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IMPROVING THE ENERGY EFFICIENCY OF INDIVIDUAL HOUSES IN RUSSIA WITH THE USE OF EFFICIENT THERMAL INSULATION

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Abstract. The paper presents the thermal calculation of enclosing structures existing individual house. Proposed energy-saving solutions. Estimated the economic effect of the proposed measures.

Key words: energy efficiency; energy saving; construction; construction economics; thermal insulation.

ПОВЫШЕНИЕ ЭНЕРГОЭФФЕКТИВНОСТИ ИНДИВИДУАЛЬНЫХ ДОМОВ В РОССИИ С ПРИМЕНЕНИЕМ ЭФФЕКТИВНОЙ ТЕПЛОИЗОЛЯЦИИ

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Аннотация. В статье представлен теплотехнический расчет ограждающих конструкций существующего индивидуального дома. Предложены энергосберегающие решения. Оценен экономический эффект от предложенных мероприятий.

Ключевые слова: энергоэффективность; энергосбережение; строительство; экономика строительства, тепловая изоляция.

INTRODUCTION

Energy efficiency and conservation are priority areas of science, technology and engineering in the Russian Federation, noted in the Presidential Decree of July 7, 2011 № 899. In modern architecture and construction can be achieved by improving the architectural and planning decisions, the use of external walling building with the necessary level of thermal protection, the introduction of effective systems to ensure climate and energy conservation in buildings, use of renewable energy sources, improving the quality of the design of the building [1].

LITERATURE REVIEW

Russia is the largest country in the world, in which a range of climatic conditions is very broad. There winters and warm summers provide a high thermal load on the building in most of the year.

According to the National Research Institute for Building Physics, the share of energy consumption of the building is 45 % of the total energy produced in the country. The most effective way to improve the energy efficiency of buildings and civil engineering is the application of modern design solutions using insulating materials [2].

GOALS AND OBJECTIVES

The aim of the work is the analysis and calculation of transmission heat losses, i.e. the desired value of thermal resistance of walls and other structural elements of the building according norms and requirements. Comparison of these values and economic feasibility of various measures by different methods give a clear idea of how to achieve significant cost savings and trends of the modern world.

DESCRIPTION OF THE OBJECT

The object of study is the individual 2-storey house for a family of five people, located in the city of Ufa. The walls of the house are made of bricks: the basis - full-bodied clay brick cladding is made of a ceramic tile hollow bricks. In addition, for the reinforcement and connection load-bearing wall and the top layer was applied a grid of metal bars running through the entire thickness of the wall on perimeter every 5 rows of masonry or 370 mm. As an interior decoration is plaster cement-sand mortar and gypsum plaster [3].

MATERIALS AND CALCULATION

According to national construction standard SP 131.13330-2012 the following parameters for calculating.

Table 1

Conditions and parameters required for the calculation of the residential part of an individual house in Ufa

Parameter	Parameter designation	Unit of measurement	Nominal value
Nominal temperature of external air	$t_Н$	℃	- 33
Mean temperature of external air during heating period	$t_{ОТ}$	℃	- 6
Heating period duration	$z_{ОТ}$	day/year	209
Degree-day of heating period	DDHP	℃ day/year	5643
Nominal temperature of internal air	$t_В$	℃	21

For design temperature of the outside air in the first row of Table 1 adopted the temperature of the coldest five-day week, security 0.92. The average outdoor temperature during the heating period and duration correspond to the average air temperature and the duration period with average daily temperature of not more than 8$^{\circ}C$ according table 3.1 of national standard SP 131.13330.2012. The design temperature of indoor air is taken in the minimum range of optimum temperature (20-22$^{\circ}C$) of the buildings in accordance with national standard GOST 30494-2011. However, in climates with temperatures Ufa coldest five days below -31$^{\circ}C$ living room temperature, providing optimum comfortable accommodation, taken $t_В$=21$^{\circ}C$.

