TECHNICAL TRANSACTIONS | CZASOPISMO TECHNICZNE
CIVIL ENGINEERING | BUDOWNICTWO
1-B/2016

DOI: 10.4467/2353737XCT.16.063.5412

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SYMULATION OF NIGHT COOLING IN A SINGLE DWELLING OF A LARGE PANEL BUILDING

SYMULACJA NOCNEGO CHŁODZENIA W POJEDYNCZYCH MIESZKANIACH W BUDYNKU Z WIELKIEJ PŁYTY

A b s t r a c t

When analyzing large panel buildings, it is very rare to take into consideration the requirements connected with the overheating effect. The paper presents the results of the annual computational simulations of thermal comfort conducted for one flat of W70 multi-family large panel building. Basing on the simulations the authors analyzed the influence of night cooling on thermal comfort inside the flat. Different simulation steps were taken into consideration: windows with and without shading systems, opened during entire night or just during given periods of time to keep specific thermal conditions.

Keywords: large panel building, thermal comfort, PMV (Predicted Mean Vote), balcony framings, loggia

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

Podczas analizy budynków wielkopłytowych bardzo rzadko uwzględniane są wymagania związane z ich przegrzewaniem. W artykule przedstawiono roczne symulacje komfortu cieplnego, przeprowadzone dla pojedynczego mieszkania w wielorodzinnym budynku wielkopłytowym w systemie W70. Na podstawie symulacji autorzy przeprowadzili analizę wpływu nocnego chłodzenia na komfort wewnątrz mieszkania. Analizie poddano różne warianty: okna z systemem zacienień zewnętrznych i wewnętrznych, otwierane w okresach nocnych w celu obniżenia temperatury.

Słowa kluczowe: budynki wielkopłytowe, komfort cieplny, PMV, loggia, balkon

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1. Description of problem

Overheating problems in buildings are very common and seem to be very important from occupants' point of view. Taking into consideration the fact that almost a quarter of Poles lives in large system panel buildings the issues related to this subject are very important and common. Occupants can control their thermal environment by means of clothing, operable windows, fans, heaters, internal and external sun shades.

Unfortunately at the simulation stage it is very difficult to predict the way the individual flat will be used. Looking globally at the multi-family building probably each flat should be analyzed separately after considering the requirements and expectations of inhabitants regarding temperature and humidity conditions. Many analyses were conducted by the authors and results were described in [1–4]. All of them under the assumption that all windows are closed during the entire day. For those unfavorable conditions there are problems with overheating of internal spaces even after using of internal and external shading systems. This assumption is however only theoretical as in practice the inhabitants open the windows when temperature inside exceeds uncomfortable values. Internal cooling through the windows makes sense especially during the night when external temperature is lower than internal. From the safety reasons sometimes opening of the windows during the night is impossible, especially at the lowest levels.

2. Description of analyzed building

The simulations were conducted for the W70 panel dwelling building, built in 1974. Plan area 21.5 m × 13.2 m; usage building area – 2279 m^2, 25 m high with 11 levels. Basement below the entire building, flat roof.

The building has natural ventilation and a central heating system with convection heaters. A communication area is located in the central part of the building. There are four flats at every single 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. Triple glazing windows: $U = 1.1$ W/m^{2}K to keep current national requirements, SHGC (solar heat gain coefficient) equal to 0.63. SHGC is a description of windows used in United States, refers to the solar energy transmittance of the glass. In Europe the g value describes the same parameters of the glazing.

The simulations conducted for the Polish climatic conditions (building located in Cracow). The calculations were carried out in Design Builder v.3. The program has been specifically developed around Energy Plus, allowing the simulation of the building envelope and building interiors.

Analysis based on 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.

3. Simulation settings

Simulations were conducted for one flat, located at 7th floor with balcony at south elevation and windows at west side. The flat was analyzed as one thermal zone, an assumption that all internal doors are open was made. The main aim of simulations was to determine the temperature and PMV (Predicted Mean Vote) index during the summer months. The period of time between 15th May and 15th September was taken into consideration because at this time in Poland, there is a risk of overheating.

Fig. 2. Typical zones' visualization at every building level. Analyzed flat #2

The assumptions to the simulations:
– Heating system on from September to March (22°C), 7 days a week, 24 hours a day.
– Occupancy density: flats – about 1 person per 15 m^2.
– Operating schedule: flats – 100% occupancy density between 4 pm and 7 am, 5 days a week; at the weekends between 6 pm and 9 am; 50% reduced occupancy between 9 am and 6 pm.
– Metabolic activity: factor 1.2 met, winter clothing – clo = 1.0, summer clothing clo = 0.5.
– Ventilation requirements per Polish national standards PN-83/B-03430, in every flat 70 m^3/h for kitchen and 50 m^3/h for bathroom.
– Internal solar shadings (blinds with high reflexivity slats), and external shading panel (7 panels – louvre blades).

4. Test results

Six different simulation steps were analyzed and compared with one another.
1. All windows closed.
2. All windows closed, internal and external shading systems used.
3. Night cooling of the flat between 8 p.m. and 6 a.m. without shading systems.
4. Night cooling of the flat during the night until the internal temperature drops to 20°C, without shading systems.
5. Night cooling of the flat between 8 p.m. and 6 a.m. with shading systems.
6. Night cooling of the flat during the night until the internal temperature drops to 20°C, without shading systems.

