# Criteria for climatic applicability of modern window types

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**Abstract.** Currently, the assignment of the required values of the technical and operational windows characteristics (such as resistance to heat transfer, air permeability, sound insulation, etc.) is carried out based on the technological capabilities of the window industry, and not on the basis of scientifically substantiated requirements for ensuring the microclimate and energy buildings efficiency in the design practice of most countries (as it happens in the case of external walls which are in almost identical operating conditions with windows, for example). One of the most common types of windows in modern construction practice are single windows with insulated glass units and profiles made of PVC and aluminum alloys. They were originally developed for operation in Western Europe where they have proven themselves well over many years of operation. However, their widespread use in the climatic conditions of the Russian Federation and the countries of Eastern Europe showed a number of problems during operation which is expressed in a decrease in the technical and operational characteristics of windows due to temperature deformations of their profile elements. This circumstance testifies to the limited area of application of these structures in terms of climatic conditions. The authors of the work introduce the concept of "climatic applicability of windows" in order to determine the rational application areas of types of windows which would ensure the fulfillment of the specified requirements for the comfort of the microclimate of the premises in any operation period of the building. Based on the results of the analysis of the work of third-party researchers and the authors own works the authors have determined a set of criteria for the climatic applicability of modern types of windows based on winter operating conditions. Promising areas for further research were considered.

## 1 Introduction

A distinctive feature of windows in comparison with other types of external enclosing structures is the relatively small variability of their design solutions that are used in construction. A limited number of types of windows are used in mass construction in each individual country or region. At the same time, the average statistical capabilities of the

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window industry in most cases determine the regulatory requirements for windows laid down in national design standards. The use of such an approach to the standardization of the technical and operational characteristics of windows is a global trend, although it is not based on scientifically substantiated requirements for windows as building envelopes.

In modern mass construction on the territory of the Russian Federation and most European countries, single-frame windows windows with insulated glass units and profile elements made of PVC and aluminum alloys are widely used [1] (see Figure 1).

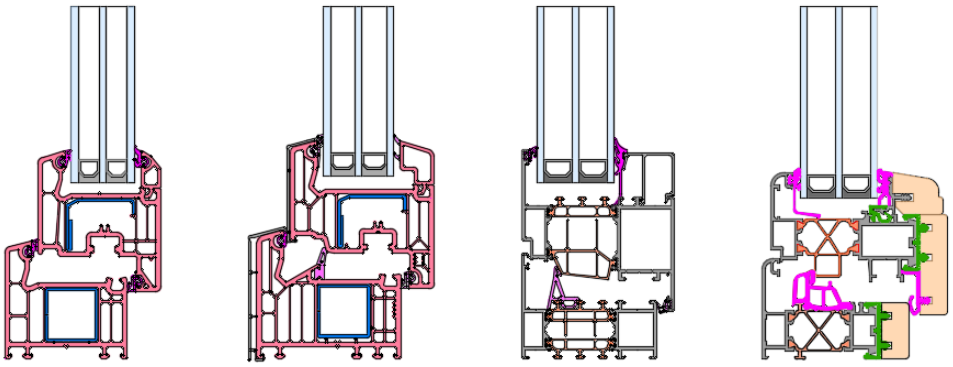


**Fig. 1.** Some types of single windows used in mass civil engineering. a, b - with PVC profiles; c, d - with profiles of aluminium alloys

These windows are presented on the market by a large number of manufacturers. The schematic diagram of the device of the windows types under consideration for all manufacturers is unchanged and the main difference lies in the constructive solution of the profile elements. There are several types of windows that differ in the material and width of their profile elements within the product line of each manufacturer. Moreover, as a rule the wider the profile the higher their technical and operational characteristics. In practice, if it is necessary to increase any technical and operational window characteristics (for example, resistance to heat transfer), profiles with a larger width are used.

The types of window structures discussed above have been used in Western Europe since the mid-50s of the last century [2]. In the Russian Federation and in the countries of the former USSR the considered window types began to be massively used only from the mid-1990s - early 2000s. It should be noted that these window types were originally developed for use in the climatic conditions of Western Europe which are quite mild compared to the climatic conditions of the Russian Federation and Eastern Europe. It is also important that for the legitimate use possibility of these structures in the territory of these countries, methods for determining (calculated and experimental) the actual values of the technical and operational characteristics of windows were borrowed and approved at the level of national standards. They are almost identical to the european standard methods and are carried out according to the same methods that do not take into account the operation climatic conditions [3,4]. The accumulated experience of using these windows in the climatic conditions of the Russian Federation and some other countries shows that a number of typical problems are observed during their operation. It is revealed that even with the formal provision of all mandatory design requirements for the design windows solution according to the current standards often they are not able to meet the mandatory requirements for providing thermal protection, ensuring their tightness [5-10], in some cases, even the destruction of the windows components (insulated glass units, profiles) is observed [11]. Moreover, this situation is observed for both winter and summer operating

