

Article

Analysis of the Effect of Using External Venetian Blinds on the Thermal Comfort of Users of Highly Glazed Office Rooms in a Transition Season of Temperate Climate—Case Study

Małgorzata Fedorczyk-Cisak , Katarzyna Nowak and Marcin Furtak

Faculty of Civil Engineering, Cracow University of Technology, 31-155 Cracow, Poland; knowak@pk.edu.pl (K.N.); mfurtak@pk.edu.pl (M.F.)

* Correspondence: mfedorczyk-cisak@pk.edu.pl; Tel.: +48-696-046-050

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Abstract: Improving the energy efficiency of buildings is among the most urgent social development tasks due to the scale of energy consumption in this industry. At the same time, it is essential to meet high requirements for indoor environmental quality and thermal comfort. The issue of overheating is most often analysed in summer but it also occurs in transition seasons, when the cooling systems do not operate. The paper attempts to evaluate the effectiveness of external mobile shading elements on the microclimate of rooms with large glazed areas in the transition season. Passive solutions, such as shading elements, which limit the increase of indoor temperature, do not always allow the acquisition and maintenance of comfortable solutions for the duration of the season, as demonstrated by the authors. Temporary cooling of the rooms may be necessary to maintain comfortable conditions for the users, or other solutions should be devised to improve comfort (e.g., reduction of clothing insulation characteristics). The novelty of the study consists in the analysis of comfort in a “nearly zero energy consumption” building (NZEB) during a period not analyzed by other scientists. This is a transition period during which heating/cooling systems do not operate. The research task set by the authors involved the assessment of the possibility to reduce office space overheating in the transition season (spring) by using external shading equipment in rooms with large glazed areas. An additional research task aimed at checking the extent to which user behaviour, such as reduction in clothing insulation characteristics, can improve comfort in overheated rooms. The results of the tests reveal that the difference in the ambient air temperature between a room with external venetian blinds and an identical room with no venetian blinds in the transition season, i.e., from 27 March to 6 April 2017, ranged from 12.3 to 2.1 °C. The use of a shading system (external venetian blinds positioned at an angle of 45°) reduced the number of discomfort hours by 92% (during working hours) compared to the room without external venetian blinds. A reduction in the thermal insulation of the clothes worn by people working in the room with no venetian blinds helped to reduce the number of discomfort hours by 31%.

Keywords: thermal comfort; overheating; transition seasons

1. Introduction

The policy of the European Union obliges member states to introduce a new standard of nearly zero energy buildings [1,2]. The implementation of the directive on the energy characteristics of buildings translates onto requirements for buildings set out in the Technical and Building Conditions [3]. Passive buildings have also become more popular in Europe [4,5]. Both standards of buildings are characterised by very low energy demand. Designing such buildings requires wide knowledge of the

discipline [6]. A number of newly designed office and public buildings are characterised by large glazed areas. Despite selecting the correct insulation characteristics for the building structure elements, excess glazing generates large and undesired solar gain especially in summer. As a result of such design solutions, uncomfortable working conditions are created. Therefore, it seems necessary to estimate thermal comfort conditions at each work station in the period of time when overheating occurs in the building. Proposals for system (need for cooling), architectural and building solutions aimed at the reduction of overheating should result from such analyses. The issue of creating and maintaining indoor conditions comfortable for users has already been described in the literature [7,8]. Fanger proposed that the subjective thermal comfort sensation of the users of rooms should be identified with PMV (predicted mean vote) and PPD (predicted percentage of dissatisfied) assessment indices. The method developed by Fanger was incorporated into European standards concerning the thermal comfort of rooms [9–11]. The need to reduce energy consumption for heating and cooling purposes, which has been increasing recently, encourages designers and researchers to carry out more exact analyses for ensuring thermal comfort. Studies are directed towards improving the comfort model [12,13] through a number of experimental tests in laboratories, as well as in real-life objects [14,15]. Many researchers include thermal comfort into indoor environment quality models, additionally taking into account acoustic and lighting comfort and proposing modifications [16–19].

Summing up, low energy consumption must not be the only design criterion. The indoor microclimate is a combined effect of design, building and use of specific rooms. Human activity, clothing insulation and environmental parameters, such as ambient air temperature, mean radiation temperature, air flow rate and relative humidity, affect thermal comfort. Thermal comfort assessment is based on such indices as PMV and PPD.

The paper describes the influence of external shading elements on thermal comfort in premises with large glazed areas. Energy-efficient windows, which are nowadays regularly installed in buildings, are reaching the point where, on an annual basis, heat gains through a window exceed losses. The architecture of contemporary public and office buildings is characterised by highly glazed facades. Even in temperate climate zones, which is where Poland is situated, the solution generates intensive solar gain in the rooms, especially in the southern and western façades. The study of indoor comfort and air quality has been undertaken by a number of research teams in different climate zones [20–22]. The studies have covered different categories of buildings: residential, office, exhibition and entertainment facilities [23–25]. The scope of the studies analysed in the paper has been limited to office premises in buildings with glazed facades. Overheating is a major problem, which occurs in this type of premises. A number of papers [26–28] quote algorithms and guidelines pertaining to the glazing area size depending on material and construction solutions, and location. Creative vision and visual effect tend to be more important for architecture designs. Designers and investors often neglect researchers' recommendations to include glazed elements in small areas of the façades. That is why the purpose of this paper is to evaluate the effectiveness of external mobile shading elements for rooms with large glazed areas. The results presented in [29] showed that the use of shading devices is of great importance in cities, where temperatures and the intensity of solar radiation are high, but it also helps to reduce the demand for cooling in locations of temperate maritime climate. The authors of papers [30,31] analysed the impact of selected shading devices on the heat and lighting characteristics of rooms. Many of the studies are purely simulations. They are usually carried out for the summer or winter periods [32]. In transition seasons in temperate climates there are more cloudless days with a high value of direct solar radiation intensity. The issue of the overheating of rooms in these seasons is not often analysed in the literature.

In Poland's climate zone, energy for heating purposes in buildings with well-insulated structure is supplied from mid-October to mid-March. This is the period when it may be necessary to cool rooms on sunny days. Typically, the cooling system operates from May to September. Simulation analyses and design calculations for the period are used as the basis for selecting the parameters of the outer casing of building partitions and installation systems.

Researchers studying thermal comfort in buildings typically focus on the summer and winter periods when heating and cooling systems are turned on. The novelty of the authors of this article is the analysis of the transition period when the heating or cooling systems of the room do not work. An additional value is the analysis of thermal comfort in a building with “almost zero energy consumption” (NZEB). NZEB buildings comply with the requirements of Directive 2010/31/EU and will be a standard in Europe from 1 January 2021. The article makes a valuable contribution to the design and use of this type of buildings, so that, in addition to the low energy consumption required by regulations, also achieving comfort of use.

