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CONTEXT / MUNDARIJA

Comparative analysis of various types of enclosing structures` effectiveness on multi-storey reinforced concrete frame buildings for conditions of Central Asia

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Abstract: The effectiveness of external and internal walls of modern multi-storey frame buildings made from traditional brick materials, small cellular aerated concrete blocks, as well as the proposed new frame-sheathing wall structures (FSW) in the temperature, climatic and seismic conditions of Central Asia is considered.

Keywords: brick, wall, frame-sheathing wall (FSW), light steel thin-walled structures (LSTS), thermal profile, seismic resistance, energy saving, ecology, thermal insulation.

1. Introduction

The most important factors in the reliability and durability of buildings and structures in Central Asia are their seismic resistance and the ability of structures to resist the destructive effects of temperature and humidity conditions in a sharply continental, dry, hot climate. Ensuring the reliability and durability of buildings and structures in these conditions is even more relevant in modern conditions when the trend towards the construction of high-rise and super-tall buildings is growing. At the same time, requirements for energy saving of buildings, increasing their comfort and efficiency of their architectural environment are increasing from year to year.

In this regard, among the sought-after design factors of modern buildings, the most relevant are lightweight, reliable enclosing structures, which at the same time have significant energy-saving characteristics. Research in this direction is now becoming more extensive, allowing us to expand the range of proposals for similar designs. An important indicator, in this regard, is a comparative analysis of new design solutions in this direction, which, with the correct formulation of the problem, gives a clear idea of the effectiveness of energy-saving enclosing structures.

2. Materials and methods

Currently, among the objects under construction in urban areas, the vast majority are multi-storey reinforced concrete frame buildings. The popularity of this type of building is due to the strength and seismic resistance of their spatial system, the possibility of almost unlimited design and implementation of architectural solutions, the presence of comparative advantages in price, well-established construction technologies and the availability of building materials.

As is known, the load-bearing capacity of frame buildings is ensured by the spatial operation of a reinforced concrete or metal frame. At the same time, depending on the specified parameters and design solutions of the building, its spatial rigidity is ensured by appropriate additional connections, diaphragms and cores. In some cases, the enclosing structures of frame buildings also serve as stiffening diaphragms, but their main task is to ensure the functionality of the architectural environment of the building and create conditions for the life of its infrastructure.

In this regard, such characteristics of enclosing structures (especially external ones) as thermal conductivity, sound permeability, moisture resistance, total mass, thickness, fire resistance, efficiency, manufacturability, environmental friendliness, biocompatibility, non-toxicity, and safety come to the fore. A comparative analysis of enclosing structures taking into account these parameters make it possible to identify the most optimal ones. For this purpose, such an analysis was carried out between the traditional, most common structural solutions of walls (brick walls, walls made of light porous cellular concrete), as well as the new proposed structural solution - frame-sheathing wall structures (FSW).

Brick walls. Brick is considered as one of the main wall materials, from which 40% of current residential and public buildings are built. Brick walls are made from burnt and unfired bricks with a standard size of 250×120×65 mm, thickened brick - 250×120×88 mm.

The calculated thickness of brick walls is determined by the size of the brick but can also be taken in accordance with the thickness of the adjacent structure. With brick dimensions of 250×120×65 or 250×120×88 mm (modular brick), the wall thickness can be 0.5, 1, 1.5, 2, 2.5 bricks, which is equal (considering the thickness of the vertical joints of the masonry) 120, 250, 380, 510, 640 mm respectively. Based on average density, bricks are divided into light (less than 1450 kg/m³), lightened (from 1451 to 1650 kg/m³) and heavy (more than 1650 kg/m³).

Despite the known advantages of brickwork, such as fire resistance, environmental friendliness, biocompatibility, non-toxicity, there are several significant disadvantages. The main disadvantage of solid brick walls is their volumetric weight and high thermal conductivity. The weight of 1 meter of a brick outer wall of a building with a thickness of 1.5 bricks with an average floor height of 3 meters is 1650–2000 kg/m³ [1]. To ensure thermal insulation of buildings with brick walls, it is necessary to increase their thickness,

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sometimes up to 2–2.5 bricks, which inevitably leads to an increase in the already high mass of the structure. This, in turn, is extremely unproductive from the buildings` seismic resistance point of view. In addition, thickening the walls leads to higher construction costs, and the rigid structure of the brickwork leads to its brittle destruction under seismic influences, which has a particularly negative effect when constructing brick walls in multi-story reinforced concrete frame buildings.

