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IMPROVING THE ENERGY EFFICIENCY OF BUILDINGS BY PROVIDING BETTER PROTECTIVE STRUCTURES BASED ON THE UNIVERSITY'S KNOWLEDGE HUB

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BACKGROUND AND OBJECTIVES. Modern university buildings use a large number of resources, such as heat, cold and hot water, as well as electricity, which is the main consumed energy resource and is used for lighting, office equipment, ventilation and air conditioning systems. In order to improve the energy efficiency of university buildings, it is necessary to carry out heat and energy modernization of internal and external envelopes, which will allow for internal billing and qualitative analysis of consumption, which contribute to prompt decision-making on heat and energy modernization of the premises.

METHODS. To assess the potential for improving the energy efficiency of buildings by improving the quality of protective structures, methods for assessing the temperature and humidity conditions of multilayered enclosing structures in a wide range of humidity under stationary boundary conditions were developed on the basis of the University Hub of Knowledge.

FINDINGS. On the basis of the University Hub of Knowledge, Kyiv National University of Technologies and Design, the moisture content profile was calculated for the general estimation of the moisture condition for building No. 4, the planes of the highest moisture content were determined to find the most dangerous, from the moisture condition point of view, section of the structure, the calculation of the enclosing structure modernization according to the maximum allowable moisture condition for the analysis of moisture accumulation in the coldest month of the year was made.

CONCLUSION. The advantage of the proposed method of increasing the energy efficiency of buildings by improving the quality of protective structures based on the University Hub of Knowledge is the possibility of calculation in a wide range of moisture content of materials, including supersorption moisture zone, as well as applicability to structures with multizone condensation of moisture. The clarity and simplicity of the proposed method makes it available for the practical implementation of energy efficiency improvements in all university buildings.

KEYWORDS: HUB of knowledge on energy efficiency; university; building envelopes; thermal energy modernization.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
10	3	1

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ПІДВИЩЕННЯ ЕНЕРГОЕФЕКТИВНОСТІ БУДІВЕЛЬ ЗА РАХУНОК ПОЛІПШЕННЯ ЯКОСТІ ЗАХИСНИХ КОНСТРУКЦІЙ НА БАЗІ УНІВЕРСИТЕТСЬКОГО ХАБ ЗНАНЬ

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ПОСТАНОВКА ПРОБЛЕМИ ТА ЗАВДАННЯ. Сучасні університетські будівлі використовують велику кількість ресурсів, таких як тепло, холодна і гаряча вода, а також електрична енергія, яка є основним енергоресурсом, що витрачається, і використовується на освітлення, роботу оргтехніки, систем вентиляції та кондиціювання. Для підвищення енергоефективності університетських будівель необхідне проведення теплоенерго модернізації внутрішніх та зовнішніх огорож, що дозволить проводити внутрішній білінг та якісний аналіз споживання, які сприяють оперативному прийняттю рішень щодо теплоенерго модернізації приміщень.

МЕТОДИ. Для оцінки потенціалу підвищення енергоефективності будівель за рахунок покращення якості захисних конструкцій на базі університетського Хаб знань були розроблені методи оцінки температурно-вологісного режиму багатошарових конструкцій, що захищають, у широкому діапазоні вологості за стаціонарних граничних умов.

РЕЗУЛЬТАТИ. На базі університетського Хаб знань Київського національного університету технологій та дизайну виконано розрахунок профілю вмісту вологи для загальної оцінки вологого режиму для корпусу №4, визначено площини найбільшого зволоження для виявлення найбільш небезпечного, з погляду вологого режиму, перетину конструкції, виконано розрахунок модернізації огороджувальних конструкцій по гранично. допустимого стану зволоження для аналізу накопичення вологи в найхолоднішій місяць року.

ВИСНОВКИ. Перевагою запропонованого методу підвищення енергоефективності будівель за рахунок покращення якості захисних конструкцій на базі університетського Хаб знань є можливість розрахунку в широкому діапазоні вологості матеріалів, включаючи надсорбційну зону зволоження, а також застосування до конструкцій з мультизональною конденсацією вологи. Наочність та простота запропонованого методу робить його доступним для практичної реалізації підвищення енергоефективності всіх будівель університету.