Studies on thermal comfort in this article are connected with a transition period in the climate in Poland (spring). The analyzed time is the turn of March and April. At this time, at noon, the solar altitude of the Sun is 38.04° to 49°. This not-too-large angle of the Sun’s height allows for intense penetration of solar radiation into the interior of the room. During this period, heating and cooling systems usually do not work. Most solar energy for the analyzed location is generated in July, June and May. Most thermal comfort tests in buildings are related to summer (cooling) or winter (heating) periods. In the transition periods (spring, autumn) it is assumed for a standard construction to avoid heating or cooling the rooms.

The NZEB building was used for analysis, which by definition should be characterized by good insulation of external partitions, adequate protection against overheating, and a correspondingly low value of energy used for heating and cooling. The authors wanted to show that with modern buildings, with a well-insulated block, strongly glazed passive solutions, limiting the temperature increase in the room, such as shading elements, even for a transitional period may not be sufficient to obtain and maintain comfortable conditions throughout the period, which the article showed the authors. The rooms analyzed were characterized by a large ratio of the glazed area to the floor area of 5.63. The tested rooms are an example of the current solutions of office buildings, characterized by high heat capacity of ceilings, light internal walls and large glazed surfaces.

Avoiding the use of external shading devices due to investment costs results in obtaining thermal conditions uncomfortable for users or the necessity to cool rooms by up to 10 K.

An additional goal of the research presented in the article was to indicate that in the case of objects with a large area of external glazing, the need for cooling should be included in the calculation of energy demand also for spring months. This, of course, is associated with an increase in energy demand indicators for the building and an increase in operating costs.

Tests were carried out in an experimental laboratory building, which serves a public function. The building in which the tests were carried out is situated in the centre of Cracow, among city centre structures. It is a passive technology building, which meets the requirements for nearly zero energy buildings (NZEB) in Poland. It is also an experimental building, designed for performing energy efficiency tests.

The research questions posed by the authors for the studied case are the following:

- How can solar gain affect thermal comfort conditions in highly glazed rooms in the transition season of temperate climates?
- Will the use of external shading devices in highly glazed rooms help to maintain conditions comfortable for users?
- What is the degree of thermal comfort improvement owing to user behaviour involving reduction in clothing insulation characteristics?

2. Materials and Methods

Tests on thermal comfort were carried out in an experimental building of the Krakow University of Technology—Małopolskie Laboratorium Budownictwa Energooszczędnego (MLBE—Energy-Efficient Building Laboratory of Lesser Poland). The MLBE building is dedicated to such experiments. The tests were performed in rooms with the same area 37.2 m², on the second and third floors. The location of rooms P1.06 and P2.04 is shown in Figure 1. The external façade of the selected MLBE rooms was

southward and westward-oriented. This is a glazed façade with a total area of 26.20 m² in each room. Room P2.04 had external mobile shading venetian blinds fitted. Room P1.06 had no shading system (Figure 1).



Figure 1. Location of test room P2.04 (with external venetian blinds) and P1.06 (with no venetian blinds).

The rooms selected for the tests represent typical office premises in office buildings of contemporary design.

The MLBE building was designed to meet the requirements of thermal protection for passive buildings [4]. The experimental MLBE building fulfils the Polish requirements for NZEBs presented in [3]. The thermal insulation parameters of the MLBE building and of the external partitions of passive buildings, and the Polish thermal insulation requirements included in [3] are presented in Table 1.

Table 1. Heat-transfer coefficient U W/(m²·K) for Energy-Efficient Building Laboratory of Lesser Poland (MLBE) building, requirements according to Polish regulations [3] and requirements for passive buildings [4].

Type of Partition	MLBE Building U Parameters W/m ² K	Effective Requirements in Poland WT2017	Requirements for NZEB Buildings in Poland (Since 2021) WT2021	Requirements for Passive Buildings
External walls:	0.11	0.23	0.20	0.15
Roofs and floors:	0.12	0.18	0.15	0.15
Floor on the ground	0.11	0.30	0.30	0.15
Windows	0.8 g = 0.6 [-]	1.10	0.90	0.80

The experimental MLBE building, where tests were performed for the purpose of the study, was divided into 14 independent heating and cooling zones. This means that every zone can be heated or cooled independently. The MLBE building's control system was used to stabilise the conditions in the rooms adjacent to the test rooms. During the experiment, the control system was designed so that a temperature of +20 °C was maintained in the rooms adjacent to the test rooms.

The thermal comfort test presented in the paper was carried out for the transition season when the heating/cooling systems in the rooms were not in operation. The representative period lasted for 11 representative days, between 27 March and 6 April 2017. The representative period was selected with regard to the greatest number of cloudless days with direct solar radiation.

The air was supplied by an Air Handling Unit (AHU) with a recuperator with 90% heat recovery (Figure 2a). The quantity of the air supplied by a system of intake ventilators (Figure 2b) was constant and amounted to 25 m³ per hour (assuming that only one user was present). The supplied air temperature was +18 °C.



Figure 2. (a) View of the Air Handling Unit (AHU) with a recuperator with 90% efficiency. (b) The view of the intake vent grille in room P1.06; the grille is located in the central part of the ceiling.

The test was carried out using two sets of sensors for thermal comfort tests. The set of sensors placed in room P2.04 is shown in Figure 3a,b. The analyzed building is an office building. The building in which the tests were carried out is a building that meets the requirements of the building “with almost zero energy demand” (NZEB). Buildings of this type will be standard in European Union countries from 2021. NZEB buildings are characterized by high wall insulation and high tightness of the building envelope. The building is equipped with a heating and cooling system, the power of which has been calculated assuming that the system works in the summer and winter season. The system was not expected to work during the transition period. Most charts present round the clock measurements, but the detailed analysis focuses on working hours. The rooms analyzed are small office rooms with an area of about 37 m². The research assumed that each room is used by one person between 8.00 a.m. and 8.00 p.m.

The parameters of the sensors are presented in Table 2.

