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EXPERIMENTAL RESEARCH OF HEAT TRANSFER THROUGH HEAT-INSULATED WALL ENCLOSURE STRUCTURES

Abstract: *The article provides an experimental analysis of the behavior and changes in thermophysical properties of the thermal insulation systems most commonly used in construction during the entire life of the buildings. Experimental data on temperature fluctuations and distribution of heat flow density of a thermally modernized section of a wall-enclosing structure insulated by various methods for 6 years were obtained and the values of the actual coefficients of thermal conductivity of various heat-insulating materials were compared in the first approximation. The need to assess the influence of the service life on the thermophysical properties of heat-insulating materials used in the thermal modernization of buildings of various purposes is experimentally substantiated.*

Keywords: *energy efficiency, thermomodernization, thermal insulation, heat transfer, heat flow.*

Introduction

At the current stage of the development of technical solutions aimed at increasing the efficiency of the use of energy carriers, the main factor of energy saving in buildings is the degree of thermal energy saving. One of the instruments of influence on the reduction of energy dependence of the state is the introduction of energy efficiency requirements into the legislative framework. The modern direction of Ukraine's development dictates the need to adapt the current legislative and regulatory framework to the European one, as well as the need to develop new standards in the field of energy efficiency of the building stock, including the quality of the microclimate in buildings. The system complex of regulatory documents establishes mandatory requirements for energy safety, standardization of physical indicators characterizing the fulfillment of these requirements, rules for evaluating energy efficiency indicators at the stage of designing construction objects, their experimental manufacture and use when putting buildings into operation, and during their operation, test methods and criteria for evaluating the conformity of construction products and objects according to energy efficiency indicators [1].

In the new edition of DBN V.2.6-31:2021 "Thermal insulation and energy efficiency of buildings", the normative heat transfer resistance of the external walls of residential buildings for the I climate zone is 4 m^2K/W (increase by 20%), and for transparent enclosing structures 0.9 m^2K/W (20% increase) [2].

Table 1 shows the dynamics of changes in normative heat transfer resistances of enclosing structures of residential and public buildings.

Table 1. *Dynamics of changes in normative heat transfer resistance indicators of the enclosing structure of residential and public buildings*

Type of enclosing structure	Normative heat transfer resistance Rq min, m²K/W							
	1981	1993	2006 I zone	2013 II zone	2017		2022	
					I zone	II zone	I zone	II zone
Outside walls	0.95	2.2	2.8	3.3	3.3	2.8	4.0	3.5
Translucent fencing structures	0.48	0.53	0.6	0.75	0.75	0.6	0.90	0.70

At the moment, Ukraine is dynamically moving towards European standards of thermal insulation, which is reflected in the consistent growth of normative heat transfer resistance values for enclosing structures (Fig. 1).

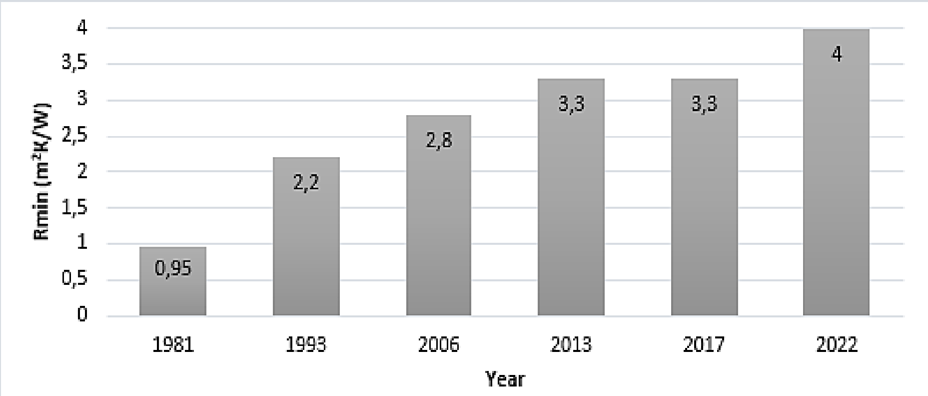

Figure 1. *Dynamics of the development of the coefficient of normative thermal resistance Rn, external walls in the territory of Ukraine*

The main method of bringing the thermal insulation of the enclosing structures of buildings to the standards is the measures of full or partial thermal modernization [1], namely thermal renovation of the enclosing structures, the main measures of which are the replacement of window structures and the installation of an additional layer of thermal insulation on the external walls.

Since thermal renovation measures require significant capital investments, there is a need for a comparative analysis of the heat-technical and economic efficiency of using one or another heat-insulating material. At the same time, it is also important to take into account the durability of coatings under different operating conditions. In this regard, there is a need for multi-variant thermal renovation of individual rooms and experimental studies of their air-temperature regimes and the corresponding amounts of heat loss through the fences of each room.

An innovative project was aimed at solving this problem, the purpose of which was to substantiate ways of reducing the heat consumption of existing administrative buildings by reducing heat loss due to the implementation of optimal options for thermal renovation of enclosing building structures and researching the effectiveness of thermal renovation measures during long-term operation of the structure. The object of the research and the place of application of the project results was the construction of building No. 1 of the Institute of Engineering Thermophysics National Academy of Sciences of Ukraine on Bulakhovsky St., 2 in Kyiv.

