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THRMAL COMFORT OF THE INDIVIDUAL FLATS OF MULTI–FAMILY PANEL BUILDING

KOMFORT CIEPLNY MIESZKAŃ W BUDYNKU WIELKOPŁYTOWYM

Abstract

The paper presents the results of the annual computational simulations conducted for the W70 panel building. The calculations were carried out in the Design Builder program which allows preparing the simulation of the building envelope as well as the separate parts of the building interior. It is very rare to considerate the requirements connected to the overheating effect in the panel buildings. This issue is closely related to the thermal comfort in the building, especially during the summer months. Based on the conducted simulations, authors indicated the influence of building orientation, individual flat location and thermal insulation on the thermal comfort in the different flats of prefabricated panel building.

Keywords: panel building, W70 system, thermal comfort of the panel buildings, PMV (Predicted Mean Vote), PPD (Predicted Percentage of Dissatisfied)

Streszczenie

W artykule zostały przedstawione wyniki symulacji komputerowych przeprowadzonych dla budynku wielkopłytowego wzniesionego w systemie W70. Symulacje wykonano w programie Design Builder, który pozwala symulować obudowę budynku, a także poszczególne części wnętrza budynku. Problematyka przegrzania pomieszczeń jest bardzo rzadko analizowana w przypadku budynków wielkopłytowych. Problem ten jest ściśle związany z komfortem cieplnym budynku, szczególnie w miesiącach letnich. W oparciu o przeprowadzone symulacje autorzy określili wpływ termomodernizacji oraz orientacji poszczególnych mieszkań w budynku wielkopłytowym na komfort cieplny.

Słowa kluczowe: budynek wielkopłytowy, system W70, komfort cieplny w budynkach wielkopłytowych, PMV, PPD

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1. Panel buildings in Poland

It is estimated that about 4 million flats in Poland are made of prefabricated elements in different systems. Moreover, at present more than 10 million Poles live in system buildings. It makes the problems connected with the proper usage and thermal insulation very important and common. The most important aspect is the improvement of the building energy certificate of those buildings. It is connected with thermal modernization of the building envelope and change of the windows.

Unfortunately, at the stage of considering and designing thermal modernization no-one takes into account the thermal comfort and overheating issues which seem to be very important from the occupants' point of view.

2. Thermal comfort

Thermal comfort is related to the thermal balance of the body which is affected by different parameters: personal and environmental such as human activity, clothing insulation and the environmental parameters (air temperature, average radiation temperature, air flow speed and relative humidity). The evaluation of thermal comfort is based on the PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) indices.

The 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" uses Fanger's method to estimate thermal comfort. This method combines the following environmental features: air temperature, air velocity, mean radiant temperature and relative humidity and two personal variables: clothing insulation and activity level into the index that can be used to predict the average thermal sensation of a large group of people.

3. Building description

The aim of the building simulations was to analyze the influence of thermal insulation and flat location on the thermal comfort in the particular parts of the panel building. The simulations were conducted for the W70 panel dwelling building, built in 1974. Plan area of 21.5 m × 13.2 m; usage building area – 2279 m^2, 25 m high with 11 stories. Basement below the entire building, flat roof. Thermal modernization of external walls was conducted in 2006. The picture and visualization of the building are presented in Figure 1.

Building with the natural ventilation, central heating system with convection heaters. Communication area located in the center part of each building level. Four flats at every story located in the corners of the building. Exterior walls made of prefabricated panels in W70 system, insulated with 15cm of styrofoam with plasters at both sides: $U = 0.20$ [W/m^2K] (before thermal modernization $U = 0.75$ [W/m^2K], double glazing windows: $U = 1.7$ [W/m^2K].

The percentage share of glazing areas at the elevations is as follows: N – 7.3%, S – 40%, E – 26%, W – 26%.

Fig. 1. West building elevation and visualization of the analyzed building

The calculations were carried out in the Design Builder v.3. The program has been specifically developed around Energy Plus allowing the simulation of the building envelope and building interiors. It provides extensive databases of building materials, constructions, window panes, glazing units, shadings and blinds. The simulations conducted for the Polish climatic conditions (building located in Cracow, Krowodrza district) allowed the evaluation of the thermal comfort of the entire building and of the particular rooms.

