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INNOVATIVE SOLUTIONS FOR THE USE OF AERATED CONCRETE BLOCKS IN RESIDENTIAL BUILDINGS

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Abstract:

This dissertation presents the results of theoretical and practical studies of thermal physics in the example of aerated concrete exterior walls in order to increase the performance characteristics and energy efficiency of aerated concrete exterior barrier structures of residential buildings. The study determined the total heat transfer resistance of the aerated concrete exterior wall sample of residential buildings, the thermal conductivity of the wall layers, the heat flux through the wall, the temperature in the wall layers and the heat resistance of the wall for summer and winter. Comparing with the theoretical thermal-physical and practical studies of the wall model, recommendations were developed to increase the thermal protection of the outer walls of buildings built on the basis of modern projects.

Keywords: *residential buildings, heat is transferred, thermal physics, Construction, aerated concrete, Multi-porous, Complete gas block.*

Introduction

In Uzbekistan, in order to save energy reserves of natural fuel, increasing the thermal protection of exterior walls of buildings, the construction of energy-efficient buildings using non-traditional, renewable energy sources is one of the topical issues. As a result of the research it is necessary to give practical recommendations on thermophysical improvement of external walls consisting of small multi-hollow gas concrete blocks in civil and industrial buildings, previously not studied for the conditions of Uzbekistan, and increase their energy efficiency. Therefore, in the laboratory of the department "Design of buildings and structures" SamSACU and in cooperation with LLC "AGROMIR BUILDINGS" in Qorasuv massive of Samarkand prepared small gas concrete blocks with many cavities, the outer wall of them is set model, conducted theoretical studies and practical experiments in terms of thermal physics. In a small block were carried out thermophysical theoretical studies of the number, size, shape and location of holes. External barriers increase the energy efficiency of structures if small blocks with several or more layers of free air, such as lightweight concrete, ceramic bricks and aerated concrete, are used as external barriers. The smaller the size of the air layers in a small block and the greater the number of these layers, the better its thermal properties. Because the amount of heat from the empty layers of air passes not only through thermal conductivity, but also through radiation and convection. In addition, in the case of small voids in the material, the heat transfer coefficient of air is small. For the thermal and physical substantiation of this theory, we have developed several types of calculation schemes for shallow block aerated concrete with 12, 18 and 36 air layers. We recommend the size of aerated concrete blocks 600x300x300 mm and 600x300x250 mm (Fig. 1), and this block is made from local materials. Thermal physical properties of such blocks, including heat transfer resistance and thermal conductivity coefficient, for the conditions of Uzbekistan and thermal justification have not been studied. In addition, it has not been studied whether the heat transfer resistance and heat transfer coefficients of the outer wall reconstructed from these blocks with thermal insulation installed on the outer surface depend on the number of these empty small cavities. These structures consist of heterogeneous materials arranged perpendicularly or parallel to the direction of heat flow. Thermal calculation of heterogeneous structures is determined in the following order: We partition the structure into separate layers by cutting it with a plane parallel to the direction of the heat flux (Fig. 1). The average heat transfer resistance of this structure is determined by the following formula (1).

$$R_{\text{II}} = \frac{F_I + F_{II} + F_{III} + \ldots}{\frac{F_I}{R_I} + \frac{F_{II}}{R_{II}} + \frac{F_{III}}{R_{III}} + \ldots} \qquad (1)$$

Here R_{I}, R_{II}, R_{III} are the average heat transfer resistance of the given structure. F_{I}, F_{II}, F_{III} are the surfaces of individual layers.

The average heat transfer coefficient for heterogeneous parts of a small block is determined by the following formula (2):

