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EVALUATION OF THERMAL RESISTANCE OF EXTERNAL PROTECTION DURING THERMAL RENOVATION OF THE BUILDING

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Currently, the problem of energy-saving construction remains extremely relevant. The application of thermorenovation measures for existing public and residential buildings is one of the ways to solve the problem of rational use of fuel and energy resources. In this article, one of the thermorenovation measures is considered, in particular, the installation of additional external insulation to insulate external walls on the example of a general secondary education institution.

The results of the research made it possible to evaluate the thermal stability of the fences as a result of insulation, so it was established that gas consumption and gross carbon dioxide emissions when using insulation with a thickness of 150 mm is reduced by almost 4.5 times.

The proposed thermoregulation measures bring buildings into compliance with state regulations and increase indoor comfort by equalizing the average temperature and eliminating cold bridges.

Keywords – energy saving, thermal renovation, thermal insulation, thermal imaging, mineral wool, natural gas.

Introduction

Today, the problem of energy independence of our country is acute. According to statistics, the total consumption of natural gas in Ukraine for 2021 amounted to 26.8 billion m^3, in turn, gas production amounted to 19.8 billion m^3. The difference is 7 billion m^3 (www.epravda.com.ua; www.nova.poltava.ua; www.zakon3.rada.gov.ua).

It is worth mentioning the situation with a shortage of natural gas in 2021, the price of which in the countries of the European Union reached record values and reached more than 2,000 euros per thousand cubic meters.

Considering the situation that has developed in connection with the aggression of the Russian Federation against Ukraine, we can predict an even greater shortage of energy resources, including natural gas. Drawing parallels with the situation on the fuel market, we see that prices do not have a certain "ceiling". Thus, in 2021, during the heating season, the price of natural gas for legal entities reached 73.262 hryvnias per 1.000 cubic meters (January 2022). Today, one of the most important conditions for the economic and social development of the state is the solution to the problems of energy intensity of production and energy conservation of the economy, which in recent years have threatened national security in the economic sphere. Today, solving the problem of forming a balanced system of energy security of the state and bringing Ukraine to the level of energy self-sufficiency remains relevant. (Zhangabay N., 2022)

One of the problems in the housing sector remains the obsolescence and emergency of residential real estate, which determines the need for major repairs and thermal modernization in order to bring it into compliance with the minimum requirements for the energy efficiency of the building, thus ensuring during the expected life cycle of the building the satisfaction of human needs and the creation of optimal microclimatic conditions conditions for her stay and residence (Reis A., 2022; Erba S., 2022; Nasrollahzadeh N., 2021; Pungercar V., 2021). The set of thermal modernization works involves improving the thermal performance of the building's enclosing structures, the consumption of energy resources by engineering systems, and ensuring the energy efficiency of the building is not lower than the established minimum requirements for the energy efficiency of the building and requires significant financial investments (Spindler U., 2022). The problem of thermal renovation is acute not only in Ukraine, this problem is solved with various scientific and technical approaches (Barahona B., 2021; Fernandez-Luzuriaga J., 2022; Li H., 2022; Mehregan M., 2022; Popescu L. L., 2021) taking into account ethnic, economic and climatic features in many countries of the world (Echlouchi K., 2022; Gonzalez-Caceres A., 2022; Milovanovic B., 2022; Ricci M., 2022; Wu H., 2022; Zhang X., 2021). In addition to the energy-saving effect, thermal renovation measures reduce the negative impact on the environment by reducing carbon dioxide emissions into the atmosphere (Chen R., 2021; Kalbasi R., 2022; Nema-tchoua M. K., 2022).

Today, heat consumption in the housing and communal economy of Ukraine is twice as high as in Belarus and 3–5 times more than in European countries with a similar climate. Almost half of the heat is lost due to poor insulation of buildings and lack of control and management of heat distribution systems. All this requires the use of such a reserve as energy saving in all spheres of activity, especially in the residential and communal sphere. That is why, in the updated version of the Energy Strategy of Ukraine for the period until 2030, one of the priorities is the formation of an energy-efficient society, the functional task of which involves energy saving and energy efficiency along with the formation of energy-efficient consciousness among the citizens of our country (www.epravda.com.ua; www.nova. poltava.ua; www.zakon3.rada.gov.ua).

