Вісник Тернопільського національного технічного університету
https://doi.org/10.33108/visnyk_tntu
Scientific Journal of the Ternopil National Technical University
2024, № 3 (115) https://doi.org/10.33108/visnyk_tntu2024.03
ISSN 2522-4433. Web: ***visnyk.tntu.edu.ua***

UDC 658.5 (691.12)

FEATURES OF INCREASING THE ENERGY EFFICIENCY OF BUILDINGS AND TRANSPARENT FENCING STRUCTURES

Volodymyr Bobyk; Halyna Kramar

Ternopil Ivan Puluj National Technical University, Ternopil, Ukraine

Abstract. *On the basis of thermograms the heat losses of various parts of buildings are analyzed and measures to reduce them are proposed. It is determined that he main causes of heat loss through the walls, roof, roofhatch, floor, and windows are the irrational use of materials and absence or unprofessional insulation. It is shown that to increase the energy efficiency of the building, it is necessary to ensure the use of modern high-quality thermal insulation materials and control over the quality of work. The heat transfer resistance of single- and double insulating glass units of arbitrary dimensions (1.2 m x 1.2 m) with aluminium, steel and plastic spacer frame are calculated and their influence on the heat transfer resistance is evaluated. 3.2% increase in the heat transfer resistance of the single chamber insulating glass units and 12.6% increase in the heat transfer resistance of double chamber one is achieved due to the application of plastic spacer frame instead of metal one.*

Key words: *energy efficiency, translucent fencing structures, insulating glass units, heat loss, heat transfer resistance***,** thermally improved spacer (TIS). *polyurethane, composite based on spherulite.*

https://doi.org/10.33108/visnyk_tntu2024.03.044 *Received 03.08.2024*

1. INTRODUCTION

At the state level, the introduction of laws, standards, and requirements for incresing the energy efficiency of buildings are tools for reducing energy consumption and the country's energy dependence as well [1–4]. At the consumer level, for the residents of multi-apartment and private houses, the increase in the cost of energy carriers resulted in the necessity to identify the sources of heat leaks and find ways to avoid them. Therefore, it is important to identify places of heat loss in various premises, including those through transparent fencing structures, and to develop recommendations for improving their energy efficiency due to the application of innovative materials with increased thermal insulation characteristics.

Until 2022, the improvement of energy efficiency of buildings has been an important task for the innovative development of Ukraine and its economy. This problem has not lost its relevance under martial law, as on relatively peaceful territories of Ukraine, construction is an important source of budget revenues, and the loss of the significant part of power generation has resulted in severe restrictions on the use of electricity by existing housing stock and to the increased requirements for energy efficiency of buildings to be constructed in the future. These problems, as well as Ukraine's orientation towards joining the European Union, will accelerate the transition to European energy efficiency and energy consumption standards during the thermal modernization of existing buildings and the construction of new ones.

For a long time the problem of increasing the energy efficiency of buildings has been and remains the focus of attention of Ukrainian and foreign scientists [5–8]. Evaluation of the energy efficiency of buildings, including individual elements of the thermal insulation shell, is carried out both experimentally on the basis of thermograms obtained from the energy audit results [9] and analytically on the basis of various energy modeling models, which take into account the maximum possible number of micro- and macro-parameters of influence on thermal characteristics of the building [10–12]. In paper [10], it is concluded that under uncertainty and difficulty in determining the values of indicators of a large number of micro-parameters, the macro-parameters are the main

 Corresponding author: Halyna Kramar; e-mail: vr@tntu.edu.ua

ones for modeling. Other researchers [6, 8, 9], as well as the methodology [2], focus on micro-parameters and the intensity of their impact on energy efficiency of buildings, and the data concerning the effect of various factors are wide-ranging.

