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# WASTES INTO PRODUCTION

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## PHYSICAL-CHEMICAL PROPERTIES AND STRUCTURE OF FOAMED SLAG GLASS BASED ON THERMAL POWER PLANT WASTES

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The possibility of producing heat-insulating composite glass material based on slag wastes from thermal plants (foamed slag glass) is examined. A series of foamed slag glass (FSG) compositions has been developed. The water absorption, density, apparent porosity, compression strength and thermal conductivity have been determined. The microstructure of FSG samples with optimal properties has been studied, and the composition for the production of high-quality heat-insulating material has been determined.

***Key words:*** energy conservation, resource conservation, slag from thermal power plants, foamed slag glass.

Ash-slag wastes produced at thermal power plants (TPP) take up a great deal of space. It is expedient to utilize such wastes for improving the environment and for efficient use of fuel and energy resources.

The objective of the present work is to develop a composition and technology for an advanced, cost-effective, heat-insulating material — foamed glass based on ash-slag wastes from thermal power plants. The use of slag from the Novocherkassk thermal power plant as a base for foamed glass is made possible by the fact that the chemical and mineralogical compositions of TPP wastes are very close to that of silicate glasses [1 – 3].

The chemical composition of the slag from the Novocherkassk TPP [4] is as follows (wt.%): 54.56 $SiO_2$, 19.21 $Al_2O_3$, 1.64 MgO, 0.98 $Na_2O$, 11.92 $Fe_2O_3$, 3.72 CaO, 3.35 $K_2O$, 0.98 $TiO_2$, 0.98 $SO_3$, 0.12 $P_2O_5$, and 3.44 other; total 100 [4].

A series of foamed slag glass (FSG) with the following composition was synthesized on the basis of previous studies (wt.%): 10 – 70 slag, 15 – 75 cullet, 15 boric acid and 5 foaming agent (chalk, graphite, anthracite) > 100%.

A high-quality heat-insulating material must possess the following properties: high porosity, low density, adequate strength and minimal water absorption.

The basic properties of the material were determined by generally accepted methods:

– the water absorption W and porosity ρ of foamed glass samples by saturation in water following GOST 2409–80;

– the ultimate compression strength $R_c$ of foamed glass samples following GOST 473.6–81.

The density was determined for the same foamed glass samples for which water absorption was determined. Taking account of previous measurements, the apparent porosity $P_a$ was determined using the relation

$$P_a = (W_a - W_d)/(W_a - W_w) \times 100\%,$$

where $W_a$ is the mass of the water-saturated sample in air, g; $W_d$ is the mass of the dry sample, g; and, $W_w$ is the mass of the water-saturated sample in air, g.

The thermal conductivity for construction foamed glass is expressed by the equation

$$\lambda_{+25} = 0.000213\gamma + 0.0191,$$

where λ is the thermal conductivity of the foamed glass, W/(m · K), and $\gamma_g$ is the density of the foamed glass, kg/m$^3$.

On the basis of the results obtained for the apparent porosity and water absorption of the synthesized FSG (Fig. 1*a* and *b*) it is evident that for the compositions with chalk as the foaming agent the water absorption for all values of the slag content are very close to the values of the apparent po-

