

Study into the feasibility of manufacturing liquid glass using resource-saving technology

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Abstract. The authors' views on the problem of resource-saving in the production of building materials are outlined, with three main modes of resource-saving indicated: the use of cheap raw materials, a reduction in the production costs, and an increase in the efficiency of the produced materials and products. The research provides information on the production and use of liquid glass in industry, including the construction industry. The theoretical substantiation of the possibility of developing a resource-saving technology for the production of liquid glass for construction purposes is given. The work provides information on promising alternative raw material components - diatomite, natural rock and black ash, industrial waste. Their properties are given as well as the justification of their effective use as raw materials. The method of preparation of the components and their mixtures, the preparation of sodium silicate through roasting, and the identification of the suitability of the obtained product for the manufacture of efficient building materials are described. Conclusions are made in regards to the feasibility of producing liquid glass using resource-saving technology.

1 Introduction

The issue of resource-saving is a constant one. However, in the opinion of designers, production engineers, researchers and consumers, different things can be meant by this term. The same difference can be observed when the term is applied to construction, manufacture, and use of building materials and products.

Production engineers try to use the cheapest and most readily-available raw materials as well as to decrease production costs in order to reduce the cost price. [1-4]. Sometimes such policies can unfortunately lead to a decrease in product quality. Resource-saving for consumers of construction materials and products implies a level of reliability, durability and comfort of the buildings made from such materials.

In evaluating these processes, we found that the primary role in the provision of resource-saving as regards this matter should be defined by the producers of construction materials and by research aiming to develop and create new methods and technologies that ensure the production of economical but efficient building materials and products. Nonetheless, one of the main conditions for the use of relatively cheap industrial waste and

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so-called "local materials" is that such materials should in no case lead to a degeneration in the performance characteristics of building materials and products.

Therefore, scientific developments in this field should not aim at simply finding a replacement for a raw material with a cheaper one, but at developing technologies to produce highly effective materials and products that can reduce the consumption of resources in the long-run.

2 Materials and Methods

It is known that a material called "liquid glass" can be used as the foundation for producing highly effective building insulation materials, the distinguishing characteristic of which is high porosity and fire resistance. Such materials include foam-silicate plate products, highly porous granular aggregates, and others [10-14].

Usually, the term "liquid" or "soluble" glass refers to an aqueous solution of alkali metal silicates (usually sodium). Conventionally, the chemical composition of liquid glass can also be expressed by the formula $R_2O * nSiO_2 * mH_2O$.

The technical production of liquid glass began only in the first half of the XIX century, although the technology was already well known in the Middle Ages.

Primary materials used in the production of liquid glass include silica components appearing in the form of quartz sand, natural and artificial silica, and alkaline components in the form of soda, potassium carbonate, sodium sulphate, and the like.

Liquid glass can be obtained by fusing together the raw components at a high temperature (about 1300 ° C), followed by cooling the resulting molten mass and then dissolving it in water.

Liquid glass has many diverse uses. About 30% of its production is used in mechanical engineering, about 31% in the chemical industry, about 15% in paper and cardboard production, and about 10% in construction. However, its high-level performance characteristics and high fire resistance of building materials which are made of it allow us to assert that the use of liquid glass in construction can be greatly enhanced [15-18].

The main factors limiting the use of liquid glass in construction include special requirements for its raw materials components and a relatively high final cost. This high cost is due to the complexities of its production process, including the extreme temperature at which it is produced, the difficulty in obtaining scarce raw materials in "pure" form, and high standards of the composition and characteristics of the finished liquid glass due to its widespread use in different applications. Therefore, the development of low-cost technology for the production of liquid glass for building applications is a very relevant topic.

The authors of this work propose a technology for the production of liquid glass, based on the following postulates:

1. Standard requirements for homogeneity, composition, etc. should not be applied to liquid glass used for construction purposes. In this case, it should only meet the requirements for thermal intumescence, and the products obtained on its basis should meet specified operational characteristics (porosity, thermal conductivity, strength, durability, fire resistance, etc.).

2. Primary materials should originate from accessible local sources, preferably industrial wastes.

3. Crystalline materials such as silica, being that they are more refractory and have a higher resistance to heat, should be replaced with materials of a more amorphous structure having a lower melting point and greater chemical activity.

