Calculation of Properties of the Building Materials Coated with Composite Paint consisted of Hollow Ceramic Microspheres (THERMOSHIELD)

Kabashnikov V.P. *, the Doctor of Sciences,

Nekrasau V.P., Ph.D.,

УП "Institute NIPTIS", Minsk

*GNU Institute of physics, named by B.I. Stepanov, Belarussian National Academy of Science.

The modern building represents complex energy consumption system with various components in which various physical processes of absorption, transformations and transfer of energy proceed / 1-2/.

Now for energy savings in buildings paints with fillers from spherical balls, as hollow, as well as complete are widely used. Presence of balls of the micron size results to the modification of radiating properties of such paints. Energy efficient paints are issued for internal and external application. To estimate influence of such paints on a thermal mode of a building it’s necessary to create the corresponding physical and mathematical models in which, with reasonable accuracy, all kinds of heat exchange are taken into account.

In the given work we formulated the physical and mathematical model for calculation of a thermal mode of a building which in an obvious kind takes into account orientation of fence construction of a building depending of parties of the world, that allows to calculate radiating cooling (heating) of fence constructions, climatic conditions and work of the engineering equipment in premises. The structure of walls, both internal, and external, can be set independently from each other, including with a window /3/. Optical properties of paint Thermoshield are taken into account by a degree of blackness in boundary conditions. These factors can experimentally be determined or calculated from radiative transfer equation.

For the account of influence of a sunlight radiation on a thermal mode of a building the special program which allows to take into account position of the sun in a firmament at any time year, orientation of external walls for the set breadth of district has been written. In our numerical examples calculation of a thermal mode of a building are given for the breadth of Minsk equal to approximately 54.

For a finding of distribution of temperature in external and internal walls in view of their structure and temperature of air in premises we solve system of the equations 1 – 2 with boundary conditions () - (8). In process of solution of the given system of the equations convection & radiating heat exchange with the external air, convection heat exchange with internal air, radiating heat exchange between internal sides of internal & external walls & a window is taken into account.

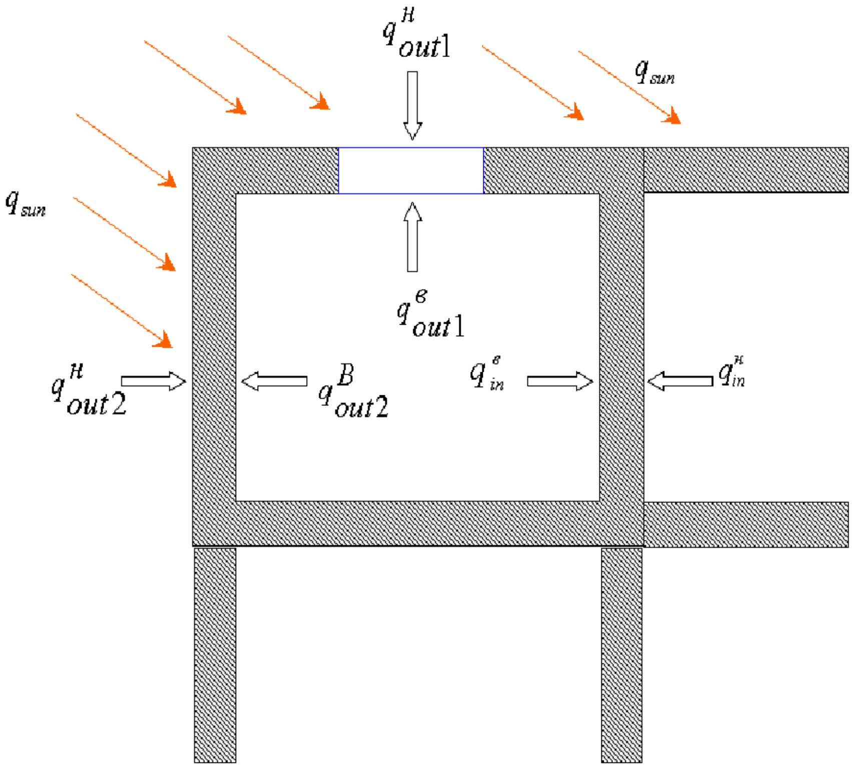
The given model of a thermal mode of a building can be described by system of the equations:

Boundary conditions is written in a general view: Expressions of boundary conditions for a window coincide with boundary conditions for the first external wall.

