Decorative coatings based on the processing of fine waste crushing concrete scrap

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Abstract. Experiments were carried out to determine the rational range of the proportion of fillers from sand and the dropout of crushing concrete scrap as a replacement part of the cement to obtain colloidal cement glue and to assess the effect of fillers of different specific surface area and the degree of filling on the kinetics of the set of strength of the hardened stone. It is established that the composition of the concrete scrap crushing drop-out contains about 30% of non-hydrated Portland cement, which determines its use as an active micro-filler in the production of fine cement systems. According to its chemical composition, the elimination of crushing of concrete scrap from heavy concrete is presented in the form of compounds of oxide groups, which, as a result of the interaction, provide the process of solid-phase synthesis of new compounds and are not able to enter into chemical interaction with pigments, the color of which is determined by the type and content of iron oxides, and therefore has no contraindications for use in decorative thin-milled cement systems.

1 Introduction

Improving the energy efficiency of construction is essential when using green technologies in construction. The green technologies include innovative solutions in the field of processing and recycling of materials, waste water treatment, energy saving, air pollution control, environmental protection, renewable energy sources [1-4]. Currently, due to the development of green building technologies, the problem of rational use of natural resources is extremely acute. Therefore, every day more and more popular methods of environmentally safe production and technology to produce waste. One of the innovative directions of "green technologies" in construction is processing (recycling) and involvement in the production of construction waste [4-9]. The problem of waste utilization of concrete and reinforced concrete structures and old asphalt concrete is relevant in connection with the need for industrial, civil and road construction, the growth of traffic volumes and the need to reduce pollution of territories with construction waste. Environmental and economic feasibility and necessity of repeated and multiple use of natural resources by involving part of production and consumption wastes in economic turnover as secondary raw materials has been proved by long-term practice in many countries of the world. As a result of the destruction of residential buildings, structures and building structures, a certain amount of

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waste is always generated: a mixture of loose, lump, sheet, dust, etc. materials that, to some extent, are both of commercial interest and a certain danger to the environment. Therefore, there is a need for the processing of such waste and their use as secondary raw materials for various materials and structures. For the rational use of raw materials is of interest to use as fillers of various industrial wastes, including fine-grained screenings of processing of concrete scrap, which is currently not widely used [8-9]. Use as a filler in colloidal cement glue screenings from the concrete crushing process will contribute to ensuring environmental safety in construction activities and the efficient management of the process of rational use of construction waste generated at certain stages of the life cycle of real estate (manufacturing, construction, reconstruction, renovation, demolition).