The purpose of the study is to analyze the results of experimental studies of heat transfer through heat-insulated wall enclosing structures in real climatic conditions of long-term operation.

Results

Thermal renovation was carried out by replacing the old windows in the premises with modern double-glazed windows and by installing heat-insulating coatings made of different types of materials on part of the area of the outer surface of the fences on the north facade of the building (Fig. 2). In order to exclude the influence of a roof without an attic and a floor without a basement, measures were taken in the premises of the second floor of the investigated building.

By means of a comparative analysis of literature data on the heat-technical characteristics of heat-insulating materials, the following insulation options were selected: basalt wool, foam glass, spraying polyurethane foam, extruded polystyrene foam, PPS-15, PPS-25 and PPS-35 polystyrene foam.

Figure 2. *Scheme of insulation of the enclosing structures of the upper floor of building No. 1 of the Institute of Engineering Thermophysics National Academy of Sciences of Ukraine*

To experimentally determine the dependence on weather conditions of the temperature state of building structures with a layer of insulation, a measuring complex is used, which includes sensors, secondary devices, a convector and a personal computer equipped with special software for further data processing [3].

Quantification of heat loss of wall enclosing structures is determined by installing heat flow converters with a built-in platinum resistance thermometer (PRT) and copper resistance thermometers (CRT), which were used to record temperature indicators. These sensors are installed between the wall and the insulation and on the outer surface of the insulation. They were located practically on one axis, perpendicular to the surface of the wall in such a way as to avoid the influence of sources of heat and moisture release, as well as supply and exhaust openings in the center of a typical thermally homogeneous area (Fig. 3).

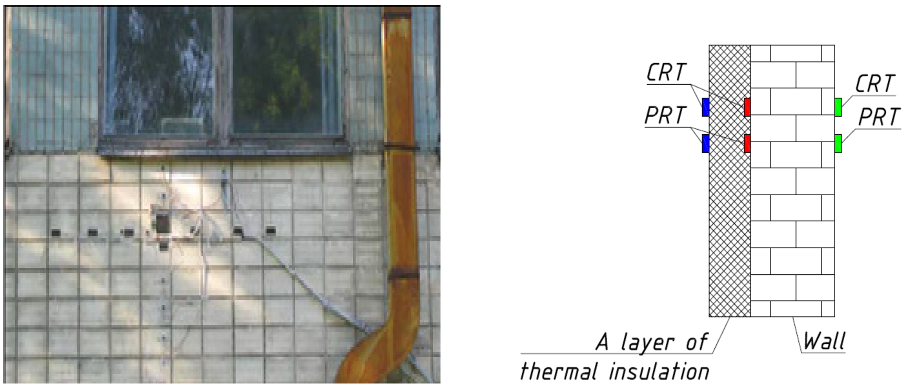

Figure 3. *Installation of resistance thermometers*

The defining thermophysical characteristic of heat-insulating materials is their coefficient of thermal conductivity, which actually determines the reduced resistance of heat transfer through the enclosing structure. To prevent the influence of solar radiation, the most stable experimental data from temperature and heat flow sensors obtained at night are used for calculations.

When calculating heat losses through the enclosing structures of buildings and structures, the value of their heat transfer resistance is usually used:

$$R_{\sum} = \frac{1}{\alpha_1} + \sum_{i=1}^{n} \frac{\delta_i}{\lambda_i} + \frac{1}{\alpha_2} \quad (1)$$

where:

α_1 – coefficient of heat transfer from indoor air to the enclosing structure (8.7 W/m²·K);

α_2 – coefficient of heat transfer from the enclosing structure to the outside air (23 W/m²·K);

δ_i – the thickness of the layer of the enclosing structure, m;

λ_i – coefficient of thermal conductivity, W/m·K.

Over the course of five years, a series of experimental studies of heat transfer through a wall-enclosing structure was conducted in the conditions of the real climate of Kyiv, and a large array of experimental data was obtained. Since the system works in the mode of permanent fixation of the values of the heat flow densities through the thermomodernized enclosing structure, the temperatures of the surfaces of the OC layers and the air of the internal and external environment, the analysis of the information obtained in this way for the entire period makes it possible to determine the effectiveness of various heat-insulating materials in terms of reducing heat loss through the fences of the house and improving the temperature regimes of each of the premises. Temperature and heat flux values were recorded and recorded every 10 minutes.

Experimental and calculated values of thermal conductivity coefficients of heat-insulating layers were determined by the average values of all necessary parameters. A comparative analysis of the actual coefficients of thermal conductivity, calculated based on the data of 2013 and 2019, is shown in the diagram of Figure 4.

