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IMPROVING THE EFFICIENCY OF MANUFACTURING FINE-GRAINED CONCRETE THROUGH THE USE OF MAN-MADE SANDS AND COMPOSITE BINDERS

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ABSTRACT

In this paper, an attempt has been made to substantiate the need for utilization of man-made sands and sands of mechanical origin obtained from local rocks as a result of mining, processing into crushed stone and sawn materials. The use of waste products contributes to the expansion of the raw materials base of the construction industry, increase in the number of composite binders when used as a filler, large-scale propagation of fine-grained concrete for various products along with minimization of material and energy costs, expanding the practice of using stone-crushing, stone-sawing products and managing new technologies for environmental conservation. The decision to utilize man-made waste materials (sands) of mechanical origin is particularly important for large-scale expansion of the production of fine-grained concrete for a region where no metal (reinforcement steel) is manufactured.

Keywords: man-made sands of mechanical origin, particle size distribution, chemical mineralogical composition, hardness, fineness modulus, fillers, composite binders.

INTRODUCTION

The Kyrgyz Republic has significant reserves of rocks during the processing of which generates large volumes of manmade sands, the involvement of which in construction is important both from the perspective of economy and for the purpose of expansion of the raw material base of the construction industry.

This paper addresses the issue of integrated utilization of raw materials contributing to the large-scale propagation of fine-grained concrete and composite cement binders with fillers.

Numerous works of leading researchers such as Bazhenov, P.I., Bazhenov, Y.I., Shestoperov. S.V., Skramtaev, B.G., Popov, N.A., Motsanskiy, N.A. Soroker, V.I., Abrams *et al*. deal with the issues of improving the structure and technological properties of fine-grained concrete.

Thus, Bazhenov, Y.I. developed extra strong fine-grained concrete for armored structures.

The basis for obtaining fine-grained concrete with the improved performance properties consists in the creation of a quality structure of material in which modifiers, reactive mineral ingredients, and composite binders can be manifested to the fullest extent.

The structure of fine-grained concrete and its properties primarily depend on the structure of hardened cement paste, dependency of technological viscosity from the quantity of water added to concrete.

Fine-grained concrete mixture is characterized by increased content of hardened cement paste, lower grain fineness, increased void ratio and fineness of filler, reduced capability for the control of the properties of filler by changing the ratio between certain fractions, more strict requirements to sand, lower fluidity of cement-sand mixture, i.e. sands that are used in fine-grained concrete mixture must be controlled with special care.

This paper is aimed at studying the influence of the grain-size distribution of sands, as well as shape and morphological composition of grains of various rocks on the technological properties of mixtures and strength properties of fine-grained concrete mixture.

The following tasks were solved for achieving this goal:

- The study of chemical mineralogical and petrographic composition as well as the technological properties of sands from various rocks;
- The influence of morphological composition of grains of sand origin on the technological properties of fine-grained concrete mixture;
- Properties of fine-grained concrete mixture from crushed sands, plasticizing agents and composite binders.

MATERIALS AND METHODS

Portland cement PTs400 D20 manufactured by Kant cement plant was used in the operation (see Table-1). It was used as a basis for obtaining the composite binders filled with pyrogenous mill tailings of antimony ores (flotation refuse ores of antimonic production).

Table-1. Properties of portland cement.

Material	Normal consistency, %	Setting time		T, %, passed through circular hole-sieve 008	Fineness, m2/g	Breaking strength, MPa		SO_3, %
		Start time, h, min.	End time, h, min.			Deflection strength	Compression breaking strength	
ПЦ 400 Д 20	23.0	3.45	4.30	89.2	312	6.5	42.2	1.7

The mineralogical composition of portland cement is characterized by the following content of cement minerals (in %): C3S - 63.3; C2S - 15.9; C3A - 5.4; C4AG - 12.5.

The chemical composition of cement clinker and mill tailings of antimony ores is presented in Table-2.

