The required level of thermal protection of enclosing structures of administrative buildings in the transport infrastructure in Russia and European countries

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Abstract. Comparison of various standard values and calculation methods adopted in Russia and European countries has always aroused quite a lot of interest, and many works are devoted to this topic. However, the last comparisons were carried out quite a long time ago, and the purpose of this study is to compare the required level of thermal protection of the building envelopes of administrative buildings in the transport infrastructure in Russia and European countries according to the current regulatory documents to determine the ratio of these values to each other. The normalized values of the level of thermal protection of external enclosing structures are related to the degree-days of the heating period. Moreover, the definition of this value in Russia and the EU countries differ from each other. And it is possible to compare the level of thermal protection of enclosing structures in different countries only according to the same characteristic, that is, with the same (or very close) value of the degree-day of the heating period. Also, the level of required resistance to heat transfer of external enclosing structures in Russia is set taking into account heat-conducting inclusions in the enclosing structure, and in European countries without taking into account. That is, it is impossible to compare these two quantities in the original form - you need to take into account the design of the outer shell of the building.

1 Introduction

All over the world, an important role is given to energy saving in buildings, which is aimed at reducing the consumption of the country's fuel and energy resources [1-7]. The complex value of the characteristics of the energy saving level of a building is the maximum value of the heat transfer coefficient of individual building envelopes in European countries or the required resistance to heat transfer of external fences in Russian regulatory documents. The rationing of the level of thermal protection of buildings in different countries is very different, since they are determined by such factors as: climatic, economic and cultural characteristics,

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as well as especially the state policy in the field of energy saving [8-16]. In this vein, it is interesting to compare how much the requirements of Russian regulatory documents differ from foreign ones.

2 Methods

The main characteristic of the thermal properties of building envelopes in the EU is the heat transfer coefficient of the building envelope, W/(m^{2}·°C), or as it is called in European regulations "U-factor". This value is given without taking into account the heat engineering inhomogeneities present in the building envelope, since in European countries the accounting for heat engineering inhomogeneities is not rigidly fixed in regulatory documents, and the reduction in the reduced resistance to heat transfer due to existing cold bridges can be in a fairly large range [17].

To determine the maximum allowable value of the heat transfer coefficient in European countries, the following regulations were used in the latest version as of 2021:

1. Finland - National Building Code of Finland 2012 – Section D3 on Energy Management in Buildings;
2. Sweden - Boverket's Building Regulations, BBR18 - (BFS 2011:26);
3. Ireland - Building Regulations: Part L Conservation of Fuel and Energy: Dwellings and Part L - Conservation of Fuel and Energy Buildings other than Dwellings;
4. Germany - Energy Conservation Regulations (EnEV);
5. Denmark - Building Regulation 10 (BR10);
6. England and Wales - The Building Regulations 2010 Conservation of fuel and power in new dwellings (L1A) and in new buildings other than dwellings (L2A);
7. Austria - OIB - Richtlinie 6;
8. Netherlands - Bouwbesluit 2012 - Chapter 5 (NEN 7120:2011).

The normalized values of the heat transfer coefficient are related to the number of degree-days of the heating period (GSOP), °C.day, which is calculated by the formula:

$$GSOP = z_{ot} \left(t_v - t_{ot}\right) \tag{1}$$

where t_{ot}, z_{ot} - average outdoor temperature, °C, and duration, days/year, of the heating period; t_v - design temperature of the internal air of the building, °C.

Methods for calculating this value differ between Russia and European countries [18, 19]. In the EU, for public buildings, when assessing the GSOP in buildings, the indoor air temperature is assumed to be 18 °C, while according to Russian standards this value is 19 °C. The outdoor air temperature at which the heating period begins in the EU countries is considered to be 15.5 °C, and in Russia in public buildings the heating period begins at an average daily outdoor temperature below or equal to 8 °C. And a comparison of the required levels of heat transfer resistance of the enclosing structures of a public building is possible only with the same (or very close) value of the GSOP.

