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IMPACT OF WINDOWS PARAMETERS ON THE THERMAL PERFORMANCE OF A MULTI-FAMILY BUILDING

WPŁYW PARAMETRÓW OKIEN NA CHARAKTERYSTYKĘ ENERGETYCZNĄ BUDYNKU WIELORODZINNEGO

A b s t r a c t

The paper presents an analysis of the influence of various window types on the thermal performance of a multi-family building. In the analysis several different fenestration system configurations were considered. For these systems, heating and cooling demand of the building was estimated according to the simple hourly method proposed in ISO 13790. The results were used to compare, both the overall thermal performance of the building, as well as the actual thermal energy balance of analyzed windows.

Keywords: *windows*, *fenestration*, *energy performance*

S t r e s z c z e n i e

W artykule przedstawiono wyniki analizy wpływu zastosowania różnych rodzajów okien w charakterystyce energetycznej budynku wielorodzinnego. W analizie rozpatrzono zastosowanie kilku różnych systemów okiennych. Dla analizowanych systemów obliczono zapotrzebowanie na ciepło oraz chłód, posługując się prostą metodą godzinową zgodną z ISO 13790. Wyniki obliczeń wykorzystano do porównania zarówno całkowitego zapotrzebowania na energię budynku, jak i do określenia rzeczywistego bilansu badanych okien.

Słowa kluczowe: *okna*, *przeszklenie*, *charakterystyka energetyczna*

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1. Introduction

New regulations, such as the European Directive 31/2010 Recast, impose new demands on the construction industry and investors. New low-energy buildings should be built using advanced technology and design techniques.

Windows play an important role in ensuring the comfort of indoor climate conditions. Commonly used factor for windows thermal efficiency is the heat transfer coefficient *U*. This factor, however, does not describe the full energy balance of the window. In fact, windows are also a source of solar heat gains and allow air infiltration. That means that the lowest *U*-factor does not guarantee the best thermal performance.

2. Methodology

In order to analyze the influence of thermal parameters of the fenestration system on the energy characteristic of a multi-family building, a two stage method has been used. The first step of the analysis was to calculate the energy characteristics of a reference multi--family building for various fenestration systems. The energy characteristic was calculated according to the simple hourly method of the ISO 13790 standard. Obtained heating/cooling energy demand was used to compare the overall building thermal characteristic depending on the fenestration parameters. To analyze the results on a window scale windows energy performance was calculated for both heating and cooling seasons. The general concept of the calculation procedure is presented in Fig. 1.

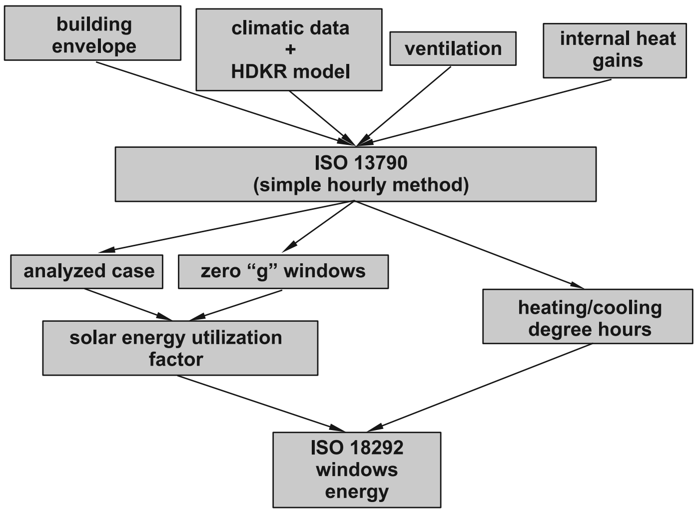

Fig. 1. Calculation algorithm

The assessment procedure in ISO 18292 requires data on both solar heat gains and heat loss through windows. Since both of these parameters depend largely on the climate and the energy characteristic of a building; detailed calculations for each reference building located in the three climate zones in accordance with the procedure proposed in ISO 13790 have been conducted. As not all of the available solar energy can be utilized for heat demand reduction, utilized fraction of the available solar energy is calculated on an hourly basis for the reference house. Solar energy utilization factor is calculated as a ratio of the effective reduction of the heating demand (calculated as a difference of the heating demand of the reference building and the building with windows for which solar energy transmittance equals 0) to the total solar irradiation through windows. Finally, the energy performance of windows is calculated as a difference between the utilized transmitted solar energy and the thermal heat losses during the heating and cooling seasons.

$$E_{\text{ref,heating}} = I_{\text{heating}} \cdot g - D_{\text{heating}} \cdot U \tag{1}$$

$$E_{\text{ref,cooling}} = I_{\text{cooling}} \cdot g - D_{\text{cooling}} \cdot U \tag{2}$$

where:

$E_{\text{ref,heating}}$ – window energy balance for the heating season [kWh/m^2],
$\mathrm{E}_{\text{ref,cooling}}$ – window energy balance for the cooling season [kWh/m^2],
I_{heating} – utilizable solar irradiation during the heating season [kWh/m^2],
I_{cooling} – utilizable solar irradiation during the cooling season [kWh/m^2],
g – solar energy transmittance of the window [–],
U – heat transfer coefficient of the window [W/(m^2·K)],
D_{heating} – heating degree hours [kKh],
D_{cooling} – cooling degree hours [kKh].

