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LONG TIME TESTING OF THERMAL PARAMETERS IN SELECTED WINDOWS

DŁUGOFALOWE POMIARY WŁAŚCIWOŚCI TERMICZNYCH W WYBRANYCH OKNACH

A b s t r a c t

The paper presents an evaluation of the measured data of the temperatures of three window constructions made from different materials and with different glazing systems. Measurements were carried out at different points on window friezes and glazing and they underway continuously throughout the year. These windows are suitable for low-energy buildings. Window structures were placed in the pavilion type testing laboratory. The windows were installed in an outer wall of known thermal characteristics, in a room with a constant indoor climate. The windows were exposed to the real effects of external climate conditions. The article shows the results of temperature measurements and thermo-optical properties.

Keywords: windows, surface temperature, condensation of water vapor

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

W artykule przedstawiono ocenę danych z pomiarów temperatury trzech różnych konstrukcyjnie okien zbudowanych z różnych materiałów i z różnymi układami szybowymi. Pomiary są przeprowadzane w różnych miejscach ram i przeszkleń nieprzerwanie przez okres jednego roku. Okna te są odpowiednie dla budynków niskoenergetycznych. Okna są umieszczone w laboratorium (typ pawilonu), gdzie okna są zainstalowane w zewnętrznej ścianie pomieszczenia o znanej charakterystyce cieplnej oraz stałych warunkach wewnętrznych. Jednocześnie są wystawione na działanie rzeczywistych zewnętrznych warunków klimatycznych. W artykule przedstawiono wyniki pomiarów temperatury oraz właściwości termooptycznych.

Słowa kluczowe: okna, temperatura powierzchni, kondensacja pary wodnej

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1. Introduction

Window constructions are one of the most important elements of building facades. They not only constitute a significant structural element, they also contribute to the final architecture. Recently, they have become considerably involved in energy losses and in the creation of an optimal indoor environment.

The window constructions evaluated in this article were installed in the testing laboratory of the Department of Building Engineering and Urban Planning, Faculty of Civil Engineering, University of Žilina. This is so-called "pavilion type" laboratory, where the windows are fixed into an outside wall of known thermal characteristics, in a room with a constant indoor climate and they are exposed to real effects of external climate conditions.

Fig. 1. Exterior and interior of climatic chamber with integrated samples of window constructions

In the chamber, an internal environment identical to basic boundary conditions of thermal standard according to the STN 73 0450:2002 [6] is formed, i.e., the indoor air temperature θ_{ai} is maintained at 20°C and the relative humidity φ_{ai} is 50%.

1.1. Climatic chamber

The climatic chamber must be suitably calibrated so that the samples of window constructions show the correct values. This state is crucial in ensuring the correct operation of the chamber with regard to the elimination of heat losses. These could arise from heat transmission through the ceiling, because above the chamber, there is a double-coat roof construction, and through the external wall, which isolates the room from the external environment. Obviously, heat losses also arise through the window constructions themselves.

We can determine the equation of heat balance of the indoor air (in afore-mentioned climatic chamber) according to the scheme of the thermal balance of the air (Fig. 2):

$$Q_h + Q_s + c_p \cdot (Q_v + Q_t) \cdot (\theta_e - \theta_i) + \sum h_{sj} \cdot S_{jp} \cdot (\theta_{jp} - \theta_i) = 0 \qquad (1)$$