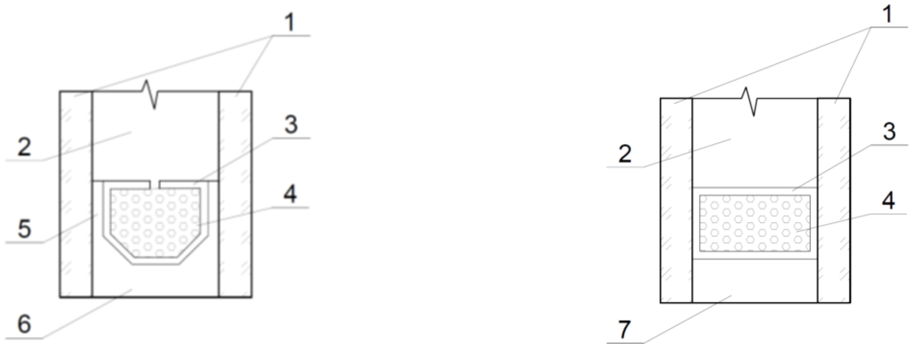
An important element in reducing heat loss and increasing energy efficiency of buildings is transparent fencing structures and their thermal characteristics [13–16]. The evaluation of their energy efficiency and ways of its improvement relate, mainly, to the materials of insulating glass unitsand frames, places where transparent fencing structures adjoin the walls, the type of heating, as well as their geometric parameters and structural features of profile systems. Computer programs for calculation of energy efficiency of such structures, including windows and doors, at the design stage – «OKNA.ua Window and Door Energy Calculator» [17], WinDoPlan [18] have been developed. They have a wide range of possibilities, however, they include standard materials and the nomenclature of components of transparent structures used by manufacturers.

2. EXPERIMENTAL METHODS

To identify the locations of heat losses in the building, the causes of heat loss through the transparent fencing structures, particularly where the windows adjoin the wall, to determine the causes of their occurrence and to develop organizational and technical solutions for their elimination thermograms obtained due to the thermal imaging were used.

The effect of materials and structural features of the spacer on the reduced heat transfer resistance of insulating glass unitswere analyzed.

A typical design of the spacer made of aluminum or stainless steel with seal layer (butyl sulfide) and sealant (polysulfide) (a) and the proposed structure consisting of polyurethane or polypropylene spacer and spherolite based composite sealant (b) are shown in Fig. 1.



a) b)

Figure 1. Examples of spacer structures: 1 – glass, 2 – chamber, 3 – spacer (metal (a), polyurethane (b)), 4 – molecular sieve, 5 – butyl sulfide, 6 – polysulfide, 7 – spherolite based composite

The spacer is considered to be TIS if condition is met [19]:

$$\sum (d\,\lambda) \leq 0{,}007 \text{ W/m}\cdot\text{K}, \quad (1)$$

where d is thickness of the spacer, mm;
λ is the material thermal conductivity, W/m·K.

The heat transfer resistance was calculated for insulating glass units with arbitrary sizes (1.2 x 1.2 m) (Fig. 2): ordinary glass, spacer width – 16 mm, single- and double-chamber ($4M_1$-16-$4M_1$ and $4M_1$-16-$4M_1$-16-$4M_1$ respectively), chamber environment – air, profile material – PVC, spacer materials – aluminium, stainless steel (wall thickness 0.25 mm), plastic (6 mm).

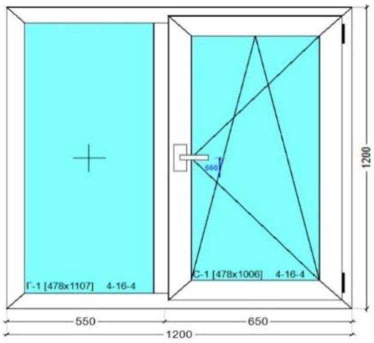


Figure 2. The structure of the insulating glass unit for the calculation of the reduced heat transfer resistance

3. RESULTS AND DISCUSSION

Energy-efficient measures for reducing heat loss are relevant for existing buildings, especially those ones built before 1993. Their reduced heat transfer resistance usually does not meet the existing standards which result in significant energy consumption costs.

The procedure for calculating heat loss through the building fencing strusture is based on the values of heat transfer resistance [3]. For the 1st temperature area, which includes most regions of Ukraine, the reduced heat transfer resistance (R*qmin*) for external wall fencing structures should be at least 4 $m^2 \cdot K/W$

Heat loss of the building is determined by the following formula:

$$Q = A(Tp - Text)(1 + \sum \beta) n / R, \quad (2)$$

where A is a calculated area of fencing structures;
R is a heat transfer resistance of the fencing structure,
Tp is a calculated air temperature,
$Text$ is a calculated outdoor air temperature of the cold season for calculation of heat loss through the external fencing or air temperature of the colder room for calculation of heat loss through the internal fencing,
$\sum\beta$ are additional heat losses as a share of the main losses,
n is a coefficient determined depending on the position of outer surface of the fencing structure.

