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The Study of Shrinking Deformations of Repair Compositions on Barkhan Sands

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***Abstract*—Maximal use of local natural substandard raw materials in the technology of repairing concrete and ferro-concrete structures determines the possibility of obtaining modified repair compositions with improved characteristics based on barkhan sands in order to restore the bearing capacity of products and structures and prolong their service life. The research determined the theoretical provisions for obtaining a modified compound with a comprehensive use of “Portland cement – barkhan sand - calcium sulfate dehydrate - C-3” binder and polymer components, with the help of which it is possible to adjust the hardening process and shrinkage deformation, increase adhesion, and reduce the total volume of capillary pores, which, as a result, increases the physicomechanical and operational properties of the proposed composites.**

Keywords—repair compositions, barkhan sands, expanding additive, calcium sulfate dihydrate, adhesion, operational properties, deformations, vibroactivation

I. Introduction

Expanding cement with its characteristic expansion at an early age prevent further negative shrinkage deformations. The described feature will allow creating such modified repair compositions, which can be successfully used in repair work in the restoration of concrete and reinforced concrete products, such as, embedding sinks, chips, potholes, defects, cracks, etc.

Expanding cements and additives with expanding effect harden in the water and in the air, provide an increase and consolidation of volume, and at the end of the expansion, the cement stone acquires self-stress, and this property is also important in the production of repair works.

The ability to regulate its internal deformations, that is, deformations that occur without the application of any external mechanical effects, is necessary for repair compositions of fine-grained concrete.

Internal deformations are divided into two groups: unconditional and forced [1, 4, 6]. The first of them arise at the initial stage of the formation of a concrete compound during the course of physicochemical processes, and continue until the end of the hydration processes in concrete. Internal forced deformations appear when concrete is affected by various environmental factors, usually temperature or humidity.

According to many scientists it is necessary to use non-shrinkable, expanding binders and additives in repair compounds [10-13] for the elimination of shrinkage deformations.

An expanding additive helps to reduce shrinkage deformations during shrinkage of hardening concrete in humid conditions, which is important for the repair of structural defects. It is known [2, 3, 5] that chemical expansion cannot prevent shrinkable deformations of hardening concrete in humid conditions, since the flow of these processes does not coincide in time intervals, but it is possible to reduce the value of tensile stresses in those cases hardening conditions will be under the action of self-stress. This state can be compared with the effect of pre-tensioning steel reinforcement in concrete products.

The achievement of the effect of self-stress is reasoned by the use of an expanding additive in the course of the mutual formation of strength and volume expansion of hardening cement stone. This effect will be realized in enclosing structures operating under variable temperature conditions, since an expanding additive will increase the frost resistance of concrete. When volume expansions are compensated, the shrinkage deformations are eliminated [7-9].

Thus, in order to control the deformation properties of concrete composites, it is necessary to use expanding additives, in addition to ready-made cements for the same purpose, which will allow creating of fine-grained concretes with the effect of expansion, self-stressing or non-shrinkage.

In addition, it should be noted that the preference is given to already existing expanding additives rather than to ready-made expanding and pre-stressing prefabricated cements, and this is connected with a number of positive aspects. For example, a certain quality and stability of the properties of modified repair composition of fine-grained concrete is ensured, there is a possibility of adjusting the composition depending on the operating conditions of a structure, the expanding additives are used directly during the production of repair composition [5, 13].

Expanding and non-shrinking compounds made of such additives will help to fix cracks, defects, seams and other repair tasks.

II. METHODS AND MATERIALS

In this research, the shrinking deformations of repair compounds modified by the complex use of fine-grained binders using barkhan sands and modern effective polymer components were investigated. Calcium sulfate dihydrate was used as an expanding component, which in combination with vibro-mechanically chemically activated binder on barkhan sand will manifest the effect of expansion and prevent further shrinkage deformation. In order to obtain fine-grained activated binder, the local raw materials were used along with 500 class additive-free Portland cement of the Chiri-Yurtovskoye cement plant and barkhan sands of the Shelkovskoye deposit.

The activation was carried out by joint grinding in a vibration mill VM-20 for 10 min. The recipes of fine-grained binders are shown in Table 1. The feature of the proposed binder is barkhan sands; therefore the main task of the work was the investigation of barkhan sands.

The granulometric composition of barkhan sand is characterized by the predominance of particles less than 0.1 mm in size, the modulus of their size is less than 1, which makes it possible to assign these sands to the category of fine sands.

TABLE I. THE RECIPES OF FINE-GRAINED BINDERS

No. of composition	Activation mode	Conventional designation	Component content of fine-grained binder, %		
			PC	*Barkhan sand*	*C-3*
1	Joint vibroactivation VM-20	PC	100	–	–
2		FGB -85	84	15	1.0
3		FGB -75	74	25	1.0
4		FGB -65	64	35	1.0

Visual analysis with the help of a binocular microscope showed that these sands are light and sometimes are grayish-yellowish in color. Generally they are represented by grains of white, transparent and turbid quartz. The study of particles of sand with the method of scanning electron microscope (Figure 1) showed the presence of grains of irregular shape with oval, smooth contours, in addition there are acute-angled fragments in a small amount.