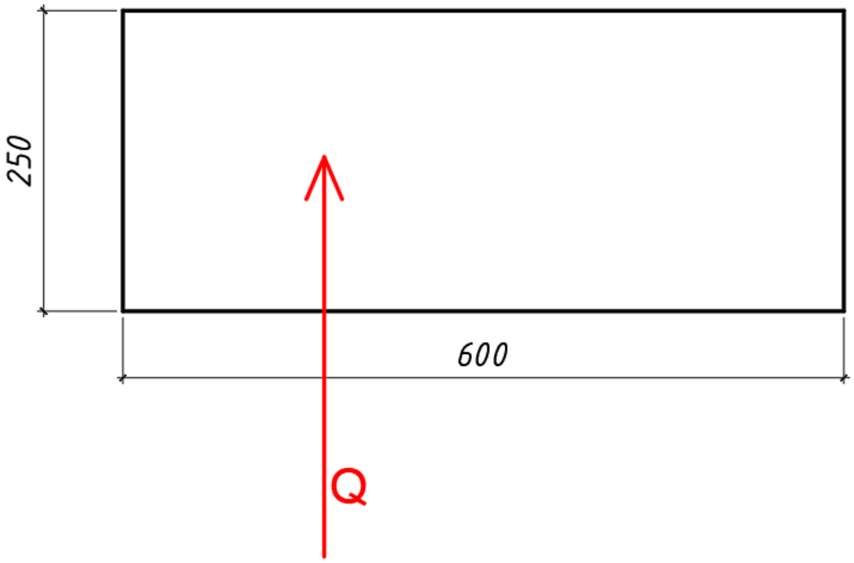
$$\lambda_{\text{ўр}} = \frac{\lambda_I \times F_I + \lambda_{II} \times F_{II} + \lambda_{III} \times F_{III}}{F_I + F_{II} + F_{III}} \qquad (2)$$

Here λ_{I}, λ_{II}, $\lambda_{III......}$ are the thermal conductivity of the materials of which individual layers are composed; F_I, F_{II}, F_{III} are the surfaces of individual layers.

If an exterior wall made of a small multi-cavity block is cut by planes parallel and perpendicular to the heat flow, and thermophysical calculations are performed, the calculations become more complicated by increasing the planes. Therefore, for practical calculations, it is possible to determine the average heat transfer coefficient of a single multi-cavity subblock, and to determine the thermal transfer resistance of a single exterior wall consisting of this subblock [1,2] .

To determine the heat transfer resistance and heat transfer coefficients of small blocks of multi-cellular aerated concrete, we first perform the thermophysical calculation of the exterior wall of a 16-story apartment building under construction in the Qorasuv massive.

The calculation scheme of the complete aerated concrete is shown in Figure1.



$Density;\ \gamma_o = 600\frac{kg}{m^3}$, $heat\ transfer\ coefficient$; $\lambda = 0.22\ Vt/m^oC$,

Dimensions 600x300x250mm

Figure 1. Diagram of a complete aerated concrete block.

Calculate the heat transfer resistance:

$$\boldsymbol{R}_т = \frac{\delta}{\lambda} = \frac{0.25}{0.33} = 0,757\ m^{2\ o}C/Vt$$

Determine the total heat transfer resistance:

$R_u = R_i + R + R_t = 0,115 + 0,757 + 0,039 + 0,028 + 0,043 = 0,982\ м^{2\ o}C/Вт$

On the outer surface of the wall is laid a thermal insulation layer, consisting of monolithic gas block, rigid mineral wool boards with synthetic and bituminous binder. We determine the total thermal resistance of the outer wall of this house under construction in Qorasuv:

$R_u = R_i + R + R_t = 0,115 + 0,757 + 0,039 + 0,892 + 0,043 = 1,846\ m^{2\ o}C/Vt$

Thus, for the second and third levels of thermal protection of residential buildings over 3 floors, listed in QMQ 2.01.04-18, the thermal resistance of the outer walls is 2,2 and 2,6 (〖 m〗 ^(2 o)

C)/Vt. As can be seen from the above calculations, the thermal protection of the buildings under construction is insufficient and does not meet the requirements of QMQ.

