Especially The Use Of Windows And Curtain Wall In Climatic Conditions Of Russia

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Abstract. The use of translucent enclosing structures (TES - window and certain walls) in the climatic conditions of various regions of Russia requires special attention. Now the main operational parameters of this class of the protecting designs are considered strictly separately. Tests are also carried out for individual characteristics. In this case, neither the mutual influence of temperature characteristics on the possible change of operational parameters nor the assessment of the actual performance of the structure for a given region of construction are taken into account. A significant problem in the design of exterior cladding structures (including translucent) for cold climatic zones of Russia and other countries is to assess the feasibility and acceptability of their use. There is currently no explicit criterion for assessing applicability in regulatory documents. The authors carried out a large amount of experimental and theoretical work in order to develop criteria for assessing the range of applicability of this class of structures for different climatic regions of Russia. It is proposed to evaluate the possibility of using the TES for different climatic regions of Russia the use of a new complex parameter range of climatic applicability. this parameter includes the complex of the main operational characteristics of the TES - limit values of temperature and climatic influences on the TES (minimum outdoor temperature, the change of the reduced resistance to heat transfer, taking into account the different values of outdoor temperature, the maximum value of wind pressure, the value of air and water permeability, thermal deformation), in which the specified design standards

1. Introduction
Windows and curtain walls (CW) are elements of the building envelope. As external enclosing structures, they are called on the one hand, to provide communication between people inside the room with the outside world, maintain the necessary level of natural light and insolation of premises. On the other hand, these types of enclosing structures should provide protection from external climatic influences and ensure maintenance inside a comfortable microclimate.

2. Climatic characteristics and regulatory requirements for windows and curtain walls
The constructive decisions of windows and curtain walls have changed significantly in recent years. The level of achievable thermal engineering characteristics increased by 2 ÷ 3 times, air permeability decreased several times. Annually new technical solutions and profile systems are developed from PVC, aluminum, steel, fiberglass. Glasses with low-emissivity and multifunctional coatings, new designs of double glass unit are developed and produced. At the same time, since 1999, the requirements for heat engineering characteristics of translucent structures have remained unchanged.

The basic requirements for the level of thermal protection of the enclosing structures of buildings are determined by the requirements [1]. In this case, there are 3 basic approaches to determining the required values for the thermal characteristics of structures:
- elementwise (the reduced resistance to heat transfer of the structure is selected according to the requirements of Table 3 [1]);
- sanitary-epidemiological (the minimum temperature on the internal surface is normalized);
- integral based on the development of the "Energy Passport of the Building".

As the construction practice showed, as well as many years of experience in conducting construction site expertise, even formal fulfillment of the requirements [1] often does not ensure the satisfaction of comfort conditions in the interior of buildings and the requirements for compliance with energy efficiency.

Under the climatic characteristics is understood a set of parameters of outside air, characterizing the region of construction. In Russia, the main set of climatic characteristics is determined [2]. This document presents the main climatic characteristics of the regions of Russia for the cold and warm periods of the year. Some of them, such as the temperature of the coldest five-day period, minimum temperatures of the coldest days and absolute minimum temperatures, diurnal temperature amplitudes, directly determine the applicability of the enclosing structures for the construction region.

In addition, a typical climatic year for the construction region can be used as a significant parameter for assessing the thermal characteristics of enclosing structures and evaluating the effect of extreme temperature changes on structures [3]. This approach has not yet found wide application in Russia due to the laboriousness and the need for additional processing of a large amount of meteorological data.

The microclimate parameters in the room are determined by the requirements [4]. At the same time, the temperature of the internal air depends on the temperature of the coldest five-day period for the construction region.

Daily temperature fluctuations for individual regions of Russia can reach 30 °C, which is very important for low-inertial enclosing structures.

In 2015-2016, on behalf of the Ministry of Construction of Russia, in conjunction with the Union of Glass Enterprises, NIISF RAABS, a complex of experimental studies in the climate chamber of various structures of PVC windows, aluminum alloys, wood with double and triple glass unit was carried out. As a result of the completion of this work, new principles for the standardization of this class of structures for various regions of Russia were formed, and proposals were prepared for adjusting [1] with regard to the requirements for curtain walls.