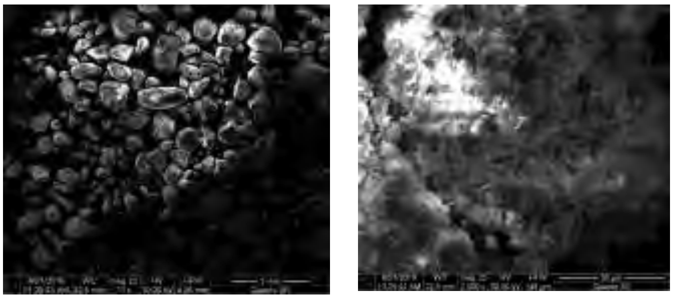

Fig. 1. Micrograph of barkhan sand grains.

The chemical composition, mineral composition and main physic and mechanical properties of barkhan sand were studied. The results of the research are presented in Tables 2-4.

TABLE II. CHEMICAL COMPOSITION OF BARKHAN SAND, %

MgO	Al_2O_3	SiO_2	K_2O	CaO	Fe_2O_3	Na_2O	SO_3	ppp
2.41	7.81	59.54	1.44	17.52	2.6	1.35	0.21	7.12

TABLE III. MAIN PHYSICAL AND MECHANICAL PROPERTIES OF BARKHAN SAND

Sieve size, mm	1.25	0.63	0.315	0.14	Residue on sieve bottom
Partial residues, %	3.5	2.7	3.1	31.7	59
Complete residues, %	3.5	6.2	9.3	41.0	
Size modulus	0.6				
Content of dust and clay particles, %	5.4				
Real grain density, kg/m^3	2650				
Average bulk density, kg/m^3	1390				
Void ratio of sand, %	48				
Water demand, %	12				

TABLE IV. MINERALOGICAL COMPOSITION OF BARKHAN SAND

Minerals	Specific fractions content, %						
	0.5-0.25	*0.25-0.1*	*0.1-0.05*	*0.05-0.01*	*0.01-0.005*	*<0.005*	*% of groundmass sand*
Quartz	60	52.7	45.7	45.7	40	31.3	48.0
Feldspathic rock	5	12.6	11.7	11.9	10	30.6	10.5
Carbonates	–	0.72	11.1	41.8	40	2.7	13.0
Mica	–	–	–	6.08	10	37.4	2.5
Others	35	34.0	31.3	4.1	–	–	6

The studied natural barkhan sands were used in order to obtain fine-grained binders in the production of repair compositions with improved exploratory characteristics.

Moreover, calcium sulfate dihydrate and acrylate polymers were used in order to obtain the modified repair compositions from fine-grained concrete based on barkhan sands, the use of which will significantly change the technological parameters such as mobility and water demand, workability and water separation, dissemination and persistence, adhesion with the old base, strength generation etc. The modern effective superplasticizers SIKA VISCOCRETE 5 NEW and "Hidatal-GP-9" beta "β" based on carboxylate esters and acrylic dispersion AKREMOS 101 were used.

III. RESULTS

Deformations of the modified repair composition of fine-grained concrete were determined prismoidal samples of 40×40×60 mm. As a result, 9 compositions of modified fine-grained concretes on barkhan sands were investigated. The prepared prismoidal samples were kept for 24 h in a climatic chamber at the temperature of +20 °C and in relatively humid (95%) environment. Then, the samples were decalcified and hardened in air for 7 days covered with a damp cloth at the temperature of +20 °C, the next 3 days the samples were immersed in a vessel with water where they were stored until the test.

The UB-40 device determined shrinkage and linear expansion of the deformation of the prism samples with a cross section of 40×40 mm according to State Industry Standard 24544-81. In order to determine the strength characteristics of the investigated repair compounds (Table 5) of fine-grained concrete, the samples of cubes of 3 cm in size were made, which hardened in the climate chamber for 10 days at the temperature of +20 °C in relatively humid (95%) environment. The research results are presented in Table 6 and Figure 2.

The composition No. 7 on the basis of fine-grained binder and calcium sulfate dehydrate had an expanding effect above 0.025 mm/m, an explanation for this phenomenon is the formation in the first day of the hardening of the fibers of hydrosulfoaluminate and calcium hydrocarbosulfoaluminate, contributing to the rapid process of structure formation and the increase in the volume of cement matrix.