4. Simulation settings

The main aim of simulations was to determine the temperature and PMV index of the particular flats at different stories during summer months (Fig. 2).

Every single flat is the separate thermal comfort zone. Orientations of the flats are as follows: flat number 1 – East and South with the balcony at South side, flat number 2 – West and South with balcony at South, flat number 3 – West and North – balcony at West, flat number 4 – East and North – balcony at East side.

The analysis of the microclimate of particular rooms in the separate flats will be the subject of the further research.

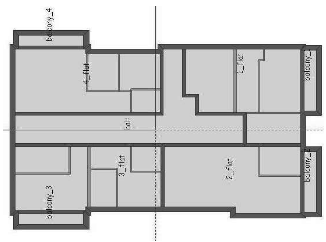

Fig 2. Visualization of typical zones at every building level

The simulations were conducted for the building model before thermal modernization (base case) and next compared with the current service conditions (after the thermal modernization). The Authors compared data for flats located at four different levels: ground floor, third floor, seventh floor and tenth floor. The period of time between 15th May and 15th September was chosen as there may be a risk of overheating at this time in Poland.

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 – 0.08 person per m^2.
3. Operating schedule: flats – 3 people per flat between 4 pm and 7 am, 5 days a week; at the weekends 3 people – all inside between 6 pm and 9 am; 50% reduced occupancy between 9 am and 6 pm.
4. Metabolic activity: factor 0.9, 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 kitchen and 50 m^3/hour for bathroom.

5. Test results

All simulation results presented below have shown that during a few days between 15th May and 15th September the average interior air temperatures of different dwellings exceed 30°C and the PMV factor is higher than 2. Those microclimate building conditions exceed the optimal internal summer temperature of 25°C and recommended value $-0.5 < PMV < +0.5$.

Taking the orientation of the flats into account, in the first step of simulations the results for flat 2 – South-West orientation (the worst thermal conditions) and flat 4 – North-East orientation were compared. Figures 3a and 3b present the number of discomfort hours for South-West flat (number 2) and North-East flat (number 4) at four different levels in the building before thermal modernization. Comparing the diagrams the highest number of discomfort hours is noticeable at third floor. The values are slightly lower for North-East flat orientation. Overheating problem is noticeable in all analyzed months, both before and after the thermal modernization in flats at all levels. The worst conditions are observed during July and August at third floor. At ground level the number of overheating hours is the lowest.

In the dwelling located at the South-West building side, on the third floor, the operative temperature for most of the time is significantly higher than 25°C. The daily maximum interior temperature is 34.70°C and the PMV value is above 3. The number of discomfort hours in the assumed period of time is 2079. Those negative flat conditions continue almost for the entire day and do not change significantly at night. The flats can be cooled down during the night through the open windows.

In case of flats at the third floor temperatures above 32°C are higher than for other levels. It is connected with the direction of solar radiation during summer months and presence of balconies at southern building elevation.

Figures 4a and b present similar results but for the building after the thermal modernization. The number of discomfort hours is much higher and for temperatures above 32°C has almost doubled. The daily maximum interior temperature is 35.80°C and the number of discomfort hours in the taken period is 2532.

Figures 5a and b compare the results for flats with different orientations before and after the thermal modernization but located at the same, third floor. There are only slight differences between dwellings at the same level. The number of overheating hours is much higher after the modernization, for temperatures above 32°C increased from about 350 hours to almost 600 hours. Figure 6 presents a diagram with the comparison of PMV index for South-West flat at different stories, after the thermal modernization. PMV index in all cases exceeds the value of 2 and in July it is even higher than 3.

