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Fine-grain concrete from mining waste for monolithic construction

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Fine-grain concrete from mining waste for monolithic construction

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Abstract. The technology of a monolithic construction is a well-established practice among most Russian real estate developers. The strong points of the technology are low cost of materials and lower demand for qualified workers. The monolithic construction uses various types of reinforced slabs and foamed concrete, since they are easy to use and highly durable; they also need practically no additional treatment.

1. Introduction
The primary advantage of a monolithic construction is very high speed of building. The rapidness is achieved due to the use of various products from concrete that, if necessary, can be made immediately on the construction site. Concrete constructions are made using only natural materials, which positively affects the final cost. Since the majority of concrete structures are made directly on the construction site, the economy is in elimination of transportation costs.

The most important and promising direction in the recycling of industrial by-products is their implementation in construction and production of building materials. The building industry today has vast positive experience in using the by-products of cementing products, dense and porous fillers for different concretes, in production of ceramic, autoclave, heat insulating and other building materials and products.

Currently, fine-grained concretes with industrial waste are increasingly popular in construction, in particular, siftings after the crushing of associated extracted ores, such as quartzitic sandstone, low-mineralized quarzites, granite gneiss, amphibolite, and shales [1–3]. The most valuable raw material for production of the filler is the siftings after quartzitic sandstone crushing. By present, they are widely used to produce various concretes, a large number of products and as a component of composite cementing agents.

However, metallurgical industries also produce huge amount of blastfurnace slag; there is also particular experience in using the waste of metallurgical enterprises. The total percentage of ferrous metallurgy slag is about 60%; the recycling of blastfurnace slag is slightly better, approximately 80%. However, the usage of industrial by-products is promoted slowly, which leads to the accumulation of such waste.

Annually, the waste piles grow by 30 mln tones of slag. Also, the steep drop of cement production industry should be accounted, which is the major consumer of metallurgical waste.

The slag can be used with high efficacy (30–50%) as a concrete filler instead of natural gravel. Specific capital investments into the production of molten-slag gravel is 2–3 times lower than that for gravel from natural rocks; for slag pumice the figure is 1.5–2 times lower than that for expanded clay; for mineral wool from flaming slag, it is 1.6 times lower that that for corresponding products from natural rocks [4, 5].

2. Materials and methods

To produce the materials, as the binder, composite cementing agents and Portland cement were used; as the fine-grained filler, the blastfurnace slag was used. The strength of concretes was tested on cubic specimens with the dimensions of 10x10x10 cm. The deviation of the dimensions along the edges did not exceed 1%. The specimens were produced in series with 3–6 pieces in a lot. The strength testing of the specimens complied with GOST 10180-2012 standard on the P-125 universal hydraulic press (Russia).

3. Results and Discussion

Currently in Russia, the results of former research works are weakly implemented regarding the usage of industrial waste in building and production of construction materials.

At the same time, only thermal power industry annually produces about 90 mln tones of ash and slag waste. Despite these, by-products have variable chemical and mineral composition, the ash and slag waste can be effectively used to produce a wide range of building materials, including Portland cement.

The crushing process yields up to 30% of siftings, which according to economic reasons are reasonable to be used as a fine filler [6].

Many properties of cementing agents, including activity and curing speed, are determined by not only a chemical and mineralogical composition of the clinker, the shape and the size of mineral crystals and presence of various impurities, but primarily by the milling fineness of the product, particle composition and powder particle shape. The present paper is aimed at the production of finely dispersed cementing agents: TMC-50 and VNV-50 with a specific surface area of 5000 cm^2/g produced from Portland cement CEM I 42.5H. One of the research work tasks is the study of the dispersity and granular composition of produced cementing agents, and initial Portland cement as well.

The physicomechanical properties of produced cementing agents and initial Portland cement are presented in Table 1.

Table 1. Physicomechanical properties of cementing agents

Cementing agent (CA) type	Paste normal consistency [%]	Curing time [min]		CA/C	CA activity [kg/cm^2] (MPa)	
		start	end		bend	compression
CEM I 42.5H	26.2	2-40	3-50	0.4	7.2	49.7
TMC-50	27.6	2-20	3-30	0.35	6.5	46.8
VNV-50	22.8	2-10	3-10	0.28	8.8	52.2

The study of the composite cementing agent properties has demonstrated that the activity of VNV-50 is comparable to that of the initial Portland cement; also, the normal consistency and CA/C ratio decreases from VNV-50 to cement, so it is reasonable to use for preparation of fine-grain concrete.

The usage of such cementing agents allows obtaining technological and economic effect almost in all field of application of cementing agents and practically in all aspects comprising the variety of concrete works. Also, it should be noted that the most energy consuming material in concrete is Portland cement; the energy-consumption of the cement in concrete is 70%. One of the main directions for solving the problem of reduced expenditures for the production of cementing agents is the production of multi-component cements, which production considerably reduces the consumption of fuel and clinker [7, 8]. Currently, there is a sufficient number of mineral resources represented by diverse industrial waste and mineral slugs to produce high-quality building materials with their effective usage and rational consumption of cement, gypsum and composite cementing agents.