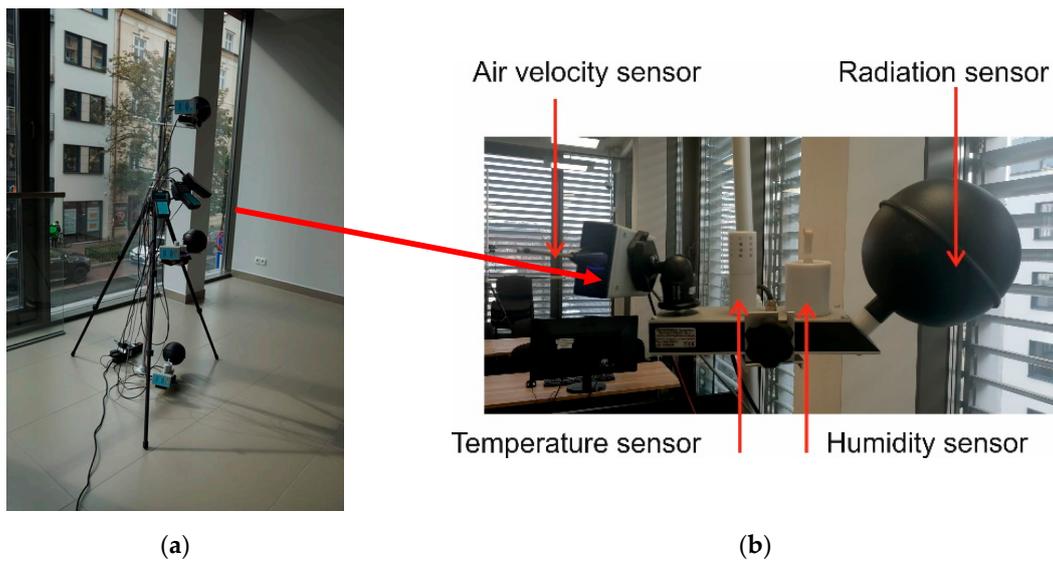


Figure 3. (a) View of microclimate meter. (b) Description of sensors.

Table 2. Sensors' specifications.

Type of Sensor	Measurement Range	Scale	Accuracy
Temperature Sensors	-20 °C + 50 °C (wet thermometer 0 °C + 50 °C)	0.01 °C	±0.4 °C
Humidity Sensors	0–100%	0.1 RH (relative humidity)	±2% RH (relative humidity)
Air Velocity Sensors	0–5 m/s	0.01 m/s	for 0–1 m/s +/0.05 + 0.05 × Va m/s, for 1–5 m/s ± 5%

Figure 4 presents the arrangement of the test equipment in rooms P1.06 and P2.04. The microclimate meter is placed at the intended workstation.

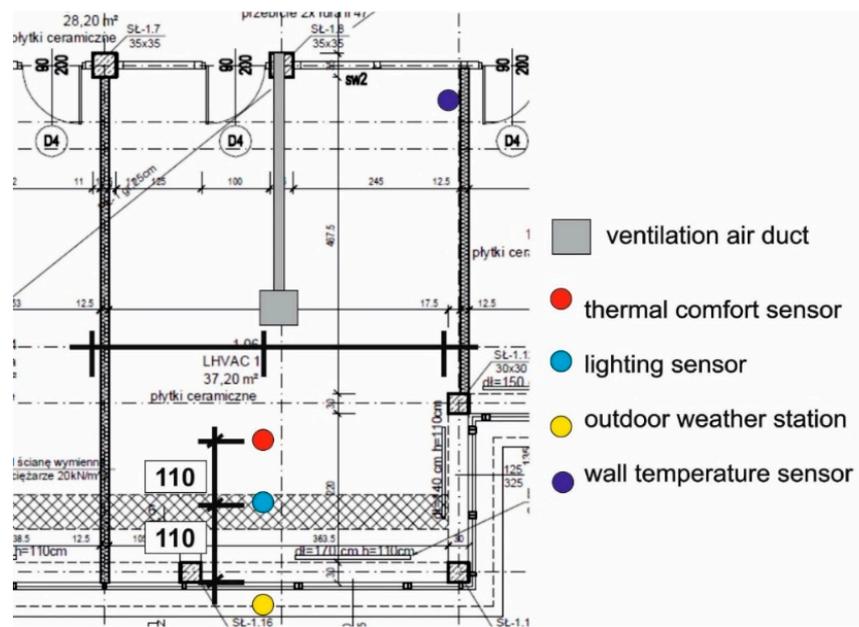


Figure 4. Arrangement of sensors in rooms P1.06 and P2.04.

The tests were carried out using measuring equipment that meets the requirements of the PN-EN 7726 [33] standard. The measuring equipment (Figure 3) is a microclimate meter.

The measured parameters included:

- t_a ambient air temperature;
- t_g temperature of blackened sphere (heat radiation meter)—the black sphere, according to the standards, should have a diameter of 15 cm;
- t_{nw} natural wet-bulb temperature;
- RH relative air humidity;
- V_a air flow rate.

The data were collected every 10 min.

The data from the sensors are given in Table 2.

On the basis of measurements, thermal comfort parameters PMV and PPD were calculated from formulas [9,34,35].

External environmental parameters were collected from weather stations located at the laboratory's south elevation (Figure 5). The weather station recorded the following data (Figure 6):

- Outdoor temperature T_e °C
- Relative humidity (outdoor) RH_e %
- Outdoor air velocity a_e m/s
- Total outdoor radiation intensity I_e W/m²



Figure 5. Weather station on the southern façade.

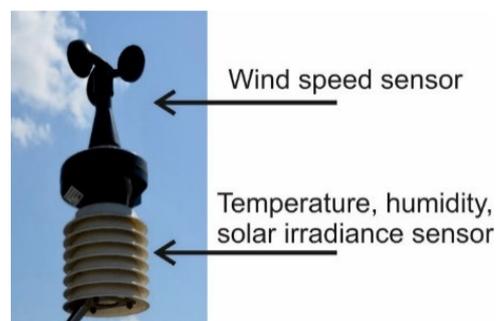


Figure 6. Description of sensors in the weather station.

The scope of measurement and accuracy of the sensors in the weather station are presented in Table 3.

Table 3. Data of weather station sensors.

No.	Location	Measured Parameter	Measurement Scope	Accuracy
1	Weather station on the southern façade	Wind speed a_e m/s	0.00–50.00 m/s (possible max. = 60)	+/-1.0 m/s or +/-5%
2		Relative humidity (outdoor) RH_e %	0 ÷ 90%	+/-3%
3		Relative humidity (outdoor) RH_e %	90 ÷ 100%	+/-4%
4		Outdoor temperature T_e °C	-40 ÷ 60 °C	+/-0.5 °C
5		Total solar radiation intensity i_e W/m ²	0 ÷ 1500 W/m ² (possible max. = 2000)	+/-5%

3. Results

Sunny days with minor cloud cover dominated in the period selected for the analysis, i.e., from 27 March to 6 April 2017. As a result of minor cloud cover, the air temperature during the day was fairly high but low during the night. Figure 7 presents the waveform of locally measured values (weather station on the southern façade) of outdoor air temperature and total solar radiation intensity. In Figures 7–17 the hours of use of the rooms (8 a.m.–8 p.m.) are marked with a rectangle.

