Збірник наукових праць. Галузеве машинобудування, будівництво
Academic journal. Industrial Machine Building, Civil Engineering
http://journals.nupp.edu.ua/znp
https://doi.org/10.26906/znp.2021.56.2507

UDC 692.23:699.86

Improving the technology of replacing window frames in precast concrete walls

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The constructive-technological decision of the junction design of a block frame window to an uninsulated precast concrete wall which practically excludes a possibility of condensate formation on a surface of internal window jamb is proved. The study was performed by constructing two-dimensional temperature fields in nodes of different designs and comparing the lowest temperature on the internal window jamb surface with the dew point temperature. It is established that thermal reliability can be ensured by the condensate formation criterion by insulating the exterior window jamb with mineral wool or expanded polystyrene slabs and local facade insulation in the form of an outside window casing with 50 mm thickness and 200…250 mm width. The block frame window should be installed at a distance of 60… 80 mm from the outer surface of the precast concrete wall.

Keywords: condensate, precast concrete walls, temperature regime, thermal failure, window-wall junction

Удосконалення технології заміни віконних блоків в залізобетонних панельних стінах

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З метою підвищення комфортності житлових будинків другої половини 20-го століття часто здійснюється заміна дерев'яних віконних блоків на сучасні металопластикові конструкції. В зимовий період температура поверхні внутрішнього відкосу поблизу віконної коробки може опускатися нижче точки роси, що призводить до теплової відмови за критерієм утворення конденсату. Для обгрунтування надійного конструктивно-технологічного рішення вузла примикання віконних блоків до неутеплених стін з керамзитобетонних панелей побудовані та проаналізовані двомірні температурні поля у вузлах різної конструкції. Найменша температура на поверхні внутрішнього віконного відкосу порівнювалася з температурою точки роси. Показано, що на температурний режим експлуатації вузла примикання віконного блоку до стіни істотно впливає конструкція вузла та положення вікна в товщі стіни. Утеплення зовнішнього віконного відкосу та зміщення вікна всередину приміщення підвищує температуру критичної зони вузла. На прикладі поширених панельних стін з керамзитобетону товщиною 300 мм показано, що для забезпечення належного температурного режиму експлуатації вузла необхідно виконати утеплення зовнішнього віконного відкосу та локальне фасадне утеплення у вигляді обрамлення віконного прорізу шириною 200 мм або 250 мм. Віконний блок слід відповідно встановлювати на відстані 80 мм чи 60 мм від зовнішньої поверхні стінової панелі. З технологічної точки зору для утеплення краще використовувати плити з пінополістиролу, кріплення яких до стінових панелей та зовнішнє оздоблення є менш трудомістким і дешевшим порівняно з використанням плит з мінеральної вати. Локальне фасадне утеплення навкруги віконних прорізів з товщиною, яка задовольняє вимоги норм до опору теплопередачі стін, у майбутньому може стати частиною повного фасадного утеплення при термомодернізації будівлі.

Ключові слова: конденсат, панельні стіни, примикання вікон, температурний режим, теплова відмова

Introduction

A significant part of the Ukrainian cities' housing stock consists of prefabricated houses built in the second half of the 20th century. One of the main disadvantages of such buildings is the insufficient resistance to heat transfer of enclosing structures. This leads to increased heat loss and can cause discomfort when staying indoors near walls.

An additional problem of prefabricated houses is wooden casement windows. They not only wear out during long operation periods but also do not meet modern requirements for heat loss.

Complete thermal modernization of existing buildings with the installation of facade insulation is a very complex and costly measure. Therefore in practice, quite often they are limited to a half-measure in the form of replacing worn-out block frame windows with modern metal-plastic structures with sufficiently high thermal characteristics. This reduces heat loss to some extent but does not exclude the possibility of condensation on the surface of the internal window jamb.

Review of the research sources and publications

The junction between the window and wall is a zone of increased thermal conductivity. Requirements for thermal characteristics of such junctions and walls, in general, are set in DBN [1], and for European countries are covered in works [2, 3]. The main requirement for thermal reliability is the inadmissibility of condensation due to the temperature drop of the inner wall surface below the dew point temperature.

