Thermal insulation materials based on polyurethane foam modified by the polymethylphenylsiloxane

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Abstract. In this work, the modification process of thermal insulation materials based on polyurethane foam by the organosilicon polymer polymethylphenylsiloxane was studied. The current state of thermal insulation materials based on polyurethanes problem and ways to improve the thermal and operational properties of foamed polyurethanes, such as maintaining the stability of characteristics under the influence of adverse factors, reducing moisture absorption and water absorption, were also analyzed. The influence of polymethylphenylsiloxane on the morphological characteristics and density of the resulting foams was studied. It was found that the introduced modifier affects the density of the resulting foam materials slightly. In this case, the introduction of an organosilicon product regardless of the ratio of the initial components leads to a decrease in water absorption. Studies have shown that the introduction of an organosilicon modifier in an amount of 2.5-5 m. h. leads to an increase in the heat resistance of the material. The heat resistance of modified samples increased by an average of 30-40 °C. Thus, the conducted research showed a real possibility of using the developed modified polyurethane foams for thermal insulation of industrial and civil objects.

1. Introduction
Due to the rising cost of energy carriers in the construction industry, effective thermal insulation begins playing an important role [1-7]. An important goal of building structures thermal insulation is not only to reduce energy consumption for building heating but also to reduce heat losses in industrial units and heating mains. Currently, thermal insulation materials based on foamed polyurethanes are widely used in the construction industry [8-11].

Polymer polyurethane thermal insulation materials usage can increase the degree of work industrialization, reduce the need for other building materials, and reduce the weight of structures. Existing polyurethane-based materials have good thermal insulation properties, simple production technology and relatively low cost of the resulting material. Their disadvantages are low resistance to external factors, such as temperature, moisture and UV radiation [12-16].
In this regard, the purpose of the presented work was to improve the performance of polyurethane insulation by introducing modifying additives based on reactive polyorganosiloxanes into the composition.

2. Materials and methods
As the object, an industrial composition for obtaining polyurethane foam insulation was used, that includes the following main components: component A (based on Laprol-373), component B (polyisocyanate of the PM-200 brand).

As a modifying additive, polymethylphenylsiloxane resin (PMPR) with reactive hydroxyl groups was used. It was produced at the JSC «Himprom» enterprise in Novocheboksarsk. PMPR was chosen because it is widely distributed organosilicon product and has several valuable properties, primarily high heat resistance, frost resistance and moisture resistance, small changes in physical characteristics over a wide temperature range.

The apparent density and sorption wetting of foam were determined according to Russian State Standard (GOST) 17177-94 “Thermal insulating materials and products for building application test methods”.

Heat resistance was determined in accordance with GOST 16781-71 by determining the temperature at that changes in the size of samples begin to be observed during heating.

3. Results and discussion
At the first stage of the work, the effect of polymethylphenylsiloxane resin (PMPhS) on the morphological characteristics and density of the resulting foams was studied because these indicators are closely related to the thermal characteristics of thermal insulation. It showed that the introduction of PMPhS leads to a partial reduction in the size of cells. This was probably because the PMPhS microparticles distributed in component A are nucleating agents that favourably affect the morphological structure of the foam. However, the excess content of PMPhS (higher than 2.5 m. h.) did not affect the cell size significantly.

Studies on the apparent density of rigid polyurethane foam modified with polymethylphenylsiloxane have shown that in studied range, the introduced modifier affects the density of the resulting foams slightly. The obtained values lays within the limits of the experiment error.

Moisture absorption is one of the most important indicators of thermal insulation material used in adverse conditions. Studies have shown that the introduction of an organic silicon product PMPhS, regardless of the ratio of the initial components, leads to a decrease in water absorption (Fig. 1). This is a consequence of the fact that most organosilicon compounds have strong hydrophobic properties. Due to the interaction of reactive groups (hydroxyl groups) in its composition, compounds that give the material hydrophobic properties were formed [17-20]. With the further introduction of the modifier in the composition after 2.5 m. h. significant changes in the level of moisture absorption was not observed (curves 1,2,3).
One of the most relevant indicators for thermal insulation materials is their heat resistance. The study results showed that the introduction of an organic silicon modifier in the amount of 2.5-5 m. h. leads to an increase in the heat resistance of the material. The heat resistance of modified samples increased on average by 30-40 °C. In addition to increasing the heat resistance, there is also destructive processes decrease. Thus, the mass loss of the modified PU at the destruction temperature is reduced by 1.5-2.5 times, compared to the non-modified one. The main indicators of the developed material are shown in the Table 1.

**Table 1. Unmodified and modified foam characteristics.**

| Characteristic             | Values          |
|---------------------------|-----------------|
| Density, kg/m³            | 220-250         |
| Impact strength, Kj/m²    | 1.0-1.2         |
| Moisture absorption, %    | 4.8             |
| Heat Resistance, °C       | 140-160         |
| Thermal conductivity, W/m·K | 0.032-0.039     |

A significant usage increase of synthetic cellular materials based on various polymers made it an exceptional problem of their performance properties stability during ageing. At the same time, it is very important to study the changes in material properties over time, depending on the conditions of their long-term operation and storage. Such research will, first of all, provide the designer or consumer with data that explains the behaviour of foam over time and thus make it possible to choose the right materials. For climate tests in the middle zone of Russia, a method for determining weather resistance was used, the essence of which is to determine the change in specific (assigned from the conditions of use of the material) characteristics of foams under the influence of natural factors at the earth's surface during tests on open stands. As a result of tests, it was found that modified samples have an average of 25-30% higher resistance to UV rays, as well as to temperature changes and seasonal weather changes, compared to non-modified materials.
Polyurethane foams are widely used both in construction and in household items manufacture, so the fire resistance of products is of great importance. In the course of the work, the influence of polymethylphenylsiloxane on the combustibility of foam was studied. The combustibility of the material was determined by the time of combustion and the loss of the samples mass. The test results showed that all modified samples are prone to self-extinguishing, the burning time of modified samples does not exceed 27 seconds. Even after applying the flame, no sample burned for more than 30 seconds. Thus, an increase in the content of PMPhS in the composition leads to a decrease in the combustible characteristics of the foam, and the best results were achieved when the content of component A in the amount of 10 m. h. the graph shows that the introduction of an organosilicon compound helped to reduce the mass loss of the foam sample. During combustion of modified samples on their surface, the appearance of a carbonized layer was observed, that was formed during the combustion process and prevented the further spread of the flame.

Figure 2. Modified polyurethane foam product of the “Shell” type.

Experimental work on obtaining the product «shell» for pipelines (Fig.2) and the developed composition showed highly technologically efficient when receiving products using the filling method. Thus, the research showed a real possibility of using the developed modified polyurethane foams for thermal insulation of industrial and civil facilities.

4. Conclusions
In the chosen range of studies, the introduced modifier affects the resulting foams density slightly. The resulting differences in apparent density values are within the experimental error range.

Polymethylphenylsiloxane resin, regardless of the initial polyurethane components ratio, helps to reduce moisture absorption, due to the interaction of reactive groups in its composition with reactive groups of polyurethane, giving the material hydrophobic properties.

The introduction of an organic silicon modifier in the amount of 2.5-5 m. h. leads to an increase in the heat resistance of the material. The heat resistance of the modified samples increased by an average of 30-40 °C.

When modified with polymethylphenylsiloxane resin, a partial decrease in the flammability of the foam was observed.
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