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EXPERIMENTAL RESEARCHES OF HEAT EXCHANGE PROCESSES IN VERTICAL VENTILATED CHANNELS

Об'єктом дослідження є процеси тепло- і масообміну у відкритих огороджуючих конструкціях, які моделювалися в кліматичній камері для зменшення втрат тепла. У роботі проведено аналіз цих процесів, який дозволить скоротити втрати тепла через конструктивні елементи будинку в холодний період року, а також зменшити надходження тепла в теплий період. Дослідження розподілу температур у вертикальній відкритій огороджуючій конструкції виконані на експериментальному стенді. Із отриманих даних випливає, що температура у відкритих огороджуючих конструкціях на 1,5–2 °C вища, ніж у звичайних, але вологість зменшується суттєво. Можна зробити висновок, що волога в зовнішніх невентильованих огороджуючих конструкціях починає накопичуватись у середньому наприкінці року, тобто з початком холодного періоду – в листопаді чи грудні. І за три-чотири місяці набуває максимального значення і потім конструкція починає сохнути. Проте визначення річного розподілу вологи огороджуючої конструкції протягом року ще не дає відповіді на питання, як волога поводить себе у товщі шарів багатошарової конструкції. Вентильовані огороджуючі конструкції суттєво впливають на розподіл вологи всередині стіни. При контакті повітря з холодною поверхнею каналу при певних умовах може відбуватися конденсація. Поверхневі шари каналу висушуються, проте волога може проникати в шари конструкції. Під час проведення досліджень вдалося встановити, що суттєве зменшення вологи у відкритих огороджуючих конструкціях дозволяє уникнути хвороботворних мікроорганізмів, які дуже стрімко розвиваються в вологому середовищі. Також є можливість використання нагрітого повітря у подальшому в житлових приміщеннях. У процесі дослідження усунуті недоліки існуючих методик, а саме: при використанні рівняння теплового балансу на зовнішній поверхні даху застосовують поняття «рівноважної температури», що не завжди коректно описує процес теплообміну на зовнішніх поверхнях відкритих огороджуючих конструкцій.

Ключові слова: *теплова потужність, відкриті огороджуючи конструкції, теплообмін в огороджуючих конструкціях.*

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1. Introduction

One of the effective ways to solve the problem of optimizing the consumption of energy resources, indicated in the framework of existing and planned state and international programs to improve energy efficiency and energy saving, is to design passive houses using solar radiation [1, 2]. Passive heating of the house is carried out using renewable energy sources, one of which is solar radiation. The design of the house should be designed and placed so as to most effectively perceive the solar radiation in the cold season. Passive home design can significantly reduce the operating costs that go to create the necessary microclimate conditions. That is why the study of modern trends and methods of energy saving in buildings is relevant [3–5]. A significant number of studies are devoted to the study of energy-efficient construction, among which there are works [6–8]. The existing methods for calculating the temperature of air in ventilated channels are based on the use of traditional equations of heat transfer by convection and radiation. However, none of them provides for setting the function of the temperature distribution of the channel surface along its length. Therefore, in this paper, studies of the temperature distribution in a vertical enclosing structure with open air layers (VES) on an experimental stand were performed. A pass-through VES can act as an air supply channel in a room. In this case, the outside air is heated when moving along the layer and is fed into the room. Due to this, a part of the heat coming through the external VES surface of the house is used. The walls can be used VES with a single, double or multiple air movement [9, 10].

Thus, *the object of research* is the processes of heat and mass transfer in open walling, simulated in a climate chamber to reduce heat loss. And *the aim of research* is analysis of these processes, which will reduce heat loss through the structural elements of the house during the cold season, as well as reduce the heat input in the warm period.

2. Methods of research

A sufficiently deep analysis and understanding of the heat exchange processes occurring in the VES will reduce heat loss through the structural elements of the house during the cold season, as well as reduce the heat input during the warm period.