Studies of the window junctions temperature regime to the walls in the winter were carried out in [4…9], where the impact of the window position in a cavity wall was analyzed. The calculations performed in [4…6] for brick walls showed that a simple replacement of the window with a better one does not solve the condensation problem. The temperature of the internal jamb in the junction area of the block frame window to a wall may fall below the dew point at real values of outside air temperature.

In articles [4...9] it is shown that the temperature of the internal window jamb can be increased due to additional insulation or by shifting the block frame window to the inner side of the building. In [7], the example of several nodes at two positions of block frame window shows that the design of the window junction to the wall significantly affects heat loss, the position of the zero isotherms in the wall, and the possibility of condensation on the inner wall surface. There was an increase in the temperature of the inner wall surface as a result of shifting the block frame window inside the building.

The influence of the window position of the cavity wall on the temperature of the inner surface and the possibility of condensation has been studied in more detail in the works of the authors [4, 5, 6, 8].

In [4] the temperature dependence of the metal-plastic window junction critical zone to the brick wall with a thickness of 510 mm from its position was obtained. It is shown that in the conditions of Kirovograd region window installation close to the outside surface of the wall the temperature of the internal jamb is about +8 °C, and the shifting of the block frame window inside the building significantly increases the temperature at the critical jamb point. The obtained graph makes it possible to establish the position of the block frame window at which the surface temperature of the internal jamb exceeds the dew point temperature and thus avoids the condensate formation.

In the article [8] by a method similar to [4], obtained a nomogram and analytical expression that allows setting the desired position of the block frame window in the cavity of the brick wall depending on the allowable temperature of the inner wall surface in the critical zone (dew point temperature) and outside air temperature.

A detailed analysis of the window junction temperature regime to the wall of different designs was carried out in [5, 6]. In particular, the junctions to the brick and precast concrete wall are shown in Figures 1 and 2, which are taken from [5] with minor editorial changes. The designations of the node elements are given in table 1.

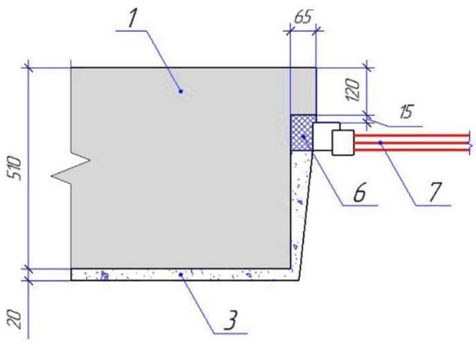

Figure 1 – The junction of the metal-plastic window to the brick wall

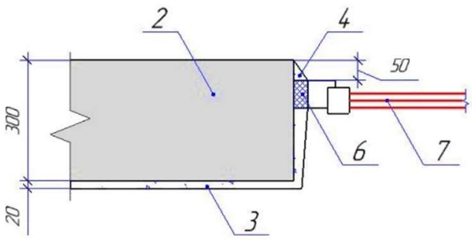

Figure 2 – The junction of the metal-plastic window to the precast concrete wall

Figures 1, 2 show the junctions at the initial design position of the block frame window. When shifting the block frame window inside the brick wall, the space between the outside casing and the window frame is filled with an effective thermal insulation material (mineral wool or polystyrene slabs). The external jamb of the precast concrete wall is made of cement-sand plaster.

The simulation results of these nodes in [5] showed that shifting the block frame window in the cavity of the brick wall inside the room by 150…170 mm from the outside casing allows raising the temperature of the critical zone to the dew point equal to 10.7 °C. In this way, thermal failure by the criterion of condensate formation can be avoided. It is impossible to achieve such an effect in a precast concrete wall. Even with the maximum possible shift of 150 mm from the outer surface of the wall, the temperature of the critical zone on the internal jamb does not rise above 9,2°C. Articles [5, 6] show that this problem is successfully solved with proper facade insulation of brick and precast concrete walls in accordance with the requirements of [1]. Without such insulation, condensation can be formed on the surface of the internal window jamb of the precast concrete wall.

