TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO

3-B/2014

KATARZYNA NOWAK*, MAŁGORZATA ROJEWSKA-WARCHAŁ*

THERMAL COMFORT OF OFFICE ROOMS WITH A LARGE AREA OF GLAZING

KOMFORT CIEPLNY POMIESZCZEŃ BIUROWYCH O DUŻEJ POWIERZCHNI PRZESZKLEŃ

A b s t r a c t

The paper presents an attempt at assessing the impact of how the type of construction of a building influences the thermal comfort of office rooms with a large area of glazing, in summer months. The results of simulations are presented for a two-storey office building. The calculations were carried out in the Design Builder program. Simulations were carried out for the climate in Poland, which allowed for assessment of the conditions for the thermal comfort of the building in the spring and summer. The main aim of the analysis was to determine how the material and design solutions as well as the applied glazing and shades influence the protection of the building against overheating and the thermal comfort conditions.

Keywords: *thermal comfort*, *energy – efficient windows*, *overheating rooms*

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

W artykule podjęto próbę oceny wpływu rodzaju konstrukcji budynku na warunki komfortu cieplnego panującego w okresie letnim w pomieszczeniach biurowych z dużymi powierzchniami przeszkleń. Przedstawione zostaną wyniki obliczeń symulacyjnych dla dwukondygnacyjnego budynku biurowego. Obliczenia wykonano przy użyciu programu Design Builder. Dla polskich warunków klimatycznych przeprowadzone zostały symulacje pozwalające na ocenę warunków komfortu cieplnego budynku w okresie wiosenno-letnim. Głównym celem przeprowadzonych analizy było określenie, w jaki sposób rozwiązania materiałowo-konstrukcyjne oraz zastosowane przeszklenia i osłony słoneczne wpłyną na ochronę budynku przed przegrzaniem i na poprawę warunków komfortu cieplnego.

Słowa kluczowe: *komfort cieplny*, *okna energooszczędne*, *przegrzanie pomieszczeń*

* Ph.D. Eng. Katarzyna Nowak, M.Sc. Eng. Małgorzata Rojewska-Warchał, Institute of Building Materials and Structures, Faculty of Civil Engineering, Cracow University of Technology.

1. Introduction

The architectural solutions in modern design office buildings are characterized by large glazed facades. They form large external glazed surfaces and generate high heat losses in winter causing a greater increase of energy demand for the heating of the buildings and influencing the development of unfavourable conditions with regard to thermal comfort in summer.

The parameters that strongly influence the climate conditions in a room are: the air temperature; the temperature of the surfaces of the partitions; the velocity of air movement. They are dependent not only on the architectural and construction solutions such as the thermal capacity of the partitions and the size and type of the glazing, but also on the installation systems and service load of the rooms.

2. The object of simulation calculations

Computational analysis was performed for the two-storey office building in Fig. 1. It is a two-storey building measuring 6.8 m × 18.5 m × 5.4 m. The building has seven offices with a surface area of approximately 18 m^2 each and a conference room with a surface area of 25 m^2. The windows in the rooms are primarily facing the south and their total area is approximately 60% of the facade (Table 1). The northern part of the building is the communication zone in which there are no glazed surfaces provided (Fig. 2)

