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Article

Heat-resistant concretes based on cement binders and waste from the metallurgical industry

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Abstract. The main direction of the development of heat-resistant concrete production is the use of new materials, ensuring mechanization and industrialization of construction, increasing the performance characteristics of refractory compositions, reducing material consumption, introducing waste-free technologies in the production of concrete with increased physical and mechanical characteristics under prolonged exposure to high temperatures on cement binders and waste from the metallurgical industry and reducing environmental pollution. A significant environmental impact on the environment is exerted by large-tonnage technogenic waste produced by JSC «Aluminum of Kazakhstan» – bauxite sludge obtained by processing bauxite into alumina containing 42.7% Fe_2O_3. The prospects of its application as a filler in heat-resistant concretes are considered, which makes it possible to increase the physico-mechanical and thermal characteristics. The composition and properties of this waste and the change in the properties of heat-resistant concrete during the introduction of filler have been studied. Reactive alumina has been studied, which is 99.9% submicron alumina with a very low content of Na_2O oxide. It is shown that the properties of concrete change after the introduction of iron-containing waste in the amount of 5% and reactive alumina – 37.5% and 38.8%. Their volumetric weight, control strength, and other properties are increased. The improvement of physical, mechanical, and thermal characteristics depends on the structure and neoplasms in the obtained samples. Samples of heat-resistant concrete were analyzed using electron probe X-ray spectral qualitative and quantitative microanalysis and X-ray fluorescence spectrometry and it was shown that the iron-alumina waste contributes to the compaction of the structure due to its resistance to delamination and has increased fluidity at low humidity in the cementing mass. For further investigation of the physical-thermal characteristics, depending on the structure and neoplasms in the obtained samples, a petrographic method using a polarization microscope in transmitted and reflected light is required.

Keywords: waste, heat-resistant concrete, metallurgical industry, bauxite sludge, reactive alumina, perlite.

1. Introduction

One of the most acute environmental problems currently is the pollution of the environment by the production and consumption of waste and, first of all, hazardous waste. One of the solutions to the urgent problem related to the environmental situation is the effective disposal of large-scale industrial waste. As practice shows, the formation of high-tonnage waste occurs in industrial areas, and the nomenclature of substandard raw materials has a wide range. However, the widespread use of waste is difficult due to high transport and other costs, so it is advisable to use them in the regions where they are concentrated. To solve this problem, first of all, waste-generating enterprises must change their approaches to the status of these entities, that is, treat waste as promising and inexpensive raw materials and apply various innovative technologies involving the use of man-made resources. For example, slags, enrichment sludge, etc. are formed at ferrous and non-ferrous metallurgy enterprises, and various thermal installations are used to produce metals that require continuous repair and maintenance of furnaces with special heat-resistant, refractory, and thermal insulation materials made of concrete or others. The proximity of most industrial waste in chemical composition to classical binders opens up a wide range of opportunities for scientists in this field to develop and design new effective heat-resistant concrete compositions with the required physical and thermal properties [1].

According to [2], the authors have established a connection between the phase processes of formation during heating and the thermomechanical properties of heat-resistant concrete from metallurgical slags. Methods of X-ray phase analysis (XFA) and differential thermal analysis (DTA) were used to study the physico-chemical changes occurring in samples of slag products. Based on these methods, methods for predicting high thermomechanical properties of heat-resistant concrete based on metallurgical slags are proposed. To produce heat-resistant concrete, ash-containing wastes were widely used, which are formed in large quantities as a result of the operation of thermal power plants (CHP). Today, many foreign countries have experience in developing effective ecological and economic systems of waste-free technology. For Kazakhstan, this experience can be useful in terms of using innovative solutions in the field of processing and disposal of sludge and ash and slag waste in domestic practice. Thus, ash and slag are a complex system, the properties of which depend on the type of fuel and its combustion mode, boiler design, and many other factors. This determines the relevance of researching the possibilities of using solid man-made waste from the Pavlodar region in the production of building materials. The continuous growth of metallurgical production leads to an increase in man-made environmental impacts in the form of accumulated production waste. This makes the problem of waste disposal by recycling them with additional recovery of the contained useful components urgent. In the Pavlodar region, one of the types of such waste is sludge from alumina production. In the production of aluminum, bauxite is used as the main raw material, as a result of which large quantities of waste are formed in the form of aqueous suspensions of dispersed particles – sludge. About four tons of sludge are produced per ton of alumina. A characteristic feature of bauxite slurries is the high content of iron and aluminum oxides. Nepheline, bauxite, sulfate, white, and monocalcium slurries are of industrial importance for the production of building materials. The aluminum plant uses bauxite, respectively, the waste is red bauxite sludge.