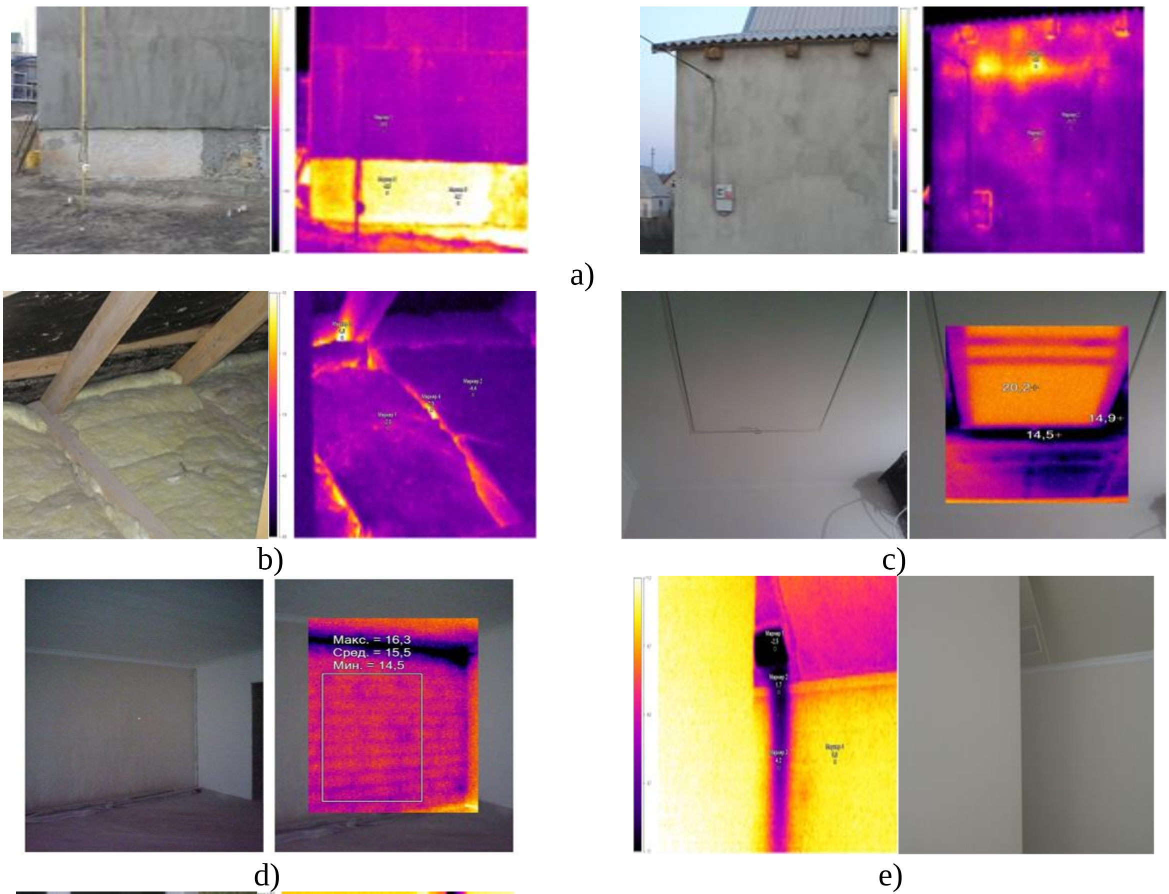
Comfortable indoor air temperature for human habitation should be 18–24°C [1] and it depends on the type of the room. Different types of heating systems are used to maintain such temperature indicators in the cold season, but it is not always possible to achieve the desired result. One of the significant reasons for this situation is the heat loss of the house.

The main places of heat losses localization in the building, as their intensity decreases, are losses through walls, ventilation/chimney, roof, windows, floor/basement. The heat losses of building elements using thermograms (Fig. 3) obtained in paper [5] are analyzed.

The main amount of heat in the house is lost through the walls (Fig. 3 a), their area is larger compared to other fencing structures. It is evident from thermograms that the temperature is unevenly distributed on the wall surface. In certain areas, the wall are heated up more strongly than in others – in these areas heat losses are greater. The reason in the first case is the lack of insulation in the foundation part of the building, and in the second case, inefficient insulation. Probably, in these places the foam is damaged, unprofessionally installed or absent. «Cold bridges» associated with the use of materials with lower heat transfer resistance during construction and wall insulation are shown in the thermogram. Therefore, it is necessary to ensure not only the use of high-quality thermal insulation materials, but also the quality of installation work in the process of building insulation. Among the wide range of thermal insulation materials, the most common ones for wall insulation and heat loss reduction are: foam, mineral wool, polyurethane foam, etc. It is known that in terms of rational location of the dew point, the buildings are usually insulated from the outside.