Enclosing structures with open and closed air layers are widely used in the construction. Enclosed air layers are not combined with either external or internal indoor air. A closed layer of air is used in building fencing structures as an insulating element. Air voids make small and well isolated from each other. Placing closed cavities 5–7 cm wide in the wall [11, 12] can significantly reduce the number of bricks and improve the thermal properties of the building envelope. In addition, it allows to reduce the thickness of the

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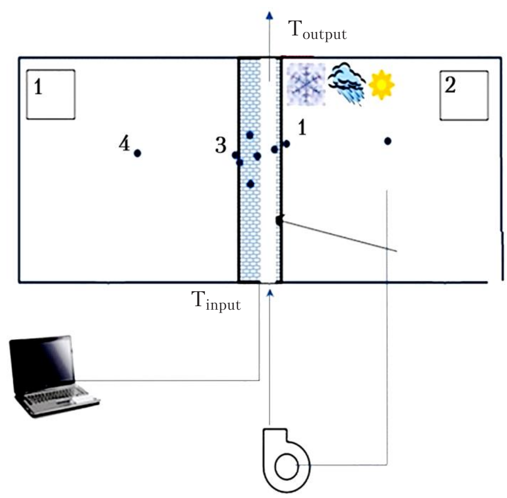
wall compared with the conventional design. The insulating properties of the walls do not deteriorate, and the cost of construction will be less. Improving the thermal properties of a wall with closed air layers is the result of reduced values of the thermal conductivity of a structure with cavities.

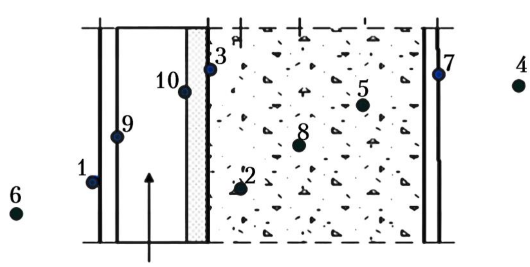
Let's note that the VOS purpose functionally differs from designs with closed air spaces. The main task of structures with closed air gaps is to increase thermal resistance and reduce heat loss through the building envelope. But VES is traditionally used to remove moisture from the structures of the house. The movement of air in the VES intensifies heat exchange between the air and the surface along which it circulates. In addition, VES plays a significant role in the design and construction of energy-efficient homes. Depending on the time of year, VES plays a specific function [13].

Open enclosing structures are widely used in construction in walls, ventilated facades, in horizontal partitions – attics, floors. VES is also used in the structural elements of the building for passive solar heating (the Trombe wall).

Heat and mass transfer in vertical VES is studied in the climate chamber (Fig. 1).



a



b

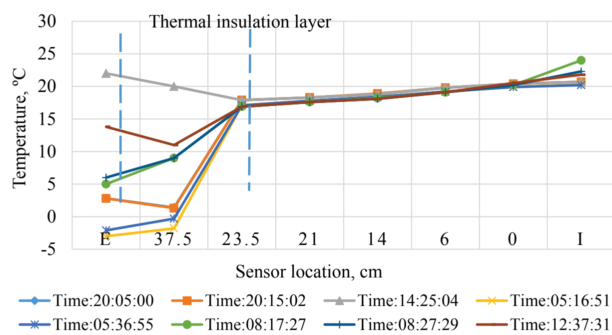
Fig. 1. Investigation of heat and mass transfer in the climate chamber: *a* – camera simulating external weather conditions; *b* – measurement scheme; 1 – DS18B20 temperature sensor; 2 – DS18B20 temperature sensor; 3 – DS18B20 temperature sensor; 4 – DS18B20 temperature sensor; 5 – DS18B20 temperature sensor; 6 – DS18B20 temperature sensor; 7 – DS18B20 temperature sensor; 8 – DS18B20 temperature sensor; 9 – DS18B20 temperature sensor; 10 – DS18B20 temperature sensor

In part 1 of the climatic chamber, the conditions of the interior are reproduced, the temperature (sensor 4) and the air humidity are recorded. Part 2 creates environmental conditions (temperature, humidity, air velocity, precipitation). Between chambers 1 and 2 in a special window, two studied fragments of VES with a height of 3000 mm, a width of 500 mm, and a thickness of 400 mm are installed. One of them is made without a ventilated channel (solid). The layout of the sensors is the same. During the experiments, the temperatures in the chambers and humidity, the speed of air movement in the VES, the controlled parameters – temperatures – were set, sensors No. 1, 2, 3, 5, 8, 9, 10 and humidity were shown.

