Energy-efficient installation of windows in multi-storey residential buildings

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Abstract. In this work we analyze existing technologies of installing window blocks in the zone of insulator of external walls, which are used when building multi-storey residential buildings in mass constructions. The comparison was made on a number of parameters (providing normative sanitary and hygienic parameters during operation, the possibility of carrying out work from inside the room, etc.). On the basis of the analysis, a remote installation system of window units in the insulation zone is proposed, which allows year-round performance of glazing of multi-storey residential buildings with external walls with mineral wool or basalt insulation. To substantiate the possibility of using the system in climatic regions with low outdoor temperatures during winter operation, a laboratory experiment was set up. A model of an external wall with a mounted window unit was assembled for the experiment. During the experiment, the actual work of the proposed system for installing window units was simulated in negative outdoor temperatures (-20 °C). The experiment showed that the proposed technical solution of the system meets the requirements of the current regulatory documents on sanitary and hygienic parameters of premises. Studied technical solution for installing window blocks in the insulation zone of external walls is proposed to be used for glazing typical multi-storey buildings in mass constructions as well as in high-rise buildings with increased requirements of thermal protection in external enclosing structures. A plan is proposed to study the system further. It is planned to develop a method for statistical calculation of structural elements of the system components for the effect of operational loads (wind pressure, the own weight of the window unit, etc.), to optimize the technology for various structural variants of the external walls.

1. Introduction

Modern trends in the architecture and construction of multi-storey residential buildings are associated with an increase in the proportion of the usage of translucent external enclosing in buildings and the usage of large-format window blocks, even in mass building sites. It is generally known that the share of translucent structures accounts for the majority of the heat loss through the external enclosing of the building [1-7].

At present, due to the increasement of regulatory requirements of indicators of thermal protection in mass construction buildings, both modern types of translucent structures with increased heat engineering characteristics and new technologies for their installation are being introduced. At some mass residential development sites, the technologies of installing window blocks in the zone of insulation of the external wall were introduced. From the point of view of thermal physics, this
arrangement of the window unit in the wall is the most optimal, since it ensures the minimal heat loss in the zone of the construction weld of the window [8-10]. However, the wide usage of this installation technology is constrained, first of all, by their relative complexity and increased cost in comparison with the traditional technology of installing window blocks in the load-bearing layer of external walls.

2. Analysis of existing technologies for installing window blocks in the insulation zone of external walls used in multi-storey residential buildings of mass construction

Currently, as a rule, one of the following options is used for installing window units in the insulation zone of external walls in mass residential buildings:

- With the usage of an additional mounting frame made of wood or metal profile (figure 1, 2);
- Using remote metal brackets (figure 3).

![Figure 1](image1.png)  
**Figure 1.** An example of a technical solution for the installation of the upper and lateral junction of the window unit in the insulation zone of external walls (option where a wooden mounting frame is used)

![Figure 2](image2.png)  
**Figure 2.** An example of a technical solution for the arrangement of the upper and side connection of the window unit in the insulation zone of external walls (option where metal mounting frame is used)

![Figure 3](image3.png)  
**Figure 3.** An example of a technical solution for the installation of an upper and side junction of a window unit in the insulation zone of external walls (option where remote metal brackets and mounting plates are used)

Each of the presented mounting options has its advantages and disadvantages.

Application of the installation technology of window units using additional mounting frames made of wood or metal in the construction of multi-storey residential buildings requires the installation of scaffolds or the usage of mounting platforms. Mounting frames mounted in the insulation zone of 
external walls require protection from corrosion / rotting, as in the cold season they are in the most unfavorable conditions - zero-temperature areas.

At the same time, using this approach to install window blocks in the insulation zone, makes it possible to use traditional technologies for sealing joints and fixing the window blocks used in the installation of window blocks in the bearing layer of walls.

The advantage of the option of using of remote brackets is the possibility of installing windows from inside of the room without any preliminary preparations of opening the external walls. The disadvantage of this technology is the difficulty in carrying out high-quality sealing of the window joints due to the lack of adhesion of the mineral wool insulation to the mounting foam and sealing tapes (or sealants).