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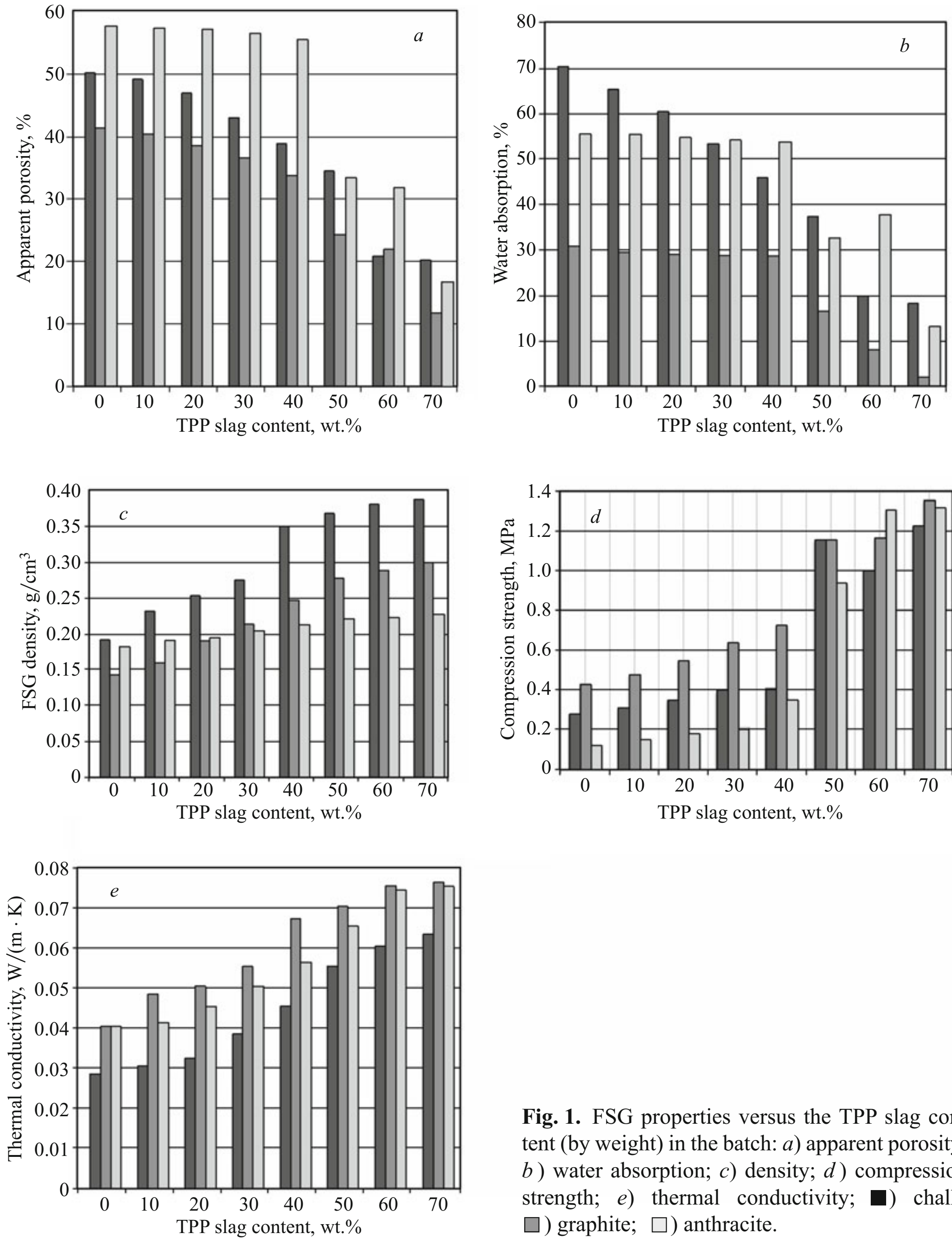


**Fig. 1.** FSG properties versus the TPP slag content (by weight) in the batch: *a*) apparent porosity; *b* ) water absorption; *c*) density; *d* ) compression strength; *e*) thermal conductivity; ■) chalk; ▩) graphite; □) anthracite.

rosity. This shows that practically all pores are filled with water. For these compositions the apparent porosity lies in the range 19.94 – 49.45% and the water absorption in the range 17.97 – 69.56%. For FSG with graphite as the foaming agent the apparent porosity is significantly lower for all values of the slag content; this indicates that closed pores predominate in these samples. Correspondingly, the apparent porosity and water absorption values are 11.35 – 40.98 and 1.40 – 30.25%. The FSG samples with anthracite as the foaming agent possess medium porosity as compared with samples with chalk and graphite. The apparent porosity and water absorption of these compositions lie in the ranges 16.46 – 57.45 and 12.83 – 55.12%, respectively. The apparent porosity of these foamed slag glasses is somewhat higher than their water absorption, which also attests to the presence of closed pores in the structure of the samples. Thus, the water absorption and apparent porosity decrease with increasing slag content. A correlation between the slag content and density of the material is also observed (Fig. 1*c* ). In all compositions, the density increases with increasing slag content. The samples containing anthracite as the foaming agent have the lowest density, which lies in the range 0.179 – 0.224 g/cm$^3$.

The compression strength is lowest in samples containing chalk 0.28 – 1.23 MPa (Fig. 1*d* ), since during kilning

