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INFLUENCE OF SHADING SYSTEMS ON THE MICROCLIMATE CONDITIONS IN LARGE PANEL BUILDINGS

WPŁYW ZACIENIEŃ NA WARUNKI MIKROKLIMATU W BUDYNKU WIELKOPŁYTOWYM

A b s t r a c t

The thermal comfort conditions of multi-family buildings, including large panel buildings, are rarely analyzed. Simulations of large panel buildings conducted by authors in the Design Builder program show very unfavorable microclimate conditions in buildings after thermal modernization. The simulation results of the influence of internal and external shadings on the thermal comfort of dwellings in multi-family large panel building are presented in this article.

Keywords: *large panel building*, *internal and external shading system*, *thermal comfort of the panel buildings*, *PMV* (*Predicted Mean Vote*), *PPD* (*Predicted Percentage of Dissatisfied*)

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

Warunki komfortu cieplnego wielorodzinnych budynków mieszkalnych, w tym budynków wielkopłytowych, są analizowane bardzo rzadko. Symulacje budynków wielkopłytowych przeprowadzone przez autorów w programie Design Builder wykazały bardzo niekorzystne warunki mikroklimatu w budynkach po termomodernizacji. W artykule przedstawiono wyniki symulacji wpływu zacienień wewnętrznych oraz zewnętrznych na komfort cieplny lokali mieszkalnych w wielorodzinnym budynku wielkopłytowym.

Słowa kluczowe: *budynek wielkopłytowy*, *zacienienia zewnętrzne i wewnętrzne*, *komfort cieplny w budynkach wielkopłytowych*, *PMV*, *PPD*

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1. Description of problem

In considering and designing thermal modernization, no one takes into consideration the thermal comfort and overheating issues which seem to be very important from the occupants' point of view. The thermal modernization of the large panel buildings is usually limited to the insulation of external walls and the replacement of windows, which significantly reduces the energy demand. Unfortunately, those treatments negatively affect the microclimate conditions inside buildings. The modernization process should be more complex and solutions for reducing the problem of overheating should be taken into consideration. The usage of internal and external shading was analyzed based on the simulations conducted in the Design Builder program.

Analysis of thermal comfort is based on international standard 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" [1].

2. Description of analyzed building

Conducted simulations allowed the influence of internal and external shadings on the thermal comfort in the particular parts of the analyzed five-storey large panel building to be analyzed. The simulations were conducted for a part of a W70 multi-family panel building – basement below entire building, flat roof. Visualizations of different building elevations are presented in Fig. 1.

The building has natural ventilation and a central heating system with convection heaters. There is a communication area located in the central part of each building level. In the analyzed part of the building, there are three flats on every level. Exterior walls made of prefabricated panels in the W70 system, insulated with 15 cm of styrofoam with plasters at both sides: $U = 0.20$ [W/m^{2}K], double glazed windows: $U = 1.5$ [W/m^{2}K]).

Fig. 1. South-east and south elevations of analyzed building

The calculations were carried out in the Design Builder v.3. This program has been specifically developed around Energy Plus allowing the simulation of the building envelope and building interiors. The simulations conducted for the Polish climatic conditions (building located in Cracow) allowed for the evaluation of the microclimate conditions of the entire building as well as of particular dwellings.

3. Simulation settings

The main aim of simulations was to determine the temperature and PMV index of the particular flats at different elevations during the summer months. Figure 2 presents a typical arrangement of dwellings on the building storey.

Every single flat was modeled as a separate thermal comfort zone due to the small usage area of different flats. It was assumed that the doors between rooms are usually opened. Three different flats were analyzed:

1. Flat M1 – usage area 56 m^2, balcony at south elevation.
2. Flat M2 – usage area 31 m^2, balcony at south elevation.
3. Flat M3 – usage area 36 m^2, balcony at east elevation.