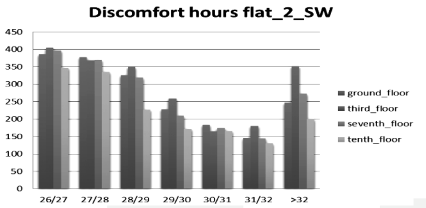

Fig. 3a. Number of overheating hours for flat 2 (South-West) at four levels – base case

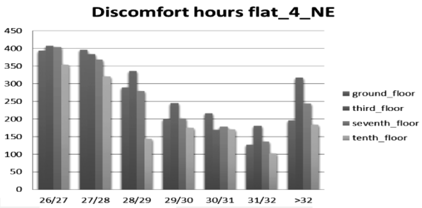

Fig. 3b. Number of overheating hours for flat 4 (North-East) at four levels– base case

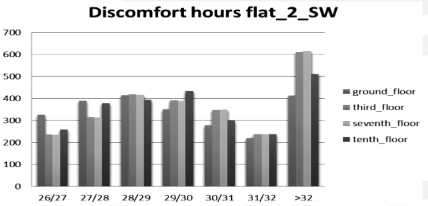

Fig. 4a. Overheating hours for flat 2 (South-West) at four levels – after thermal modernization

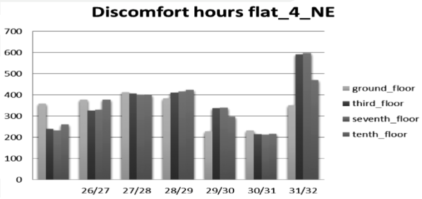

Fig. 4b. Overheating hours for flat 4 (North-East) at four levels – after thermal modernization

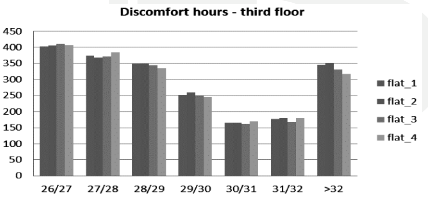

Fig. 5a. Number of discomfort hours for different flats at third floor – base case

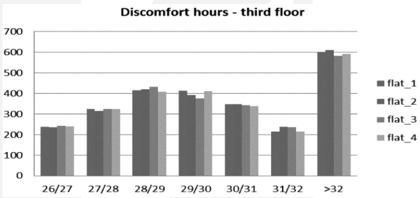

Fig. 5b. Number of discomfort hours for different flats at third floor – after thermal modernization

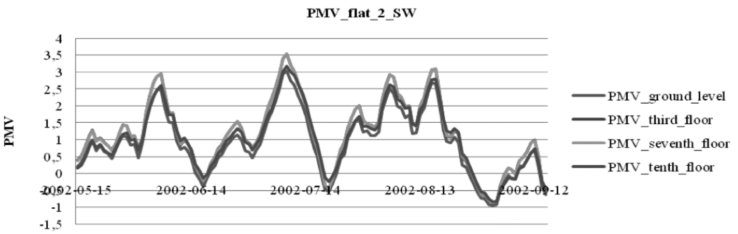

Fig. 6. PMV comfort index for South-West flat at different levels – after thermal modernization

6. Conclusions

The results of conducted analysis show that the overheating problems in summer months occur in panel buildings, both before and after the thermal modernization. Windows in the prefabricated panel buildings in most cases are poorly shaded from solar radiation. Glazing is the source of the excessive heat gains and results in the overheating of the dwellings. The microclimate conditions in all flats are very uncomfortable and the parameters describing thermal comfort exceed the acceptable values.

The modernization of the building should be preceded by the extensive analysis of how the changes influence the thermal comfort of the particular flats. The priority aim is reduction of heating costs in the winter season. The conducted analyses show that improving only the building envelope thermal insulation can unfavorably affect the internal conditions during summer season. In the process of thermal modernization of panel buildings, using internal or external shadings to reduce summer overheating should be considered. Those solutions are the subject of authors' further research.

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] PN-83/B-03430 Wentylacja w budynkach mieszkalnych zamieszkania zbiorowego i użyteczności publicznej – Wymagania.
[3] Nowak K., *Modernizacja budynków a komfort cieplny pomieszczeń*, Energia i Budynek, 11 (54), 2011.
[4] Dębowski J., *Cała prawda o budynkach wielkopłytowych*, Przegląd budowlany, 9/2012.
[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.