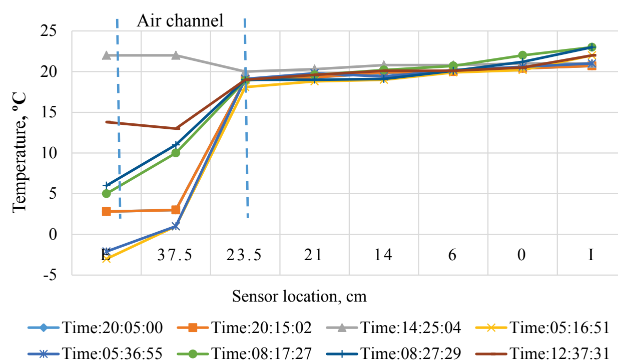
The main element of the research stand was a multipoint electronic recording thermometer AVT5330 (Poland) with appropriate software for working in the Windows environment. This made it possible to automate measurements in the time interval from 2 seconds to 24 hours. Up to 8 temperature sensors DS18B20 (Poland) can be connected to the recorder, each of which is connected to the recorder with a cable of about 2 meters in length and insulated with shrink sheath. Before being placed at the point of measurement, the sensors were calibrated in a specialized laboratory. The sensors were placed inside the ornate structure in channels with a diameter of 8 mm at a fixed depth.

3. Research results and discussion

The measurement results for the day in which the drop in external temperature is obtained in the form of graphs (Fig. 2).



a



b

Fig. 2. Temperature distribution of selected measurement intervals: *a* – in a wall without VES; *b* – in a wall with VES

Fig. 2 shows the temperature distribution characterizing the entire measurement cycle. From the obtained data it follows that the temperature in the VES is 1.5–2 °C higher than in the normal one. But the humidity decreases significantly. From the conducted studies on a full-scale object, it can be concluded that moisture in external non-ventilated enclosing structures begins to accumulate on average at the end of the year. That is, from the beginning of the cold period – in November or December, for 3–4 months it takes the maximum value and then the structure begins to dry. However, the determination of the annual moisture distribution of the enclosing structure during the year still does not answer the question of how moisture behaves in the thickness of the layers of the multilayer structure.

VESs significantly affect the distribution of moisture inside the wall. When air comes into contact with the cold surface of the channel, condensation may occur under certain conditions. The surface layers of the channel are dried, but moisture can penetrate into the layers of the structure. For comparison in Fig. 3 the graphs of the moisture distribution inside the wall are shown, where it is possible to see that the amount of moisture in the VES is much less. Humidity measurements were performed using a Testo 176 instrument (Poland). Measuring range –20 to +70 °C, accuracy ±0.2 °C (–20 to +70 °C)±1 digit. Humidity is capacitive, measurement range from 0 to 100 % RH, accuracy – depending on the probe Severis 2H2 (Poland), diameter 12 mm, length 1.2 m, error of measurement of humidity 0.03 %).

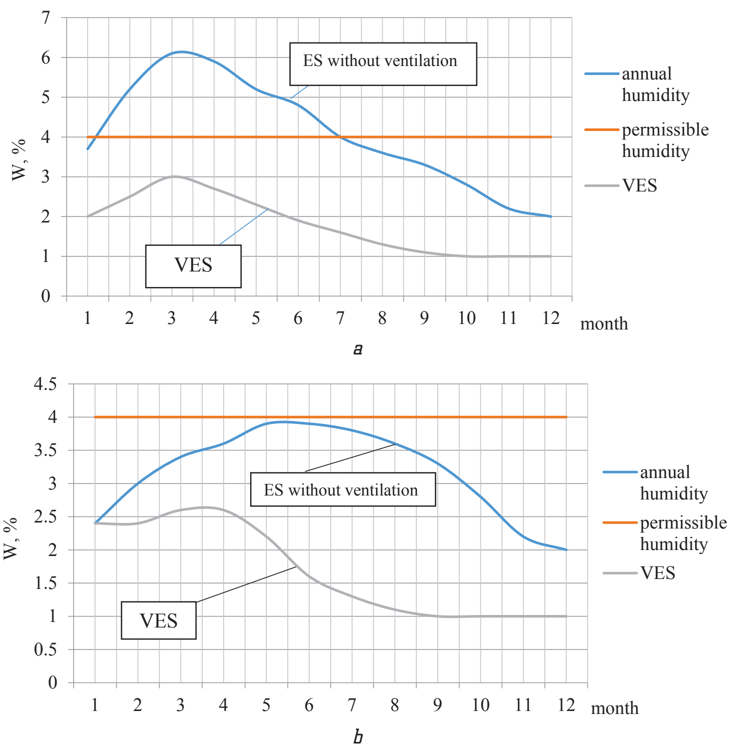


Fig. 3. Distribution of moisture inside the open enclosing structure (VES): *a* – wall without insulation; *b* – wall with external insulation

The obtained data indicate a significant decrease in the amount of moisture in the building envelope when using VES. The temperature of the wall in this case will be more, since the humidity of the wall decreases, the coefficient of thermal conductivity also decreases.