Lightweight porous cellular concrete blocks. Cellular concrete is a type of lightweight concrete. During their production, a characteristic "cellular" structure is formed. The porosity of cellular concrete can be adjusted, producing concrete of different densities and purposes. According to their purpose, cellular concrete is divided into three groups: structural, structural and thermal insulation, and thermal insulation. Among blocks made of cellular concrete, foam concrete and gas aerated concrete blocks are most widespread.

Foam concrete blocks. Foam concrete is made from cement, sand, water and foaming agent. Foam concrete products are distinguished by good sound and heat insulation properties and low weight. The material is non-flammable and does not collapse from exposure to high temperatures. The properties of foam concrete are greatly influenced by the quality of the foaming agent. Currently, synthetic foaming agents based on organic compounds, both domestic and imported, are mainly used. By changing the ratio of the components of the foam concrete mixture, it is possible to obtain foam concrete of varying densities (400–1800 kg/m³). With increasing density, the strength of foam concrete increases, but the heat transfer resistance decreases. Foam concrete blocks are used as enclosing structures in frame buildings, as well as thermal liners for the enclosing structures of multi-storey residential buildings. In low-rise housing construction, foam concrete blocks of grades (marks) D500 and higher are used as load-bearing structures. As a rule, D400 brand blocks are used as thermal insulation [2].

Gas aerated concrete blocks. Aerated concrete is produced from a binder (cement, lime), quartz sand, water, with the addition of gas-forming substances (due to which small air pores are distributed evenly). That is why building elements made of aerated concrete are lightweight and have good thermal insulation properties. Aerated concrete is a structural and thermal insulating building material. Its use for the construction of enclosing structures can significantly reduce the weight and thickness of the walls, which not only reduces the time and volume of construction work, but also reduces the cost of construction due to the reduced weight of the building and savings on the construction of the foundation. Structures made of aerated concrete have higher thermophysical properties in comparison with blocks made of heavy concrete, ceramic and silicate piece materials. For example, for constructing an external wall, blocks of porous concrete with a thickness of 375 mm (density 400 kg/m³) are sufficient.

Aerated concrete is a non-flammable material and can be used for all fire safety classes. It is not destroyed by high temperature and prevents the spread of fire. Due to its structure, aerated concrete is a frost-resistant building material. In addition, aerated concrete blocks are easy to process (sawed, drilled, milled, chipped, nailed), and do not corrode or rot. At the same density, the strength of aerated concrete is almost 2 times greater than the strength without autoclaved foam concrete [2].

A feature of aerated concrete as a highly porous material is its high vapor permeability and significant water absorption. Therefore, in enclosing structures made of aerated concrete blocks, it is necessary to ensure free transit of steam from inside the room to the outside. This can be achieved by installing either a ventilated facade or an external insulation system using a finishing layer with high vapor permeability. If it is impossible to install external insulation or there is high humidity inside the room, it is necessary to reliably protect the enclosing structure from the penetration of steam from the inside (for example, mounting a vapor barrier film on the inside) [2].

The advantages of cellular concrete are its low weight, comparative cheapness (15-20% cheaper than conventional lightweight concrete), availability of raw materials (sand and cement), and ease of mechanical processing. The disadvantages include significant cracking, reduced frost resistance, poor connection with textured layers, and the development of corrosion processes in the reinforcement [2].

Frame-sheathing wall (FSW) is a multilayer combined structural system consisting of a frame, materials for insulation/sound insulation that fill the cavity of the frame, wall sheathing (external and internal), fastening elements, vapor barrier and wind protection, external sheathing (facade), and a set of technical and technological solutions that determine the rules and procedure for installing this system in the design position.

External non-load bearing FSW with a frame made of LSTS are enclosing structures that take the load from their own weight, wind and process loads and transfer them to the load-bearing structures of the building [3-5, 8,9].

FSW is a promising, new energy-saving technology that can rightfully be used in residential high-rise housing construction. FSW will ensure energy saving using effective insulation and thermal profiles with slots that increase the path of heat flow and, as a result, resistance to heat transfer, and will also reduce material, labor and operational costs in mass construction with high quality and performance indicators and will reduce construction time due to assembly technology.

It should be noted that, for example, in Europe, lightweight fencing structures are used mainly in "fast" cottage construction technologies and are popular in Northern European countries. Thus, in Finland the share of frame house construction accounts for 75%, and in Sweden – up to 90% of modern cottages. The use of a metal frame in these structures made it possible to improve their workmanship and reliability, as well as solve fire safety issues, which opens the possibility of using such products as external walls of multi-story buildings. It is important to note that currently in Sweden, Norway and Finland the use of lightweight curtain walls in multi-storey buildings reaches 70% of the total volume of housing construction, in the Netherlands and Germany - 50% [4-7].

