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# SIMULATION OF AN ENERGY-SAVING NECESSARY FENCE WITH A VENTILATED ELASTIC STATION

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## Abstract

This article presents a physical and mathematical model for the utilization of a part of the heat flow passing through the exterior fence of a building. The option of using this flow to heat the supply air in the outer wall of the building, which has a ventilated layer in its design, is being considered. The article analyzes the thermal characteristics of walls with a ventilated interlayer, calculates the amount of recycled heat flow and evaluates the energy-saving effect of this approach. Possible problems and limitations of using this technology are also considered. The results obtained can be useful in the design and construction of energy-efficient buildings.

**Keywords**: Energy-saving fencing, ventilated air layer, heat loss modeling, thermal insulation, computer modeling, heat flow, ventilation optimization, heat transfer, energy efficiency

## Introduction

Various energy saving methods are actively used in the design and construction of buildings to increase energy efficiency and reduce energy consumption costs. Some of the most common methods include:

1. The use of effective thermal insulation materials: The use of modern thermal insulation materials with high thermal insulation properties helps to reduce heat loss through building fences and reduce energy consumption for heating and air conditioning.

2. Heat recuperators: Heat recuperators allow you to use the heat generated during the extraction of air from the room to preheat fresh supply air, which reduces the energy consumption of ventilation and heating systems.

3. Solar installations: Solar installations use solar energy to produce electricity or thermal energy. Installing solar panels on the roof of the building allows you to get clean and free energy.

In addition, there are many other ways to save energy, such as using energy-efficient equipment, installing LED lighting, implementing energy management systems, etc. All these measures help to reduce the energy consumption of the building, make it more environmentally friendly and resistant to changes in energy prices[2-6].

Such events, as a rule, are characterized by high cost, therefore, the search for cheaper and more efficient energy–saving solutions is one of the main tasks solved in the process of designing an energy-efficient building. Building operation experience shows that exterior fences with ventilated air layers are superior to solid structures in terms of energy efficiency and also have a lower weight.

Back in the 70s of the last century, the Central Research Institute of Housing developed enclosing structures with single and multiple air movement, two-layer expanded clay concrete panels with a ventilated large-porous layer, lightweight hinged panels with a ventilated interlayer.

The latter in these and other systems, ventilation of the air layer located in the thickness of the external fence of the building, is one of the important aspects of the design to ensure effective thermal insulation and air exchange. Ventilation allows for air circulation in the interlayer, which helps to prevent condensation, reduce heat losses and improve the quality of the indoor microclimate.

Ventilation of the air layer can be organized using special air ducts or openings through which outside air can enter the layer and the heated air is discharged into the room. This ensures continuous air renewal, which

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is important for maintaining a healthy indoor atmosphere.

To optimize the ventilation of the air layer, it is necessary to take into account such factors as the air flow rate, ensuring uniform distribution of air throughout the entire layer, ventilation control depending on the external conditions and needs of the building, as well as providing protection from negative weather conditions.

Thus, ventilation of the air layer plays an important role in creating energy-efficient buildings with improved thermal insulation properties and comfortable conditions for people to stay. Its proper design and implementation helps to reduce energy consumption and increase the energy efficiency of the building[1-4].

At the same time, the utilization of heat flow through the air gap in the outer enclosure of the building leads to an energy-saving effect by using part of the heat that would otherwise be lost through the fence. This process reduces heat loss and increases the energy efficiency of the building.

The magnitude of the energy-saving effect depends on a number of parameters, including the geometric and thermal energy characteristics of the air layer. Some of the key parameters affecting the efficiency of heat flow utilization include:

1. Cross-section and length of the interlayer: the larger the cross-sectional area of the air interlayer and the longer its length, the larger the surface for heat exchange and the possibility of heat recovery.

2. Location of the interlayer in the structure: the correct location of the air layer in accordance with the air and heat flows allows efficient use of the heat flow.

3. Outdoor and indoor air temperatures: The temperature difference between outdoor and indoor air determines the available heat flow for disposal.