4.1. Influence of shadings

In the first simulation step there is an assumption that all building windows are closed for the entire day. It affects the internal temperatures significantly. All simulation results have shown that during some days in the analyzed period of time the average interior air temperature exceeds 30°C and the PMV factor is even higher than 2. Those microclimate building conditions exceed the optimal internal summer temperature of 25°C and recommended value $-0.5 < PMV < +0.5$. In the second step, the internal and external shading systems were used at all windows. Those solutions affected the results significantly however did not eliminate the overheating temperatures entirely. Figures 3 and 4 present the number of overheating hours in the analyzed months. The number of discomfort hours, with the temperature above 25°C in the first simulation step is 2549, usage of shading systems reduces this number by about 35% to 1659.

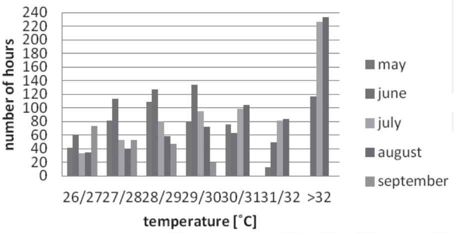

Fig. 3. Number of overheating hours in different months

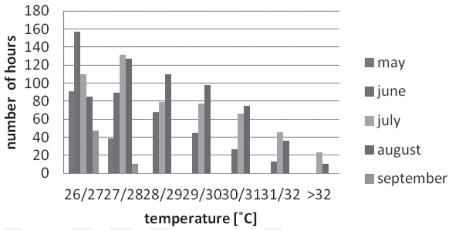

Fig. 4. Number of overheating hours, with internal and external shading systems, in different months

4.2. Influence of night cooling on thermal conditions

Simulation steps #3 through #6 assume night cooling of the flat which, in program, was modelled as additional ventilation rate. It represents the cooling of the flats by opened windows and was modelled as 5 air ventilation exchanges of the flat volume for a flat with and without shading systems. Night cooling itself was also analyzed in two different options. First case when the windows are opened between 8 p.m. and 6 a.m. (steps 3 and 5), second option – windows are opened until the internal temperature drops to 20°C, then windows are closed (steps 4 and 6).

Table 1 presents comparison of the number of discomfort hours in all analyzed cases.

Night cooling exerts significant influence on the internal thermal conditions. In all cases (3 thru 6), night cooling affected the number of discomfort hours significantly, decrease up to 80% can be observed comparing to the assumption when all windows are closed (steps 1 and 2). Temperatures above 30°C were almost entirely eliminated.

Using both shading systems and night cooling eliminated temperatures above 30°C entirely. From the overheating point of view the most favorable solution is using of night cooling together with internal and external shading systems (steps 5 and 6). However in those cases low temperatures even below 20°C can be observed. Figures 5 through 7 present the number of hours below 25°C and PMV factor in 6th simulation step. Values are even lower than –2.0 and temperatures drops down to 15°C. Number of hours below 20°C is 433 and those are very unfavorable conditions for inhabitants.

Table 1

Number of overheating hours (above 25°C) in different simulation steps

Simulation step	Number of overheating hours	Temperatures above 30°C
Step 1	2549	1144
Step 2	1659	296
Step 3	591	71
Step 4	727	79
Step 5	229	0
Step 6	278	0

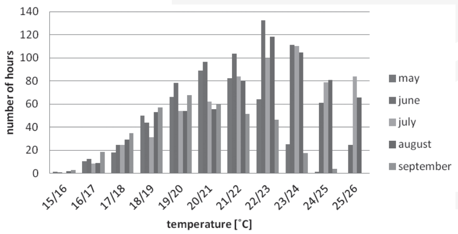

Fig. 5. Number of hours below 25°C in different months

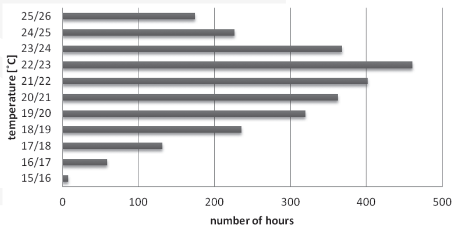

Fig. 6. Total number of hours below 25°C

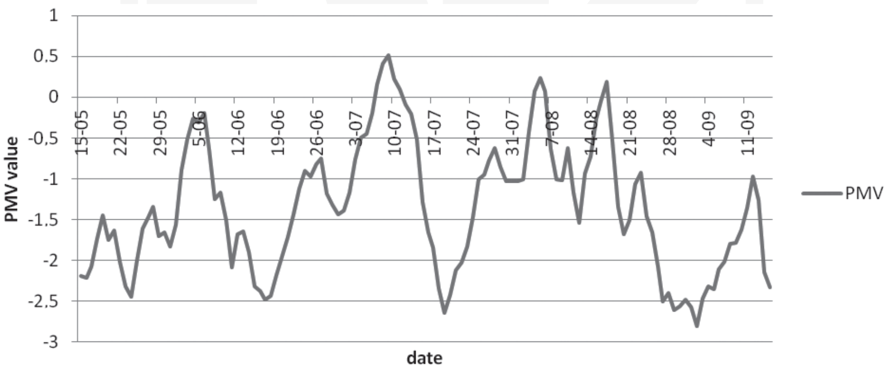

Fig. 7. PMV factor in 6th simulation step (night cooling plus internal and external shading systems)

5. Conclusions

The results of the conducted analysis show that the overheating problem occurs in large panel buildings. 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. Using of internal and external shading systems reduces the number of discomfort hours however the most significant results are observed when internal spaces are cooled by opening the windows during the night. In practice this solution is commonly used by inhabitants. Modelling of this process is however complicated and difficult as it depends on the way separate flats are used. Cooling of the flats during every night would result in too low temperatures which affects the thermal conditions unfavorably. Simulations of night cooling by ventilation air exchanges is a simplification used for analyses purposes. Modelling of different air exchanges is the subject of authors' future works.

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