The flux of a solar energy in a room through two glasses is determined as:

$$q_{sun} = S_{win} \cdot \cos\varphi \cdot Q_{\text{ýôô}} \frac{1-r}{1+3r} \qquad r = \frac{1}{2}(r_{II} + r_{\perp})$$

Equations for walls



Room Configuration

$$\frac{\partial T_i}{\partial t} = \chi_i \frac{\partial^2 T_i}{\partial x^2}, \tag{1}$$

i = 1 : external walls with wind ows,

i = 2 : blind external walls,

i = 3 : internal walls,

i = 4 : windows

Equations resolved by end difference method

Equations for determine air temperature in apartment.

$$\frac{dU}{dt} = \frac{1}{\rho_{âîçä}\, ń_p V_{ęîě}} \left\{ S_{out1}\alpha^{â}_{out1}\left(T^{â}_{out1} - U\right) + S_{out2}\alpha^{â}_{out2}\left(T^{â}_{out2} - U\right) + S_{in}\alpha^{â}_{in}\left(T^{â}_{in} - U\right) + S_{win}\alpha^{â}_{win}\left(T^{â}_{win} - U\right) + q_{čňňî÷} + q_{sun} \right\} + \frac{Q(t)}{V_{ęîě}}\left(U^{ĺ}_{1} + U\right) \tag{2}$$

Boundary conditions

$$q^{â}_{out1} = \rho_i c_i \chi_i \left.\frac{\partial T}{\partial x}\right|_{x=l} = \varepsilon_{eff}\sigma\left[\left(T^{â}_{in}\right)^4 - \left(T^{â}_{out1}\right)^4\right]\cdot\Omega_{1čç3} + \varepsilon_{eff}\sigma\left[\left(T^{â}_{out2}\right)^4 - \left(T^{â}_{out1}\right)^4\right]\cdot\Omega_{1čç2} + \alpha^{â}_{out1}\left(U - T^{â}_{out1}\right) \tag{3}$$

$$q^{\text{í}}_{out1} = \rho_i c_i \chi_i \left.\frac{\partial T}{\partial x}\right|_{x=0} = q_{\substack{sun \\ \text{ír ńň}1}}(t) - \varepsilon_{eff} \cdot \sigma (T^{\text{í}}_{out1})^4 + \alpha^{\text{í}}_{out1}(U^{\text{í}}_1(t) - T^{\text{í}}_{out1}) \tag{4}$$

$$\begin{aligned} q^{\text{â}}_{out2} = \rho_i c_i \chi_i \left.\frac{\partial T}{\partial x}\right|_{x=l} &= -\varepsilon_{eff} \sigma \left[\left(T^{\text{â}}_{out2}\right)^4 - \left(T^{\text{â}}_{out1}\right)^4\right] \cdot \Omega_{2\text{čç}1} - \\ -\varepsilon_{eff} \sigma \left[\left(T^{\text{â}}_{out2}\right)^4 - \left(T^{\text{â}}_{win}\right)^4\right] \cdot \Omega_{2\text{čç}4} &- \varepsilon_{eff} \sigma \left[\left(T^{\text{â}}_{out2}\right)^4 - \left(T^{\text{â}}_{in}\right)^4\right] \cdot \Omega_{2\text{čç}3} + \alpha^{\text{â}}_{out2}\left(U - T^{\text{â}}_{out2}\right) \end{aligned} \tag{5}$$

$$q^{\text{í}}_{out2} = \rho_i c_i \chi_i \left.\frac{\partial T}{\partial x}\right|_{x=0} = q_{\substack{sun\ \text{ír} \\ \text{ńň}\ 2}}(t) - \varepsilon_{eff} \cdot \sigma \left(T^{\text{í}}_{out2}\right)^4 + \alpha^{\text{í}}_{out2}\left(U^{\text{í}}_1(t) - T^{\text{í}}_{out2}\right) \tag{6}$$

$$\begin{aligned} q^{\text{â}}_{in} = -\rho_i c_i \chi_i \left.\frac{\partial T}{\partial x}\right|_{x=0} &= -\varepsilon_{eff} \sigma \left[\left(T^{\text{â}}_{in}\right)^4 - \left(T^{\text{â}}_{out1}\right)^4\right] \cdot \Omega_{3\text{čç}1} - \\ -\varepsilon_{eff} \sigma \left[\left(T^{\text{â}}_{in}\right)^4 - \left(T^{\text{â}}_{win}\right)^4\right] \cdot \Omega_{3\text{čç}4} &- \varepsilon_{eff} \sigma \left[\left(T^{\text{â}}_{in}\right)^4 - \left(T^{\text{â}}_{out2}\right)^4\right] \cdot \Omega_{3\text{čç}2} + \alpha^{\text{â}}_{in}\left(U - T^{\text{â}}_{in}\right) \end{aligned} \tag{7}$$

$$q^{\text{н}}_{in} = \rho_i c_i \chi_i \left.\frac{\partial T}{\partial x}\right|_{x=l} = \alpha^{\text{н}}_{in}(U^{\text{н}}_2 - T^{\text{н}}_{in}) \tag{8}$$

The analysis of results for numerical calculations of heat exchange of a building with an environment is complicated, as depends on many external parameters, such as: structure external and internal walls, temperature or change of temperature of external air, temperature of air in surrounding premises, a season (it is clear, is cloudy), speed of a wind, etc. To facilitate work of the user the special program on input of the initial data has been written to visualization of results of calculations.