4. Air velocity: The speed of air movement in the interlayer also affects the efficiency of heat exchange and heat recovery.

5. Heat transfer coefficient: a characteristic that determines the efficiency of heat transfer between the pads and the air layer.

Given these parameters, it is possible to optimize the design of the air gap to maximize the energy-saving effect. Proper design and consideration of all factors can significantly reduce the energy consumption of a building and increase its energy efficiency[1-8].

Such a task of non-stationary heat transfer through an external enclosure with a ventilated air layer is complex and requires the use of mathematical models and numerical analysis methods, such as the finite difference method. In this case, to solve the problem of non-stationary heat transfer, it is necessary to take into account the change in heat flow and temperature over time along the entire thickness of the wall with a ventilated interlayer.

To solve the problem, thermal conductivity equations are usually used, which describe the distribution of heat flow and temperature in the wall material. For the numerical solution of these equations, the finite difference method is used, which consists in approximating differential equations with difference formulas on a grid of calculated points. Then, using iterative methods, the numerical solution of the obtained systems of equations is performed.

The application of the finite difference method makes it possible to obtain a numerical solution to the problem of non-stationary heat transfer through an external fence with a ventilated air layer and to estimate changes in temperature and heat flow in the wall at various points in time. This approach allows for a qualitative analysis of the efficiency of using heat flow to heat the supply air and optimize the wall design taking into account energy efficiency.

This task was greatly simplified by Bogoslovsky V.N., who solved the system of heat balance equations for the element dx of the exterior fence, introduced the concept of average daily air temperature values tx in the section x of the interlayer for the combined coating of the building and developed an appropriate calculation model [7-10]. Taking into account the concept of the tx value, a methodology was developed for the utilization of heat from the upper layers of the earth in ventilated underground channels [7-9].

## A method for evaluating the energy-saving effect when disposing of part of the heat flow by an external fence having a ventilated layer in its design

To assess the energy-saving effect when disposing of part of the heat flow by an external fence with a ventilated interlayer, the following steps must be performed:

1. To study the thermal characteristics of an external fence with a ventilated interlayer, such as the thermal conductivity coefficient of structural materials, thermal insulation properties of the interlayer, etc.

2. Calculate the amount of heat flow that can be disposed of by an external fence with a ventilated layer.

3. Evaluate the energy-saving effect of heat flow utilization by comparing the costs of heating or air conditioning in the room before and after the installation of such a fence.

4. Conduct an economic analysis to assess the effectiveness of using a fence with a ventilated

interlayer in terms of installation costs and energy savings.

5. Analyze possible problems and limitations of the use of a fence with a ventilated interlayer, such as maintenance, additional costs, etc.

Thus, the methodology for assessing the energy-saving effect when disposing of part of the heat flow by an external fence with a ventilated layer will determine the effectiveness and expediency of using this method to reduce energy consumption of the building.

Therefore, our analysis of the location of the air gap in the building structure allows us to determine the optimal position to maximize the efficiency of heat transfer and utilization of heat flow. When examining various options for placing the interlayer inside the fence, it becomes clear that the most intense heat exchange occurs where the heat flow is strongest, and the thermal resistance of the dividing partition is minimal.

The placement of the air layer on the side of the inner surface of the outer fence has the following advantages:

1. Maximum utilization of heat flow: the location of the interlayer on the side where the heat flow is most intense allows efficient utilization of this heat to maintain a comfortable temperature in the room.

2. Minimum thermal resistance: placing the interlayer on the inner surface of the outer enclosure reduces the thermal resistance between the room and the interlayer, which contributes to more efficient heat exchange and improved energy efficiency of the building.

3. Improving the microclimate: the correct location of the interlayer can also help improve air quality and control indoor humidity.

