Soil-concretes from Yakutia's clay materials

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Abstract: The article presents the results of experimental studies on the choice of the optimal technological parameters (the initial moisture of the soil-cement mixture, pressing force, amount of cement) for the preparation of samples of soil-concrete by semi-dry pressing. Research has shown that the predicted strength of the soil-concrete can be obtained not only by varying the amount of Portland cement injected, but also by selecting the pressing force and the initial moisture of the initial mixture. The obtained experimental data allow predicting the construction and operational properties of soil-concretes materials from clay raw materials of a specific field, to clarify the methods of manufacture and the area of their application (foundations of airfields, roads and engineering structures, building products and structures).

Keywords: concrete, soil, cement, particle, strength, water absorption, brick.

1. Introduction

Yakutia has huge reserves of natural mineral raw materials for the production of a wide range of building materials and products \cite{1}. However, in most areas there are no fine (sand), coarse (crushed stone) and porous (expanded clay) aggregates for the production of effective concrete. In the conditions of the complete absence of basic building materials for remote areas of the North, materials using soil can be of practical interest.

As is known, available sandy-clay soils stabilized with cement or other binders and additives are used for the manufacture of soil-concrete, mainly to strengthen the foundations of airfields, roads and railways \cite{2} and civil structures \cite{3}. Concrete and clay materials have been previously used in rural construction, however, such materials are not widely used in modern building construction technology.

Analysis of publications devoted to the study and application of soil-concrete shows the increased interest of builders in the use of soil materials as bases for airfields, roads and engineering structures, as well as the complete absence of practical use of soil-concrete construction materials in modern residential construction \cite{2-6}. The use of soil concrete in construction is one of the directions for soil stabilization. The appearance of unique additives, new specialized equipment allows you to use this method. This greatly simplifies and speeds up the process of performing work with a decrease in cost.

The problems of soil stabilization, improvement of the quality of soil concrete, improvement of the production technology of firing and unburned wall materials, selection of the optimal composition of raw mixes are described in numerous works \cite{6-8}.

At present, the types of soil-concrete are not fully investigated. Soil-concrete for the conditions of Yakutia is a new and promising material. The use of soil-concrete in the rural construction of Yakutia will make it possible to make extensive use of local building materials (soil, wood waste, etc.), reduce the cost and speed up the commissioning of buildings and structures for various purposes.
To this end, it is necessary to conduct comprehensive scientific and practical research on the development and implementation of the technology for the manufacture of soil-concrete based on local raw materials in relation to the extreme climatic conditions of Yakutia, taking into account the real possibilities and needs of various segments of the population.

The purpose of this work is an experimental study on the choice of optimal technological parameters (initial moisture content of the mixture, pressing force, amount of cement) for the manufacture of wall products from clay soils using the semi-dry pressing method.

2. Basic materials
The experimental studies used clay soils with the following characteristics:
- chemical composition, %: SiO₂ – 58.6; TiO₂ – 0.78; Al₂O₃ – 14.9; Fe₂O₃ – 3.4; MnO – 0.12; MgO – 3.63; CaO – 4.38; Na₂O – 2.18; K₂O – 2.68; P₂O₅ – 0.2; SO₃ – 0.14; loss on ignition – 6.5; H₂O – 1.08;
- granule size, %: particles less than 0.001 mm – 31.4; 0.05-0.002 mm – 51.9; more than 0.002 mm – 16.7;
- plasticity number - 7.3-13.1.

Cement grade CEM I 32.5B was used as a binder: residue on sieve No. 008 - 7%; normal viscosity - 26%; start setting - 1 hr 45 min; end of setting - 2 hr 50 min; compressive strength - 41 MPa; flexural strength - 7.3 MPa.

As the fine aggregate used sand according to GOST 8736-2014 with a particle size module of 1.2-1.4, organic aggregate - sawdust (pine).

Prevention of the composition of the soil-concrete is made in accordance with the requirements of GOST 27006-86. Tests of soil-concrete samples were carried out using standard methods, certified instruments and equipment. Evaluation of strength is made in accordance with the requirements of GOST 10180-2012. Determination of water absorption of samples was carried out according to the method GOST 12730.3-78.

The microstructure analysis of the soil was performed on a JEOL JSM-7100F scanning electron microscope. Statistical processing of experimental data was carried out using the programs MathCAD 2001i and ImageJ.

3. Result and discussion
The first stage of experimental research is the assessment of the particle size distribution of the used soil. In figure 1 shows micrographs of a sample of clay soil.

![Micrographs of clay soil](image1)

**Figure 1.** The microstructure of clay soil

Analysis of micrographs shows (Figure 1) that soil particles have a high specific surface. And also there is a high content of dust and clay particles. Grains have an irregular shape and a rough surface.
Micrograph data were processed using the ImageJ program [9]. The results of processing are shown in the form of a histogram of the distribution of particle size of the soil (Figure 2).

![Histogram of the distribution of soil particles](image)

**Figure 2.** Histogram of the distribution of soil particles

An analysis of the histogram (Figure 2) shows that a distinct distribution peak is observed in the soil sample. This indicates a monodisperse distribution of particles, which is consistent with the image of the soil structure (Figure 1).