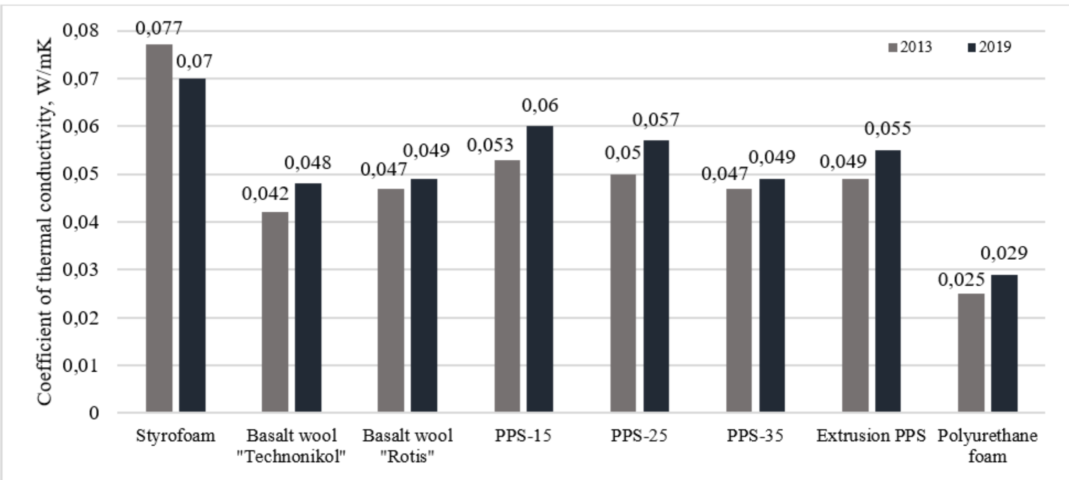

Figure 4. *Experimental and calculated resistances of heat transfer of the enclosing structure for various insulation options*

The graphs in Figure 4 show that the coefficient of thermal conductivity increases during operation. In the future, this factor should be taken into account when conducting engineering calculations. At the same time, the value of thermal conductivity of heat-insulating materials depends on the density of the material, temperature and humidity.

Based on the calculated values of thermal conductivity coefficients of thermal insulation layers according to formula (1), the heat transfer resistance of the entire enclosing structure was calculated for each layer of insulation (Fig. 5).

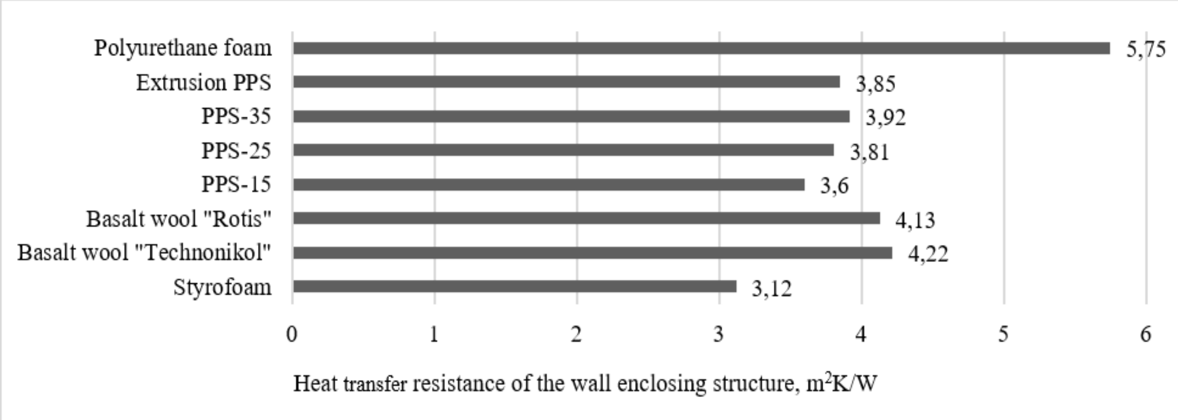

Figure 5. *Experimental and calculated resistances of heat transfer of the enclosing structure for various insulation options*

The main factors of energy efficiency there are the quality of thermal protection of protective structures, ensuring the requirements of thermal comfort of premises, the use of energy-saving systems, technologies and measures. According to the results of impact studies he used of heat-insulating materials in buildings can be claimed to be highly effective in reducing heat loss, buildings through protective structures.

Conclusions

From the results of experimental studies, it follows that an additional layer of insulation on the outer surface of the supporting wall structure contributes both to an increase in the temperature of this surface and to a decrease in the range of its fluctuations with a significant change in the ambient temperature. During long-term operation, heat-insulating materials are constantly exposed to seasonal temperature cyclical effects, and are in a somewhat moistened state, which leads to deterioration of the thermophysical characteristics of the materials.

The need to assess the influence of the service life on the thermophysical properties of heat-insulating materials used in the thermal modernization of buildings of various purposes is experimentally substantiated.

Also, the given results show that the thermal conductivity coefficient increases during operation and should be taken into account during engineering calculations in the future.

The use of experimental and theoretical studies makes it possible to obtain comprehensive information about the thermal properties of enclosing structures and their influence on the energy efficiency of buildings. An important, little-studied factor in the choice of thermal insulation and the design of the building's thermal envelope is the change in the thermal physical characteristics of thermal insulation materials during long-term operation during the service life of the building itself.

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