One of the main ways to recycle red sludge in the field of construction production is to use it as an iron-alumina component of the raw material mixture in the manufacture of Portland cement clinker. According to research [1], raw mixtures containing red sludge are characterized by high reactivity during firing, especially in the temperature range corresponding to the passage of reactions in the solid phase. The iron oxide and alkalis contained in the sludge lower the temperature of the appearance of the liquid phase by 343-323 ° C, which favorably affects the absorption of calcium oxide during clinker firing. Raw sludge containing red sludge is not prone to delamination and has increased fluidity at low humidity. Also, the possibility of using bauxite sludge as an additive in the grinding of cement clinker has been obtained. Thus, the addition of 5% sludge significantly increases the grinding capacity and grade strength of cement. In Japan, concrete has been developed in which red sludge is used as a substitute for some cement, sand, and pigment. Studies have shown that dry red sludge is a good substitute for sand as a fine aggregate in concrete. At the same time, the resistance to variable freezing and thawing is higher than that of conventional concretes. In Germany, studies have been conducted on the possibility of manufacturing brick products from a mixture of waste such as red bauxite sludge, bleaching clay used in the purification of edible oils, as well as household garbage. Pressed bricks are fired for 40 hours at a temperature of 1060 ° C. During their sintering, the alkalis of the red sludge react with $C0_2$ from household waste and are neutralized as a result of the formation of clay materials [1].

German specialists have developed methods for manufacturing building materials based on red sludge and silica materials. In the first method, the red sludge is mixed with sand activated in a vibrating mill, burnt lime, and a 50% solution of sodium alkali. The resulting mixture is fired for 30 minutes at a temperature of 350 ° C. The compressive strength of the resulting material is 36-45 MPa. According to the second method, the red sludge is mixed with activated silicon dioxide and alkaline earth metal compounds, then the products are molded and fired. According to research [3], sufficient plasticity of red sludge is noted in the works.

Based on the generalization of the voluminous literary and scientific material, it can be concluded that the red sludge of individual plants was studied as an additive that increases the mechanical strength of concrete. However, comprehensive studies of bauxite sludge in carbonate concrete have not been conducted. At the same time, the landfill sludge of the Pavlodar aluminum plant is specific in composition and properties, cheap raw materials in Kazakhstan, which have not been studied in this direction. Its high content of iron oxides and a limited amount of calcium oxides do not allow it to be considered as a base for a binder. This bauxite (red) sludge can be used as a modifying component of the latter, taking into account the complex nature of its effect on the properties of concretes. Also, the use of sludge contributes to a significant reduction in the cost of concrete by 2-3 times and additionally allows you to solve the environmental problem of freeing land plots of JSC «Aluminum of Kazakhstan» from production waste. The analysis of literature sources on the subject of the study revealed the main directions of application of industrial waste, in particular, fuel ashes and slags, as well as dump bauxite sludge in the production of construction products. Mainly as binders, as an active additive (modifier) in the production of Portland cement, and as large and small aggregates for both heat-resistant, heavy, and light concrete, for the construction of upper and lower layers of road foundations.

Heat-resistant concretes are characterized by the ability to maintain physical and mechanical properties within certain limits under prolonged exposure to high temperatures. The main field of application of heat–resistant concrete is the lining of thermal units and structures, where heat-resistant properties allow for safety and proper operating conditions, as well as heat-resistant concrete, which is used as a thermal insulator. For the manufacture of heat-resistant concretes, Portland cement grades M400-M500 and FHC (fast-hardening cement), slag Portland cement according to [4], and liquid glass according to [5] alumina cement is used as binders. These types of cement have good water retention properties due to the acceptable granulometry of the grain composition and fineness of grinding. It should be noted that heat-resistant concretes based on alumina cement are more widely used, since they have high values: a) fire resistance (up to 1700 °C); b) compressive and bending strength even at temperatures of 1150-1200 °C; c) abrasion resistance; d) heat resistance, as well as low wettability with molten metals [6].