In general, works [4…9] showed that the position of the block frame window in the cavity wall can significantly affect the surface temperature of the internal window jamb and the possibility of condensation in this area.

The study of the temperature regime of enclosing structures operation can be performed using the open-source program THERM [11], which allows to build two-dimensional temperature fields for fragments of structures using the finite element method and obtain temperatures at specified critical points of the nodes.

Definition of unsolved aspects of the problem

The results of previous studies indicate the need for facade insulation to ensure the thermal reliability of the block frame window junction to the brick and precast concrete walls of residential buildings. It is possible to improve the conditions of the operating units of the insulated brick walls, provided that reinforced-plastic windows are installed with a shift inside the building. In the case of precast concrete walls, this solution does not give a positive result. The analyzed works do not contain recommendations for ensuring the thermal reliability of the block frame window junction to the precast concrete wall of residential buildings.

Problem statement

To offer a rational constructive insulation scheme and technology of the metal-plastic window junction to the uninsulated walls of prefabricated houses based on the results of temperature field analysis.

Basic material and results

The subject of the study is the junctions of metal-plastic windows to the uninsulated walls of prefabricated residential buildings. The five types of junctions are compared below:

1) the junction according to the scheme of Figure 2 at different shift values of the window inside the building;
2) the junction according to the scheme of Figure 3 with insulation of the outer jamb;
3) the junction from Figure 4 with insulation of the external jamb and local insulation of the facade in the form of an outside window casing with a width of 150 mm;
4) the same with the casing width of 200 mm;
5) the same with the casing width of 250 mm.

Insulation of the exterior window jamb and local facade insulation in the form of the outside window casing is performed by slabs made of expanded polystyrene or mineral wool, which according to [13] have sufficiently close thermal conductivity coefficients. From the technological point of view, it is more profitable to use expanded polystyrene plates which are much cheaper and can be pasted to a surface of the expanded clay precast concrete wall without the performance of labor-consuming operations on the attachment of a mineral wool plate by dowels. The use of expanded polystyrene in the form of local insulation is also permissible from the point of view of fire safety, as such a scheme of insulation does not allow the fire to spread on the surface of the facade. Constructions of window junctions to the walls are performed in accordance with the requirements of the current standard [12].

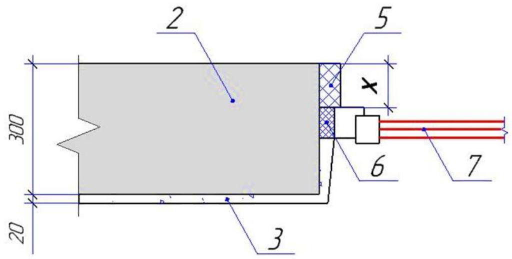

Figure 3 – The junction of a metal-plastic window to a precast concrete wall with external jamb insulation

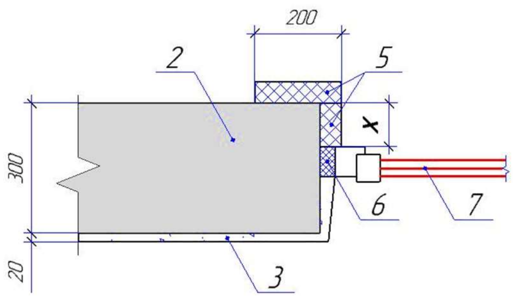

Figure 4 – The junction of a metal-plastic window to a precast concrete wall with additional local insulation of a facade

When modeling temperature fields, the values of density ρ and thermal conductivity λ of materials are taken into account, as shown in Table 1. To simulate a metal-plastic block frame window the reduced value of thermal conductivity, which is shown in table 1 is used in the program THERM [11].

The outside air temperature according to [14, 15] is assumed to be equal –24°C. For the Kirovograd region and most of the central regions of Ukraine, this value with a certain margin corresponds to the temperature of the coldest five days with a reliability level of 0.92…0.95, which is used for the design of massive walls.

At the design indoor air temperature of +20°C and relative humidity of 55%, as indicated in the standard [1] for residential premises, the dew point temperature value of +10,7°C is set according to psychrometric tables.