Materials and Methods

The object of the research was a public building built in 1829. Today, an institution of general secondary education of the 1st degree (ZZSO) functions in it. The building has three floors and a basement. The dimensions of the building are 38.52×14.59 m, the height is 13.5 m. The outer wall consists of brickwork of solid brick, clay brick, ordinary brick on a cement-sand mortar with a thickness of 510 mm, reinforced concrete floor slabs with a thickness of 220 mm. The roof is insulated with a layer of mineral wool 0.2 m thick. Windows and doorways are filled with window and door blocks made of metal-plastic profiles. The area of the transparent fence does not exceed the value determined by the current regulatory documents. The general appearance of the building is presented in Fig. 1.

Fig. 1. General view of the school building.
(Source: https://www.google.com/maps/)

The building is of sufficient age and in the course of its operation current and capital repairs took place. Today, it does not meet the necessary requirements for external building structures according to DBN V.2.6-31:2016 “Thermal insulation of buildings”. Therefore, the task was set to evaluate the effectiveness of thermal renovation measures on the example of this building, since there are still quite a few such objects in operation today.

Results and discusions

To solve the set goal, the research was carried out in two stages. At the first stage, a thermal imaging survey of the building envelope and thermal engineering calculation of the existing external protections were carried out. Surveys were carried out in the cold period of the year during the heating period. On Figs. 2 and 3 shows the typical results of the work carried out.

a *b*

Fig. 2. Results of thermal imaging of an element of the external facade of the building.
a – photo of the element of the facade of the building; b – temperature field of the facade element

During the inspection, it was found that the construction of the outer wall has unsatisfactory thermal protection. So, in particular, with Fig. 2 (b) it can be seen that at the temperature of the outside air tout = -3.3 °C, the surface of the outer wall has a temperature, twall, respectively: point 1 – $twall_1$ = 10.0 °C; point 2 – $twall_2$ = 9.9 °C; point 3 – $twall_3$ = 8.8 °C. This is due to the lack of a layer of thermal insulation in the structure of the outer wall, which is the cause of excessive transmission heat losses. The thermal engineering calculation of this structure confirmed the low thermal stability of the external protection, which consists of solid brickwork with a thickness of 510 mm, and plaster of cement-lime mortar on both sides (Fig. 3).

It can be seen from the figure that at the temperature of the outside air tout = -19 °C and the temperature of the air in the room tin = 20 °C, the temperature of the inner surface of the outer wall is tin.wall = 14.5 °C. This distribution of temperatures indicates intense heat loss and has an adverse effect on the human body, since the temperature difference is $\Delta t \approx 5$ °C.

Therefore, after analyzing the conducted research on the basis of thermal imaging and thermal engineering calculation of the outer wall, it was proposed to introduce one of the thermal renovation measures – the application of additional thermal insulation from mineral wool, the technical characteristics of which are presented in Table 1.

Table 1

Physical and technical characteristics of thermal insulation

No.	Name of insulation	Thermal conductivity coefficient, λ, W/mK
1	Mineral wool	0.036

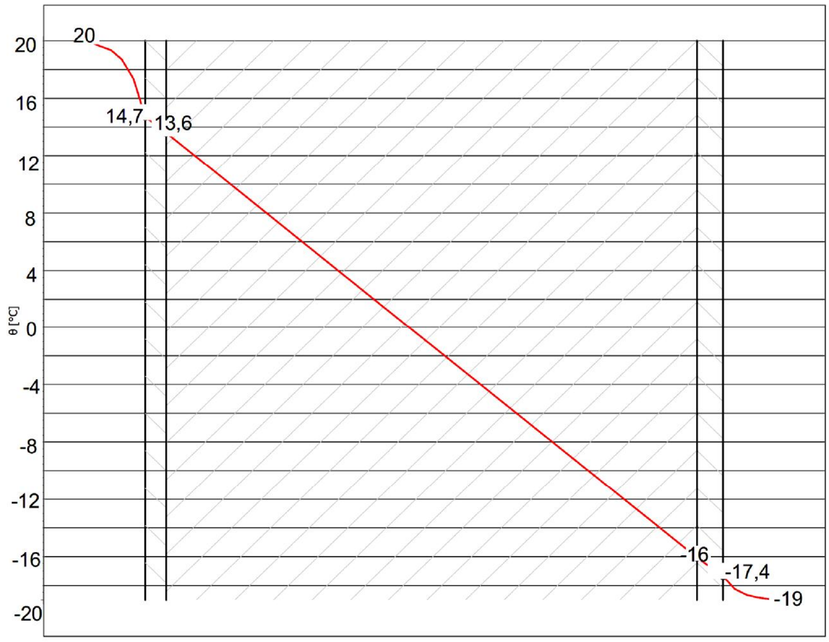


Fig. 3. Temperature distribution in the thickness of the non-insulated outer

The application of thermal insulation was proposed to be carried out on the facade of the building outside the enclosing structure. Fastening of the insulation to the bearing structure of the wall is provided by gluing with a special adhesive solution, and in characteristic places it is additionally provided with special dowels. On top of the insulation, it is planned to stick a reinforcing mesh, prime the reinforced surface and apply decorative plaster.

