DOI 10.34185/1562-9945-1-150-2024-12
UDC 536.212: 699.059

O.V. Kravets, K.V. Makhonina

THE INFLUENCE OF THE MATERIAL AND THE THICKNESS OF THE INSULATION LAYER ON THE HEAT FLOW THROUGH A MULTI-LAYER EXTERNAL WALL PANEL OF A RESIDENTIAL BUILDING

Abstract. Solved the actual problem of heat flow research through a multi layer external wall panel of a residential building, depending on the material and thickness of the heat insulating layer.
Key words: multi layer external wall panel, heat flow, thermal insulation material, temperature, insulation of a residential building.

Introduction. Taking into account the limited non-renewable organic energy resources on Earth, as well as the insufficient power of renewable energy sources, the issues of energy conservation, in general, and heat preservation in residential premises, in particular, become actual. Heat losses in the room can be significantly reduced thanks to properly selected heat-insulating materials and the optimal thickness of the corresponding layer of the multilayer external wall panel. This direction of research contributes to solving the problem of energy saving, which is urgent for Ukraine, one of the most important directions of technical policy in the field of construction.

Analysis of recent research and publications. Industrial and residential buildings must meet certain requirements, the main of which include: durability, reliability and economy. At the same time, the fulfillment of thermo- and physical laws is of great importance when studying the influence of the environment on the microclimate inside the room and vice versa when there is a wide use of new building materials and technologies. External enclosing wall panels affect heat flows that are lost by the house in the cold period of the year and enter the premises in the spring and summer period. At the same time, a thermal calculation is carried out, in the process of which the temperature field and heat flows are calculated, after which the thermal insulation condition of the enclosing structures is evaluated, that is, the heat absorption of the room is determined.

In [3], a one-dimensional numerical model was developed that characterizes the coupled heat exchange between a three-layer wall and a closed cavity. This model is applied to study the passive control and stability of the indoor air temperature of a closed cavity that can simulate a living space. The exposed wall consists of a phase-changing material enclosed in a rectangular container and framed with insulating and building material. Numerical analysis was carried out using an implicit finite-difference scheme. Numerical simulations were performed with three types of phase-changing material. The results showed that for indoor air temperature stability and control, the choice of phase change material is based on its melting point, which is preferably chosen close to the thermal comfort temperature and with significant latent heat. The authors assure that the presented calculation algorithm can be extended to the multilayer wall and the porous layer of the multilayer wall and used to determine the optimal position and thickness of the layer of the phase-changing material.

Daily characteristics of air temperature near the surface and the surface energy balance of building massifs under different environmental conditions are studied in [5]. Direct solar radiation, wall height, and wall orientation are important factors that affect diurnal variations in wall surface temperature. Two types of buildings were studied: the "hollow" model means hollow concrete buildings and the "water" model, whose walls are partially filled with water. In the course of research, it was found that the water model has a smaller average daily temperature range in the room than the hollow model due to heat accumulation. This study can provide experimental data to validate numerical and theoretical models for research on the influence of climatic conditions on the thermal quality of building structures.

Ecological buildings and ecological projects require architectural designers to improve existing basic building codes and regulations in order to improve the overall energy efficiency of the building, optimize the ventilation of the building, minimize the environmental impact during the life cycle and create a comfortable living environment.

The work [4] presents a study of the influence of the geometric dimensions of the room on air ventilation in it, taking into account the heat exchange between the human body and the environment. Solar effects were taken into account only on the roof of the building. The results showed that the presented technique can help in ventilation design and reasonably predict the ventilation flow. The method developed in this study can be extended to design and analyze other types of natural ventilation in buildings.

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

Composite-aluminum honeycomb panel is a reliable construction heat-insulating material; its advantages: a small value of the coefficient of thermal conductivity, low weight and high plasticity. This material can be used as insulation for brick and panel buildings in order to create light, high-strength and heat-insulating external walls. However, the application of composite aluminum honeycomb panels in practice is still not well researched because it is difficult to determine the optimal core size and number of layers with the best structural organization and the least heat transfer.

In the article [6], three main mechanisms of heat transfer are systematically analyzed for a composite-aluminum honeycomb panel: thermal conduction, thermal convection, and thermal radiation. The influence of the geometric dimensions of the cell, including its height and wall thickness, on the process of heat transfer in stationary conditions was investigated by experimental methods.

With the help of the ANSYS software, taking into account the experimental data, a liquid-solid heat transfer model was created for the composite-aluminum honeycomb plate in order to simulate the steady-state heat transfer characteristics of single-layer and multi-layer composite sheets. As a result of the comparison, it was found that the values of the effective thermal conductivity of the composite-aluminum cellular panel under different boundary conditions and different geometric parameters are basically consistent with the experimental data.