Table 1 – Thermal characteristics of materials

	Materials and products	ρ, kg/m^3	λ, W/(m^2·K)
1	Brickwork	1800	0,81
2	Expanded clay concrete slab	1000	0,41
3	Lime plaster	1600	0,81
4	Cement plaster	1800	0,93
5	Effective insulation	135	0,039
6	Construction foam	25	0,03
7	Block frame window	30	0,037

Simulation of the described junctions is performed in the environment of the THERM program. Junctions of types 1 and 2 are calculated at five positions of the block frame window in the cavity of the wall, which is given by the distance X from the outer edge of the wall to the outer surface of the window frame. The smallest distance X = 25 mm corresponds to the maximum possible approach of the window to the outer surface of the wall. The biggest distance X = 125 mm, taking into account the thickness of a window frame of 70 mm corresponds to the position of a window near the middle of a 300 mm wall. A further shift of the window inside the building reduces the width of the window sill too much and worsens the conditions of natural lighting. Junctions of types 3, 4, and 5 are calculated at six positions of the block frame window in a cavity of the wall. The position at a distance of X = 0 mm corresponds to the absence of an external jamb. At the same time, the joint of the block frame window with a wall is covered by local front insulation in the form of an outside window casing.

As a result of the performed calculations, the temperature fields and temperature values in the critical zone of the nodes were obtained. In all nodes, the critical zone with the minimum temperature of an internal surface of a wall is placed on a surface of an internal window jamb near a window frame. Figure 5 shows examples of temperature fields of types nodes 1, 2, and 4 with a shift of the window frame inside the building by 100 mm. The figure shows that the insulation of the exterior jamb and additional local facade insulation significantly changes the position of the isotherms in the wall thickness and increase the surface temperature of the internal window jamb. As the insulation improves, the temperature of the critical point, given in a separate window on the temperature field figures, also increases. For junctions of types 1 and 2, it is lower than the dew point temperature, which indicates the possibility of condensation. In the type 4 junction, the temperature of the critical point +11,1°C exceeds the dew point. This indicates a low probability of condensation on the surface of the internal window jamb.

The results of critical zone temperature calculations of all types of junctions at the considered positions of the block frame window are presented in table 2. Changes in these temperatures when the window frame is shifted inside the cavity of the wall are shown in Figure 6, which is made according to table 2.

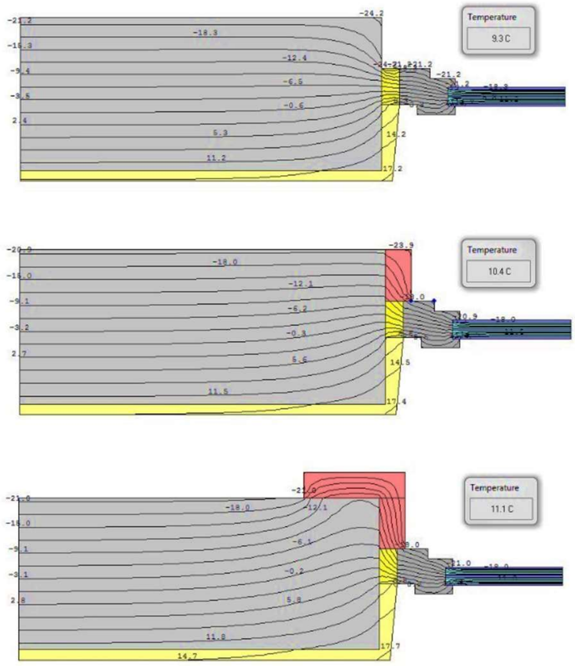

Figure 5 – Temperature fields of type 1, 2, and 4 junctions

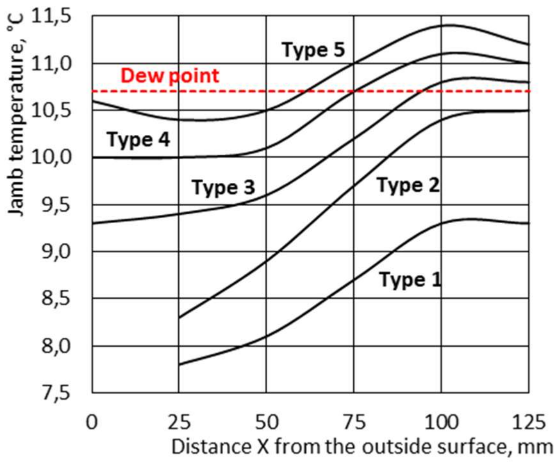

Figure 6 – Temperatures in the critical zone of the window junctions to the precast concrete wall with different schemes of additional insulation and different positions of the window frame