3. Range of climatic applicability for windows and curtain walls

At present, there is no clear and unambiguous criterion for the use of windows and curtain walls for the chosen construction region. Even if the requirements of Table 3 [1] and the classification of structures "can be used throughout Russia", the minimum internal temperature requirements specified in clause 5.7. [1] may be violated. It is proposed to use the term "range of climatic applicability" for this type of construction.

The range of climatic applicability is the maximum values of the temperature and climatic influences on the curtain walls (the minimum outside temperature, the change in the reduced resistance to heat transfer, taking into account the different values of the outside air temperature, the maximum value of wind pressure, the value of air and water permeability, temperature deformations) at which the specified technical design or design standards performance characteristics.

The range of climatic applicability is determined for newly developed curtain walls, as well as for combinations of different types of profile systems, translucent and opaque filling.

The range of climatic applicability is determined by the totality of the limiting values of temperature and climatic influences and is determined by the totality of the limiting values of external climatic influences on the curtain walls, in which the performance characteristics specified by the technical design or design norms are preserved. To determine it, you must set:

- the value of the outside air temperature, at which the permissible temperature values on the inner surface of the structure are preserved according to paragraph 5.7 [1];
- the value of the reduced resistance to heat transfer taking into account different values of the outside air temperature;
- values of the difference between the external and internal pressure \( \Delta P_{w} \), Pa, at which the preset value of the air permeability of the structure is maintained;
- the values of the difference between the external and internal pressure \( \Delta P_\text{o} \), Pa, at which the design is waterproof;
- values of external and internal pressure difference \( \Delta P_\text{o} \), Pa, at which the maximum relative deflection of the structure meets the requirements [5];
- the values of the thermal deformation of the profile system under the influence of the set values of the external \( t_\text{ext} \) and internal \( t_\text{int} \) air temperature;
- permissible increase in air permeability of the structure due to thermal deformation of the profile system;
- permissible increase in sound insulation of the structure due to thermal deformation of the profile system.

The range of climatic usability is determined as a result of laboratory tests.

A preliminary assessment of the individual parameters of the range of climatic applicability is possible on the basis of heat engineering calculations according to [6] and the results of laboratory tests in accredited laboratories. Specialized GOST for carrying out thermal engineering tests of curtain walls in the climate chamber is currently not available, and the requirements [7, 8] can be used for testing.

In order to determine and normalize complex operational characteristics such as thermal deformation, increase in air permeability due to thermal deformation, decrease in the increase in sound insulation of the structure due to thermal deformation, it is necessary to develop test procedures and subsequent development of normative documents.

To conduct heat engineering tests, it is necessary to use high-precision climatic chambers with a range of temperatures in the cold zone, exceeding the climatic parameters of the regions of Russia. According to NIISF RAABS estimates and the requirements [2], it is sufficient to use a climatic chamber with minimum temperatures in the cold zone \( t_\text{ext} = -50 \div -55 \, ^\circ C \). The climate chamber KTK-2009 (Fig.1.) Has precisely such parameters that made it possible during recent years to conduct a number of unique experiments that allow us to formulate the principles for the normalization of curtain walls for the climatic regions of Russia. Separate results of the research were published in [9].

Separate attempts to introduce the "range of climatic applicability" indicator were made in the preparation of the project of SP "Curtain walls of buildings and structures. Design rules" and the draft new revision GOST 23166° "Windows. General specifications." Proposals were rejected until the development of testing procedures and the introduction of a parameter into the system for rating performance. Similar proposals come from the developers of PVC profile systems. They propose to introduce the concept of a "system passport" into profile systems, where to reflect parameters similar to the proposed "range of climatic applicability". An obstacle to the implementation of proposals is also the small distribution of test equipment of this class and the weak methodical training of test specialists.

![Climatic chamber KTK-2009](image)

**Fig. 1.** Climatic chamber KTK-2009 with a temperature range in the cold zone \( t_\text{ext} = -55 \, ^\circ C \)
4. Limitation on the minimum temperature on the inner surface of the structure

According to the requirements of clause 5.7. [1] the minimum temperature on the inner surface of the translucent filling should be $\tau_{int} \geq 3 \, ^\circ C$, in the non-transparent part of the structure it is above the dew-point temperature. There is a contradiction between the values of the humidity of the internal air, given by [1] and the requirements of [4].