Thus, the review of the latest research shows that, despite the diversity of research on the thermal efficiency of the external walls of buildings, the issue of choosing the material for the thermal insulation layer of multilayer wall panels and their geometric dimensions remains actual.

The purpose of the study: to determine the dependence of the amount of heat flow through a four-layer wall panel of a residential building on the material and thickness of the heat-insulating layer.

Presentation of the main material of the study. Calculated cases of the location of building materials in the layers of the wall panel and their coefficients of thermal conductivity are presented in the table 1.

Table 1

The location of building materials in the layers of the wall panel and their thermal conductivity coefficients λ, $kcal/(m \cdot h \cdot grad)$

<table>
<tr><td></td><td colspan="4">Wall panel layers</td></tr>
<tr><td>Material of a layer</td><td>Concrete inner textured layer</td><td>Cement fibrolite</td><td>Thermal insulation layer</td><td>Concrete outer textured layer</td></tr>
<tr><td>Layer thickness, mm</td><td>80</td><td>70</td><td>55, 70, 90, 110, 200</td><td>40</td></tr>
<tr><td>Number of a layer / Calculation case number</td><td>1</td><td>2</td><td>3</td><td>4</td></tr>
<tr><td>1</td><td rowspan="5">1,400</td><td rowspan="5">0,130</td><td>mineral wool plates 0,060</td><td rowspan="5">1,400</td></tr>
<tr><td>2</td><td>peat insulation plates 0,055</td></tr>
<tr><td>3</td><td>building felt 0,050</td></tr>
<tr><td>4</td><td>urea-formaldehyde foam plastic (mipora) 0,045</td></tr>
<tr><td>5</td><td>polystyrene foam 0,040</td></tr>
</table>

The scheme of the arrangement of layers in a multilayer wall panel in relation to the interior and the environment is shown in Figure 1.

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

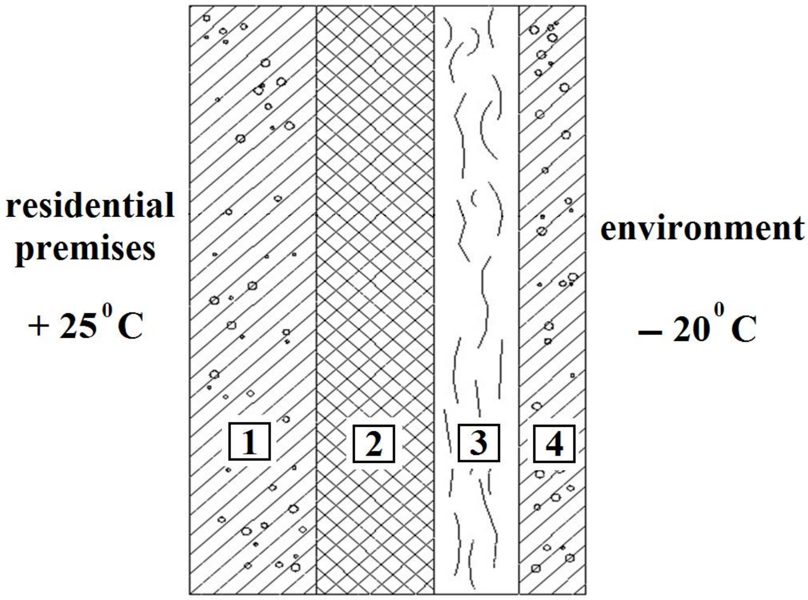

Figure 1 - Scheme of a multilayer external wall panel:
1 – concrete inner textured layer; 2 – cement fibrolite;
3 – thermal insulation layer; 4 – concrete outer textured layer

Figure 2 shows a graph of the heat flow through a four-layer wall panel for five cases of a thermal insulation layer.

