FUNDAMENTALS OF ENERGY EFFICIENCY, CALCULATIONS OF INSULATION FOR A RESIDENTIAL BUILDING

Pulatova Zukhra Umetovna
Assistant of the Department "Technology of Building Materials, Products and Structures"

Maxammatov Muzaffar Safarovich
assistant of the Department Technology of Building Materials, Products and Structures"

ABSTRACT:

Heat loss through the walls is about 20% of all heat loss. Therefore, to insulate the house, you need a high-quality and durable insulation, which will not lose its properties over time. To choose it, you need to understand what qualities it should have.

Keywords: Extruded polystyrene foam, energy-efficient house, heat loss, extrusion.

INTRODUCTION:

The constant increase in energy prices, the desire to build a comfortable and economical house has led to a surge in interest in the construction of energy-efficient housing.

Extruded polystyrene foam - is a material that is constantly gaining momentum in the insulation market, and in this article we will help you figure out how to make calculations for insulation with this material. This effective polymer thermal insulation material is made by the method of extrusion from polystyrene with the addition of a gaseous pore-forming agent and technological additives.

So, we will consider:

- Basic principles of energy-efficient (energy-safe) construction.
- Calculations of the required thickness of extruded polystyrene foam (XPS).
- "Breathing" walls-myth or reality.
- What engineering systems do an energy-efficient home need.

Energy efficiency: basic principles:

An ordinary, unprepared developer at the mention of the phrase "energy-efficient housing" in the head there is an image of a premium-class cottage that requires significant investment. Hence-the reluctance to invest in the construction of a well-insulated and energy-efficient house.

Practice suggests otherwise. If we summarize the experience, we can say that the construction of an energy-efficient house increases the construction budget by 15-20%. At the same time, the operation of such a home, on average, costs 50-75% cheaper in comparison with traditional construction.

If you build an energy-efficient house, then the savings invested in its construction begin already in the first heating season.

The heating season (depending on the climate zone) in our country, from October 15, the heating season begins in social facilities, and from October 17 — in multi-storey residential buildings and lasts until April (from 6 to 8 months).

Table 1Heat loss at home during the season

№	Fuel type	Unit measure ments	Price (sum)
1	Brown coal	Kg	650
2	Coal stone	Kg	241
3	Firewood	m^3	800
4	Liquefied gas	l	2800
5	Natural gas (main line).	m^3	380
6	Electricity	kVt*h	295

Table 2

№	Fuel type	Calorific value without boiler efficiency, kW-kg (litre)	EF, %	Heat of combustion, taking into account the efficiency of the boiler, kW-kg (liter)	Price (sum)	Amount for the heating season 7 months
1	Natural gas (main line).	9,3	92	8,6	0,59	2660
2	Firewood	3,4	78	2,7	0,94	5600
3	Liquefied gas	12,5	92	11,5	1,48	19600
4	Coal stone	7,5	70	5,3	1,14	1687
5	Brown coal	3,6	70	2,5	1,59	4550
6	Electricity	1	99	1,0	1,26	2065

To understand the basic principles of building an energy-efficient house, you need to understand what energy is spent on in the house. The main energy consumers are electrical appliances, the hot water system and the heating system.

Since the territory of our country mainly has a sharply continental climate, the share of expenses in a standard house, with large heat losses, goes to heating.

An energy-efficient house is a building in which all energy losses and the level of energy consumption are reduced by about 30-70% of the level of consumption in a normal house.

The main sources of heat loss in the building are the floor, walls, windows, doors, roof and ventilation system.

The basic principle of building an energy-efficient building is to minimize all heat loss through the enclosing structures. To do this, a closed and sealed thermal insulation circuit is built and all "cold bridges" are eliminated.

The energy efficiency of the house can be judged by the coefficient of seasonal use of thermal energy - E.

Table 3

Standard house	E<=110 kVt/(m^2/y)
Energy-efficient house	E<=70 kVt/(m^2/y)
Passive House	E<=15 kVt/(m^2/y)

The main task of additional thermal insulation of the building is to increase energy efficiency and, as a result, reduce heating costs. This results in cost savings and a lower cost of home ownership in the long run.