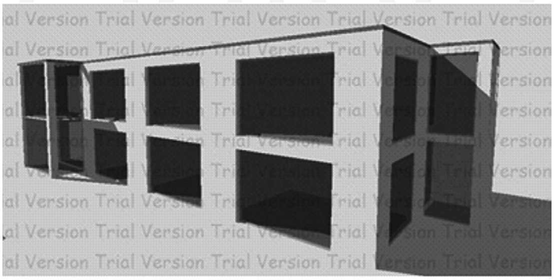

Fig. 1. Building visualization

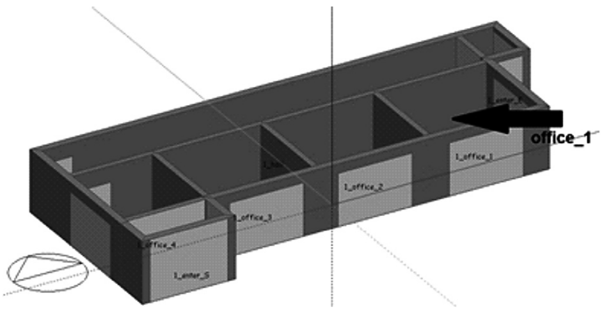

Fig. 2. Building zones visualization

Table 1

Summary of the flooring space and windows in each room

	Ground floor				First floor			
room	office 1	office 2	office 3	office 4	office 1	office 2	office 3	conference room
Flooring area [m^2]	18.7	19.0	18,4	14.3	18.7	18.7	18.7	25.4
Volume[m^3]	50.5	51.3	49.6	38.7	50.5	50.5	50.5	68.58
Window area **S** [m^2],	7.36	7.36	7.36	9.3	7.36	7.36	7.36	9.13
External wall [%]	57	56	58	100	57	57	57	100
Window area **E** [m^2],	6.20	–	–	–	6.20	–	–	–
External wall [%]	58	–	–	–	58	–	–	–
Window area **W** [m^2],	–	–	–	6.90	–	–	–	6.90
External wall [%]	–	–	–	63	–	–	–	41

The building is characterized by proper insulation of individual partitions. They meet the requirements imposed by Technical Requirements [2]. For initial analysis, a window of thermal transmittance $U = 1.1$ [W/m^{2}K] and solar heat gain coefficient of 0.63 were used. The glazing used is characterized by a visible radiation transmittance coefficient of 0.8.

The building has only natural ventilation and is heated by convection heaters with the use of a gas boiler.

Simulation calculations were made with the use of the Design Builder v.3 program. The climate data from the database of the Energy Plus program was used and the calculation simulations were done for a building located in Kraków. The aim of the analysis was to determine the air operative temperature in spring and summer in separate areas of the building depending on the thermal capacity of the rooms and the extent of the glazing. A dominant aspect of the calculations was the assessment of thermal comfort. External heat gains connected with the functions of the rooms were taken into account for the individual rooms and such factors influencing the thermal comfort as the physical activity of the persons working in the rooms and the insulation features of their clothing. The thermal isolation of the clothing of clo = 0.5 was adopted for summer time.

3. The results of the analyses conducted.

The following assumptions were adopted for the purposes of the simulation analysis: offices of 18 m^2 each, 3 persons working from 8.00 in the morning to 7.00 in the evening; a conference room with 10 persons present there from 10.00 in the morning to 2.00

in the afternoon; 3 persons present during the remaining hours; at weekends the building is not in use. An air exchange of 20 m^3/h for person in accordance with norm specifications was assumed.

A comparative analysis was conducted with reference to the described office building constructed using three different types of technology. Two of the variants adopted were two-layer walls with an insulation layer of polystyrene. One variant was a load-bearing wall made of aerated concrete and another was a heavy monolithic concrete wall. The third technology was a light-frame wooden construction. An in-depth analysis was conducted concerning the office rooms located on the first floor with the glazing facing south and east (Office_1) – Fig. 2.

Table 2

A summary of the thermal capacity of individual rooms in the analysed technologies

	Ground floor				First floor			
room	office 1	office 2	room	office 1	office 2	room	office 1	office 2
	Enclosure – aerated concrete							
Heat capacity [kJ/K]	4709	4780	4658	3865	4244	4244	3718	5627
Heat capacity/area	251.82	251.57	253.15	270.28	226.95	226.95	198.82	221.54
	Enclosure – concrete							
Heat capacity [kJ/K]	10518	10099	9853	8368	13272	13272	12732	17643
Heat capacity/area	562.46	531.5	535.5	585.17	709.73	709.73	680.86	694.61
	Enclosure – light core							
Heat capacity [kJ/K]	3409	3365	3269	2683	2276	2276	2144	2961
Heat capacity/area	187.31	177.1	177.66	187.62	121.71	121.71	114.65	116.6

The initial simulations for the construction of light aerated concrete that were carried out allow for a positive assessment of the thermal comfort of this room through the whole period tested (Fig. 3).

Based on the results presented in Fig. 3 it may be observed that, during the period from 15 May to 15 September, there are days when the PMV thermal comfort index reaches short-term values of much over 5. Such conditions of the microclimate in the building greatly exceed the optimum temperature for summer which is 25ºC and the recommended value of the coefficient $-0.5 < PMV < +0.5$.