КЛЮЧОВІ СЛОВА: ХАБ знань з енергоефективності; університет; огороджувальні конструкції; теплоенерго модернізація.

INTRODUCTION.

The reduction of energy natural reserves acutely puts the problem of energy conservation and energy efficiency of buildings (Di Stefano, 2000). From the point of view of I. Gryshchenko, V. Shcherbak, O. Shevchenko solution of this problem is closely connected with increasing requirements for the quality of building design, since design errors lead to a decrease in the thermal protection properties of building envelopes and increase the energy costs of building operation (Gryshchenko et al., 2017).

The choice of a rational design solution at the design stage of technological modernization of operating university buildings according to V. Kaplun, V. Shcherbak is connected with the problem of research of heat and mass exchange processes (Kaplun and Shcherbak, 2016), forecast of temperature and moisture conditions of enclosing structures and increasing the accuracy of thermal calculations (Liu et al., 2019), since temperature and moisture conditions of enclosures directly affect the microclimate of rooms, thermal protection properties, reliability and environmental safety (Shaposhnikova and Shimov, 2016).

The most difficult, from the point of view of V. Scherbak, L. Ganushchak-Efimenko, O. Nifatov, P. Dudko, N., Savchuk, I. Solonenchuk, is to predict the temperature and humidity conditions in thermally heterogeneous sections of fences (marginal zones) in which the heat and moisture transfer occurs in two and three-dimensional schemes (Shcherbak et al., 2019). More than 40% of the total heat loss of the enclosure is noted through the peripheral zones according to E. Vieira, B. dos Santos, N. Zampieri, S. da Costa, E.de Lima (Vieira et al., 2020). Moisture localization in these areas above permissible values (Xing et al., 2019) leads to a deterioration of the moisture regime, reducing the thermal protection and life of the entire building. At the same time, the absence of modern methods for calculating temperature and moisture conditions in three-dimensional areas of enclosing structures, convenient for practical application, makes it difficult to assess the impact of edge zones on the thermal protection and energy efficiency of operating university buildings (Nikolayeva, 2018).

Thus, the problem of energy saving and improving the energy efficiency of operating university buildings leads to the need to study the processes of heat and mass transfer and the development of methods for calculating the temperature and humidity conditions of the enclosing structures (On energy saving: Law of Ukraine, 2021). This determines the relevance of the problem of improving the thermal protection and energy efficiency of operating university buildings in the absence of scientific and methodological apparatus for the formation of requirements to enclosure structures, taking into account the characteristics of temperature-moisture regime in the marginal zones of enclosures on the basis of the university Hub of Knowledge.

The purpose of this paper is to substantiate the necessity of using the university Hub of Knowledge to form requirements for fencing constructions taking into account the peculiarities of temperature and humidity conditions of operating university buildings. The research of the condition of the enclosing structures of operating university buildings of Kyiv National University of Technology and Design was carried out in 2021.

MATHERIALS AND METHODS

Calculation of the moisture content profile. The basis of this method are linear distributions of temperature *t(x)* and absolute moisture potential *θ(x)* in the structure (1–2):

$$t(x) = t_{int} - \frac{t_{int} - t_{ext}}{R_h^{con}} R_h(x); \tag{1}$$

$$\theta(x) = \theta_{int} - \frac{\theta_{int} - \theta_{ext}}{R_m^{con}} R_m(x), \tag{2}$$

where $R_h(x)$, $R_m(x)$ – heat and moisture transfer resistance to the section under consideration x;
R_h^{con}, R_m^{con} – total heat and moisture transfer resistance of the enclosure, respectively.