Figure 1. Diagram of a frame-sheathing wall

The most important parameter for the use of FSW in residential construction is its thermal insulation and heat-energy efficiency. According to the German company KNAUF, when using the FSW system, it is possible to provide a heat transfer resistance of the enclosing structure equal to 5.0 m² °C/W with a thickness of only 22 cm. At the same time, to achieve a similar indicator for a brick wall, masonry with a thickness of at least 34 cm is required, and, considering the presence of a thermal insulation layer, and for a wall made of a lightweight concrete block - 49 cm. Such features of the FSW system will significantly reduce the cost of primary energy necessary for heating and cooling the premises. The reduction in primary energy consumption can be up to 50% compared to traditional construction methods [4-6].

Along with this, compared to traditional materials, FSW provides a significant lightening of the structure. The outer wall accounts for an average of 30% of the mass of a wall built with conventional brick masonry methods and 25% compared to concrete structures, which in turn also improves the seismic resistance of the building as a whole. In addition, FSW increases the sound insulation characteristics of enclosing structures.

Possibility of increasing the useful space of premises with better energy efficiency (on average 25% more space compared to brickwork with a constant heat transfer coefficient), providing more effective thermal insulation outside the building, reducing primary energy consumption by up to 50%, which means a significant reduction in CO_2 emissions into the atmosphere determine the best environmental performance of FSW [4-6].

The use of construction technology from light steel thin-walled structures allows the construction of buildings and structures for both commercial and individual use. The main factor in the use of light steel structures is rapid erection, efficiency, low weight of the structure, and environmental friendliness.

3. Conclusion

Despite such obvious advantages of the FSW system, due to a lack of research, these structures are not widely used in multi-story construction, including in Uzbekistan.

To solve the problem of using FSW as external enclosing structures (walls) of multi-story frame buildings, it is necessary to consider and prove the feasibility and possibility of their use in this capacity. To do this, it is necessary to carry out reliable modeling of a frame building with external walls made of reinforced concrete, taking into account their joint spatial work, under the influence of static and dynamic loads.

Energy saving measures must be envisaged already at the first stage of design, comprehensively applying the latest technical solutions and developments. Therefore, for the prospect of widespread use of new frame-sheathing wall structures to become more realistic and justified, it is necessary to create a reliable array of data on operational characteristics and reliable methods for their calculation. This data will help to select the most economically feasible wall structure for certain climatic conditions.

References

[18] Solving the problem of energy efficiency of buildings using energy-saving enclosing structures, “Development of the business environment and ways to increase the investment attractiveness of Uzbekistan” Proceedings of the international scientific and practical conference May 24–25, 2023, Andijan, Uzbekistan.

[19] “Modern building. Structures and materials”, Big manual, 2006.

[20] Album of technical solutions for the application of products made from autoclaved aerated concrete of the “H+H” trademark in the construction of residential, public and industrial buildings, St. Petersburg, 2011.

[21] Album of technical solutions Knauf AQUAPANEL® External wall. External non-load-bearing frame-sheathing walls with a frame made of steel thin-walled cold-formed galvanized profiles using KNAUF materials, 2020.

[22] A.A. Khodjaev, I.S. Karimjonov. Modern energy-efficient lightweight external wall structures for multi-storey

buildings // Technical science and innovation 2023, No. 1. p. 59-64.

[23] Khodjaev A.A., Karimjonov I.S. Reducing the energy consumption of multi-storey buildings by dint of new solutions for external structures // "The Scientific-Practice Journal of Architecture, Construction and Design", 2022, No. 4. p. 182-187.

[24] Dubatovka A.I. Modern constructive solutions of frame buildings with the use of light enclosing structures.

[25] Kurazhova V.G., Nazmeeva T.V. Types of nodal joints in light steel thin-walled structures. Inzhenerno-stroitel'nyi zhurnal. 2011. No. 3(21). pp. 47-52.

[26] Petrov K.V., Zolotareva E.A., Volodin V.V., Vatin N.I., Zhmarin E.N. Reconstruction of the roofs of St. Petersburg on the basis of light steel thin-walled structures and an anti-icing system. Inzhenerno-stroitel'nyi zhurnal. 2010. No. 2. S. 59-64.

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