UDC [628.8]536.1
DOI https://doi.org/10.32782/tnv-tech.2025.1.58

DETERMINATION OF HEAT TRANSFER RESISTANCE OF EXTERNAL WALLS OF BUILDINGS IN NATURAL CONDITIONS

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Energy saving is one of the most important problems of the 21st century. Most of the energy resources in Ukraine are used for heating residential and industrial premises, so reducing energy consumption for heating is relevant and this problem needs to be solved. It can be solved by carrying out a mass reconstruction of existing buildings in order to increase the thermal insulation properties of buildings. For this, it is necessary to conduct a wide audit of them. The existing method consists in determining the heat transfer resistance of the enclosing structure, which is determined based on measuring the air temperature in the room and outside, the temperature of the internal and external surfaces of the structure and the heat flow through it. Such a method requires a lot of time for measurement, complex devices and is not very accurate. The purpose of the work is to develop a method for determining the heat transfer resistance of external walls of buildings in full-scale operating conditions, which would not require measuring the heat flow through the wall and the temperature of its external surface and would significantly simplify the measurement process. The method is based on the fact that the heat transfer resistance of the wall R_0 consists of the thermal resistance of the wall and the heat transfer resistances of its inner R_2 and outer R_3 surfaces, which are connected in series, as a result of which the temperature difference on the specified resistances is proportional to their value $q=\frac{t_2-t_3}{R_0}=\frac{t_2-\tau_2}{R_2}$, where q is the heat flux density, t_2 and t_3 are the indoor and outdoor temperatures, τ_2 is the temperature of the inner wall surface. The resistance R_0 is determined by building codes $R_0=\frac{1}{\alpha_2}$ where α_2 =8.7 W/(m^2 K) is the heat transfer coefficient of the inner surface, therefore $R_0=\frac{1}{8,7}\frac{t_2-t_3}{t_2-\tau_2}$ m^{2}K/W. The method works as follows: measurements are made during the heating period in natural operating conditions of the temperature in the room, the external and internal surface temperatures of the wall. The heat transfer resistance is calculated through the ratio of temperature differences and the known heat transfer coefficient of the internal surface. The proposed method for determining the heat transfer resistance of walls excludes the measurement of heat flow, measurements are made in natural operating conditions. These advantages allow using this method when conducting a thermal audit of buildings

Key words: *heat transfer resistance, natural conditions, simplification of measurements.*

Івашина Ю. К., Гончаренко Т. Л., Заводянний В. В. Визначення опору теплопередачі зовнішніх стін будівель в натурних умовах

Енергозбереження є однією із найважливіших проблем 21 сторіччя. Більша частина енергоресурсів в Україні іде на опалення житлових та виробничих приміщень, тому зменшення енерговитрат на опалення є актуальним і ця проблема потребує вирішення.

Її можна розв'язати шляхом проведення масової реконструкції існуючих будівель з метою підвищення теплоізоляційних властивостей будівель. Для цього необхідно провести їх широкий аудит. Існуючий метод полягає у визначені опору теплопередачі огороджувальної конструкції, який визначається на основі вимірювання температури повітря в приміщені і зовні, температури внутрішньої і зовнішньої поверхонь конструкції і теплового потоку через неї. Такий метод потребує багато часу на вимірювання, складних приладів і не відрізняється високою точністю.

Мета роботи – розробити метод визначення опору теплопередачі зовнішніх стін будівель в натурних експлуатаційних умовах, який би не потребував вимірювання теплового потоку через стіну і температури її зовнішньої поверхні і суттєво спростив би процес вимірювання. Метод базується на тому, що опір теплопередачі стіни R_0 складається із теплового опору стіни і опорів тепловіддачі її внутрішньої R_2 і зовнішньої R_3 поверхонь, які з'єднані послідовно, внаслідок чого різниця температур на вказаних опорах пропорційна їх величині $q=\frac{t_2-t_3}{R_0}=\frac{t_2-\tau_2}{R_2}$*, де q – густина теплового потоку,* t_2 *і* t_3 *– температури в приміщені і зовнішня,* τ_2 *– температура внутрішньої поверхні стіни. Опір* R_4 *визначається будівельними нормами* $R_0=\frac{1}{\alpha_2}$*, де* α_2*=8,7 Вт/(м²K) – коефіцієнт тепловіддачі внутрішньої поверхні, тому* $R_0=\frac{1}{8{,}7}\frac{t_2-t_3}{t_2-\tau_2}$ *м²К/Вт.*

