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Assessment of the Negative Temperatures Influence on the PVC Windows Air Permeability

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Abstract. The analysis of negative temperatures influence on air permeability of modern PVC windows was made. For this purpose, complex tests of several types of PVC windows with different profile thicknesses were performed in the laboratory. The determination of the windows air permeability was made under standard conditions (+20 °C) and negative outside temperatures (-5°C, -15°C, -25°C, -35°C, -45°C). For the windows air permeability determination at negative outdoor temperatures was created the special test stand. It was found that at negative temperatures there is a significant decrease in the windows air permeability is observed. However, this process occurs differently for PVC windows with different profiles thickness, this process also depends on the outdoor temperature. The research results are proposed to be used to calculate the buildings heat balance. This will increase the calculations accuracy, since this will use the windows air permeability data, determined not under standard conditions (as it is now), but under real winter conditions. The further research directions of the issue are given.

1. Introduction

Nowadays, modern PVC windows are widely used in mass civil building [1]. One of the reasons for the wide PVC windows distribution is their high thermal performances. In addition, they have low air permeability [2]. Air permeability is one of the key windows performance characteristics and characterizes their tightness. It affects both the building heat loss in the winter caused by the cold air infiltration into the rooms, and also has an impact on the provision of the necessary temperature and humidity conditions and air exchange in the rooms [3-6]. Therefore, air permeability determines the windows operation as enclosing elements of the building, primarily in winter.

It is obvious that at justification of the necessary windows constructive decision operated in climatic conditions with low winter temperatures in calculations it is necessary to use their air permeability at negative temperatures. This will allow calculations taking into account real physical model of windows work at negative temperatures of external air and, respectively, will increase the design solutions quality in terms of energy efficiency and thermal protection of buildings [7-9]. However, in the existing design practice, the windows air permeability under standard conditions (i.e. at + 20 ° C) is included in the calculations. This is due to the fact that according to current standards, the windows air permeability determination in laboratory conditions have to do at room temperature.

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But the introduction into practice of laboratory methods for windows air permeability determining at negative outdoor temperatures is associated with significant technical difficulties in making the stand in terms of creating an air overpressure in the test stand with a given negative temperature.

Despite this, on the windows air permeability issue at low outside temperatures have already done some research. All studies have shown that at low outside temperatures there is a significant reduction in the windows air permeability. This is due to the temperature deformations of the windows profile elements (mullions, casements caused by the temperature difference of the external and internal air, as well as with the sealing gaskets elasticity reducing [10-15]. However, all of the researches are made for a limited window sizes number (thickness profiles), which does not allow to assess the impact of negative temperatures on the windows air permeability with different thickness profiles. Some researchers have attempted to determine the windows air permeability on standard test stands but retrofitted with air conditioning systems [16]. But the design features of such stands allow only cooling the test window to the required temperature, but do not allow to determine its air permeability at a controlled negative temperature (due to the fact that the pressure drop is created by forcing warm air from the laboratory room). During the tests, the cold air in the working chamber is mixed with the warm air from the room. This leads to the fact that the air temperature in the working chamber directly during the tests does not meet the specified conditions. Since the air density and its kinematic viscosity largely depends on its temperature, it becomes obvious that the approach proposed in the above work is not correct.

In the framework of this work, the authors aim to determine the air permeability of modern PVC windows at negative outdoor temperatures but taking into account the adjustment of research methods in the above works. Therefore, research will do for several windows types with different thickness profiles. To determine the windows air permeability at negative outdoor temperatures a special test stand will be made.

2. Description of the research methodology

Determination of the PVC windows air permeability at negative outdoor temperatures was made on the basis of the Research Center "Facades SPK" NIISF RAACS (Moscow).

Three PVC windows with different profile thicknesses (58 mm, 70 mm, 82 mm) were selected for testing (see figure 1). The window with the profiles thickness of 58 and 70 mm had two sealing contours, and the window with the profiles thickness of 82 mm – three sealing contours. The overall dimensions of all the windows were HxW = 1.40 x 1.20 m. A vertical mullion was installed in the middle of the windows. Each window had one casement and a fixed light. Insulating glass units were installed in all windows. The window profiles color was white.