Fig. 2. Typical zones' visualization at every building level

According to the recast to the European Energy Performance of Buildings Directive, buildings designed and modernized after 2021 should be zero-energy buildings. In connection with those provisions, since 1st of January 2014, the new requirements regarding building envelope thermal insulation were introduced in Warunki Techniczne 2013 [4]. According to those regulations, thermal transmittance U of the heated building components cannot exceed 0.25 W/m^2K and after 1st of January 2021, 0.2 W/m^2K.

The starting point for further analyzes was the simulation of the building with the external walls modernized to the standard being in force since 2021.

The assumptions for the simulations:

1. Heating system on from September to March (22°C), 7 days a week, 24 hours a day.
2. Occupancy density: flats – about 1 person per 15 m^2,
3. Operating schedule: flats – 100% occupancy density between 4 pm and 7 am, 5 days a week; between 6 pm and 9 am at the weekends; 50% reduced occupancy between 9 am and 6 pm.
4. Metabolic activity: 1.2 met, winter clothing – clo = 1.0, summer clothing clo = 0.5.
5. Ventilation requirements per polish national standards PN-83/B-03430 [2], in every flat 70 m^3/hour for kitchens and 50 m^3/hour for bathrooms.

Table 1 presents the number of discomfort hours in the analyzed period of time between 15th of May and 15th of September hours in all analyzed dwellings on different levels. In this particular period of time in Poland, there is the highest risk of overheating.

Table 1

Number of discomfort hours for all analyzed flats at different levels

		Number of overheating hours
M1	1st level	946
	2nd floor	1235.5
	3rd floor	1477
	4th floor	1746.5
M2	1st level	1391.5
	2nd floor	1916
	3rd floor	2225.5
	4th floor	2392
M3	1st level	1377
	2nd floor	1718
	3rd floor	1985
	4th floor	2153.5

The worst thermal conditions can be observed on the fourth level in flat M2 at the south-east corner of the building. The total number of hours in the analyzed period of time is 2952 which means that for more than 80% of hours in flat M2, temperatures are above the acceptable value of 25°C. Those conditions are very uncomfortable for the occupants. In practice, those hours are being lessened by night cooling of the internal space through the opening of windows. At the lowest levels however, due to security reasons, this kind of solution cannot be used widely.

In many flats, occupants use the internal shading systems (shading panels) to decrease the solar gains. In the next step of simulations, the influence of internal shadings on the microclimate conditions was analyzed.

Figures 3a and 3b present the number of overheating hours for flat M2 at different levels with and without internal shading. The number of discomfort hours decreased as follows:

- at the first floor – from 1391 to 1307 – 6% decrease,
- at the second floor – from 1916 to 1829 – 5% decrease,
- 3rd floor – 2225 to 2126 – 4% decrease,
- 4th floor – 2392 to 2348 – only 2% decrease.

Internal shading systems only slightly decreased the number of overheating hours.

The next step of simulating the external shading system consisted of four steel louver blades (width 20 cm) covering 1m height of all windows. This solution again improved the thermal comfort conditions and decreased the number of overheating hours. Table 2 shows the number of overheating hours in three simulation steps.

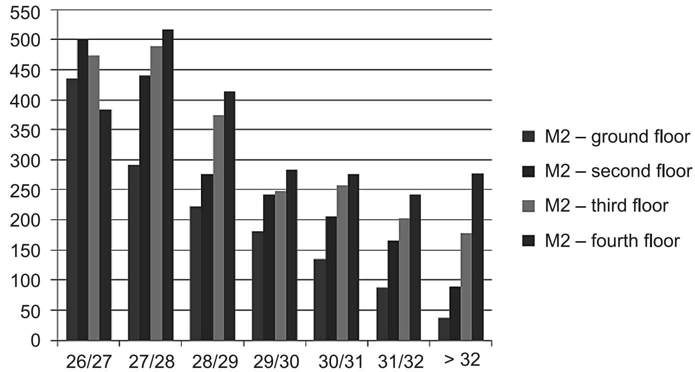

Fig. 3a. Number of overheating hours for flat M2 at different levels – without any shading

