Journal of Information Systems Engineering and Management
2025, 10(17s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Particular Qualities of Energy Efficiency through Multilayer Enclosing Structure in Dissimilar Temperature Modes

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ARTICLE INFO

Received: 04 Dec 2024
Revised: 27 Jan 2025
Accepted: 10 Feb 2025

ABSTRACT

Nowadays passive efficiency of buildings, are saved huge amounts of energy. As a result, we get a passive house, which requires no more than 20% of an ordinary house for operation. Moreover, it does not cost the developer almost any additional investment during construction. All that needs to be done is to create the correct architectural design of the future building and bring it to life with high quality. Additional costs for increasing the thickness of the insulation, as a rule, are offset by the compactness of the building. And the supply and exhaust ventilation system is, by and large, mandatory for absolutely any type of building, and not only for energy-efficient houses. After all, controlled ventilation is the only method that ensures 100% air quality at all times. Additional energy for building maintenance can already be actively saved: with the help of appropriate engineering equipment, powered by alternative energy sources. This kind of engineering in a passive building is optional, but optional. It can significantly by 10 - 30% increase the estimated cost of a building, but with its help it is possible to reduce the costs of operating building and its harmful impact on the environment to practically zero, having received a so-called “zero energy” house, and if desired, the availability of funds, even building "additional energy"..

Keywords: Air temperature, energy efficiency, heat pumping units, thermal protection, thermal resistance, passive building, ventilation.

INTRODUCTION

The world is tirelessly looking for ways to reduce emissions of carbon dioxide into the environment, so the construction of passive "eco - houses" is becoming a priority for many countries. If until recently the concept of “conscious consumption” was associated with something far and very “niche” by the majority, now it is a young trend that is about to turn into a real “hype”. Passive buildings are characterized by very low energy loss due to the use of passive energy saving methods.

Ideally, a passive house should be an independent power system that does not require the expense of providing a comfortable temperature. Heating of such a house should be due to the heat generated by people living in the house and household appliances. If additional heating is required, alternative energy sources can be used. Hot water supply can be provided by various devices: heat pumps or solar water heaters. It is supposed to solve the problem of air conditioning of the building by means of an appropriate architectural solution, and if necessary additional cooling due to alternative energy sources, for example, a geothermal heat pump.

Global trends in increasing the energy efficiency of heat supply systems for buildings and structures, in general, are aimed at using natural renewable energy sources, decentralizing heat supply, as well as switching to low-temperature heating systems.

The solution to the problem of increasing the energy efficiency of buildings is of particular relevance for our republic due to the fact that there is a significant increase in the cost of energy consumption, as well as insufficiently introduced innovative methods for thermal protection of buildings. Providing design solutions with technological features of maintaining comfortable sanitary and hygienic conditions in individual rooms is an integral part of modern energy-efficient construction of buildings and structures at the design stage. To solve problems, it is necessary to provide scientific

Technical expedient daily, seasonal and year round thermal regimes of buildings through the coordination of dynamic internal and external thermal effects use of natural energy sources. It is also necessary to optimize the thermal effect of insolation and the influence of the environment on the building by improving its geometric and thermal performance. Passive exposure to atmospheric air energy and solar radiation heat, depending on the time of day and seasons, serve as a powerful reserve for increasing the energy efficiency of the thermal regime of buildings.

The latest heat supply systems for energy-efficient buildings, in many cases, are diverse with a high degree of automation of control of the parameters of the processes of maintaining the norms of temperature and humidity conditions in premises.

When using heat pumping units as part of heat supply systems, preference is given to low-temperature water under floor heating systems. This is due to the fact that with this type of heating, the heat exchange area between the coolant and the air in the room is much larger compared to other systems and, accordingly, the temperature potential of the coolant can be reduced. In addition, under floor heating provides the most comfortable sanitary and hygienic conditions for a person to stay in a room. The year-round change in the thermal parameters of the environment on both sides of the external enclosing structures of buildings predetermines the need to take this phenomenon into account when calculating the processes of heat transfer through the fence.

It is advisable to take the reference climatic year as the basis for calculations. It is a set of year-round dynamics of changes in the average statistical parameters characterizing the climate of the area for the previous years under consideration.

METHODS OF RESEARCH

Fluctuations of heat flux and temperature on the surface of fences and inside them are carried out according to a harmonic law. This approach can be considered correct, since harmonic functions make it possible to formalize practically any dependences of a set of harmonics of various frequencies, amplitudes and phase displacement. However, there is no unambiguous specification of the number of harmonics included in the set and their parameters. Replacing a set of harmonics with one of its representatives is a rather rough approximation, and can only serve as some approximate model of heat transfer, and nothing more.