In order to minimize it, it is advisable to adopt the partition structure in the form of a thin plate. The outside air entering the interlayer moves at a predetermined speed, controlled by an exhaust fan located at the outlet of the interlayer. The inlet opening of the channel is closed with a plug using a mechanical or electric drive. If necessary, the channel opening on the inside of the wall can be opened. Based on the above-mentioned calculation model, we have compiled the following system of equations for an external wall with a ventilated air layer.

Thus, the analysis of the location of the air layer showed that its optimal placement on the side of the inner surface of the outer fence helps to maximize the efficiency of heat transfer and utilization of heat flow, which ultimately has a positive effect on energy efficiency and comfort of the building.

The value of the average daily temperature tx of the air in the interlayer was determined by the formula:

$$t_x = t_s - (t_s - t_n) \cdot e^{-Ax} \quad (1)$$

where is the value $t_c$:

$$T_s = C_0/D_0 \quad (2)$$

The parameters C0 and D0 are complex evaluation criteria related to the heat transfer coefficients and thermal resistances of the structural layers of the outer fence. The parameter from equation (1) is determined by the formula:

$$A = \alpha_c \cdot D_0/(G \cdot c), \quad (3)$$

where $\alpha_c$- is the coefficient of convective heat transfer between the air in the interlayer and its surfaces, assumed to be equal to:

$$A_c = 3{,}25 \cdot \delta_{pr}^{-0,2} \cdot v_{pr}^{0,8}, \quad (4)$$

where $\delta_{pr}$ is the height of the interlayer, m; vpr is the air velocity in the interlayer, m/s. An amount of air passes through the layer:

$$G = v_{pr} \cdot \varrho \cdot \delta_{pr} \cdot \delta^I{}_{pr}, \quad (5)$$

where ϱ - is the density of the supply air, kg/m³;

$\delta I_{pr}$ - is the width of the interlayer, m;

c is the specific heat of the air, c = 1005 J/(kg·°S)

## Determination of the energy-saving effect in a numerical experiment

An assessment of the energy efficiency of using this method of heat recovery was carried out for a 10-storey building with an air layer in the structure of the outer wall (Fig.5.1). The air that has passed through the entire layer enters the apartment, which has geometric dimensions 9,6·6·3 M. The structural solution of the wall is shown in Fig.5.2. In the calculation model, the following initial data were taken: outdoor air temperature tn =+ 1 ° C, room temperature tb = +20 °C, the volume of supply air was assumed to be 172.8 m3/h (it provides a standard air exchange in the volume of 3 m3 of air per 1m2 of room area per hour), the air velocity in the layer vpr = 0.4 m/s, channel cross section 1.2m·0.1 m (0.1 is the thickness δ of the air layer). When solving the computational model, the following were found: the coefficient of convective heat transfer between the air in the interlayer and its surfaces according to the formula (4):

$\alpha_c = 3{,}25 \cdot 0{,}1^{-0,2} \cdot 0{,}4^{0,8} = 2{,}47$ W/(m²·°C);

the average daily values of the air temperature $t_x$ in the section x of the interlayer according to the formula (1): $t_x = 18{,}9 - (18{,}9 - 1) \cdot e^{-0,043x}$,

the values of the evaluation criteria for determining the value $t_c$: $C_o$=22,2 ºC; $D_o$=1,18.

