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Article

Study of The Properties of Chemically Resistant Hydrophobic Polymer Composite Materials Based on Sulfur

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Abstract: Today, the processing of industrial waste and the use of resource-saving processing methods in production remain one of the main challenges. This article examines the analysis of components based on secondary raw materials in sulfur-based organomineral polymer materials, methods of their mechanical activation, and the influence of activation on the properties of the material. Additionally, when activating filler materials, the bonds formed during the simultaneous activation of two or more fillers are analyzed. The properties of the material obtained from the new composition were compared with the properties of M450 grade cement concrete, and the optimal amount of the new composition was proposed. It has been determined that the quantity and shape of gravel, which serves as an inert filler in a sulfur-based composite material, are the main factors determining the mechanical properties of the material.

Keywords: mechanical activation, sulfur, concrete, composite, filler, reinforcing, glass fiber

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1. Introduction

Sulfur concrete is a modern composite material that contains inert aggregates and fillers performing constructive reinforcement functions. Composites based on sulfur, including sulfur concrete, are considered thermoplastic materials. Taking into account such properties and reactive characteristics of sulfur, it is possible to obtain structures with high strength, materials with thermal insulation properties, and materials resistant to highly aggressive environments from this material [1]. This is achieved through the study of physicochemical processes between the filler and the binder during the formation of the structure in the polymerization process [2].

Today, several types of concrete modifications have been developed, including polymer-concrete, cement-concrete, reinforced concrete, lead-concrete, and sulfur-concrete. Among the aforementioned types, sulfur-concrete stands out from other types of concrete due to its operational, mechanical, and physical properties in aggressive environments [3].

A review of literature sources indicates that materials with improved mechanical properties based on gas processing waste (sulfur) are widely used in various fields. The increasing demand for such materials remains promising, especially in areas related to their performance, resistance to various aggressive environments, as well as water impermeability. The use of sulfur-containing organomineral polymer composite materials, which can be obtained from the sulfur released in large quantities during gas purification at gas processing and gas-chemical plants, can solve several important problems [4]:

a. Providing the country's construction market with products with high strength;
b. Increasing operational reliability and reducing the cost of materials that ensure the design of the product;

c. Reduction of the cost of structures by increasing their resistance to mechanical loads and aggressive chemical environments;
d. Reduction of harmful effects on the environment through the utilization of technical sulfur [5].

Production of structures from organomineral composite polymer materials leads to a 40% reduction in CO_2 emissions compared to the production of structures from traditional ceramic composite materials [6]. This allows for the conversion of mineral limestone into cement, which releases a large amount of carbon dioxide, for other purposes. In addition, a temperature of 140°C is sufficient for obtaining organomineral composite materials. Cement production requires a temperature of 1400°C [7].

2. Materials and Methods

A vibroplanetary activator was used to increase the surface activity of the dispersed fillers used in the preparation of samples. The difference from existing analogues of the vibroplanetary activator is that this activator has the possibility of better surface activation by simultaneously applying Coriolis force to the filler particles in different directions. Active dispersed particles introduced into the material as fillers improve structural bonds in the heterosystem by forming secondary Van der Waals and hydrogen bonds during mechanical activation [8], [9], [10], [11].

For the mixing of mechanically activated aggregates and a sand-gravel mixture in combination with sulfur by heating at a temperature of 140 - 160 °C, the "IN-test" MLA-20 mixing unit was used. The technical characteristics of the MLA-20 laboratory mixer are presented in Table 1.

Table 1. Technical specifications of the MLA-20 laboratory mixer.

No	Name	Amount
1	Mixing chamber capacity	10 l
2	Temperature control accuracy	± 3 °C
3	Mixing time	1 - 9999 second
4	Mixer speed	48 rpm.
5	Temperature	10°C ÷ 400°C
6	Nasby humidity	< 80%

The flowable mixture was stirred in a MLA-20 mixer at a temperature of 160°C for 15 minutes, placed in molds with dimensions of 100×100×100 mm, and dried in air for 24 hours. The resistance properties of the obtained samples to mechanical loads were determined on a press E160PN181.

3. Results

The sand-gravel mixture was heated at a temperature of 170 °C for 15 minutes to remove moisture from the mixture, then modifying silica was added and mixed until evenly distributed throughout the volume. After reducing the temperature to 150°C, sulfur was added to the mixture and stirred until the bone phase was formed. After the mixture reached a fully fluid state, samples were poured into standard molds. In this way, a number of samples were prepared by changing the amount of components that make up the material. Table 2 shows the quantitative indicators of the constituent components in the composition of the obtained samples [12], [13], [14], [15].

Table 2. Results of physical and mechanical tests of sulfur concrete samples under laboratory conditions.

Sample number	Composition of the charge, wt. %				Density, g/cm3	Water absorption, wt. %	Load, MPa
	Sulfur	Sand	Gravel	Silicasm			
No1	30	60	10	2	1,262	0,0006	22,006
No2	50	10	35	5	2,028	0,0004	18,953
No3	30	15	50	5	1,577	0,0006	32,679
No4	30	20	45	5	1,420	0,0006	43,087
Concrete grade M450 (GOST 26633-2012)					2,5	< 0,038	44,95

4. Discussion

Studies have shown that in the process of obtaining organominiran sulfur polymer composite material, in order to remove moisture from the surface surfaces of fillers, they are heated to 150-170°C, and when activated sulfur powder is added to it in a vibroplanetary activator, sulfur initially transitions to a liquid state. In the process of mixing the components, when the temperature exceeded 170 °C, the polymerization of sulfur occurred, and a state of thickening of the mixture was observed. Samples 1 and 2, presented in Table 2, are samples poured into a liquid state before the start of the polymerization process in the composition. Samples 3 and 4 were heated to 180°C and poured into molds after the composition transitioned to a thick state.

The addition of 5% silica as a filler to the composition allows achieving a high degree of filling of the composition due to the specific surface area of the filler particles, as well as improving the rheological properties of the modified compositions, high electrical insulation (due to low contamination), and high mechanical properties of the modified compositions.

We can see that the water absorption capacity of the material depends on the amount of binder in its composition and changes inversely proportional to it.

5. Conclusion

Based on a thorough scientific analysis of the obtained results and experimental studies, it can be concluded that the compressive strength of a composite material containing 30% sulfur binder, 20% sand, 45% gravel, and 5% silica is close to the strength of M450 cement. Thus, temperature plays an important role in obtaining a sulfur-based composite material, and the materials obtained after the start of polymerization in the mixture have relatively high strength.

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