3. The reference building

The energy performance of windows may vary in various building mostly due to a different solar energy utilization potential (as a result of various heat gains/heat loss factor). The selection of the reference building is not random, residential buildings play an important role in the overall national energy consumption. That makes optimization of their construction a very important factor for the national energy policy. Therefore in this study, an average sized multi-family building was chosen. In order to include in the study the impact of the building's overall energy performance on the windows, two different constructions were considered. One for a building constructed in 1970s and the other constructed according to current standards (Technical Requirements 2008); the general building construction for both reference building construction types was the same:

- heated/cooled space – 4466.17 m^2,
- building volume – 14960 m^3,
- number of floors – 4,
- ground floor/roof area – 1298.30 m^2,
- roof pitch – 0º.

The most important thermal properties of the building envelope are presented in Table 1. The values were taken according to respective standards, that is:

- in case of current standard (TR 2008) – Ordinance of the Minister of Infrastructure on the technical requirements for buildings and their location building design from 2008,

– building from 70s – PN-64/B-03404 and PN-74/B-03404 polish standards representative for most of existing buildings.

Table 1

Selected construction types

Construction type	**Walls** *U* [W/m²K]	**Roof** *U* [W/m²K]	**Ground floor** *U* [W/m²K]
TR2008	0.3	0.25	0.45
70s standard	1.16	0.5	0.7

One of the factors that may influence the energy performance of windows is their area and distribution. However due to practical requirements in case of residential buildings windows fraction on facades is similar in most buildings. In the study. windows distribution for the reference building was assumed according to the Table 2.

Table 2

Windows distribution and facades

Orientation	**Window fraction on a facade [%]**
N	31.3%
E	9.2%
S	31.3%
W	9.2%

Other important factors, that may influence thermal performance of buildings are:
– ventilation airflow – the airflow was calculated in accordance with the norm PN-83/B-03430/AZ3:2000. The design ventilation airflow equals 11200 m^3/h,
– building's thermal capacity – typical for polish conditions building construction is traditional masonry construction and concrete/masonry construction. Therefore the reference building's thermal capacity was assumed to be $C = 260\,000$ $J/(K \cdot m^2)$,
– internal heat gains – Internal heat gains were estimated according to the ordinance of the Minister of Infrastructure on the methodology of building energy performance calculation [2], assuming floor area distribution: living room and kitchen – 35%, bedroom – 35%, other – 30%, giving in average heat flow of 4.1 W/m^2.
– climate – as climate in various regions of Poland does not differ significantly, the relative differences in the energy performance of windows is insignificant, meaning that a good window in a colder region should also be good in a warmer region. To represent average climate as a representative dataset of weather; data was chosen for Warsaw.

4. Analyzed window types

Windows, substantially, influence the building's thermal performance in two ways: on one hand by an increase of transmission heat loss through the envelope and on the other by an increase of solar heat gains. That means that comparison of windows based only on one parameter (usually thermal energy transmittance for the whole window U_W) may not be optimal and may lead to incorrect window selection. If we want to make a reliable comparison of windows we should take into account both the U_W factor and the g_w coefficient that describes solar energy transmittance of windows. Both values may vary considerably depending on used materials and window construction. In order to analyze the influence of the parameters on the energy performance of the reference building six, different window types were taken into account (Table 3).

Table 3

Selected window types

No.	U_w [W/m²K]	g_w [–]
1	1.6	0.40
2	1.6	0.55
3	1.4	0.35
4	1.4	0.46
5	1.0	0.20
6	1.0	0.27

5. Results

For the selected window types the reference building energy performance was calculated for both heating and cooling seasons. In order to unify calculations, building energy demand for heating was calculated with an assumption of a set length of the heating season (from 26 September to 5 May). This assumption allowed calculation of the solar energy utilization factor during the heating season, required for further analysis. In case of the cooling demand such unification was not possible. However, it wasn't necessary as there is no need for solar energy utilization factor calculation as this energy is not utilized, but must be removed from the building. Moreover, the impact of windows on the number of hours when the set temperature would be exceeded, in case of cooling, is much more significant than in case of heating. Therefore this impact should be included in calculations.