Table 2 – Temperatures at critical points of the junctions

X, mm	Temperatures in junctions of different types				
	1	2	3	4	5
0			9,3	10	10,6
25	7,8	8,3	9,4	10	10,4
50	8,1	8,9	9,6	10,1	10,5
75	8,7	9,7	10,2	10,7	11,0
100	9,3	10,4	10,8	11,1	11,4
125	9,3	10,5	10,8	11,00	11,2

Analysis of table 2 and figure 6 showed that the type of junction and the position of the block frame window in the wall cavity significantly affect the temperature of the internal window jamb. The conclusion about the possibility of condensation can be made by comparison with the temperature of the dew point, which is equal to +10,7°C and is shown in Figure 6 by a horizontal line.

The figure shows that the junctions of types 1 and 2 do not have a sufficient level of thermal reliability at any position of the window frame. Additional local insulation of the facade in the form of a window casing significantly increases the level of unit thermal reliability. The formation of condensate on the surface of the internal jamb becomes unlikely when shifting the window frame by about 90 mm for node type 5 and by 60 mm for node type 3.

Conclusions

1. Replacement of block frame windows with modern metal-plastic structures is often implemented in the practice of residential buildings renovation that was built in the second half of the 20th century. It does not solve the problem of energy efficiency, but to some extent increases the comfort of living in these houses.

2. The critical area with the lowest temperature of block frame windows junctions to the expanded clay precast concrete walls is the surface of the internal jamb near the window frame. When the temperature drops below the dew point temperature in this zone, thermal failure can be realized in the form of condensate formed on the jamb surface.

3. The operation temperature mode of the block frame window junction to the wall is influenced by the design of the junction and the position of the window in the cavity wall. Insulation of the external window jamb and shift of the window into the room increases the temperature of the critical area of the node.

4. In block frame window junctions to expanded clay precast concrete walls with a thickness of 300 mm without insulation of an external jamb the temperature of a critical zone does not rise above +9,3°C regardless of the window frame position. The temperature, less than the dew point +10,7°C causes the possibility of condensation.

5. In units with external jamb insulation the temperature of the critical zone can reach +10,5°C, i.e. also does not exceed the dew point and can cause condensation on the surface of the internal window jamb.

6. To ensure the proper temperature of the unit, it is necessary to perform insulation of the exterior window jamb and local insulation of the facade in the form of an outside window casing. When the width of such a frame is 150…250 mm, the corresponding shift of the block frame window inside the room by 90…60 mm increases the temperature of the inner surface of the window jamb above the dew point temperature.

7. For practical use in precast concrete walls with a thickness of 300 mm, we can recommend the design of the unit with insulation of the exterior window jamb and local insulation of the facade in the form of outside window casing with a width of 200 mm or 250 mm. The window frame should be installed at a distance of 80 mm or 60 mm from the outer surface of the wall (according to the selected width of the frame). It is better to use plates from expanded polystyrene as insulation. Attaching them to the wall and exterior decoration is less time-consuming and cheaper compared to the use of mineral wool slabs.

8. Local insulation of the facade around the outside window casing should be arranged with a thickness that meets the requirements of thermal insulation on the resistance to heat transfer of external walls according to DBN B.2.6-31: 2006. In this case, the executed local insulation will become a part of the front insulation of the building in the course of full thermal modernization in the future.

9. Further research is focused on the probabilistic assessment of thermal reliability of the block frame window junctions to the walls and other problematic units of buildings, taking into account the random nature of the influencing factors.

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