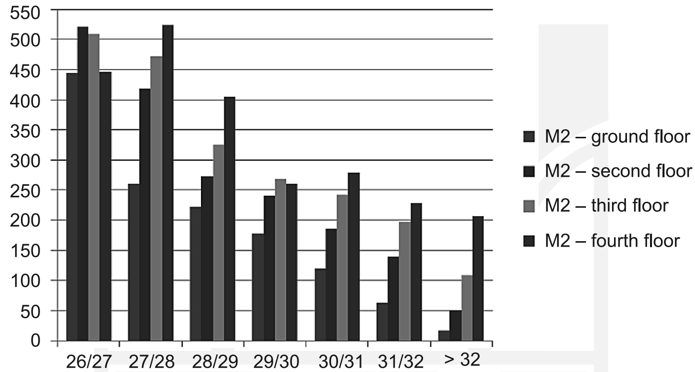

Fig. 3b. Number of overheating hours for flat M2 at different levels – with internal shading

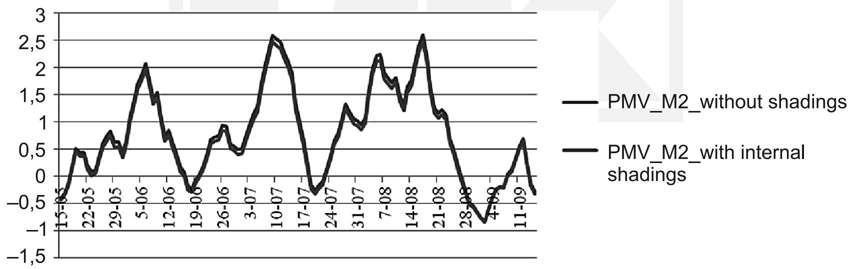

Fig. 4. PMV comfort indexes for flat M2 without any shading and with internal shading system

In case of flat M2 on the fourth floor, the number of discomfort hours was lessened by a further 2%, which gives a total decrease of only 4% from 2392 to 2304.

The most significant improvement of thermal conditions, about 14% decrease of discomfort hours from 1235.5 to 1064, can be noticed in flat M1 due to the biggest usage area of this particular flat. However, this is still not a considerable improvement compared to the installation cost of external shading systems.

T a b l e 2

Number of discomfort hours for all analyzed flats without any shading, with internal shading and with both internal and external shading systems

		Number of discomfort hours – without any shadings	Number of discomfort hours – with internal shadings	Number of discomfort hours – with internal and external shadings
M1	1st level	946	891,5	836,5
	2nd floor	1235,5	1135,5	1064
	3rd floor	1477	1388,5	1314
	4th floor	1746,5	1656,6	1581,5
M2	1st level	1391,5	1307,5	1218
	2nd floor	1916	1829,5	1727
	3rd floor	2225,5	2126	2055,5
	4th floor	2392	2348	2304
M3	1st level	1377	1305	1246
	2nd floor	1718	1638,5	1572,5
	3rd floor	1985	1916	1852,5
	4th floor	2153,5	2081	2038,5

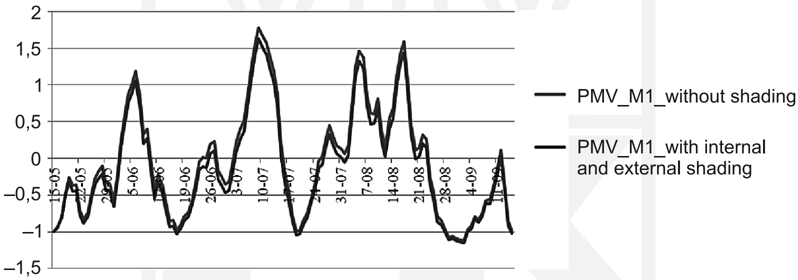

Fig. 5. PMV comfort indexes for flat M1 without any shadings and with internal and external shading systems

4. Conclusions

The results of the conducted analysis show that the microclimate conditions in all flats of the building after thermal modernization are very uncomfortable and the parameters describing thermal comfort exceed the acceptable values. Using different shading systems, internal and external ones, only slightly reduce the number of overheating hours during summer months. The smaller the usage area of the analyzed dwelling, the lower the reduction of discomfort hours.

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