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About the possibility of obtaining cementitious soil composites of high strength on the basis of belozems of carbonate composition

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Abstract. The problem of manufacturing high strength cementitious soils based on belozems of carbonate composition, which experience compression (no less than 10 MPa), without application of surface active substances is considered.

The portland cement of type 400 was used as a binding agent to develop compositions of cementitious soil composites, and the ordinary pipe water was used to obtain solutions of cementitious soils.

The chemical and mineralogical composition of the initial ingredients and the granulometric composition of belozems were determined.

The measurements showed that the upper and lower plasticity limits, the optimum moisture content, and the maximal density of the skeleton of belozems, as well as the considered compositions of cementitious soils, are insignificant, while the plasticity index of cementitious soils is less than one for belozems.

It is experimentally proved that an increase in the portland cement amount lead to an increase in the compressive strength of cementitious soils with a decreasing speed. But for the same amount of portland cement used in the cementitious soil compositions, the values of the strength ratio of the pieces tested at the age of 60 and 28 days remain the same and are approximately equal to 1.2.

A comparison of experimental data showed that it seems to be real to manufacture a cementitious soil on the basis of belozems of carbonate composition, which contain 10% of cement of the weight of dry mixture and have strength more than 10 MPa, without adding any surfactants to the material composition.

1. Introduction

Abroad, the cementitious soils (ground-concrete) are widely used as building materials for constructing roads and runways in airports (layers under external coverings), for covering the canals and dams, for manufacturing blocks and stones, and for constructing one- and two-storey houses as well as monolithic ground mixes for preparation for floors [1, 2].

Modified cement mortar compositions (cementitious soils) and technologies for their application in construction of underground parts of buildings have recently been developed up to a mark of ± 0.00 , including foundations of various types (belt, column, cushion-walls), cellar walls, and socles [1]. In this case, as a rule, preference is given to the prefabricated cement mortar (cementitious soils) as the most suitable material for constructing the underground parts of buildings.



Such a wide application of cementitious soil materials usually composed of clayey rocks rich in calcium compounds (such as clay, sandy loam, loams, etc. [2]) is due to the relatively low laboriousness of manufacturing the material, its relatively good physical and mechanical characteristics, and its cheapness, especially if the soil is taken from a pit excavated under the construction [1].

It is known that the structurally unstable, under-compacted subsidence grounds (soils) are widespread in almost all continents of the globe. According to geological engineers, such soils occupy about 10% of the total land area, and the thickness of their formation varies from 10 to 40 m [3]. In some regions of the globe, these formations reach the thickness of 100 m [3].

Because of structurally under-compacted soils in Armenia, much attention is paid to belozems, which are most common in some areas of Yerevan and in the districts of Armavir, Kotayk, Lori, etc. [4].

Belozem is the name of strongly carbonate, often gypsum, suffosion-unstable, subsidence, light dusty-sand loams and heavy dusty sandy loams. On the other hand, because of their suffosion stability and subsidence, the belozems are most unfavorable [5].

The low water resistance of belozems, the appearance and intensive development of suffosion phenomena in them were recorded already in the 1920s, when the irrigation systems were operated in Armenia [5]. Despite this, in some regions of the country, active construction was carried out on the territory of belozem distribution, and its negative consequences were manifested rather soon. As an example, we can point out some buildings in the residential area of Ajapnyak, Yerevan, whose normal exploitation is currently violated. During the exploitation, the sewage waters penetrated into the grounds of basements of these buildings and caused their intensive saturation. The resulting subsidence was accompanied by formation of large cracks in the buildings and, in some cases, by subsidence of their individual parts.

The observations show that similar phenomena develop especially intensively in hydraulic engineering structures, where the filtration losses in soils are of catastrophic character (slaking of the belozems occurs very quickly — within 3–5 minutes [5]) and the water is accumulated in developed large voids [5].

It obviously follows from the above that, due to their engineering-geological features, the building on the territory of under-compacted belozem distribution requires artificial reinforcement, i.e., it is necessary to increase the physical characteristics of buildings including their suffosion stability and mechanical strength.

The goal in this work is to develop, without using any plasticizers, compositions of cementitious soil composites of increased strength on the basis of belozems which satisfy the requirements for building materials of this type.

2. Experimental part

The cement soil usually contains ordinary bound soils (clay, loam, sandy loam), mineral binders (for example, portland cement of at least 400 grade [1]), and water. It should be noted that, to increase the technological characteristics of the cement mortar (for instance, its workability) and to increase the indices of its physical and mechanical properties, purposefully selected plasticizers are sometimes introduced into the material composition [1].

