Energy Efficient Major Overhaul in Residential Buildings of the First Mass Series

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Abstract. The article shows the need for energy-efficient major overhaul in apartment buildings of the first mass series. Calculated thermo-technical indices of enclosing structures in reconstructed buildings of typical series 1-447c-37 in Volgograd are determined. The required thickness of fencing structures’ insulation should be calculated for each region of energy-efficient construction. Calculated results confirm principal possibility of achieving high requirements for thermal protection and energy saving in Russia’s cold climate. The highest energy performance can be achieved only with the insulation of the entire building envelope and implementation of highly efficient engineering systems with automatic control, which reduces the cost of thermal energy for heating and ventilation by 70%.

1. Introduction

The need for energy-efficient major overhaul of buildings is induced by high energy consumption in Russia’s cold climate. A significant part of Russia’s housing stock was built in the USSR, in the era of industrial housing. Many buildings of the first mass series have high bearing capacity and meet the requirements of mechanical and fire safety. However, the level of thermal comfort of such buildings, constructed in 60–70s of the last century, is quite low [1–5]. Thermal energy demand for building heating is 150–200 kWh·h/(m²·y.), which exceeds the specified value 2–2.5 times. To reduce the consumption of thermal energy, special attention should be paid to development and implementation of effective engineering solutions into the practice of modern construction [6–13]. Low level of energy consumption in buildings can be achieved by increase of resistance to heat transfer of enclosing structures, implementation of energy-efficient window designs, air permeability of the envelope (while maintaining ventilation standards), passive use of solar energy, employment of ventilation systems with heat recovery. Modern energy-efficient buildings actively use renewable energy sources [14–20].

By energy efficient overhaul in a building, we understand a complex of repair and construction works aimed at replacing or restoring building structures and engineering systems for improving thermal insulation and energy performance of a building. Thus, unlike conventional overhaul, energy-efficient overhaul mainly affects heat-shielding properties of buildings. From this point of view, the subject of the article is certainly relevant.

The purpose of this study is to assess the need for energy-efficient overhaul in apartment residential buildings of the first mass series in Russia’s climatic conditions on the basis of increasing insulation level of enclosing structures and improving engineering systems.

The object of study is an apartment residential building constructed according to standard series 1-
447c-37 in 1968 in Volgograd (figures 1 and 2). According to the plan the building is rectangular. The number of floors is 5, the number of sections is 4, the number of apartments is 90. The building has an unheated basement and no attic.

![Figure 1. General view of the building series 1-447c-37.](image1)

![Figure 2. Thermogram of the building’s front facade fragment.](image2)

The structural system of the building is frameless, with longitudinal bearing walls. The spatial rigidity of the building is provided by longitudinal bearing walls, transverse walls, diaphragms and inter-floor discs. Foundations are strip, concrete blocks are prefabricated. The outer walls of the building are brick, 510 mm thick, with external cladding of 40 mm thick silicate modular tile (see figure 1). Double-glazed windows are in separate wooden bindings (mainly), as well as in the form of double-glazed windows in PVC profiles (replaced by residents). Covering is combined non-ventilated with a roll roof. The building provides for external unorganized drainage.

The building is supplied with heat through heating networks of the centralized heat supply system. The building has natural general ventilation.

Main design characteristics of the building:
- Total area of the building is 4089 m².
- Total area of apartments is 3817 m².
- Heated volume is 11354 m³.
- Glazing coefficient of building facades is 0.24.
- Building compactness index is 0.36 m⁻¹.
- Degree-day of heating period is 3925 K per day / year.

2. Methods

The results of thermal imaging control revealed numerous temperature anomalies and thermal defects of the building envelope (figure 2). The elements of enclosing structures with lower temperature of inner surface are determined. Some of them can have moisture condensation at the design temperature of the cold period of the year.

Increased temperature differences of internal air and inner surface of walls indirectly characterize high values of heat flows through enclosing structures. The results of external thermography of envelope revealed increased heat losses through walls, especially in placement of heating devices in wall niches. From the thermal-engineering point of view windows and balcony doors are the weakest element. Thermal imaging control showed a generally low level of thermal insulation of enclosing structures (figure 2), which does not meet the minimum requirements of the Russian standard SP 50.13330.2012 on the basis of sanitary-hygienic and comfortable conditions.

Calculation of thermal characteristics of enclosing structures and thermal power indicators of the surveyed building is made according to the standard SP 50.13330. Assessment of efficiency is made on the basis of specific characteristics of heat consumption for heating and ventilation of buildings according to Order of the Ministry of Construction of the Russian Federation No. 1550/Pr.
3. Results and discussion

Along with thermal engineering defects, construction and operational defects of enclosing structures were established (figure 3).

![Figure 3](image-url)

**Figure 3.** Construction-operational defects of enclosing structures:
- a) destruction of coating elements;
- b) failure to provide required roof slopes;
- c) destruction in the area of blind to basement junction;
- d) non-insulated basement structures.

