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DETERMINATION OF THERMAL CONDUCTIVITY OF COMPOSITE MATERIAL CONTAINING GLASS AND ALUMINOSILICATE MICROSPHERES FILLED WITH AIR

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ВИЗНАЧЕННЯ ТЕПЛОПРОВІДНОСТІ КОМПОЗИЦІЙНОГО МАТЕРІАЛУ, ЩО МІСТИТЬ СКЛЯНІ ТА АЛЮМОСИЛІКАТНІ МІКРОКУЛЬКИ, НАПОВНЕНІ ПОВІТРЯМ

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ОПРЕДЕЛЕНИЕ ТЕПЛОПРОВОДНОСТИ КОМПОЗИЦИОННОГО МАТЕРИАЛА, СОДЕРЖАЩЕГО СТЕКЛЯННЫЕ И АЛЮМОСИЛИКАТНЫЕ МИКРОСФЕРЫ, НАПОЛНЕННЫЕ ВОЗДУХОМ

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The article gives an analysis of the requirements for traditional heat-insulating materials. In connection with the introduction of new norms on energy saving, including in the residential sector, as well as increasing the requirements for the heat protection of buildings, the issue of the development of essentially new thermal insulation materials that meet the requirements of the time has become most urgent. One of these materials is liquid composite systems filled with glass and aluminosilicate microspheres based on polymer binders.

Key words: *heat-insulating materials, energy saving, thermal protection of buildings, composite systems, glass and aluminosilicate microspheres.*

У статті надано аналіз вимог, що висуваються до традиційних теплоізоляційних матеріалів. У зв'язку з впровадженням нових норм з енергозбереження, у тому числі і у житловому секторі, а також підвищенням вимог до теплозахисту будівель питання розроблення саме принципово нових теплоізоляційних матеріалів, що відповідають вимогам часу, стало найбільш актуальним. Одним з таких матеріалів є рідкі композиційні системи, наповнені скляними та алюмосилікатними мікросферами на основі полімерних зв'язуючих. Однією з причин високого інтересу до рідкої теплоізоляції є трудомісткість монтажу вентильованих фасадів, а також проблема утеплення фасадів старих будинків, що потребують реставрації. Але склади на полімерній основі з часом потребують зміни, оскільки всі полімери «старіють», а склади на гіпсовому в'яжучому не можна застосовувати зовні. Тому актуальним залишається питання в дослідженні складів, де в якості основного теплоізоляційного компонента застосовують мікросфери, що наповнені повітрям, а в якості в'яжучого – цемент. Такі склади можна ефективно застосовувати як у внутрішній, так і зовнішній теплоізоляції огороджувальних конструкцій.

Ключові слова*: теплоізоляційні матеріали, енергозбереження, теплозахист будівель, композиційні системи, скляні та алюмосилікатні мікросфери.*

В статье дан анализ требований, предъявляемых к традиционным теплоизоляционным материалам. В связи с внедрением новых норм по энергосбережению, в том числе и в жилом секторе, а также повышением требований к теплозащите зданий вопросы разработки именно принципиально новых теплоизоляционных материалов, отвечающих требованиям времени, стало наиболее актуальным. Одним из таких материалов являются жидкие композиционные системы, наполненные стеклянными и алюмосиликатными микросферами на основе полимерных связующих. Одной из причин высокого интереса к жидкой теплоизоляции является трудоемкость монтажа вентилируемых фасадов, а также проблема утепления фасадов старых домов, нуждающихся в реставрации. Но составы на полимерной основе со временем потребует изменения, поскольку все полимеры "стареют", а составы на гипсовом вяжущем нельзя применять снаружи. Поэтому актуальным остается вопрос в исследовании составов, где в качестве основного теплоизоляционного компонента применяют микросферы, наполненные воздухом, а в качестве вяжущего - цемент.

Ключевые слова: *теплоизоляционные материалы, энергосбережения, теплозащита зданий, композиционные системы, стеклянные и алюмосиликатные микросферы.*

Introduction. Characteristic signs of modern construction are new constructive and technological solutions and new structural, finishing, waterproofing, heat-insulating materials. The introduction of new energy efficiency standards, including in the residential sector, as well as increasing the requirements for heat protection of buildings gave point to the issue of the development of fundamentally new heat-insulating materials that meet the requirements of the time.

Analysis of recent research and publications. The main general requirements for heat-insulating materials (HIM) and structures, depending on the field of application are: low average density, and for enclosing structures of buildings - not higher than 500 kg/m^3; a low coefficient of thermal conductivity, which should not exceed for high-efficiency heat-insulating materials and structures 0.09 W / m · ° C, high temperature stability - the material and the construction of heat insulation should not burn and sustain combustion, smolder after removing the open flame and must withstand the temperature limits of their use. In addition, the material must have a constant volume, which is determined by the resistance of self-compression during shrinkage and vibration during operation, a low water absorption when immersed in water and low hygroscopicity, frost resistance, biostability, anti-corrosion properties, harmlessness. Materials should not evolve a specific smell, substances harmful to human health and animals, as well as substances that reduce the strength of structural elements, should be harmless both during installation and operation, economic [1-5].