2 Problems

The purpose of the presented research is to establish the dependence of the characteristics of concrete screenings on the technological and operational properties of colloidal fine cement systems for decorative coatings. The essence of the technology of obtaining colloidal thin-milled cement systems is the possibility of increasing the production efficiency by using the technology of changing the structure of binders and fillers. In this regard, based on the physical concepts of the structure and properties of the fine cement system, the process of changing the structural and physical, energy properties of the state of binders under the influence of vibration-speed grinding is important. This opens up opportunities for changing material properties by activating the surface and grinding to micro levels. To ensure the positive effect of fillers and active mineral additives on the properties of fine cement systems, the composition, physical and chemical characteristics, as well as the input quantity and specific surface area of materials are important. For research, we used materials that meet the requirements of existing regulations and provide a colloidal cement material specified technical characteristics. The portlandcement of Bukhtarma cement company, natural sand of Mykolaiv Deposit, various fillers, additives and pigments were used as the main components in the production of colloidal mixtures. As a filler, the screening of crushing of secondary crushed stone from concrete scrap was used. Waste concrete obtained from Portland cement PC400-D0 according to GOST 10178, subjected to crushing and screening to separate fractions with grain sizes up to 5 mm and less. Due to its high specific surface area, fine-milled concrete scrap is able to act as a micro-filler in colloidal cement systems and participate in the formation of a dense matrix due to further hydration of unreacted and mechanically activated cement, which is able to participate in the formation of cement stone. According to the chemical and mineralogical analysis of the screening of crushing meets the requirements for the filler, the grain composition of the sand module size (Ms) is 2.8, the total residue on the sieve of 0.63 and 0.16 refers to the large. It was determined that the screening of concrete scrap is advisable to be subjected to fine grinding to a specific surface area of not less than 500 m^2/kg, since with fine grinding this product is able to exhibit residual (secondary) binding properties due to the presence in the screenings of not completely deflected particles of Belite ($3CaO \cdot SiO_2$), as well as portlandite ($Ca(OH)_2$). The true density of sand from the concrete scrap of 2.5-0.16 fraction was 2640 kg / m^3, the fraction of 1,25-0,16 – 2560 kg / m^3. The bulk density of the sand fraction of 2.5 to 0.16 amounted to 1586 kg/m^3, fraction 1,25-0,16 – 1594 kg/m^3. The sand has a emptiness of 39.6 % for the fraction of 2.5-0.16 and 38.5 % for the fraction of 1.25-0.16. Studies have shown that the intergranular emptiness of a rationally selected mixture is achieved for sand 1,25-2,5 and 0,16-0,315 at a fraction ratio 2,3:1. It was found that the sand and the elimination of crushing of concrete scrap have a good grinding ability and for 90 minutes the specific surface of the sand increases to 1001 m^2/ kg, at the dropout of crushing of concrete scrap to 990 m^2/kg. It can be concluded that the grinding time to the desired specific surface area for sand and concrete scrap crushing dropout is almost the same. Good grinding capacity of concrete scrap screenings is explained by lower hardness of minerals included in the screenings, in comparison with quartz sand, as well as by the fact that the screenings contain a mortar part, which has lower strength. Quartz sand and screenings of secondary crushed stone from concrete scrap regardless of the grinding time are represented by sharp-angled particles, with large particles having an isometric, angular shape with a complex surface relief, and small particles have a sharp-angled shape with uneven fractures. With the increase of the specific surface of the fillers, there is an increase in the angular and isometric properties of particles of both large and small fractions, this allows us to suggest that such a morphology of the particles will contribute to the improvement of adhesion to cement. Newly formed particle surface has a much higher value of surface energy, which makes them a higher adhesion activity by improving conditions of wetting.

3 Results

These studies have shown that the grinding of sand or the elimination of crushing of secondary crushed stone from concrete scrap (chemical composition of the elimination of crushing of concrete scrap is given in Table 1, grain composition in Table 2) allows not only to increase their specific surface area, to obtain the required particle size distribution, but also to improve the surface quality of particles by removing and destroying the surface inactive films, which increases the reactivity of the filler in various processes in the production of decorative coatings based on colloidal cement systems.

Table 1. The chemical compositions of screenings from the concrete crushing

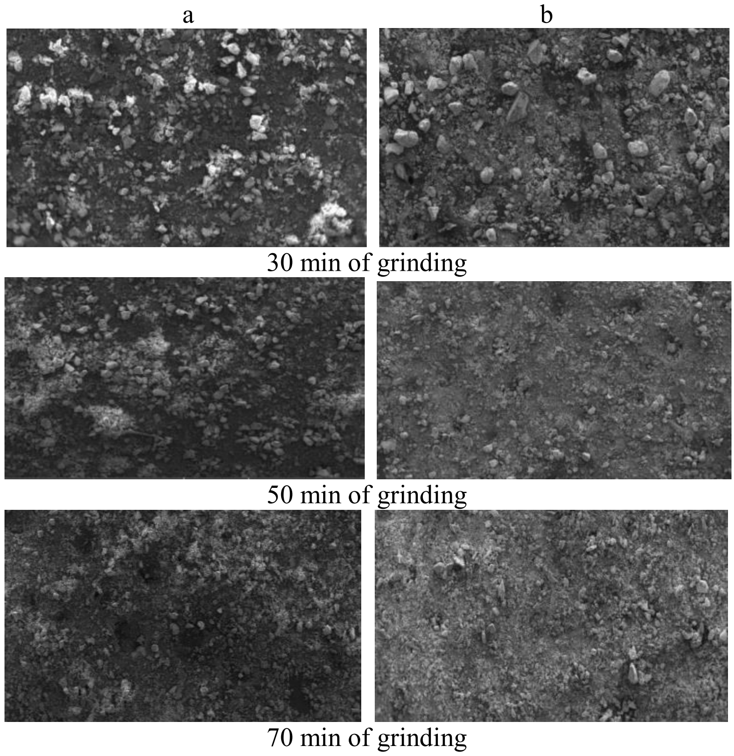
The content of oxides, %										
SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	TiO_2	MnO_2	ClO_2
49.45	5.43	3.78	36.87	1.29	0.71	1.51	0.54	0.34	0.078	0.22

Values of drum rotation speed and mixing time for optimally selected ratio of the additive ingredients necessary for the granulation process were defined. The procedure was proposed for formation of the additive granules (S–3SSA) composed of, mass %: superplasticizer S–3 – 10; soap stock – 20; salt of inorganic acid – 30 and ash – 40.