Consideration of unsteady heat transfer is used, the ratio for the average period of the density τ of the heat flux on the inner surface of the fence will have the following values:

$$q_0 = \frac{T_{inside} - T_{outside}}{R} \quad (1)$$

T_{inside}- the average value of the air temperature in the room over the period τ;

$T_{outside}$- outside air temperature;

R - resistance to heat transfer of the fence, m^2 K / W.

Consequently, the amplitude of oscillations is used, respectively, of the heat flux density $q_0 - A_q$ and temperature $T_{inside} - A_T$. Periods of change are then accepted q_0 and $T_{outside}$.

The amplitude ratio has the following meaning:

$$Y_0 = \frac{A}{A} \quad (2)$$

Thus, consider the coefficient as the heat absorption of the inner surface of the fence, W / (m^2 K).

$$s = \sqrt{\frac{2\pi\lambda C\rho}{\tau}} \quad (3)$$

Let us also consider the coefficient of heat assimilation of a structure having the same condition as Y. Note that the value of s depends on a very uncertain value of the oscillation period τ - either the heat flux density, or the temperature of the inner wall.

The variety of methods for calculating the thermal parameters of the thermal regime of premises with a large number of empirical values is a consequence of the complexity of solving this problem in an analytical form. This is due to the fact that the non-portability of the temperature field in the building envelope, the processes of acclimatization of premises, the non-isothermality of the surface of low-temperature heating systems, as well as the influence of a large number of physical factors on the results of the calculation of individual values. The discrepancy in the obtained values according to the existing methods reaches almost 35%.

Also, in a separate way, it should be noted that there is no direct accounting for the year-round thermal effect of insolation on the enclosing structures.

The method for calculating the thermal parameters of the enclosing structures provides for a stationary linear temperature distribution in each of the wall layers, the room is heated regularly, and the temperatures of the cold season are quite stable. In real conditions, the temperature of heating devices often changes due to various kinds of objective and subjective factors: emergency situations, planned and unplanned decrease and increase in the temperature of the coolant, etc., and the outside air temperature almost never remains constant even during the day, so thus, unsteady heat transfer is almost always present. The constant change of boundary conditions determines the permanent process of redistribution of temperature values in the thickness of the enclosing structures. There are two types of heating or cooling conditions: a change in temperature and a change in the heat flux on the surface of the structure. In real conditions of heat transfer through the protective structure, the surface temperature changes, and the heat flux entering the wall surface changes in the case of a stepwise change in the heat transfer of the heating devices of the heating system.

Of scientific interest is the general problem of calculating non-stationary heat transfer through multilayer structures, which would make it possible to note the features of a number of issues in the design of such structures, such as compliance with the regulated methodology of real operating conditions; change in temperature values in the structure under various operating modes and the distribution of the temperature field in a complex design.

Regardless of one or another technical solution for cooling indoor air in summer, energy costs and devices are needed for the perception of heat. The most rational and cost - effective is the organization of heat removal without additional devices.

In addition, this is possible if this problem is solved when using as the main source of energy for heat supply of buildings, insolation and a water under floor heating system with a heat pump and a ground heat accumulator. Unlike radiator heating, such a system works with a significantly smaller temperature difference between the coolant and the room air of about 9 – 13 C °.

Therefore, when using heat extraction from premises in the warm season, the potential of the coolant will turn out to be quite high and it can be sent to, of course, not working at the moment, heat pumps. To avoid uncomfortable sensations during such cooling, the floor surface temperature should be reduced by no more than 1.5 C ° with regulation of the heat carrier flow.

The high-temperature circuit of heat pumps must be adjusted to the temperature of the intermediate heat carrier of solar collectors, the heat of which is supplied through the accumulator during the warm season, or to the temperature of the hot water supply. In both cases, the cooling energy is not consumed in the environment and the required area of the solar collectors is reduced.

One of the most effective ways to reduce the heat losses of buildings is to replace the windows of outdated structures with low thermal resistance with modern ones with energy-saving double-glazed windows.

The most common in practice is a double-glazed unit; it has three glasses, the space between which is filled with air or other gas. Such double-glazed windows have higher thermal resistance values than single-chamber ones, depending on the quality characteristics of the glass, its thickness, the distance between the glasses, as well as the layout of the translucent structure in the window armhole. So the surface of a conventional window glass is characterized by a high degree of absorption capacity of about 0.85 in the infrared range of radiation. With a decrease in the radiation component of the heat flux through the window structure, so-called low-emission coatings with low absorption capacity in the corresponding radiation range are applied to the inner surfaces of the glass. To reduce the conductive component of the heat flux, the space between the glass is filled with inert gases, as well as sulfur hexafluoride, has a higher viscosity, which leads to a decrease in the intensity of convective flows in the chambers by reducing the convective component of heat transfer through the glass unit. Since argon and krypton have less thermal conductivity than air, such a gaseous environment also contributes to an increase in the thermal resistance of a glass unit.