In our opinion, the successful application of this method can greatly reduce the cost of production of liquid glass for construction, which will eventually result in an expansion of the nomenclature of effective thermal insulation materials.

On the basis of the stance put forward by the authors, sodium liquid glass was obtained at a temperature of 950-980 degrees Celsius. In this case, naturally-occurring diatomite was used as the main silica component and black ash ball derived from industrial waste was used as the sodium component.

Diatomite is a sedimentary, fine-porous siliceous rock. Deposits of diatomite are very significant. For example, in the Ulyanovsk region, the total explored reserves are more than 720 million cubic meters. Usually diatomite is composed of 65% to 97% amorphous silica. The authors used the diatomite of the Inzen deposit of the Ulyanovsk region, which was composed of 86.5% SiO_2 in its amorphous form. Its density was 3620 kg/cubic meter.

Black ash (molten soda), a by-product of industrial caprolactam production, was obtained from the enterprise "KuibyshevAzot" (Togliatti). It appeared in the form of broken plates 10-15 mm thick and light yellow colour. Its composition is represented by the following oxides, wt. %: Na_2CO_3 -53.4; NaOH - 18.6, Na_2SO_4 - 13.0; NaCl - 2.5 and others.

Studies on the production of liquid glass were carried out as follows:

- the components (diatomite and black ash) were finely ground (until particles were able to pass through a sieve with an opening of 0.15 mm), mixed in various proportions and fired at temperatures which ensured the formation of a powdered mixture of sintered material;

- the obtained sintered samples were ground and kept in boiling water for 1 hour;

- the resulting compositions were evaluated for their ability to distend.

3 Results

It is known that chemical processes are significantly accelerated when the reacting components are in liquid form, for example in molten form. Therefore, our task at the first stage is to establish a minimum temperature at which test samples reach molten state, which in our opinion will allow for an intensive interaction of the raw components.

Tests showed that at a firing temperature of up to 950 degrees Celsius, samples remained in a free-flowing state, which indicated that the components had not melted or fused together. The samples were observed to sinter at temperatures above 950 degrees Celsius.

The second task was to determine the depth of interaction and the intensity of formation of sodium silicates. Since the resulting material is X-ray amorphous, the use of X-ray diffraction methods was not practical. Therefore, we used an indirect method based on the fact that aqueous sodium silicate solutions have the ability to expand when introduced to a heat source. Moreover, this method allowed for the immediate characterization of new porous structures in the resulting compounds.

It was found that the optimal temperature for roasting the mixture of diatomite and black ash is one equal to 950-980 degrees Celsius.

At these temperatures and at mass ratios of 5/5 to 3/7 of diatomite to black ash, sufficient distension of the resulting compositions is observed. The intensity of distension (coefficient of distension), constituting the increase in volume compared to the initial volume, was 5-7, which, in our opinion, is quite sufficient for liquid glass used for manufacturing insulation materials and construction products.

4 Discussion

Comparing the standard technologies of liquid glass production to the ones proposed by the authors, one can immediately note the pros and cons of the latter.

The obvious pros are as follows:

- The new technology allows for the use of more affordable components;
- The new technology also allows for lower firing temperatures, significantly reducing levels of energy consumption.

Among disadvantages of the technology can be the inconsistency of the characteristics of the resulting sodium silicate with the standard requirements for liquid glass. But is this consistency really necessary? Strict requirements for ordinary liquid glass production are necessary because of its widespread application (in metallurgy, in the chemical and paper industry, etc.). In other words, ordinary liquid glass must satisfy a spectrum of requirements, which are sometimes conflicting to each other. Is this necessary? In our opinion, no! It is similar to applying the same requirements and design for engines used both for wide fuselage aircrafts and smaller ones, such as 2-4 seaters.

Therefore, we believe that one of the conditions for implementing resource-saving methods of liquid glass production should be that only those requirements that will ensure the production of specific products of a specified quality must be adhered to, not that the same requirements must be fulfilled for each and every type of liquid glass being produced. For example, for the production of liquid glass for construction purposes specifically, it should fulfil the requirement to intensively distend.

5 Conclusions

Thus, the authors have proven that it is possible to use resource-saving and low-cost production technology for liquid glass intended for construction purposes, i.e. it is potentially suitable for manufacturing effective thermal insulation materials and products.

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