For the computational analysis of heat transfer processes in ventilated air ducts, on the bench presented above, studies were performed using the method of the planned mathematical experiment.

The following factors were taken as controlling factors: X_1 – the Reynolds number for air in the VES channel; X_2 – air temperature at the channel inlet in terms of sensor No. 6; X_3 – indoor air temperature according to sensor No. 4. For experiments, a second-order orthogonal composition plan was chosen.

Table 1 shows the limits of variation of selected factors.

Table 1

The boundaries of the variation factors

No.	Factor	Code value	–1	0	+1	Δ
1	Reynolds number for air in the VES channel	X_1	200	1900	3600	1700
2	Temperature of the air entering the channel according to the indicators of sensor No. 6	X_2	–10	10	30	20
3	Internal air temperature according to sensor No. 4	X_3	16	20	24	4

Calculations were performed using Statgraphics Plus 5.0. The model was based on an orthogonal factor experiment 23 with star points for three factors.

Temperature sensors were installed at the entrance to the channel at the end of the mixing zone, over which the surface temperature remained almost unchanged.

The equation for determining the surface temperature depending on the outdoor temperature, indoor air temperature and Reynolds number is as follows:

$$T_1 = 17.74 - 3.82 \cdot X_1 + 18.97 \cdot X_2 + 6.52 \cdot X_3 + \\ + 6 \cdot X_1 X_2 - 3.5 \cdot X_1 X_3 - 4.9 \cdot X_2^2 - 4.5 \cdot X_2 X_3. \quad (1)$$

Fig. 4 shows the Pareto graph for the studied dependences and graphs of the surface temperature on factors.

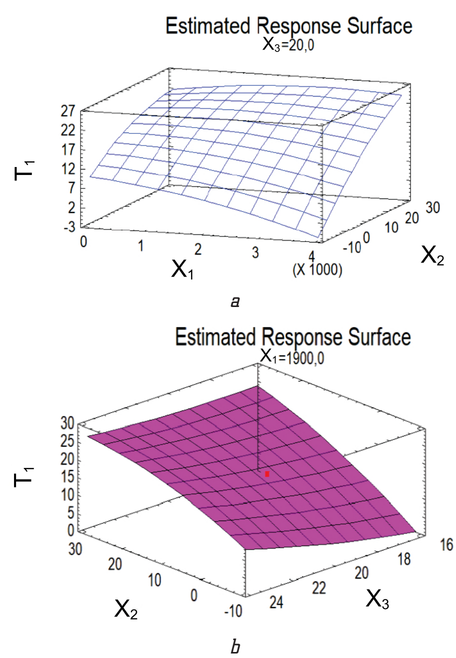


Fig. 4. Calculated graphs of temperature on the surface: *a* – on the temperature of internal air; *b* – on the outdoor temperature and the Reynolds number

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All factors of influence were significant. As expected, the outside temperature has the greatest impact, but with large Reynolds numbers. For small values of Re, all factors influence the temperature almost equally.

4. Conclusions

The experimental studies carried out in the work allow to determine the dependences of temperatures on various physical parameters that determine the heat load of the energy supply system of houses. From the obtained data, it follows that the temperature in the VES is 1.5–2 °C higher than in normal, but the humidity decreases significantly. From the conducted studies on a full-scale object, it can be concluded that moisture in external non-ventilated enclosing structures begins to accumulate on average at the end of the year. That is, from the beginning of the cold period – in November or December, for 3–4 months it takes the maximum value and then the structure begins to dry. However, the determination of the annual moisture distribution of the enclosing structure during the year still does not answer the question of how moisture behaves in the thickness of the layers of the multilayer structure. When comparing the calculation results obtained using the regression model, with experimental data it can be argued about their adequacy. The maximum error does not exceed 8 %, the minimum – 3 %.

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