Long-Term Window Evaluation: Comparison of Pavilion Laboratory and Climate Chamber Measurement

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Abstract. In the pavilion laboratory there are three different windows evaluated since 2011. These windows are suitable for low-energy or passive houses. Two different plastic based windows were modelled and the temperatures were compared to the real measurement with different outdoor temperatures. One of the windows, with the theoretically worst properties was recently removed and another one was mounted into the laboratory. Than the window was tested in the climate chamber. Result is the comparison of temperature courses with simulation of the same winter day as recorded with the weather station. Similar results were obtained and the degradation of thermal properties of the window were confirmed.

Keywords: Triple glazing · Window · Long term measurement · Climate chamber · Evaluation

1 Introduction

Building envelope, which main function is to protect the indoor environment against the outdoor climate consists of several parts, such as wall, roof, etc. Those can be divided to non-transparent and transparent parts. Windows belong to the transparent part. The window not only protects the indoor environment like a non-transparent part, but it has more function. Very important is the insolation of the space [1], view, contact with outdoor, ventilation, etc. With increasing the thermal protection of building, windows are also developing. Thermal properties of used materials, both for glazings (triple, gas fillings, heat mirrors and low emissivity surfaces) and frames (wooden, aluminum, plastic with thermo modules, more chambers etc.) are improving [2, 3]. Nonetheless is the advance with incorporating the photovoltaics into the glazing or usage of transparent thermal insulations [4]. Overcome of overheating is also a problem which has to be dealt with in the low-energy buildings even more than before [5–7]. Another problem is the minimizing of thermal loss through the thermal bridges around the windows [8]. The use of triple glazing helps with avoiding the cool radiation from the glass surface and also the vapor condensation at the bottom of the glazing.

The Slovak standard [9] dealing with thermal protection (STN 73 0540:2019) followed the EC directive about Energy performance of buildings (EPBD) 2010/31/EU

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[10]. Valid values for windows are since 2016 $U_w = 1.0$ W/(m^2 K) and from 2021 is recommended value the level 0.6.

In the laboratory of Department of Building Engineering and Urban Planning are since 2011 evaluated three different windows [11]. This is the so-called laboratory of the pavilion type, it has the controlled indoor environment and outdoor climate is real and recorded with weather station [12, 13]. The windows were back there suitable for low-energy and nearly-zero buildings and nowadays are still among the best between the common windows. Several outcomes were published through the years regarding the temperature measurements [11, 14], heat flow [15] and *U*-value [16], comparison with model in FEM software Therm [17] and analysis of the results from different years [15]. During autumn 2020 was the building envelope of the building renowned with new ETICS and one of the windows was dismounted and taken for measurement in the climate chamber. Comparison of the pavilion results and measurement with same boundary condition in climate chambers are described in this paper.

2 Methods

The analyzed window was built into the testing laboratory of the Department since 2011 (Fig. 1). This is a so-called "laboratory of the pavilion type", which nowadays consists of three different rooms aimed on the nearly zero building envelopes [18, 19].

The window was oriented to the south with slight declination to the west (15°). From outside, windows are exposed to the real climate boundary conditions. The outdoor climate is monitored and recorded by the mobile experimental weather station placed on the nearby building's roof [12]. Exact monitoring of outdoor boundary conditions in-situ enables the possibility for more precise measurement and simulations. The indoor climate is controlled by the AC unit, which is set to maintain the Slovak standard indoor boundary conditions: 20 °C, 50%. The indoor air temperature is recorded and showed small amplitude about ±1 °C, during the very cold night about −2 to 3 °C, which is taken into the account for calculation of the thermal transmittance coefficient.

Fig. 1. Outer view on the built-in windows before and after façade renovation.

Sensors used for the measurement consist of NiCR-Ni thermocouples [20] and heat flux plates (HFP) equipped also with thermocouples with correction (standard ones

(120 × 120 mm) and half-sized for window sashes and frames) [21]. Monitoring positions are frame, sash and glazing (Fig. 2). The pattern of the positions is the same on all three windows to make the possibility of direct comparison. Totally 57 thermocouples are used, there are 6 positions on each window on both sides. The datalogger and both sensor types are from Ahlborn. For this measurements the recording interval was five minutes.