How to choose a heater and calculate its thickness?

Having understood the basic characteristics of an energy-efficient house, you can proceed to determine the optimal thickness of the insulation. Judging by the requests on the portal, this is one of the leading questions among our users when building a warm and comfortable home.

As mentioned above, heat loss through the walls is about 20% of all heat loss. Therefore, to insulate the house, you need a high-quality and durable insulation, which will not lose its properties over time. To choose it, you need to understand what qualities it should have.

Effective insulation is a heat-insulating material that, having a small thickness, increases the resistance to heat transfer of enclosing structures (denoted by R), i.e. prevents the transfer of heat from a room with a higher temperature (from the room) to an external environment with a lower temperature (to the street).

The coefficient (R) is measured by the temperature difference in degrees Celsius (or Kelvins) required to transfer 1 W of heat across 1 sq. m. of area, if the temperature difference on both sides is 1°C. Unit of measurement R — (m^2 * °C)/W.

Starting from this definition, we turn to thermal conductivity, since this is the main characteristic of the insulation. The coefficient of thermal conductivity is expressed in the ability of a material to conduct heat from a more heated part to a less heated one. Let's look at this parameter in more detail.

Any material passes through itself thermal energy. A good example is wood and steel. If you heat these two materials, the steel, due to the high thermal conductivity, will quickly heat up, while the wood, due to the lower coefficient, will remain warm. To illustrate this process, imagine a frying pan with a wooden handle placed on a gas stove.

Each building material has its own coefficient of thermal conductivity. This coefficient determines the amount of heat energy that passes through 1 sq. m of material area in 1 second at a temperature difference of 1°C. λ is measured-W/(m*°C).

The lower the coefficient of thermal conductivity — (λ), the lower the heat transfer, i.e. the higher the thermal resistance of the structure — (R). This directly affects the thermal insulation properties of the enclosing structure.

Example of calculating the insulation of a house with extruded polystyrene foam:

Due to its characteristics-low coefficient of thermal conductivity (0.028-0.034 W / (m*°C), high compressive strength (200-1000 kPa) and minimum coefficient of water absorption (0.2-0.4%) - this material is used for insulation of the following structures:

- Floor and floor coverings.
- Foundations and ground floors.
- Roofs.

For example, take a wall made of solid brick with a thickness of 0.51 metrs.

The thermal insulation layer in each Ro structure must provide heat transfer resistance not lower than the value that is calculated for each group of buildings for each climatic region of Uzbekistan, depending on the value of the degree-day of the heating period.

The degree-day of the heating period is calculated by the formula:

$$D_d = (t_v - t_m) \cdot Z_{s.p.} \quad (1)$$

where t_v - indoor air temperature [2]. Indoor climate parameters;

t_m, $z_{s.p.}$ - the average temperature and duration of the period with an average daily air temperature of no more than 10^0C, taken according to CMC 2.01.01-94.

The required heat transfer resistance is determined according to Table 16[2] "Second level of thermal protection", depending on the values of the degree-day of the heating period:

$$R_0^r = a \cdot D_d + b \quad (2)$$

The heat transfer resistance of the enclosing structure must not be lower than the required heat transfer resistance R_0^r.

The heat transfer resistance of the enclosing structure is determined by the formula:

$$R_0 = \frac{1}{\alpha_B} + R_K + \frac{1}{\alpha_H} \quad (3)$$

where α_i - the heat transfer coefficient of the inner surface of the enclosing structures determined by table 5 [1].

α_o- the heat transfer coefficient for winter conditions of the outer surface of enclosing structures, determined by Table 6 [1].

R_K - the thermal resistance of the enclosing structure is the sum of the heat transfer resistances of its constituent layers and is determined by the formula:

$$R_K = \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3} + \frac{\delta_4}{\lambda_4} \quad (4)$$

where δ - layer thickness by project;

λ - calculated coefficient of thermal conductivity of the layer material (material characteristics).

Calculation example:

Calculation of the thickness of the thermal insulation layer made of expanded polystyrene for the conditions of insulation of the exterior walls of a house built in the Samarkand region. The walls of the house are ceramic bricks with a thickness of 380 mm.