Setting the task. Taking into account the pollution of large areas with man-made raw materials and a significant decrease in natural raw materials, new methods and methods should be found to replace them with industrial waste of a man-made nature for the production of heat-resistant concrete.

Purpose: taking into account the increasing requirements for heat-resistant materials of the construction direction, to create concrete with increased physical and mechanical characteristics (indicators) based on a binder – alumina cement, filler – perlite, an iron-containing component – bauxite sludge (waste from the metallurgical industry), an additive - technical (reactive) alumina.

2. Methods

2.1 Raw materials

According to the set goal, the following raw materials were used to create heat–resistant concrete: alumina cement grade 400 as a binder, contains perlite as a filler, technical (reactive) alumina as an additive, and bauxite sludge (red) and water as an iron-containing component.

The chemical oxide composition of raw materials and the element-by-element chemical composition of bauxite sludge was performed using an EDX9000B X-ray fluorescence spectrometer and is presented in Table 1.

Table 1 – Oxide chemical composition of raw materials, %

	SiO_2	Al_2O_3	Fe_2O_3	CaO	SO_3	MgO	TiO_2	Na_2O	K_2O	Cl
Alumina cement	7.11	40.2	8.22	37.2	-	-	-	-	-	-
Bauxite sludge	17.09	4.07	42.7	40.1	0.61	0.59	1.15	0.03	0.13	0.0037
Perlite	125.3	13.9	0.62	5.13	0.02	0.51	0.24	0.02	1.71	0.0038
Reactive alumina	0.08	99.2	0.05	0.10	-	-	-	0.37	-	-

Alumina cement M400, manufactured by «Kislotoupor Kazakhstan» LLP, was used as a binder, designed to work in an aggressive hydrogen environment, while the content of iron oxide should not exceed 0.05% and silica oxide 0.1% according to [7]. The true density of alumina cement is 3200 kg/m^3, the bulk density is 1100 kg/m^3. The normal density is 24-28% [7]. The raw materials for the production of alumina cement clinker are pure limestones ($CaCO_3$) and rocks containing alumina, for example, bauxite ($Al_2O_3 \cdot nH_2O$). Alumina cement contains mainly two minerals: calcium mono aluminate (CA) and helenite (C_2AS) and related minerals: dicalcium silicate (C_2S), calcium aluminum ferrites (C_6A_2F), and some other minerals [8].

Perlite, manufactured by «Argo» LLC, was used as a filler, with a volume weight of 150-200 kg/m^3, fractions of 5-15 mm according to [9].

Water – according to [10].

Waste from the metallurgical industry of JSC «Aluminum of Kazakhstan» – bauxite sludge was used as an iron-containing filler for the production of heat-resistant concretes. It is a by-product of the processing of bauxite into alumina. The studied sludge is obtained after complete scattering with slow cooling, while its color turns red, and is a wet loose sand-like material having a size of 0-5 mm. The size modulus is 1.6-2.2, the density of the sludge is in the range of 2.86-2.98 g/cm^3, and the bulk mass in the dry state is 1000-1200 kg/cm^3 [11].

The element-by-element chemical composition of bauxite sludge is presented in Table 2.

Table 2 – Element-by-element chemical composition of bauxite sludge, %

Na	Mg	Al	Si	P	K	Ca	Ti	Mn	Fe	Sr
0.40	0.85	8.48	24.62	8.85	0.49	32.73	1.83	0.15	21.57	0.01

The oxide and element–by-element chemical compositions of the studied sludge showed a high content of oxide Fe_2O_3 and elemental iron Fe – 42.7%, respectively (see Table. 1) and 21.57%.

Mineralogical composition of bauxite sludge: sodalite ($3Na_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot Na_2SO_4$) 4-40 %; aluminogetite (iron oxide with an admixture of aluminum) 10-30 %; hematite (iron oxide) 10-30 %; silica (silicon dioxide), crystalline and amorphous 5-20%; tricalcium aluminate ($3CaO \cdot Al_2O_3 \cdot 6H_2O$) 2-20 %; boehmite ($AlO(OH)$) 0-20%; titanium dioxide 2-15%; muscovite ($K_2O \cdot 3Al_2O_3 \cdot 6SiO_2 \cdot 2H_2O$) 0-15 %; calcium carbonate 2-10%; gibbsite ($Al(OH)_3$) 0-5%; kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) 0-5% [12].