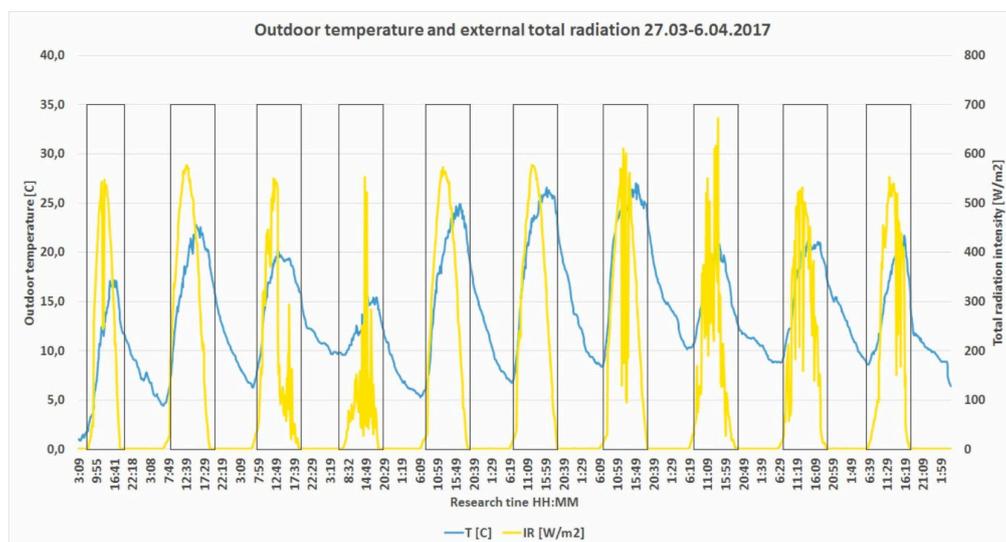


Figure 7. Waveform of outdoor air temperature and total solar radiation between 27 March and 6 April 2017. Measurements were carried out by means of a weather station on the southern façade.

No heating or cooling systems were operated in the test rooms, as was described in the “Materials and Methods” section. The rooms were not used in the reference period and, as such, no internal heat gains were generated. The only external façade of rooms P1.06 and P2.04 is glazed. Other walls were adjacent to the rooms, where there were constant temperature conditions (+20 °C).

3.1. Room P1.06

Figure 8 presents the wavelength of outdoor and indoor temperatures in room P1.06—with no venetian blinds installed.

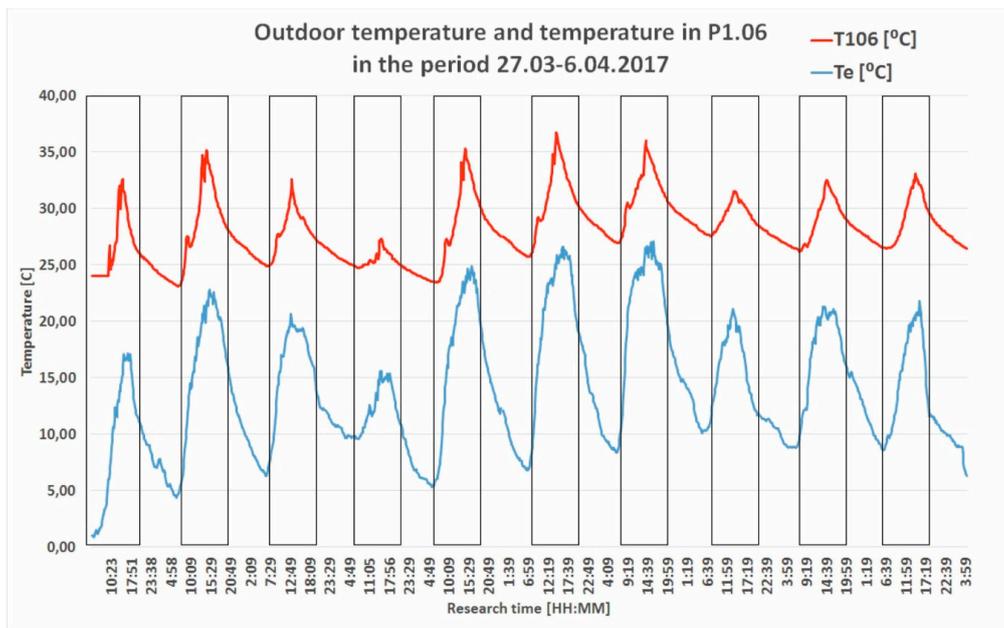


Figure 8. Waveform of outdoor and indoor temperatures in room P1.06—with no venetian blinds installed.

The duration of maximum and minimum air temperature values in room P1.06 corresponds to the wavelength of the maximum and minimum outdoor temperatures. This is shifted by about two hours against the maximum values of solar light intensity for the southern façade.

The ambient air temperature in the analysed room reaches very high values. From 23.25 °C at night, to 35.13 °C in the early afternoon. Despite low outdoor temperatures at night (decreasing to ca. 5 °C), intensive solar radiation during the day (max. value 672 W/m²) contributes to such a temperature wavelength. Another factor which affects temperature distribution in the room is the continuous air supply at a constant temperature of 18 °C and the stabilised temperature conditions in the adjacent rooms (P1.04, P1.07 and P1.10).

Figure 9 presents indoor temperature (T_i), mean radiation temperature (T_r) and operating temperature T_o in room P1.06. The T_r value was identified based on the recorded temperature measurements of a blackened sphere. Significant differences, which sometimes exceed 20%, can be observed.

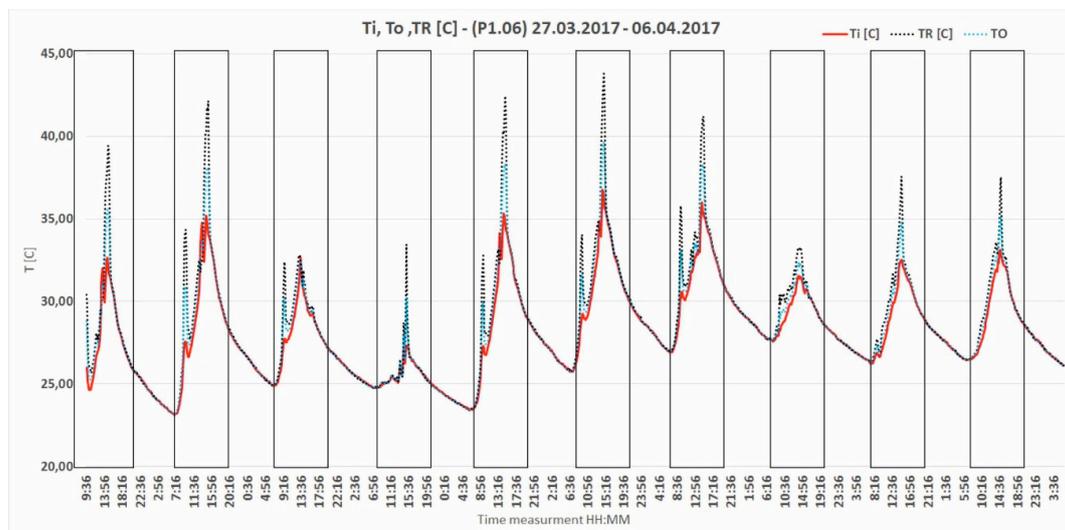


Figure 9. Ambient air temperature (T_i °C) and infrared radiation temperature (TR °C) in room P1.06.