Modern insulation materials are mainly made of foam polymers and mineral fibers [1-4, 19, 20]. Along with undoubted merits, they also possess many of the drawbacks mentioned above. In the authors opinion, composition materials, especially inorganic ones, don't have these drawbacks[5, 21]. Appearance of glass and aluminosilicate microspheres in the market brings new ways for their improvement [6, 22, 23]. The improvement should be based on the knowledge of colloid chemistry and the physico-chemical mechanics of disperse systems and materials [7, 8], especially taking into account the electro-surface properties of the components of composites [7, 9, 10], and also on modern methods of formulation development [11, 12]. This will allow to provide the required thermal characteristics of the composites, as well as sufficient strength and high durability (especially compared to polymers) [13-16].

Materials and structures from them must allow processing with cutting tools, applying to the surface with light techniques (a sticker, applying in the form of stucco mixes or with help of brushes), applying finishing layers on them. HIM and structures from them should be manufactured in an industrial way and meet the requirements of existing state standards and technical conditions.

All existing heat-insulating materials to a greater or lesser extent do not meet in full all indicated requirements. However, many requirements can be met by building a rational insulating structure. For example, to take precautions against moisture, increase its mechanical strength. The choice of material and design of heat insulation should take into account the positive and negative qualities, as well as the real possibilities of obtaining materials and their cost. It should be borne in mind that the high quality of the insulating fencing is determined by three conditions: a properly chosen material, a rationally designed structure and a quality performance of installation work. Therefore, the choice of insulation material regardless of design and, conversely, the choice of design without taking into account the thermal insulation material are fundamentally irrational.

Depending on the main heat-insulating material, heat insulating structures are divided according to its name. Depending on the composition of the main heat-insulating layer, the heat-insulating structures are divided into simple ones consisting of one basic heat-insulating material and composite ones consisting of several heat-insulating materials. Depending on the geometric shape and configuration of isolated objects, heat-insulating structures are divided into structures: for flat and curved surfaces.

The introduction of new energy efficiency standards, including in the residential sector, as well as increasing the requirements for heat protection of buildings, the development of fundamentally new heat-insulating materials that meet the requirements of the time has become the most urgent. One of such materials is liquid composite system filled with glass and aluminosilicate microspheres based on polymeric binders. One of the reasons for the high interest in liquid heat insulation is due to the laborious installation of ventilated facades, as well as the problem of the insulation of the facades of old houses in need of restoration.

The most effective use of thin heat insulation of liquid type is advisable to apply for internal and external insulation of walls, roof and floor of residential and industrial buildings, as well as structures that are easily installed (garages, pavilions, kiosks, etc.); for the fire treatment of walls and ceilings on the evacuation routes of people (elevators, common corridors, staircases, etc.); for the protection of the outer walls from heating by solar radiation.

Task set. Since at the present time, including in the construction industry, materials consisting of the hollow microspheres (aluminosilicate and glass) as their main heat-insulating component, are gaining popularity. Such compositions can be easily applied to any curvature of the surface and consist of a single heat insulating material - microspheres filled with air. The compositions are also known based on gypsum binder, or acrylic water-soluble polymers filled with microspheres, used in construction for the purpose of haet insulation of external enclosing structures. But polymer-based compositions will eventually require replacement, since all polymers "age," and compositions on a gypsum binder can not be used externally. Therefore, the issue remains in the study of compositions where microspheres filled with air are used as the main heat insulation component, and cement is used as binding element. Such compositions can be effectively used, both in internal and external insulation of enclosing structures.

The main material and results. For the studies, a composite heat-insulating material was used, where the main components were white portland cement, glass and aluminosilicate microspheres filled with air from 5 μm to 30 μm in diameter, chemical additives to regulate hydration processes, rheological properties and strength, vapor permeability (fig. 1, 2).