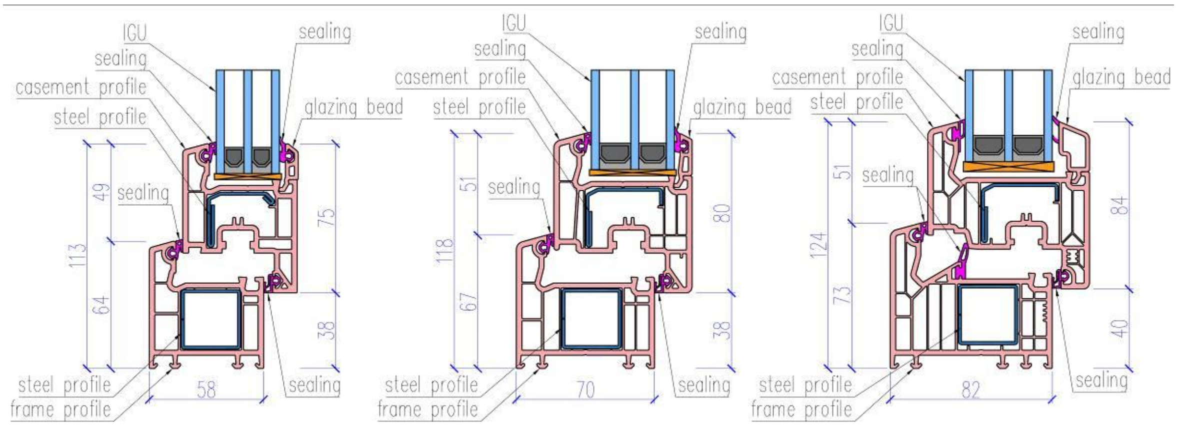

Figure 1. Cross-section of the profiles combination "frame + casement" of the tested windows.

The research was done in laboratory conditions in a specially climatic chamber. Climate chamber had two compartments – cold and warm. Between the compartments was installed thermally insulated

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partition. In this partition was made an opening for the window installation. The window installing were done taking into account existing standards. In the cold compartment was installed a climate system for air cooling. Each window was tested at the following temperatures in the cold chamber: +20 ° C, -5 ° C, -15 ° C, -25 ° C, -35 ° C and -45 ° C. In the warm compartment was also installed climate system to maintain a constant air temperature of +20 ° C.

The determination of the PVC windows air permeability at negative air temperatures in the cold compartment was carried out only after the stationary temperature conditions were reached in the climate chamber and the stress-strain state of the window profiles was stabilized. To do this, air temperature sensors were installed in each chamber compartment, and contact-type temperature sensors as well as heat flux sensors were installed on the inner and outer window profiles surfaces and insulating glass units. To determine the window profile elements deformations the linear displacement sensors were used. The determination of windows air permeability was carried out by means of the additional stand with the fan mounted from the warm compartment and pumping out air from this compartment. A volume flow sensor was installed in the cold compartment of the test stand. The schematic schema of the test stand is shown in figure 2. The general view of the test stand from with the installed PVC window and measuring equipment is shown in figure 3.

The air permeability of windows was determined for each of the specified negative temperatures. For this purpose, the negative pressure of -50 Pa, -100 Pa, -150 Pa and -200 Pa was created in steps in the warm compartment of the chamber. Such a test scheme allowed us to create the most unfavorable for the window deformed state, in which the deformations due to temperature and air pressure differences occur in one direction.

In addition, immediately after installation of the test window in the stand, the window air permeability was determined at a temperature in the cold compartment of + 20 ° C.

The window air permeability was determined as the difference between the actual air permeability of the “window + stand” system and the air permeability of the test stand. The air permeability of the test stand at the indicated pressure differences was determined at the air temperature in the cold compartment +20 ° C immediately after the installation of the test window. To do this, the opening with the window was sealed using a polyethylene film.

