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METHOD OF EVALUATING THERMAL PROTECTIVE PROPERTIES OF OUTER BUILDING WALLS

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The problem of reducing energy costs for heating is urgent and needs an immediate solution. For this, it is necessary to conduct a wide audit of the heat-insulating properties of buildings. The existing method is based on the experimentally determined indoor and outdoor air temperatures, the temperature of the inner and outer surfaces of the structure and the heat flow through it. Such measurements require a lot of time, complex devices and are not very accurate.

The purpose of the work is to develop and test in practice a method of assessing the thermal insulation property of the outer walls of buildings in natural operating conditions, which would not require the measurement of the heat flow through the wall and would significantly simplify the measurement process.

The method we used is based on the fact that the thermal resistance of the wall and the heat transfer resistance of its inner surface are connected in series. As a result, the temperature difference at the specified resistances is proportional to the resistances $\frac{R_0}{R_a} = \frac{t_k - t_3}{t_k - \tau_6}$, where R_0 is

the heat transfer resistance of the wall, R_a is the heat transfer resistance of its inner surface, t_k and t_{out} are the temperatures of the air in the room and outside, τ_{out} is the inner surface temperature of the wall. This ratio can be used to determine the effectiveness of thermal protection of the wall. For the experimental verification of the proposed method, we conducted a study of heat transfer through the outer wall of a building with walls made of expanded clay concrete panels with two types of thermal insulation.

The results show that the additional thermal insulation of the walls significantly changes the ratio of the heat transfer resistance to the heat transfer resistance of the inner surface. Experiments and calculations proved the correctness of the application of the method of determining the effectiveness of thermal protection of the outer walls of buildings based on the determination of the ratio of the temperature difference in the room and the outside to the temperature difference in the room and on the inner surface of the wall.

Key words: heat-insulating properties, heat transfer resistance, additional thermal insulation.

Івашина Ю. К., Заводяний В. В. Спосіб оцінки теплозахисної властивості зовнішніх стін будівель

Проблема зменшення енергозатрат на опалення є актуальною і потребує негайного вирішення.

Для цього необхідно провести широкий аудит теплозахисних властивостей споруд. Існуючий метод, базується на основі визначених експериментально температур повітря в приміщенні і зовні, температури внутрішньої і зовнішньої поверхонь конструкції і теплового потоку через неї. Такі вимірювання потребують багато часу, складних приладів і не відрізняються високою точністю.

Мета роботи – розробити і перевірити на практиці методіку оцінки теплозахисної властивості зовнішніх стін будівель в природних експлуатаційних умовах, яка б не потребувала вимірювання теплового потоку через стіну і суттєво спростила б процес вимірювання.

Методика, яку ми використали, ґрунтується на тому, що тепловий опір стіни і опір тепловіддачі її внутрішньої поверхні з'єднані послідовно. Внаслідок цього різниця температур на вказаних опорах пропорційна опорам $\frac{R_0}{R_6} = \frac{t_k - t_3}{t_k - \tau_6}$, де R_0 опір теплопередачі

стіни, R_6 опір тепловіддачі її внутрішньої поверхні, t_k і t_3 температура повітря в приміщенні і зовнішня t_{out} температура внутрішньої поверхні стіни. Вказане відношення може бути використаним для визначення ефективності теплового захисту стіни. Для експериментальної перевірки запропонованої методики нами проводилося дослідження теплопередачі через зовнішню стіну будинку зі стінками із панелей з керамзитобетону з двома видами теплового утеплення.

Результати свідчать, що додаткова тепла ізоляція стін суттєво змінює відношення опору теплопередачі до опору тепловіддачі внутрішньої поверхні. Експерименти і розрахунки довели коректність застосування методики визначення ефективності теплового захисту зовнішніх стін будівель на основі визначення відношення різниці температур в приміщенні і зовнішньої до різниці температур в кімнаті і на внутрішній поверхні стіни.

Ключові слова: теплоізоляційні властивості, опір теплопередачі, тепла ізоляція.

Introduction. One of the most important problems facing society today is energy conservation. This is due to both the limitation of hydrocarbon reserves and the pollution of the atmosphere associated with the production and consumption of energy. Most of the energy resources in our country are used for heating domestic and industrial premises, therefore the problem of reducing energy consumption for heating is urgent and requires an immediate solution.