S-3 (TU 6-14-19-25279) was used as a plasticizing agent (0.1-1.0 %)

The tailings of flotation benefication of antimony ores of JSC "KSK" were formed in the process of manufacture of antimony from rocks, refinement of cinnabar during the heat treatment at a temperature of about 1200 °C, the main components of material are: silicon dioxide, calcium carbonate, and aluminous component.

Silica is somewhat amorphized, thus this product is a highly reactive additive.

Composite cement binders with 50% of mill tailings of antimony ores are characterized by normal consistency that is equal to 28%. The addition of plasticizing agent S-3 (1.0%) has plasticizing influence; the water demand of mixture is (23%).

Naturally occurring materials were used for obtaining crushed sands: fine-grained basaltic rock, limestone from Kurmenty deposit, granite, wollastonite.

The chemical composition of raw materials is presented in Table-2.

The fluidity of cement-sand mixture is influenced by the following factors: water/cement ratio, grain composition, coarseness, and grain shape of fillers.

The grains of natural sand are mostly spherical in shape. Unlike them, the sands obtained from rock materials in the shattering process are represented by cubical-shaped grains with high content of flaky grains and needle-like particles. The fineness, void ratio and water demand of sand increase with the transition from spherical shape to flaky and needle-like grain shape. This reduces the resistance of sand to compressive, impact and abrasive loads which is reflected on the properties of fine-grained concrete mixture.

The use of blended sand from coarse fractions of screenings and clean natural sand is especially efficient (see Table-5). The coarse fractions of screenings and fine natural sand with the fineness modulus of 2.3 were used; the content of clays was 15.5 % (before sedimentation) and 0.5 % (after sedimentation); the water demand was 10.2%.

Grain coarsening additive contains 20 to 60 flaky grains and its fineness modulus is 3.75.

30 to 70 % of grain coarsening additive was added to blended sand. The increase in the fineness modulus of 4.3 for additive and blended sand results in reduced void ratio and water demand of fine filler. The increase in the amount of additive causes the increase in void ratio, but reduces the water demand.

The decrease in the content of flaky grains and grain coarsening additive slightly increases the slump of the cone of concrete mixture. The increase in the amount of grain coarsening additive increases the strength of fine-grained concrete mixture from 33.0 to 37.0 MPa.

Table-2. Chemical composition of raw materials.

Material	POI	Oxide content, %										
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	TiO_2	FeO	K_2O	Na_2O	Σ
Cement clinker KTSK	0.20	22.44	4.65	4.11	65.59	1.75	0.33	-	-	-	-	-
Basaltic rock	6.23	47.44	16.75	2.35	6.87	5.18	0.52	1.86	0,24	0.28	-	-
Limestone	43.08	0.88	0.45	0.24	54.78	0.56	0.01	-	-	-	-	-
Granite	2.55	59.07	16.76	9.4	2.91	0.56	0.06	0.63	-	4.59	3.46	-
Natural sand	-	68.72	14.21	3.24	3.25	2.68	2.61	6.63	-	-	-	101.3
Mill tailings of antimony ores	7.23	70.93	6.92	0.73	12.67	0.03	0.82	-	-	0.67	-	99.97

Table-3. Grain-size distribution and mechanical-and-physical properties of man-made sands.

S. No.	Name of material	Total solids, %							ρ_{prs}, g/cm3	ρ_{hist}, g/cm3	ρ_{avg}, g/cm3	void ratio, %	Clay content
		$M_{кр}$	2.5	1.25	0.63	0.315	0.16	bottom					
1	Natural sand	2.3	13	14.5	11.5	27	27	6.5	1.57	2.48	2.45	35,9	16
			13	27.5	39	66	93	99.5					
2	Lime sand	4.3	61	24	9	3.5	2	0.5	1.49	2.47	2.45	39.1	-
			61	85	94	97,5	99.5	100					
3	Wollastonite sand	3.47	41.26	13.69	15.1	14.8	11.8	2.48	1.52	2.7	2.6	41.5	-
			41.26	54.95	70.05	84.85	95.96	92.13					
4	Granite sand	3.16	38.5	11.5	16.5	11	6.0	16.5	1.4	2.6	2.5	44.0	-
			38.5	50	66.5	77.5	83.5	100					
5	Basalt sand	4.1	58	21.6	5	7.2	4.5	3.5	1.45	2.63	2.23	34.9	-
			58	79.6	84.6	91.8	96.3	99.8					

Table-4. Specification of fineness, water demand and cement need of man-made sands.

