Scientific Approach To The Development Of The Fundamentals Of Thermal Protection Of Civil Buildings

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ABSTRACT

The building is a complex energy system. In this regard, the work analyzed and considered to investigate the process of interaction of its enclosing structures with climatic factors in order to establish the physical parameters of fences responsible for the formation of the microclimate of premises, it is most advisable using the method of mathematical modeling of its thermal regime, which allows to estimate the optimal conditions of the internal environment with minimal cost.

Keywords: Temperature, Outdoor Environment, Humidity, Outdoor Air, Moisture Exchange, Durability, Air Environment.

One of the main issues in the design of buildings is to find the optimal design and engineering solution for isolating its internal space from the effects of the external environment, that is, minimizing heat loss in the premises, provided that comfort is provided in accordance with current standards. The enclosing structures, which are a barrier between the indoor environment and the outdoor air, are in a state of constant heat and mass transfer. It is possible to describe the processes occurring in enclosing structures using the scientific basis of building thermophysics – the theory of general thermodynamics. However, solving problems of thermodynamics using differential equations describing it requires complex mathematical calculations, which significantly complicates the work of designers. Engineering calculation methods developed in building thermophysics use simplifications of the mathematical apparatus and simpler versions of the kinetics of heat and mass transfer processes in enclosing structures. In this regard, currently the required thermal protection of buildings is determined based on the thermal characteristics of the fence in conditions of stationary heat transfer. In the summer conditions of areas with a dry, hot climate, the unsteadiness of heat transfer is most pronounced. And here the heat storage characteristics of fences play a significant role in energy saving. Their capabilities have not been sufficiently studied, but they are of great interest as a reserve for improving the thermal protection of buildings.

Considering the building as a single thermal power system, such components of this system as the internal heat supply of the building, including heating, ventilation, air conditioning, etc., were specifically excluded. In other words, the optimization problem for the building was solved in relation only to the external and internal geometry of the building architecture and the thermophysical properties of the material in their interaction with the external environment. This approach allowed us to obtain objective estimates of the energy efficiency potential of the building in its pure form. Therefore, the third block "the model of the thermal energy balance of the building premises" was idealized in accordance with the approach described below.

A point source is introduced that provides a quasi-uniform stationary temperature field in an arbitrary flat region S with different boundary conditions in certain sections of the boundary. The thermal conductivity coefficient a of the material of the region is a function of temperature and for this material is represented by const. Using normalization for temperature variables T* and power q* of the i-th source

$$T = \frac{T^* - T_0}{T_f - T_0}, \quad q_i = \frac{q_{i_i}^*}{a(T_f - T_0)}, \qquad (1.1)$$

the criterion of optimality of the temperature field was presented as:

$$T(x, y) \equiv 1 \qquad (1.2)$$

The system of differential equations describing the temperature field will have the following form:

$$\begin{aligned}
&\Phi_1(q_1, x_1, y_1) = a_1 \frac{1}{S}\int |1 - T(x,y)| dS + a_2 \max|1 - T(x,y)| + a_3 \frac{1}{S}\int |grad[T(x,y)]| dS + \\
&+ a_4 \max|grad[T(x,y)| + C \\
&\Phi_2(q_2, x_2, y_2) = a_1 \frac{1}{S}\int |1 - T(x,y)| dS + a_2 \max|1 - T(x,y)| + a_3 \frac{1}{S}\int |grad[T(x,y)]| dS + \\
&+ a_4 \max|grad[T(x,y)| + C \\
&\vdots \qquad\qquad \vdots \qquad\qquad\qquad\qquad\qquad\qquad (1.3)\\
&\Phi_i(q_i, x_i, y_i) = a_1 \frac{1}{S}\int |1 - T(x,y)| dS + a_2 \max|1 - T(x,y)| + a_3 \frac{1}{S}\int |grad[T(x,y)]| dS + \\
&+ a_4 \max|grad[T(x,y)| + C \\
&\vdots \qquad\qquad \vdots \qquad\qquad \vdots \\
&\Phi_n(q_n, x_n, y_n) = a_1 \frac{1}{S}\int |1 - T(x,y)| dS + a_2 \max|1 - T(x,y)| + a_3 \frac{1}{S}\int |grad[T(x,y)]| dS + \\
&+ a_4 \max|grad[T(x,y)| + C,
\end{aligned}$$

Where C= $a_5 \sum_{i=1}^{n} q_i$ - the stabilizing term due to the incorrectness of the Tikhonov A.H. optimization problem [1].