Roof insulation is an important element of thermal modernization of the building, as up to 30% of heat is lost due to the lack of insulation or improper roof structure**.** For example, at the junction between mineral wool and wooden beam, there are additional heat losses caused by insufficient sealing (Fig. 3 b). The places where cold enters the room are hatches in the attic (Fig. 3 c) or the junction of roof windows and the roof. In order to prevent the negative impact of external and internal environments during new construction or repair of old private cottage-type houses, hydro-, vapor-, windproof films made of polyethylene reinforced with aluminum tape, polypropylene, polyvinyl chloride, membrane materials – diffusion ones with small holes and superdiffusion, which have higher properties for steam penetration – are used. For effective thermal insulation of the roof, it is necessary to combine rationally the under-roof layers of films for various purposes and insulation with the provision of structure ventilation.

According to various sources, heat loss through the floor ranges from 5 to 20% and is typical for private houses and the first floor of multi-storey buildings, where the floor is in direct contact with the foundation or basement (Fig. 3 d). An important element for reducing heat loss is insulation and waterproofing of the foundation, especially if the building has a basement. In new construction, a fixed formwork is used for this purpose. Extruded polystyrene foam (XPS), buried 15–20 cm below ground level, is an effective base insulation material for shallow foundations during building repairs. It can be used for floor insulation as well.



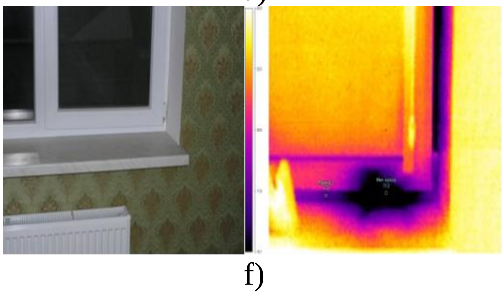


Figure 3. Heat loss through building elements: walls (a), roof (b), roof hatch (c), floor (d), ventilation (e), windows (f) [5]

In order to prevent fairly large (up to 35%) losses due to the ventilation (Fig. 3 e), it is important for air to be removed from the room through the ventilation channels, without moving in the opposite direction, forcing cold outdoor air inside. This causes drafts and cools the room down.

Heat loss through transparent fencing structures is mainly due to the application of cheap, low-quality windows with worn and sagged seals; single-chamber ordinary double-glazed windows; insufficient pressing of the window to the window frame; poor installation of the window (Fig. 3 f). All these factors result in the increase of heat loss in the building up to 20–25%. This problem is especially relevant while using panoramic windows and for facades with continuous glazing.

Windows replacement is one of the most important stages in the process of thermal modernization of the building, as they determine the level of energy efficiency, thermal comfort and heating costs. Modern insulating glass unitsare chosen depending on the needs and requirements of State Building Standards (SBS) to ensure sufficient insolation and sound insulation of the room, to obtain additional thermal energy from sunlight for room heating, and to protect against burglary and breakage.

In the double-glazed window, glass occupies more than 85% of the window area. However, even the most perfect double-glazed unit in combination with high-class profile becomes unusable if cold bridges are formed and heat losses occur (Fig. 3 f).

The primary issue is to improve the thermal insulation characteristics of the junctions between windows and walls, where not only heat loss but moisture accumulation occur. The main drawbacks to the quality of window companies' work are related to assembly seams. Unqualified installation creates significant heat loss around the structure perimeter and results in the destruction of the assembly seam in a short period of time. Therefore, the durability of the assembly joints and their technically correct sealing play an important role in the level of energy consumption and tightness of the structure. In this regard, when replacing windows, professional installation («warm installation»), in accordance with the requirements of DSTU [20] is an important factor.

The difference between "warm" and ordinary installations is that in the former one, the foam layer is protected on both sides by vapor barrier and waterproofing films (Fig. 4), since the mounting foam loses its thermal insulation properties under the influence of moisture.