Reactive alumina [13], produced by LLC «Shiber» is a synthetic product of corundum composition with a low content of impurities. LISAL 07RA reactive alumina is made from high-purity technical alumina and is a ready-to-use fine powder.

Thanks to the special technology for the production of reactive alumina LISAL 07RA, it is possible to obtain heat-resistant concrete with the necessary parameters of particle size, Na_2O content, specific surface area, and modality (mono, two, and multimodal) powders.

The technological process of heat-resistant concrete production includes preparation of the molding mass, molding of products, and heat treatment. It should be noted that heat-resistant concretes require special heat treatment for their solidification and a set of vintage strength. The heat treatment takes place up to 1200 °C. An increase in temperature to 200 °C takes place at a speed of 60 °C/h, and up to 1200 °C – already at a speed of 150 °C/h. Then it is kept for 2 hours and cooled together with the oven. Compositions for the production and physical and mechanical properties of heat-resistant concretes are presented in Tables 3 and 4.

Table 3 – Components of heat-resistant concrete, mass. %

Composition No.	Alumina cement	Perlite	Bauxite sludge	Reactive alumina	Water
1	16.25	37.50	5.0	37.50	other
2	20.00	38.20	5.0	38.80	other

Table 4 – Physical and mechanical properties of heat-resistant concrete

Volume weight, kg/m^3	Control strength of Rc, MPa	Thermal conductivity, λ_{600}, W/(m·°C)	Thermal stability in the water heat exchange of the theater Tw, the number of cycles	Note
		Composition 1		
850	35.6	2.4	20	Racks in a gaseous environment of carbon monoxide and hydrogen
		Composition 2		
950	36.6	2.4	20	Racks in a gaseous environment of carbon monoxide and hydrogen

As can be seen from Table 3, due to the use of bauxite sludge and reactive alumina as an iron-containing component and additive, contributes to the production of heat-resistant concretes with high physical and mechanical properties.

2.2 The principle of X-ray fluorescence spectrometry

X-ray fluorescence spectroscopy is a modern instrumental method of analysis. Incident X-rays (primary X-rays) are generated through an X-ray tube to excite the measured sample; each element in the excited sample emits characteristic X-ray radiation (secondary X-ray radiation). X-rays - this characteristic of X-ray radiation has certain characteristics of energy and wavelength (Mosley's law). The energy and number of secondary X-rays emitted are measured by the detection system, and these radiation signals are converted into the specific content of the various constituent elements in the sample.

Equipment: one X-ray fluorescence spectrometer EDX9000B; electronic scales (accuracy 0.01 g); one mechanical tablet press (pressure not less than 40T); one jet drying oven; one ball mill; non-metallic sample sieve (200 mesh).

Reagents: boric acid powder; national building reference material; sample of raw materials [14].

Air drying or drying of samples is carried out following the [14]. After grinding, the samples are passed through a 200-mesh sieve and dried at 105 °C for use.

Electronic scales are used to weigh 3.00 g of sifted (200 mesh) bauxite standard substance or sample and 14.00 g of boric acid powder (edge material), weighing error ± 0.05 g. Then it is placed in a tablet press to form a tablet, the pressure is 30T (pressure range 20-30T), and the pressure holding time takes 30 seconds.

Construction of the working curve and analysis of the sample

Appropriate measurement conditions are established using the EDX9000B to scan national standard materials (called standard samples) and establish a linear working curve of the content and intensity of the corresponding elements in standard samples of the material under study.

Measurement of the limits of detection of chemical elements and oxides in a sample of the test material

The EDX9000B is equipped with three sets of filters to create the best test conditions according to the characteristics of the studied sample elements. The national standard sample of the material (cement and refractory material) is used to calibrate the device and build the working curve of the material. According to the working curve of the sample, high-purity SiO_2 is used as a blank substrate and continuously tested 5 times according to the detection limit formula: 3 times the standard deviation of the blank substrate divided by the sensitivity of the device [15].