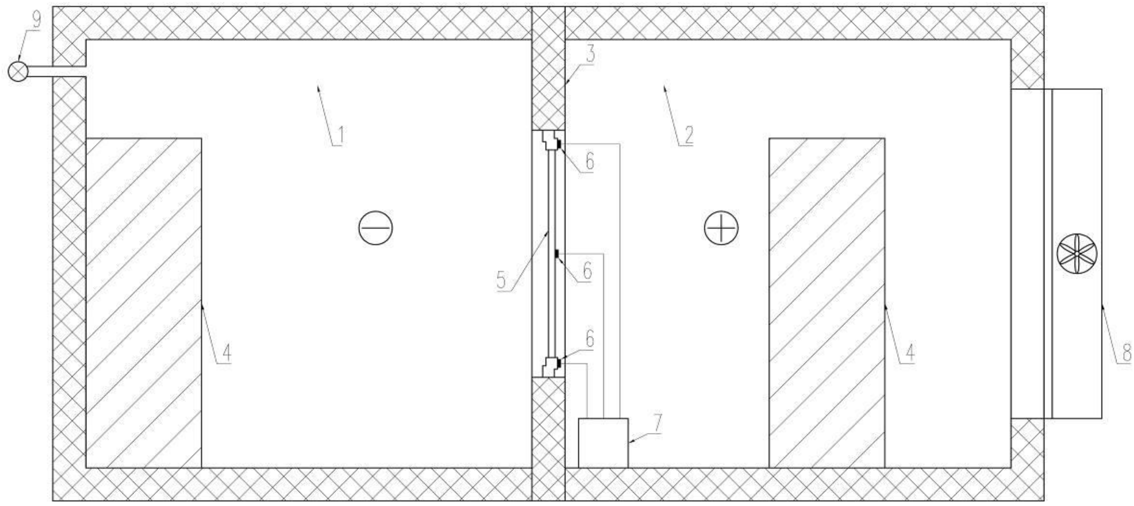

Figure 2. Scheme of the test stand to determine the windows air permeability at negative outside temperatures. 1 – cold compartment; 2 – warm compartment; 3 – insulated partition; 4 – climate system with air temperature control; 5 – test window; 6 – temperature and heat flux sensors; 7 – work station; 8 – additional stand with fan for air pumping; 9 – volume flow sensor.

(a) (b)

Figure 3. General view of the test stand with the installed window and measuring equipment (a) and the view of the additional stand with fan for air pumping (b).

3. Experimental results

The results of determining the PVC windows air permeability of at low temperatures are presented in Figure 4.

On the basis of the conducted laboratory researches the following is established:

1. The windows air permeability, determined at a pressure differential of 50-200 Pa and negative outside temperatures of not less than 1.9 times greater than the air permeability determined under standard test conditions (+20 °C).

2. The PVC windows air permeability increases with decreasing outdoor temperature. At the same time, the windows with a thickness of profiles 70 and 82 mm at low outside temperatures (-35 °C and below) there was a decrease in air permeability in the pressure range of 100-200 Pa.

3. At low temperatures of outdoor air (-35 ° C and below), the windows air permeability with the differential pressure of 50 Pa exceeds the standard value and does not correspond to the highest class of air permeability.

4. The greater is the thickness of the profile elements, the more the window air permeability depends on the difference in operating temperatures. This is due to the fact that thicker PVC profiles are more susceptible to temperature deformation, as their cross-section has a more pronounced asymmetry with respect to the reinforcing steel profile (see figure 1).

4. Discussion

The research made the assessment of the PVC windows air permeability at negative outdoor temperatures for a limited range of pressure differential (50-200 Pa). In the future we plan to do similar works in the entire normalized pressure range (50-600 Pa). However, this will require additional measures to increase the stand tightness.

At the same time, according to the authors, the results obtained in this work can be used to estimate the infiltration heat losses value of buildings that use PVC windows. This will increase the calculations accuracy, because the calculation model will take into account the real physical model of PVC windows in the winter conditions.

The research have shown that at low outdoor temperatures (-35 ° C and below) there is a decrease in the PVC windows air permeability. This phenomenon can be caused by the following reasons:

- increasing the rigidity of PVC window profiles due to the fact that the temperature decreases the elastic modulus of PVC increases [17];
- increasing the density and kinematic viscosity of air with decreasing temperature.

Obviously, this issue requires further research.