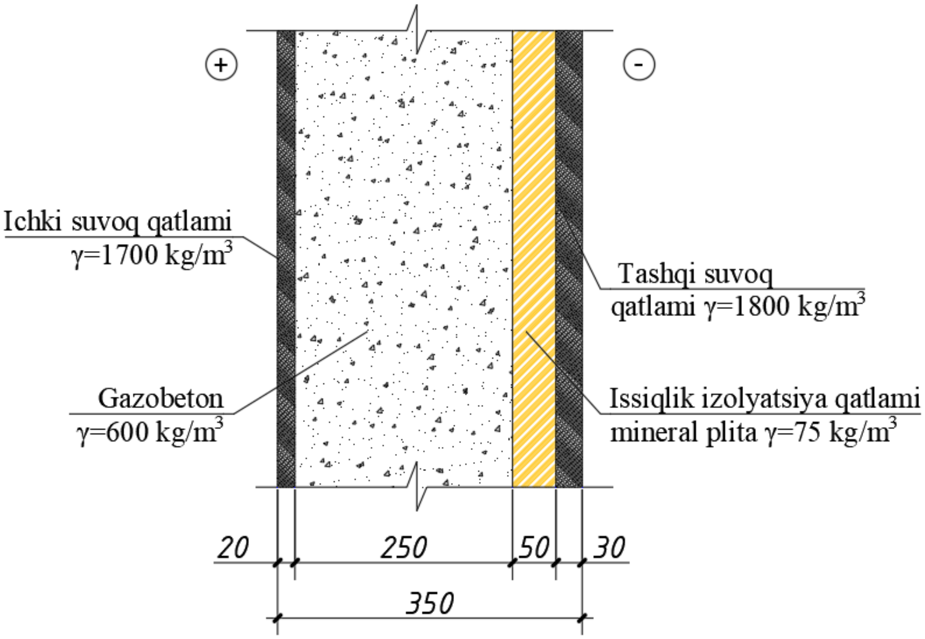


Figure 2. A thermal insulation layer is placed on the outside of the continuous aerated concrete wall.

Therefore, to improve the energy efficiency of residential buildings under construction, we have developed schemes of blocks consisting of small aerated concrete blocks at the expense of thermal and physical improvement of their outer walls. Their calculation scheme consists of heterogeneous aerated concrete blocks with 12, 18 and 36 holes. The calculation diagrams are shown in Figs. 3 and 4 below. Thermal calculation of a small aerated concrete block with twelve holes.

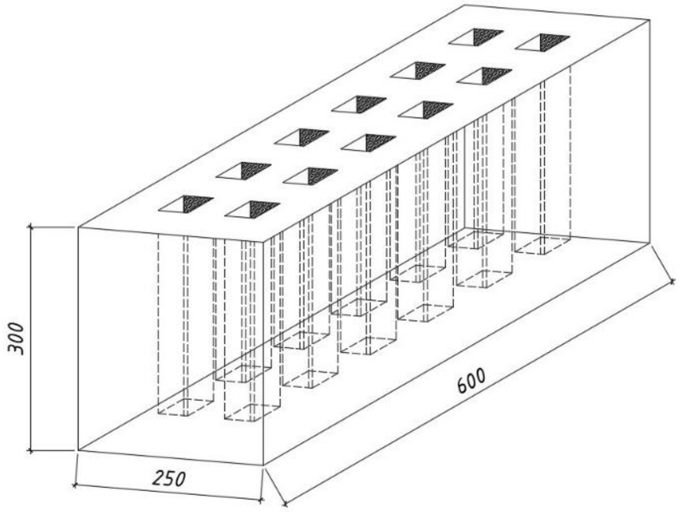


Figure 3. Scheme of making a block of fine aerated concrete with twelve holes.