Table 2. Grain composition of sand from the screening of crushed concrete scrap

Residues on the sieves, %	The size of the holes, mm					Passed through a sieve 0.16, %	The fineness modulus, M_f
	2.5	1.25	0.63	0.315	0.16		
Partial	23.35	12.78	15.60	29.82	10.73	7.72	2.8
Full	23.35	36.13	51.73	81.55	92.28		

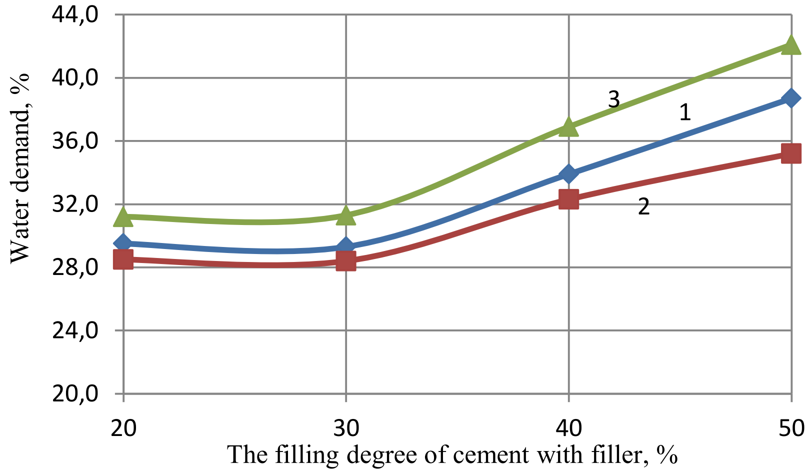
The shape and morphology of the sand particles and the concrete scrap crushing screening (Figure 1) were investigated at different grinding times (30, 50 and 70 min), taken as the main fillers for further study. The figure shows (pictures taken on a scanning electron microscope at 100 magnification) that the surface of the particles of ground fillers from quartz sand and concrete scrap has an angular shape with a complex surface relief, with angular fractures.



a) natural sand; b) screening crushing concrete scrap

Fig. 1. The morphology of fine particles of sand and sifting crushing of concrete at different time of grinding

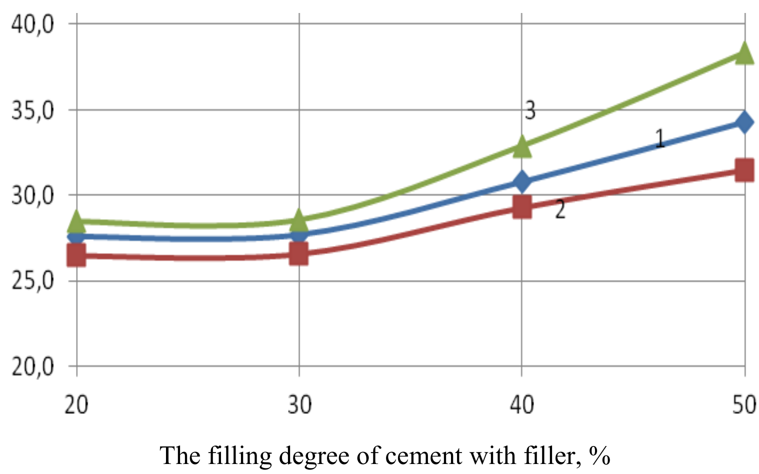
For fine-milled cement systems with a sufficiently high specific surface area, the amount of water required to obtain a test of normal consistency, increases in proportion to its content in the mass of cement. When the degree of filling of cement 30-50% of the water requirement of fine ground cement mixtures varies in the range of 26.5-45.1 per cent. Water demand of compositions in relation to the filled cement, that is, in terms Of b/(C+H), with an equal degree of filling, it is possible to adjust the specific surface area within a wide range. The introduction of a coarse filler with a specific surface area of 300 m2/kg in the amount of 30% in the cement with a specific surface area of 450 m2/kg and more contributes to the increase of water demand, which is 29.4%, with a degree of filling of 50%, water demand is 38.7 % (Figure 2). In the case of the filler with a specific surface area of 860 m2 / kg, the same composition will show higher water demand – 31.3-42.8% depending on the filling of cement.