For this design, a thermal engineering calculation was performed and the temperature distribution in the thickness of the proposed protection was obtained (Fig. 4).

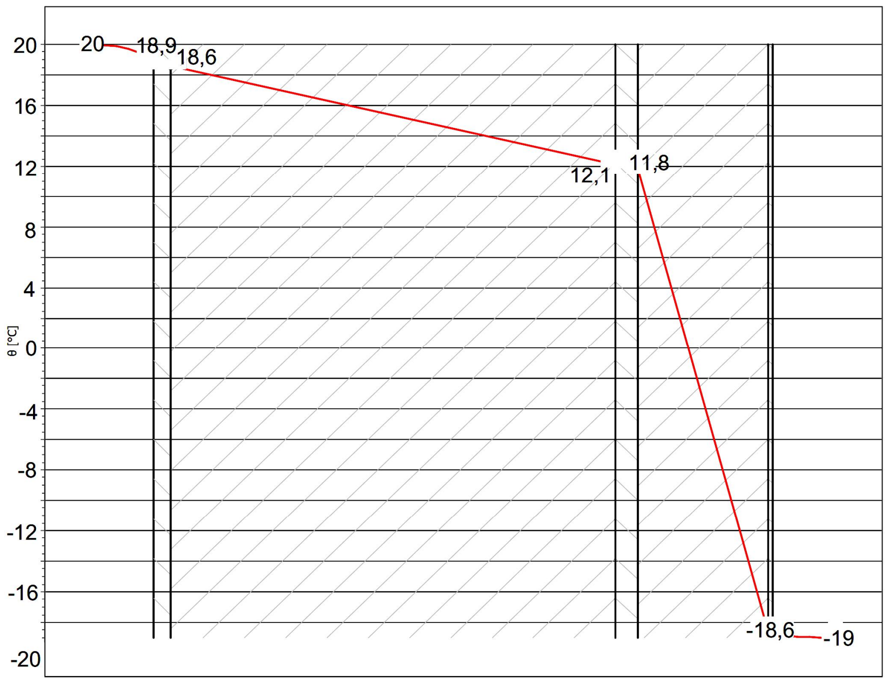
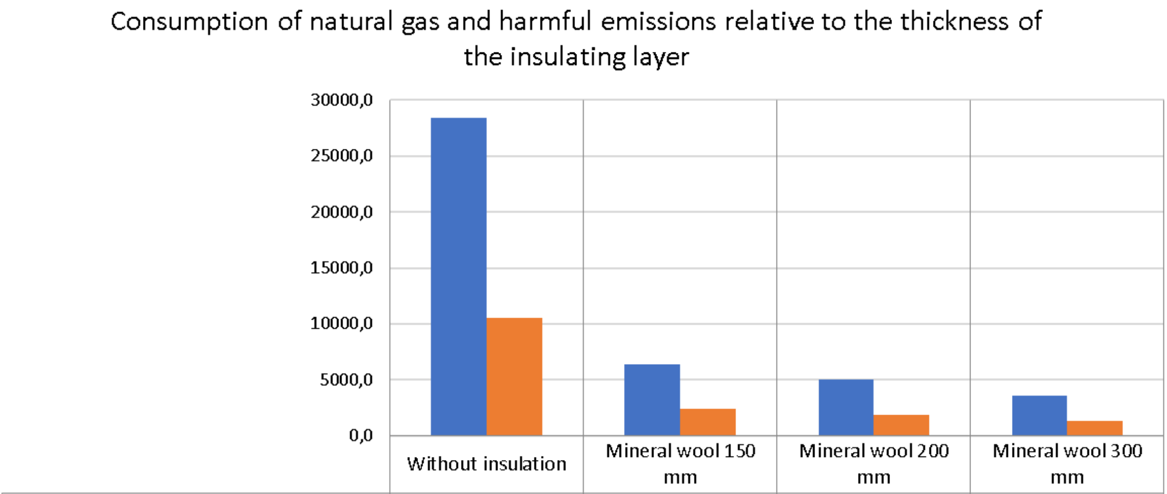


Fig. 4. Temperature distribution in the thickness of the insulated outer wall

It can be seen from the figure that the installation of additional thermal insulation made it possible to increase the temperature of the inner surface of the outer mesh from 14.5 °C to 19 °C. This, in turn, significantly improves the overall thermal condition of the building by raising the average temperature in the premises. In addition, improving the thermal stability of the outer shell of the building due to the installation of thermal insulation made it possible to reduce the cost of thermal energy for heating the building.