S. No.	Name of material	Fineness, PSH-2, cm2/g	ρ_{prs}, g/cm3	Water demand, %	Mk	Cement need, %	Void ratio, %	Porosity (estimated), %
1	Natural sand	1384.4	1.57	7	2.3	0.48	34.0	2.8
2	Lime sand	980	1.45	5.9	4.3	0.41	39.1	5.5
3	Wollastonite sand	1102	1.5	6.4	3.47	-	41.5	3.06
4	Granite sand	1305	1.4	7.2	3.16	0.44	44.0	6.1
5	Basalt sand	1178	1.45	6.5	4.1	0.43	34.9	5.0

Table-5. Properties of blended sand and fine-grained concrete mixture.

Properties of additive		Amount of additive	Properties of blended sand				Remoldability		Breaking strength, MPa	
Fineness modulus	Flaky grains content, mass content, %		Fineness modulus	Void ratio in bulk concrete, %	Void ratio in vibrated concrete %	water demand	Cone slump (CS)	Stiffness (C)	on R_{dfl}	on R_{cbr}
3,75	20	30	2.01	40.7	32.2	10	9	27	6.2	30.3
		70	3.16	41.0	31.7	7.7	12	11	7.0	33.3
	60	30	2.01	40.4	31.9	9.0	11	25	5.8	27.4
		70	3.16	41.7	32.4	7.9	15	14	7.2	33.6
4.3	20	30	2.3	37.0	30.7	7.5	16	11	5.8	27.8
		70	3.75	39.2	32.0	4.6	11	4	7.0	37.1
	60	30	2.3	37.0	31.1	8.0	18	9	5.9	30.8
		70	3.75	38.8	31.3	5.4	11	15	7.5	36.0

The properties of fine-grained concrete mixture depending on the type of sand, grain shape, chemical and mineralogical composition, strength of basic rock and sand to cement ratio are presented in Table-6.

The strength of fine-grained concrete mixture is stipulated by abovementioned factors. The increased strength of fine-grained concrete mixture based on sands with spherical surface, has been observed, since the water/cement ratio decreases in this case.

Sand grain shape and surface influences the water/cement ratio of mixtures in which they are used as fillers.

Spherical, parallelepipedic surface of sand grains causes a decrease in water/cement ratio of fine-grained concrete mixtures. Carbonate sand, basalt sand, and quartz sand have decreased water/cement ratio = 0.34:0.35 in case of their use in fine-grained concrete mixture (1:1 composition). Furthermore, the specimens are characterized by the strength of 32.7; 32.8; 31.2 MPa.

When these same sands are used in fine-grained concrete mixture (1:2 composition) the water/cement ratio is 0.51:0.41, and the strength of specimens is 23.4; 18.93 and 25.4 MPa.

Certainly, the strength of original rock influences the strength of specimens as well.

However, it is evident that in the use of carbonate sands, the specimens from fine-grained concrete mixture are characterized by the strength that is close to the

strength of granite sand (32.7 MPa on carbonate sand and 36.6 MPa on granite sand), despite the fact that the strength of granite is 120 MPa, and the strength of limestone is 50 MPa.

When carbonate sands are used, chemical activity is manifested; it becomes more intense during attrition grinding. The hydrocarbonates of calcium are jellous, are formed during the hydration process in contact zone; they improve coupling with hardened cement paste.