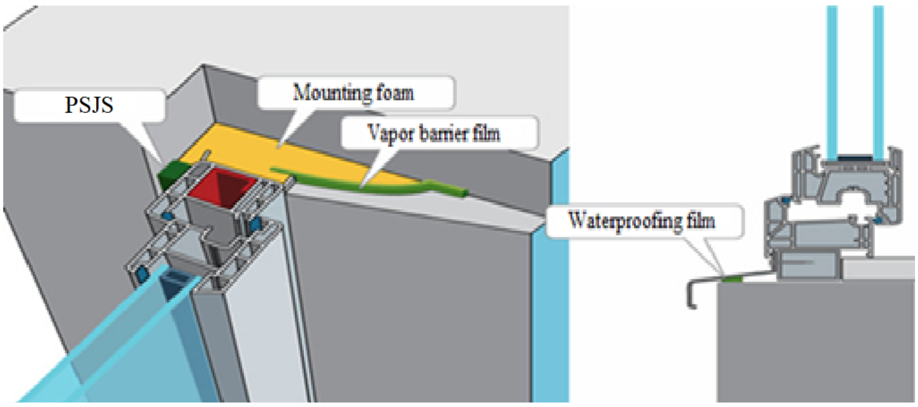


Figure 4: Elements of «warm installation» of PVC windows according to DSTU

Thus, during «warm installation» of windows, high thermal insulation performance is achieved by means of several layers of insulation. Internal sealing is ensured by the application of vapor barrier tape, which prevents the penetration of moisture inside the room. The middle layer is heat- and sound-insulating polyurethane foam that works effectively in dry state. The waterproofing film in the outer layer prevents the penetration of moisture from the outside and at the same time makes it possible to remove excess moisture from the inside.

While using vapor barrier and waterproofing films, there is no blowing of the installation seam, the thermal insulation of the entire structure and the durability of the installation seam are increased. However, this increases the cost of installation due to the additional use of consumables, and there is the need of preliminary preparation of the opening for the window and for making internal and external slopes for a certain period of time in order to prevent the destruction of films under the influence of ultraviolet radiation [16]. Warm installation is more expensive than ordinary one, but its costs are recouped by reducing energy costs. It is not reasonable to mount well-equipped window without protecting the mounting seam from moisture.

The requirements for thermal properties of transparent fencing structures are constantly increasing. Thus, according to [3], the minimum value for R_{qmin} is 0.9 m² K/W. In order to increase energy efficiency, the double-glazed chambers are filled with gas (argon, krypton, xenon) and i-glass with low-emission energy-saving coating is used. Taking into account the fact that the greatest heat losses in insulating glass units occur in the edge zone, the materials and design features of the spacer frame deserve special attention.

As a rule, manufacturers install spacers in insulating glass units. They are made of aluminum or stainless steel, which have high thermal conductivity, are heat conductors and reduce the temperature on the glass on the inside of the window. To compensate the high thermal conductivity, metal spacers are produced with small thickness – aluminum 0.03 mm, stainless steel 0.1...0.2 mm. The alternative to metal spacers is 6 mm thick plastic spacer (*thermally improved spacer (TIS)*).

The main advantages of the TIS are reduction of heat loss of the insulating glass units in the edge area due to the lower thermal conductivity of the plastic spacer compared to aluminum; reduction of the risk of fogging effect on the windows at the edges; prevention of condensation and ice, which can result in the formation of mold hazardous to health; maintaining the tightness of insulating glass units for a long time, especially when they are filled with inert gases; reduction of gas loss rates from insulating glass units from 20–30% to 0.6% per year, increase in sound insulation of insulating glass units by 18%; increased impact resistance of insulating glass units [21, 22].

More than 15 types of spacers are used on the world market. They differ in material and geometry [19]. It is possible to reduce the thermal conductivity and increase the heat transfer resistance of the plastic spacer by replacing polyvinyl chloride or polycarbonate with solid polyurethane or polypropylene, which have lower thermal conductivity.

Polyurethane can also be used to replace butyl sealant. In addition, in order to increase the energy efficiency of insulating glass units, it is reasonable to replace butyl with innovative thermal insulation material such as spherolite, whose thermal conductivity does not exceed 0.032 W/m·K, with various fillers.

The formula (1) condition was verified for spacer shown in Fig. 1 (b). For polyurethane spacer with 6 mm thickness, the thickness of spherolite based sealant was determined. The coefficient of thermal conductivity of polyurethane is 0.02 W/m·K, of spherolite – 0.032 W/m·K. The calculated value d should not exceed 0.2125 m, which is significantly larger than the actual dimensions of the spacer and indicates that the selected materials are effective as TIS.

To increase the energy efficiency of the insulating glass units, it is important to determine the patterns of influence of the spacer material on its reduced heat transfer resistance, which is calculated by the following formula:

$$R_o = S_{igu} /(S_v / R_{igu} + S_{wf} / R_{wf} + K\,L), \text{m}^2\cdot\text{K/W} \tag{3}$$

where S_{igu} is the total area of the insulating glass unit;
S_v is the total area of the visible part of the insulating glass unit;
R_{igu} is the heat transfer resistance of the calculated insulating glass unit;
S_{wf} is the total area of the opaque element (window frame);
R_{wf} is the heat transfer resistance of the window frame;
K is linear coefficient of heat transfer resistance of the spacer in the insulating glass unit;
L is the total length of the spacer in the insulating glass unit.