The research of cement stone VNV-50 has shown its larger density as compared to typical Portland cement; it is represented by very densely packed grains in the whole mass of new buildups. This is predetermined by the presence of very fine films of water between the grains of the cementing agent and dominating formation of low-basic calcium hydrosilicates and other newgrowths in the constrained volume.

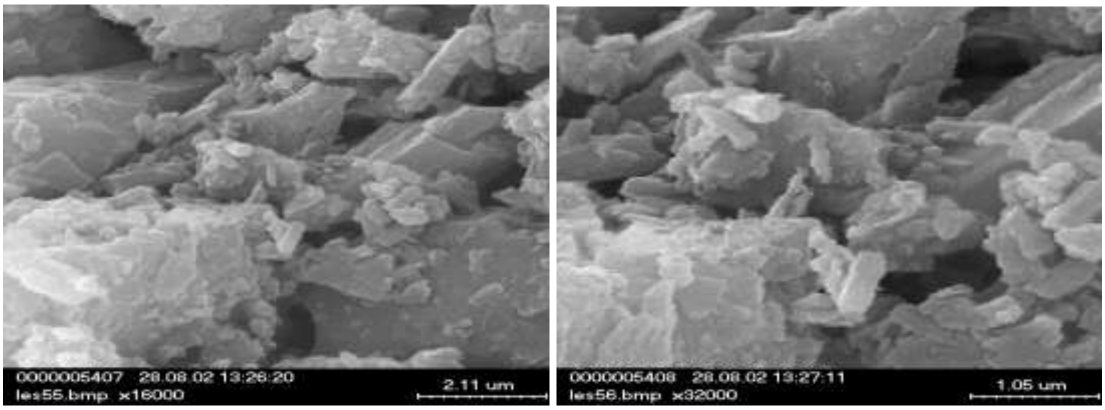

Figure 1. Morphology of newgrowths of cement stone CEM I 42.5H

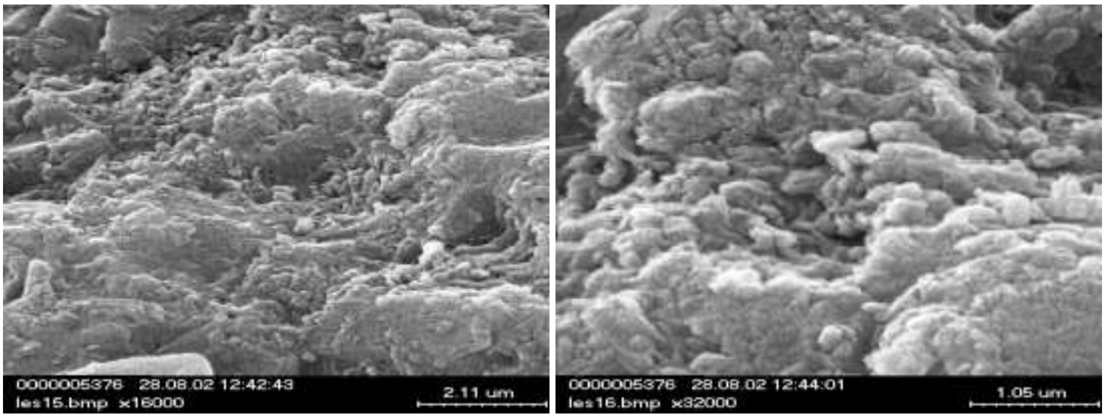

Figure 2. Morphology of newgrowths of cement stone VNV-50

To establish the usability of the slag as the filler for fine-grained concrete, the authors have analyzed the physicomechanical characteristics with already widely used materials.

Table 2. Physicomechanical characteristics of fillers

Filler type	Fraction [mm]						Fineness modulus	Bulk density [kg/m^3]
	2.5	1.25	0.63	0.315	0.14	<0.14		
Natural quartz sand	-	1.5	8	42.5	40.5	7.5	1.55	1540
Quartzite sandstone	40	19	15	8	6	12	3.43	1470

crushing siftings								
Blastfurnace slag	22	23	14	30	8	3	3.12	1710

The research and analysis of the received data have established that the siftings of the granulated blastfurnace slag is characterized by the lower fineness modulus and increased bulk density as compared to the quartzite sandstone crushing siftings. Also, more uniform slag fraction size distribution should be noted, which will facilitate more dense packing of the particles of the composite.

To study the filler effect on the fine-grain concrete properties, concrete specimens were produced, which strength was further studied.

Table 3. Results of fine-grain concrete strength testing

Filler type	Ratio of materials		CA/C	Remoulding effort grade	Compression strength at age of 28 days [MPa]
	VNV-50	Filler			
Natural quartz sand	1	3	0.45	P1 (OK=2 cm)	10.3
Quartzite sandstone siftings	1	3	0.4		34.3
Slag	1	3	0.36		31.1

4. Conclusions

The strength testing has demonstrated that the best results were obtained for the filler from quartzite sandstone crushing siftings; despite these results, the usage of concretes on the basis of slag is also reasonable, since they have shown insignificantly poorer strength. Moreover, their usage will allow appreciably widening the existing range of raw materials for industry of building materials.

The usage of metallurgical and fuel slags has no need in new natural deposits and also allows utilizing the waste in waste piles, which will improve the ecological situation.

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