TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
ARCHITECTURE | ARCHITEKTURA
8-A/2014

MAŁGORZATA ROJEWSKA-WARCHAŁ*

THE INFLUENCE OF GLAZING TYPE, FRAME PROFILES SHAPE AND SIZE OF THE WINODOW OF THE FINAL VALUE OF WINDOW THERMAL TRANSMITTANCE *U*

ANALIZA WPŁYWU PRZESZKLENIA, RAM ORAZ KSZTAŁTU I WIELKOŚCI OKIEN NA WSPÓŁCZYNNIK PRZENIKANIA CIEPŁA *U*

Abstract

The paper presents the analysis of the relation between window thermal transmittance and the window shape, size, frame profile, glazing type and opening area division. The analysis was performed in the Window 6.3 program developed by the Lawrence Berkeley National Laboratory, which has the possibility of a comprehensive analysis of the heat flow through the various types of windows, according to the current assessment procedure developed by the National Fenestration Rating Council (NFRC) and comply with ISO 15099. For the purpose of the analysis a number of computer simulations of various window frames were conducted.

Keywords: thermal transmittance, energy efficient windows

Streszczenie

W referacie podjęto próbę analizy zależności wielkości współczynnika przenikania ciepła *U* dla okien w zależności od kształtu, wymiarów, rodzaju ram, podziału i typu zastosowanego zestawu szybowego. Analizę przeprowadzono w programie Window 6.3 opracowanym przez Lawrence Berkeley National Laboratory, który ma możliwość wszechstronnej analizy przepływu ciepła przez różnego rodzaju okna, zgodnej z aktualną procedurą oceny opracowaną przez National Fenestration Rating Council (NFRC) i zgodną z normą ISO 15099. Dla celów analizy przeprowadzono szereg symulacji komputerowych dla różnych rozwiązań ram okiennych.

Słowa kluczowe: współczynnik przenikania ciepła, okna energooszczędne

* M.Sc. Małgorzata Rojewska-Warchał, Division of Building and Building Physics, Faculty of Civil Engineering, Cracow University of Technology.

1. Introduction

Windows are important elements of energy efficient buildings in terms of developing thermal balance. The significance of heat loss through windows depending on their shape and on the architectural and construction solutions, may constitute an important element in the total thermal balance of a building. The growing costs of maintenance are spent on balancing the heat lossx via glass surfaces in winter months and for the maintenance of cooling systems in summer. While designing a window, it should be taken into account that not only does its construction influence the aestheticx features of a building and the amount of sunlight let inside, but also it influences the thermal transmittance U. It is not enough to determine the thermal parameters of windows x by only providing the thermal transmittance U_g of the glass surfaces. The thermo-insulating properties of a glass pane are only a component parameter of the total value of the thermal transmittance of a window unit U_w. In recent years the thermo-insulating power of windows has improved due to the use of new window profiles with insulation layers and glazing filled not only with air but also with special gases.

The heat transfer through windows is characterized by very complex physical phenomena and so the thermal characterizations of windows are determined on the basis of laboratory research and complex numerical analysis of thermal balance done with the use of computer simulations. Thanks to computer simulations the thermal transmittance U_w may be described as a function of the type, shape and size of a frame, of the glass surfaces, and the type of gas filling the glazing cavity.

The analysis was conducted in the Window 6.3 program developed by the Lawrence Berkeley National Laboratory, which gives the opportunity to perform a comprehensive analysis of heat conduction in various types of windows in agreement with the current procedures of assessment as developed by the National Fenestration Rating Council (NFRC) in accordance with the ISO 15099 norm.

2. Determining thermal transmittance

The value of the total thermal transmittance for windows is calculated in accordance with the norm [2] in the following way:

$$U_w = \frac{\Sigma A_g \times U_g + \Sigma A_f \times U_f + \Sigma l_g \times \Psi_g}{\Sigma A_g + \Sigma A_f} \tag{1}$$

where:

- U_g – the thermal transmittance of the glass [W/m^{2}K],
- U_f – the thermal transmittance of the framing [W/m^{2}K],
- Ψ_g – the linear thermal transmittance resulting from the combination of the heat effects of the glass and the frame [W/mK],
- A_g – the surface of the glass [m^2],
- A_f – the surface of the frame [m^2],
- l_g – the perimeter of the glass element [m].