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The degree-day of the heating period is calculated in advance according to the formula:

$$D_d = (t_v - t_m) \cdot Z_{s.p..}$$

Based on the condition:

- construction site-the city of Samarkand;
- buildings for their intended purpose – residential;
- internal air temperature,
- indoor air humidity 55 %;
- average design temperature of the heating period:
- for a period with an average daily air temperature, the average temperature is the duration of the period172 days;
- for a period with an average daily air temperature, the average temperature is the duration of the period133 days;
- determine the average temperature with an average daily air temperature of no more than 10^{0}C:

$$t_m = \frac{3{,}1 + 4{,}8}{2} = 3{,}95^oC;$$

- we determine the duration of the heating period:

$$Z_{s.p.} = \frac{133 + 172}{2} = 152{,}5 \approx 153 \text{ суток.}$$

- room humidity - normal.

We determine the degree-day of the heating period:

$$D_d = (t_i - t_m) \cdot Z_{s.p.} = (20 - 3.95) \cdot 153 = 2455$$

The required heat transfer resistance is determined by the formula:

$$R_0 = a \cdot D_d + b$$

For residential, health-care and children's institutions, schools, boarding schools, hotels and dormitories for walls, the koefficients are assumed to be equal:

a = 0.00035 и b = 1.4.

$$R_0 = a \cdot D_d + b = 0.00035 \cdot 2455 + 1.4 = 0{,}86 + 1{,}4 = 2{,}26$$

$$м^2 \cdot {}^oC/\text{ВТ}.$$

The heat transfer resistance of the enclosing structure is determined by the formula:

$$R_0 = \frac{1}{\alpha_i} + R_К + \frac{1}{\alpha_o}$$

where α_i - the heat transfer coefficient of the inner surface of the enclosing structures is determined according to Table 5. $\alpha_i = 8{,}7$ ВТ/(м·^oC).

α_o - the heat transfer coefficient for winter conditions of the outer surface of enclosing structures is determined according to Table 6 [1]. ВТ/(м·^oC).

The thermal conductivity coefficient of expanded polystyrene is 0.042 Layers in the proposed design

Table 4

№	**Name of the material**	**Density kg/m³**	**Coefficient of thermal conductivity Vt/m⁰C**	**Thickness**
1	Cement-lime plaster	1700	0,7	0,03
2	Ceramic brick wall	1800	0,56	0,51
3	Extruded Polystyrene Foam	150	0,03	X
3	Cement-lime plaster	1800	0,7	0,03

The total equation for determining the heat transfer resistance of the enclosing structure will be as follows:

$$R_0 = \frac{1}{\alpha_i} + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2} + \frac{\delta_3}{\lambda_3} + \frac{\delta_4}{\lambda_4} + \frac{1}{\alpha_o}$$

and it must be no less than the required heat transfer resistance

R_0 :

$$\frac{1}{8{,}7} + \frac{0{,}03}{0{,}7} + \frac{0{,}51}{0{,}56} + \frac{X}{0{,}05} + \frac{0{,}03}{0{,}7} + \frac{1}{23} = 0{,}115 + 0{,}043 +$$

$$= 1.154 + \frac{X}{0{,}05}$$

$$2{,}6 = 1{,}154 + \frac{X}{0{,}03}$$

From the equation we define X=0,04м=4см=40мм

We translate it into cm, round it up (taking into account the multiplicity of the thickness of the produced thermal insulation of 10 mm) and get-4 cm.

Inference:

To bring the value of the thermal resistance of a brick wall to the normalized value, it is necessary to mount a layer of 40 mm thick extruded polystyrene foam on the outside of the wall.

In the long-term operation of the building, it should be taken into account that the extruded polystyrene does not accumulate moisture, which means that it does not lose its thermal insulation characteristics.

Thus, a thin layer of insulation allows you to achieve the required standard for the thermal resistance of enclosing structures (R). And when warming from the inside, due to the use of effective insulation, we can reduce the total thickness of the wall structure being built up, without disturbing the internal useful area of the house.

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