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HEAT-SHIELDING QUALITIES AND METHODS FOR ASSESSING THE HEAT-SHIELDING QUALITIES OF WINDOW BLOCKS AND THEIR JUNCTION NODE WITH WALLS

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Annotation:
This article is devoted to the heat-protective quality and classification of the heat-protective characteristics of window blocks and their junctions to the wall, the thermal resistance of the structures of window blocks of a constructive solution, the method of calculating the temperature field in the external enclosing structures of buildings and in the junctions of window blocks to the wall.

Keywords: Window block, temperature, extruded polystyrene, temperature and humidity, rectangular grid

1. Introduction. The choice of a constructive solution for window blocks for use in the construction of new or reconstruction of existing buildings is recommended to be made taking into account the architectural, compositional and technical and economic requirements for such buildings.
Architectural and compositional requirements determine the solution of a set of issues, including the designation of the dimensions of structures, the choice of shape and material, the color scheme of windows, etc. These parameters are set on the basis of the general architectural design of the building, the required level of natural light in the premises, and the climatic features of the construction area.
The technical and economic requirements for window blocks should provide for the solution of issues, including the assessment of their physical and technical characteristics (resistance to heat transfer and air permeability, light transmission, load-bearing capacity, etc.), determination of one-time costs for the supply and installation of structures and the cost of their operation and repair.

The choice of window block designs according to technical and economic indicators should be considered in conjunction with the solution of issues related to the design and operation of heating, ventilation and air conditioning systems in rooms.

Window blocks installed in buildings must provide:

- Normalized level of natural lighting in the premises in accordance with the requirements of building codes;
- Maintenance of microclimate parameters in the premises in accordance with the requirements of sanitary and hygienic standards;
- Normalized resistance to heat transfer;
- Protection of premises from atmospheric influences (rain, wind, temperature);
- Protection of premises from the adverse effects of production activities (noise, dust, exhaust gases, etc.);
- Connection with the environment.

The choice of materials for the manufacture of window blocks should be made taking into account their physical and technical characteristics and restrictions on the scope, due to the parameters of the temperature and humidity conditions in the premises, classified by KMK 2.01.04-97*, and the degree of aggressive environmental impact, determined by KMK 2.03.11-96.

Window blocks made of wood with a relatively small volumetric weight have sufficient strength, have low thermal conductivity, are easy to process, maintainable and are environmentally friendly. At the same time, wood products are characterized by natural defects (knots, cracks, structural heterogeneity, etc.), combustibility, hygroscopicity, and the possibility of damage by microorganisms. Therefore, wooden window blocks must have a reliable protective paint coating in accordance with KMK 2.03.11-96 and be used in residential, public and industrial buildings with dry or normal temperature and humidity conditions.

Window blocks made of aluminum profiles are characterized by high strength with a relatively small volumetric weight, do not corrode in a humid environment, are durable and maintainable.

At the same time, products made of aluminum profiles have a high thermal conductivity and, upon contact with elements from other metals, electrolytic corrosion can occur in them.

Window blocks made of aluminum profiles can be used in public and industrial buildings with different temperature and humidity conditions in the premises, as well as in buildings with damp or wet conditions and aggressive environments, subject to the instructions of KMK 2.03.11-96.

Window blocks made of aluminum profiles are not recommended for natural lighting in rooms with a high content of chloride compounds in the air.

Window blocks made of PVC and fiberglass profiles have high thermal performance, have minor temperature deformations, and are resistant to moisture and various aggressive environments. They can be operated at an ambient temperature ranging from minus 45 to plus 65 °C. Window blocks made of PVC and fiberglass profiles can be used for natural lighting in rooms, buildings for various purposes with dry, normal, wet and wet humidity conditions.

Window blocks made of steel have high strength and have a relatively low cost. In terms of resistance to heat transfer and resistance to aggressive environmental influences, they are inferior to window blocks made of other materials. Therefore, such products must have an anti-corrosion coating in accordance with the requirements of KMK 2.03.11-96.

Window blocks made of steel should, as a rule, be used in buildings of industrial enterprises with dry and normal temperature and humidity conditions and non-aggressive or slightly aggressive indoor environments.