To solve this problem, it is necessary to carry out mass reconstruction of existing buildings in order to improve the thermal insulation properties of the enclosing structures. For this, it is necessary to conduct a wide audit of the heat-insulating properties of buildings. The existing method, which is applied to existing structures, consists in determining the heat transfer resistance of enclosing structures, which is calculated on the basis of experimentally determined indoor and outdoor air temperatures, the temperature of the inner and outer surfaces of the structure, and the heat flow through it. Such measurements require a lot of time, complex devices and are not very accurate.

The aim of research is to develop and test in practice a method of assessing the thermal insulation property of the outer walls of buildings in natural operating conditions, which would not require the measurement of the heat flow through the wall and would significantly simplify the measurement process.

The main part. Heat transfer through a flat wall is of important practical importance and is described in detail in [1]. As a rule, the material of the wall, its thickness, heat transfer coefficients of the outer and inner surfaces of the wall are specified. With stationary heat transfer, the density of the heat flow passing through the wall, the wall layers of the surrounding medium, and the outer and inner surfaces of the wall are equal. From this it follows that the thermal resistances of the heat transfer of the inner and outer surfaces of the wall and the resistance of the wall itself are connected in series.

According to standards [2], the heat transfer resistance of the walls of buildings is equal to R_0

$$R_0 = R_i + R_{\text{out}} + R_r, \quad (1)$$

Where R_i і R_{out} are the resistance of the heat transfer of the inner and outer surfaces of the wall, R_r is thermal resistance of the structure (wall).

Heat transfer resistance of the inner surface of the wall

$$R_B = \frac{t_B - \tau_B}{q} = \frac{1}{\alpha_B} = \frac{1}{\alpha_{\text{кв}} + \alpha_{\text{ін}}} \quad (2)$$

where t_b and τ_B are the temperatures in the room and the inner surface of the wall, α_B the coefficient of heat transfer of the inner surface of the wall, α_{k_b} i α_{r_b} are the coefficients of convective and radiant heat exchange of the inner surface of the wall. Similarly, R_{out} is determined:

$$R_3 = \frac{\tau_3 - t_3}{q} = \frac{1}{\alpha_3} = \frac{1}{\alpha_{k_3} + \alpha_{r_3}} \quad (3)$$

Where α_3 is the heat transfer coefficient of the outer surface of the wall, τ_3 i t_3 are the temperatures of the outer surface of the wall and the outside air.

Thermal resistance of a wall that has several layers of different materials

$$R_k = \sum \frac{\delta_i}{\lambda_i}, \quad (4)$$

where λ_i i δ_i are the coefficients of thermal conductivity and the thickness of the i -th layer of the wall. The heat transfer coefficients of the inner and outer surfaces are determined by building regulations [4].

There are a number of methods of experimental determination of heat transfer resistance of enclosing structures. The samples are measured in laboratory conditions according to [5]. In natural conditions – according to [2]. In these methods, the heat flow through the structure and the temperature of its inner and outer surfaces are measured, which requires special devices and considerable time. There is not always access to the outer surface of the wall.

When designing buildings, the heat transfer resistance of walls and other enclosing structures is calculated according to [2–4] using expressions (1)–(4). The disadvantages of using this method to determine the heat transfer resistance of existing buildings are that it is not always possible to determine the material and thickness of the layers of the structure, in the process of operation there is a gradual degradation of the operational characteristics of the enclosing structures and a change in the thermal conductivity coefficients of the materials [6].

For conducting a mass thermal audit of existing buildings for the purpose of their reconstruction, the specified methods for determining the heat transfer resistance can have only limited application due to their complexity and considerable labor intensity.

The method we used is based on the fact that the thermal resistance of the wall and the heat transfer resistance of its inner surface (the resistance of the wall layer of air) are connected in series, and the same heat flow q passes through them. As a result, the temperature difference at the indicated resistances is proportional to the resistances

$$q = \frac{t_k - \tau_a}{R_a} = \frac{t_k - t_3}{R_0} \quad (5)$$

where R_a is the heat transfer resistance of the inner surface of the wall, t_k i t_3 are the temperatures of the air in the room and outside, τ_a the inner surface temperature of the wall. It follows from (5).

$$\frac{R_0}{R_a} = \frac{t_k - t_3}{t_k - \tau_a} \quad (6)$$

The ratio of the heat transfer resistance of the wall R_0 to the heat transfer resistance of its inner surface R_a is equal to the ratio of the temperature difference in the room and the outside, to the temperature difference on the inner wall layer of air, which is the essence of the patent [7]. Since R_a is determined according to the standards according

to formula (2), where the heat transfer coefficient of the inner surface $\alpha_e = 8,7 \frac{Bm}{M^2 K}$ [4], the heat transfer resistance will be proportional to R_e and the ratio of the temperature difference. Thus, the ratio of temperature differences in (6) is proportional to the heat transfer resistance of the wall and can be used to determine the effectiveness of thermal protection of the wall. For this, it is necessary to determine only the temperature in the room and outside, which is quite simple, and the inner surface temperature τ_B . It can be determined using a thermocouple or an infrared pyrometer.