Differences between T_i , T_R and, consequently, the operating temperature T_o are clearly noticeable during the hours of intensive solar radiation. Sample wavelengths of the temperature values for the selected day are presented in Figure 10. At high indoor temperature that day in room P1.06 (26.9 °C–35.6 °C), the operating temperature reached the maximum value of 38.3 °C.

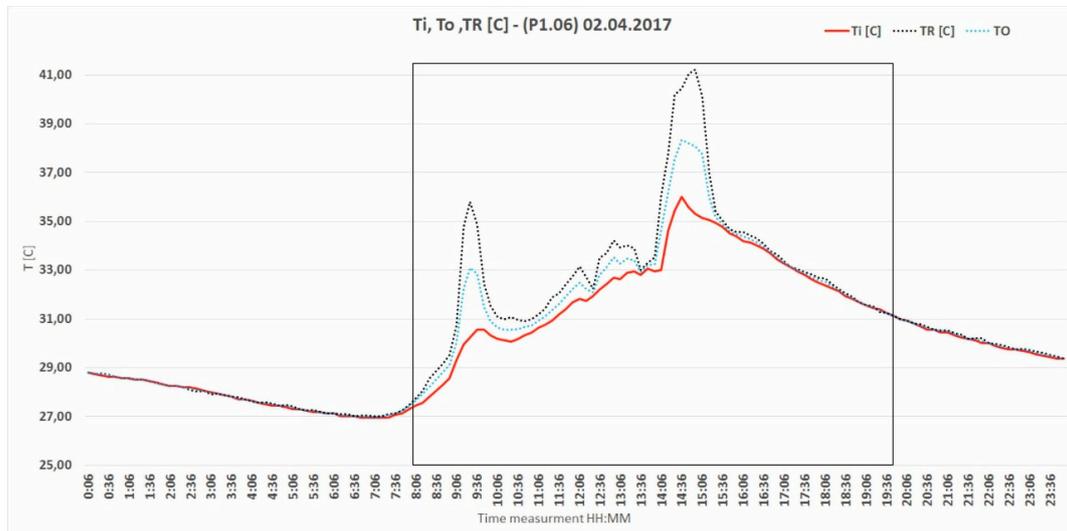


Figure 10. Values of ambient air temperature T_i , mean temperature of a blackened sphere TR and resultant operating temperature T_o (Room P1.06) on 2 April 2017.

3.2. Room P2.04

Room P2.04 is equipped with a system of external sun shading devices—venetian blinds—with panels that can be positioned at any angle. For the entire period of the experiment, the venetian blinds were positioned at an angle of 45°. Figure 11 shows the values of total solar radiation on the southern façade, indoor air temperature in rooms P1.05 and P2.04 and external temperature.

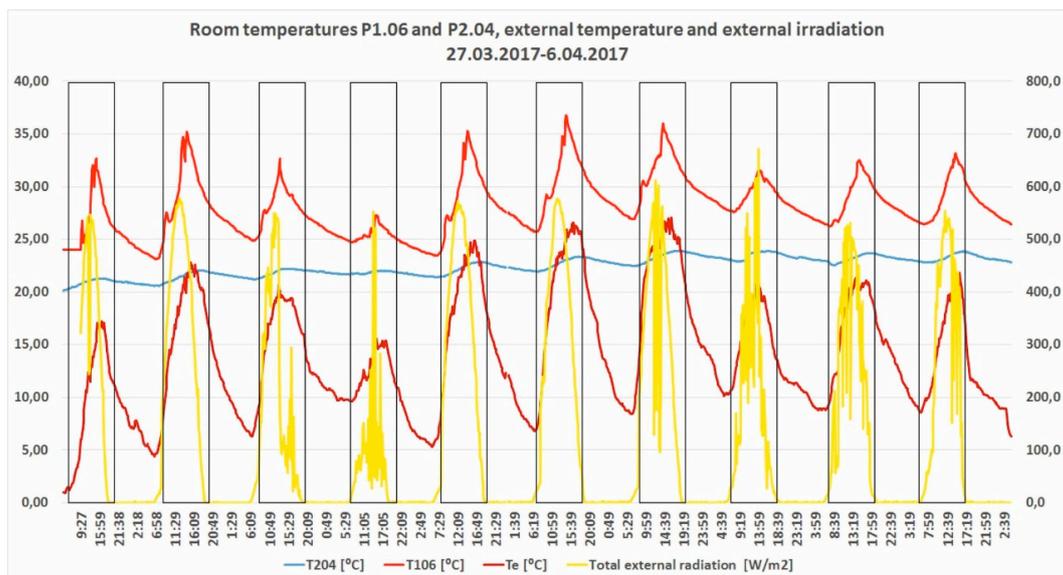


Figure 11. Wavelength of external radiation and indoor temperature in room P2.04—with external sun shading devices.

Figure 12 presents a wavelength of outdoor and ambient air temperatures in room P2.04.

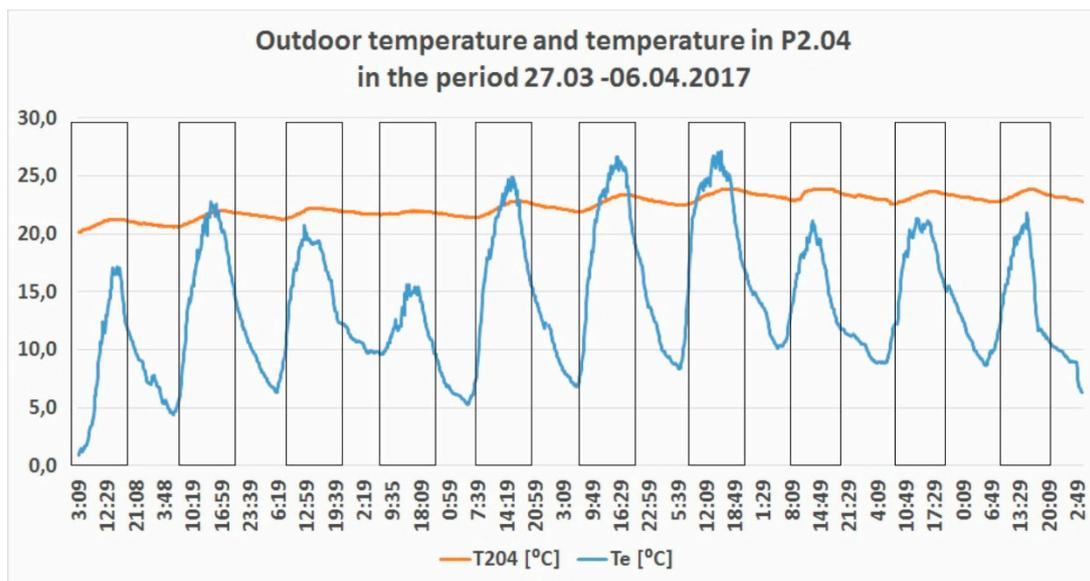


Figure 12. Wavelength of outdoor and indoor temperatures in room P2.04—with external sun-shading devices.