Combined wood-aluminum window blocks are recommended to be used for natural lighting in rooms with dry and normal modes.

Window blocks made of combined profiles using aluminum and plastic can be used for natural lighting in buildings for various purposes, including those with aggressive environments.

2. The Main Part

In building thermal physics, forecasting the temperature and humidity conditions of enclosing structures is carried out on the basis of solving differential equations of heat and mass transfer [9]. The theoretical foundations of methods for calculating temperature and humidity conditions were laid by the works of V.N. Bogoslovsky, O.E. Vlasov, V.G. Gagarin, A.V. Lykov, V.D. ., Ushkova F.V., Fokina K.F., Franchuka A.U., Shklover A.M. and other scientists. The main technique used to solve the problems of building thermal physics is their numerical solution in finite differences. This is due primarily to the simplicity of approximating derivatives in differential equations.

With a difference in air temperatures from one side of the fence to the other, the temperature line continuously decreases. Graphically, temperature changes during the passage of a heat flux through a flat homogeneous wall are shown in Fig. 2. 1..

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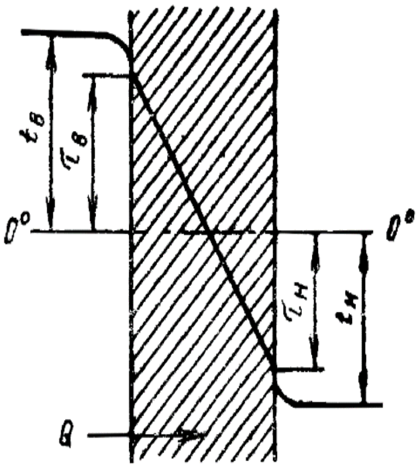

Fig.2.1. Change in temperature in a homogeneous wall

Air from the inside of the wall has a temperature $t_в$, a c, and from the outside $t_н$, and $t_в > t_н$. The temperature line shows that the temperature drop occurs not only in the thickness of the wall, but also near its surfaces, since the temperature of the inner surface of the wall $\tau_в < t_в$ and the temperature of the outer surface $\tau_н > t_н$. Since the temperature drop during the passage of the heat flow is caused by thermal resistances, it can be seen from the temperature curve that the heat transfer resistance of the fence consists of three separate resistances:

1) Resistance to the transfer of heat from the internal air to the inner surface of the fence;
2) Resistance to the passage of heat through the thickness of the fence itself;
3) Resistance to the transfer of heat from the outer surface to the outside air;

Thus, the resistance to heat transfer of the fence can be expressed as the sum of these resistances:

$$R_о = R_в + R + R_н \qquad (1)$$

If the heat transfer resistances depend mainly on external factors and only to a small extent on the surface material of the fence, then the thermal resistance of the fence R depends solely on the thermal conductivity of the materials that make up the fence, as well as on the structure of the fence itself. To determine R, it is necessary to know the coefficients of thermal conductivity λ of the materials that make up the fence, their location, as well as the dimensions of the individual elements of the fence.

If the fence in thickness consists of several consecutively placed homogeneous layers of different materials located perpendicular to the direction of the heat flow, then the thermal resistance of the fence will be equal to the sum of the thermal resistances of all its layers. Therefore, for a multilayer fence, its thermal resistance is determined by the formula

$$R = R_1 + R_2 + R_3 + \cdots + R_n = \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3} + \cdots + \frac{\delta_n}{\lambda_n}. \qquad (2)$$

where $R_1, R_2...$ - thermal resistances of individual layers; $\delta_1, \delta_2...$ - thicknesses of individual layers in m; $\lambda_1, \lambda_2...$ - coefficients of thermal conductivity of materials of individual layers; n is the number of layers that make up the fence.

When using this formula, it must be remembered that the layer thicknesses δ must be taken in meters.

Formula (2) shows that the thermal resistance of the fencing layer is directly proportional to its thickness and inversely proportional to the thermal conductivity of its material; thermal resistance of the fence does not depend on the order of the layers. However, other thermotechnical indicators of the fence, such as heat resistance, temperature distribution in the fence and its humidity regime, depend on the order of the layers. Therefore, to facilitate calculations of the heat resistance and humidity regime of fences, the numbering of the layers is carried out sequentially from the inner surface of the fence to the outer.