In the study outlined in the framework of the problems considered in this paper, the following starting materials were used:

- the belozems taken from the areas adjacent to the territories of the Institute of Physics located in the residential district of Ajapnyak, Yerevan;
- the portland cement (type 400) produced by the Ararat Cement Plant (Republic of Armenia);
- the ordinary pipe water.

Table 1. Chemical and mineralogical composition of the portland cement.

Chemical composition							Mineralogical composition					
CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	SO ₃	Loss on ignition	Hydroxide moisture	Insoluble sediment	3CaOSiO ₂	2CaOSiO ₂	3CaOAl ₂ O ₃	4CaOAl ₂ O ₃ Fe ₂ O ₃
62.7	21.8	5.1	3.1	3.2	2.2	0.95	0.48	1.35	52	23	7–9	15

Table 2. Chemical composition of belozems.

SiO ₂	Fe ₂ O ₃	FeO	TiO ₂	Al ₂ O ₃	CaO	MgO	MnO	P ₂ O ₅	SO ₃	Na ₂ O	K ₂ O	H ₂ O	Loss on ignition
30.64	1.56	1.81	0.35	5.60	27.88	1.99	traces	0.15	no	1.70	1.20	1.92	24.82

Table 3. Characteristics of the portland cement.

Volume weight, g/cm ³	Specific weight, g/cm ³	Stiffening deadline (GOST 310.3-76)		Normal density of cement mortar (paste), % (GOST 310.3-76)	Ultimate strength for age of 28 days, MPa (GOST 310.4-76)	
		start (min.)	end (hour)		for bending	for compression
1.21	3.04	48–51	8.0	24–25	5.5	38.6

Table 4. Average granulometric composition of belozems.

Particle size, mm	2–1	1–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.01	0.01–0.005	< 0.005
%	2.0	7.0	6.2	13.1	15.0	7.2	40.0	9.5

It is known that one of the main stages of the process of developing the composite materials, including the cementitious soils, consists of certain analyzes of the main ingredients of these materials. Therefore, the chemical and mineralogical analyzes of the portland cement and belozems were carried out (tables 1 and 2). The parameters of the physical and mechanical characteristics of the portland cement (table 3) and the granulometric composition of belozems sieved through sieve No. 2 (table 4) were determined.

The data presented in table 2 show that the component SiO₂ contained in belozems has a property contributing to the process of concrete formation in the cementitious soil, and the component CaO has a property contributing to the formation of concrete and increasing the cementitious soil strength by carbonization. Also, we note that the components Al₂O₃, K₂O, and Na₂O of belozems (table 2) can significantly increase the cement mortar workability.

As a result of analysis of the salt composition of belozems, it was found that no medium-soluble salts are contained in the soil, and the amount of readily soluble and sparingly soluble salts (CaO₃) is 20.02% and 20.3% of the mass, correspondingly.

Table 5. Water-physical parameters of belozems and cementitious soil.

Cement content, %	Plasticity limit			Optimum moisture content, W_{opt}	Max. density of the skeleton, g/cm^3
	upper limit, W_L	lower limit, W_P	plasticity index, I_p		
0	0.245	0.190	0.055	0.212	1.58
5.0	0.230	0.187	0.043	0.200	1.585
6.0	0.244	0.196	0.048	0.211	1.62
8.0	0.248	0.198	0.50	0.217	1.62
10.0	0.230	0.188	0.042	0.209	1.61

According to the data in table 4, the belozems used in the cement mortar compositions are represented by dusty sandy loams.

The investigation stages considered here are the following ones:

- development of preliminary compositions of cement;
- obtaining dry mixtures from original ingredients;
- production of cementitious soil mixtures on the basis of dry mixtures and water;
- production of test pieces (cylinders of diameter of 5.0 cm and height of 20.0 cm) from cement mortar mixtures by direct compression in appropriate forms;
- determination of the average density and compressive strength of test pieces at the age of 28 and 60 days.

The investigation stages are summarized below.

In view of the above discussion, in the process of developing the cementitious soil compositions, the portland cement of type 400 (table 3) was used with an addition of cement in an amount of 5, 6, 8, and 10% of the weight of dry mixture of the main ingredients. This approach to the development of preliminary cementitious soil compositions was applied with the aim of revealing the laws of changes in the indices of the soil basic physical and mechanical characteristics depending on the content of cement in its composition.