2.3 The method of electron probe X-ray spectral qualitative and quantitative microanalysis of the composition of samples

The Hitachi TM 4000 Plus desktop scanning electron microscope is characterized by its compact size and wide capabilities. The device normally has a low vacuum mode, which allows you to do without sample preparation and examine non-conductive samples without pre-spraying metal. An ordinary laboratory table is sufficient to use a microscope. The microscope is controlled through a simple and intuitive interface, in which the functions of automatic adjustment of focus, contrast, and brightness are available. The device is ready for operation within 3 minutes after switching on, and the sample change time does not exceed 2 minutes. The microscope is equipped with two detectors – secondary and reflected electrons, so it can provide comprehensive information on the surface of the objects under study. The new TM4000Plus optimizes the operation of the detector, thereby significantly improving the image quality when working at low accelerating voltages.

The study was carried out under native conditions in a low vacuum mode without spraying a conductive layer at an accelerating voltage of 15 kV and on a working interval from 7.5 to 10.5 mm. The samples were mounted on a table with a diameter of 80 mm using conductive double-sided tape. The only requirement for the samples is that they must be «dry». The maximum size is 80 mm while moving around the field of the object is available within 35x35 mm.

The built-in energy dispersion spectrometer allows for obtaining elemental composition data ranging from light elements (B – boron, atomic number 5) to heavy actinoids (Cf – californium, atomic number 98).

Among the advantages of the equipment used, can be noted: the possibility of large magnification with scaling and measuring the size of the details of interest in the image; the choice of a place on the sample and the area of the analyzed area for elemental analysis and control; the expressiveness of obtaining information; non-destructive research method; large size of the sample under study; the equipment compact dimensions and the absence of special requirements for the room [16].

3. Results and Discussion

The conducted studies have shown that bauxites are a rock consisting mainly of aluminum hydroxide, iron oxide, and oxide of mineral components (Table 1). The main components of bauxite are gibbsite (hydrargillite), boehmite, and diaspore. In addition, bauxites contain iron minerals (hematite, hydrohematite, siderite); and silica in the form of quartz, hydroxide (opal, etc.). In smaller quantities, bauxite contains calcium and magnesium carbonates, as well as impurities of organic substances. The quality of bauxite is characterized by two factors: the content of $A1_20_3$ and the flint module (weight ratio $Al_20_3/Si0_2$). The content of impurities is also essential for the characterization of bauxites, which complicates the processing of raw materials (in particular, carbonates, sulfates, iron oxides, chlorides, and organics), as well as the mineralogical features of bauxites, and the content of the clay component.

The oxide and element–by-element chemical compositions of the studied sludge showed a high content of oxide Fe_2O_3 and elemental iron Fe – 42.7%, respectively (Table. 1) and 21.57%.

Energy dispersion spectral analysis showed that the bauxite particle contains a large amount of aluminum Al and oxide O, which allows it to be attributed to a rock consisting mainly of aluminum hydroxide, iron oxide, and oxide of mineral components.

Figure 1 below shows the spectra of a bauxite sludge sample and the results of its semi-quantitative analysis.