Ambient air temperature in room P2.04 was highly stabilised and ranged from 20.13 °C to 23.80 °C in the analysed period. This result is mainly caused by the significant reduction in solar gain owing to the system of external venetian blinds. The external panels were positioned at a 45° angle towards the windowpane. The nearly unchanged temperature values in room P2.04 were also related to the constant air supply temperature (18 °C) and the stabilised temperature conditions in the adjacent rooms (P2.03, P2.05 and P2.08). Solid reinforced concrete floors with a high heat capacity, limiting the room at the top and bottom, were another factor which alleviated temperature fluctuations.

The maximum temperature in room P2.04 was normally recorded in late afternoon hours. The time difference between the value of the greatest solar radiation intensity and the highest temperature in room P2.04 was up to six hours. This resulted from the position (inclination) of the panels of the external venetian blinds, which protected the room from direct solar radiation gain contrary to room P1.06, which was not equipped with a system of sun shading devices.

As a result of using external sun shading devices in room P2.04, the ambient air temperature distribution and the value of the mean radiation temperature were stable, which contributed to a favourable distribution of operating temperature (Figure 13).

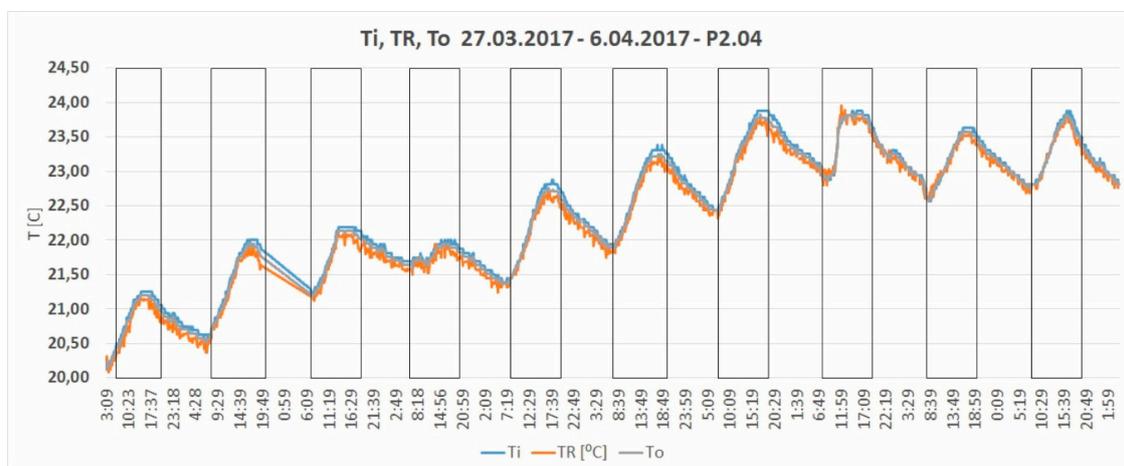


Figure 13. Wavelength of indoor air temperature changes in room P2.04 (T_i) and mean radiation temperature (TR).

In this case, contrary to room P1.06, the values of ambient air temperature T_i , radiation T_R and T_o were similar, even during intensive solar radiation hours. The recorded differences do not exceed 0.25 °C.

The identified mean radiation temperature value for the room with external venetian blinds is lower than the ambient air temperature recorded during that time. The opposite occurs in room P1.06 (Figures 9 and 10), where solar radiation penetration was strong. The mean surface radiation temperature reaches much higher values than ambient air temperature.

Figure 14 presents a wavelength of outdoor and ambient air temperatures in rooms P1.06 (with no venetian blinds) and P2.04 (with external shading devices).

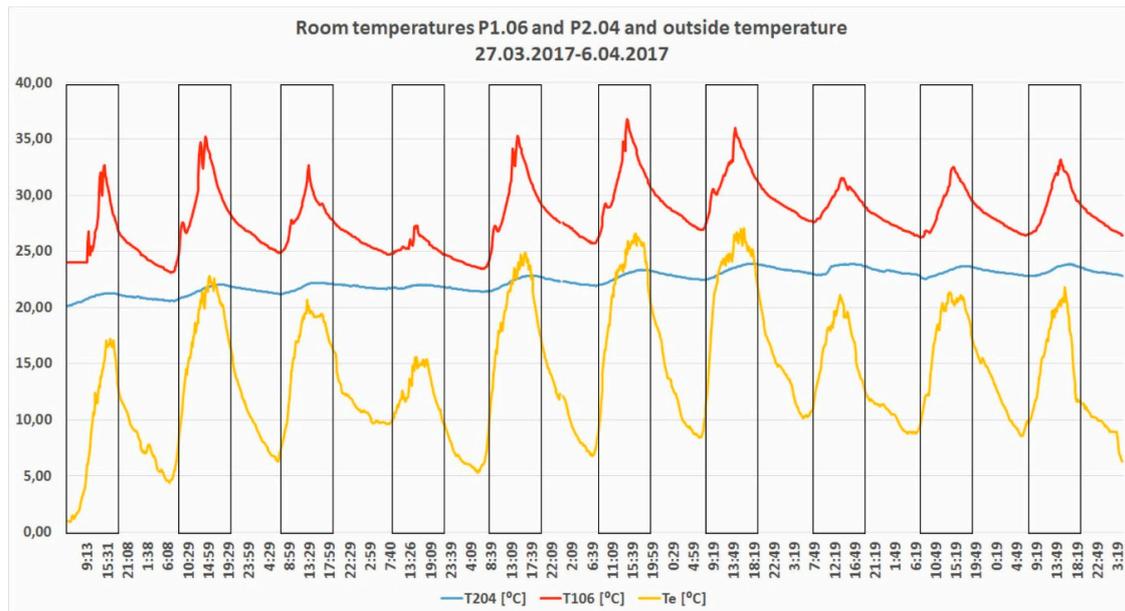


Figure 14. Wavelength of outdoor and ambient air temperatures in rooms P1.06 (with no venetian blinds) and P2.04 (with external shading devices). Visible data gaps are caused by technical problems with the measuring equipment. The sensors had to be submitted for technical inspection.

3.3. Comparison of Results

When identifying thermal comfort indices PMV and PPD, it was assumed for both rooms that their users worked in clothes characteristic for the winter/spring season. The thermal insulation values of the clothing, Clo, were adopted based on standard [9], which applies to people doing office work.

The Clo and Met values adopted for analysis are shown in Table 4.

Table 4. Clo and Met values adopted for thermal comfort analyses for the transition season between 27 March and 6 April 2017.