TABLE V. REPAIR COMPOSITIONS RECIPES

No of composition	Consumption of concrete materials, kg/m^3										W/C
	C	*FGB-75*	*AKREMOS 101*	*GKZH-11*	*FF*	*MF*	*Hidetal*	*Sika Viscocrete*	*calcium sulfate dihydrate*	*W*	
1	430	–	–	–	1510	100	6	–	–	189	0.44
2	430	–	–	–	1510	100	–	6	–	180	0.42
3	420	–	–	–	1520	90	–	6	15	200	0.48
4	420	–	77	7	1520	90	–	–	–	117	0.28
5	–	530	–	–	1510	–	–	5	–	164	0.31
6	–	530	–	–	1510	–	5	–	–	175	0.33
7	–	520	–	–	1520	–	–	5	15	182	0.35
8	–	520	94	9	1520	–	–	–	–	130	0.25
9	540	–	–	–	1400	–	–	–	–	292	0.54

Note: FGB-75 – fine grained binder, joint vibroactivation for 10 min (PC 74 % + barkhan sand 25 % + C–3-1 %) Scon = 480 m^2/kg; FF – fractionated filler obtained by enriching crushing screenings (60 %) barkhan sands (40 %); MF – microfiller, barkhan sands vibroactivated for 10 min Scon = 410 m^2/kg; AKREMOS 101 acryl dispersion, consumption 18 % of cement mass; GKZH-11 sodium methylsiliconate consumption of 10 % by weight of acrylic dispersion; composition number 8 – control sample on quartz sand of Chervlenskoye deposit.

TABLE VI. THE RESULTS OF DETERMINATION OF CONSTRUCTIVE DEFORMATIONS OF REPAIR COMPOSITIONS ON BARKHAN SANDS

No. of composition	Average density, kg/m^3	Samples deformation, mm/m In the age of a day			Bending strength 10 days , MPa
		1	*3*	*10*	
1	2215	0.017	–0.006	–0.014	50.4
2	2225	0.001	–0.005	–0.018	54.5
3	2230	0.004	0.009	0.012	52.8
4	2230	0.014	–0.013	–0.016	55.7
5	2214	0.002	–0.004	–0.012	65.3
6	2212	0.003	–0.008	–0.011	63.1
7	2216	0.005	0.016	0.025	68.6
8	2265	0.010	–0.01	–0.014	70.1
9	2200	0.006	–0.022	–0.032	47.0

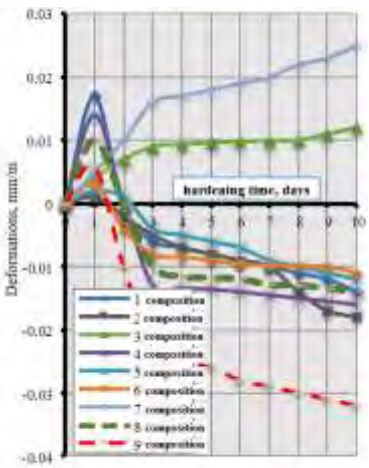

Fig. 2. Dynamics of deformation development in modified repair compounds of fine grained concrete.

The research results showed that in modified repair compositions of fine–grained concrete using an additive of calcium sulfate dehydrate in the amount of 3% of mass of cement, an expending effect is clearly observed. In composition No. 3 with the complex use of cement, fine barkhan sand powder and calcium sulfate dehydrate, the expansion deformation for the 10th day was 0.012 mm/m.

Repair compositions containing FGB-75 and microfiller of barkhan sand with carboxylate additives Sika Viscocrete and Hidetal showed shrinkage deformation values 62% less compared to control samples on quartz sand. Shrinkage deformations are caused by the decrease in the volume of concrete due to evaporation of water from it.

Repair compositions containing acrylic dispersion AKREMOS 101 and GKZH-11 showed shrinkage deformation, there is no expansion effect in this case. This fact can be explained by the presence of polymer in these repair compounds. In the process of globules coalescence, a film is formed, which contracts and tightens the skeleton of cement stone, thereby reducing the volume of the composite, and shrinkage deformations increase. In 10 days of hardening, shrinkage deformations are still present, and then this process slows down. But in any case, the shrinkage of samples of repair compounds with AKREMOS 101 is less than the control samples by 56%.

The resulting expanding additive, which includes Portland cement, barkhan sand, 25% superplasticizer C–3 1% and 3% calcium sulfate dehydrate allows production of modified repair compositions with a given formula. It is important to take into account this property in the production of repair work.

IV. Conclusion

As the result of the research, it was found that the use of an additive of calcium sulfate dehydrate in repair compositions in combination with fine–grained binder based on barkhan sands and carboxylates shows the expanding effect, which is an important indicator in the performance of repair work.

Therefore, the development of effective recipes of a binder with the use of barkhan sands as a local natural resource for the subsequent production of modified repair compositions with improved characteristics helps to improve the quality of repair and restoration of the bearing capacity of structural elements of buildings and structures.

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