The level of required resistance to heat transfer of external enclosing structures in Russia is set taking into account heat-conducting inclusions in the enclosing structure, and in European countries without taking into account. That is, it is impossible to compare these two values in their original form from regulatory documents - it is necessary to take into account the design of the fence. It was decided to perform a comparison according to the normalized values of the heat transfer coefficients without taking into account heat-conducting inclusions in the building envelope. Thus, for the enclosing structures of the EU countries, the standardized value can be taken from regulatory documents, and the normalized value of this parameter for enclosing structures in the Russian Federation should be obtained by recalculation.

The minimum requirements for thermal protection in Russia are prescribed in SP 50.13330.2012 (hereinafter referred to as SP 50). The norms at two levels establish the required resistance to heat transfer of enclosing structures R_0^{norm}, m^{2}·°C/W:

- reduced heat transfer resistance of a real structure R_0^{fact}, m^{2}·°C/W, according to the conditions of energy saving should be equal to the base value of the required heat transfer resistance of the enclosing structure R_0^{norm},

- the reduced resistance to heat transfer of a real structure R_0^{fact}, m^{2}·°C/W, provided that the values of the specific annual consumption of thermal energy for heating and ventilation do not exceed the normalized SP 50 values, can be reduced by reducing factors to the calculated required heat transfer resistances for energy saving: $R_0^{fact}=R_0^{norm}*m_p$ at m_p=0.63 for walls, m_p=0.80 for other enclosing structures (except for translucent structures), m_p=1.00 for translucent structures.

In the normative document of the Russian Federation on the thermal protection of buildings, the heat transfer coefficient is defined as the reciprocal of the conditional heat transfer resistance of the building envelope R_0^{cond}, that is, the heat transfer resistance of a homogeneous part of the structure, m2 ° C / W, which can be determined by adding the thermal resistances of all its layers and heat transfer resistances on both surfaces of the structure:

$$U_{max} = \frac{1}{R_0^{cond}} \tag{2}$$

To recalculate the normalized value of the reduced resistance to heat transfer into the value of the heat transfer coefficient without taking into account heat-conducting inclusions, you can use the coefficient of thermal uniformity r, which, being an auxiliary value, characterizes the effectiveness of the insulation of the structure and is determined by the formula:

$$r = R_o^{norm} \frac{1}{R_0^{cond}} = R_o^{norm} \cdot U_{max} \tag{3}$$

where R_0^{norm} is the base value of the required resistance to heat transfer of the enclosing structure, m^{2}·°C/W, should be taken depending on the degree-days of the heating period, (GSOP), °C·days/year, the construction region according to SP50;

R_0^{cond} - area-averaged conditional resistance to heat transfer of a fragment of a heat-shielding shell of a building or a dedicated enclosing structure, m^{2}·°C/W, excluding heat-conducting inclusions;

U_{max} - the maximum allowable heat transfer coefficient of the homogeneous i-th part of the fragment of the heat-protective shell of the building (specific heat loss through the flat element of the i-th type), W/(m^{2}·°C).

For comparison, structures with two types of building facades were selected: facade heat-insulating composite systems with external plaster layers (SFTK) and hinged facade systems (NFS). From the generalization of the results of multivariate calculations of the reduced resistances to heat transfer, it was found that the average value of the thermal engineering uniformity coefficient r=0.7 corresponds to the SFTC, and the NFS r=0.5. The indicated discrepancy in the values of the coefficient of heat engineering homogeneity indicates that in the Russian Federation, with the same reduced heat transfer resistance R_0^{fact} of external walls with a different facade, their conditional heat transfer resistances R_0^{cond} will be different. Therefore, the European thermal protection standards can be closer to the thermal protection of one design and diverge from the thermal protection of another, although these designs correspond to the same RF standard in terms of the reduced resistance to heat transfer.