Спосіб працює наступним чином: проводять вимірювання в опалювальний період в натурних експлуатаційних умовах температури в приміщенні, зовнішньої і температури внутрішньої поверхні стіни. Опір теплопередачі розраховують через відношення різниць температури і відомий коефіцієнт тепловіддачі внутрішньої поверхні.

Запропонована методика визначення опору теплопередачі стін виключає вимірювання теплового потоку, вимірювання проводяться в натурних експлуатаційних умовах. Ці її переваги дозволяють використовувати дану методику при проведені теплового аудиту будівель.

Ключові слова: *опір теплопередачі, натурні умови, спрощення вимірювань.*

Introduction. Energy conservation is one of the most important problems of the 21st century. This fact is a consequence of the limited reserves of hydrocarbons and the need to combat air pollution associated with the production and consumption of energy. In addition, most of the energy resources in Ukraine and other countries with a temperate climate are used for heating residential and industrial premises, so the problem of energy conservation in the field of heating is relevant and needs to be studied and solved.

Analysis of recent research and publications. This problem can be solved by carrying out a mass reconstruction of existing buildings in order to increase the thermal insulation properties of the enclosing structures. For this, it is necessary to conduct a wide audit of the thermal insulation properties of buildings. The method applied to existing buildings is to determine the heat transfer resistance of the enclosing structures [1]. It is calculated on the basis of experimentally determined external temperature, indoor temperature, temperatures of the internal and external surfaces of the structure and the heat flow through it. This method requires a lot of time for measurement, complex devices and is not very accurate. We have proposed a method for assessing the heat-shielding properties of building walls that does not require measuring the heat flow [2], but it does not allow determining the heat transfer resistance, which is regulated by building codes [1,3].

Research Objective. The purpose of the work is to develop a method for determining the heat transfer resistance of external walls of buildings in full-scale operational conditions, which would not require measuring the heat flow through the wall and the temperature of its outer surface and would significantly simplify the measurement process. Presentation of the main material Heat transfer through a flat wall is of important practical importance, has been studied by many scientists and is described in detail in [4]. The problem is solved on the basis of data on the wall material, its thickness, and the heat transfer coefficient of the outer and inner surfaces. In a stationary process, the density of the heat flow passing through the wall and the air layers near the wall is the same, therefore the thermal resistance of the structure (wall) R_1, the heat transfer resistance of its inner R_2 and outer R_3 surfaces are connected in series. According to the standards [1], the heat transfer resistance of the wall R_4 is equal to

$$R_0=R_1+R_2+R_3 \tag{1}$$

Thermal resistance of a wall that has several layers of different materials [1,3]

$$R_1 = \sum \frac{\delta_i}{\lambda_i} \tag{2}$$

where δ_i i and λ_i are the thickness and thermal conductivity coefficient of the i-th layer of the wall. Heat transfer resistance of the inner surface of the wall [1,3]

$$R_2 = \frac{t_2 - \tau_2}{q} = \frac{1}{\alpha_2} = \frac{1}{\alpha_{20} + \alpha_{21}} \tag{3}$$

where q is the heat flux density, t_2 and τ_2 are the temperatures in the room and the inner surface of the wall, α_{20} and α_{21} are the coefficients of convective and radiant heat transfer of the inner surface of the wall, α_2 is the heat transfer coefficient of this surface. The resistance R_3 is determined similarly