During the period which was analysed, the greatest thermal load caused by the external temperature for the location in Kraków takes place in the first half of August. The coolest days

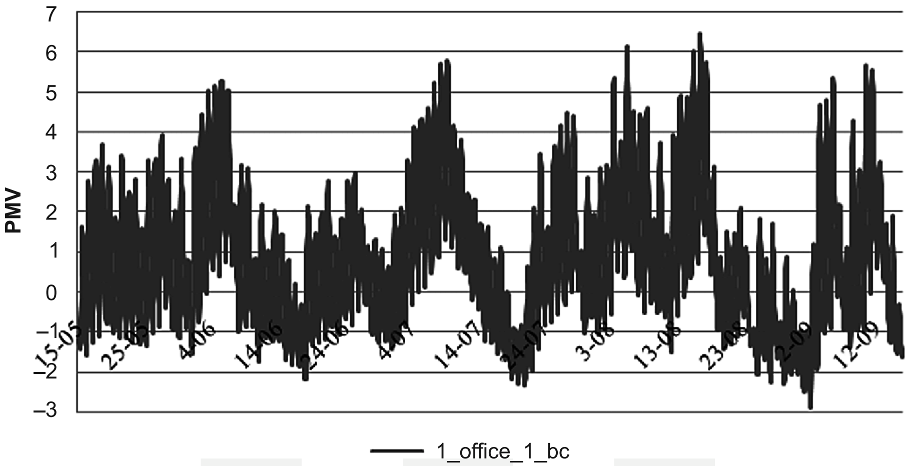

Fig. 3. Hourly flow of the PMV comfort index for an office room (Office_1) in the period from 15 May to 15 September

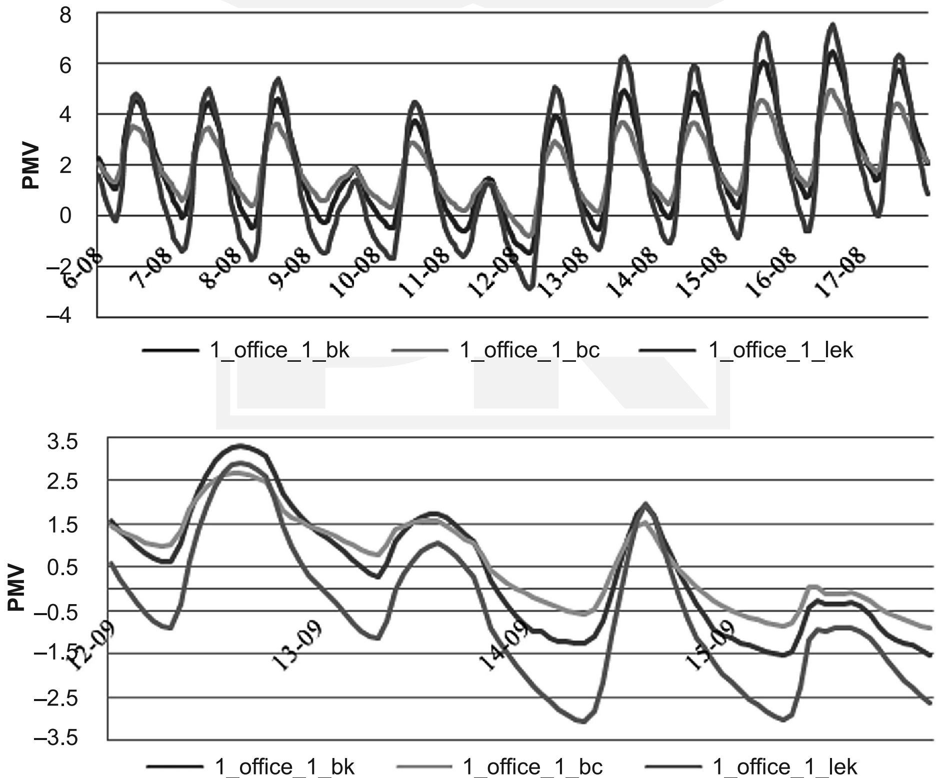

Fig. 4. Hourly flow of the PMV comfort index for an office room (Office_1) in the period from 6 August to 17 August and from 12 September to 15 September

come in the second half of September. Hourly graphs for the analysis, both of the operative temperature that may be in the room, and for the flow of the PMV thermal comfort index for the cases studied were shown for the period from 6 August to 17 August and for the period from 12 September to 15 September.