Room	Clothing Insulation Properties Clo	Metabolism Met
P1.06	1.0	1.21
P2.04	1.0	1.21

The results of analysis and measurements of PMV and PPD comfort indices for both rooms are presented in Figures 15 and 16.

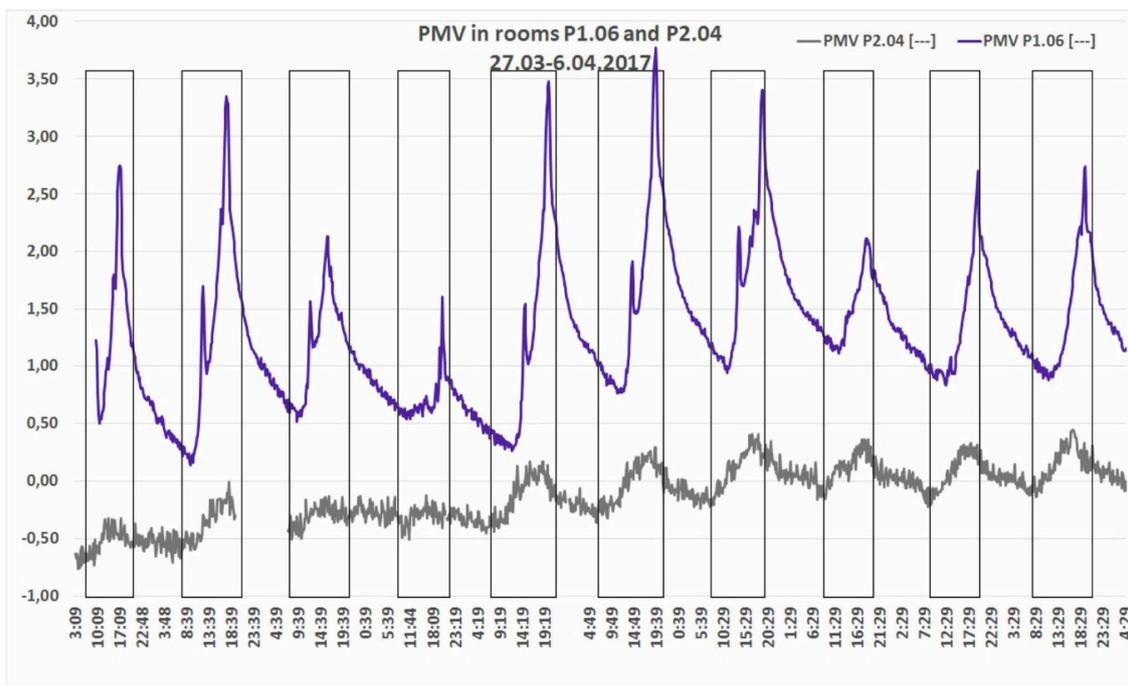


Figure 15. Values of predicted mean vote (PMV) index in rooms P1.06 and P2.04. Visible data gaps are caused by technical problems with the measuring equipment. The sensors had to be submitted for technical inspection.

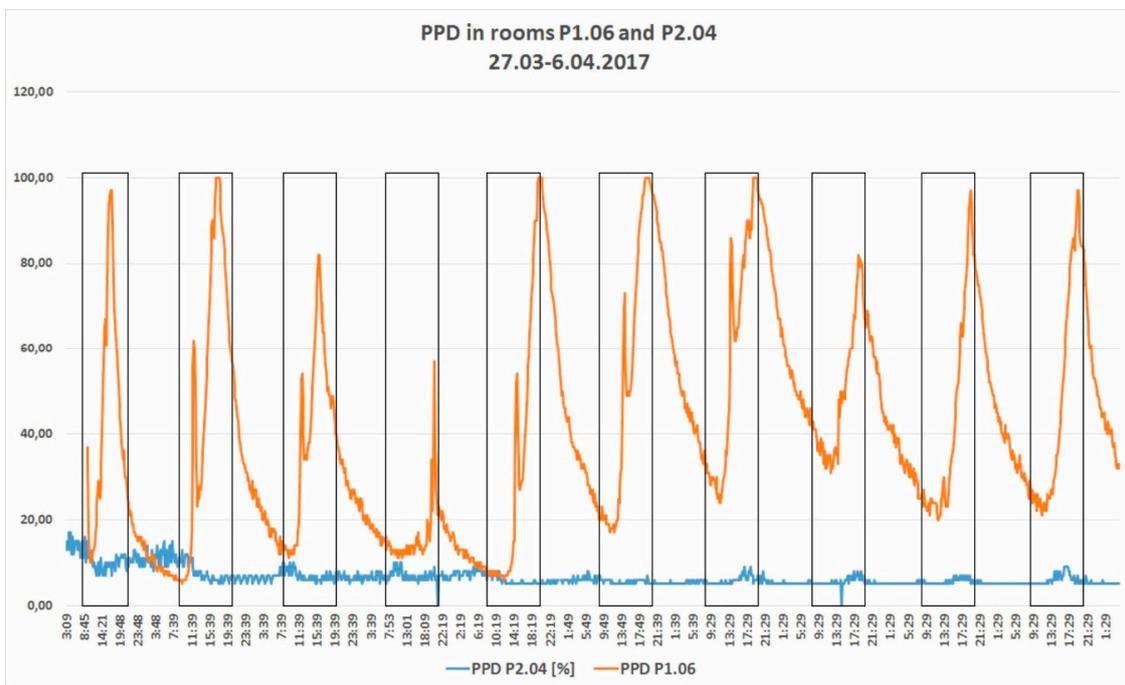


Figure 16. Values of predicted percentage of dissatisfied (PPD) index in rooms P1.06 and P2.04.