A screw mixer was used to prepare both dry (up to 1600 g) and cementitious soil (up to 1900 g) mixtures in each case under study. The mixing time of dry and cement mortar mixtures was 15 min for the above-indicated amounts. The degrees of homogeneity of the mixtures were determined by a known method.

The cylindrical test pieces were manufactured from cementitious soil mixtures was by direct pressing with the value of pressure 4.8–5.3 MPa ensuring the production of a material with the maximum density of the skeleton.

After manufacturing, the test pieces were released from the molds after 14 days, and further, till the time of testing at the age of 28 and 60 days, they were stored in a laboratory room at an average temperature of 23°C and a relative humidity of 57%.

The strength of cylindrical test pieces was determined on a universal testing machine ZD 10/90 at a loading speed of 3 mm/min. For each case under study, 3–4 test pieces (twins) were tested. The maximum spread of strength indices in relation to their average arithmetic value was equal to +5.7% and –6.2%.

3. Discussion of the obtained results

The indices of main water-physical characteristics of belozems and cement mortar. determined by standard methods [6], are given in table 5.

According to the data in table 5, the difference between the indices of both the upper and lower limits of belozem plasticity and the considered compositions of the cementitious

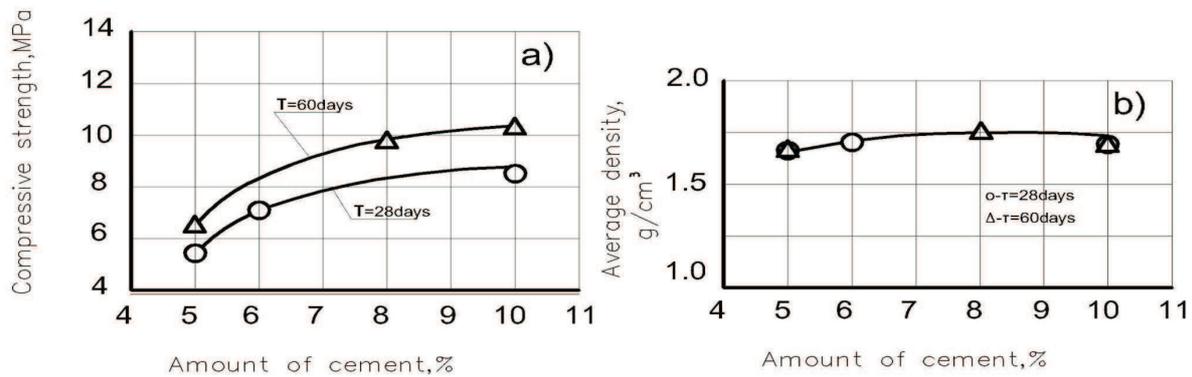


Figure 1. Curves of the strength (a) and the average density (b) of cementitious soil cylindrical test pieces depending on the amount of portland cement.

soil was insignificant. The values of these parameters vary within the limits, from 0.230 to 0.248 and from 0.188 to 0.198, correspondingly. A similar phenomenon occurs for the optimal humidity (from 0.200 to 0.217), as well as for the maximum density of the skeleton (from 1.58 to 1.62 g/cm³) of these materials.

It also follows from the data in table 5 that the plasticity index of the considered cementitious soil composition is always lower than that of belozem. However, no experimentally determined clear pattern of variation in the plasticity index of cementitious soil in dependence on the amount of portland cement used in its composition has been observed.

The experimentally obtained results in the form of labels, whose ordinates correspond to the average arithmetic values of the measured characteristics of cementitious soil, are shown in figure 1.

Before analyzing the data given in figure 1, we note that all cementitious soil cylindrical test pieces acquired a light pink color at the time of the tests.

Comparing the data given in figure 1b, we see that the value of the average density of cementitious soil contained in the same amount of portland cement slightly depends on the age of the considered test pieces at the time of measurements. At the same time, an increase in the consumed portland cement amount from 5% to 6–8% of the weight of dry mixture leads to an increase in the average density of the cementitious soil by approximately 3%. In comparison with the average density of the material contained in the portland cement composition in the amount of 6–8%, the further increase in the portland cement amount from 8% to 10% leads to a decrease in the average density by approximately 1.2%.