It is a complicated process to determine an individual thermal transmittance included in the equation (l). When determining the thermal transmittance for the central area U_g of the window, one should perform a simulation analysis, which takes into account the heat conduction through glass surfaces, radiation and convection heat transmission of the glazing cavities, the number of glass panes in the glazing as well as the climatic conditions, indoor temperature and the angle of the window. Due to its dual nature, the heat transfer through the area by the edge is significantly different from the heat transfer through the central area. Materials used for insulation layers between the glass panes in the areas by the edge of the glazing, have greater thermal conductivity than the gas layers in the glazing cavities.

An analysis of two-way heat transfer, which takes into account the different conductivity, would complicate the calculation of the heat balance of the entire window. A simplification was adopted on the basis of x tests of the area of the glazing by its edge conducted in the United States. The area by the edge was defined as the area limited by the frame and the line placed at a distance of 63.5 mm [4] from the edge. The thermal transmittance of the frame depends on the type and the material from which it is made and on the presence of thermal bridges, because the dominant mode of heat transfer in all types of frames is conduction.

3. Subject of the analysis

The analysis was conducted in the Window 6.3 program developed by the Lawrence Berkeley National Laboratory. The computational analysis was conducted with reference to the following assumptions:

- In all of the analyzed cases, x glass of 4mm thickness was adopted

Table 1

The optical properties of the glass used in the glazing

Type of glass	T_{sol}	R_{sol1}	R_{sol2}	T_{vis}	R_{vis1}	R_{vis2}	T_{ir}	emis1	emis2	λ W/m²K
P	0,847	0,078	0,078	0,902	0,081	0,081	0,000	0,840	0,840	1,0
PNE	0,708	0,116	0,127	0,833	0,109	0,166	0,000	0,840	0,149	1,0
PSS1	0,569	0,268	0,310	0,855	0,082	0,075	0,000	0,837	0,037	1,0
PSS2	0,370	0,341	0,470	0,765	0,074	0,055	0,000	0,840	0,037	1,0

P – clear glass,
PNE – clear glass with low emissivity,
PSS – spectrally selective clear glass,
T_{sol} – transmissivity of solar radiation through the glass,
R_{sol1}, R_{sol2} – reflectivity of solar radiation through glass,
T_{vis} – transmissivity of solar radiation through the glass,
R_{vis1}, R_{vis2} – reflectivity of visible radiation through the glass,
T_{ir} – transmissivity of infrared radiation through the glass,
emis1, emis2 – emissivity of infrared radiation through the glass, respectively the glass surface from the outside and inside.

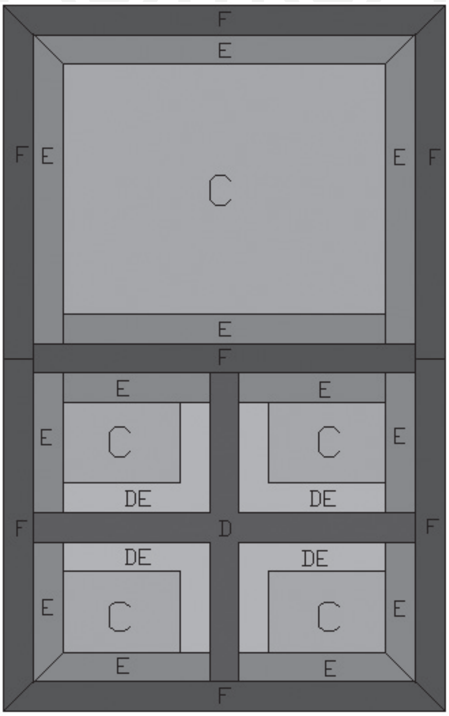
- Double-pane glazing and triple-pane glazing were adopted

Table 2

Thermal properties of glazing used (central surface)

Type of glazing	The heat transmittance U_g [W/m^{2}K]
Double-pane glazing	
P – Argon – P	2.575
PNE – Argon – PNE	1.309
Triple-pane glazing	
PSS1 – Argon – PSS1 – Argon – PSS1	0.595
PSS2 – Argon – PSS2 – Argon – PSS2	0.594

The values refer to the central area of the window shown in Ill. 1.