The required thermal resistance for different elements through which the transmission loss is calculated as follows:

$$R_0^{req} = a \bullet DDHP + b \quad (1.1),$$

stated in SP 50.13330.2012, which, in turn, the value of the heating degree-days period (DDHP) were calculated using the formula:

$$DDHP=(t_в - t_{от}) \cdot z_{от} = (21^{\circ}C - (-6^{\circ}C)) \cdot 209\,day/years = 5643^{\circ}C \cdot day/years \quad (1.2)$$

The coefficients a and b in the formula (1.1) are accepted for groups of buildings, residential and public and for the constructive element – a wall equal: a = 0,00035, b = 1,4 for SP 50.13330.2012 Table 3. As a result, according to the formula (1.1) for the walls:

$$R_0^{req} = 0{,}00035 \cdot 5643^{\circ}C \cdot day / years + 1{,}4 = 3{,}38(m^2 \cdot {}^{\circ}C)/W \qquad (1.3)$$

Similar calculations for the required thermal resistance values for different elements (windows and skylights, exterior doors, floors), a table 2, which contains these values.

Table 2

Minimum required values to the level of thermal protection exterior walling in accordance with regulatory requirements SP 50.13330.2012

№	Type of exterior wall	Value R_0^{req}, m²·C/W
1	Exterior wall	3.38
2	Window	0.57
3	Balcony door	0.93
4	Overlap	4.44

For the calculations necessary to know the geometric parameters of the walls, which are presented in Figure 1.

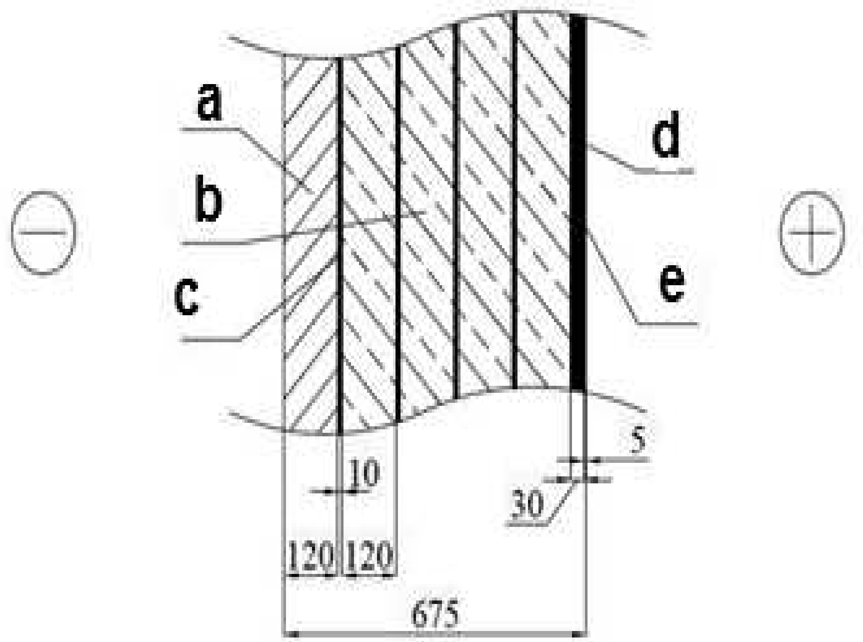

Figure 1. Diagram of exterior wall structure

Thermal resistance to heat the multilayer structure is determined by the method described in Section 9 Code of national standard SP 23-101-2004. The formula is:

$$R_0 = \frac{1}{\alpha_в} + R_k + \frac{1}{\alpha_н} \qquad (1.4),$$

Where

$$R_k = \sum_{i=1}^{n} R_i = R_a + R_b + R_c + R_d + R_e \qquad (1.5)$$

– thermal resistance of multilayer enclosing structure, which consists of the thermal resistance of each layer, defined as:

$R_i = \frac{\delta_i}{\lambda_i}$, $\alpha_в$, $\alpha_н$

– heat transfer coefficients inner and outer surfaces of enclosures, respectively, and are assumed equal to 8.7 and 23, respectively, Table 4 and 6 of SP 50.13330.2012. All values of thermal resistance and thermal performance necessary wall elements are shown in national construction standard SP 131.13330-2012.