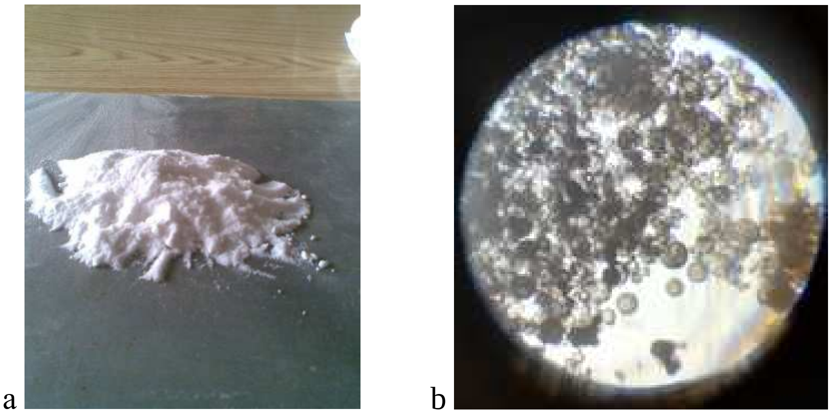
a b

Fig. 1. Glass microspheres: a – in the loose state; b – with an increase of x10^3

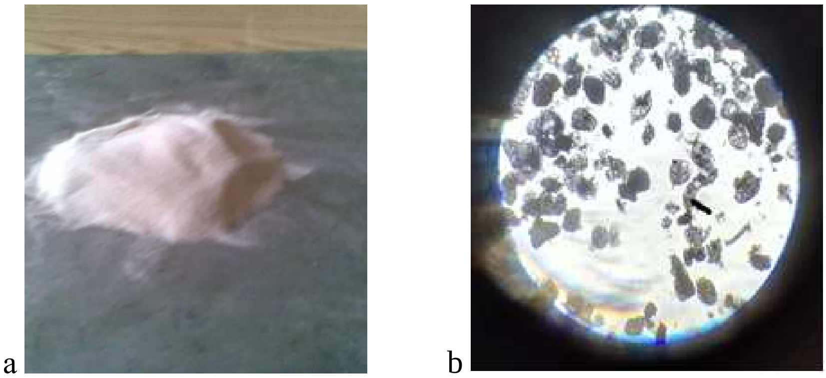
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Fig. 2. Aluminosilicate microspheres: a – in the loose state; b – with an increase of x10^3

The task was set in the work, namely, to determine the heat conductivity of the composite material, the main component of which are microspheres filled with air. To set up the experiment, a plastic container was used, on the part of the outer surface of which a composite heat-insulating material was applied. The second part of the outer surface of the container remained uncoated (fig. 3, a). The temperature on the surface was determined using a thermal imager (fig. 3, b). The container, in which the water, was poured was heated to a certain temperature.

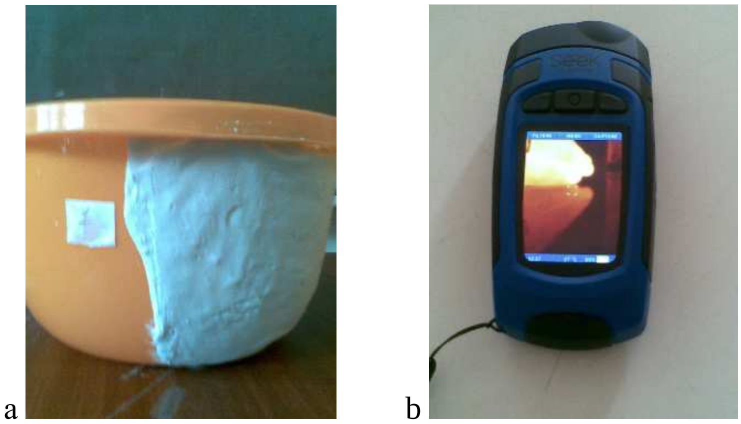
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Fig. 3. A test container with a heat-insulating layer (a), thermal imager, general view (b)

Let us consider the process of heat transfer through bodies of different structures under steady-state conditions. With a constant or stationary thermal regime, the temperature of the body in time remains constant. Under given conditions, the temperature will change only in a direction perpendicular to the plane of the wall (fig. 4) [17, 18].

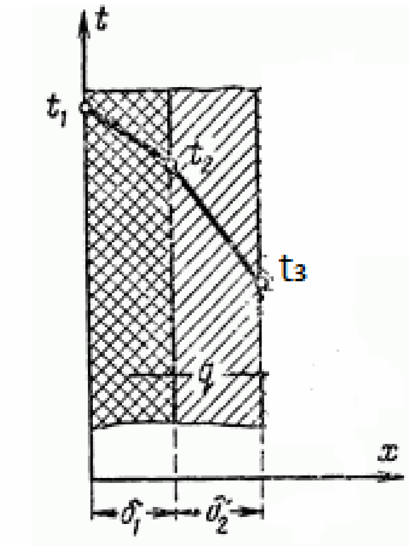

Fig. 4. Two-layered flat wall

The protective wall of the container with hot water consists of two layers that fit tightly to each other. The thickness of the first layer (plastic container) – δ_1, the thickness of the second layer (composite coating material) – δ_2. Accordingly, their thermal conductivity coefficients λ_1 and λ_2. Since the temperatures of the outer surfaces of the plastic wall of the container t_1 and the coating t_2 are known, and the thermal contact between the surfaces is assumed to be ideal, then the temperatures at the points of contact are indicated by t_1 and t_2. Under steady-state conditions, the heat flux density is constant and for all layers is the same, therefore, one can record the heat flux density for each layer:

$$g = \frac{\lambda_1}{\delta_1}\left(t_1 - t_2\right), \tag{1}$$

$$g = \frac{\lambda_2}{\delta_2}\left(t_2 - t_3\right), \tag{2}$$

where δ_1 and δ_2 are the thickness of the plastic layer and the coating respectively, λ_1 and λ_2 are the thermal conductivity of the plastic and the coating respectively, t_1 and t_2 are the temperature on the plastic and coating surface, respectively.

The temperature of the water poured into the container was 78°C, the temperature on the surface of the plastic container was 73°C, the temperature on the surface of the heat-insulating layer 1 mm thick was 51°C, and on a layer 2 mm thick – 28°C (fig. 5).

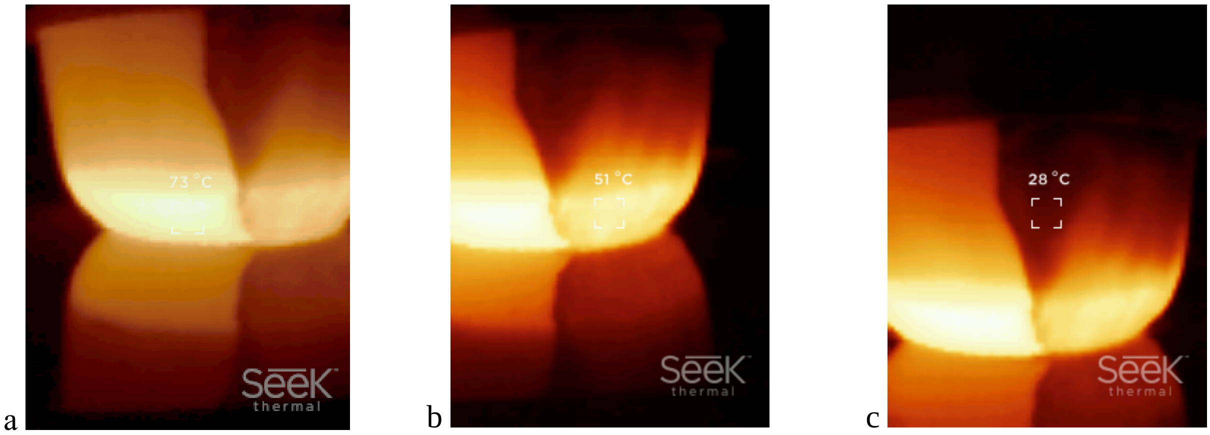

Fig. 5. Measurement of the surface temperature with the thermal imager: a – on the surface of the plastic container (73°C); b – on the surface of the coating with a thickness of 1 mm (51°C); c – on the surface of the heat-insulating coating with a thickness of 2 mm (28°C)

The coefficient of thermal conductivity of the plastic, from which the container is made, is known and is equal to λ1 = 0.15 W/m · °C, and also the wall thickness of the container is known, it is possible to calculate the density of the heat flux, which was 750 W/m^2. If a known value of the density of the heat flux, which is the same for all layers, it is possible to calculate the thermal conductivity of the heat-insulating coating for thickness of 1 mm and thickness of 2 mm, respectively:

$$\lambda_2 = \mathrm{g} \cdot \delta_2 / t_2 - t_3 /= 750 \cdot 0{,}001/22 = 0{,}0340 \text{Вт/м} \cdot {}^0\,\text{C};$$

$$\lambda_2 = \mathrm{g} \cdot \delta_2 / t_2 - t_3 /= 750 \cdot 0{,}002/45 = 0{,}0333 \text{Вт/м} \cdot {}^0\,\text{C};$$

The results obtained of calculating the thermal conductivity coefficient from the surface temperature readings with the thermal imager show a slight discrepancy in the third sign, which confirms the reliability of the results obtained.

Results. Thus, the heat-insulating composite obtained on the basis of glass and aluminosilicate spheres, cement binder, chemical additives has a coefficient of thermal conductivity of 0,0340-0,0333 W/m · °C, which corresponds to the coefficient of thermal conductivity of the foam plastic 0,037 W/m · °C up to 0,043 W/m · °C. The thermal conductivity of the air is 0,026 W/m · °C. That is, the resulting heat-insulating material based on aluminosilicate and glass microspheres filled with air and connected to each other in a composite heat-insulating material with a modified cement binder is promising from the point of view of thermophysical characteristics and requires further research.

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