Modern effective technologies applied for constructing external walls

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Abstract. The development of the construction industry should be based on resource and energy-saving principles. The energy efficiency issue is being discussed at various levels, including the government one. The issue of energy saving technologies and structures is crucial for the construction industry, as they can reduce the amount of energy consumed and save money. One of the main components of the energy efficiency of buildings is thermal protection. In the construction industry, one of the simplest and most rational ways to save energy is to reduce heat losses through the building envelopes. One of the options for increasing the energy efficiency of building envelopes is effective heaters. It is difficult to choose materials and structural designs of supporting structures since they determine all other structural elements of the building. For Russia whose regions are located outside the climate control zone, energy efficiency issues are crucial. Currently, energy conservation is one of the government priorities. This is due to the shortage of basic energy resources, increasing energy production costs and global environmental problems.

1. Introduction
The construction industry is one of the most important sectors of the national economy ensuring the constitutional rights of citizens and integrating many related economic sectors.

The current level of scientific and technological development requires resource-saving technologies when performing construction works. The construction industry is one of the energy- and resource-intensive industries. However, it is necessary to reduce the cost of construction material production [1].

In the construction and housing sectors, the principles of sustainable development were declared by the International Construction Council - CIB (Conseil International du Batiment) created in 1953 under the auspices of the UN. The concept is based on the limited consumption of natural resources, the efficient use of the potential of related industries, and energy-efficient solutions. This approach is the main one for the national economic programs of a large number of countries, including Russia.

Russia with its harsh climate is one of the largest energy producers and consumers. An important task of all the national long-term development programs focused on energy saving is to ensure the most effective thermal insulation of building envelopes.

2. Materials and methods
Development of the construction industry requires new materials, technologies and approaches. In the construction industry, global trends are resource efficiency and a reduced construction period. However, in Russia, due to its climatic features (temperature extremes, permafrost, seismicity and wind), it is also necessary to build very warm wall structures.
In addition to the thermal insulation rules developed in the Soviet era, much attention is paid to sustainable development.

The solution that can reduce materials consumption and improve energy intensity is Poroplast CF02 as an insulant for multilayer building envelopes [2, 3]. Liquid urea-formaldehyde foam has been applied in foreign countries for a long time [4, 5]. In Russia, it is produced using reliable production technologies [3].

Poroplast CF02 is produced from available inexpensive materials on-location. The main physical and mechanical and operational properties of the composite are presented in Table 1.

**Table 1.** The main physical, mechanical and operational properties of the composite "Poroplast CF02".

| Name of the parameter                                    | Measurement unit | Standard       |
|---------------------------------------------------------|------------------|----------------|
| Density, within                                          | kg/m³            | 8-30           |
| Compressive strength at 10% linear strain, not less than | MPa              | 0,01           |
| Estimated Mass Moisture                                   | %                | 15             |
| Sorption moisture by mass, not more than                  | %                | 18             |
| Water absorption by volume when completely immersed in water for 24 hours, no more than | %                | 16             |
| Maximum permissible increment of moisture, by weight     | %                | 50             |
| Thermal conductivity                                     | W/(m·ºC)         | 0,029 - 0,035  |
| Vapor permeability, no more than                          | mg/(m·h·Pa)      | 0,27           |
| Combustibility group                                      |                 | G1, incombustible |
| Durability, not less than                                 | year             | 50             |

The thermal insulation is carried out by pouring the foam into the cavity of the building envelope without joints and gaps. The advantage of the composite over plate insulants is its ability to restore insulating properties of the building envelope by re-pumping the insulation material into the voids through the technological holes.

When designing and operating the multi-layer walls, the most important problem is moisture condensation inside the structure. It can lead to excessive wetting of the insulation layer and the gradual loss of its thermal properties.

3. Results

To test properties of the building envelope consisting of Poroplast CF02, we determined moisture content under unsteady heating and mass transfer using a MODEN 2.0.

The calculation was performed for the external wall which consists of four layers: A - cement-sand plaster, B - clay brick, C - Poroplast CF02, D - ceramic brick. The diagram is shown in Figure 1 (where:

\[ d_i \] – thickness of the \( i \)-th layer, m; \( \gamma_i \) – density of the \( i \)-th layer, kg/m³; \( c_i \) – heat capacity of the \( i \)-th layer, kJ / (kg·ºC); \( \lambda_i \) – thermal conductivity of the \( i \)-th layer, W/(m·ºC); \( \mu_i \) – vapor permeability of the \( i \)-th layer, mg/(m·h·Pa); \( \beta_i \) – moisture conductivity coefficient, kg / (m·s); \( T_i \) – temperature on the axis of the \( i \)-th layer, ºC; \( T_{int}, T_{ext} \) – temperature of internal and external air, respectively, ºC; \( T_{0}, T_{10} \) – temperature on the inner and outer surfaces, respectively, ºC; \( e_i \) – partial pressure of water vapor on the \( i \)-th layer, Pa; \( e_{int}, e_{ext} \) – partial pressure of water vapor of internal and external air, Pa; \( E_i \) – saturated water vapor pressure on the axis of the \( i \)-th layer, Pa; \( E_{int}, E_{ext} \) – saturated water vapor pressure corresponding to the temperature of internal and external air, Pa; \( I \) – the boundary between the room air and the inner surface of the 1st layer; \( II, III \ldots IX \) - the boundaries of the joints of the layers, X - the boundary between the outer surface of the 9th layer and the external air).
The thermal characteristics of the materials are summarized in Table 2.