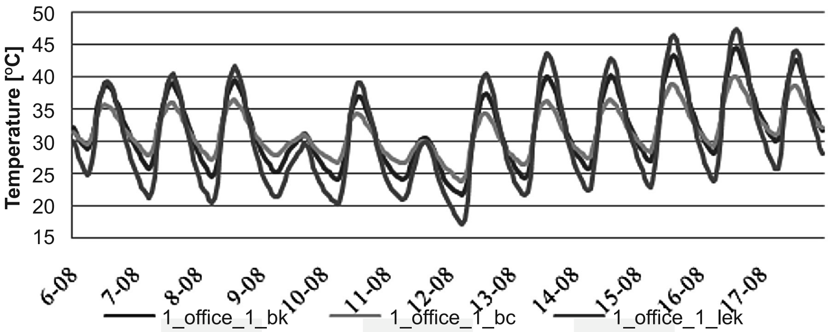

Fig. 5. Hourly flow of the operative temperature for an office room (Office_1) in the period from 6 August to 17 August

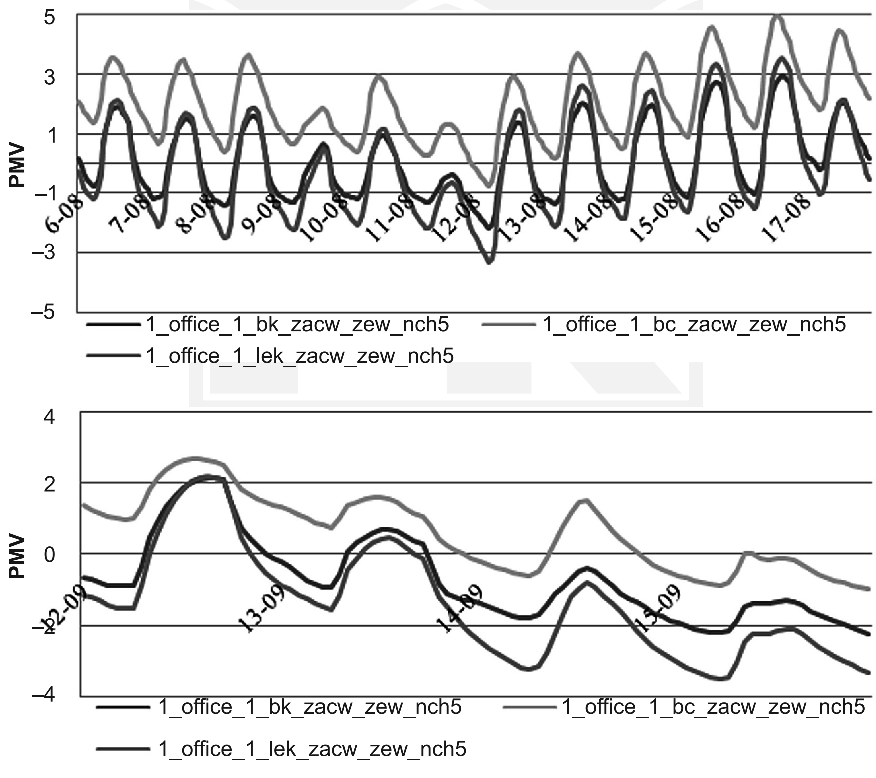

Fig. 6. Hourly flow of the PMV comfort index for an office room (Office_1) with shading and night cooling in the period from 6 August to 17 August and from 12 September to 15 September

In order to observe the influence of the heat capacity of the construction on the possibility of shaping the internal microclimate, in Fig. 4 and 5 the authors prepared a summary of comparative flows of the PMV thermal comfort index and the operative temperature for all the analysed technologies.

The results of the simulations presented in Fig. 4 and 5 show that in the complex conditions of usage, the most favourable parameters of the microclimate are present in a building with a heavy construction of monolithic concrete.