Ill. 1. The division of the surface of the window into fragments: centre-of-glass C, edge-of-glass E, divider D, divider-edge DE, and frame areas F for a typical fenestration product

- The adopted frames were made from PVC, wood and aluminum with various thermal transmittance U_f

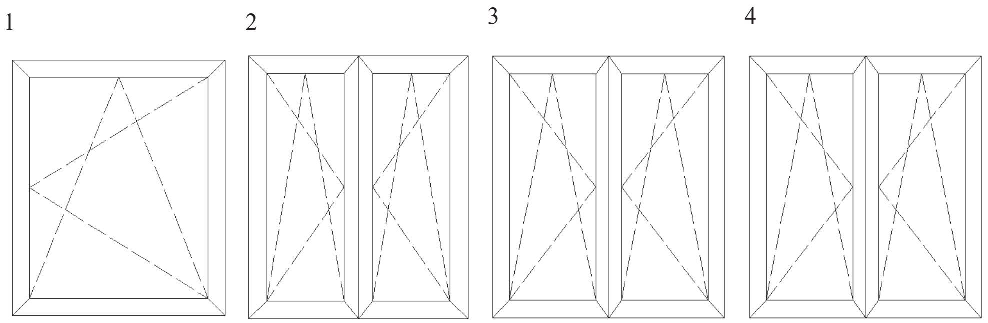
The following types of window frames and their thermal transmittance are currently used profiles in residential and public buildings: 5 – and 6 – chamber PVC profiles and wooden profiles used in conventional buildings, and 6 – chamber profiles with increased depth and 8 – chamber PVC profiles in energy efficient buildings. Aluminum profiles are mostly used in public buildings.

Table 3

Thermal properties of window frames in use

Type of profile	The thermal transmittance U_f [W/m^{2}K]
PVC	
5 – chamber profile with the depth of 70 mm and the width of the 112 mm of the combination	1.3
6 – chamber profile with the depth of 70 mm and the width of the 112mm of the combination	1.03
6 – chamber profile with the depth of 88 mm and the width of the 125 mm of the combination	0.9
8 – chamber profile with the depth of 70 mm and the width of the 112 mm of the combination	0.96
WOOD	
Glulam with the depth of the profile of 68	1.5
Glulam with the depth of the profile of 78	1.4
ALUMINUM	
A profile with the depth of 51mm and the width of frame of 108 mm	2.6
A profile with the depth of 69mm and the width of frame of 114 mm	2.0

- simulation analyses were carried out in relation to the following types of windows (the size were taken from currently produced windows):



Ill. 2. Types of windows: 1) 1230 × 1480 mm, 2) 1230 × 1480 mm, 3) 1465 × 1435 mm 4) 2065 × 1839 mm

These types of windows were adopted because, according to the equation (1) it is clear that an important parameter affecting the overall thermal transmittance is not only the size, but also the division of the glazing. The ratios between the size of the glass panex and the frame have a significant effect on the overall thermal transmittance.

4. Results of the analysis

Simulation analyses of the total thermal transmittance for each variant were done in the Window 6.3 program and the results are shown in Table 4a and 4b, 5a and 5b.

Table 4a and 4b

The thermal transmittance for windows with PVC frames for all kinds of sizes, profiles and window glazing

System		1230 × 1480 mm area. 1.832 m^2 Window No. 1			1230 × 1480 mm area. 1.832 m^2 Window No. 2		
		U_w			U_w		
U_f		$U_g = 2.575$	$U_g = 1.3$	$U_g = 0.6$	$U_g = 2.575$	$U_g = 1.3$	$U_g = 0.6$
1	1.3	**2.258**	1.469	1.069	**2.210**	1.561	1.251
2	1.03	**2.175**	1.386	0.986	**2.105**	1.458	1.148
3	0.96	**2.153**	1.365	0.965	**2.078**	1.431	1.121
4	0.90	**2.080**	1.330	0.950	**1.978**	1.385	1.099

System		1465 × 1435 mm area. 2.168 m^2 Window No. 3			2065 × 1839 mm area. 3.798 m^2 Window No. 4		
		U_w			U_w		
U_f		$U_g = 2.575$	$U_g = 1.3$	$U_g = 0.6$	$U_g = 2.575$	$U_g = 1.3$	$U_g = 0.6$
1	1.3	**2.238**	1.537	1.190	**2.301**	1.456	1.050
2	1.03	**2.143**	1.441	1.096	**2.229**	1.394	0.979
3	0.96	**2.119**	1.417	1.07	**2.211**	1.375	0.960
4	0.90	**2.035**	1.375	1.052	**2.147**	1.346	0.948

The figures in bold in the table show the thermal transmittance in excess of U_{max} which define the current technical specifications [1].