conditions. Based on this, we can say that the currently used approaches to determining the technical and operational windows characteristics are not universal. It can also be said that modern windows types that have proven themselves well in operation in the climatic conditions of Europe (see Figure 1) cannot be considered the optimal solution for each individual climatic region. At the same time, it is possible to identify their rational applications by examining these windows types and determining the nature of changes in their technical and operational characteristics in different climatic conditions of operation. The implementation of these works will also allow us to begin to operate in the windows design with such a concept as "climatic applicability of windows" which will allow us to give a comprehensive idea of the actual technical and operational windows characteristics for a definite climatic region of construction. The purpose of this work is to substantiate the criteria for the climatic applicability of modern window types based on winter operating conditions and to develop promising areas for further research for the introduction of the concept of "climatic applicability of windows" ("range of climatic applicability») in the existing practice of their design.

It should be noted that such a concept was already used in practice in the USSR. It was applied not only to windows, but also to various types of other products (for example, electronics, appliances, etc.). At the same time, in the case of windows the only factor that was used to classify windows according to climatic applicability was the operational temperature difference between indoor and outdoor air during the winter period of operation which is characteristic of a given construction region [12] (see Figure 2).

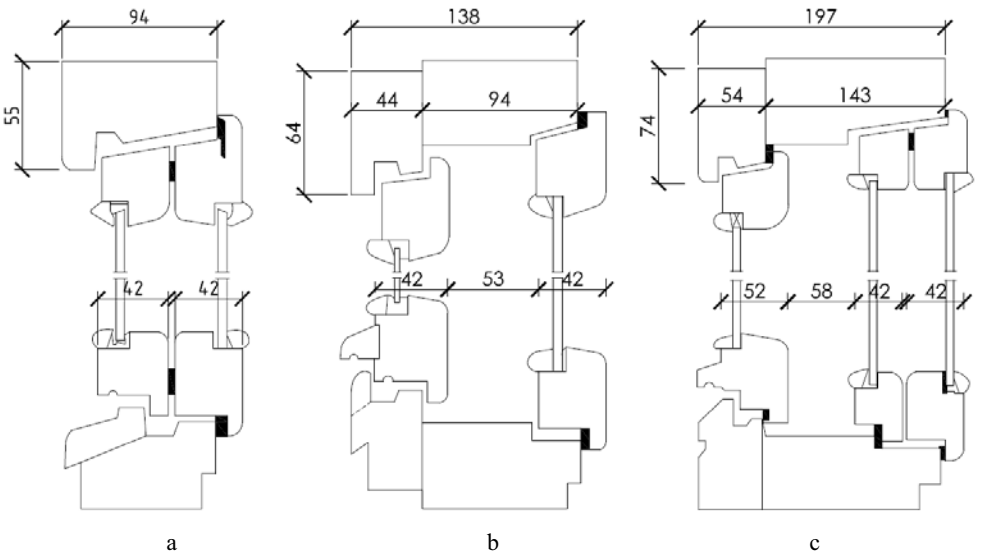


**Fig. 2.** Standard sections of wooden windows of civil buildings of the period 1960-1989, used in the USSR. A – for differences of 25-40 °C.; B - for differences of 44-49 °C; C - for differences over 49 °C. [12]

## 2 Methods

In addition to their architectural role in a building windows perform, first of all, enclosing functions to ensure the required indicators of the internal microclimate [13-17]. Based on this, we can say that in each individual region of construction it's should be used windows, design solution of which should ensure the fulfillment of these requirements in any

operation period (both summer and winter). In this paper, we will consider the issue of climatic applicability only based on winter operating conditions.

A number of experimental researches, including those conducted by the authors of this work, show that modern window types with profiles made of PVC and aluminum alloys cannot meet the above requirements in the winter operation period. This is due to the fact that they are subject to significant thermal deformations caused by the difference between outdoor and indoor air temperatures [18]. The window profile deformations induced by temperature loads are comparable in magnitude to the deformations induced by wind loads [19]. PVC windows are especially susceptible to this effect (results of the research conducted by the authors are presented in [20,21]), and for aluminum windows it is observed only on large dimensions, as evidenced by the test results presented later in this work.