For the existing buildings, a crucial aspect is the actions which allow for a decrease in the operative temperature in the rooms. Such activities include the possibility of intensive ventilation of the premises at night time and the possibility of using shades. In order to perform an assessment of the influence of those actions, simulations were performed that took into account the night ventilation in the amount of 5 exchanges of air per hour in the rooms.

The limitation of solar gain was achieved through the use of both external and internal shades. The results of the simulation are presented in Fig. 6.

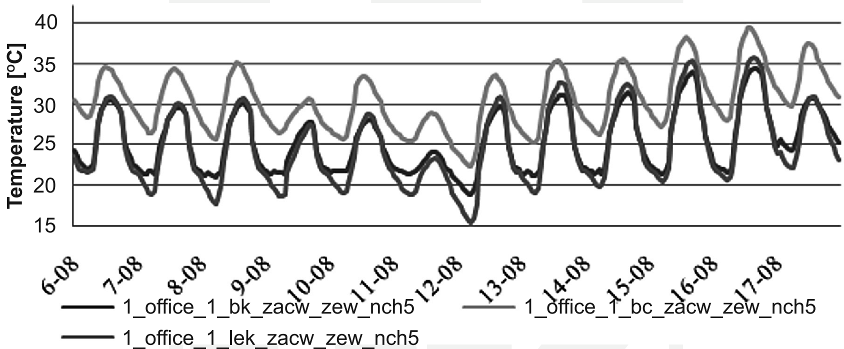

Fig. 7. Hourly flow of the operative temperature for an office room (Office_1) with shading and night cooling in the period from 6 August to 17 August

The results of the simulation presented in Fig. 6 and 7 show that in the case of greater limitation of the solar gains and intensive night ventilation, partitions of a lower thermal capacity are a more beneficial solution.

4. Conclusions

Many newly designed office buildings and buildings of public service are characterized by extensive glazing, despite the use of appropriate insulation of separate elements of a building, the size of the glazing generates solar gains that are too big in summer and so create uncomfortable working conditions.

When such architectural solutions for the facades are proposed, it seems necessary to determine the conditions of thermal comfort not only for the whole building, but especially for particular work stations at the stage of developing the concept of the building.

The results of the simulations that are presented in the article constitute an initial stage of the work on the impact the thermal capacity of housing, the type of the glazing how to limit the availability of solar gains on the thermal comfort in the rooms with extensive glazed surfaces.

This stage of the studies and analyses allows the following conclusions to be posed:

1. In the case of the application of the solutions that limit thermal gains, it is more beneficial to use construction solutions of lower thermal capacity. Such building enclosures enable the dynamic reaction of the partitions to the change of environmental conditions.
2. With an extensive surface of glazing in a building it is necessary to apply solar shadings in order to achieve comfortable thermal conditions.
3. The lack of shading systems (external or internal) may result in the necessity to cool the in order to avoid overheating.

The work reported in this paper has been partially funded by the project L-1/115/DS/2013.

References

[1] PN-EN ISO 7730 Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria.

[2] Rozporządzenie Ministra Transportu, Budownictwa i Gospodarki Morskiej z dnia 5 lipca 2013 r. zmieniające rozporządzenie w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie.

[3] Lyons P. Arasteh D., *Window Performance for Human Thermal Comfort 2000*, ASHRAE Winter Meeting, Dallas, TX, February 5–9, 2000 LBNL-44032TA-412.

[4] Huizenga Ch., Zhang H., Mattelaer P., Yu T, Arens E., Lyons P., *Window performance for human thermal comfort*, Final Report to the National Fenestration Rating Council, February 2006.

[5] Nowak K., Nowak-Dzieszko K., Rojewska-Warchał M., *Thermal comfort of the rooms in the designing of commercial buildings*, Research and Applications in Structural Engineering, Mechanics and Computation. SMEC Cape Town, 2013, 651-652.

[6] Nowak K., Nowak-Dzieszko K., Rojewska-Warchał M., *Thermal comfort of individual rooms in the design of commercial buildings*, 2nd Central European Symposium on Building Physics, Vienna, Austria, September 9–11, 2013, 343-349.