Under the same conditions, the decrease in the product $K\,L$ results in the increase of the reduced heat transfer resistance of the insulating glass units. Therefore, the influence of the spacer material on the heat transfer resistance of the insulating glass unit was evaluated by the percentage of the third term in the denominator of formula (3). Taking into account that relative and not absolute values were determined, the heat transfer resistance was calculated for insulating glass units with arbitrary sizes (1.2 x 1.2 m) (fig 2).

The initial data for the calculation are shown in Table 1.

Table 1

The initial data for the calculation of the reduced heat transfer resistance of the insulating glass units

Number of chambers in the insulating glass units	S_{igu}, m^2	S_v, m^2	S_{wf}, m^2	R_{igu}, m²·K/W	R_{wf}, m²· K/W	K, W/m K [19]			L, m
						Aluminiun	Stainless steel	Plastic	
1	1.44	1.01	0.43	0.32	-	0.05	0.05	0.03	6.14
2				-	0.52	0.07	0.07	0.04	12.28

The calculation results (Table 2) testified that the application of plastic spacer in single-chamber insulating glass units with given dimensions has increased the heat transfer resistance by 3.2%. For metal spacer, the percentage of the product $K\,L$ is 7.74%, and for plastic it is equel to 4.78%.

Table 2

The reduced heat transfer resistance of the insulating glass units with different material of spacer

Number of chambers in the insulating glass units	R_o, m²·K/W		
	Aluminium	Stainless steel	Plastic
1	0.363	0.363	0.375
2	0.436	0.436	0.491

For double chamber insulating glass units, this difference is even more significant. For metal spacers, the percentage of the product $K\,L$ is 26%, and for plastic spacer equals to 16.75%, which resulted in the increase of the heat transfer resistance by 12.6%. Thus, the replacement of the materials of all elements of the spacer due to the reduction of their thermal conductivity increases the heat transfer resistance of the insulating glass units and ensures optimal indoor climate.

The reduction in building heating costs as the result of the application of TIS in insulating glass unitswill provide micro-level savings for a specific consumer. However, if a large number of windows with warm distance are installed during new construction or during thermal modernization of the old housing stock, a significant result is obtained at the macro level. The reduction of heat loss results in less energy consumption, especially non-renewable energy for heating. Positive result is also achieved from the environmental point of view, as emissions of carbon dioxide and other greenhouse gases into the atmosphere are reduced and the need for fossil fuels is minimized. The application of TIS with innovative materials will have positive effect on the micro- and macrolevels.

Analysis of the causes for unpredictable heat loss in the building, including through transparent fencing structures, testified that the main problems are related to the irrational use of materials and technological shortcomings at different stages of construction or reconstruction. Thus, to improve the energy efficiency of the building, it is necessary to analyze trends in the development of new technologies and materials and use analytical models of energy consumption at the design stage, to monitor the performance of work at the construction or reconstruction stage, and to replace worn or damaged structural elements in a timely manner during operation.

4. CONCLUSIONS

On the basis of thermograms analysis the localization of the main places of heat loss in residential buildings through the walls, roof, roof hatch, floor, ventilation was analyzed and organizational and technical solutions for their reduction were proposed. It is determined that the main causes of heat loss are the irrational use of materials and technological shortcomings at different stages of construction or reconstruction.

It is shown that professionally performed «warm» installation is effective in the improvement of energy efficiency of transparent fencing structures in the places where windows join the wall. In order to improve the thermal characteristics of the insulating glass units spacer, it is reasonable to use heat insulating materials with low thermal conductivity coefficient – polyurethane or polypropylene and spherolite based composite.

The regularities of the influence of spacer frame material on the heat transfer resistance of the insulating glass units are determined. It is shown that, under the same conditions, the percentage of metal spacers contribution to the formula for the calculation of heat transfer resistance of insulating glass units is 7.74%, and that of plastic spacers is 4.78%, which resulted in the increase of the heat transfer resistance of the single-chamber insulating glass units with arbitrary dimensions (1.2 m x 1.2 m) by 3.2%. For two-chamber insulating glass units, the percentage of contribution of metal spacers is 26%, and plastic spacer 16.75%, while the heat transfer resistance increased by 12.6%.