According to KMK 2.01.05 - 19 “Natural and artificial lighting”, the minimum allowable value of the resistance to heat transfer of the translucent enclosing structure of residential and public buildings should be at least 0.75 m^2 • K / W and 0.60 m^2 • K / W, respectively, for I and II climatic zones of our country.

In accordance with KMK 2.01.05 - 19 “Natural and artificial lighting”, façade translucent structures, including glass walls and doors, windows, must be designed and manufactured in such a way that the risks associated with the material itself are taken into account. The parameters of glass structures must be calculated, and the choice of the type of glass used must be carried out in such a way that the destruction of the structure does not cause the danger of a person falling down through the structure and in order to avoid possible injury of people by falling fragments of broken glass. At the same time, the requirements for natural lighting of premises of public, residential and industrial construction are preserved, given in the KMK Natural and artificial lighting. Wind loads on window structures are calculated according to KMK 2.01.07 - 96 “Loads and Impacts”.

The fire resistance class of translucent energy-saving structures that perform the functions of external enclosing walls of buildings should be determined according to separate methods developed for the development of SHNK 2.01.19 - 09 “Determination of categories of premises, buildings and outdoor installations for explosion and fire hazard”. The efficiency of energy-saving glazing is characterized by the value of the reduced thermal resistance, the characteristics of glass units are calculated for 1 climatic zone.

It is possible to achieve such a value for window structures when using multi-chamber double-glazed windows, which include glass with a low-emission coating of various types, as well as increased sealing of the perimeters of window sashes or doors of balcony blocks that can be opened.

In accordance with technological standards, an increase in the wall thickness and the number of frontal chambers in the profile, in addition to increasing the strength and elasticity, also leads to an increase in the reduced coefficient of thermal resistance of heat transfer of the entire window structure.

General technical conditions as: reduced heat transfer resistance not less than 0.75 m^2 • k / W, air permeability up to 8 m3 n / (h / m^2), water resistance not more than 360 Pa, sound insulation 35 dB, total light transmittance not less than 0.54, resistance to wind loads not less than 400 Pa. At the same time, it is proposed to use an arbitrary four or five-chamber profile system and the corresponding locking fittings in climatic design 1. The light transmittance of a glass unit in the visible part of the spectrum must be at least 0.73 to achieve the norms of natural illumination.

During the warm period of the year, pipelines can be used to create a heat barrier, while supplying a propylene glycol solution with the same temperature of 5. Such heat loss must be compensated by an additional heat source of a higher temperature potential than the energy of the soil. The tool for increasing it can be a heat pump that uses the residual heat of propylene glycol after the thermal barrier as a heat source. The use of a thermal barrier will reduce the use of high-grade heat.

It is suggested to use a soil array as a heat source or heat sink. Heat can be extracted or given to the soil, for example, by means of soil heat exchangers in energy piles. The energy pile can be part of the foundation of a building with a built-in pipeline, through which circulates a liquid that removes natural heat from the soil. Energy piles can be made in industrial conditions (ready-made driving piles) or directly on site (drilling piles made of monolithic concrete).

The optimal formula of two-chamber translucent glass units consists of three glasses, two of which have a low-emission coating inside. The optimum distance between all windows is 10 - 12 mm.

The research of the quasi-stationary process of heat exchange between the coolant, the air in the room and the enclosing structures was carried out in a series of experiments at different thermal loads on the system and at different hydraulic regimes of the coolant flow in the heating circuit. According to the readings of the heat meter installed in front of the entrance of the circuit to the floor, the constant heat load on the heating circuit of the floor was determined, corresponding to a discrete value of 600 W, 800 W, 1000 W.

After the establishment of a new regime for the experiment, the control parameter indicates the stabilization of heat exchange processes, is the registration of a constant temperature field of air in the laboratory room above the floor. The time to reach the quasi-stationary operating mode of the system, in any case, averaged almost 36 hours. When carrying out all the experiments, days were chosen with minimal daily fluctuations in the values of the outside air temperature and the speed of its movement, which almost ensured the constancy of heat loss in the room over time.

Each experiment was carried out under different regimes of coolant flow in the heating circuit, with laminar and transient processes. By changing the rotational speed of the circulating pump rotor, the value of the speed of movement of the coolant was changed and recorded by a heat meter.