The program for the solution of the above-stated equations with boundary conditions is written in language - FORTRAN. Program of data input and visualization of calculation - in language Object Pascal.

Results of the decision of system of the equations (1) - (2) are submitted on fig. 1.

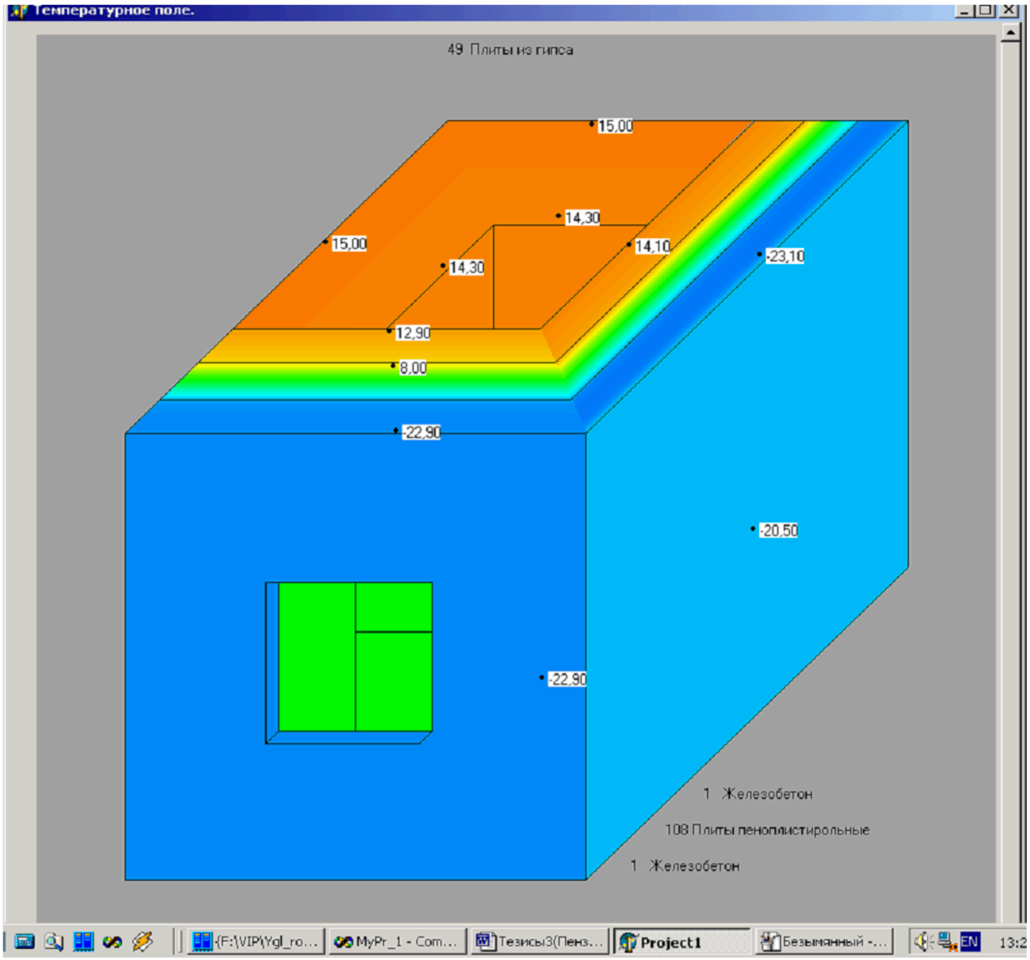


Fig. 1. Distribution of temperature in an angular room of a building which external walls will consist of heavy concrete, пенополистерола. Calculation was carried out for a cold five-day week: January - temperature of external air - 25+5, with, speed of a wind - 3m/s, an atmosphere cloudless, orientation of a wall with a window - the south, a blank wall - the east, basic temperature in a room + 18, system of heating is taken into account in this calculation.

Figure refers to 17 hours of the second day after the beginning of the account.

Convection heat exchange on an external surface of fence construction was determined basically by speed of a wind, blowing of a surface and by the direction of air movement relatively to surface.

At a direction of a wind along a surface the coefficient of convection exchange determined as.

$$a = 5{,}8 \cdot v^{0,8} \cdot l^{-0,2}$$

For calculation of heat exchange on a surface of external walls at frontal blowing by a wind it is recommended to use the formula:

$$a = 11{,}6\sqrt{v}$$

For verification of mathematical model the comparison of results of numerical calculations with experimental values of temperatures has been carried out. On the fig. 2 comparison of temperature distribution (both: calculated & experimental) for an external surface of a wall is given in dependence on time. Comparison shows good concurrence of numerical calculation to experimental data.