Fig. 2. Inside view in the room with test windows. Visible positions of sensors and heat flux plates. Sketch of window with marked position of sensors.

The window properties based on the manufacturer's data are summarized in Table 1. It is good to mention, that "paper" based values complied the nowadays standard values several years ago.

Table 1. Specified properties of measured window based on the manufacturers data.

Material	No. of chambers	Glazing	Gas	Heat gain	U_w	U_f	U_g
				[%]	[W/(m^2 K)]		
Plastic	6	Triple	Ar	36	0.80	1.0	0.5

For the measurement in the climate chamber the 1st march 2018 was selected. The outdoor temperature varied from –3.4 °C during the sunny day up to −16.7 °C during the night. Indoor air temperature was also used. Both temperature courses are shown in Fig. 3.

Measurement in the climate chamber, which is from Weisstechnik, outdoor chamber is WK 7.2´/30–80 and indoor chamber is WK 6.6´/10–50. Two variant of modeling the indoor climate were used, one is with constant indoor temperature and measured with hotbox, another one is without the hotbox application and with the same temperature course as recorded in the pavilion (Fig. 2). Instead of thermocouples for temperature measurement were used PT100 and NTC sensors. Used HFP are similar types as in the pavilion measurement.

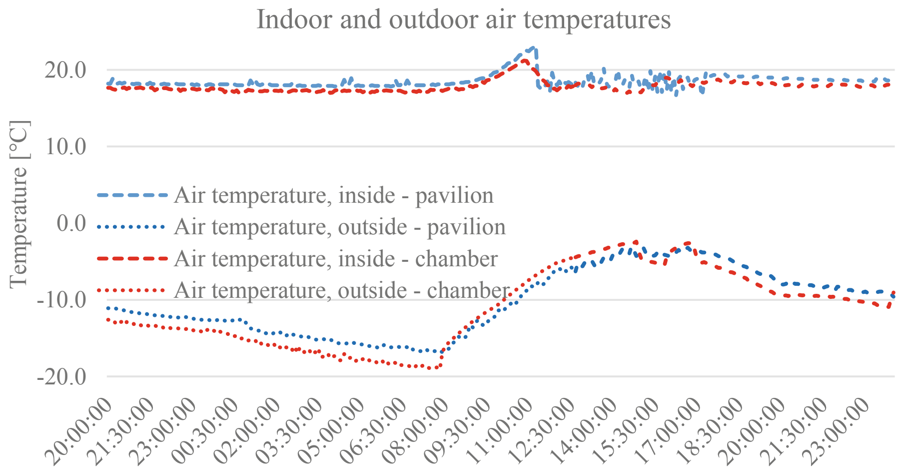

Fig. 3. Temperature courses used for measurement in the climate chamber (red), based on the measurement in pavilion on 28.2–1.3.2018.

3 Results

Results of comparison for individual positions are presented in Figs. 4, 5, 6, 7, 8, 9 and 10. In this case, temperature courses for selected time interval (recorded from 20:00 of 28.2 to 23:59 1.3.2018) were compared. Although there are 6 (9) positions within the window, only 4 specific positions are compared. On the rest of positions are the results similar. Courses are divided to the exterior and interior side of the window.

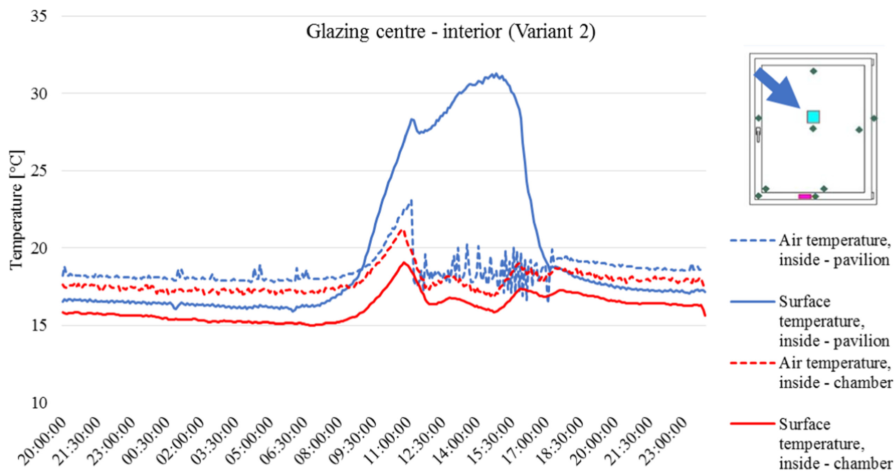

Fig. 4. Temperature courses for Centre of glazing. Very good match of courses in the night (without solar radiation).