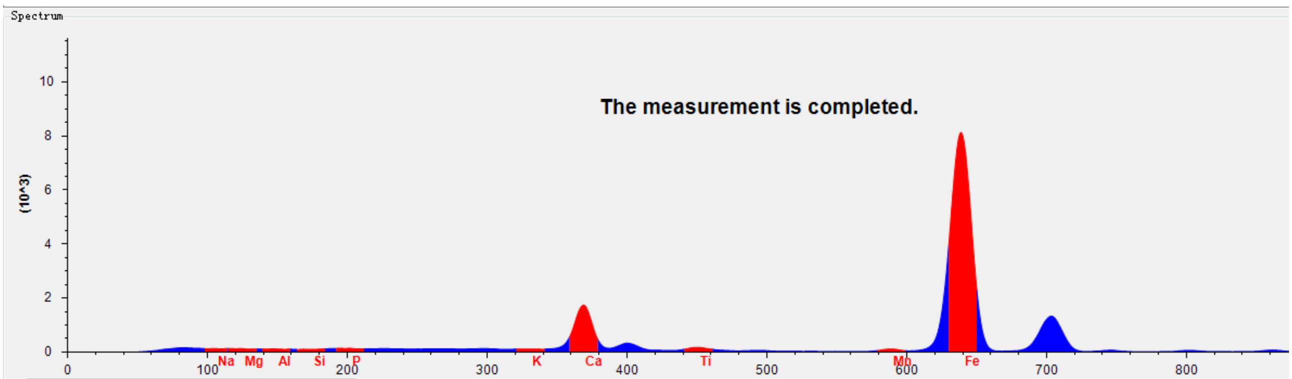


Figure 1 – Spectra of bauxite sludge in comparison with refractory material

As shown in Figure 1, matrix effects have a significant effect on the linearity of the calibration curve. The EDX spectrometer software easily eliminates all matrix effects occurring in an iron-based matrix and contains four of the most widely recognized algorithms for automatic matrix correction. In addition, each element can have several calibration curves, and depending on the concentration range (low or high), a specific curve is accessed. The specific curves in the sludge are determined by the high content of calcium, iron, and silicon. The improvement of the physical-thermal characteristics largely depends on the element-by-element chemical composition and structure in the obtained samples.

A preliminary analysis of the chemical composition of the sludge allows us to assume the expediency of their processing with the extraction of iron oxides contained in them. As scientific studies have shown [1], [11], [17], the use of bauxite sludge is possible as additives in agglomeration, pelletizing, blast furnace smelting of iron ores, raw materials for iron production, a slag-forming agent for refining cast iron and steel, a partial clay substitute in the manufacture of molds, additives in the production of cement and ceramics, filler in production of heat-resistant concrete, building bricks and refractories.

In [17], the structure of the sample is amorphous fine-grained, and unevenly porous. Small white inclusions in the amorphous silicate mass are clearly distinguished. Inclusions along the contour are fused and consist of mineral growths. The grain size ranges from 0.01 to 0.5 mm, 0.1 mm is predominant. The pores are irregularly shaped, more often fractured, isolated, and not evenly distributed in an amorphous granular mass. The pore size ranges from 0.1 to 1.0 mm, with 0.5 mm predominate.

An effective tool is the function of mapping the elemental composition by the field of view of the microscope (Figure 2).

