Use of Light Structural Materials (Foam Blocks) in the Construction of Residential Buildings

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Abstract: The use of materials with a thin layer of air in external barrier constructions dramatically increases the thermal and technical properties of the wall. Therefore, the heat transfer of an air layer is different from the heat transfer of a solid, solid layer. The thermal resistance of a solid layer is directly proportional to its thickness, the amount of heat passing through the layer is inversely proportional to its thickness.

Keywords: External barrier construction, heat insulation, glass wool, heat flow density, isothermal surface, straight line equation.

We assume that the heat transfer coefficient of the material does not depend on the temperature. Temperatures on the outer surfaces of the wall are kept constant t1>t2; the temperature changes only in the x direction, which is perpendicular to the wall surface, that is, the temperature field is one-dimensional, the temperature gradient is equal to dt/dx. We find the density of the heat flow passing through the wall and determine the description of the temperature change according to the wall thickness. Inside the wall, we distinguish an elementary layer with a thickness dx, bounded by two isothermal surfaces. The Fourier equation for this layer has the following form:

$$q = -\lambda \frac{dt}{dx} \qquad (1)$$

Or:

$dt = -\frac{q}{\lambda} dx$ and $t = -\frac{q}{\lambda} dx + c$

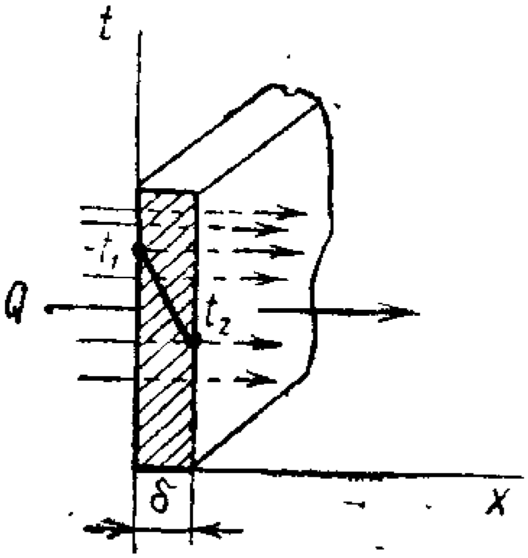


Figure 1. A flat single-layer wall.

The integration constant C is determined from the boundary conditions: t=t1 when x=0. From this, C=t1, so the equation will look like this:

$$t = -\frac{q}{\lambda}x + t_1$$

From this equation, it is possible to determine the density of the heat flow passing through the considered wall. If we put the value x=□ into this equation, we get t=t2, from this:

$$q = \frac{\lambda}{\delta}(t_1 - t_2) = \frac{\lambda}{\delta}\Delta t \qquad (2)$$

The heat flow density on a flat wall is directly proportional to the heat transfer coefficient λ, temperature difference (t1–t2) and inversely proportional to the wall thickness □. It should be noted that the heat flow is determined not by the absolute value of the temperature, but by their difference - heat pressure t1-t2=□t. The ratio l/□ is called the thermal conductivity of the wall; its size [W/(m2□grad)]. Equation (3) can be written in a different form:

$$q = \frac{t_1 - t_2}{\delta/\lambda} \qquad (3)$$

The heat flow density on a flat wall is directly proportional to the heat transfer coefficient l, temperature difference (t1–t2) and inversely proportional to the wall thickness □. It should be noted that the heat flow is determined not by the absolute value of the temperature, but by their difference - heat pressure t1-t2=□t. The ratio l/□ is called the thermal conductivity of the wall; its size [W/(m2□grad)]. Equation (3) can be written in a different form:

$$Q = qF\tau = \frac{\delta}{\lambda}\Delta tF\tau \qquad (4)$$

If we add the value of q from formula (3) to formula (2), we can get the equation of the temperature curve.

$$t = t_1 - \frac{\Delta t}{\delta}x \qquad (5)$$

This equation is called the equation of a straight line. Thus, when the value of λ does not change, the temperature changes linearly along the thickness of the homogeneous wall. For the air layer, such proportionality does not exist. In a solid material, heat transfer is carried out only by heat conduction, and in the air layer, heat is transferred again by means of convection and radiation. Heat flow in external barrier structures depends on the parallel and perpendicular arrangement of pores. If we take into account these factors, the calculation becomes complicated. In practical calculations, assuming that the material consists of pores, the average heat transfer coefficient of the pores is determined.

Let the pores in the foam concrete block be parallel to the heat flow. We determine the thermal resistance of heat transfer using the following formula:

$$R = \frac{F_1 + F_2 + F_3 + \cdots}{\frac{F_1}{R_1} + \frac{F_2}{R_2} + \frac{F_3}{R_3} + \cdots}$$

Here:

$$R\_1, R\_2, R\_3$$
$$- \ thermal\ resistance\ of\ separate\ elements\ of\ the\ barrier;$$

$$F_1, F_2, F_3 are\ surfaces\ of\ individual\ elements.$$

The average value of the heat transfer coefficient:

$$\lambda_{o\prime rt} = \frac{\lambda_1 \cdot F_1 + \lambda_2 \cdot F_2 + \lambda_3 \cdot F_3 + \cdots}{F_1 + F_2 + F_3 + \cdots}$$

Here: 1_1, 1_2, 1_3 is the heat transfer coefficient of individual elements of the layer. The density of foam concrete is 1000 kg/m3 and the thermal conductivity coefficient is equal to λ= 0.41 W/m·K. According to QMQ 2.01.04-97, if the thickness is 16 mm, it is equal to R= 0.136 m2 · 0S/W. Considering that the foam concrete is located symmetrically with respect to the central axis, and that the structure of the foam concrete is the same in height, as a calculation surface we take the half width of foam concrete, that is, 95mm.