References

1. Law of Ukraine “On Energy Efficiency of Buildings” [Electronic resource]: as of June 2, 2017. Verkhovna Rada of Ukraine. Officer. Ed.-k., Vedomosti Verkhovna Rada, 2017. 204 p. [In Ukrainian].
2. Methodology for determining the energy efficiency of buildings Order of the Ministry of Regional Development, Construction and Housing and Communal Economy of Ukraine dated July 11, 2018, no. 169. Registered in the Ministry of Justice of Ukraine on July 16, 2018 under No. 822/32274. Available at: https://zakon.rada.gov.ua/laws/show/z0822-18#Text. [In Ukrainian].
3. SBS V.2.6-31:2021 Thermal insulation and energy efficiency of buildings. [In Ukrainian].
4. DSTU 9191:2022 Thermal insulation of buildings. The method of choosing heat-insulating material for building insulation. [In Ukrainian].
5. Fareniuk H. G. Basics of ensuring energy efficiency of buildings and thermal reliability of enclosing structures. K., Gama-Print, 2009, 216 p. [In Ukrainian].
6. Ratushnyak G. S., Pankevich V. V. Hierarchical classification of influencing factors on increasing the energy efficiency of the thermal insulation shell of buildings. Modern technologies, materials and structures in construction, 2020, no. 1, pp. 87–94. Doi: 10.31649/2311-1429-2019-2-204-209. [In Ukrainian]. https://doi.org/10.31649/2311-1429-2019-2-204-209
7. Kuznetsova O. O., Zhukinska I. S. Evaluation of saving energy resources for heating during thermal modernization of a residential building. Visnyk KNUTD, 2015, no. 5 (90), pp. 81–90. [In Ukrainian].
8. Yang S. et al. Comparison of sensitivity analysis methods in building energy assessment. Procedia Engineering, vol. 146, 2016, pp. 174–181. https://doi.org/10.1016/j.proeng.2016.06.369

9. Ratushnyak G. S., Ocheretny A. M. Energy audit of multi-story residential buildings using thermal imaging. Modern technologies, materials and structures in construction, 2017, no. 1 (22), pp. 84–93. [In Ukrainian].
10. Wei Tian. A review of sensitivity analysis methods in building energy analysis /Renewable and Sustainable Energy Reviews, vol, 20, April 2013, pp. 411–419. https://doi.org/10.1016/j.rser.2012.12.014
11. Yusuf Yıldız, Zeynep Durmuş Arsan. Identification of the building parameters that influence heating and cooling energy loads for apartment buildings in hot-humid climates. Energy, volume 36, issue 7, July 2011, pp. 4287–4296. https://doi.org/10.1016/j.energy.2011.04.013
12. Hangxin Li, Shengwei Wang, Howard Cheung. Sensitivity analysis of design parameters and optimal design for zero/low energy buildings in subtropical regions. Applied Energy, volume 228, 15 October 2018, pp. 1280–1291. https://doi.org/10.1016/j.apenergy.2018.07.023
13. Ratushnyak G. S., Pankevich O. D.,. Pankevich V. V. Heat-technical features of translucent enclosing structures of buildings. Modern technologies, materials and structures in construction, vol. 30, no. 1, 2021, pp. 148–156. [In Ukrainian]. https://doi.org/10.31649/2311-1429-2021-1-148-156
14. Ratushnyak G. S., Pankevich O. D., Pankevich V. V. Evaluation of energy efficiency of translucent enclosing structures of buildings. Modern technologies, materials and constructions in construction, 2021, no. 2, pp. 81–87. [In Ukrainian]. https://doi.org/10.31649/2311-1429-2021-2-81-87
15. Pravilenko N. M., Zhirma S. O. Reducing the heat loss of buildings by applying energy-efficient design and technological solutions of junction nodes of modern translucent enclosing structures. Collection of works of young scientists of KNTU. Kirovohrad, KNTU, 2014, issue III, pp. 800–801. [In Ukrainian].
16. Zhao J, Du YH Multi-objective optimization design for windows and shading configuration considering energy consumption and thermal comfort: A case study for office building in different climatic regions of China. SOLAR ENERGY, 2020, vol. 206, pp. 997–1017. https://doi.org/10.1016/j.solener.2020.05.090
17. Energy calculator of windows and doors. OKNA.ua. Available at: https:// okna.ua/enereffektivnost_okna. [In Ukrainian].
18. WinDoPlan. Available at: https://veka.ua/ua/partners/spravochnik/articles/profile/windoplan-pravilne-ta-zruchne-proektuvannya-vikon-za-normami/. [In Ukrainian].
19. DSTU-N B V.2.6-146:2010 Structures of buildings and structures. Guidelines for the design and arrangement of windows and doors. [In Ukrainian].
20. Warm remote frame"-an innovation in the energy saving market. Available at: https://www.okna-modern.com.ua/ua/tyoplaya-distancziya-v-steklopakete-–-innovacziya-na-ryinke-energosberegayushhix-okon.html. [In Ukrainian].
21. Warm remote frame. Available at: https://www.swisspacer.com/en/insights/warm-edge-knowledge.
22. Mi-SuShin, Kyu-NamRhee, Ji-YongYu and Gun-Joo Jung Determination of Equivalent Thermal Conductivity of Window Spacers in Consideration of Condensation Prevention and Energy Saving Performance. Energies 2017, 10, 717. Doi: 10.3390/en10050717. [In Ukrainian]. https://doi.org/10.3390/en10050717
23. DSTU B EN ISO 10077-1:2022 Thermal properties of windows, doors and blinds. Calculation of the heat transfer coefficient. Part 1. General conditions (EN ISO 10077-1:2006 + EN ISO 10077-1:2006/AC:2009, IDT). [In Ukrainian].
24. DSTU B EN ISO 10077-2:2022 Thermal properties of windows, doors and blinds. Calculation of the heat transfer coefficient. Part 2. Numerical calculation methods for window frames (EN ISO 10077-2:2012+EN ISO 10077-2:2012/AC:2012, IDT). [In Ukrainian].
25. DSTU B V.2.6-79:2009 Structures of buildings and structures. Seams of connecting points of abutments of window blocks to wall structures. General technical conditions.