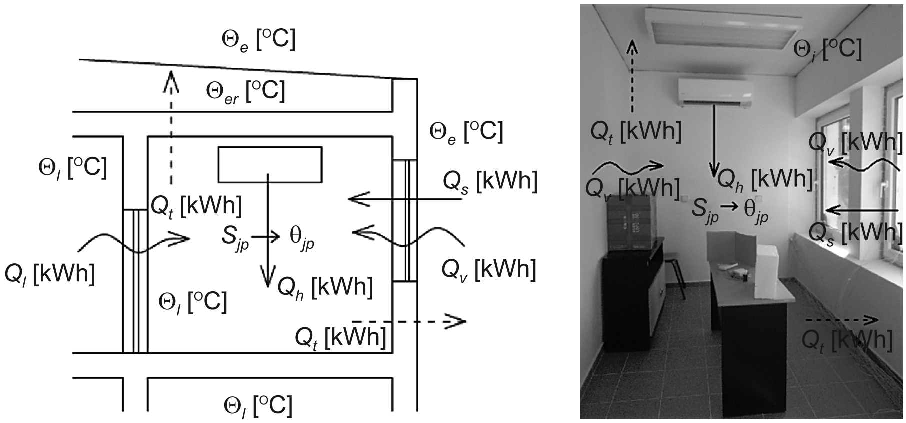

Fig. 2. The scheme of thermal balance of indoor air in the climatic chamber: Q_v – air infiltration [kWh], Q_s – solar gains [kWh], Q_h – heat gains from the air handing unit [kWh], Q_t – transmission of heat [kWh], θ_e – outdoor air temperature [°C], θ_i – indoor air temperature [°C], θ_{er} – under roof space temperature [°C], θ_{jp} – surface temperature [°C], S_{jp} – surface area [m^2], c_p – specific heat capacity at constant pressure (J/kg·K), h_{sj} – convective heat transfer coefficient on the inner surface [W/m^2·K]

1.2. Method of measurement of the thermal parameters of window constructions

Samples of window constructions, which were installed in the climatic chamber, are of various materials and various glazing types. Two of these constructions are plastic and one of them is wooden. The difference between the two plastic windows is in the addition of thermal modules on one of them – such window should fulfil thermal properties better. All three of the windows have different glazing systems (Fig. 3).

For purposes of this article, measurements were taken of internal and external surface temperatures in the middle of the glazing on the studied window constructions, on the frieze of the leaf, and on the glazing in the close contact with the rail frieze.

profile	color	No. of chambers	glazing	gas of glazing	embedment depth of glazing [mm]	U_w [W/(m^2·K)]	U_f [W/(m^2·K)]	U_g [W/(m^2·K)]	thickness of constr. [mm]
	white	6	insulating triple glass	Ar	12	0.8	1	0.5	86
	white	6	insulating triple glass	Kr	12	0.78	0.85	0.5	86
	gray		insulating triple glass		18	0.79	0.8	0.6	

Fig. 3. The samples of window constructions and their parameters

Surface temperatures of these windows are measured through the use of thermocouples, which are protected against sunlight using the special tapes. Each data logger recorded in the long-term with the time period of 30 minutes. For purposes of this article, the relevant measurements were realized between the 27th January and the 2nd February 2012 ($\theta_{ae,\min}$ = = –18.9°C, $\theta_{ae,\max}$ = +4.6°C) – the heating period of the year (Fig. 4).

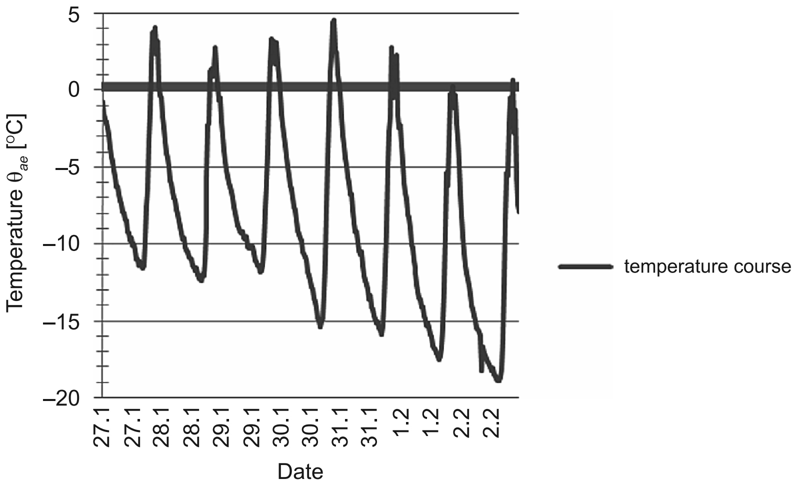

Fig. 4. The shape of external temperatures θ_{ae} [°C] during the evaluated measuring period

2. Analysis of samples of window constructions

For window constructions, it is important in terms of energy savings and the prevention of thermo-humidity failures, to fulfil the requirements specified in the Slovak standard STN 73 0540-2 [6]. All fragments of window construction have to be made in the right way and are required to be of the high-quality material in order to ensure one of main functions of the window – this being the capturing of excessive heat and cold from the outside and the prevention of heat transmission from the interior during the heating period.

Figures 5–7 show the surface temperatures $\theta_{si,w}$ [°C] of the external and internal sides of the considered window constructions. Comparing these figures with Fig. 4, it may be observed that the surface temperatures depend on the outside air temperature and the solar irradiation.

