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Features of Application of High-MG Technogenic Raw Materials as a Component of Composite Binders

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Abstract: Now a days there is an acute problem of shortage of natural raw materials for the production of building materials, due to rapidly evolving tempo of construction. In this regard, the urgent task of building industry is refocusing companies on consumption of anthropogenic materials. The most large-capacity raw material is byproducts of mining and in particular waste of Wet Magnetic Separation (WMS/MMC), formed by the ore benefication. On the territory of the Russian Federation Kovdorskoye deposit is one of the largest of this type and it is located on the Kola Peninsula. Study of the composition and properties of the WMS waste, as well as a comparative analysis with other sands of anthropogenic origin which are currently used in the manufacturing of building materials, showed the possibility of application of this raw material as a component of the composite binder which would reduce the amount of binder as the most expensive and energy-intensive material without reducing the strength of the final product.

Key words: Composite binders, technogenic raw materials, waste of wet magnetic separation

INTRODUCTION

Recovery of industrial wastes which are accumulating in the dumps and alienate huge spaces of land and increase the human impact on the environment is an important task of modern materials science. Building materials industry occupies a special place in the consideration of this issue as today it is the only field which is already capable of extensive and effective usage of industrial wastes, solving problems with the resource-saving in the construction and environmental protection.

Mining and processing of minerals produce a large volumes of cleaning rejects which storage requires isolation of large areas, leads to changes in relief, disruption of engineering-geological, hydrogeological and ecological and geological conditions in the region of waste repository.

The greatest amount of waste is produced during enrichment of minerals such as gold, diamonds, etc. There is a need to develop low-waste technologies and comprehensive use of mineral resources. Enrichment should be realized by a non-waste technology.

It should be noted that there is a number of papers (Lesovik, 2009), devoted to the utilization of industrial waste in concrete which not only solves the problem of comprehensive usage of secondary resources but also reduces the cost of construction as a whole.

In some countries there are also entire programs and national strategies for utilization of industrial wastes (Boswell, 2004).

The most large-capacity raw material is byproducts of mining, formed by the ore benefication. On the territory of the Russian Federation Kovdorskoye deposit is one of the largest of this type and it is located on the Kola Peninsula. Mining and ore benefication of this deposit produce a large number of by-products and in particular waste of Wet Magnetic Separation (WMS); they occupy vast areas and raise dust causing considerable damage to the environment (Prokofieva and Bagautdinov, 2000).

The aim of this study was to increase the efficiency of use of natural resources Kovdorskoe field and expanding the resource base of building materials.

MATERIALS AND METHODS

The mineral composition of the wet magnetic separation waste was obtained by the analysis of radiographs with method of quantitative analysis of full profile.

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Granulometric composition of powdered materials was determined by method of laser granulometry that allows the direct determination of the particle size and the percentage of their content in the analyzed material.

To determine the water demand of sand initially set water-cement ratio of cement paste in which it shows on the shaker table slump flow of 170 mm which corresponds approximately to its normal density (Lesovik, 2007). Then water-cement ratio of the mortar was determined in a ratio of 1:2 on the investigated sand, whereby it has the same slump flow (170 mm) on a shaking table. Water demand of sand (%) was calculated as the difference of the water-cement ratio of mortar and cement divided by two and multiplied by 100%.

The denominator represents the number of parts of sand per one part of cement, because water demand of sand characterizes the water demand of aggregates mass unit. Water demand of sand shows the amount of water that is required to add during the introduction of the sand into the cement paste to maintain the mobility indicator.

Cement demand of fine aggregate was determined by the following method: a mixture was prepared with a constant ratio of C/W = 2.5 and the amount of fine aggregate was adjusted so that the slump flow determined on a shaking table was 170 mm (Zhernovsky *et al*., 2012).

Cement demand was calculated as the ratio of the volume of the cement paste in the mixture to the volume of sand in the mixture.

Quality factor of siliceous components as component in composite binders was determined by the method of defining activity of Fine-Grained Concrete (FGC), prepared on different sands and its comparison with the activity of control FGC prepared using sand of Volsky deposit. For testing FGC-50 was prepared with a surface area ≈500 m^2 kg^{-1}.

Mineral component quality factor was calculated as the ratio of activity of FGC-50 prepared using studied sand to the activity of FGC-50 prepared using sand of Volsky deposit, MPa (Lesovik and Zhernovsky, 2008).

THE MAIN PART

WMS wastes of this field have a specific structure and properties due to its genesis, production technology and processing of ores.

Visually, this is anthropogenic fine-dispersed sand with dark grey color and a bulk density of 1545 kg/m^3 and a fineness modulus of 0.75, the most representative is the fraction of 0.14 or less.

The mineral composition of wastes of wet magnetic separation is substantially different from traditionally used in the manufacturing of building materials natural quartz sand and consists mostly of olivine, dolomite, calcite and biotite (Table 1). At the same time, compared to WMS by-products from other deposits kovdorskiy deposit has low silica content and high magnesium oxide content.