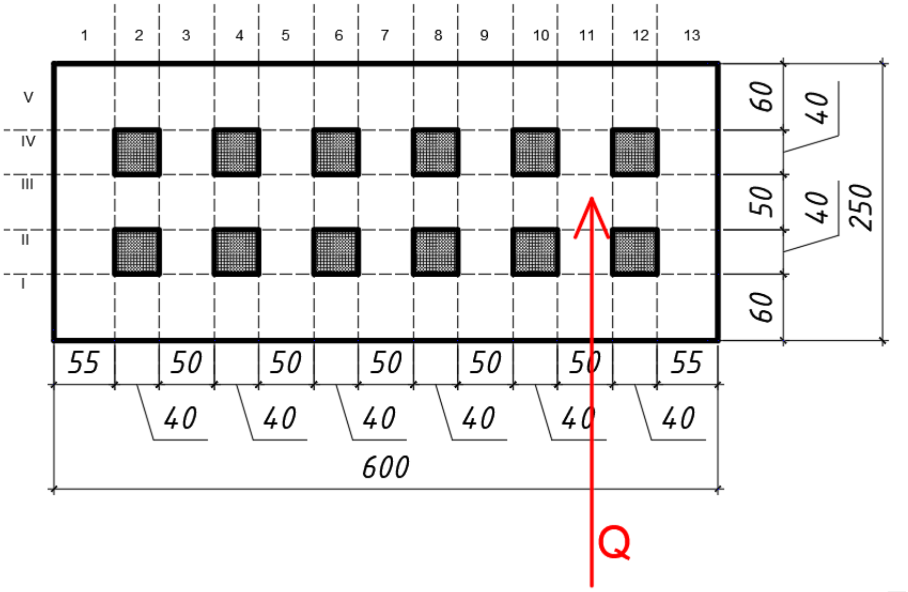


Figure 4. Calculation diagram of a small aerated concrete block with twelve holes.

1.We divide the small block into separate parts cutting it along the plane parallel to the heat flow.

The thickness of the holes is 40 mm. Two edges 55mmx2=110mm. Square of gas concrete 50mmx5=120 mm. L=240+110+250 = 600 mm.

Part I $R_I = \frac{0.250}{0.22} = 1{,}136 \frac{m^2\,^{o}\mathrm{C}}{Vt}, \quad F_I = 0{,}055\, m^2$

Part II consists of aerated concrete and 2 layers of free air.

$$R_{II} = \frac{0.22}{0.22} + 0.14\text{x}2 = 1.28\ \text{м}^2\,^{o}\mathrm{C}/Vt\ , \quad F_2 = 0{,}04\, m^2$$

Part III $R_{III} = \frac{0.25}{0.22} = 1{,}136 m^2\,^{o}\mathrm{C}/Vt \qquad , \quad F_3 = 0{,}05\, m^2$

The rest of the gas block consists of the same structure.

The heat transfer resistance is determined by the following formula:

$$R_{II} = \frac{0{,}055 + 0{,}04 + 0{,}05}{\frac{0{,}055}{1{,}136} + \frac{0{,}04}{1{,}28} + \frac{0{,}05}{1{,}136}} = \frac{0{,}145}{0{,}048 + 0{,}031 + 0{,}044} = 1{,}179\, m^2\,^{o}\mathrm{C}/Vt$$

Divide the block into 1, 2, 3, 4 and 5 layers, cutting it with a plane perpendicular to the direction of heat flow. Determine the heat transfer resistance of layers 1, 3, 5:

$$\mathrm{R} = \frac{0.06}{0.22}\mathrm{x}2 + \frac{0,05}{0,22} = 0,545 + 0,227 = 0,772\ \text{м}^2\,{}^{\mathrm{o}}\mathrm{C}/Vt$$

$$\lambda = \frac{\delta}{R} = \frac{0.04}{0.15} = 0.266\ \ Vt$$

The 2nd and 4th layers consist of aerated concrete and layers of free air. Therefore, the average heat transfer coefficient for this layer is determined by the following formula:

$$\lambda_{o'rt} = \frac{0.22\mathrm{x}0,055 + 0.28\mathrm{x}0,04 + 0,22\mathrm{x}0,05}{0,145} = \frac{0,0443}{0,145} = 0,305\ \ Vt$$

In that case

$$\mathrm{R} = \frac{0.25}{0.305} = 0,819\ \ \text{м}^2\,{}^{\mathrm{o}}\mathrm{C}/Vt$$

$$R_{\perp} = 0,772 + 0,819 = 1,591\ \text{м}^2\,{}^{\mathrm{o}}\mathrm{C}/Vt$$

$$\mathrm{R} = \frac{R_{II} + 2R_{\perp}}{3} = \frac{1,179 + 2\mathrm{x}1,591}{3} = \frac{4,362}{3} = 1,454\,m^2\,{}^{\mathrm{o}}\mathrm{C}/Vt$$

Determine the total heat transfer resistance of the outer wall of cellular aerated concrete:

$R_u = R_i + R + R_t = 0,115 + 0,028 + 1,454 + 0,039 + 0,043 = 1,679\ \ m^2\,{}^{\mathrm{o}}\mathrm{C}/Vt$

From the thermophysical calculations it is found that the thermal resistance of the outer walls for the second and third level of thermal protection for residential buildings with more than 3 floors specified in QMQ2.01.04-18 is 2.2 and 2.6 ($m^2\,{}^0C$)/W. As can be seen from the above calculations, the thermal protection of this wall is not sufficient and does not meet the requirements of QMQ. Therefore, on the outer surface of the wall, consisting of 12-grain gas blocks, we lay a thermal insulation layer of solid mineral boards with synthetic and bituminous binder. Its calculation scheme is shown in Figure 5 below.