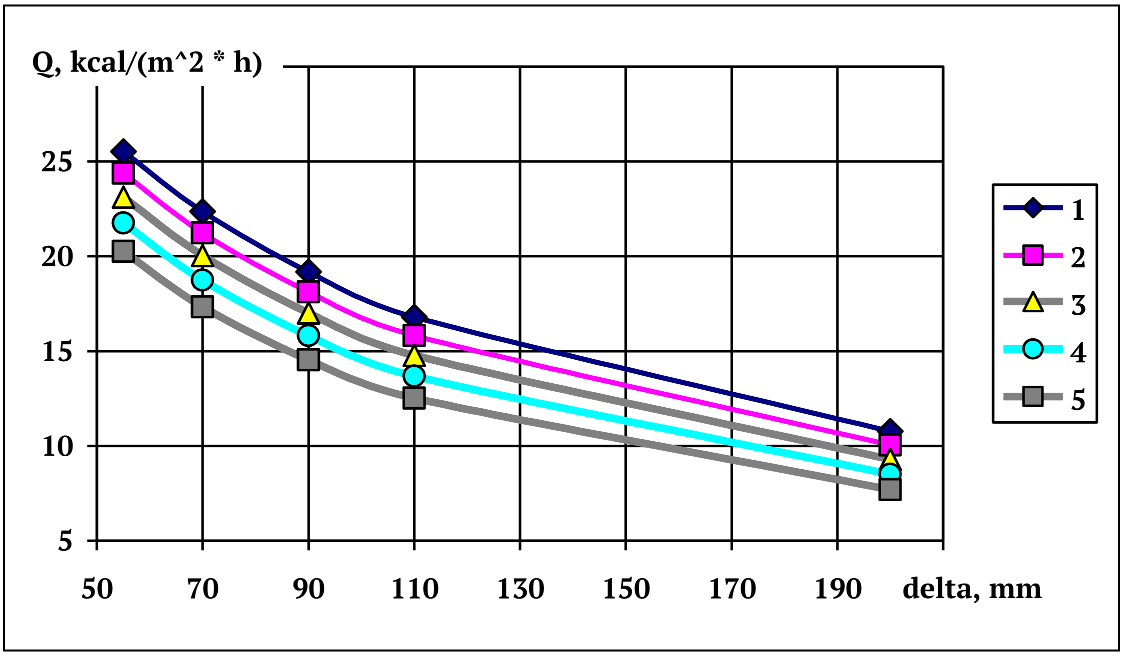

Figure 2 - Heat flow through a four-layer wall panel depending on the material and thickness of the heat-insulating layer:
1 – mineral wool plates; 2 – peat insulation plates; 3 – building felt;
4 – urea-formaldehyde foam plastic (mipora); 5 – polystyrene foam

The value of the heat flow Q of the curves in Figure 2 was obtained using the method described in [2].

Analysis of the curves in Figure 2 shows that reducing the heat flow through a multilayer external wall panel can be done in two ways:

– first, by increasing the thickness of the heat-insulating layer (at the same time, the optimal option is considered when the tangent to the curve in Figure 2 is almost horizontal at the selected thickness value);

– second, by choosing a heat-insulating material with the lowest possible coefficient of thermal conductivity. Among the listed materials is polystyrene foam.

The presented results at the XX International Conferences "Human and Space" [1] were tested.

Conclusions. In the course of the task, the following types of work were carried out and the following conclusions were obtained:

1) the problem of heat preservation and the need to use heat-protective coatings were considered;

2) the methodology and basic principles of conducting thermal calculations of a multilayer flat wall were studied;

3) stationary calculations of temperatures and heat flows through a four-layer flat wall using five types of heat-insulating materials were carried out;

4) graphs of the dependence of temperature and heat flow (given in the work) on the thickness of the multilayer wall, which allows to optimally choose a heat-protective coating and determine the thickness of the heat-insulating layer of the multilayer outer flat wall of a residential building were constructed;

5) ways of reducing the heat flow through a multilayer flat external wall panel of a residential building are proposed.

LITERATURE

1. Кравець О.В. Тепловий розрахунок багатошарової стінової панелі / О.В. Кравець, К.В. Махоніна. – XX Міжнародна наук.-практ. конф. „Людина і космос". – Дніпро. – 11-13 квітня 2018. – С. 35.

2. Фокин К.Ф. Строительная теплотехника ограждающих частей зданий / К.Ф. Фокин. – М.: Стройиздат, 1973. – 287 с.

3. Chebah R. Passive Control and Stability of the Indoor Temperature of a Closed Cavity Based on the Process of Integrating Phase Change Materials / R. Chebah, A. Laouer, E. Mezaache // Energy Ecology and Environment. – 2022. – V. 8. – № 1. – Pp. 89-99.

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)

4. Chen L. A farmers market architecture and ventilation design and its airflow analysis / L. Chen, C. Huang, C. Xu // International Journal of Ventilation. – 2023. – V. 22. – № 1. – Pp. 3-23.
5. Wang D. Urban Thermal Environment and Surface Balance in 3D High-rise Compact Urban Models: Scaled Outdoor Experiments / D. Wang, Y. Shi, G. Chen, L. Zeng, J. Hang, Q. Wang // Building and Environment. – 2021. – V. 205. – № 11. – Pp. 115-122.
6. Wu M. Study on Thermal Performance of Single-layer and Multilayer Stone Aluminum Honeycomb Composite Panels / M.Wu, J. Liu // 3rd International Conference on Fluid Mechanics and Industrial Applications. – China. – 2019, June, 29-30. – Pp. 672-685.