**Table 2.** Thermotechnical characteristics of materials.

| Name of the material       | Density $\gamma$, kg/m$^3$ | Thickness $d$, m | Thermal conductivity coefficient $\lambda$, W/(m$^2$C) | Vapor permeability coefficient $\mu$, mg/(m$^2$hPa) | Specific heat capacity in a dry state, kJ / (kg°C) |
|----------------------------|-----------------------------|------------------|--------------------------------------------------------|--------------------------------------------------|--------------------------------------------------|
| Cement-sand mortar         | 1800                        | 0,02             | 0,076                                                  | 0,091                                            | 0,84                                             |
| Clay brick                 | 1800                        | 0,25             | 0,7                                                    | 0,11                                             | 0,88                                             |
| Poroplast CF02             | 15                          | 0,14             | 0,030                                                  | 0,27                                             | 1,63                                             |
| Ceramic brick              | 1600                        | 0,12             | 0,14                                                   | 0,14                                             | 0,88                                             |

Figure 2 shows moisture distribution over the building envelope during the conditional annual cycle (heat insulation density: 15 kg/m$^3$ and relative moisture of external air: a - 55%; b - 60%; I - moisture at the beginning of the wetting period (November); II - moisture at the end of the wetting period; III - moisture during the period of maximum moisture (February); IV - maximum sorption moisture). Temperature and moisture conditions comply with GOST 30494-2011. In the Siberian region, the average moisture content in Poroplast is within the sorption moisture value. Thermophysical properties of the envelope materials do not change. A moisture content increases only in the layer adjacent to the outer milestone of the façade brick. It can increase thermal conductivity of Poroplast by 9%.
Therefore, the multilayer building envelope consisting of Poroplast CF02 can retain its energy-saving properties for a long period.

4. Discussion
The role of effective thermal insulation in constructing walls is crucial. Based on the world experience, one can conclude that 1 m$^3$ of effective thermal insulation saves 1.4-1.6 tons of standard fuel per year. The thermal layer increases the resistance to heat transfer, saves energy costs for heating buildings and decreases the consumption of materials and laboriousness of construction works.

Density of foam and porous plastics is 6-10 times lower than the density of mineral wool, 4-8 times – than mineral wool slabs, 25-50 times – than wood, 30-60 times – than brick and 100-200 times – than concrete and reinforced concrete. Foam and porous plastics can increase thermal resistance and reduce weight of the building envelope.

Table 3 shows the data on the heat transfer resistance of external building envelopes (walls and roofs) of residential buildings in various countries in accordance with the construction area.

| Country    | Wall  | Roof  |
|------------|-------|-------|
| Germany    | 2,0-2,5 | 3,0-3,6 |
| Denmark    | 3,3-5,0 | 5,0-7,0 |
| Canada     | 3,0-4,1 | 4,5-6,15 |
| Norway     | 4,0    | 4,35   |
| Russia     | 2,1-5,6 | 2,8-7,3 |
| USA        | 1,08-2,5 | 3,57-7,14 |
| Finland    | 2,9-3,57 | 2,2-4,55 |
| Sweden     | 3,3-4,0 | 5,0-5,9 |
In order to ensure the required heat transfer rates, the wall thickness should be 1.5-2.8 m. Accordingly, such a thickness will increase the consumption of materials and labor and construction costs. Therefore, it is necessary to construct multilayer structures made from structural materials and effective insulants [6,7,8,9,10,11,12].

Figure 3 shows the comparative cost characteristics of 100 m² of the facade insulation system.

Figure 3. The cost of facade insulation systems per 100 m², thousand rubles [13].

Thus, the three-layer structure can decrease construction costs

5. Conclusion
In Russia, the issues of energy efficiency and energy saving are crucial due to harsh climatic conditions and regular natural disasters. It is advisable to implement program-targeted mechanisms and scientific achievements.

However, despite the technological progress, it is difficult to ensure the durability of materials used in building envelopes and the economic unprofitability of the latter in the long term.

One of the attempts to solve the problem is the use of Poroplast CF02 as an insulant. Field surveys of the building envelope consisting of Poroplast CF02 showed that the moisture content is 17-24% which allows us to consider Poroplast CF02 as a reliable and stable insulant for multilayer building envelopes.

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