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MODERN APPROACHES TO ENERGY EFFICIENT OPERATION OF BUILDINGS

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Abstract. *The problem of energy efficiency of buildings is extremely relevant in the context of increasing energy consumption, rising energy prices and global climate change. According to the International Energy Agency (IEA), buildings consume about 36% of the world's energy and generate 37% of greenhouse gas emission. One of the critical elements in the construction of buildings that contributes to heat loss is the corner zones of external walls. It is in these places that freezing, condensation and mold formation are often observed, which not only increases heating costs, but also harms the indoor microclimate and contributes to structural damage.*

Optimizing the thermal insulation of corner sections of buildings allows to significantly increase their energy efficiency. The choice of appropriate thermal insulation materials and structural solutions should be based on a combination of thermal performance, economic feasibility, ease of installation and safety. Studies show that the correct selection of insulation can reduce heat loss by up to 30%.

Numerical modeling of heat transfer processes is an effective tool for analyzing the thermal insulation characteristics of corners and allows developing optimal technical solutions. The results of such studies are important for the modernization of existing buildings, especially in regions with cold climates, and for the design of new energy-efficient facilities.

Keywords: *building, energy efficiency, modeling, heat transfer, thermal insulation.*

Introduction.

Modern construction is increasingly oriented towards the principles of energy efficiency, which is due to both environmental challenges and economic feasibility. One of the key tasks in this context is to minimize heat loss through building envelopes, in particular through external walls. Particular attention should be paid to corner zones, which, as studies show, are most vulnerable to the formation of cold bridges and significant energy losses. Heat loss in such areas not only reduces the overall energy efficiency of the building, but also causes risks of condensation, mold and premature wear of structures.

Thus, the purpose of this study is to identify the features of heat flows in the corner zones of the building and assess the effectiveness of existing thermal insulation solutions in order to further optimize the energy efficiency of buildings of this type.

Main text.

To conduct the study, modern numerical methods were used, which ensure high accuracy and reliability of the results obtained. Based on numerical modeling using software that uses the finite element method (FEM).

The finite element method is the main tool for modeling thermal processes in this study. It involves breaking down the complex geometry of the walls into simple elements for which heat conduction equations are formulated . This approach allows taking into account the peculiarities of materials, geometry, and boundary conditions.

The research of Petkova-Slipets [3] shows the effectiveness of using FEM for analyzing the thermal characteristics of building materials. The authors compared perforated ceramic bricks with a clay -sand matrix, emphasizing the accuracy of the modeling results using Ansys .

Ansys program is one of the leading ones for numerical modeling of thermal processes. In this study, Ansys was used to create three-dimensional models, determine the thermal characteristics of angular and straight walls when using insulation from different materials. The high accuracy of the modeling is confirmed by the results of previous studies, such as Assad and al [4], who showed that Ansys provides more accurate prediction of temperature distribution compared to other programs that use the FEM method.

Ansys software was used, which allows for numerical analysis taking into account real operating conditions [4, 5]. The input parameters were carefully selected based on data from the design documentation and relevant regulatory acts regulating construction in the first climatic zone of Ukraine [6, 7].

Temperature conditions for modeling were determined by winter climatic indicators. The external temperature was minus 22°C, which is typical for the cold period of the year in this region. The internal temperature was set at plus 20°C, which meets the regulatory requirements for the microclimate in sports facilities [7, 8]. The selected temperature range allows us to assess the effectiveness of thermal insulation in extreme conditions.

The heat transfer coefficients that affect the heat flows through the enclosing structures were also taken into account. For the inner surface of the wall, the heat transfer coefficient was 8.7 W/(m^2 ·K), and for the outer surface – 23 W/(m^2 ·K). The indicated values of the heat transfer coefficient correspond to real operating conditions and ensure the correctness of the modeling [7].

During the numerical analysis, four layers of materials were used that are part of the structures of the studied walls. Each layer has certain physical and technical characteristics, in particular thermal conductivity, density and thickness, which affect the overall thermal efficiency of the wall. The parameters of the selected materials are given in Table 1, which allows us to characterize the thermophysical properties of the structures.

Table 1 – Physical and technical characteristics of materials used in modeling

Material	Thermal conductivity (W/(m·K))	Density (kg/m³)	Thickness (m)
Brickwork	0.81	1800	0.38
Insulation " RockWool "	0.048	100	0.15
Cement-sand plaster	0.93	1800	0.02
EPS 100 expanded polystyrene insulation	0.038	25	0.15

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This combination of materials makes it possible to estimate heat losses in different conditions and for different thermal insulation solutions.

To study the thermal characteristics of external enclosing structures, four wall models were created, representing two types of structures: corner (Corner Wall) and straight (Straight Wall) walls. The models used two insulation materials: expanded polystyrene (EPS 100) and mineral wool (RockWool) 150 mm thick. For research in the software environment, the following models were considered: model No. 1 - corner wall with insulation " EPS 100"; model No. 2 - corner wall with insulation " RockWool "; model No. 3 - straight wall with insulation EPS 100; model No. 4 - straight wall with insulation " RockWool ". The geometric dimensions of each model were determined in accordance with the technical documentation.

The length of the corner wall was 3520 mm for one segment and 1910 mm for the other segment, which corresponds to its configuration in the real structure. The straight wall had a length of 3520 mm, which allows it to be considered as a standard facade section. The height of all models was the same and was 3900 mm, which corresponds to the total height of the second floor of the building.

The width of the wall is not indicated separately, since it is a complex value consisting of several layers of materials (brickwork, insulation and cement-sand plaster). This representation ensures the accuracy of taking into account design features during thermal process modeling. The results of the study of the temperature characteristics of corner and straight walls are given in Table 2.

The results of the study confirm that the geometry of structures is the main factor affecting the thermal characteristics of walls. The results demonstrate the need for additional thermal insulation to minimize heat loss in corner walls.

Table 2 – Results of the study of temperature characteristics of corner and straight walls

	Model 1	Model 2	Model 3	Model 4
Wall type	Corner wall	Corner wall	Straight wall	Straight wall
Length (cm)	3520x1910	3520x1910	3520	3520
Height (cm)	3900	3900	3900	3900
Internal temperature (°C)	20	20	20	20
Outdoor temperature (°C)	-22	-22	-22	-22
Convection internal ($W/m^2 \cdot K$)	8.7	8.7	8.7	8.7
Convection external ($W/m^2 \cdot K$)	23	23	23	23
Average temperature (°C)	2.3995	2.1317	4.0678	3.6698
Average heat flux (W/m^2)	9.66E-04	1.18E-03	9.46E-04	1.16E-03

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Conclusions.

Studies have confirmed that corner walls are critical areas with increased heat loss due to geometric features that disrupt the uniformity of the thermal insulation layer.

EPS 100 insulation showed better results, providing 22.15% less heat loss in corner walls and 22.62% in straight walls compared to RockWool . At the same time, mineral wool has advantages in the form of high fire resistance, sound insulation and vapor permeability , which makes it a reasonable choice for buildings with increased safety and microclimate requirements.

The results emphasize the importance of structural geometry for thermal performance: straight walls demonstrate a more stable temperature distribution with average temperatures 69.53% (EPS 100) and 72.15% (RockWool) higher than angular ones. The proposed recommendations for the selection of insulation materials can be used to improve energy efficiency in new construction and reconstruction of buildings.

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