1) specific surface area (Ssa) of filler-300 m2 / kg; 2) 550 m2/kg; 3) 860 m2/kg

Fig. 2. Dependence of water demand of thin-milled cement systems on the degree of filling at the specific surface of the cement of 450 m2 / kg or more

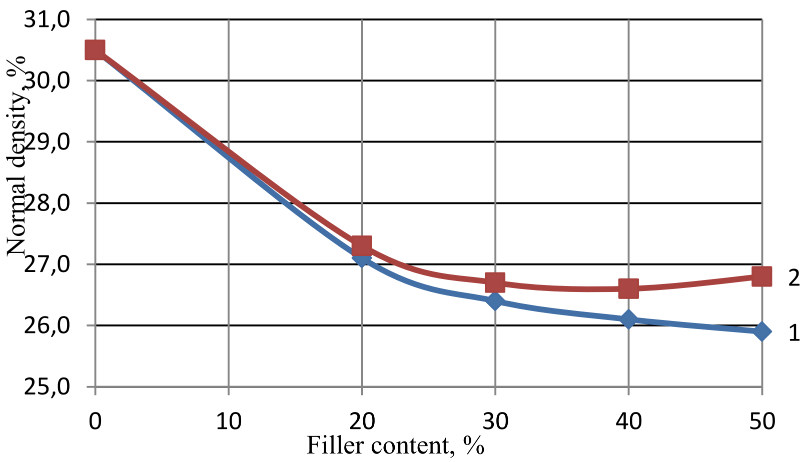
It was experimentally established (Figure 3) that the optimal dispersion of cement and filler 550-560 m2/kg, which provides a minimum water demand, it is recommended to bring the joint domol of cement with filler to this specific surface.



1) S_{sa} of filler - 300 m^2/kg; 2) 550 m^2/kg; 3) 860 m^2/kg

Fig. 3. Dependence of water demand of thin-milled cement systems on the degree of filling and specific surface area of cement 550-560 m2/kg.

During the research the dependence of the influence of the filling of cement systems on the water demand by changing the normal density (ND) of the binder was determined, the results are shown in Figure 4. It was found that the introduction of fillers (natural sand and concrete scrap) slightly reduces the water demand of fine cement systems. This is due to the denser internal structure of the particles. Thus, when introducing fillers up to 30%, the minimum value of normal density (Nd) in sand is 26.4%, the dropout of concrete scrap – 26.7%, a further increase in the content has virtually no effect on the water demand of the system, but leads to the manifestation of the process of slight water separation.



1) natural sand; 2) screenings of crushing of concrete scrap

Fig. 4. The influence of the degree of cement filling on the normal density of the cement paste.

An important characteristic of any binder is the setting time, which was determined on the equi-movable systems. The rheological characteristics of colloidal cement systems with different fillers are related to their structure, determined by the processes of setting as a result of hydration of binders.

Previously, the main factors affecting the rheological characteristics of fine cement systems with different fillers were identified: the type of filler, specific surface area and cement content; particle size distribution, the shape of the filler particles and its content; the type and dosage of modifying additives. Metakaolin at optimal dosage allows to achieve qualitatively new characteristics in fine-milled cement systems, showing a plasticizing effect and providing a modified mixture of high plasticity, resistance to delamination, helps to reduce shrinkage deformation during drying, as well as the absence of sticking to the tool [10]. To determine the effect of metakaolin on the properties of the binder was prepared of a mixture composition cement: sand: metakaolin in the ratio of 70:23:7 (composition 1), 60:33:7 (composition 2) and 50:43:7 (composition 3). Natural sand and concrete scrap screenings were used as a filler. From the data of Table 3 it is seen that the type of filler (sand or screenings of crushing of concrete scrap) practically do not have a significant impact on the setting time.

Table 3. The impact of the introduction of the filler and metakaolin on the setting time of the binder

Name and composition	Setting time, min	
	start	finish
Portland	2-55	7-20
The filler is quartz sand		
Composition 1	3-07	7-37
Composition 2	3-13	7-46
Composition 3	3-26	7-53
Filler screenings of concrete scrap		
Composition 1	2-57	7-31
Composition 2	3-34	7-39
Composition 3	3-47	7-59

Analysis of the data of Table 3 showed that the introduction of fillers in the composition of the colloidal cement mixture up to 30 % reduced the start time setting of the binder with sand from 20 to 28%, the end of setting time from 3 to 5 %. With the filler from the dropout of concrete scrap, the beginning of setting is reduced from 2 to 36 %, the end of the setting time is reduced from 2 to 5.5 %.