In pictures 5–7, the dew point temperature which corresponds to the value of θ_{dp} = 9.26°C is highlighted. This value is specified in the Slovak standard STN 73 0540-2. It determines that the dew point occurs when the temperature of internal air is θ_{ai} = 20°C and humidity is φ_{ai} = 50% for all fragments of the window i.e. for frames, and translucent and lightproof panels. Internal surface temperatures for all of the windows in the glazing (in close contact with the rail frieze) fall below this value.

During the research, some pictures using the infrared camera were taken at the end of January 2014, i.e. in the winter period. To avoid the contamination of the data by sunlight,

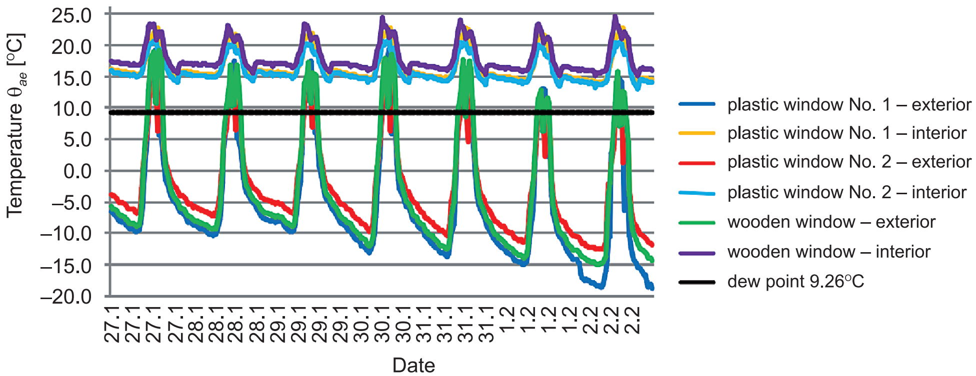

Fig. 5. The shape of the surface temperatures $\theta_{si,w}$ [°C] from the external and internal side of the window constructions, in the middle of glazing

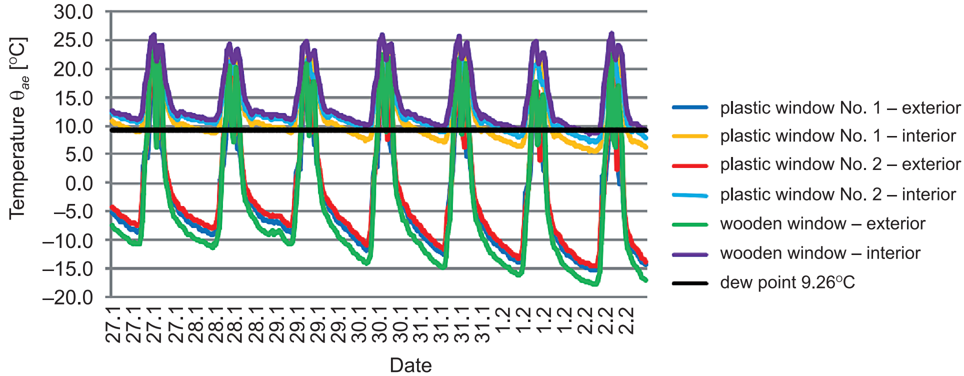

Fig. 6. Surface temperature curves $\theta_{si,w}$ [°C] from the external and internal sides of the window constructions on the glazing in close contact with the rail frieze

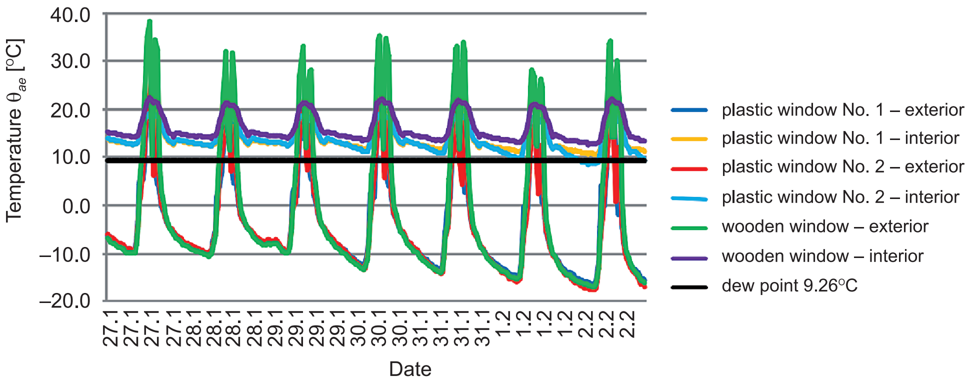

Fig. 7. Surface temperature curves $\theta_{si,w}$ [°C] from the external and internal side of the window constructions on the rail frieze