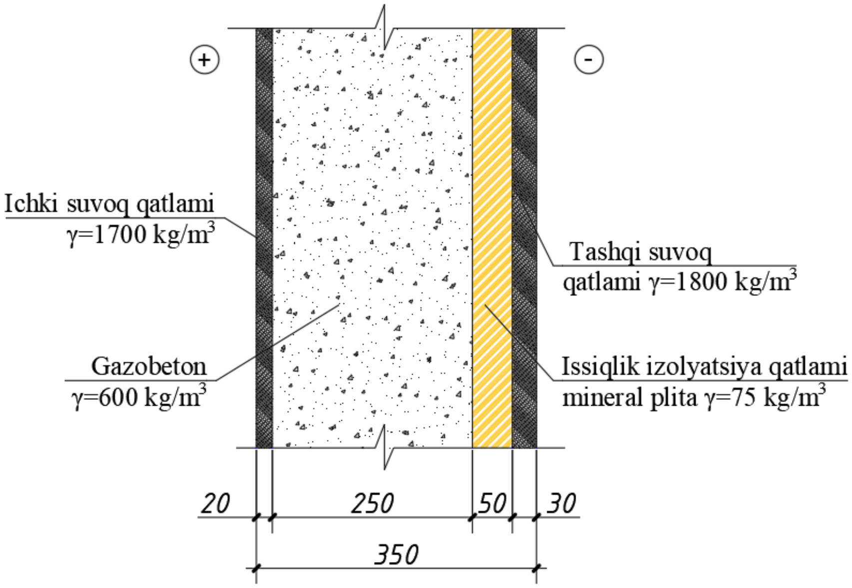


Figure 5. Averaged calculation diagram of the synthetic bituminous binder thermal insulation layer from the exterior surface of the wall consisting of 12cavity gas blocks.

We determine the total heat transfer resistance of the outer wall of this building:

$$R_u = R_i + R_1 + \ldots + R_n + R_t = R_i + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \ldots + \frac{\delta_n}{\lambda_n} + R_t$$

$$R_u = 0{,}115 + 0{,}039 + 1{,}454 + 0{,}892 + 0{,}039 + 0{,}043 = 2{,}581 = 2{,}6\ m^2\,{}^{o}\mathrm{C}/Vt$$

From the thermophysical calculations it was found that the thermal resistance of the outer walls for the second and third levels of thermal protection for residential buildings with more than 3 floors, listed in QMQ2.01.04-18, is 2.2 and 2.6. $(m^2\,{}^0C)/W$. As can be seen from the above calculations, the thermal protection of this wall is sufficient and meets the requirements of the QMQ.

But in order to verify whether the above theoretical studies are close to the truth, it is necessary to conduct thermal-physical practical research on the mentioned samples of walls under laboratory conditions.

As a result of the research theoretically developed a structural solution for the design of exterior walls of aerated concrete blocks for residential buildings, previously not studied for the conditions of Uzbekistan. The results of theoretical research should be based on the results of practical thermophysical research. For this reason, the professor of department "Design of buildings and constructions" SamSACU, candidate of technical sciences, under the leadership of Shukurov, the wall blocks consisting of aerated concrete were tested in the laboratory of the department. The blocks, consisting of gas concrete blocks with a density of 800-1000 kg/m3 and size 600x300x250 mm, were installed in a microcamera in the laboratory SamSACU of the department "Design of buildings and structures. Thermal sensors were installed between the layers of blocks. The size of the sample installed on the walls of the gas concrete blocks is 600x1200 mm. and conducted experiments on a sample of exterior walls made of gas concrete blocks with a density of 800-1000 kg/m3. The experiments were conducted in accordance with the requirements of “Uzstandard” agency 809-97

"Determination of thermal resistance of enclosing structures" and GOST 10-2-81 "Methods of testing the insulating properties and air permeability of enclosing structures in buildings" (1.3.4.)

Two types of barrier structures, with the same temperature and humidity conditions in the room from the inside are selected for testing.