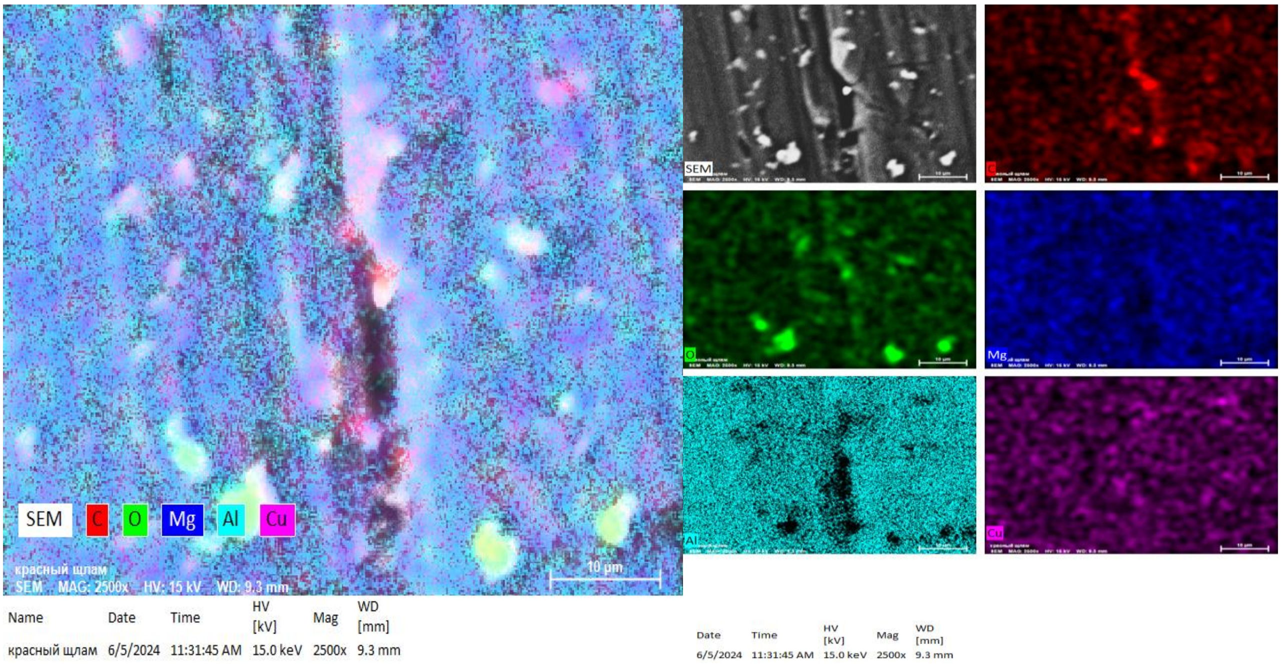
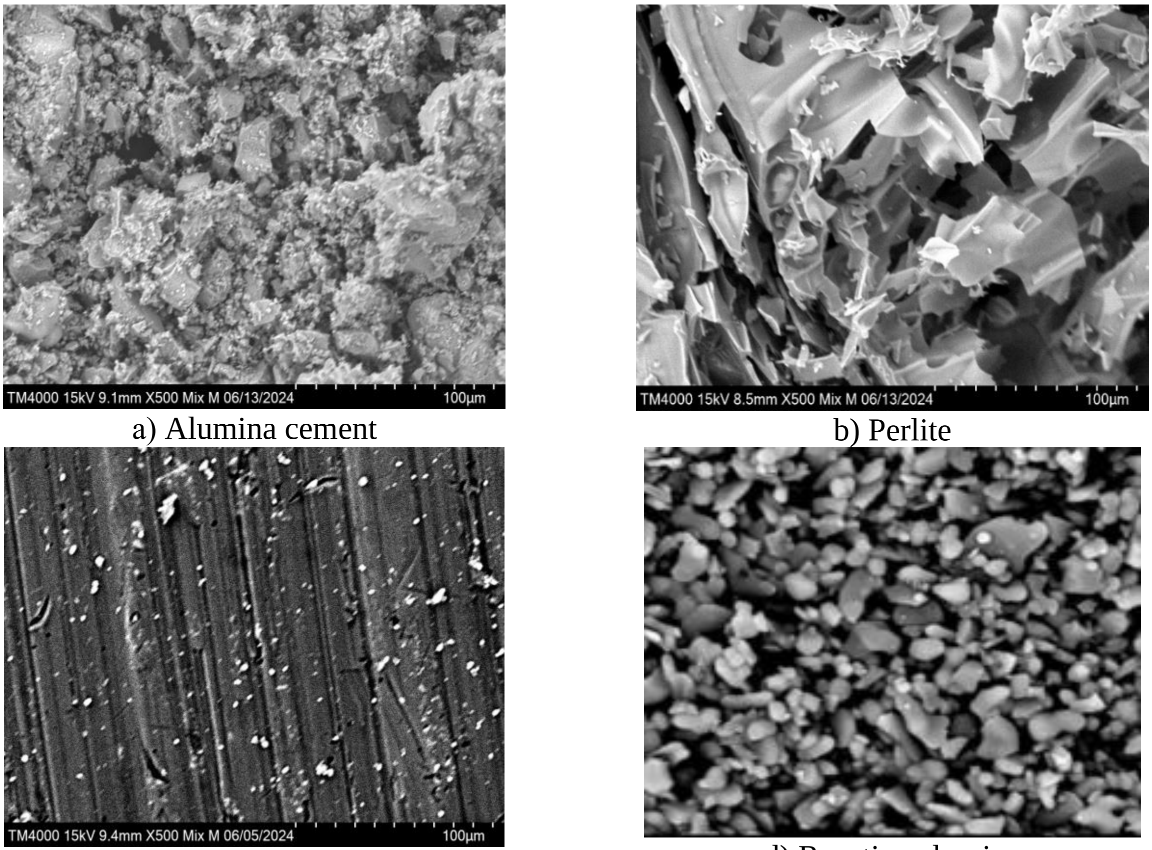


Figure 2 – Mapping the surface of the bauxite (red) sludge

The color graphical distribution of elements by area, depending on the atomic number, presents the results of the research in the most visual form, the black-and-white image of the topography provides information about the morphology of the sample surface. This largely objectifies the selection of analyzed sites with introduced elements and controls.