thermographic diagnostics was taken during the night. According to the pictures, it is obvious that the critical points of the windows are the points of contact between the window and the wall and also the points of contact of the glazing with the rail frieze.

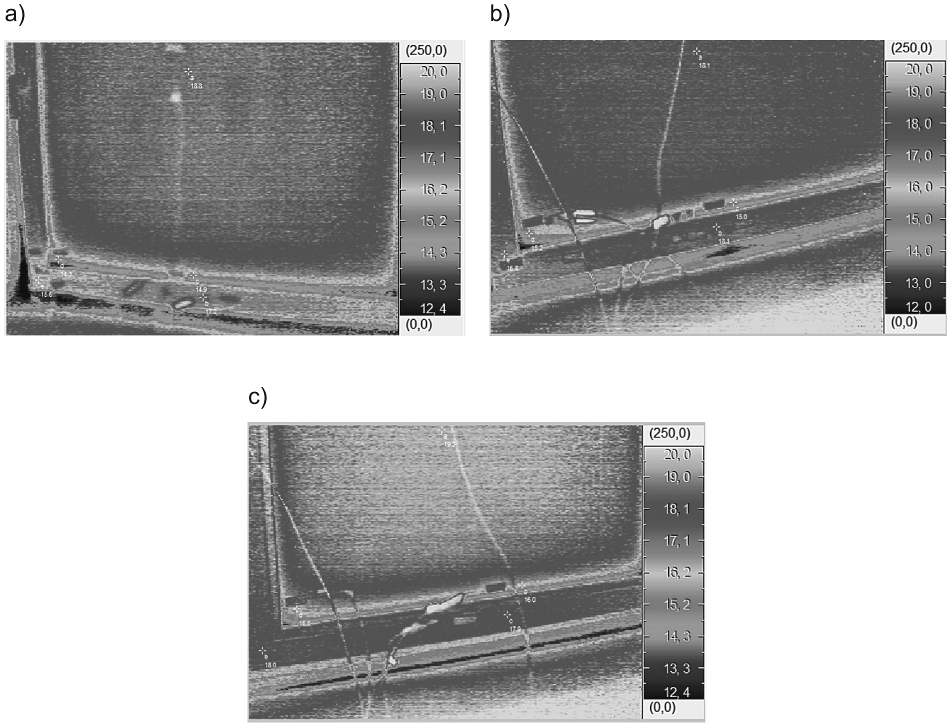

Fig. 8. Pictures of window constructions from infrared camera: a) plastic window without thermal modules; b) plastic window with thermal modules; c) wooden window

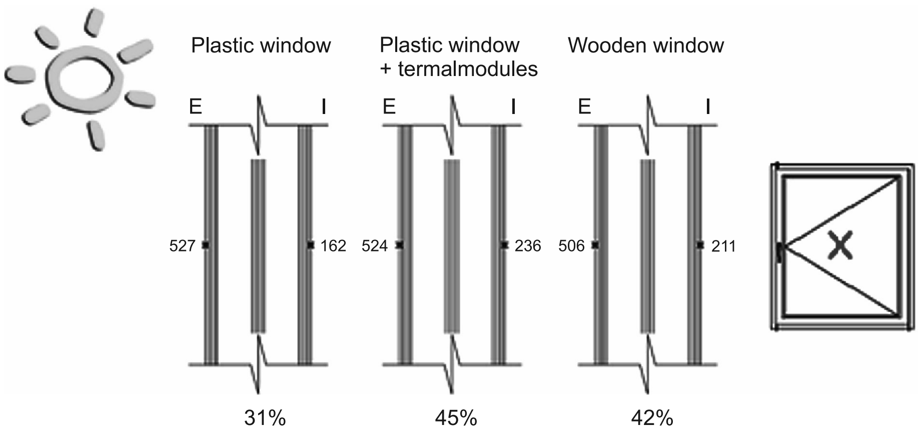

Fig. 9. Measured values of solar transmittance permeability

Solar radiation transmittance was measured on samples of window constructions through the use of a pyranometer. The measurement was taken at 12^{20} (at the end of October 2013) under a bright sunny sky. The pyranometer was placed in the centre of each glazing sheet. From the measured values, it is obvious that a transmittance of solar radiation above 50% was not reached by any window. Comparing the declared values with the measurement shows that the measured values were lower. These values are identical with a permissible deviation of 5–10%. This deviation could be attributed to fouling of the window panes.