The slowdown in the setting time of the cement paste with the increase in the filler is due to the fact that in conditions of a changing amount of cement, the relative content of minerals in it that react with hydration with water decreases and, as a result, there is not enough calcium hydroxide to bind amorphous SiO2 and the formation of calcium hydrosilicates. Filler, metakaolin and polymer additives injected from the moment of mixing with water have on the cement paste peptizyde and structure-forming action, thereby accelerating the process of hydration and hardening of cement stone..

In the course of the research, the physical and mechanical characteristics of decorative coatings were studied and the optimal parameters were determined to ensure their manufacturability and durability. The optimal dispersion and ratio of cement and filler contributes to the formation of fine-grained structure of cement stone, while the strength and rate of hardening increase while the filler grains are surrounded by hydration products. The excess of the filler as the crystals grow contributes to the formation of heterogeneity of the microstructure. Therefore, to determine the optimal composition of colloidal cement mortar, it is advisable to investigate various compositions of the binder, which is a mixture of filler and cement domolotyh to the optimal specific surface area.

From the data in Table 4 it can be seen that the different specific surface area and the degree of filling of cement differently affect the strength.

Table 4. Influence of fineness of cement and filler grinding on the strength of samples

Com-po-sition	Specific surface area, m^2 / kg		The degree of filling of cement, %			
	cement	filler		30	40	50
			strength at the age of 28 days, MPa			
1	550	300	compression	55,4/55,0	53,2/52,7	48,8/48,5
			bend	13,07/13,15	11,38/13,11	9,69/10,05
2	550	550	compression	54,8/55,0	52,5/53,1	49,1/50,9
			bend	12,88/1305	11,24/11,48	9,58/9,97
3	550	860	compression	52,1/51,3	50,2/49,7	48,6/49,1
			bend	13,31/12,16	10,75/10,64	9,48/9,58
Note – Before the slash is the filler of quartz sand after slash – screenings from the concrete crushing						

The greatest strength, both in bending and compression is characterized by a composition 2. In this case, the structure becomes not just compacted, but the concentration of stresses decreases and their relaxation occurs. Due to the internal interactions, the solution based on the modified colloidal glue is not destroyed and the adhesion force is increased. Analysis of data shows that with the increase of the degree of filling of cement systems, the value of the tensile strength decreases. Taking into account the significant energy consumption when grinding components, the use of compounds with a high specific surface area of more than 550 m2/kg is impractical. However, in cases where the coatings of the colloidal cement solution have increased requirements, it is possible to use compounds with a high specific surface area. For this formulation, the optimal specific surface area of fine cement systems is 550 m2/kg.

According to physical, mechanical and construction characteristics, the developed mixtures with the addition of concrete scrap screenings meet the requirements for these types of construction materials, and in some respects they are much higher than them and can be used for the production of finishing coatings.

4 Conclusions and recommendations

The use of concrete scrap crushing screening as a filler instead of natural sand makes it possible to obtain fine-milled colloidal cement systems for effective decorative coatings. It was found that the content of about 30% of non-hydrated Portland cement in concrete scrap determines its use as an active micro-filler in the production of fine cement systems.

When grinding, the surface of the particles of ground fillers is formed from quartz sand and concrete scrap with an angular shape with a complex relief, with sharp-angled fractures.

Studies have shown that the optimal dispersion of cement and filler is 550-560 m2 / kg, which provides a minimum water demand. Therefore, it is recommended to bring the joint grinding of cement with the filler to this specific surface.

Due to the introduction into the cement system of fine-grained filler from the screenings, formed in the preparation of secondary crushed stone when crushing heavy concrete, provides a reduction in cement consumption, significantly increases durability, protective properties of facade systems, reduces the cost of the final product.

The creation of decorative coatings based on colloidal cement systems with filler from the screenings of crushing concrete scrap, which has a wide range of applications and protective action, can not only increase the durability of buildings and structures, improve environmental issues, the introduction of green technologies in the construction, as well as provide comprehensive energy conservation and, accordingly, energy efficiency.

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