A visual analysis of the structure reveals the presence of numerous shapeless, relatively large soil particles (sand particles). First, these particles are distributed relatively evenly over the entire surface. The most optimal way to obtain building materials with desired performance properties is to apply a semi-dry pressing technology with simultaneous stabilization of the material by the introduction of cement.

Tests of samples of soil-concrete materials stabilized with Portland cement were carried out after 28 days of natural storage [10]. The composition of the mixture is the following, %: clay soil - 70, sand - 30, cement (3, 5 and 8% to the soil mixture). Experimental dependences of the strength and water absorption of soil-concrete samples on the pressing force 2.5–15.0 MPa were obtained at two initial moisture levels of the initial mixture of 10 and 15%, respectively (Table 1).

| Cement content (by weight), % | Pressing force, MPa | At 10 % humidity | At 15 % humidity |
|------------------------------|---------------------|------------------|------------------|
|                              | 2.5                 | 5.0              | 10.0             | 15.0             |
| 3                            | 3.2/21.7            | 4.1/17.7         | 6.9/19.5         | 9.0/14.8         |
| 5                            | 4.8/15.6            | 5.5/16.8         | 7.8/13.8         | 12.4/15.6        |
| 8                            | 5.0/14.8            | 7.0/13.2         | 8.7/10.5         | 13.2/12.9        |

To the line - compressive strength, behind the line - water absorption

The maximum compressive strength of samples of 13.2–14.2 MPa is achieved with a pressing force of 15 MPa with an initial moisture content of a mixture of 10 and 15%, respectively. The maximum
water absorption of 17.7-21.7% is observed for samples made by pressing with a minimum force of 2.5-5.0 MPa and a low cement content of 3% (Table 1).

Indicators of strength of samples made with a pressing force of 2.5-5.0 MPa are typical for soil-concrete obtained in removable formwork by tamping, and with a pressing force of 5.0-10.0 MPa – soil-concrete obtained by rolling with a roller up to 10 tons while strengthening ground road bases.

In the experimental indicators of water dehydration table. 1, there is some variation in the data, which does not prevent us from establishing that a decrease in the water absorption of the samples is facilitated by an increase in the amount of stabilizer added - Portland cement to a greater extent than an increase in the pressing force.

The increased values of the strength parameters of the soil-concrete are explained by the peculiarities of the process of compaction of samples at the stage of their manufacture. Compaction of samples is accompanied by physico-chemical processes in which the entire system is involved: solid phase (mineral particles), liquid (water) and gaseous (air). In the initial stage of pressing, the solid particles move in different directions, large pores that are formed from the grains at the moment of filling the form are destroyed, and the air is partially removed [11].

Increases the contact surface between the powder grains. As the pressure increases, the particles further condense. At the same time, the air that had not managed to retire is trapped between the grains of the powder and compressed. With further compaction of the powder, the movement of the grains occurs on their increased contact surfaces having aqueous films. At the last stage of pressing, the product is most compacted due to the further development of the contact surfaces [12].

4. Conclusions
1. Analysis of the granulometric composition of the soil studied showed its monodisperse composition.
2. Sand particles were found in the ground, while these particles are distributed evenly over the entire surface.
3. It is established that the introduction of cement into the structure of the soil-concrete allows improving the basic strength characteristics of the material.
4. In the manufacture of soil-concrete by the method of semi-dry pressing with a force of 10 MPa, the guaranteed brand of brick from ground-cement mixture (8-10% of cement) is M75 - M100, and the brand of brick the same clay raw material - M100-M150.
5. The experimental dependences of the compressive strength and water absorption of soil-concrete samples, made by the method of semi-dry pressing, on the values of the pressing force (2.5-15.0 MPa), the initial moisture content of the mixture and the amount of introduced cement will predict the construction and operational properties of soil-cement materials from clay materials.

References:
[1] Sevostyanova R F and Sitnikov V S 2018 J. Journal of the Mining Institute 234 599
[2] Zege S O and Brid I I 2007 J. Soil Mechanics and Foundation Engineering 44 143
[3] Murat M and Eyubhan A 2018 J. Materials Journal 115 855
[4] Cong M and Bing C 2015 J. Construction and Building Materials 76 61
[5] Jianguo F, Dongyuan W and Duo Q 2018 J. Journal of Rock Mechanics and Geotechnical Engineering 10 791
[6] Mohammad R A and Ali T 2017 J. Journal of Rock Mechanics and Geotechnical Engineering 9 623
[7] Estabragh A R, Ranjbari S and Javadi A A 2017 J. Materials Journal 114 195
[8] Kharum M and Svintsov A P 2017 J. Key Engineering Materials 730 358
[9] Udwawatta R P and Anderson S H 2008 J. Geoderma 145 381
[10] Estabragh A R, Khatibi M and Javadi A A 2016 J. Materials Journal 113 709
[11] Venkatarama B V and Gupta A 2005 J. Materials and Structures 38 639
[12] Cong M and Bing C 2015 J. Construction and Building Materials 76 61