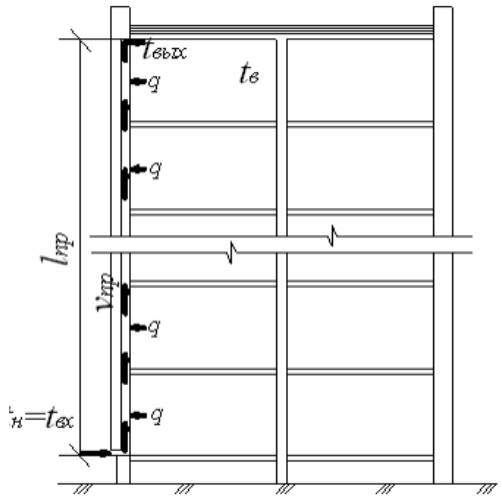



Fig. 1. Heat recovery scheme

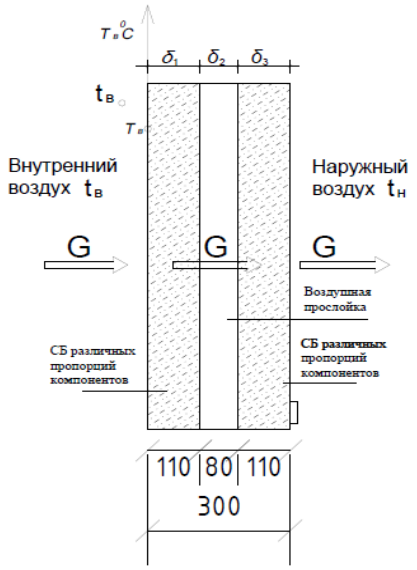



Fig.2. Structural diagram of a wall with an air layer:1-the main wall (here: brickwork); 2-the air layer;

the amount of air G passing through the interlayer to find the parameter A in the formula(1):G=0,4·1,3· 0,1· 1,2=0,067 кg/s ,

The parameter is found by the formula (3):

A=2,47·1,18/(0,067·1005)=0,043.

The main indicator in determining the effectiveness of the considered method of heat recovery by an external enclosure is the value of the temperature $t_x$ in any section of the air layer. Figure 3 shows the values of the tx parameter found by formula (1).

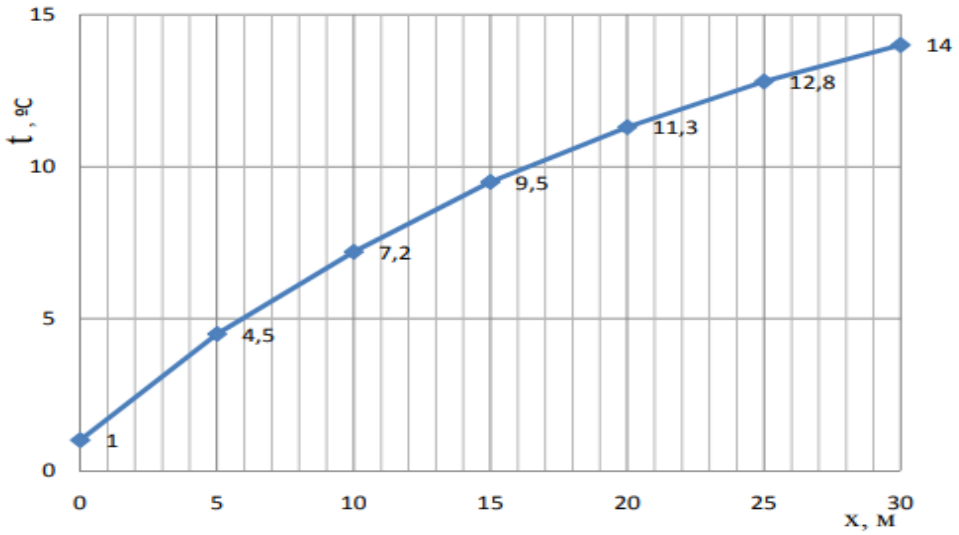



Fig.3. Dependence of the air temperature tx in the air layer on the distance to the entrance to the layer at a supply air temperature of +1 ° C and at an air velocity of 0.4 m/s in the layer.

According to the developed methodology, in order to identify the possibility of using the considered method of heat recovery at low outdoor temperatures, the calculated parameters for the outdoor temperature - 8°C were determined, taking into account the same initial data. Figure 4 shows the dependence of the air temperature $t_x$ in the air layer on the distance to the entrance to the layer. Obviously, at low temperatures $t_n$ of the supply air, the scope of application of this method of heat recovery is limited, since not only is there a high probability of abundant condensation on the surface of the plate from the room, but also its icing near the entrance of the outside air. To reduce the probability of condensation formation at positive

values of tn, it is recommended to close the channel on the inner surface of the outer wall with a plate made of painted metal sheet having practically no thermal resistance taken into account in calculations. Condensate will drain from the wall of the channel into the water intake tank, the evaporation of which reduces such an unfavorable parameter of the microclimate of the heated room as air dryness.