Table 4 presents heating and cooling demand values for selected window types and building construction standards. Note that better energy performance was not necessarily achieved through selection of windows with a lower U_w value. In particular the heating demand for the window type #2 (U_w = 1.6 W/m²K) was lower than for the window type #5 (U_w = 1.0 W/m²K). This difference was a result of a much lower solar energy transmittance of the window type #5. The results shows the importance of this factor for energy performance optimization. On the other hand the results confirm that regardless of the construction standard the classification of thermal performances is the same therefore windows' performance should behave in the same manner.

Table 4

Building energy performances for selected window types and building construction standards

No.	U_w W/m²K	g_w [–]	TR2008 E_h [kWh]	TR2008 E_c [kWh]	1970s E_h [kWh]	1970s E_c [kWh]
1	1.6	0.40	416 091	–16 059	649 321	–15 431
2	1.6	0.55	394 055	–30 008	628 639	–25 265
3	1.4	0.35	409 018	–13 542	643 098	–13 505
4	1.4	0.46	392 662	–22 719	627 782	–20 108
5	1.0	0.20	402 522	–6 339	637 791	–7 864
6	1.0	0.27	391 827	–10 282	627 816	–10 911

In order to classify windows, energy performances for selected window types was calculated on the basis of ISO 18292 standard. Required for the calculations values of degree hours and irradiation were calculated for selected window types and building construction standards.

Table 5

Values of heating/cooling degree hours and irradiation for selected window types and building construction standards

No.	TR2008 D_h [kDh]	TR2008 I_h [kWh/m²]	TR2008 D_c [kDh]	TR2008 I_c [kWh/m²]	1970s D_h [kDh]	1970s I_h [kWh/m²]	1970s D_c [kDh]	1970s I_c [kWh/m²]
1	87.7	197.7	0.8	66.3	87.7	183.9	0.5	49.6
2	87.7	195.8	2.2	103.1	87.7	182.5	1.1	70.5
3	87.7	198.9	0.6	58.4	87.7	184.8	0.3	45.1
4	87.7	197.5	1.4	84.8	87.7	183.8	0.8	61.7
5	87.7	201.8	0.1	34.4	87.7	187.1	0.1	30.1
6	87.7	200.9	0.4	48.6	87.7	186.5	0.2	38.8

For the calculated heating/cooling degree hours and irradiation values windows energy balances were calculated.

The results (Table 5) indicate that due to a set heating season length the utilizable irradiation varies only slightly. In case of cooling the differences were much higher, however, as using various datasets for windows classification might be difficult; therefore a similar analysis for a reference dataset based on averaged values was conducted.

Comparison of results (Tables 6 and 7) indicate that there are differences in the reference heating/cooling energy balances depending on the used dataset. However it does not change the general classification of windows meaning that windows could be compared on a basis of a reference dataset of heating/cooling degree hours and irradiation values.

Table 6

Heating/cooling balances for selected window types and building construction standards

No.	U_w [W/m²K]	g_w [–]	TR2008 E_h [kWh/m²]	TR2008 E_c [kWh/m²]	1970s E_h [kWh/m²]	1970s E_c [kWh/m²]
1	1.6	0.40	–61.2	25.2	–66.8	19.1
2	1.6	0.55	–32.6	53.3	–39.9	37.0
3	1.4	0.35	–53.2	19.5	–58.1	15.3
4	1.4	0.46	–31.9	37.0	–38.2	27.3
5	1.0	0.20	–47.3	6.8	–50.3	5.9
6	1.0	0.27	–33.4	12.7	–37.3	10.2

Table 7

Heating/cooling balances for selected window types and a reference climatic data set

No.	U_w [W/m²K]	g_w [–]	D_h [kDh]	I_h [kWh/m²]	D_c [kDh]	I_c [kWh/m²]	E_h [kWh/m²]	E_c [kWh/m²]
1	1.6	0.40	87.7	191.8	0.7	57.6	–63.6	21.9
2	1.6	0.55					–34.8	30.6
3	1.4	0.35					–55.7	19.2
4	1.4	0.46					–34.6	25.5
5	1.0	0.20					–49.3	10.8
6	1.0	0.27					–35.9	14.8

6. Conclusions

U-value of windows cannot be used to compare energy performance of windows. Therefore, in order to provide decision makers information on the actual performance of windows, it is necessary to develop a windows rating scheme based on an overall energy performance during both heating and cooling seasons. The development of a such system is possible as the performance of windows does not differ significantly for various building construction standards.

Thermal performance of windows is not the only aspect that should be taken into account; windows are an important source of natural daylight that allows for reduction of electricity consumption for lighting, therefore a method of daylight potential implementation into the windows rating system should be developed. Windows are also providers of natural ventilation, thus improving the indoor thermal climate and reducing cost/energy consumptions for mechanical ventilation. These effects should be considered in future studies.

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