Nowadays, program automation is widely used when using under floor heating. Modeling heat transfer in a water floor heating system without taking into account the natural convection of air in the room and the movement of water in the heating circuit, while in the calculations of this work, heat transfer by radiation is taken into account. The main purpose of this part of the work was a numerical study of the thermal regime of a room with low-temperature water floor heating of various designs. The design model of a typical room is a parallelepiped with dimensions 4.5 x 2.8 x 2.8 m, consisting of two zones: air and elements of the under floor heating system. The under floor heating system conventionally consists of layers: surface finishing layer 1 ceramic tiles 8 mm thick; monolithic heating plate (panel), 2 cement mortar with a plasticizer - 50 mm, inside which there is a heating circuit 3 metal-plastic pipe with a diameter of 16x3 mm, thermal insulation 4 extruded polystyrene foam - 55 mm thick, the base of the under floor heating 5 concrete - 150 mm thick.

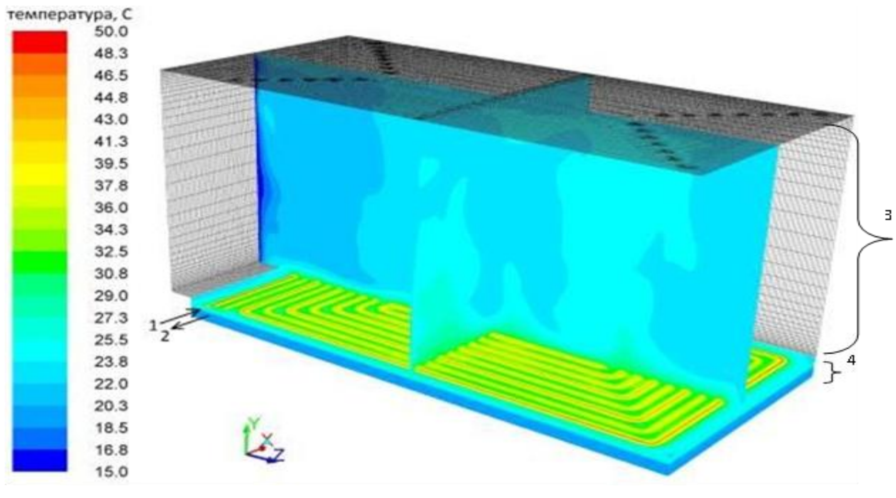

Fig. 1. Arrangement of the model of the thermal state of the room

1 - coolant inlet, 2 - coolant outlet 3 - indoor air; 4 - water underfloor heating system

The investigated tube laying scheme is a bifilar double helix. Mathematically simulated four different floor heating system designs with heating circuit closure steps of 0.125; 0.15; 0.175; 0.200 m.

The calculation was carried out using a system of equations for the conservation of momentum and energy. The system of differential equations characterizing the processes of heat transfer and hydrodynamics in the water floor heating system includes the equation of continuity, motion and energy for air and water, as well as the equations of thermal conductivity for the i-th layer of the floor. The calculation is made for a stationary operating mode of the heating system. Numerical modeling was carried out with a laminar flow of the coolant in the pipe. Due to the fact that the mode of air movement in the room is transient, better agreement of the simulation results with experimental data was obtained in the laminar mode.

RESULTS

The results of comprehensive studies of complex heat transfer through the building envelope and in engineering heating and air conditioning systems made it possible to develop scientific and technical provisions for creating an energy - efficient building with an estimated specific energy consumption of less than 15 kWh / (m^2 year). To increase the thermal insulation capabilities of the enclosing structures, a thermal air curtain of the facades of the house was proposed for use.

The diagram of a combined heat supply system for an energy efficient house has been developed, it includes heating system circuits, ground heat exchangers circuits, thermal solar collectors, a heat pump and a solid fuel boiler, which can provide reliable efficient heat with redundant energy sources.

CONCLUSIONS

Consenquently, the research of the energy parameters and the efficiency of the combined heat supply system of an energy - efficient buildings showed the value of the average seasonal conversion factor of the heat pump about 3.5, which is acceptable for the corresponding operating conditions.

Experimental studies of the thermal regime of a conventional energy - efficient room have shown that the most uniform distribution of air temperature along the height of the room turned out to be during the operation of the underfloor heating system or the simultaneous use of all circuits. This is positively characterized for sanitary and hygienic reasons and the comfort of a person's stay in the room.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

Tutiyo Egamberdieva, Sadriddin Sayfiddinov: Conceptualization, Methodology, Software, Writing-original draft, Reviewing and editing, Visualization. Ulugbek Akhmadiyorov: Conceptualization, Reviewing and editing, Visualization. Pakhriddin Akhmedov: Methodology, Reviewing and editing, Visualization.

CONFLICT OF INTEREST

The author declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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