Specificity of shape and surface morphology of WMS of by-products (Fig. 1) is associated with ultrabasic composition of raw rocks, structural and textural features. Fraction of mineral individuals with markedly manifested hipidiomorphism can be attributed to the olivine component as having the largest crystallization ability in the examined system.

Carbonate mineral individuals are characterized with xenomorphic morphostructures of limitation surfaces. On some surfaces of mineral individuals growth accessories of post-crystallizational stage of rock formation were marked.

Table 1: Mineral composition of WMS by-products

Factional composition	Weight ratio of mineral (mass %)			
	Olivine	Calcite	Dolomite	Biotite
WMS by-products	48.4	25.8	16.0	9.8
Fraction 0.63-0.14	31.9	44.2	13.5	10.4
Fraction <0.14	31.2	28.6	20.7	19.5

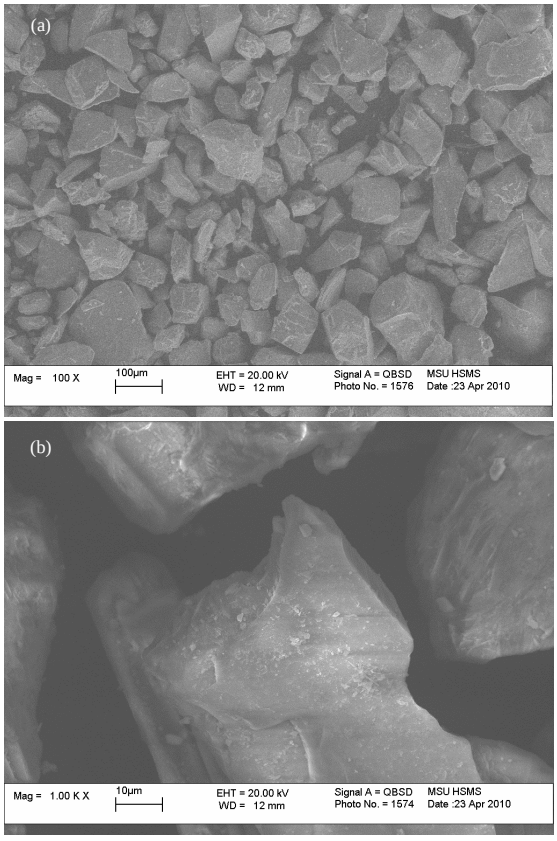

Fig. 1: General view of the WMS waste particles

A high water (14%) and cement demand (0.84) of wastes and low quality factor (0.52) of WMS by-products of Kovdorskiy deposit as concrete aggregate were determined that can be explained by their ultrabasic composition and character of the grain surface (Shi and Qian, 2000). High values of these integral characteristics of WMS by-products necessitate overrun of the most expensive part of the concrete mix binder for the production of equally strong material compared to traditional fillers. It is therefore necessary when using this raw material to use superplasticizers which will help to improve the rheological properties of concrete mixtures and as a result, to reduce binder expense per 1 m^3 of mixture. It should be noted that the benefication of wastes by sieving of silt fraction improves water (12.5%) and cement (0.72) demand and quality factor (0.66) as concrete aggregate.

Based on the fact that the production cost of CB (Composite Binders) is largely determined by costs on disintegration of binder components, studies of comparative characteristics of grindability of WMS wastes of Kovdorskiy deposit and sands of Nizhneolshanskii deposit were carried out.

Analysis of the results showed that the wastes of wet magnetic separation have the highest grindability: their surface area increases in 40 min up to 577.8 $m^2 kg^{-1}$ which is 25% higher than that of quartz.

This is due to the fact that the feedstock is a polymineral technogenic sand, consisting of mineral aggregates conglomerate which tensile strength of the contact zone between rock-forming minerals is significantly lower than the strength of the crystals. In addition, the hardness of the rock-forming minerals of WMS by-products is lower then hardness of quartz.

Thus, in response to better grindability of wastes of WMS compared to quartz sand their application as a component of the binder will result in reducing energy consumption. So, for dispersing natural quartz sand to the specific surface area of 450 $m^2 kg^{-1}$ electricity consumption amounted to 0.733 kW·h and for wastes of wet magnetic separation 0.550 kW·h.

Due to the necessity to assess the suitability of the studied rocks for the production of composite bindiers their quality factor (K_C) as a component of CB was determined and a comparison with other anthropogenic sand deposits (Table 2) was made. Based on the data of previous research on improving performance of cement- and water demand of WMS by-products after sieving of silty fraction K_C of fraction 0.63-0.14 was determined.

Analysis of the results indicates that the investigated wastes possess quality factor, comparable to natural quartz sand and increases after sieving of silty fraction, approaching the rate of Volsky depositsands.

Table 2: Indicators of the quality coefficient of rocks of different genesis as a component of composite binders

Name of FGC component	Quality coefficient
Sand stone crushing screenings, fraction 0.315-5	1.29
Sand of Stoderovsky mine	1.02
Wastes of WMS of Lebedinsky deposit	1.02
Sand of Volsky deposit	1
Wastes of WMS of Kovdorsky deposit, fractions 0.63-0.14	0.98
Sand stone crushing screenings	0.96
Sand of Nizne-Olshansky deposit	0.95
Wastes of WMS of Kovdorsky deposit	0.92
Screenings of Soldato-Alexandrovsky mine	0.77
Public company Arkhangelsk diamondiferous province	0.31

The major characteristic of the binder is the specific surface area associated with the particle size distribution which has an effect on water demand, the rate of strength development activityof binder and allows to extend the submission of materials.