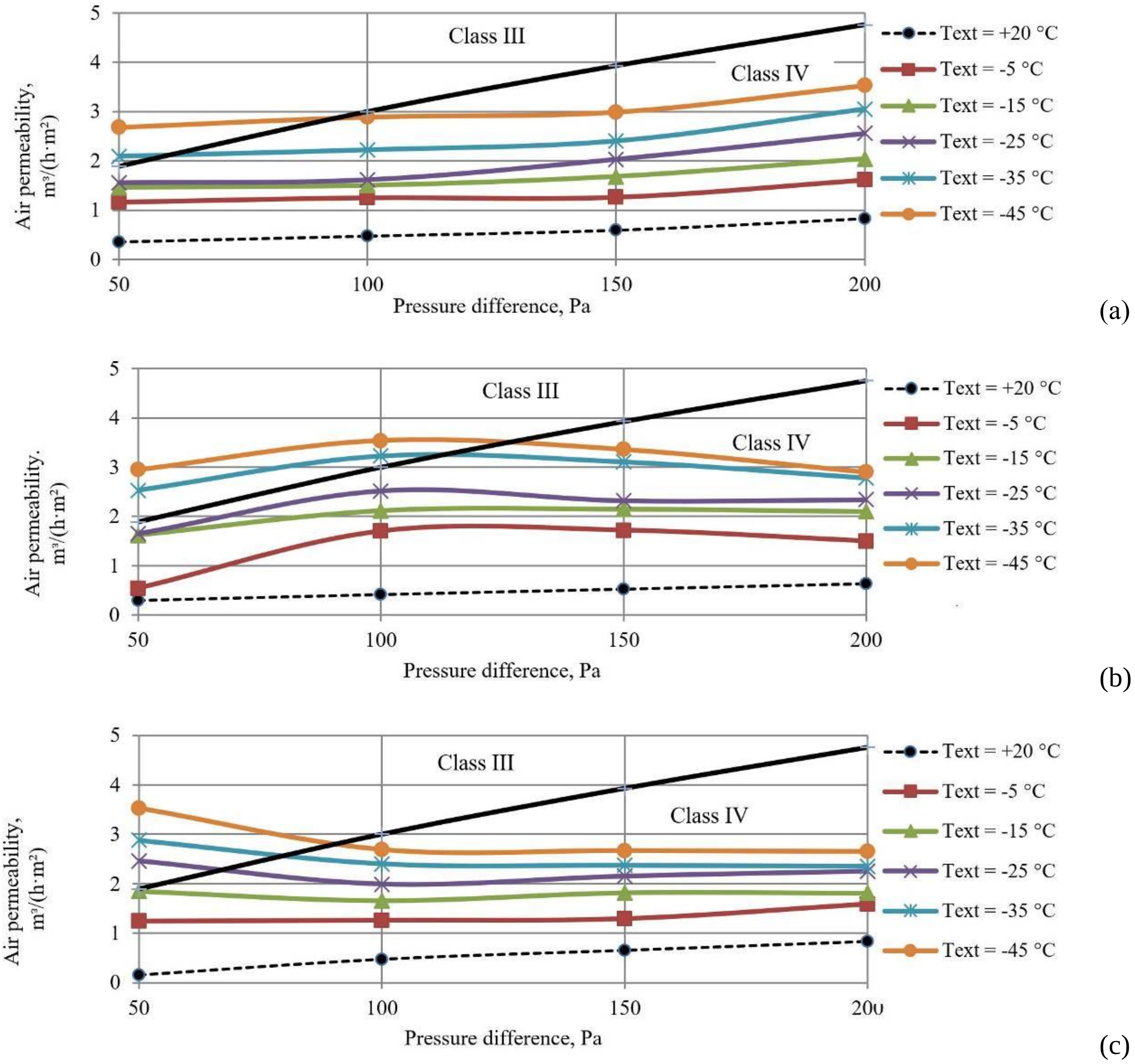

Figure 4. The results of determining the PVC windows air permeability at different outdoor temperatures and pressure drops. (a) for the window with a profile thickness of 58 mm; (b) for the window with a profile thickness of 70 mm; (c) for the window with a profile thickness of 82 mm.

5. Conclusions

The research has shown the following results:

1. The air permeability of PVC windows is not constant and increases with decreasing outdoor temperature. However, at low temperatures of outside air (-35 ° C and below), the reverse process is observed, i.e. a reduced air permeability. This phenomenon is manifested in PVC windows with a large thickness of the profile elements (70mm and more).

2. Air permeability of PVC windows at negative temperatures depends on the design solution of its profile elements. Modern PVC windows with a large profile elements thickness are subject to significant temperature deformations under the influence of operating temperature difference between the outside and inside air due to the significant asymmetry of the profiles relative to their steel reinforcing elements.

3. For climatic regions with negative temperatures in winter in the appointment of a constructive solution of PVC windows have to use data on their air permeability at the calculated winter outdoor temperature, and not under standard laboratory conditions (+20 °C). Only in this case the data on PVC windows air permeability laid in calculations will correspond to their real work during the winter operation period.

4. The current practice have to introduce laboratory methods for determining the windows air permeability at negative outdoor temperatures. However, at the moment this is due to a number of technical difficulties with the technical arrangement of new stands (or completion of existing test stands) to create in their test chamber the air overpressure with the given negative temperature.

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