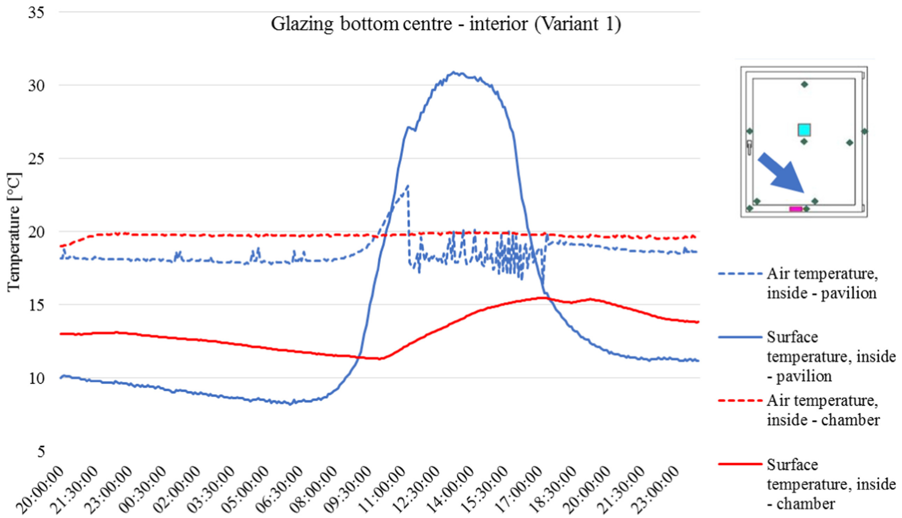

Fig. 5. Temperature courses for bottom of glazing. Variant 1 with constant indoor temperature. Difference about 3 °C on surface temperatures.

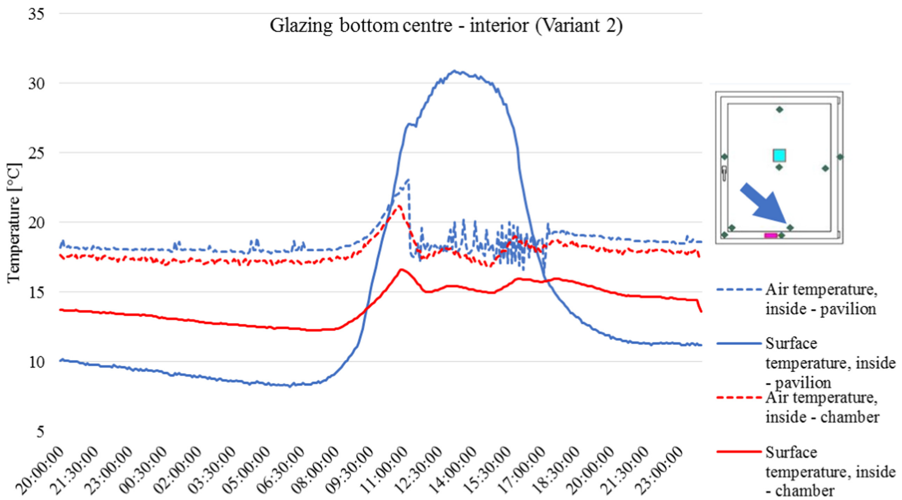

Fig. 6. Temperature courses for bottom of glazing. Variant 2 with non-steady indoor temperature. Difference about 4 °C on surface temperatures.

In Fig. 4 there are temperature courses for centre of glazing from the interior side. Temperatures were measured by the HFP. In Figs. 5 and 6 is the comparison of different indoor temperature. In the first case is steady – constant indoor air temperature used with hotbox in climate chamber. In second figure, non-steady temperature is used as boundary condition in chamber. Figures 7 and 8 showed temperature courses for another positions from indoor side. Figures 9 and 10 showed courses from the exterior for same position as Figs. 4 and 7 for interior.