The micrograph shown in Figure 3 contains detailed information about the microstructure of materials, as well as the behavior of the material under various conditions, phases detected in the system, failure analysis, grain size estimation, and elemental analysis.



a) Alumina cement
b) Perlite
c) Bauxite sludge
d) Reactive alumina

Figure 3 – Electronic micrography of materials

Detailed analysis with large magnifications made it possible to detect, measure and analyze individual particles.

The microstructure of materials, as shown in Figure 2: a) Fine-grained unevenly porous. The particle size ranges from 0.1 to 9.1 mm, the more predominant size is 1 mm; b) Thin-porous with pore formations in the form of curved cracks. The size of the cracks ranges from 0.5 to 8.5 mm; c) Thinly porous in the form of slit-like straight lines. The size of the gap ranges from 0.05 to 9.4 mm; d) Fine-grained porous with formations in the form of uneven small pores. Non-finely ground alumina powders of the R and C series with a low content of Na_2O oxide are available. The particle size of D50 is from 70 to 90 microns, the crystal size of D50 is from 0.5 to 3 microns, and the content of Na_2O oxide is 0.06-0.07%. The structures were tightly connected and compacted by filling the pore space with an alumina mass, which acts as a reinforcing material. Sealing the structure and strengthening the amorphous component with newly formed crystals increases strength, wear resistance, fire resistance, chemical resistance, the ability to strengthen the contact zone with the main fillers, and also reduces water absorption.

4. Conclusions

1) The content of belite in bauxite sludge reaches 45-55 % by weight. The ticket in the sludge is partially hydrated. Iron oxides are represented by magnetite and hematite. A small amount of sodium sulfoaluminate and calcium carbonate of secondary origin. The main components of the sludge are calcium, silica, aluminum, and iron oxides. The sludge has a high content of elements and oxides, in the amount of CaO – 41.181; Fe_2O_3 – 44.201; Ca – 62.172. Elements P, S, Fe, Cl, Ca, Mn, Ni, Cr, Fe, Co, Na, Mg, Al, Si, K, Ti and Sr, as well as oxides Na_2O, MgO, Al_2O_3, SiO_2, SO_3, K_2O, CaO, TiO_2, Fe_2O_3, Na_2O, P_2O_5, Cr_2O_3 and MnO comply with the national standard. Also, the

following elements and oxides were found in samples of bauxite sludge in comparison with refractory material (Refractory material): Ca – 32.726; Iron – 21.572 and Si – 24.621;

2) The effect of iron-containing bauxite sludge and the addition of reactive alumina on the physical and mechanical properties of heat-resistant concrete based on alumina cement has been studied. The resulting heat-resistant concretes had high mechanical strength and heat resistance.

3) The control strength of heat-resistant concrete can be increased to 40.0 MPa and higher if man-made waste production is introduced into alumina cement (see Table 4).

4) The use of alumina cement as a binder in heat-resistant concretes makes it possible to create concrete with increased physical and mechanical characteristics (fire resistance up to 1700 °C, abrasion resistance, heat resistance, as well as low wettability of molten metals).

5) The use of a synthetic product of corundum composition with a low content of impurities – reactive alumina in heat-resistant concretes allows: a) due to the high reactivity, reduce the sintering temperature and synthesis of phases during firing; b) reduce the amount of water for sealing refractory concretes without deteriorating their rheological characteristics; c) in the manufacture of refractory low- and ultra-low-cement concretes, denser packing of particles and the structure of the material can be obtained; d) improve the physical and operational characteristics of heat-resistant concrete; e) to increase the «cold» and high-temperature strength of products and their abrasive resistance; f) to obtain heat-resistant concrete with the necessary parameters of particle size, Na_2O content, specific surface area, and modality (mono, two, and multimodal) powders.

6) The use of man-made raw materials (waste from the metallurgical industry) in heat-resistant concretes allows: a) disposal of industrial waste; b) protect ecological systems and the natural environment and additionally solves the environmental problem of freeing land plots of JSC Aluminum of Kazakhstan from production waste; c) solve the issue of raw materials through the use of man-made raw materials; d) significantly reduce the cost of concrete by 2-3 times.

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