UDC 666.94

RADIATION-RESISTANT CEMENT BASED ON BARIUM ALUMINATES AND CHROMITES

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Currently, nuclear energy is one of the main types of energy production in both Ukraine and European countries. Improving the safety of operating power plants requires not only improving the designs of nuclear installations, but also creating new effective materials that provide reliable protection against various types of ionizing radiation, as well as creating reliable containers for collecting, storing, and disposing of radioactive waste, which makes such research relevant and important. The aim of the research is to develop and produce cements based on compositions of aluminates and chromites of alkaline earth elements, which include hydraulically active phases with high strength characteristics and a high mass absorption coefficient of ionizing radiation for the creation of protective concretes.

As a result of previously conducted theoretical calculations and experimental studies, areas optimal for obtaining protective heat-resistant aluminochromite cements were identified in the three-component aluminochromite $BaO – Al_2O_3 – Cr_2O_3$ system. The choice of these areas was determined by the presence in their composition of hydraulically active aluminates and heat-resistant, corrosion- and radiation-resistant barium chromites. According to the results of thermodynamic, geometric-topological, eutectic and X-ray phase analyses in the $BaO – Al_2O_3 – Cr_2O_3$ system, the $BaAl_2O_4 – BaCr_2O_4 – Ba_3Cr_2O_6$ and $BaAl_2O_4 – Ba_3Cr_2O_6 – Ba_3Al_2O_6$ cross-sections are rational for the synthesis of protective binders.

Raw material mixtures were prepared from the following starting technical materials: technical barium carbonate (CAS 513-77-9), metallurgical alumina (CAS

1344-28-1), chromite concentrate (TU U 26.2-00190503-348:11). Raw material mixtures were fired at temperatures of 1350 – 1400 °C with isothermal holding at the maximum temperature for 3 hours under a layer of kryptol to prevent the transition of Cr^{+3} to Cr^{+6}.

To optimize cement compositions, the simplex lattice experiment planning method with lattices for an incomplete third-order polynomial was used. Based on experimental data, regression equations were derived for the dependence of the compressive strength at the age of 28 days of hardening, the melting point, and the mass absorption coefficient of γ-radiation on the phase composition. From the obtained results, it was established that the calculated regression equations are adequate, since the calculated data on mechanical strength, melting point, and mass absorption coefficient of γ-radiation are in satisfactory agreement with the experimental ones.

Since the data on mechanical strength, melting points, and mass absorption coefficient of γ-radiation for the $BaAl_2O_4$ – $BaCr_2O_4$ – $Ba_3Cr_2O_6$ and $BaAl_2O_4$ – $Ba_3Cr_2O_6$ – $Ba_3Al_2O_6$ cross-sections practically coincide, the most interesting is the binary cross-section $BaAl_2O_4$ – $Ba_3Cr_2O_6$ common to them, in which it is possible to vary the content of the main phases in a wide concentration range and not to achieve strict dosage of the initial components.

It was established that the obtained cements are high-strength (compressive strength at the age of 28 days – 28 – 79 MPa, bending strength – 5.0 – 6.5 MPa; fast-hardening – the beginning of hardening from 10 min. to 2 h. 05 min., the end – from 30 min. to 3 h. 10 min.; compressive strength at the age of 3 days of hardening – 22 – 51 MPa) air-hardening binders with a water-cement ratio of 0.18 – 0.23, fire resistance 1580 – 1800 °C, mass absorption coefficient of γ-radiation 220 – 280 cm^2/g.

From the point of view of increased radiation resistance, strength and fire resistance, the optimal composition is one that contains the maximum amount of barium oxide and has the following phase composition: 60 wt. % $Ba_3Al_2O_6$ and 40 wt. % $Ba_3Cr_2O_6$. This binder is characterized by a strength of 46 MPa after 28 days of hardening, a fire resistance of 1580 °C, and a mass absorption coefficient of γ-radiation of 277 cm^2/g. However, rapid setting times (start – 10 min., end – 30 min.) require the use of setting retarders.

The results obtained indicate that the developed cement based on barium aluminates and chromites can be recommended for the production of refractory concretes, shotcrete masses, and mortars for use in high-temperature units of various industries, as well as for the production of concrete protective screens, shells, structural elements of biological protection of nuclear power systems, and containers for the burial of radioactive waste of various levels of activity.