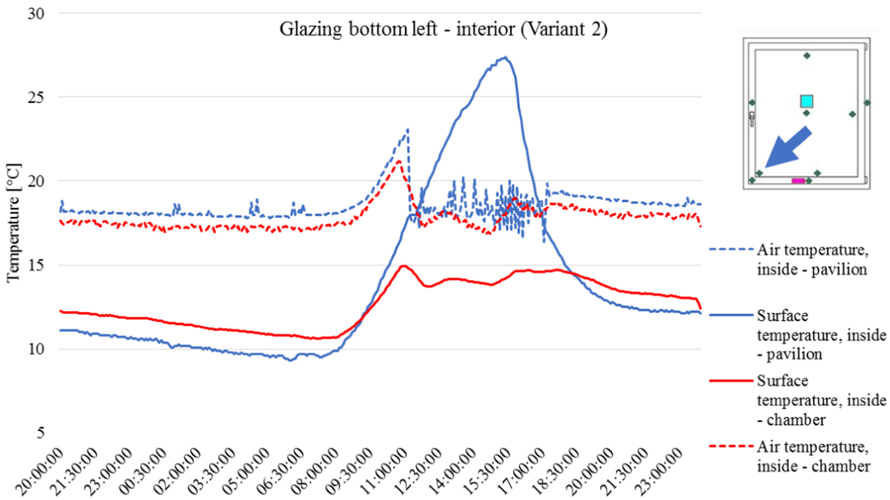

Fig. 7. Temperature courses for left side bottom of glazing. Variant 2 with non-steady indoor temperature. Difference about 4 °C on surface temperatures.

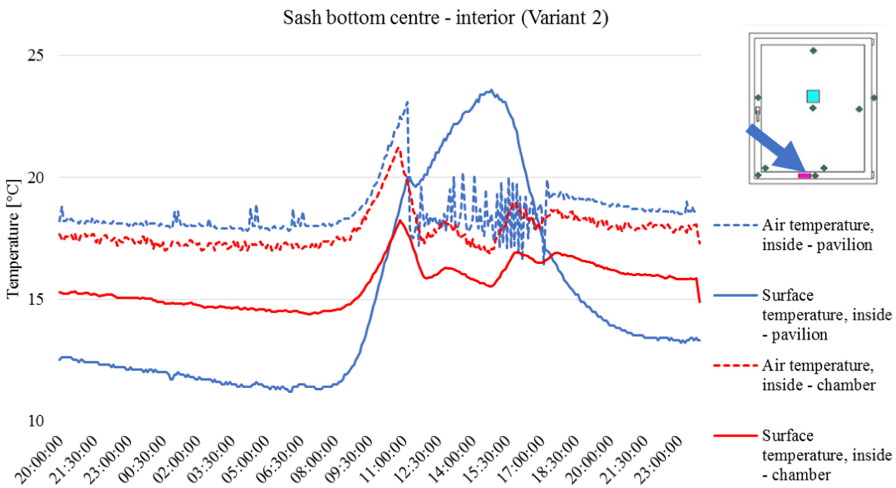

Fig. 8. Temperature courses for bottom of windows sash. Difference about 3 °C on surface temperatures.

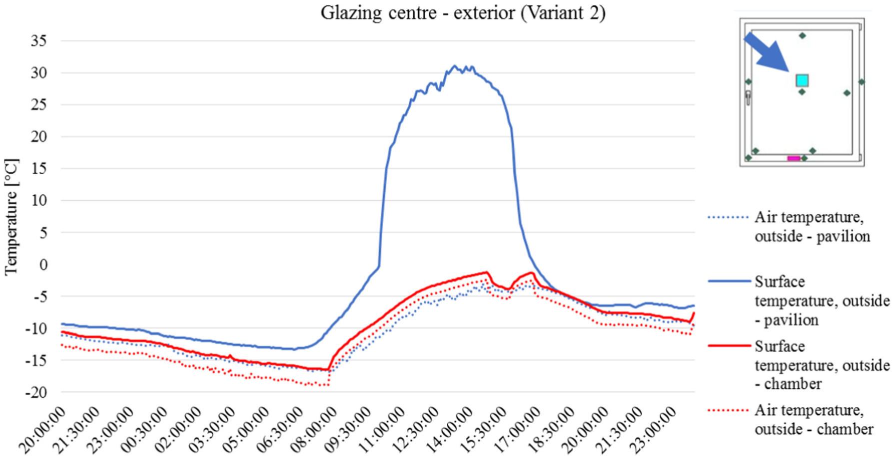

Fig. 9. Temperature courses for center of glazing from the exterior side. Difference about 2.5 °C on surface temperatures.