Using formula (2), it is possible to determine either the thermal resistance of a given fence, or the thickness of one of its layers, at which the fence will have a given value R or Ro. In the last last case, the unknown value in formula (2) will be the thickness δ of one of the layers, which serves as an insulating layer of the fence.

Multilayer structures represent the most common type of fencing in the construction industry.

The reduced resistance to heat transfer R_o takes into account the presence in the fence of heat-conducting inclusions that are heterogeneous over the area of the fence and is determined as follows.

If the structure is single-layer or consists of **n** homogeneous layers, then the value of R_o is determined by the formula:

$$R_0 = \frac{1}{\alpha_в} + \sum_{i=1}^{n} R_i + \frac{1}{\alpha_н}, \qquad (3)$$

where: **$\alpha_в$, $\alpha_в$** – heat transfer coefficients of the inner and outer surfaces of the building envelope,Вт/(м^2·^{o}C);

R_i is the thermal resistance of each of the layers of the structure, м^2·^{o}C/Вт.

If a multilayer building envelope has a layer (layers) consisting of sections of different materials, then its reduced resistance is determined in the following sequence:

a) For each inhomogeneous layer, the area-weighted average value of the thermal conductivity coefficient is found, Вт/(м·^{o}C) according to the formula: $\lambda_{i.y} = f_1 \cdot \lambda_1 + f_2 \cdot \lambda_2 + \cdots + f_к \cdot \lambda_к$, (4)

where **λ_1, λ_2, ..., $\lambda_к$** – are the thermal conductivity coefficients of various sections in the selected layer, Вт/(м·^{o}C);

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f_1, f_2, …, $f_к$ – the fraction of the area of the layer occupied by the material with the appropriate thermal conductivity, and calculate the conditional thermal resistance of the inhomogeneous layer:

$$R_{\mathrm{i.y}} = \frac{\delta_i}{\lambda_{\mathrm{i.y}}} \qquad (5)$$

The currently existing computer programs Therm or Temper-3d, with which the calculation is performed, have accompanying technical documentation and provide the ability to calculate a two-dimensional (flat) or three-dimensional (spatial) temperature field, heat flows in a given area of enclosing structures under stationary heat transfer conditions.

The input of initial data is carried out either in graphical form (from the screen of a monitor, scanner, graphic or design file), or in the form of tabular data and provides the ability to set the required characteristics of materials and boundary conditions of the calculated structure in a given area.

The presentation of calculation results provides the possibility of visualizing the temperature field, determining the temperature at any point in the calculated area, determining the total incoming and outgoing heat fluxes through specified surfaces.

The disadvantage of Therm is the presentation of the results in its own format, which allows you to analyze the results only in the built-in post-processor of the program.

The Temper-3d program allows you to perform calculations of 2- and 3-dimensional temperature fields of enclosing structures. To work, Temper-3d requires a certain configuration of computer hardware, which limits the launch of the program on a number of computer systems. In addition, the program is paid, which is not always acceptable for scientific research. However, the main disadvantage of both programs is that the source code is closed, which does not allow them to be modified and thus adjusted to specific specific tasks.

3. The Final Part

To calculate the temperature field of the junctions (mounting joints) of window blocks to the wall, a rectangular grid was used (Fig. 2.2). By placing the grid threads more densely in the field area in which we are most interested in the temperature distribution, for example, in places of heat-conducting inclusions, and more rarely in the rest of the field area, it was possible to significantly reduce the number of grid nodes, and, consequently, the number of calculation equations.