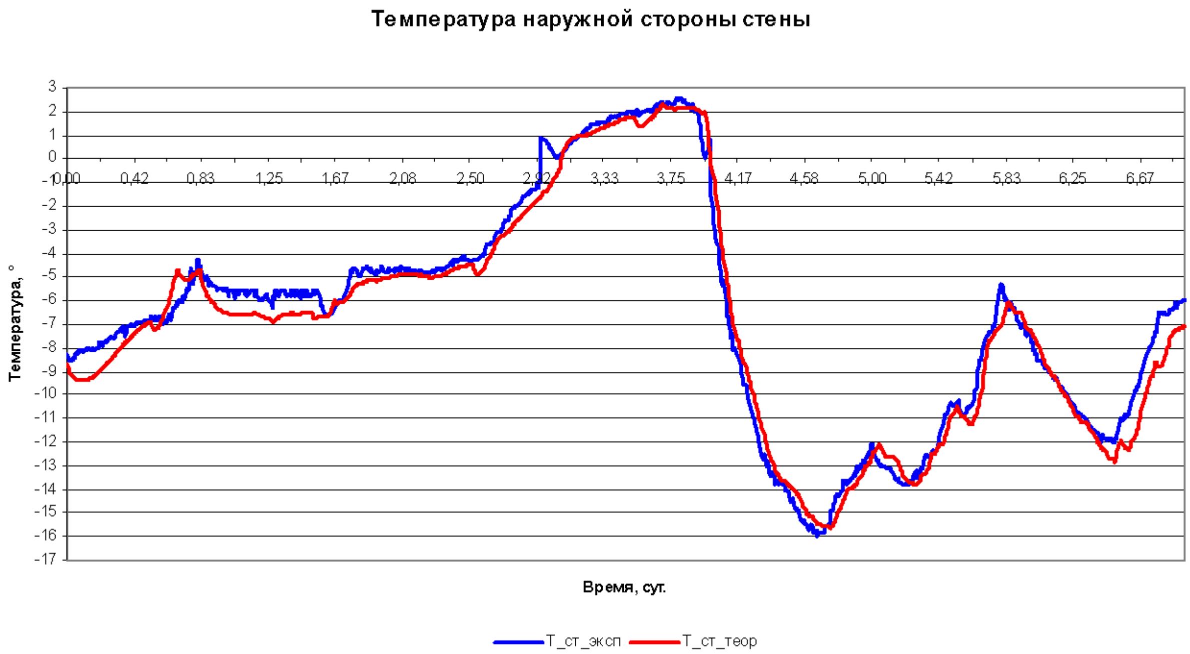


Fig. 2. Temperature of external side of a wall.

THE CONCLUSION

The developed mathematical model allows to calculate thermal balance of a building depending on:

- speed and amplitudes of change of external meteorological parameters,
- intensity of a direct and scattered radiation;
- heat engineering and constructive parameters of a building,
- quantity of window apertures and their area, orientation of the building on the parties of world,
- work of the engineering equipment.

The influence of covering Thermoshield on heat exchange inside and outside of a premise is taken into account by an effective degree of blackness of surfaces.

The specification

Where ....$T_{out1}, T_{out2}, T_{in}, T_{win}$ – distribution of temperature in the first and second external wall, an internal wall and a window accordingly, °C; $\chi = \dfrac{\lambda}{c_v \rho}$; λ - factor of heat conductivity, Wt /(m^2·°C); c_v- a specific thermal capacity of a material, Dg / (kg·°C); ρ - density of a material, kg/m^3, U - temperature of air in a room; U_1^H – temperature of external atmospheric air; U_2^H – temperature of air in premises, which surround a researched room; V - volume of a room; $S_{out1}, S_{out2}, S_{in}, S_{win}$ - the area of the first and second external walls, the area of an internal wall, the area of a window accordingly, m^2; α -

the coefficient of convection heat exchange, Wt / ($m^2 \cdot {}^\circ C$); l – the characteristic size of a surface in a direction of air movement, m; v - speed of a wind, km/s; Q - intensity of air exchange between a constant and external (external, street) air, m^3 / sec; $q_{ист}$ - capacity of a thermal emission in room air (Wt); $q_{солн}$– the solar stream getting in window (Wt); Ω – An effective solid angle on which from internal walls the external wall or a window is visible; ε_{eff} - an effective degree of blackness for given fence construction; σ - Stephan - Bolzman's constant ; r - Frenels' coefficient of reflection on border "air - glass"; β - a corner between a normal to a plane of a window and a direction on the sun.

The Literature

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