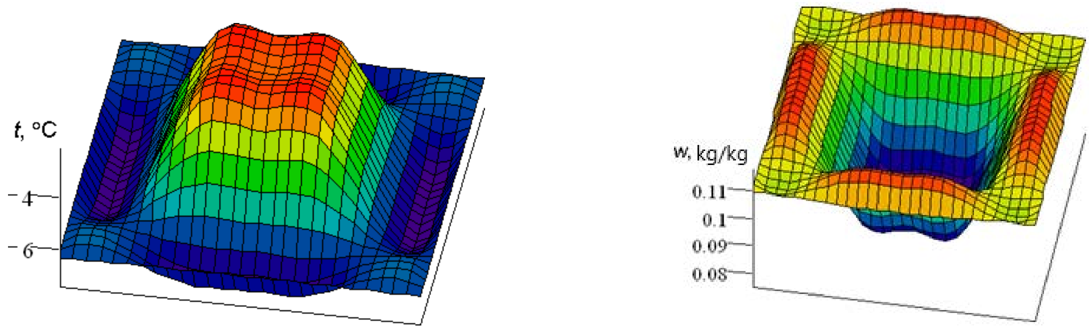
Using the *t(x)* distribution, one determines the values of the maximum sorption potential of moisture, the distribution of the relative moisture potential, and the desired moisture content distribution over the thickness of the multilayer structure. The above method provides an overall assessment of the moisture conditions of structures. The proposed method is convenient for assessing the operational suitability of enclosures to maintain the required level of energy saving.

RESULTS AND DISCUSSION.

The executed review of methods of an estimation of energy efficiency of buildings has shown, that the specified methods do not consider influence of processes of a heat and mass exchange in marginal zones of enclosing designs on a microclimate of premises, thermal protective properties and energy efficiency of buildings in view of absence of a method of calculation of a temperature-humidity mode in three-dimensional areas of external enclosures. Meanwhile, as practice shows, there is often a deterioration of temperature and humidity conditions in the marginal areas of the enclosing structures, which leads to a decrease in the thermal protection of the entire building. The specified method makes it possible to determine the most dangerous section of the structure with regard to the moisture regime without constructing moisture content profiles. In contrast to the existing calculation methods, the developed method enables to estimate the protection of envelop structures against overmoistening in a wide range of moisture content, gives a quantitative characteristic of the degree of material overmoistening and is applicable to calculation of enclosures with multizone moisture condensation.

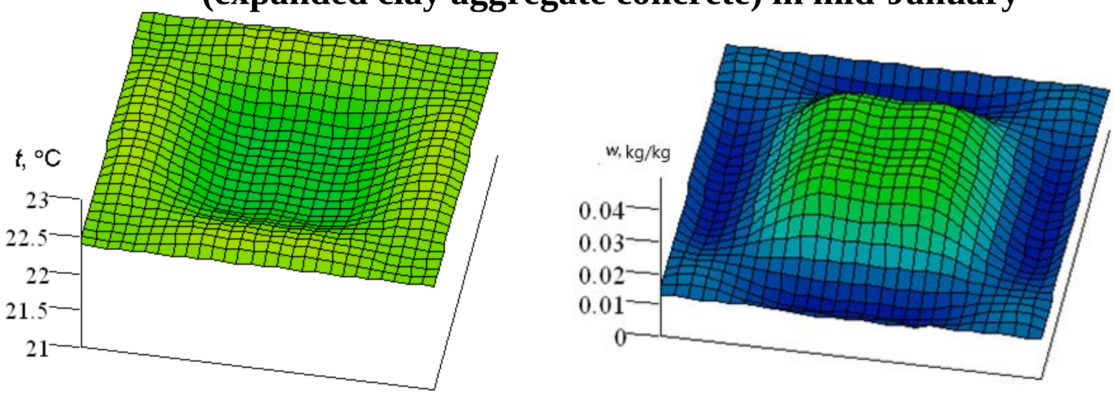
The proposed mathematical model is implemented in the computer program "Joint Moisture and Heat Transfer" in the visual object-oriented programming system Delphi 3–7. The main advantages of the model and the computer program are the following: the use of the scale of non-isothermal absolute potential of humidity that allows to simplify the mathematical model of heat and moisture transfer and makes it possible to calculate in a wide range of material humidity; the possibility of studying dynamics of temperature and humidity conditions of enclosures of complex geometric structure under variable climate and microclimate influences; applicability to studying heat and humidity processes of various intensities of the climate and microclimate of rooms.