From the data given in figure 1a, we note that the nature of changes in the compressive strength of cementitious soil cylindrical test pieces in dependence on the amount of portland cement in their compositions remains the same independently of the material age at the time of tests. In particular, an increase in the portland cement amount leads to an increase in the strength of test pieces with a significantly decreasing speed. Thus, an increase in the portland cement amount from 5% to 6%, from 6% to 8%, and from 8% to 10% leads to an increase in the strength of test pieces by approximately 30%, 17%, and 4%, correspondingly, for the composition age of 28 days, and by 25%, 18%, and 5% for the composition age of 60 days.

Comparing the data illustrated in the figure, we see that, for the same amount of portland cement in the cementitious soil composition, the values of the strength ratio of the test pieces tested at the age of 60 days and 28 days remain the same and are approximately equal to 1.2.

It should also be noted that the studies of the water resistance of the pieces formed in the compression testing of experimental cylinders showed that, during 3 weeks in the aqueous

medium, the cementitious soil composites with different content of portland cement did not show any sign of slaking.

Conclusions

Under the normal conditions of hardening, the cementitious soil with the cement content of 120 kg per 1 m³ attains the compressive strength of 1.6 MPa after 7 days, and 2.0 MPa after 28 days, but for the cement content of 180 kg per 1 m³, the cementitious soil strength increases from 25% to 70% [7].

The cement suitable for operation in relatively few loaded parts of building structures (for example, foundations of various types) must have compressive strength of at least 10 MPa. To obtain a material with such a compressive strength and the cement consumption of at most 12% of the weight of dry mixture, several surfactants are usually introduced into its composition [1, 3, 8].

The cementitious soil grade for compressive strength is determined according to GOST 18105-06 on test pieces at the age of 90 days. This permits determining the indicated characteristics of cementitious soil at the age of 28 days multiplied by 1.5 [14]. In this case, one can obtain the compressive strength of cementitious soil using the test pieces, i.e., cylinders of diameter and height of 5.0 cm, with subsequent transition to the standard cubicle of dimensions 15.0 × 15.0 × 15.0 cm with a coefficient of 0.7 [9].

The cementitious soil cylindrical test pieces of diameter of 5.0 cm and height of 20.0 cm, made on the basis of belozems and portland cement of grade 400 (the cement content in the material is 10% of the weight of dry mixture or 160 kg per 1 m³), have compressive strength of 8.5 MPa at the age of 28 days.

Taking into account the above-mentioned recommendations about the dimensions of the experimental cylindrical test pieces whose use permits establishing the compressive strength level of cementitious soil and the experimentally confirmed patterns of variation in the compressive strength of experimental concrete test pieces [10] depending on the ratio of their height to the cross-sectional dimensions, one can draw the following conclusion: it seems to be real to manufacture a cementitious soil on the basis of belozems of carbonate composition, which contain 10% of cement of the weight of dry mixture and have strength more than 10 MPa, without adding any surfactants to the composition of the material.

References

- [1] Ramzanov A A, Badaeva A D, Lanin E B, and Alnashash T A 2015 Soil-concrete in a foundation construction *Stroit. Univ. Zdanii Soorozh.* No. 3 (30) 111–28
- [2] Minke G 2004 *Clay Concrete and Its Application* (Kaliningrad: Yantarny skaz) p 232
- [3] Ananiev V P and Potapov A D 2005 *Engineering Geology* (Moscow: Vysshaya Shkola) p 400
- [4] Sidorenko A V (Editor) 1968 *The Hydrogeology of the USSR* vol XI *Armyanskaya SSR* (Moscow: Nedra) p 352
- [5] Boshnagyan P S 1956 *Questions of Geology and Hydrogeology* (Yerevan: Izd. AN ArmSSR)
- [6] Trofimov V T, Korolev V A, Voznesensky E A, et al. 2005 *Soil Science* (Moscow: Izdat. MGU) p 1024
- [7] Chudinov S A 2010 Research of influence of technology factors on soil cement durability *Vestnik Povolzhsk. Gos. Tekhn. Univ. Ser. Les. Ekol. Prirodopolz.* No. 1 46–52
- [8] Chudinov S A 2011 In-process Testing of the Grounds Reinforced with Portland Cement Containing Polyelectrolyte Additive *Izv. VUZov. Lesnoy Zh.* **6** 58–61
- [9] Ivanov V V and Eremin V Ya 2014 Up-to-date technologies and materials for construction, repairs, and reconstruction of buildings' foundations *Gradostroit.* No. 1 (29) 78–81
- [10] Karapetyan K S 1965 Influence of anisotropy on the creep of concrete during the compression as a function of the test piece height *Dokl. AN ArmSSR* **40** (5) 279–83