The revealed construction-operational and thermal defects are the main factor which reduces the safety of the building and dictates the need to restore and improve the performance properties of external enclosing structures.

![Figure 4](image-url)

**Figure 4.** The general view of the facade thermal insulation composite system (a) and hinged facade system (b).

Calculation results made it possible to conclude that thermal protection increase of enclosing
structures in an apartment building to the level of current and future norms is of prior importance. As an additional thermal insulation it is preferable to use durable materials and products. The application for thermal insulation of exterior walls of a facade thermal insulation composite system with external plastering layers or a hinged facade system (figure 4) contributes to the improvement of performance indicators of enclosing structures.

Insulation thickness of external walls is 150 mm, of combined coverage is 180 mm, ceiling above unheated basement is 80 mm. The heat transfer coefficient of windows and balcony doors is 1.23 W/(m²K), which is achieved by implementation of energy-efficient double-glazed windows with glass has low-emission soft coating and krypton filling. Implementation of hinged facade system for thermal insulation of external walls contributes greatly to improving performance indicators. To reduce air infiltration into stairwells it is recommended to seal entrance doors in the doorways with installation of closers. The actual air permeability of building envelope should not exceed the required value.

The results of calculation show principal possibility of achieving high level of thermal insulation of enclosing structures after major overhaul of the building.

To find most effective constructive solution, the following options for improving thermal protection of building envelope are considered:

1. Without additional insulation of enclosing structures (basic version);
2. Installation of energy-efficient windows and balcony doors;
3. External walls’ thermal insulation is added to measures of option 2;
4. Measures of option 3 are performed, along with insulation of flat roof;
5. Thermal insulation of the entire building envelope, that is, measures of option 4 are implemented and insulation of ceiling over the unheated basement is carried out.

The results of calculation of specific heat-shielding characteristic for all five variants are shown in figure 5. Normalized value of this characteristic, equal to 0.23 W/(m²K), is shown by a dotted line.

Figure 5. Specific heat-shielding characteristics of building according to calculation options.

As one can see (figure 5), the maximum value of specific heat-shielding characteristics equal to 0.40 W/(m²K), is marked in the basic version, that is, without additional insulation of enclosing structures. Before major overhaul complex requirement for thermal insulation in the building according to SP 50.13330 is not provided. Calculated value of specific heat-shielding characteristics of the building exceeds normalized value by 74%. Replacement of windows and balcony doors with more energy-efficient structures (option 2) leads to reduction in specific heat protection characteristics.
of the building by 12.5% if compared to basic option 1; however, in this case, complex requirement for thermal protection of the building is also not provided. Implementing energy-efficient measures under option 3 contributes to significant reduction in the specific thermal performance of the building by 42.5% compared to basic version, which meets complex requirement of thermal protection. The most effective constructive solution is provided by thermal insulation of the entire building envelope.

The results of technical and economic calculation confirm feasibility of thermal insulation of entire building envelope. In this case, the projected payback period of energy-saving measures is 9–10 years.

The following options of constructing building envelope and engineering systems are considered:

I – without overhaul of building envelope and engineering systems;
II – with major repairs of building envelope, but without major repairs of engineering systems;
III – overhaul of building envelope and engineering systems.

The results of calculation of specific thermal energy consumption characteristics are shown in figure 6. The dotted line shows normalized value of this characteristic, equal to 0.36 W / (m³K).

Figure 6 shows that before major overhaul, calculated specific characteristic of heat energy consumption exceeds normalized value by 78%. The building project does not meet regulatory requirement of Order No. 1550 / pr. The overhaul of building envelope leads to reduction in the specific heat consumption characteristic by 52% compared to the basic variant. The highest energy efficiency is achieved within the overhaul of building envelope and engineering systems.

Thus, energy-efficient major overhaul in apartment residential buildings of the first mass series is relevant and perspective in Russia’s cold climate.

4. Conclusion

The need for energy-efficient major overhaul in apartment buildings of the first mass series is shown. Calculated thermal technical performance of enclosing structures of reconstructed buildings of the type series 1-447e-37 in Volgograd is determined. Thickness of thermal insulation of outer walls is 150 mm, the combined coating is 180 mm, ceiling over unheated basement is 80 mm. Heat transfer coefficient of windows and balcony doors is 1.23 W / (m²K), which is the result of energy-efficient glass packs with low-emissive soft glass and krypton filling. The required thickness of thermal insulation of enclosing structures should be calculated for each region of energy-efficient construction.

The results of the calculations confirm fundamental possibility of achieving high requirements for thermal protection and energy saving in Russia’s cold climate. The highest energy indices can be provided only by thermal insulation of the whole building envelope and highly efficient engineering systems with automatic regulation, which allows reducing the cost of thermal energy for heating and ventilation by 70%.

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