3. Conclusions

As a result of the evaluation of measured values, we can conclude that the internal surface temperatures depend on the outside air temperature and on solar irradiation. Decreases of internal surface temperatures in places on the lower edge of the glazing occurred in all windows during the considered period as a result of extremely low temperatures. These temperatures decreased below the dew point temperature, while in the middle of glazing there was no occurrence of temperatures below 13.5°C. The lowest average surface temperature was registered on the glazing in the immediate vicinity of contact with the lower edge of the frieze rail at each window. For these constructions it´s known that the bottoms of window rails are more prone to the condensation of water vapour than the rest of the window construction and the measurements confirmed the occurrence of thermal bridges in these places, which became significantly evident by the occurrence of external temperatures below –15°C. The inner surface temperature dropped below the dew point on all of the windows. It is possible that the value of the temperature at this point is caused by the thermal bridge. Distance profiles of isolating glazing and the depth of fixing of the glazing into the frame frieze have the significant impact on genesis of such thermal bridges. It is visible, that the quality of triple glazing did not remove the problem with temperature by the extreme freeze. On the other hand, the triple glazing caused the elimination of the effects of cold radiation (average temperatures in the middle of the glazing were from 15.9 to 17.9°C) by the normal external temperatures in area of glazing. It is important that window constructions eliminate the cold radiation (especially during the heating and the transitional period) in these critical places. In conclusion, the wooden window, which is provided with the heat optimized distance frame, achieves the best values of measurement during all the measured periods. The surprising finding was the curve of internal surface temperatures compared to plastic windows in place of the lower frieze of window. The internal surfaces of windows were more undercooled at frieze of rail for window with thermal modules (in average of 0.3°C, but at maximum up to 3°C) during extreme temperatures of the external air.

Pictures taken through the infrared camera show the critical positions of window constructions. The measured values of thermographic diagnostics were few different from the values measured using thermocouples in a period. It was confirmed again that the weakest points of these constructions are the glazing margins.

The permeability of solar radiation in all of the window constructions was under 50%. These values are consistent with the deviation of 5–10% compared to the declared values from the producer. This deviation can be attributed to the pollution of windowpanes. But when we compare particular samples together, it is visible that the highest solar gains were measured in the case of the plastic window. The filling between glasses is krypton.

Internal surface temperatures during the heating period were significantly higher than the external surface temperatures. This shows the high-quality materials used for window constructions. They are able to capture the excessive heat from solar radiation and they are able to eliminate the coldness from exterior, too. The comfort of internal environment in the most problematic point of window construction is maintained.

During measurements, the temperature and relative humidity in the chamber were at a constant level. It is to say that parameters of the internal environment were maintained with air conditioner. The hot air from air conditioner does not affect the windows. Window constructions were not influenced by the flow of hot air from the radiators.

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References

[1] Ďuriníková M., Ďurica P., *The evaluation of temperature parameters in selected windows during the whole year*, 17th Interational Conference "Thermal protection of buildings 2013", Vysoké Tatry – Štrbské Pleso, 16–17 May 2013, 81-84.
[2] Ďurica P., Ďuriníková M., Rybárik J., Štaffenová D., *Long time testing of temperature parameters in selected windows*, International Conference Advanced Building Construction and Materials, Kočovce, 26–27 September 2013, 81-84.
[3] Bielek M., *Building and Energy*, Vidas, Banská Bystrica 1995.
[4] Ballast D.K., *Architect's Handbook of Construction Detailing*, John Wiley & Sons, New Jersey 2009.
[5] Humm O., *Niedrge Energie Häuser*, Verlag, Praha 1997.
[6] STN 730540:2012. Thermal properties of building structures and buildings. Thermal protection of buildings. Parts 1, 2, 3, Slovak Standards Institute, Bratislava 2012.