In (1.1) - (1.3): T_0 ▯ ambient temperature, T_f -required temperature in the S, χ - normalization coefficient of thermal conductivity of the material, a_k (k=1,2,...,5) weight coefficients.

In the functional, the first and third terms characterize the averaged properties of T(x,y), and the second and fourth terms are local.

The solution of the system (1.3) for each node of a regular grid was carried out using the finite element method [2], the algorithm of which is reduced to solving a nonlinear system of equations. The latter was solved by the linearization method using the Seidel method within each iteration [3]. The selection of point source parameters is carried out by the method of coordinate descent [4].

The optimization task for determining the indicators of architectural and engineering solutions of a building that minimize energy consumption to create a microclimate in its premises, following the approach of Tabunshchikov Yu.A. [4], was presented in the form of a generalized target function:

$$\Re_{min} = f(a_i, b_j, c_k), \qquad (1.4)$$

Where $\Re_{min}$ – the target function that determines the minimum energy consumption for creating a microclimate in the premises; a_i - indicators of architectural and engineering solutions of the building (shape, size, orientation, etc.), ensuring minimization of energy consumption under fixed external conditions; b_j – climatic parameters of environmental parameters, c_k - thermal parameters of enclosing structures.

Optimization $\Re_{min}$ providing a favorable regime of thermal and energy effects of the outdoor climate on the thermal balance of the building, was performed as a function of a given characteristic time period. At the same time, changing the shape of the building or its size and orientation, in order to optimize the influence of the outdoor climate on its thermal balance, did not require changing the area or volume of the building.

The task of determining the optimal thermal performance of external enclosing structures was formulated in accordance with climatic conditions. In other words, the optimal values of thermal engineering parameters of enclosing external structures (thickness, weight, layering, etc.) were determined from the conditions of maximum resistance to heat transfer and attenuation of external thermal influences at specified climatic parameters.

When constructing a mathematical model of the thermal regime of a building, the following simplifications were adopted:

- the objects in question are considered isothermal;
- the building's enclosing structures are considered as single-layer walls, however, in the developed algorithms this special case is easily generalized to a multilayer version;
- the thermophysical parameters of the wall layer material are constants;
- temperature fields of enclosing structures are assumed to be one-dimensional;
- the release of heat due to phase transformations of moisture in the volume of individual layers of external walls is not taken into account;
- the equality of the temperatures of the internal air of adjacent rooms is accepted;
- as a consequence of the previous simplification, the temperature field of the inner walls and ceilings (with the exception of the upper and lower ones) is considered homogeneous;
- in relation to the stationary thermal regime, the temperature of the internal walls and ceilings is assumed to be equal to the temperature of the internal air (the effect of solar radiation is neglected). In this case, the heat balance equation for internal walls and ceilings is not considered.;
- air exchange in individual rooms of the building is carried out by infiltration of outdoor air through the leaks of translucent

plots and entrance doors);

- multilayer translucent sections of the enclosing structure are considered as monolithic elements having a thermal conductivity resistance of R_{TS} and, accordingly, a thermal conductivity coefficient

$$\lambda_s = \frac{\delta_s}{R_{TS}},$$

Where δ_S - the thickness of the section;

When describing the non-stationary thermal regime of a building, it is assumed that periodic heat and mass transfer processes in its premises continue with constant amplitudes for a very long time and, accordingly, the initial conditions lose their influence on the course of these processes.

Based on the above, the mathematical model of the non-stationary thermal regime of the building was presented as a system of partial differential equations with boundary conditions, ordinary differential equations and algebraic equations.

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