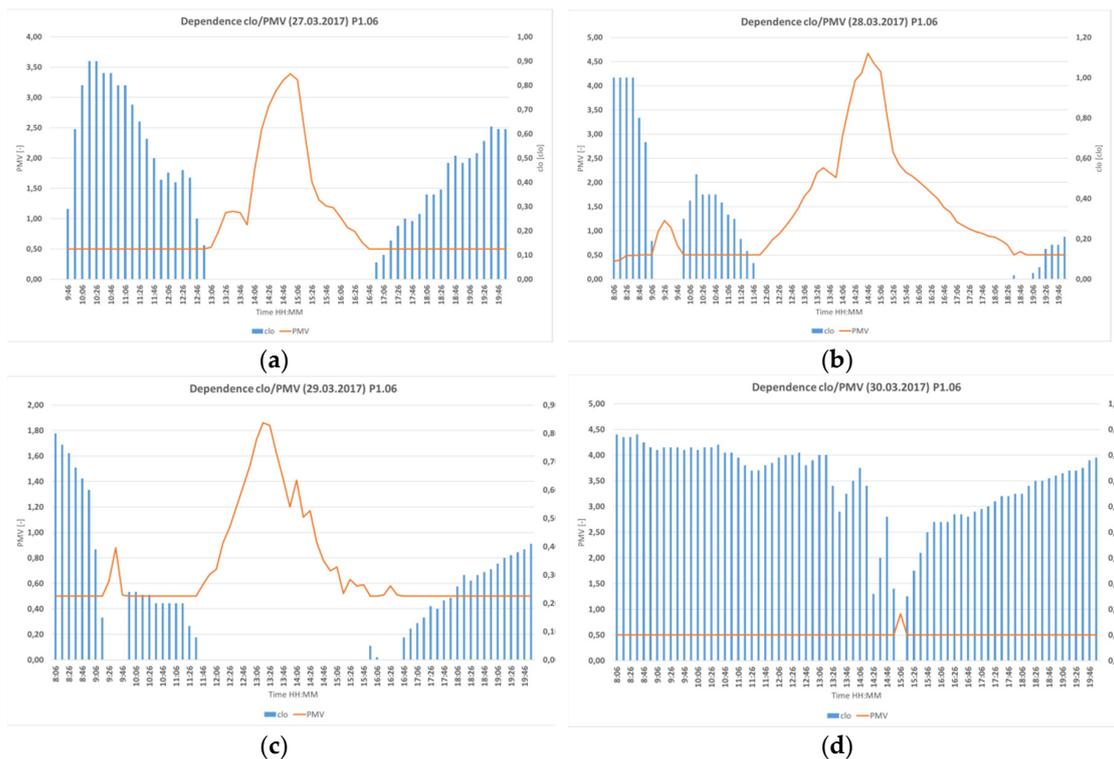


Figure 17. (a) PMV relationship (assumed value: +0.5 [−] P1.06. (27.03.2017); (b) P1.06. (28.03.2017); (c) P1.06. (29.03.2017); (d) P1.06. (30.03.2017).

4. Discussion

The wavelengths of the values of the PMV and PPD indices are presented in Figures 15 and 16. They clearly suggest the high efficiency of the external shading devices. The values of the PMV index in the room with closed venetian blinds ranged from -0.75 to $+0.17$. The percentage of dissatisfied people amounted to 5–17%. This means that the conditions in the room both during the day and at night were nearly perfect. The number of thermal comfort hours in room P2.04 (external venetian blinds installed) in the analysed period was 23, with only nine hours between 8.00 a.m. and 10.00 p.m. These hours can be treated as the office hours, which means that users do not stay in the building beyond them. A large part of the energy consumed by office buildings is used for cooling. This energy can be significantly reduced owing to shading devices. Many researchers have demonstrated the efficiency of such measures through simulations [32,36]. A simulation study in southern Italy, presented in [37], showed the possibility of reducing energy consumption for cooling purposes in highly glazed office rooms with external roller blinds by nearly 50%, compared to rooms with no external roller blinds installed. In the room marked as P1.06 (with no external sun-shading devices), conditions regarded as comfortable lasted for only 16 h. For the rest of the time, temperatures in the range of $27\text{ }^{\circ}\text{C}$ and $35\text{ }^{\circ}\text{C}$ were unacceptable for the users. The maximum PMV value amounts to 3.48 at 100% of dissatisfied people ($\text{PPD} = 100\%$). A number of researchers has studied the behaviour of users of rooms in order to improve ambient air quality, thermal comfort and building performance efficiency (performance improvement). The opening of windows is among such behaviours [38] and [39]. Studies of thermal comfort [40], presented by the team from Harbin, covered transition seasons, in addition to the winter heating season. The behaviours of people aimed at adjusting their thermal comfort were analysed for the spring season, also when heat distribution systems were not in operation. The users of office and residential premises improved their comfort by opening windows, changing the insulation characteristics of their clothing and by drinking more water. Windows were not opened in the rooms of the MLBE building analysed in the paper. The authors analysed the extent to which a change in the insulation characteristics of clothes ($\text{Clo} = 1.0$ assumed in the tests) may contribute to the thermal

comfort experience of the users under the conditions that occurred in room P1.06. The Clo value at which the thermal comfort of users would become neutral was calculated. The results are presented in Figure 17a–d. For selected days (27–30 March), the figures present the Clo value (blue bars) at which the users of the room would have to reduce the insulation characteristics of their clothes to reach an acceptable level of thermal comfort experience. For the analysed office building, the PMV should range from -0.5 to $+0.5$.

Analysing the results presented for sunny days (Figure 17a–c), it can be concluded that despite highly uncomfortable (unfavourable) thermal conditions in the room, user behaviour can improve the comfort experienced. Such improvement is possible in the pre-noon and afternoon hours. At noon and in the early afternoon, no clothing reduction helped to reach comfortable conditions.

On a cloudy day (30 March) with lower solar radiation intensity, comfortable conditions can be reached by slightly changing the insulation characteristics of clothing (clo) to the values of 0.62 – 0.92 (Figure 17d). Only the calculations for the period between 14:00 and 16:00 revealed a significant decrease in the clothing insulation characteristics due to the momentary operation of the sun (Figure 11).

An analysis of the selected period between 27 March and 6 April 2017 revealed that when the users of the rooms with no external venetian blinds changed their clothing insulation characteristics, the number of discomfort hours reduced from 117 to 81 (during the hours of use of the rooms).

5. Conclusions

The building in which the tests were carried out meets the requirements of the building “with almost zero energy demand” (NZEB). Buildings of this type will be standard in European Union countries from 2021. NZEB buildings are characterized by high wall insulation and high tightness of the building envelope. The building is equipped with a heating and cooling system, the power of which has been calculated assuming that the system works in the summer and winter season. The system was not expected to work during the transition period. Studies have shown that in the case of large glazed facades, overheating also occurs during the transition period, especially during cloudless sunny days. Such a building’s response in the analyzed time may contribute to the need to cool the rooms, and thus to increase operating costs.

Highly glazed façades in office rooms may generate significant internal thermal gains even in the transition season (spring). External venetian blinds used in the reference room helped to maintain comfortable thermal conditions ($-0.5 < \text{PMV} < +0.5$). This means that the implementation of such systems helps to reduce or even eliminate energy consumption for cooling purposes.

The aforementioned thesis is confirmed by the thermal comfort conditions observed during the test in the room with no venetian blinds. Despite the same geometry, orientation, use and equivalent schedule of ventilation equipment operation, the thermal comfort conditions obtained ($0.20 < \text{PMV} < 3.70$) varied significantly from those in the room with venetian blinds.

Another conclusion drawn based on the experiment conducted concerns the possibility of the users improving their own thermal comfort experience. Replacing clothes recommended for the heating season ($\text{Clo} = 1.0$) with summer office clothes ($0.25 < \text{Clo} < 1.0$) helped to reduce the number of thermal discomfort hours of employees by 30%. Such actions can reduce the number of operating hours of the cooling system from 12 h to even less than 4 h a day. This was a case study carried out on chilly but sunny days of the transition season.

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