The next stage of the research was the implementation of an economic and ecological assessment of the proposed thermorenovation measure. With the help of the Audytor OZC software complex, the seasonal consumption of natural gas, which is consumed during the generation of thermal energy to compensate for heat losses through the external walls of the educational institution, is determined. Calculations were carried out for thermal insulation with a thickness of 150 mm, 200 mm and 300 mm. The density of natural gas was assumed equal to 0.723 kg/m^3, the lower working heat of fuel combustion was 45.75 MJ/kg. The arrangement of additional insulation allows to reduce not only the consumption of organic fuel, but also, accordingly, the emission of carbon dioxide into the atmosphere. The results of the research are presented in Fig. 5.



	Without insulation	Mineral wool 150 mm	Mineral wool 200 mm	Mineral wool 300 mm
Gross emission of carbon dioxide, kg/year	28413,6	6337,2	5056,0	3616,1
Mass consumption of gas, kg/year	10571,6	2357,8	1881,1	1345,4

Fig. 5. Natural gas consumption for heating the school building and carbon dioxide emissions with insulation thicknesses of 150 mm, 200 mm and 300 mm

It can be seen from the figure that the seasonal consumption of gas and the gross emission of carbon dioxide when using insulation with a thickness of 150 mm is reduced by almost 4.5 times.

Conclusions

Summarizing all of the above, we can come to the conclusion that thermoregulation measures not only bring the operation of buildings into compliance with current state norms and standards in construction in order to reduce the consumption of an extremely important strategic energy resource, natural gas, the shortage of which endangers the heating season in the state, but also increase comfort in the premises by equalizing the average temperature and eliminating cold bridges.

Therefore, with constant investments of money in energy rehabilitation, thermal renovation of buildings of educational institutions, other budgetary institutions, residential buildings, these measures will ultimately lead to a significant reduction in fuel consumption, release of resources, improvement of the ecological and economic situation in the country. Thus, having evaluated the thermal stability of external protections after their insulation, using the example of one of the schools, it was established that only one of many possible thermal renovation measures allows to significantly reduce energy consumption and carbon dioxide pollution of the environment. Applying thermal insulation in the form of mineral wool with a thickness of only 150 mm makes it possible to reduce the emission of carbon dioxide and the consumption of natural gas as fuel for the heating system by almost five times.

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ОЦІНКА ТЕПЛОВОЇ СТІЙКОСТІ ЗОВНІШНІХ ЗАХИЩЕНЬ ПРИ ТЕРМОРЕНОВАЦІЇ БУДІВЛІ

Сьогодні одними з найважливіших умов економічного та соціального розвитку держави є вирішення проблем енергоємності виробництва та енергетичного збереження економіки, які протягом останніх років загрожували національній безпеці в економічній сфері. Важливим залишається вирішення проблеми формування збалансованої системи енергетичної безпеки держави та виведення України на рівень енергетичного самозабезпечення.

Також актуальною залишається проблема енергоощадного будівництва. Застосування термореноваційних заходів для існуючих громадських та житлових будинків є одним зі шляхів вирішення проблеми раціонального використання паливноенергетичних ресурсів.

Споживання тепла в житлово-комунальному господарстві України в 3–5 разів більше ніж у європейських країнах із подібним кліматом. Майже половина теплоти втрачається через погане утеплення будівель і відсутність керування та управління системами розподілу теплоти. Усе це потребує використання такого резерву як енергоощадність у всіх сферах діяльності, особливо у житлово-комунальній сфері.

В цій статті розглянуто один із термореноваційних заходів, влаштування додаткової зовнішньої ізоляції для утеплення зовнішніх стін на прикладі закладу загальної середньої освіти. Результати досліджень дали можливість оцінити теплову стійкість огороджень в результаті утеплення, так було встановлено, що витрата газу та валовий викид діоксиду вуглецю при застосуванні утеплювача товщиною в 150 мм зменшується майже у 4,5 рази.

Запропоновані заходи терморегуляції не тільки приводять експлуатацію будинків у відповідність державним нормам та стандартам у будівництві з метою зменшення споживання природного газу, дефіцит якого ставить під загрозу опалювальний сезон в державі, але й підвищують комфорт у приміщеннях за рахунок вирівнювання середньої температури та усунення містків холоду.

Ключові слова: енергоощадність, термореновація, теплова ізоляція, тепловізійна зйомка, мінеральна вата, природний газ.