Figures 2 and 3 are graphs of the temperature dependence on the inner surface of the window block from the outside air temperature in the range $t_{ext} = -10 \div -55 \, ^\circ C$. The red horizontal line indicates the limiting values of the temperature on the inner surface in accordance with paragraph 5.7. [1].

Taking into account the requirements of paragraph 5.7 [1], this type of window can be used for climatic regions with temperature $t_{ext}$ not lower than $-26 \, ^\circ C$ in temperature at the inner surface of the insulating glass unit (Fig. 2) and not below $-12 \div 13 \, ^\circ C$ on the temperature on the inner surface of the profile (Fig. 3). Additional influence on the temperature on the inner surface of the window can be provided by the type and quality of installation in the wall opening, the presence of heating appliances, the width and the location of the window sill.

![Fig. 2. Graph of temperature dependence on the inner surface of a double glass unit at external temperatures $t_{ext} = -10 \div -55 \, ^\circ C$](image)

![Fig. 3. Graph of temperature dependence on the inner surface of the profile at external temperatures $t_{ext} = -10 \div -55 \, ^\circ C$](image)

5. Reducing the thermal characteristics of curtain walls with increasing temperature difference between indoor and outdoor air

Unlike non-transparent elements of enclosing structures, the thermal characteristics of translucent structures directly depend on the gradient between the external and internal temperatures. The authors
'and foreign colleagues' studies [10] have shown that for the central part of the double glass unit, the reduction of the thermal characteristics can be up to 30% relative to the design values according to EN 673.

In addition, a process of thermal deformation of the double glass unit contributes significantly to the reduction of the thermal engineering characteristics of the structure (effect of the formation of a "lens"). The mutual superposition of these two physical processes can lead to an even more significant decrease in the heat engineering characteristics of translucent filling.

Thermotechnical characteristics of the opaque part of the structure (frame, leaf, profile elements) from the gradient of the external and internal temperatures depend insignificantly and are well predictable using modern software products. It should be noted that a significant part of the standard European programs gives a significant error in the transition to Russian climatic conditions. This is due, first of all, to the imperfection of the calculation model and insufficiently correct consideration of the convective component of heat transfer.

In Fig. 4-5. the graphs of the dependence of the reduced resistance to the heat transfer of windows with different designs of double glass unit at various temperatures of outside air are given. As can be seen from the graph, when the outside temperature $t_{ext}$ changes from $-10^\circ C$ to $-55^\circ C$, the reduced resistance to the heat transfer of the window can be significantly reduced. The class of the window is according to paragraph 4.7.1. GOST 23166 [11] on the given resistance to heat transfer can be reduced by 1-2 digits.

![Fig. 4. Graph of dependence of the reduced resistance to heat transfer of PVC and aluminum windows with various designs of double glass unit at external temperatures $t_{ext}$ = -10÷-55 °C](image)

![Fig. 5. Graph of dependence of the reduced resistance to the heat transfer of a wooden window with various designs of double glass unit at external temperatures $t_{ext}$ = -10÷-55 °C](image)

6. Thermal deformation of the profile system

Thermal deformation of the profile system means a uneven temperature expansion of the opaque part of the window structure under the influence of a difference between the external and internal temperatures. This effect is most significant for a PVC profile and a composite profile of aluminum alloys.

As a consequence, the manifestation of thermal deformation leads to a decrease in the temperature of the internal surface of the profile (Fig. 6), an increase in infiltration/exfiltration through the opening elements of the structure, a reduction in the level of sound insulation through the structure. Separate results of the study of the effect of thermal deformation are given for windows of aluminum alloys [9] and PVC windows [12]. As the results of studies in the climate chamber and field surveys showed, this effect has less significant effect on wooden windows.
Fig. 6. Thermal testing of a window made of aluminum alloys with the measurement of thermal deformation. Formation of ice on the inner surface of the structure.

7. Conclusions

The mutual influence of different window characteristics for the climatic conditions of Russian regions can have a serious impact on the possibility of applying the chosen constructive solution, the level of comfort in the room and the energy efficiency of the building.

It is necessary to solve the task in a complex way, to develop and widely implement a new class of experimental equipment that allows us to assess the mutual influence of different factor operational characteristics of translucent enclosing structures and the development of a methodology for assessing the "climatic applicability range" in laboratory conditions.

It is advisable to include the notion of "range of climatic usability" in the list of standard parameters for windows and curtain walls and to develop a normative document for its experimental determination.

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