Application of the computer program is illustrated by an example of calculation of the temperature-humidity regime of a fragment of a three-layer wall panel with a keyed connection in an annual cycle (Fig. 1, 2).



a *b*

Fig. 1. **Fields of temperature (*a*) and moisture content (*b*) at the junction of the insulation with the outer protective and finishing layer (expanded clay aggregate concrete) in mid-January**



a *b*

Fig. 2. **Fields of temperature (*a*) and moisture content (*b*) at the junction of the insulation with the outer protective and finishing layer (on the insulation) in mid-July**

The presence of extremes in temperature and moisture content (Fig. 1) is physically conditioned by the heterogeneity of the considered fragment of the structure and the non-linearity of the process of moisture heat transfer. Verification of the developed calculation method by different methods: by analytical solution and sequence of spatial and temporal grids, by different mathematical models of moisture and heat transfer, by results of field studies of indoor microclimate parameters, temperature-moisture regime and thermal protection properties of enclosing structures based on the university's Hub of Knowledge. Verification of the calculation method developed on the basis of the University Hub of Knowledge confirms its reliability, which allows you to use this method in the practice of operation and insulation of buildings KNUTD. Numerical values of indicators confirming the reliability of the above calculations.

On the basis of the results of thermal imaging survey (Fig. 3), obtained on the basis of the University Hub of KNUTD knowledge, the assessment of the influence of the marginal zones of the enclosing structures on the temperature and humidity conditions of the premises (Table 1) was carried out.

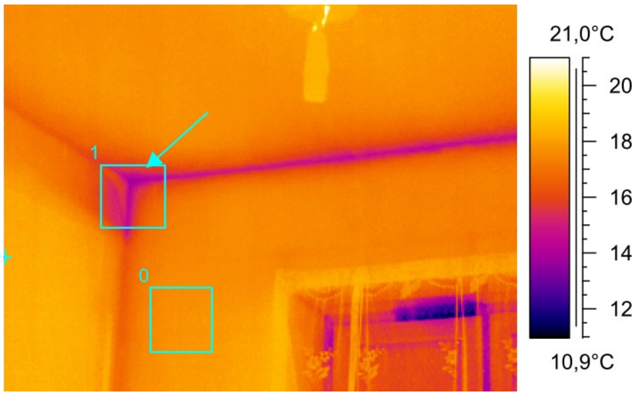


Fig. 3. Thermogram on the inner surface of the enclosures of the auditoriums of KNUTD building #4

Table 1

Comparison of calculated and measured microclimate parameters in classrooms of KNUTD Building No. 4

Parameter	Actual (measured) value of the parameter	Calculated value of the parameter	
		excluding edge zones	including marginal zones
Resulting room temperature, °C	19	19.5	19
Temperature difference, °C, between the inside air and the inside surface of the wall	4.1	1.8	4
Minimum temperature on the inner surface of the wall, ° C	8.3	—	8.4

Table 1 shows that failure to take into account the marginal zones of enclosures in the thermal modernization of buildings overestimates the resultant room temperature by 2.6%. At the same time, not taking into account edge zones leads to underestimation of temperature difference between internal air and internal surface of the outer wall by 56%, distorts the assessment of comfortable conditions in the room and creates significant risks in assessing sanitary-hygienic requirements on the condition of inadmissibility of moisture condensation on the internal surface of the enclosures. Accounting for edge zones on the basis of the proposed method for calculating the temperature and humidity conditions allows us to achieve almost complete coincidence of the calculated and measured room microclimate parameters (Table 1), ensuring high accuracy of the research results and increasing the quality of heat and power modernization. Analysis of the results shows a local decrease in the temperature in the marginal zones of the enclosures. The resulting room temperature according to the measurements is 19 ° C. The actual temperature difference between the interior air and the inner surface of the wall, reduced to design conditions, exceeds the normative value. The minimum temperature on the inner surface of the wall is lower than the dew point of the inner air, which leads to condensation in the edge zone under design conditions. Thus, the method of numerical solution of the three-dimensional problem of joint unsteady heat and moisture transfer allows predicting the temperature and humidity conditions of the enclosures in order to save energy and improve the reliability and thermal safety of the university buildings in operation.

CONCLUSION.

On the basis of the studies carried out on the basis of the university KNUTD Hub of Knowledge, a major scientific problem of improving the thermal protection and energy efficiency of operating university buildings by developing the scientific and methodological apparatus for the formation of requirements for envelope structures, taking into account the characteristics of temperature and humidity conditions in the fencing edge zones, which has important economic importance was solved.

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ABBREVIATIONS:

%	Percentage
Eq.	Formula of calculation
Fig.	Figures
HEI	Higher education institution
Hub	Common connection point
KNUTD	Kyiv National University of Technology and Design

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