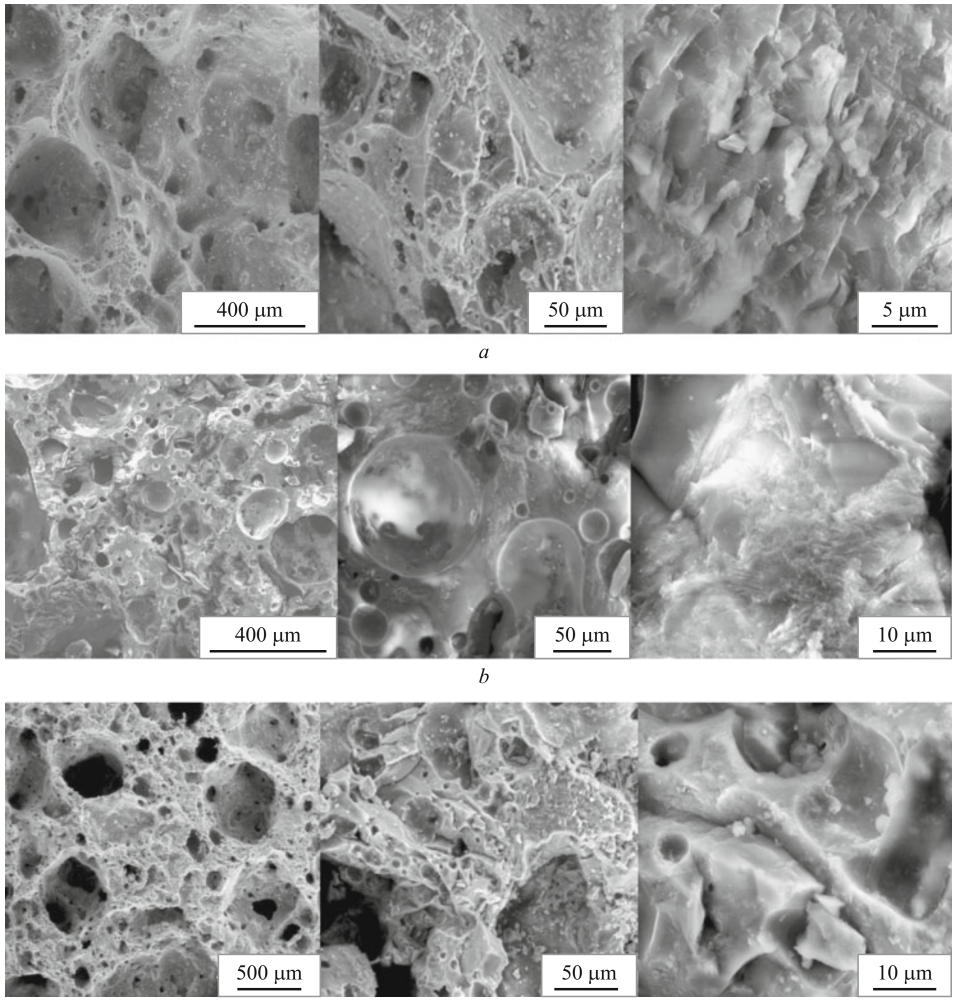


**Fig. 2.** Microstructure of FSGs with different foaming agents: *a*) with chalk; *b* ) with graphite and *c*) with anthracite.

they undergo intense foaming and significant pore growth and therefore density reduction occur. The greatest strength 0.43 – 2.34 MPa is observed in compositions with graphite as the foaming agent; this is due to the presence of fine pores and relatively high density. The ultimate compression strength in compositions with anthracite lies in the range 0.12 – 1.32 MPa, but the density of such FSG reaches its lowest values. Evidently, this is due to the pore size and distribution in the samples as well as the thickness of the pore walls. Thus, compared with the FSG compositions with chalk these low-density samples have comparatively high strength. In all FSG samples the thermal conductivity depends on the density and porosity of the material. As the density decreases, the thermal conductivity decreases because the porosity increases. The thermal conductivity lies in the range 0.028 – 0.063, 0.040 – 0.075 and 0.040 – 0.074 $W/(m \cdot K)$ for compositions with chalk, graphite and anthracite, respectively (Fig. 1*e* ).

Among the synthesized samples with different basic property values the optimal compositions for the production of FSG satisfying the requirements for heat-insulating materials are compositions with 50 wt.% slag. An electron microscope was used to study samples with different foaming agents (Fig. 2). The photomicrographs show that the sample with chalk is less porous than the samples with graphite and anthracite. In the sample with chalk, irregularly shaped communicating pores of size 50 – 120 μm predominate. In the sample with graphite most pores are spherical, closed, isolated from one another and vary in size from 2 to 800 μm; the predominant pore size is 30 – 60 μm. The sample with anthracite has the smallest pores. Closed and communicating pores are present in it, but the closed pores are considerably more numerous. The pore size fluctuates from 3 to 600 μm, and 15 – 20 μm pores predominate.

In summary, the compositions most suitable for synthesizing construction FSG (tiles, blocks) are compositions with graphite and anthracite as pore forming agents. Of the three optimal compositions, FSG with chalk as the foaming agent has the lowest compression strength and can be used to manufacture granular FSG to be used as heat-insulating filler, since strength is not a decisive parameter for it.

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