To measure the density of heat flux passing through the enclosing structure, we used means of measuring heat fluxes ITP-11 according to GOST 25380 [3].

As the primary transducers for measuring temperature are used thermoelectric transducers (thermometers) according to GOST 3044, consisting of chromel, copper and wire according to GOST 1790. DC potentiometers or millivoltmeters, which can provide an error of measurement of not more than ±0,002 Mb, are used as secondary measuring devices, working with heat exchangers and thermometers. To determine the moisture content of the materials of the enclosing structures, the measuring instruments specified in GOST 24816 are used.

Thermophysical practical classes were held in the laboratory building of the SamSACU Department of Buildings and Structures. In May 2023, a sample of aerated concrete blocks was installed in the microclimatic chamber of this building. Thermophysical practical experiments on the sample built-in wall were conducted from May 25 to 29, 2023. As a result of the experiments on the main thermophysical indicators were determined:

1. Temperature in the layers of walls made of aerated concrete blocks; 2. Temperature in the room where the experiment is conducted; 3. Temperature of the outside air; 4. Heat flow (amount) through the sample wall; 5. Heat transfer coefficient of the materials of the layers that make up the exterior wall.

According to the parameters obtained from practical experiments, thermophysical calculations were carried out in the following order:

The heat transfer resistance of the barrier structure was calculated by the following formula:

$$R = R_B + R_K + R_H = \frac{t_B + \tau_H}{q_ф} + \frac{\tau_K + \tau_H}{q_ф} + \frac{\tau_H + t_H}{q_ф} \qquad (3)$$

where $R_в$ and $R_н$ n are the heat transfer resistance of the internal and external surfaces of the barrier structure respectively, ($м^{2\circ}C$)/ Vt;

$R_к$ - is the thermal resistance of one type of zone of the barrier structure,

$t_в$ and $t_н$- are the values of measurements of internal and external air temperature respectively for the calculation period , ^{0}C;

τ_B va τ_H - are the values of measurements of internal and external surfaces for the accounting period, ^{0}C;

$q_ф$- is the average real heat flux density for the accounting period, , Vt/ $м^2$;

The thermal resistance of individual layers of the barrier structure is determined by the following formula;

$$R_{c\Delta} = \frac{\Delta\tau}{q_{ф}} \qquad (4)$$

$\Delta\tau$ here - temperature difference at the boundaries of the layers, ^{0}C;

To compare the actual values of the thermal conductivity of the materials used in the structure with the calculated values, the thermal conductivity of the layer material is determined by the following formula.

$$\lambda = \frac{\delta}{R_{c\Delta}} \qquad (5)$$

δ here - layer thickness, m.

The results of temperature measurements in the layers of the wall sample (for the winter period) are presented in Appendix 1. Using this appendix, we determine the thermal resistance of the individual layers of the wall sample using the formula given above:

$$R_{И} = \frac{t_{H} - \tau_{H}}{q_{ф}} = \frac{21{,}53 - 20{,}09}{5{,}93} = 0{,}243 \quad (м^{2^{\circ}}C)/\text{ Vt;}$$

$$R_{1} = \frac{0{,}34}{5{,}93} = 0{,}057 \quad (м^{2^{\circ}}C)/\text{ Vt;} \qquad R_{2} = \frac{0{,}56}{5{,}93} = 0{,}094 \quad (м^{2^{\circ}}C)/\text{ Vt;}$$

$$R_{3} = \frac{2{,}9}{5{,}93} = 0{,}489 \quad (м^{2^{\circ}}C)/\text{ Vt;} \qquad R_{4} = \frac{1{,}57}{5{,}93} = 0{,}265 \quad (м^{2^{\circ}}C)/\text{ Vt;}$$

$$R_{5} = \frac{8{,}68}{5{,}93} = 0{,}663 \quad (м^{2^{\circ}}C)/\text{ Vt;} \qquad R_{6} = \frac{6{,}61}{5{,}93} = 1{,}115 \quad (м^{2^{\circ}}C)/\text{ Vt;}$$

$$R_{7} = \frac{0{,}48}{5{,}93} = 0{,}081 \quad (м^{2^{\circ}}C)/\text{ Vt;} \qquad R_{т} = \frac{0{,}1}{5{,}93} = 0{,}017 \quad (м^{2^{\circ}}C)/\text{ Vt;}$$

$$\sum R_{ум} = 3{,}02 \quad (м^{2^{\circ}}C)/\text{ Vt;}$$

Thermal - the relative error of heat transfer resistance, determined as a result of physical experiments, compared with the calculated heat transfer resistance did not exceed 8 % with probability of reliability.