Since the heat transfer coefficient of the surface depends on the movement of air layers, for measurements it is necessary to choose sections of the wall where there are no curtains, furniture and other objects that could change the nature of air movement in the wall layer, and, accordingly, the coefficient α_B . Will differ from that determined by building regulations. The error in determining the heat transfer resistance of the wall according to the method [2] is less than 15%, provided that the temperature difference between the wall surfaces is greater than 33°C. Since our proposed methodology does not measure the heat flow l of the outer surface temperature the wall, the error in determining the effectiveness of the thermal protection of the walls will be determined by the error of the heat transfer coefficient α_B and the error in measuring the indoor t_k and outdoor temperatures, as well as the difference between and the inner surface t_k of the wall. According to our calculations, the relative error in determining the ratio of resistances (6), i.e., the efficiency of thermal protection of the walls, will not exceed 5% when using a graduated thermocouple and appropriate devices.

In order to experimentally verify the proposed method of assessing the thermal insulation property, we conducted a study of heat transfer through the outer wall of a nine-story building with walls made of expanded clay concrete panels. In order to identify the effect of thermal insulation on the thermal insulation property of the wall, apartments were selected that are in the same conditions (facing one outer wall of the building). In addition, the wallpaper in the rooms was of the same type. The air temperature was determined using a mercury thermometer with a division value of 0.2°C, the temperature difference between the air in the room and the inner surface of the wall – using a differential copper-constantan thermocouple. The error in determining this temperature difference was 4.4%. Measurements were carried out in rooms without insulation, with insulation of the inner surface of the wall with rolled polystyrene foam 5 mm thick and polystyrene foam plates 5 cm thick glued to the outer surface.

The results of the study are shown in Table 1. The ratio of the heat transfer resistance R_0 to the heat transfer resistance R_i was determined based on (6), $\Delta t_1 = t_k - t_3$ is the difference between the air temperatures in the room and outside. $\Delta t_2 = t_k - \tau_B$ is temperature difference on the inner wall layer of air.

The data in Table 1 show that the additional thermal insulation of the walls significantly changes the ratio of the heat transfer resistance to the heat transfer resistance of the inner surface, which is determined by the ratio of temperature differences $\frac{\Delta t_1}{\Delta t_2}$, which indicates the correctness of the application of the proposed method for determining the effectiveness of thermal protection of walls.

Conclusions. The calculation of the heat transfer resistance and the thermal resistance of the wall according to (1) and (4) performed for the case of insulation with polystyrene foam plates showed that the increase in heat transfer resistance is slightly higher than that calculated on the basis of the data in Table 1, according to which due to the

Table 1
Dependence of the ratio of the heat transfer resistance of the expanded clay wall R_0 to the heat transfer resistance of its inner surface R_i on the type of insulation

Type of insulation	$\Delta t_1, ^\circ\text{C}$	$\Delta t_2, ^\circ\text{C}$	
without insulation	26,5	2,3	
insulation of the inner surface	26,7	2,1	12,7
insulation of the outer surface	27,8	1,3	21,2

thermal insulation of the outer surface with polystyrene foam plates, the heat transfer resistance increased in 1.9 times. This can be explained by the fact that during operation, the thermal conductivity of the thermal protection increased due to contamination and wetting.

Experiments and calculations proved the correctness of the application of the method of determining the effectiveness of thermal protection of the outer walls of buildings based on the determination of the ratio of the temperature difference in the room and the outside to the temperature difference in the room and on the inner surface of the wall.

The advantage of the proposed method is that it does not require measuring the heat flow through the wall and the temperature of its outer surface, which significantly simplifies the measurement process. Determination of temperatures is carried out under natural operating conditions. Due to the simplicity of the methodology, it can be used to conduct a wide thermal audit of existing buildings.

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