This problem can be solved by using an additional layer of extruded polystyrene, which is installed in the insulation area before installing window units. However, this event can only be carried out on insulated external walls. The usage of this installation technology also requires additional measures to install support brackets in the same plane to compensate for inaccuracies in the device for opening the external walls of the building (figure 4).

As a rule, only lower support brackets are used in order to reduce installation costs. Fastening the window blocks on the sides and the top of the opening is carried out by means of standard mounting plates. However, this solution does not guarantee the immovability of the window frame under the influence of operational loads (wind pressure, opening and closing of the doors) and does not meet the requirements [7-9].

![Figure 4](image)

Figure 4. An example of the installation of window units in the insulation zone using remote brackets

3. Description of the modernized technology of installing windows in the area of outer wall insulation using remote brackets

To perform the installation of window units in the insulation zone of external walls, it is proposed to use a mounting system based on metal brackets with which the mounted window unit is fixed along the perimeter to the load-bearing layer of the wall. This installation system consists of support and side brackets, which allows us to adjust the position of the window unit when opening both in horizontal and vertical position. With the use of this installation system it is possible to fix the window unit
according to the requirements [7-9]. To seal the seams, it is suggested to use sealing tapes. The diagram of the device of the assembly seam is presented on the figure 5. The proposed system allows the installation of window units both before and after the work on the insulation zone of external walls.

![Diagram of the device of the assembly seam](image)

**Figure 5.** An example of a technical solution for the installation of an upper and side junction of the window unit in the area of the outer wall insulation (option using remote metal brackets)

4. Thermotechnical analysis of considered technologies of installing window blocks in the insulation zone of external walls

According to [8-10], the criterion for the accuracy of the technical solution of the junction of the window units in the openings of external walls is, to provide a temperature not lower than the dew point for a given outside air temperature on the inner surface of window openings.

In order to determine the accuracy of implementation of junction points of the window blocks presented in pictures 1,2,3 and 5, their temperature regime was simulating in a specialized program complex for calculating two-dimensional temperature fields Flixo 6.

We used the following initial data: the outdoor air temperature $T_e = -20^\circ C$; the temperature of the internal air $T_i = +20^\circ C$. The coefficients of thermal conductivity of the materials of the external wall were assumed to be the same for each unit (mineral wool $\lambda_m = 0.035 \text{ W/(m} \cdot \text{C})$; aerated concrete block $\lambda_c = 0.2 \text{ W/(m} \cdot \text{C})$; masonry $\lambda_e = 0.7 \text{ W/(m} \cdot \text{C})$). The results of calculations are presented in figures 6a)-6d). Calculations showed that, under given conditions ($T_e = -20^\circ C$ and $T_i = +20^\circ C$) solutions for installing window units using metal frames and remote brackets do not ensure the fulfillment of requirements [8-10]. When using the installation system proposed in clause 3, these requirements are met.

5. Laboratory experiment to investigate the temperature conditions of a window unit mounted in the insulation zone of external walls

A laboratory experiment was set up to investigate the temperature regime of the junction of the window unit mounted in the insulation zone in the testing laboratory of translucent structures and facade systems in NRU MGSU.

For the experiment, the model of the external wall with an installed PVC window block was assembled. The model of the external wall was a frame assembled from sheets of plywood, and was insulated on one side with mineral wool insulation with a thickness of 100 mm. The installation of the window unit and the installation of the mounting joint were carried out according to figure. 5, taking the requirements into account [11-13]. A wall model with an installed window unit was mounted on a multifunctional test bench to determine the operational characteristics of translucent and facade structures. The general view of the stand with the installed model of the outer wall is shown in figure 7.

To control the temperature conditions of junction points of the window unit, contact type temperature sensors were installed according to scheme 8. The measurements were recorded using the multifunctional reader complex ITP-MG 4.03. Studying the temperature regime of the junction of the window unit at the outside temperature (inside the test chamber) $T_{el} = -20-21^\circ C$, and the internal air temperature $T_{il} = +20+22^\circ C$ (laboratory room).
Figure 6. Temperature fields of the lateral and lower nodes of the contiguity of window blocks

a) using a wooden mounting frame; b) using a metal mounting frame; c) using metal support brackets and mounting plates; d) using remote brackets located along the entire perimeter of the window opening
Figure 7. General view of the stand with the installed test sample

Figure 8. Layout of temperature sensors on the inner and outer surfaces of the window opening

6. Analysis of the results
Laboratory studies showed that under the experimental conditions specified in point 5, the temperature of the inner surface of the window opening was not less than $18 \ ^\circ C$ (figure 9).
that meets the requirements [12-14]. These requirements (surface temperature not lower than the dew point) were also observed on the surface of metal brackets.