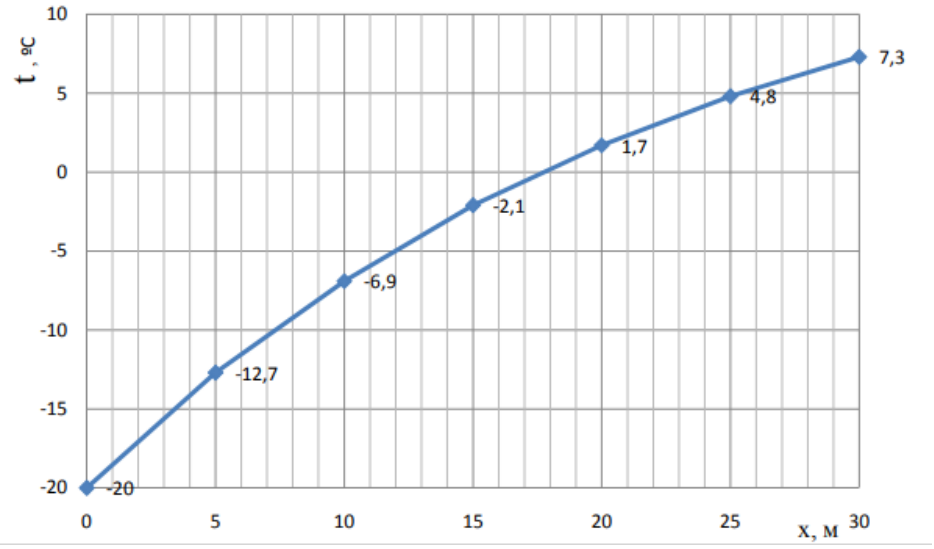



Fig.4. Dependence of the air temperature tx in the air layer on the distance to the entrance to the layer at a supply air temperature of - 20°C and at an air velocity of 0.4 m/s in the layer.

To identify the percentage of the energy-saving effect of the proposed heat flow utilization option, the heat consumption $Q_1$ for heating the required amount of ventilation air to room temperature t when the latter enters directly from the outdoor environment was considered, which was then compared with the amount of heat $Q_2$ required for heating to the same temperature of the air coming from the air layer. The calculation is given for the premises of the second floor of the building, the rest of the initial data are the same as in the above calculation example. At an outdoor temperature of + 1 ° C, the heat consumption according to the formula:

$$Q = 0{,}28 \cdot W_{vent} \cdot \gamma_n \cdot (t_{in} - t_{ot}) \quad (6)$$

$Q_1$=0,28 · 172,8 ·(353/(273+1)) · (20-1) =1184,35 Vt,

$Q_2$=0,28 · 172,8 ·(353/(273+5)) · (20-5) =921,56 Vt,

Δ=(1184,35-921,56)/1184,35=22,2%

At an outdoor temperature of -8 ° C and -6 ° C, heat consumption according to the formula (6):

$Q_1$=0,28 · 172,8 ·(353/(273-8)) · (20+8) =1804,63 Vt,

$Q_2$=0,28 · 172,8 ·(353/(273-6)) · (20-(-6)) =1663,17 Vt,

Δ=(1804,63-1663.17)/1804,63=7,83%

The results of calculating the energy-saving effect for 1,3,4 and 5 floors under the same conditions are 5.8; 7.83; 12.09; 22.2%, respectively, at a supply air temperature of +1°C and 7.83; 12.5; 23.1; 25.87%, respectively, at a supply air temperature of - 8°C. For higher floors, this method of heat recovery is not recommended due to the possibility of technical difficulties in the operation of the air layer (installation of a more powerful fan, vibration of the shielding plate, etc.).