УДК 658.5 (691.12)

ОСОБЛИВОСТІ ПІДВИЩЕННЯ ЕНЕРГОЕФЕКТИВНОСТІ БУДІВЕЛЬ І СВІТЛОПРОЗОРИХ ЗАГОРОДЖУВАЛЬНИХ КОНСТРУКЦІЙ

Володимир Бобик; Галина Крамар

Тернопільський національний технічний університет імені Івана Пулюя, Тернопіль, Україна

Резюме. *Перехід на європейські норми енергоефективності при зведенні нового житла й термомодернізації існуючого житлового фонду в Україні, обмеженість і висока вартість енергоресурсів* *роблять проблему підвищення енергоефективності будівель і споруд особливо актуальною. На основі теплограм проаналізовано тепловтрати різних частин будівель і запропоновано заходи щодо їх зниження. Причиною тепловтрат через стіни є відсутність або непрофесійно виконана ізоляція. Тому для підвищення енергоефективності будівлі потрібно забезпечити використання сучасних якісних теплоізоляційних матеріалів і контроль за якістю монтажних робіт. Для ефективної теплоізоляції даху потрібно раціонально комбінувати шари гідро-, паро-, вітрозахисних плівок і утеплювача, забезпечуючи вентиляцію конструкції. Тепловтрати через фундамент можна зменшити шляхом використання незйомної опалубки для його утеплення й гідроізоляції. Причиною тепловтрат через світлопрозорі загороджувальні конструкції є використання дешевих неякісних вікон, однокамерних склопакетів зі звичайним склом, здійснення неякісного монтажу. Для підвищення енергоефективності вікон у місцях їх примикання до стіни потрібно здійснювати «теплий монтаж», при якому використовують шари паро- і гідроізоляційних плівок. Для підвищення теплотехнічних характеристик теплої дистанційної рамки склопакета доцільно використовувати теплоізолюючі матеріали з низьким коефіцієнтом теплопровідності – поліуретан чи поліпропілен і композит на базі сфероліту. Розраховано опір теплопередавання одно- й двокамерного склопакетів довільних розмірів (1,2 м х 1,2 м) з різними матеріалами дистанційної рамки й оцінено їх вплив на опір теплопередавання. Підвищення опору теплопередавання однокамерного склопакета на 3,2%, а двокамерного на 12,6% досягнуто за рахунок використання пластикової дистанційної рамки замість металевих.*

Ключові слова: *енергоефективність, світлопрозорі загороджувальні конструкції, вікно, тепловтрати, опір теплопередавання, тепла дистанційна рамка, поліуретан, композит на базі сфероліту.*

https://doi.org/10.33108/visnyk_tntu2024.03.044 *Отримано 03.08.2024*