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With a rectangular grid, the heat transfer coefficients between nodes were determined taking into account the area over which heat is transferred; the size of the field in the direction of the z axis was taken equal to 1m. In this case, if the grid nodes lay in the area of one material with a thermal conductivity coefficient λ (uniform field), then according to Fig.2.2. obtained the following values of the heat transfer coefficients between the node with temperature τx and neighboring nodes:

to node 1 - the heat transfer area will be: $F_1 = \frac{\Delta_{y_1}+\Delta_{y_2}}{2}$; heat transfer coefficient $k_{x-1} = \frac{\lambda}{\Delta_{x_1}} F_1$;

to node 2 - $F_2 = \frac{\Delta_{x_1}+\Delta_{x_2}}{2}$; $k_{x-2} = \frac{\lambda}{\Delta_{y_2}} F_2$;

to node 3 - $F_3 = F_1$; $k_{x-3} = \frac{\lambda}{\Delta_{x_2}} F_3$;

to node 4 - $F_4 = F_2$; $k_{x-4} = \frac{\lambda}{\Delta_{y_4}} F_4$;

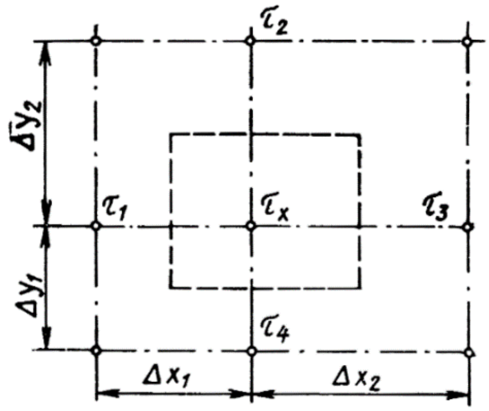

Fig.2.2. Scheme for calculating a flat temperature field when applying a rectangular non-uniform grid.

If the field is inhomogeneous, then the heat transfer coefficients between grid nodes were determined in the same way as for a square grid, but with their multiplication by the corresponding heat transfer areas *F* в *м*².

Temperature field calculations were made by the integration method as follows. We preliminarily set some arbitrary temperature values at all grid nodes. Then, according to formula (6), the temperature values at all nodes were sequentially calculated, replacing the previous values with the obtained temperature values until the temperature at each node of the field grid began to satisfy the corresponding equations at given air temperatures on one and the other side of the fence.

$$\tau_{x,y} = \frac{k_{x-\Delta}\tau_{x-\Delta,y}+k_{y+\Delta}\tau_{x,y+\Delta}+k_{x+\Delta}\tau_{x+\Delta,y}+k_{y-\Delta}\tau_{x,y-\Delta}}{k_{x-\Delta}+k_{y+\Delta}+k_{x+\Delta}+k_{y-\Delta}} \qquad (6)$$

The calculation process could be considered complete only when, within the specified accuracy, the temperatures remained constant at all grid nodes. The duration of the calculations depended on how correctly the initial temperatures were set.

The temperature field obtained for the given values of the temperatures of the indoor and outdoor air was easily recalculated for other values of these temperatures, based on the fact that the temperature difference between any point of the field and the indoor or outdoor air changed in proportion to the change in the temperature difference between the indoor and outdoor air.

For rectangles containing only one material, k=λ/Δ, where λ is the thermal conductivity of the material, Δ is the distance between grid nodes in m.

If a node with temperature $\tau_{x,y}$ lies in a plane adjacent to the air medium, then the heat transfer coefficient to air will be equal to the corresponding value of the heat absorption coefficient $\alpha_в$ or heat transfer coefficient $\alpha_н$. In this case, the values of k to neighboring nodes lying in this plane are taken with a coefficient of 0.5 based on the fact that in the direction to these nodes, heat transfer through the material will occur only over an area equal to half a rectangular grid, and through air, in which will be the second half of the rectangle, there will be no heat transfer.

Conclusion

Based on the analysis of methods for calculating the temperature in the thickness of the building envelope, the following conclusions can be drawn:

1) Far from the junction of the window block, i.e. at a distance of 1-1.5 meters from this place, to calculate the temperature along the thickness of the wall, you can use the formulas given in KMK 2.01.04-97 *.

To calculate the temperature at the junction of the window block to the outer wall, the temperature field calculation method based on the finite difference method should be used. In this case, it is recommended to place the grid threads more densely in the area of the field of the junction node, and more rarely in the rest of the field, significantly reducing the number of grid nodes, and, consequently, the number of calculation equations.

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