![Graph of temperatures distribution during the experiment](image1)

**Figure 9.** Graph of temperatures distribution during the experiment

Thermal imaging of the wall during the tests confirmed the obtained data (figure 10). The results obtained in the course of computer simulating and laboratory experiments allow us to say that the proposed system for installing window blocks in the insulation zone of external walls can be used for almost any exterior wall construction and window slope finishing options.

![Thermograms of thermal imaging of the test sample](image2)

**Figure 10.** Thermograms of thermal imaging of the test sample

7. **Discussion**

The studies carried out in the article certainly do not take into consideration all the factors that must be taken into account in the design of installation systems for window blocks in the insulation zone of external walls. The proposed version of sealing joints is not the only one. In the future, it is planned to develop solutions for the installation of seams using sealants, as well as multifunctional mounting tapes. It is planned to develop solutions and conduct similar thermal engineering studies for various design variants of external walls (ventilated facade, plaster facade with insulation from extruded polystyrene foam, etc.). It is planned to develop a method for statistical calculation of structural
elements of the system (brackets, anchor elements) for the effect of operational loads (wind pressure, the own weight of the window unit, etc.) to justify the possibility of its use in high-rise buildings.

8. Conclusions
An analysis of existing technologies for installing window blocks in the insulation zone of external walls used in the construction of multi-storey residential buildings in mass constructions was done. Their advantages and disadvantages were determined, as well as conducting a computer simulation of the temperature regime of the junction points of window units for each installation technology. The technology of installation of window blocks in external walls was offered, which allows to make installation of window blocks and closing of the external contour of a building before the work on the insulation of external walls. These technical solutions can be used for exterior walls with mineral wool or basalt insulation. Computer simulations and a laboratory experiment were performed to determine the actual operation of the proposed system at negative outdoor temperatures (-20 °C). Studies have shown that the proposed solution for the assembly of junctions of window units meet the requirements of the current regulatory documents for the provision of thermal protection of buildings. The proposed technical solution for the installation of window units in the insulation zone of external walls can be recommended for usage in multi-storey residential buildings of mass construction, as well as in high-rise buildings with increased requirements for thermal protection of external enclosing structures.

References
[1] Grynning S, Gustavsen A, Time B and Jelle B P 2013 *Energy and Buildings* 61 185-192
[2] Persson M L, Roos A and Wall M 2006 *Energy and Buildings* 38(3) 181-188
[3] Urbikain M K and Sala JM 2009 *Energy and Buildings* 41 687-695
[4] Gagarin V, Kozlov V 2011 *Vestnik MGSU* 3(1) 192-200
[5] Pacheco R, Ordóñez J and Martínez G 2012 *Renewable and Sustainable Energy Reviews* 16(6) 3559-3573
[6] Vatin N, Nemova D, Rymkevich P and Gorshkov A 2012 *Magazine of Civil Engineering* 8 4-14
[7] Bruno R 2017 *Building and Environment* 126 147-160
[8] Cappelletti F, Andrea Gasparella A, Romagnoni P and Baggio P 2011 *Energy and Buildings* 43 1435-1442
[9] Misiopecki C, Bouquin M, Gustavsen A and Jelle BP 2018 *Energy and Buildings* 158 1079-1086
[10] Sierra F and Gething B, Bai J and Maksoud T 2017*Energy and Buildings* 142 23-30
[11] GOST 30674-99 *Windows of polyvinylchloride profiles. Specifications*
[12] GOST 30791-2012 *Erection to joints of window assemblies adjoined to wall openings. General specifications*
[13] GOST R 56926-2016 *Window and balcony constructions of different functional purpose for residential buildings. General specifications*
[14] SP 50.13330.2012 *Thermal performance of the buildings. The updated edition of SNIP 23-02-2003*