For surfaces parallel to the heat flow:

Plot 1:

$$R = \frac{0{,}40}{0{,}41} = 0{,}975\, m^2 \cdot {}^\circ S/Vt, \qquad F_1 = 15mm^2$$

Area 2 16-cell foam concrete:

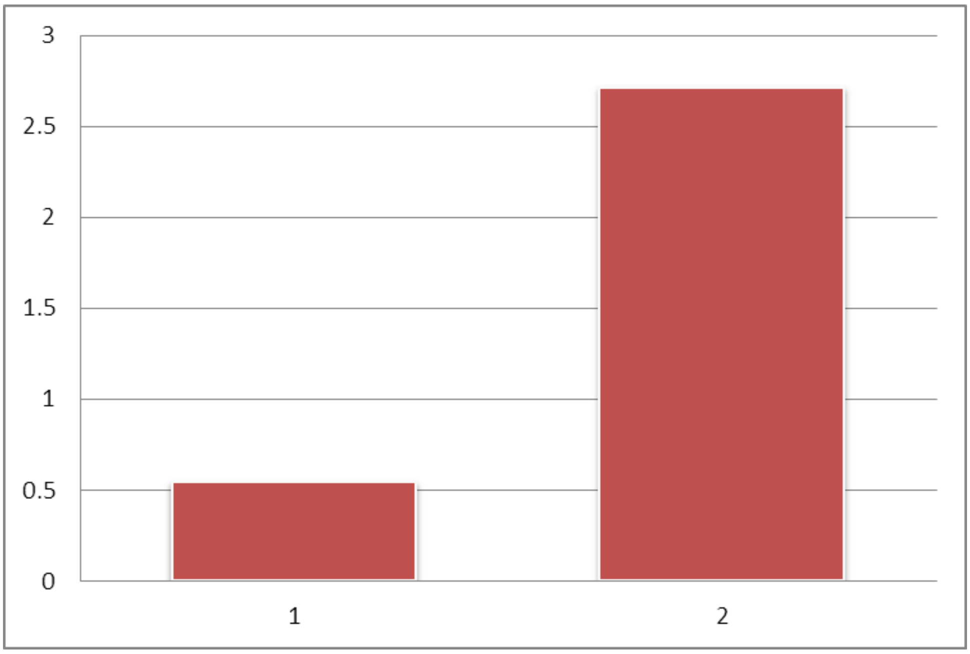
$$R = \frac{0{,}144}{0{,}41} + 0{,}136 \cdot 16 = 2{,}527m^2 \cdot {}^\circ S/Vt,\ F_2 = 60mm^2$$

3rd plot. 8-cell foam concrete:

$$R = \frac{0{,}272}{0{,}41} + 0{,}136 \cdot 8 = 1{,}75\, m^2 \cdot {}^\circ S/Vt,\ F_3 = 2060mm^2$$

Thermal resistance of foam concrete:

$$R_{\prime\prime} = \frac{15 + 60 + 20}{\frac{15}{0{,}975} + \frac{60}{2{,}527} + \frac{20}{1{,}75}} = 1{,}88\, m^2 \cdot {}^\circ S/Vt$$



1. For surfaces perpendicular to the heat flow:
2. $R = (0{,}0165{:}\,0{,}41)\cdot 2 + (0{,}0074{:}\,0{,}41)\cdot 15 = 0{,}35\ m^2\cdot {}^{\circ}S/Vt$

The equivalent coefficient of thermal conductivity for 16-cell foam concrete:

$$\lambda_{ekv} = \frac{\delta}{R} = \frac{0{,}016}{0{,}136} = 0{,}117\ Vt/m\cdot {}^{\circ}S$$

The average heat transfer coefficient of the layer:

$$\lambda_{o'rt} = \frac{0{,}41\cdot 35 + 0{,}117\cdot 60}{95} = 0{,}224\ Vt/m\cdot {}^{\circ}S$$

Thermal resistance of foam concrete:

$$R_1 = (0{,}016{:}\,0{,}224)\cdot 16 = 1{,}143\ m^2\cdot {}^{\circ}S/Vt$$

And so:

$$R = 0{,}35 + 1{,}143 = 1{,}49\ m^2\cdot {}^{\circ}S/Vt$$

For 48-cell foam concrete:

$$R = \frac{R_{,,} + 2R_1}{3} = \frac{1{,}879 + 2\cdot 1{,}49}{3} = 1{,}64\ m^2\cdot {}^{\circ}S/Vt$$

In that case, the average coefficient of thermal conductivity of foam concrete:

$$\lambda_{Penobeton} = \frac{\delta}{R} = \frac{0{,}40}{1{,}64} = 0{,}243\ Vt/m\cdot {}^{\circ}S$$

Conclusion. The following conclusions can be made on the basis of the conducted research work:

1. The coefficient of thermal conductivity of porous foam concrete is 3-4 times smaller than the coefficient of thermal conductivity of brick.

2. The thermal resistance of foam concrete to heat transfer is 2-3 times greater than that of a brick wall with a width of 38 cm, and we can see this in the following diagram: 1 for brick, 2 for foam concrete.

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