REFERENCES

1. Kravets O.V. Teplovyy rozrakhunok bahatosharovoyi stinovoyi paneli / O.V. Kravets, K.V. Makhonina. – XX Mizhnarodna nayk.-prakt. konf. „Ludina i kosmos" – Dnipro. – 11-13 kvitnya 2018. – P. 35.
2. Fokin K.F. Stroitelnaya teplotekhnika ograzhdauschikh chastey zdaniy / K.F. Fokin. – M.: Stroyizdat, 1973. – 287 p.
3. Chebah R. Passive Control and Stability of the Indoor Temperature of a Closed Cavity Based on the Process of Integrating Phase Change Materials / R. Chebah, A. Laouer, E. Mezaache // Energy Ecology and Environment. – 2022. – V. 8. – № 1. – Pp. 89-99.
4. Chen L. A farmers market architecture and ventilation design and its airflow analysis / L. Chen, C. Huang, C. Xu // International Journal of Ventilation. – 2023. – V. 22. – № 1. – Pp. 3-23.
5. Wang D. Urban Thermal Environment and Surface Balance in 3D High-rise Compact Urban Models: Scaled Outdoor Experiments / D. Wang, Y. Shi, G. Chen, L. Zeng, J. Hang, Q. Wang // Building and Environment. – 2021. – V. 205. – № 11. – Pp. 115-122.
6. Wu M. Study on Thermal Performance of Single-layer and Multilayer Stone Aluminum Honeycomb Composite Panels / M.Wu, J. Liu // 3rd International Conference on Fluid Mechanics and Industrial Applications. – China. – 2019, June, 29-30. – Pp. 672-685.

Received 22.01.2024.
Accepted 24.01.2024.

Вплив матеріалу та товщини теплоізоляційного прошарку на тепловий потік крізь багатошарову зовнішню стінову панель житлового будинку

Враховуючи обмеженість на Землі невідновних органічних енергоресурсів, а також недостатню потужність відновних енергоджерел, актуальними стають питання про енергозбереження, взагалі, і збереження тепла у житлових приміщеннях, зокрема. Суттєво зменшити теплові втрати у приміщенні можна завдяки правильно підібраним теплоі *золяційним матеріалам та оптимальній товщини відповідного прошарку багатошарової зовнішньої стінової панелі. Даний напрямок досліджень сприяє вирішенню актуальної для України проблеми енергозбереження, одному з найважливіших напрямів технічної політики в галузі будівництва. Аналіз останніх досліджень і публікацій свідчить, що в напрямку енергозбереження будівель проводяться різноманітні дослідження, а саме: теплообмін між тришаровою стінкою та замкненою порожниною, яка моделює приміщення; зміна поля температури повітря поблизу поверхні та поверхневий енергетичний баланс будівельних масивів за різних умов навколишнього середовища; дослідження впливу геометричних розмірів приміщення на вентиляцію повітря в ньому з урахуванням теплообміну між тілом людини та навколишнім середовищем; вплив на процес теплопередачі геометричних розмірів композитно алюмінієвої стільникової панелі. Але, враховуючи різноманітність теплоізоляційних матеріалів, залишаються актуальними питання по їх вибору та визначенню геометричних розмірів прошарків теплової ізоляції багатошарових зовнішніх стінових огороджень. Метою даної роботи є встановлення залежності величини теплового потоку крізь чотиришарову стінову панель житлового будинку від матеріалу та товщини теплоізоляційного прошарку. В роботі розглянуто проблему збереження тепла та необхідність застосування теплозахисних покриттів; проведено стаціонарні розрахунки температур та теплових потоків крізь багатошарову плоску стінку з використанням п'яти різновидів теплоізоляційних матеріалів; побудовано графіки залежностей теплового потоку від товщини багатошарової стінки, що дозволяє оптимально підібрати теплозахисне покриття та визначити товщину теплоізоляційного шару багатошарової зовнішньої плоскої стінки житлового будинку; запропоновано шляхи зменшення теплового потоку крізь багатошарову плоску зовнішню стінову панель житлового будинку.*

Кравець Олена Володимирівна – канд. фіз.-мат. наук, доцент, доцент кафедри аерогідромеханіки та енергомасопереносу, Дніпровський національний університет імені Олеся Гончара.
Махоніна Карина Володимирівна – бакалавр, кафедра аерогідромеханіки та енергомасопереносу, Дніпровський національний університет імені Олеся Гончара.

Kravets Olena Volodymyrivna – candidate of physical and mathematical sciences, docent, docent of the Department of AeroHydro Mechanics and Energy and Mass Transfer, Oles Honchar Dnipro National University.
Makhonina Karina Volodymyrivna – bachelor, Department of AeroHydro Mechanics and Energy and Mass Transfer, Oles Honchar Dnipro National University.

ISSN 1562-9945 (Print)
ISSN 2707-7977 (Online)