Analysis of the results of the comparison of particle size distribution of the FGC-50 using wastes of WMS taken with and without sieving of silty fraction and sand of Volsky deposit showed that distribution curves are unimodal and have slight differences at the same specific surface of binder.

The greatest ammount of particles for all binders corresponds to the size 66.4-81.1 mkm. FGC-50 with application of WMS by products without sieving of silty fraction differs with greater ammount of fraction 0.2-7.34 mkm and CB with application of Volsky deposit sand 36.4-81.1 mkm.

Comparative analysis of the microstructure of cement stone with activated during the grinding component of CB revealed that in the contact zone of cement stone with the surface of WMS by products grains without sieving of silty fraction and even more with sieving we can observe decrease of adhesion in comparison with a grains of quartz sand of Volsky deposit which predetermines a decline in the quality of the studied rocks as part of the composite binder (Strokova, 2004).

Thus, the differences in the coefficients of quality of studied wastes and sand of Volsky deposit are determined not by its granulometry but by qualitative indicators of the mineral component and in particular, by ultrabasic composition of wastes of wet magnetic separation of Kovdorskiy field as well as the presence of dust particles on their surface.

On the basis of these studies we can conclude that the decrease of cement- and water demand as well as increase the quality factor as a component of composite binder with application of highly-magnesian raw material during sieving of silty fraction is achieved by reducing the content of biotite in the total mass (Table 1) that due to the nature of its crystal lattice has a very perfect cohesion and as a result, low adhesion to the cement stone.

Table 3: Terms of experiment planning

Factors		Levels of variation			
Natural form	Coded form	-1	0	1	Interval of variation
WMS by-products (%, mass of CB)	X_1	30	40	50	10
Melment (%, mass of cement)	X_2	0	0.4	0.8	0.4

Table 4: Activity of composite binders produced with using wastes of wet magnetic separation

			Activity of composite binders (MPa)	
Experiment number	X_1	X_2	WMS by products	WMS by products of fraction 0.63-0.14
1	-1	-1	43.69	48.71
2	1	-1	36.61	39.71
3	-1	1	48.99	54.99
4	1	1	42.13	45.77
6	0	1	44.13	49.99
7	0	-1	39.76	44.12
8	1	0	39.51	41.14
9	-1	0	45.17	50.49

The next stage was aimed to definition of rational composition of the composite binder and study its properties. For this purpose a complex of research on the development of formulation and technological parameters of CB on the basis of mathematical planning of the experiment was carried out. As the factors of variation superplasticizer and the amount of waste of wet magnetic separation were taken (Table 3). The output parameters were compressive strength and density. It should be noted that the selection of the optimum composition was performed using waste of WMS with and without sieving of silty fraction.

After statistical computer processing of the experimental data mathematical models of the strength and density changing of composite binders depending on the kind, quantity of the mineral component and a superplasticizer were obtained (Table 4). Wirh regression equations analysis of the influence of studied factors was made which showed that CB produced using WMS by products fractions 0.63-0.14 have greater activity in contrast to the CB using WMS by products without sieving of silty fraction. The highest activity in both cases was achieved at 30% content of mineral component by weight of the binder and ammount of superplasticizer of 0.8% by weight of cement (LWDB-70) (Low Water Demand Binder). It should be noted that the density of the samples produced on the obtained composite binder was in inverse proportion to their strength, due to the densifying of structure in the presence of dusty fraction.

CONCLUSION

Thus, the use of composite binders with application of wastes of wet magnetic separation of Kovdorskoe field for production of small sized wall materials will provide significant environmental, economic and social effects, that consists in usage of anthropogenic raw materials, reduction of binder and energy intensity by reducing power consumption when grinding.

During the research character of the influence of enrichment (sieving of silty fraction) on reduction of cement and water demand, as well as on the increase od the quality factor of wastes of wet magnetic separation as a component of composite binder was revealed that is explained by the decrease in concentration of biotite in the total mass. The negative influence of the layered aluminosilicates (especially biotite) on their low adhesion to the cement stone is due to the peculiarities of the crystal lattice structure and consequently to quite perfect cleavage of minerals as well as to the undeveloped surface morphology of the grains. It made possible to substantiate the necessity of complex fractional application of anthropogenic raw materials. In addition to reduction of the cost of milling due to better grindability of olivine, calcite and dolomite in comparison with quartz, it helps to reduce energy consumption of composite binders production.

Relations between the compressive strength and an average density of the composite binders and amount of wet magnetic separation by products, taken before and after enrichment and a plasticizing agent in its composition were obtained that allows to determine the optimum ratio of the components of the system and provide the desired product characteristics.

The regularities of changes in the activity and density of the composite binders depending on prescription mixture parameters were determined. Compositions of CB corresponding to the activity of cement class CEM I 42.5 N were obtained.

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