As a result of the experiment, we determine the thermal conductivity coefficients of the materials of the structural layer:

$$R_{И} = \frac{t_{Н} - \tau_{Н}}{q_{ф}} = \frac{21{,}53 - 20{,}09}{5{,}93} = 0{,}243 \quad (м^{2\circ}C)/\text{Vt};$$

$$R_1 = \frac{0{,}34}{5{,}93} = 0{,}057 \quad (м^{2\circ}C)/\text{Vt}; \qquad R_2 = \frac{0{,}56}{5{,}93} = 0{,}094 \quad (м^{2\circ}C)/\text{Vt};$$

$$R_3 = \frac{2{,}9}{5{,}93} = 0{,}489 \quad (м^{2\circ}C)/\text{Vt}; \qquad R_4 = \frac{1{,}57}{5{,}93} = 0{,}265 \quad (м^{2\circ}C)/\text{Vt};$$

$$R_5 = \frac{8{,}68}{5{,}93} = 0{,}663 \quad (м^{2\circ}C)/\text{Vt}; \qquad R_6 = \frac{6{,}61}{5{,}93} = 1{,}115 \quad (м^{2\circ}C)/\text{Vt};$$

$$R_7 = \frac{0{,}48}{5{,}93} = 0{,}081 \quad (м^{2\circ}C)/\text{Vt}; \qquad R_{т} = \frac{0{,}1}{5{,}93} = 0{,}017 \quad (м^{2\circ}C)/\text{Vt};$$

$$\sum R_{ум} = 3{,}02 \quad (м^{2\circ}C)/\text{Vt};$$

From the above results of theoretical and practical thermophysical studies we can draw the following conclusions:

1. The heat transfer resistance of 12-well shallow aerated concrete, determined as a result of theoretical studies, is greater than the heat transfer resistance of full-bodied aerated concrete. Their difference is 33-40%.

2. The heat transfer resistance of an insulated wall consisting of a shallow aerated concrete block with 12 holes is 2,60 $m^{2\,o}$ C/Vt.

3. The heat transfer resistance of an insulated wall made of fine gas concrete is 1,846 $m^{2\,o}$C/Vt.

4. Heat transfer resistance of 12-channel aerated concrete wall is 30% higher than heat transfer resistance of monolithic aerated concrete wall and 1.5 brick thickness, i.e. 38 cm is 3-4 times higher than heat transfer resistance of the wall;

5. From practical experience, we know that the total heat transfer resistance of the sample wall determined in the experiment is R_u= 3,02 ($м^{2^{\circ}}C$)/ Vt.

6. The theoretically determined heat transfer resistance of this structure R_u= 2,6 ($м^{2^{\circ}}C$)/ Vt. Experimentally determined heat transfer resistance of the sample wall is 15% higher than the calculated heat transfer resistance.

7. The main reason for this is the small pores in the aerated concrete block, as well as its small heat transfer coefficient. For calculations, the heat transfer coefficient taken from QMQ 2.01.04 - 18* is 0,33 Vt/($м^{2^{\circ}}C$). As a result of the experiment, the heat transfer coefficient of aerated concrete blocks is 0,33Vt/($м^{2^{\circ}}C$). In addition, the density of aerated concrete blocks is 850 kg/m3.

8. Thus, the heat transfer resistance of the sample wall made of gas concrete blocks is 3,02 (m^2. 0^C)/ Vt, which corresponds to the requirements of the first, second and third level of thermal protection established in QMQ 2.01.04-18. Such a situation increases the energy efficiency of residential and public buildings built according to new typical projects and fully reconstructed.

Thus, the thermal resistance of the wall, reconstructed from small blocks of 12-cell aerated concrete, which we recommend, meets the requirements of the second and third levels of thermal resistance to heat transfer, established in QMQ 2.01.04-18. This situation opens the way to the design and construction of energy efficient buildings.

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