It should be noted that fine-grained concrete mixture based on feldspar sand (see Table-6 (composition 6)) is characterized by the higher strength (35.2; 30.4 MPa) compared to the strength of fine-grained concrete mixture based on quartz pit sand (31.2 and 25.4 MPa).

Table-6. Influence of grain shape on the strength of fine-grained concrete mixture.

S. No.	Sand	Sand properties			Fine-grained concrete mixture properties				
		Mineralogical composition	Grain shape and surface	Rock strength, MPa	sand/cement ratio	water/cement ratio	ρ_{avg}, g/cm3	Compression breakingstrength R_{com}, MPa	
								TBO, 1c	Standard hardness, 28 days
1	Granite sand	SiO_2 quartz, feldspars ($K_2O*Al_2O_3*6 SiO_2$)	Angular, pyramidical, prismatical, sharp edged	120	1:1 1:2	0.37 0.55	2.15 2.05	17.2 15.4	35.6 21.2
2	Carbonate sand	$CaCO_3$ $MgCO_3$	Angular, pyramidical, prismatical, sharp edged	70	1:1 1:2	0.34 0.51	2.13 1.96	16.2 16.8	32.7 23,4
3	Basalt sand	plagioclase	Spherical, diamond shaped	150	1:1 1:2	0.35 0.51	2.2 2.16	19.1 12.99	32.8 18.93
4	Wollastonite sand	$CaO*SiO_2$	Needle-like, spherical, parallelepipedic	-	1:1 1:2	0.36 0.51	2.10 2.12	18.2 14.5	30.12 21.16
5	Quartz sand	SiO_2-92,6 CaO-0,5	Angular, cubical-shaped, pyramidical, sharp edged	-	1:1 1:2	0.35 0.41	2.14 2.16	18.6 16.8	31.2 25.4
6	Feldspar sand		Spherical, pyramidical	-	1:1 1:2	0.5 0.56	2.3 2.25	16.7 17.2	35.2 30.4

The water demand of mixtures based on feldspar sand is higher (0.5; 0.56) than the water demand of mixtures based on quartz sand (0.35; 0.41), but the strength of mixtures based on feldspar sand is higher. The fineness modulus has impact in this case. Feldspar sand is finer (Mk=2.1). When it is used, the specimens are more compacted and stronger than the specimens based on quartz sand.

The results of tests of specimens that were manufactured based on a composite binder after one-day-long steam treatment of are presented in Table-6.

Almost all specimens in this age develop 50-70% of the strength of normal hardening (28c).

CONCLUSIONS

- The processing of waste materials of rock excavation, rock grinding, rock sawing contributes to integrated utilization of natural raw material, expansion of the raw material base of the construction industry - the issue of provision of high-quality fillers for concrete products and fillers for composite binders is solved;
- The manufacturing of composite cement binders contributes to the decrease in fuel consumption for the manufacture of cement and expensive cement clinker, completeness of hydration processes during hardening of reinforced concrete products, abatement of flue gas emissions in the manufacture of cement clinker;
- The involvement of sands of mechanical origin, characterized by various grain-size distribution and morphological composition with rational selection of the composition of fine-grained concrete mixture, as well as the use of modifying additives and composite binders contributes to the expansion of manufacture of high-quality fine-grained concrete mixture which is especially important for the construction in a region where there are no metals;
- Spherical, parallelepipedic surface of sand grains causes a decrease in water/cement ratio of fine-grained concrete mixtures, resulting in improved strength of specimens;
- The strength of fine-grained concrete mixture increases by 10-15 % in case of the use of reactive sands (carbonate sands) compared to sands from solid rocks (granite) due to hardening of the contact area of hardened cement paste with the filler surface;

- In the comparison of the properties of fine-grained concrete mixture based on feldspar sand and quartz sand it has been found that the dominant role in structure formation is played by the fineness modulus (2.1), which causes densification and hardening of fine-grained concrete mixture.

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