$$R_3 = \frac{t_3 - \tau_3}{q} = \frac{1}{\alpha_3} \tag{4}$$

where τ_3 and t_3 are the temperature of the outer surface and the outer, α_3 is the heat transfer coefficient of the outer surface of the wall. The heat transfer coefficients of the outer and inner surfaces are determined by building codes [1]. There are several methods for experimentally determining the heat transfer resistance of enclosing structures. In laboratories, measurements are carried out on samples according to [5]. In natural conditions – according to [1]. These methods are based on measuring the heat flow through the structure and the temperatures of its inner and outer surfaces. This requires special devices and measurements are carried out for a long time to establish the heat balance. In addition, there is not always access to the outer surface of the structure. Theoretical calculations of the heat transfer resistance of enclosing structures are performed when designing buildings according to [1,3] using expressions (1-4). But for determining R_0 of existing buildings, this method has limited application, since it is not always possible to establish the material and thickness of the layers of the enclosing structure, and because during operation there is a degradation of the operational characteristics of the enclosing structures and a change in the thermal conductivity coefficients of the materials. When conducting a mass thermal audit of existing buildings, the considered methods for determining the heat transfer resistance can have only limited application due to their complexity, significant labor intensity and significant error. We have proposed a method for determining the heat transfer resistance of the external walls of buildings in full-scale operational conditions, which does not require measuring the heat flow through the wall and the temperature of its outer surface, which significantly simplifies the process of determining R_0 [6]. Since the supports in (1) are connected in series, the temperature difference across the supports is proportional to their value

$$q = \frac{t_2 - t_3}{R_0} = \frac{t_2 - \tau_2}{R_2} \quad (5)$$

The heat transfer resistance of the inner surface R_2 is determined according to (3), where the heat transfer coefficient of the inner surface α_2=8,7 W/(m^{2}K) [1, 3], therefore, from (5) it follows

$$R_0 = \frac{1}{8,7} \frac{t_2 - t_3}{t_2 - \tau_2} \; m^2K/W \quad (6)$$

The method works as follows: measurements are made during the heating period in natural operating conditions of the temperature in the room, the outside temperature and the temperature of the inner surface of the wall. The heat transfer resistance of the wall is calculated through the ratio of the difference in temperature in the room and the outside to the temperature difference in the inner wall air layer and the known heat transfer coefficient of the inner surface of the wall.

This coefficient depends on the movement of air layers near the wall, therefore, for measurements, it is necessary to select those sections of the wall where there are no objects that could change the nature of air movement in the near-wall layer and, accordingly, the coefficient α_2 will differ from that specified by building codes.

The error in determining the heat transfer resistance of enclosing structures according to [1] is less than 15% provided that the temperature difference between the surfaces of the structure is greater than 330C. Since the method proposed by us does not measure the temperature of the outer surface and the heat flux density, the error in determining the heat transfer resistance is equal to the sum of the relative errors in determining α_2 and the error in the ratio of the temperature difference, which can be made less than 5%. Errors $\frac{\Delta\alpha_2}{\alpha_2}$ consists of the error inherent in [1] and the error of applying the tabulated value to real walls. By selecting the necessary devices and fulfilling the necessary requirements, it is possible to achieve that the total error in determining R_0 will not exceed 10%, which is less than that regulated by building codes, but the measurement process is significantly simplified.

In order to experimentally verify the proposed method for determining the heat transfer resistance, we determined the resistance of a silicate brick wall in a five-story building according to (6) and by calculations according to (1-4). For a wall without thermal insulation, the value obtained on the basis of experimental data turned out to be 5% less than calculated, and for a wall with thermal insulation with polystyrene foam plates 5 cm thick – 13% less. This can be explained by the increase in the thermal conductivity of materials, primarily due to their wetting. The results obtained indicate the correctness of the proposed method for determining the heat transfer resistance of external walls of buildings.

Conclusions and prospects for further research. Experiments and calculations have proven the correctness of the application of the method for determining the heat transfer resistance of external walls of buildings based on determining the ratio of the temperature difference in the room and outside to the temperature difference in the room and on the inner surface of the wall and the known heat transfer resistance of the inner surface.

The proposed method excludes the measurement of heat flux through the wall and the temperature of its outer surface, which significantly simplifies the measurement process. Temperature determination is carried out in full-scale operating conditions. These advantages of this method, as well as the simplicity of its application, compared to traditional ones, allow using the proposed method when conducting a thermal audit of buildings during their reconstruction to reduce heat losses.

In the future, we plan to determine the influence of different types of wall insulation on their heat transfer resistance using the developed method.

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