As for the values of the heat transfer coefficient of coatings and ceilings over unheated basements, which are given in Tables 2 and 3 for various cities of the Russian Federation, inhomogeneities were taken into account in their calculation. In the thermal calculation of coatings, the presence of parapets and ventilation shafts is usually taken into account. The calculation of the reduced resistance to heat transfer of the floor over an unheated basement takes into account the installation of partitions on the floor slab that cut the insulation if it is laid on the slab, the adjoining of the floor to the cold basement fence, the passage of plumbing and heating pipes from the basement to the building. In addition, in both floors, the insulation may collapse under the weight of the overlying layers. As a result, to take into account the above factors, the coefficient of thermal uniformity r=0.8 was adopted.

For translucent enclosing structures, the coefficient of thermal uniformity r=1.0 is adopted. At the same time, the requirements for thermal protection of translucent structures are considered for the entire window structure as a whole.

3 Results

At first, the task was to find cities with GSOP values calculated according to the European methodology, close to the GSOP values indicated in Table 1. Then, for the selected cities, determine the GSOP value according to the Russian method and determine the calculated values R_0^{fact} corresponding to these GSOPs according to the norms. etc. After that, using the indicated values of the coefficient of thermal uniformity, find the value of the heat transfer coefficient (Umax). The calculation results for the selected cities are presented in tables (Tables 2 and 3).

Table 1. Normalized values of the heat transfer coefficient and GSOP values of non-residential buildings for various European countries.

External enclosing structures	Heat transfer coefficient, W/(m^2·°C)							
	Finland	**Sweden**	**Austria**	**Denmark**	**Germany**	**Ireland**	**England**	**Netherlands**
Outer wall	0.17	0.18	0.35	0.3	0.28	0.21	0.3	0.4
Window	1	1.3	1.4	1.4	1.35	1.6	2	1.4
Ceiling over unheated underground and basement	0.09	0.15	0.4	0.2	0.28	0.21	0.25	0.4
Coating	0.09	0.13	0.2	0.2	0.2	0.16	0.2	0.4
Degree-day of the heating period (GSOP)), °C·day								
According to the European methodology	5480	3950	3460	3340	3340	3010	3000	2920

Table 2. Normalized values of the heat transfer coefficient and GSOP values of non-residential buildings for the Russian cities of Nizhny Novgorod, Kaliningrad, Rostov-on-Don.

External enclosing structures	Heat transfer coefficient, W/(m^2·°C)					
	for energy saving	**with reduction factors**	**for energy saving**	**with reduction factors**	**for energy saving**	**with reduction factors**
	Nizhny Novgorod		**Kaliningrad**		**Rostov-on-Don**	

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SFTC/NFS Exterior Wall	0.250/0.179	0.397/0.283	0.310/0.221	0.492/0.351	0.318/0.227	0.505/ 0.361
Window	1.450		1.667		1.724	
Ceiling over unheated underground and basement	0.253	0.316	0.315	0.394	0. 324	0.405
Coating	0.214	0.268	0.265	0.332	0.273	0.341
Degree-day of the heating period (GSOP)), ºC·day						
According to the Russian method	5182		3534		3336	
According to the European methodology	5334		4054		3452	

Table 3. Normalized values of the heat transfer coefficient and GSOP values of non-residential buildings for the Russian cities of Grozny, Makhachkala.

External enclosing structures	**Heat transfer coefficient, W/(m²·°C)**			
	for energy saving	**with reduction factors**	**for energy saving**	**with reduction factors**
	Grozny		**Makhachkala**	
SFTC/NFS Exterior Wall	0.332/0.237	0.526/0.376	0.360/0.257	0.571/0.408
Window	1.786		1.923	
Ceiling over unheated underground and basement	0.339	0.423	0.368	0.461
Coating	0.284	0.355	0.308	0.385
Degree-day of the heating period (GSOP)), ºC·day				
According to the Russian method	3036		2490	
According to the European methodology	3236		2722	

4 Discussion

Comparing the data obtained on the maximum requirements for the value of the heat transfer coefficient of enclosing structures, it can be seen that in most cases the regulation in European countries is stricter than in the Russian Federation. This fact can be explained by the strengthening of the policy in the field of energy efficiency of buildings [20]. In Russia, the energy efficiency program has also continued to be strengthened in recent years, in particular, in 2018, by amending SP 50, the requirements for thermal protection of translucent structures were increased. However, it is interesting to note that even the modern requirements of Russian standards for the value of the heat transfer coefficient of windows in all compared options are much lower than in European countries, except for England, where this value becomes lower.