The thermal transmittance is not dependent on the surface of the window, but on the ratio of the central area, x the area by the edge and their thermo-insulating properties. While designing windows none of the elements should be neglected as their insulating power and the surfaces they take up may deteriorate or improve the thermo-insulating power of the windows, which is shown in detail in tables 4a and 4b as well as 5a and 5b.

Table 5a and 5b

The thermal transmittance for windows with wooden and aluminum frames of all kinds of sizes, profiles and window glazing

System		1230 × 1480 mm surface. 1.832 m^2 Window No. 1			1230 × 1480 mm surface. 1.832 m^2 Window No. 2		
		U_w			U_w		
U_f		U_g = 2.575	U_g = 1.3	U_g = 0.6	U_g = 2.575	U_g = 1.3	U_g = 0.6
wood_1	1.5	**2.302**	1.542	1.141	**2.264**	1.644	1.349
wood_2	1.4	**2.226**	1.499	1.131	**2.168**	1.595	1.322
aluminum_1	2.6	**2.655**	**1.855**	1.448	**2.707**	**2.046**	1.728
aluminum_2	2.0	**2.469**	1.686	1.289	**2.473**	**1.833**	1.526

System		1465 × 1435 mm surface. 2.168m^2 Window No. 3			2065 × 1839 mm surface. 3.798 m^2 Window No. 4		
		U_w			U_w		
U_f		U_g = 2.575	U_g = 1.3	U_g = 0.6	U_g = 2.575	U_g = 1.3	U_g = 0.6
wood_1	1.5	**2.289**	1.606	1.271	**2.340**	1.520	1.113
wood_2	1.4	**2.201**	1.567	1.265	**2.273**	1.429	1.105
aluminum_1	2.6	**2.693**	**1.977**	1.625	**2.645**	**1.799**	1.378
aluminum_2	2.0	**2.479**	1.783	1.441	**2.484**	1.653	1.241

Based on the simulation analysis it has been shown that independently of the dimensions and the window profiles used, the windows with the glazing of the highest thermal transmittance U_g = 2.575 W/m^{2}K do not fulfill the requirements in the current Technical Conditions [1].

A single window with the dimensions of 1230 × 1480 mm has in all cases a lower thermal transmittance than a double window of the same dimensions with the exception of windows with the glazing of U_g = 2.575 W/m^{2}K. The greater the share of the glazing with good insulating properties x, the lower the thermal transmittance x.

The improvement of the thermal transmittance of the central area may be achieved by using multiple glazing made of glass with low emissivity with layers of gas with high thermo-insulating power. A comparison of a double-pane glazing consisting of clear glass and filled with argon U_g = 2.575 W/m^{2}K with a triple-pane glazing consisting of clear spectrally selective glass also filled with argon U_g = 0.6 W/m^{2}K shows that the thermal transmittance has decreased by four times. The use of a gas or a mixture of gases with a lower thermal transmittance than argon would also improve the heat transmittance of the central area.

The insulating powers of the frame are primarily dependent on the thermo-insulating powers of the used materials. The frame is also an element which may significantly influence the insulating power of the window, which is shown in tables 4a and 4b, 5a and 5b.

The conducted analysis took into account the available glazing, with reference to various properties of the glass, the use of selective layers and the filling of the glazing cavity with varied types of gases. This may play an important role at the stage of performing an energetic audit and design. The outcome of the analysis together with the scope of variability dependent on the adopted configuration may be beneficial as input data in simulation programs calculating the annual demand for energy of buildings with particular attention paid to buildings with high degree of glazing in the elevation.

References

[1] Dz. U. 2002 Nr 75 poz. 690, Rozporządzenie Ministra Infrastruktury z dnia 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie.

[2] PN-EN ISO 10077-1:2007, Właściwości cieplne okien, drzwi i żaluzji. Obliczanie współczynnika przenikania ciepła – część 1: Metoda uproszczona.

[3] PN-EN ISO 10077-2:2012, Cieplne właściwości użytkowe okien, drzwi i żaluzji. Obliczanie współczynnika przenikania ciepła – część 2: Metoda komputerowa dla ram.

[4] ISO 15099:2003, Thermal performance of windows, doors and shading devices – Detailed calculations.

[5] Nowak H., *Analiza i ocena możliwości kształtowania bilansu cieplnego okien*, Okno, nr 1 (8) styczeń – marzec 1997, 196-204.