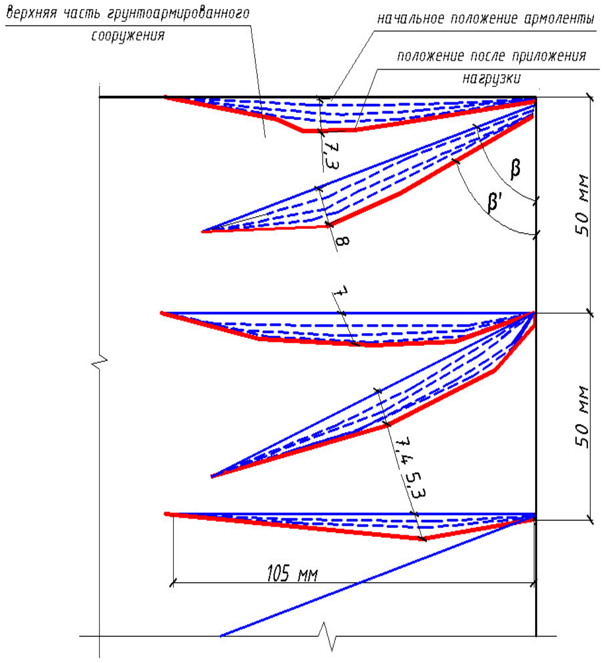


Fig. 2. The diagram of fixed deflections of horizontal and inclined reinforcing tapes, obtained using the method of photometry

Figure 2 clearly shows that inclined reinforcing tapes experience the greatest deformation and they appear at 2/3 H. This allows the most efficient use and adjustment of the parameters of the ground-reinforced mass.

The ground-filled elements with sorbents, purifying groundwater and surface water, are used as drain anchors. They are calculated according to the empirical dependencies with a load of up to 120 kPa. The deformation of the ground-filled shell was $\varepsilon = 0{,}3$ mm, and its tension is determined by the dependencies:

$$T = \frac{(h+y)(\{1-a\}+\{1-am\}y'^2)}{y''} + \\ +(1-am)\left(hy + \frac{y^2}{2}\right), \quad (1)$$

where: T is the tension force in the shell,

$$T = \frac{T_0}{\gamma_н b}, \text{ kN/m.}$$

The equation describing the shape of the shell is the elastic equation of the second kind:

$$y = \left(1 - \sqrt{1 - \frac{\sin^2\varphi}{k^2}}\right)h, \quad (2)$$

where: φ is the angle of internal friction of the backfill soil, degrees; k is the modulus of elliptic integrals.

The first and second derivatives of equation (1) take the following form:

$$y' = \frac{h\sin\varphi\cos\varphi}{k^2\sqrt{1-\frac{\sin^2\varphi}{k^2}}} \quad y'' = \frac{h(k^2\cos 2\varphi + \sin^4\varphi)}{k^4\sqrt{\left(1-\frac{\sin^2\varphi}{k^2}\right)^3}}. \qquad (3)$$

On the basis of the obtained dependencies, a program was compiled for calculating a closed ground-filled shell under load [1].

3 CONCLUSION

The study results are currently used in the design of the retaining structures to protect the urban area as a competing way.

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