Further, we continue the comparison only for external walls, coatings and ceilings above an unheated basement.

Comparison of regulatory requirements for thermal protection in the countries of Finland, Sweden and in the cities of Nizhny Novgorod and Kaliningrad, respectively, shows similarity only for a wall with an LFR calculated for energy saving. Other requirements for enclosing structures are stricter in European countries.

Please note that the thermal protection requirements in Austria for the outer wall and ceiling over an unheated basement and underground stand out from the general picture with a less rigid approach than in other considered European countries with a similar GSOP value.

This fact is difficult to explain, since each country sets its own requirements for thermal protection of buildings. Comparing the Austrian requirements with the requirements for thermal protection of enclosing structures in the Russian city of Rostov-on-Don, which has a close GSOP value, we note a great similarity for the outer wall with the NFS and the value of the heat transfer coefficient calculated with reducing coefficients for the floor over an unheated basement. At the same time, the requirements of Russian standards for external walls with SFTC and NFS and for ceilings above an unheated basement, calculated in terms of energy saving, are more stringent. The minimum Russian requirements for thermal protection of coatings and an external wall with SFTC (energy saving with reduction factors) are lower than the Austrian ones.

It is convenient to compare the thermal protection of buildings in Denmark and Germany, for which the HSOP value is close to 3300 °C·day, with the thermal protection of the Russian city of Grozny. Here, the requirements of the EU countries and the Russian Federation for energy saving are close only for external walls with SFTC and NFS. For other enclosing structures, we note the lower requirements of the Russian Federation.

Since in Ireland, England and the Netherlands the GSOP values are close to 3000 °C·day, we will compare their requirements for the maximum value of the heat transfer coefficient with the requirements of the Russian Federation for the city of Makhachkala with GPOP = 2722 °C·day. At the same time, it should be borne in mind that a lower value of the GSOP in Makhachkala initially requires less rigid thermal protection than with a GSOP of 3000 °C·day. Therefore, the comparison can be made with an eye to the requirements of the Russian Federation for the city of Grozny, where GSOP=3236 ºC·day.

The requirements for thermal protection of all enclosing structures considered by us in Ireland are approximately 2 times higher than in the city of Makhachkala, but also higher than in Grozny.

When comparing the requirements of England and the Russian Federation for the cities of Makhachkala and Grozny to the heat transfer coefficient, we notice the similarity only for the LFS wall, calculated for energy saving. Other requirements for enclosing structures are higher in a European country.

The city of Makhachkala and the country of the Netherlands have very similar requirements for thermal protection of enclosing structures. We only note that the external walls of the SFTK and NFS for energy saving are subject to more stringent requirements for thermal protection in Russian standards. And when calculating the thermal protection of the outer wall of the SFTC with decreasing coefficients, Russian requirements become lower than in the Netherlands.

At the same time, it is important to clarify that in this case, the indicated minimum requirements of the Russian Federation for thermal protection are verified by the implementation of the norms for the energy consumption of the building for heating and ventilation.

It is also interesting to note the fact that the value of the heat transfer coefficient in a number of countries (Germany, Finland) is not tied to climatic differences in specific regions of the country, but is presented in regulatory documents for the country as a whole.

5 Conclusion

The results of comparing the required levels of thermal protection of enclosing structures in public buildings in Russia and European countries leads to a fairly large scatter due to differences in the methods of accounting for thermal uniformities and not taking into account the climatic data of construction areas. Very often, the normalized resistance to heat transfer of enclosing structures in the Russian Federation is compared with the required values in Finland due to the similarity of the climate. But Russia has different climatic regions and it is necessary to compare regions with similar climates, at least in terms of the GSOP value, and also take into account the design features of the enclosing structure for the presence of thermal inhomogeneities in it.

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