Thus, it follows from (1.5) we obtain the calculated value of thermal resistance of the wall:

$$R_0 = [\ 0{,}29 + 0{,}86 + 0{,}05 + 0{,}07 + \frac{1}{23} + \frac{1}{8{,}7}\ ](m^2 \cdot {}^\circ C)/W = 1{,}43(m^2 \cdot {}^\circ C)/W$$

Comparing this with the calculated value of the normalized minimum, it is clear that: $R_0 < R_0^{req}$ to (3,38-1,43) $(m^2 \cdot {}^\circ C)/W$ =1,95 $(m^2 \cdot {}^\circ C)/W$ or less 136 %.

Similar calculations for total resistance to heat transfer other structures also showed unsatisfactory results: for windows – $R = 0{,}4(m^2 \cdot {}^\circ C)/W$, for ceilings – $R = 0{,}85(m^2 \cdot {}^\circ C)/W$.

Carry out the procedure described in [6], the calculation of transmission losses of thermal energy for heating the building $Q_{extp}, kW \cdot h / years$ according to the formula:

$$Q_{ext} = 0{,}024 \cdot DDHP \cdot \sum_i \frac{A_i}{R_i} \cdot n \qquad (1.6),$$

where 0,024 – a conversion factor of heat losses through the exterior of the building envelope W * day in kW*h - the area of the i-type of external walling – reduced thermal resistance of i-type external walling. Thus, the transmission loss of the building will make according to formula (1.6):

$$Q_{ext\ wall} = 0{,}024 \cdot 5643 \cdot \left(\frac{377{,}69 m^2}{1{,}43 W/(m^2 \cdot {}^\circ C)} + \frac{44{,}83 m^2}{0{,}4 W/(m^2 \cdot {}^\circ C)} + \frac{119{,}8 m^2}{0{,}85 W/(m^2 \cdot {}^\circ C)}\right) =$$
$$= 70036{,}64 kW \cdot h / years$$

We consider this problem from an economic point of view. Cost of 1 Gcal of heat energy to Ufa take equal 1,076 rur. According to the conversion factor values of thermal energy:

$$1 kW \cdot h / years = 3{,}6 \cdot 10^6 / 4{,}187 cal / yeras = 86 \cdot 10^{-5} Gcal / years.$$

It follows that the unjustified heat losses through the building envelope is spent to pay:

$$S = 70036{,}64 kW \cdot h / years \times 86 \cdot 10^{-5} Gcal / years \times 1076 rur. = 64809{,}1 rur.$$

The calculation of the cost of thermal energy for heating and related costs homeowner for 10, 30 and 50 years of service at home. Costs for thermal energy in the building during the life of the change in geometric progression $S_n = (a_1 - a_1 \cdot q^m)/(1-q)$, where a_1 – costs of tenants to thermal energy in the first year of operation, q- average annual rate of growth of tariffs for thermal energy (in Russian corresponds to the average value of 15 % per year, that is, q = 1,15), m – reporting period of operation. Calculations show that the costs are enormous for a family of five living in this house:

$$S_{10\,years} = (64809{,}1rur - 64809{,}1rur \cdot 1{,}15^{10})/(1-1{,}15) = 1315865{,}71rur$$

$$S_{30\,years} = (64809{,}1rur - 64809{,}1rur \cdot 1{,}15^{30})/(1-1{,}15) = 28175441{,}67rur$$

$$S_{50\,years} = (64809{,}1rur - 64809{,}1rur \cdot 1{,}15^{50})/(1-1{,}15) = 467773696\ rur$$

IMPROVING THE EFFICIENCY OF BUILDING ENVELOPES

The problem of reducing such a significant loss of heat, and therefore the financial loss, it is necessary to solve the insulation walling home [4-5].