The appearance of a large-format aluminum window with dimensions of 2.5x2.5 m during the test in a climate chamber at different outdoor temperatures (-10°C, -20°C, -30 °C, -40°C, -50°C) and installation schemes of displacement sensors are shown in Figure 3. The test procedure was similar to the work [20,21]. The results of the test are presented in Tables 1 and 2. They showed that due to the sections thermal deformations, there is a significant increase of the gap distance between the frame and the casement. In considered experiment it reaches 4 mm (see the selected cells in Table 1). The window gasket cannot ensure the tightness of the casement adjacent to the frame in the presence of such deformations (the situation is also aggravated by a decrease in the elasticity of the gasket at negative temperatures). As a result, cracks form between the casement and the window frame (see Figure 4a). This, in turn, leads to an increase in air permeability of the window (see table 2), as well as a decrease in the thermal characteristics of the window, expressed as a decrease in the heat transmission resistance [21] and a condensate (frost) formation on the internal surfaces of the window (see Figure 4b).

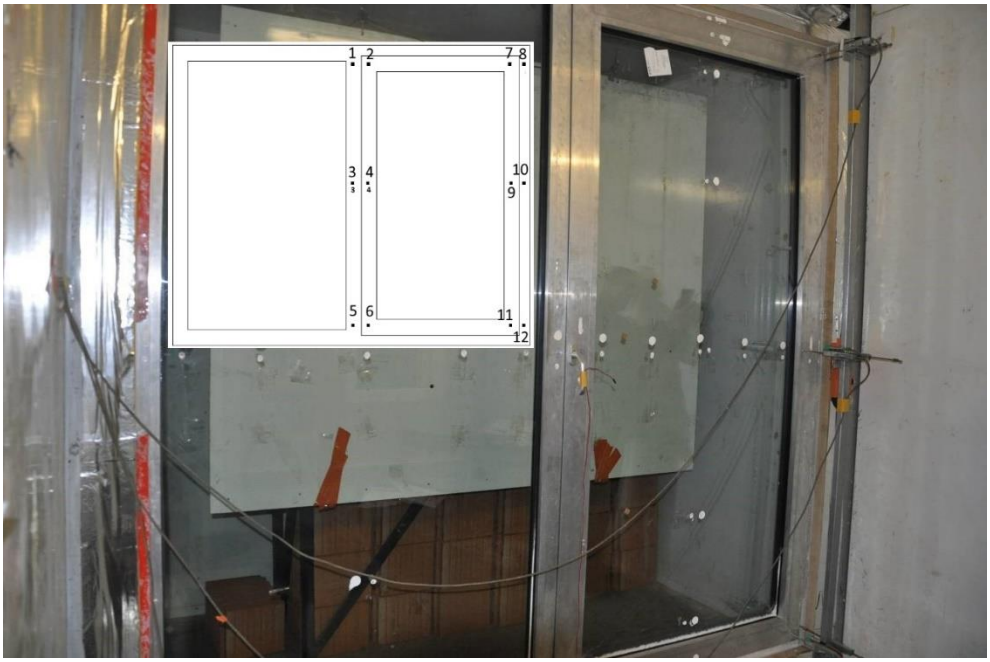


**Fig. 3.** Appearance of a large-format aluminum window installed in the climate chamber

a b

**Fig. 4.** The appearance of the window during the test. a. The formation of a gap between the frame and the casement. b. Formation of frost on the inner surface of the casement and the frame

**Table 1.** The linear displacements of window profiles obtained during the tests under the action of various temperature differences

| Point number | Linear movements of window points, mm at the values of the external Tin and internal Tex air temperature, °C | | | | | | |
|---|---|---|---|---|---|---|---|
| | initial moment +20, +20 | -10, +20 | -20, +20 | -30, +20 | -40, +20 | -50, +20 | Residual deformations +20, +20 |
| 1 | 0 | +0,72 | +0,94 | +1,16 | +1,36 | +1,53 | -0,34 |
| 2 | 0 | +0,66 | +0,86 | +1,01 | +1,25 | +1,43 | -0,35 |
| 3 | 0 | +4,02 | +5,28 | +7,28 | +8,61 | +9,79 | -0,10 |
| 4 | 0 | +3,96 | +5,23 | +7,30 | +8,83 | +9,96 | -0,10 |
| 5 | 0 | +0,37 | +0,45 | +0,45 | +0,54 | +0,67 | -0,05 |
| 6 | 0 | +0,39 | +0,52 | +0,57 | +0,71 | +0,89 | 0,00 |
| 7 | 0 | -0,06 | -0,05 | -0,04 | -0,02 | -2,30 | -0,11 |
| 8 | 0 | -1,35 | -1,43 | -1,73 | -2,64 | -2,99 | -0,07 |
| 9 | 0 | +2,51 | +2,66 | +3,53 | +3,82 | +4,93 | +0,12 |
| 10 | 0 | +1,06 | +1,04 | +1,04 | +0,84 | +0,82 | +0,03 |
| 11 | 0 | -0,62 | -0,82 | -1,24 | -1,48 | -2,25 | -0,12 |
| 12 | 0 | -1,00 | -1,03 | -1,06 | -3,20 | -3,50 | -0,02 |