## Conclusions based on the results of the study

Numerical experiment to determine the effect of heat saving for a room with dimensions 9,6·6·3 m using this method of heat recovery showed that for 1,2,3,4,5 floors of a building at outdoor temperatures of +1°C and -8°C, the energy saving effect can reach 8-22% and 11-26%, respectively. The application of the considered method of utilization of the outgoing heat flow by an external fence will significantly reduce the thermal energy for heating the supply ventilation air coming not from traditional supply openings (through vents, transom, etc.), but from the air layer of the external fence. The experiment was conducted in January 2022.

## Conclusion

Modeling of energy-saving outdoor fencing with a ventilated air layer is an urgent and important research topic in the field of energy efficiency of buildings. This process involves the use of modern technologies and modeling techniques to optimize the design of the fence in order to improve thermal insulation, ventilation and heat flow utilization.

1. Some of the key aspects of modeling an energy-efficient outdoor enclosure with a ventilated air gap include:

2. Thermal modeling: the use of computer programs to analyze heat loss and heat transfer in a structure taking into account the air layer. This allows you to optimize the thickness and materials of the fence to improve thermal insulation.

3. Ventilation design: simulation of the airflow in the ventilated layer to optimize ventilation and efficient heat distribution in the building.

4. Geometry optimization: analysis of the influence of geometry parameters on heat transfer and efficiency of utilization of heat flow through the air layer.

5. Consideration of climatic conditions: consideration of data on climatic conditions for optimal design and modeling of energy-saving fencing.

6. Energy efficiency assessment: using simulation results to evaluate the energy efficiency of a building and compare different design options.

In this way, such research can help to develop more efficient and climate-resilient buildings, contributing to lower energy consumption, improve the comfort of residents and reduce negative environmental impacts.

## Reference

1. Alt-Schuller, Or.N. On striking energy in industrial housing construction // Concrete and reinforced concrete. - 1982. - No.8. - S27-28.
2. Anisimov, M.S. Experimental study of thermal pots through coating and necessary stencils of basements / M.S. Anisimov, S.A.
3. JSC "Stromminocenter - XXI". Promising technologies and sound insulation for the production of foam concrete / / building materials, assemblies, technologies of the XXI century. -2001-. No. 10-pp.20-21.
4. Bergovoy, A.M. Due to an increase in energy consumption and structures made of various materials / A.M. Bergovoy, A.P. Pritshin, V.A. Beregovoy, S.S. Zvorgina / / Izv. universities. Builder.-2006.-No.9.- S4-9.
5. Bernatsky, A.F. The use of scrap metal for the production of thermal insulation materials / A.F. Bernatsky, O.S. Smirnova / / Izv. vuzov. Builder.-2007.-No.3.- S26-31.
6. Bizenov, K.A. Analysis of the properties of structural thermal insulating arbolite on rice husk / K.A. Bizenov, S.S. Uderbaev / / Izv. vuzov. Builder.-2006.-№1.- S29-32.
7. Bogoslovsky V.N. Construction thermophysics.- M.: Higher school.-1982.- 415 p.
8. Bodrov, V.I. The technique of unraveling the warm mode of the ominous screensaver during the period of "temperature slices" / V.I. Bodrov, M.S. Corygin / / ISV. universities. Builder.-2007.-№2.- S42-46
9. Khujaev P.S. Increasing energy consumption of structures in need in a hot climate / / Shokirov R.M. Ismatulozoda D.I. Nurov M.T. / BULLETIN. Tajik National University. The series of geological and Technical Sciences 2023. No.4 ISSN 2664-1534-pp.68-76 2023.
10. Khujaev P.S. Energy-efficient wall fences with high heat-dependent characteristics / / Ismatullozoda J. I. Khasanov F.N./ Scientific journal "Water Resources, Energy and Ecology " Institute of Water Problems, Hydropower and Environmental National Academic Science of Sciences of Tajikistan. Volume 3. Pp. 109-118 Dushanbe.