Calculate the estimated thickness of the insulation for the walls, from the condition of its resistance to heat above 70% than in the SP 50.13330.2012 normalized. Earlier in work (Table 2) indicated the minimum required value calculated for the thermal resistance of the wall equal $R_0^{req} = 3{,}38(m^2 \cdot {}^\circ C)/W$. For calculating accept 70 % higher than its value and equal: $R_0^{req} = 1{,}7 \cdot 3.38(m^2 \cdot {}^\circ C)/W = 5{,}75(m^2 \cdot {}^\circ C)/W$. Suppose used as heat insulation foamed polystyrene SPU Oy company with the lowest thermal conductivity coefficient $\lambda_{ins} = 0{,}022 \div 0{,}023W/(m \cdot {}^\circ C)$. These results were confirmed by independent tests of VNIIM im. D.Mendeleeva and Test Center SPSUACE "Block".

From the formula (1.3) express the desired thickness of insulation:

$$\delta_{ins}^{req} = \lambda_{ins}^{req} \cdot (R_0^{req} - R_0) = 0{,}023W/(m \cdot {}^\circ C) \cdot (5{,}75(m^2 \cdot {}^\circ C)/W - 1{,}43(m^2 \cdot {}^\circ C)/W) =$$
$$= 0{,}099m \approx 0{,}1m$$

From the formula (1.5) express the desired thickness of insulation: Only 10 cm of insulation will allow home not only to achieve the minimum requirements for thermal insulation of walls, but also to exceed the rated value is 70 %. Of course, in addition to improving thermal insulation of walls, it is important to increase the energy efficiency of windows, floors. Similarly, we will recommended design values of thermal resistance is also 70 % higher than the normalized set forth in Table 2 above. Then for windows –

$$R_{req\ window} = 1,7 \cdot 0,57(m^2 \cdot {}^\circ C)/W = 0,97(m^2 \cdot {}^\circ C)/W \ ,$$

for overlap –

$$R_{req\ overlap} = 1,7 \cdot 4,4(m^2 \cdot {}^\circ C)/W = 7,48(m^2 \cdot {}^\circ C)/W \ .$$

According to the procedure described above and in [6], the data for transmission losses of thermal energy for heating and economic costs of maintaining and heating the house for 1 year, 10, 30 and 50 years of operation:

$$Q^{г}_{ext\,wall} = 0,024 \cdot 5643 \cdot \left(\frac{377,69м^2}{5,75(m^2 \cdot {}^\circ C)/W} + \frac{44,83м^2}{0,97(m^2 \cdot {}^\circ C)/W} + \frac{119,8м^2}{7,48(m^2 \cdot {}^\circ C)/W}\right) =$$

$$= 17324,16 kW \cdot h / years$$

$$S = 17324,16 kW \cdot h / years \times 86 \cdot 10^{-5}\, Gcal / years \times 1076 rur. = 16031,08 rur$$

$$S_{10\,years} = (16031,08 rur - 16031,08 rur \cdot 1,15^{10})/(1-1,15) = 325490,53 rur$$

$$S_{30\,years} = (16031,08 rur - 16031,08 rur \cdot 1,15^{30})/(1-1,15) = 6969434,22 rur$$

$$S_{50\,years} = (16031,08 rur - 16031,08 rur \cdot 1,15^{50})/(1-1,15) = 115707787,1 rur$$

CONCLUSION

The above and described in this work method for determining the efficiency of residential buildings in Russia is quite justified from an economic point of view and from the point of view of reducing the negative impact on the environment. In the above transmission loss of the house for heating and maintaining a comfortable environment at the moment are $70036,64 kW \cdot h / years$, for the costs associated with losses up $64809,1\ rur$. Measures to improve energy efficiency at home will reduce to a minimum the incidental expenses and the heat losses causing them. The reduction of these parameters in more than 5 times: $17324,1 kW \cdot h / years$ and $16031,08\ rur$, at low cost energy efficiency should lead to increased comfort those who are living in the home, reduce emissions of CO2, improving the ecological and economic situation, both for the family that lives in the house, and for the country as a whole.

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