**Table 2.** The window air permeability values obtained during the tests under various temperature differences

| Pressure drop ΔP, Pa | Volume air permeability of the window, m3/ (m2·h) at the values of internal Tin and external Tex air temperature, °C | | | | |
|---|---|---|---|---|---|
| | +20, -10 | +20, -20 | +20, -30 | +20, -40 | +20, -50 |
| 200 | 0,38 | 0,44 | 0,71 | 0,73 | 0,85 |

## 3 Results

According to the analysis of conducted researches, it can be said that the deformed state of modern window types under climatic loads largely determines their enclosing performance.

Therefore, the feasibility of windows application in specific climatic conditions should be justified not on the basis of windows individual technical and operational indicators obtained under standard test conditions (calculations), as is happening currently, but in the course of a comprehensive review of each indicator under given climatic conditions. At the same time, when assessing the windows climatic applicability in winter based on ensuring that required parameters of room microclimate are met, the following basic criteria must be taken into account:

- providing the temperatures on the inner surface of window profiles and translucent filling that are set by a project. This parameter is variable. Usually, it is assigned due to hygienic conditions, i.e. the inadmissibility of condensation on the internal surfaces of window profiles. But, depending on the design tasks, it can be assigned, for example, from the condition of mold formation inadmissibility or to ensure comfortable conditions (the temperature difference between the inner surface of the enclosing structure and the internal air temperature shouldn't exceed 4 °C);
- limit the speed of air movement near the window. This parameter can be considered constant for windows of heated buildings. A number of reference documents and scientific works [22-24] limit it at the level of about 0.1 m / s;
- providing normative gaps between profiles of frame and casement that don't exceed the possible range of transverse deformations of the window gasket used in a particular window system (usually a window gasket can close the gap that is 3-5 mm).

In the course of laboratory researches (or by calculation) it is possible to confirm the fact that the design solution of a particular window meets these criteria under given climatic operating conditions, and thereby confirm the possibility of its use in a region with similar climatic conditions. The determination of the technical and operational characteristics of windows (heat transmission resistance, air permeability, etc.) should also be carried out under the considered climatic conditions.

## 4 Discussion

The above criteria for the windows climatic applicability allow us to justify the choice of a window ensuring only the required room temperature-humidity conditions in the winter period. Obviously, this is not enough for a number of climatic regions of construction. It is also necessary to form criteria for the windows climatic applicability based on summer operating conditions, which would take into account the influence of solar radiation on the stress-strain state of the window and its durability; premises overheating; water permeability of windows and their low thermal inertia. It is also possible to extent this concept and take into account, for example, urban planning situation (the presence of additional noise impact from roads), as in [25] the phenomenon of windows sound insulation dependence on operation temperature conditions is also established. Each of these factors requires detailed justification.

The development of a classification of the existing windows types by climatic applicability is associated with the need to perform a large amount of experimental research, primarily in laboratory conditions on specialized test benches and, often, using unique methods. This, of course, is extremely labor-intensive and economically costly. Therefore, it is also considered promising to perform these studies using modern computational systems of numerical modeling. However, this requires the creation of a universal numerical model of a window, which would allow not only to evaluate the stress-strain state of a window, but also their technical and operational characteristics in various operating conditions. To date, these studies have been conducted in a limited volume only by a number of researchers [26,27]. Using this model, it will be possible to determine the rational technical solutions of window profiles and maximum overall of windows for

specific climatic conditions of construction, and, as a result, to develop a classification of existing window types according to climatic applicability. The introduction of the same concept of “windows climatic applicability” in construction practice will increase the comfort of living and reduce building maintenance cost, as well as become a tool for testing the performance of new structural window types.

## 5 Conclusions

In the course of the analysis of the work carried out to study the technical and operational characteristics of modern types of windows at negative outdoor temperatures, the effect of the dependence of these characteristics on the deformed state of the windows was revealed. An approach to the development of the windows design solutions was proposed, based on taking into account the influence of the actual climatic conditions of operation on the technical and operational characteristics of the windows. For this purpose, the concept of "windows climatic applicability" was introduced. Criteria for the windows climatic applicability were proposed based on the winter conditions of operation, which allow us to provide the necessary indicators of the premise’s temperature-humidity regime in the window area, taking into account the presence of the identified effects.

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