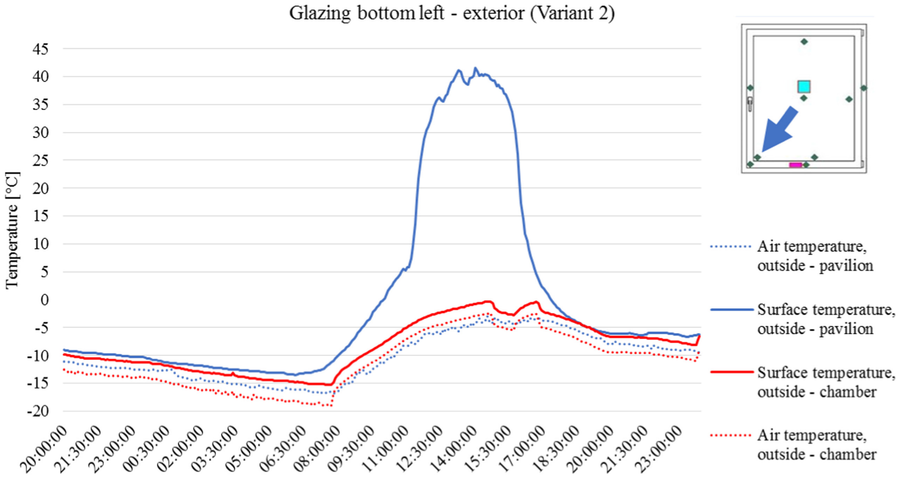

Fig. 10. Temperature courses for left bottom corner of the glazing. Difference about 1.3 °C on surface temperatures.

4 Discussion

Results in general show good course match in terms of shape in all analyzed positions. The influence of global solar radiation during the day was not simulated in the chamber. Therefore it makes sense to compare only the night temperatures.

Match of values, temperatures are quite good for position in the center of glazing, where the difference is about 1 °C. With other positions the difference increased and oscillated between 3–4 °C. Especially at the bottom part of glazing there are the highest differences. This requires further analysis. From the exterior side, differences are from 1.2 up to 2.5 °C. View at the set-up is shown in Fig. 11.

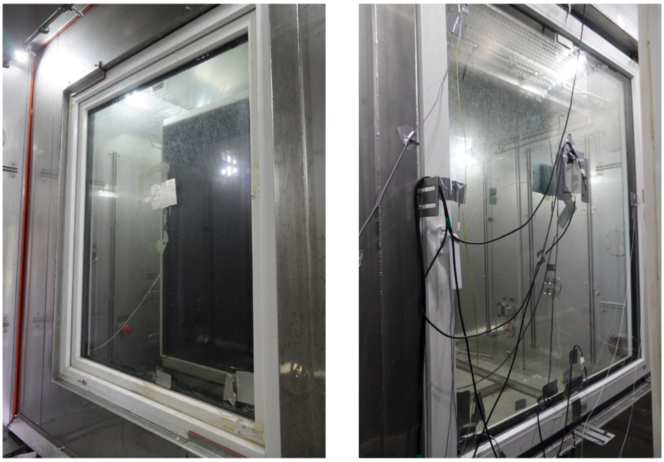

Fig. 11. Window in the masking panel of the climate chamber, left from outdoor chamber without sensors, right from indoor chamber with setup of sensors.

5 Conclusion

This paper deals with comparison of measurement conducted on the same window, which was used for nine years in the pavilion laboratory exposed to the real outdoor climate and after that it was measured in the climate chamber with the same boundary conditions as in selected winter day in year 2018.

Results showed a very good match in the shape of temperature courses and for position in the centre of glazing also in the values, where the difference is relatively small.

Some discrepancies, such as the one with bottom sensors need another analysis, e. g. influence of the masking panel compared to the wall, which has a bigger thickness. This will be a part for the next study with heat fluxes comparison and stating the U_w measured by the hotbox [22].

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