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Influence of the balcony glazing construction on thermal comfort of apartments in retrofitted large panel buildings

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Abstract

This paper presents the results of the annual computational simulations conducted for separate flats of a ten-story W70 large-panel building. The calculations were carried out in the Design Builder program which prepares a simulation of the building envelope as well as the separate parts of the building interior. The simulations conducted for the polish climatic conditions allowed the assessment of the thermal comfort of the entire multi-family building and of the particular flats. It is very rare to take into consideration the requirements connected with the overheating effect in the panel buildings. This issue is closely related to the thermal comfort of the building, especially during the summer months. For the last couple of years modernization of large panel buildings has become very popular. Most of the multi-family large panel buildings in Poland have already been insulated, windows were exchanged and in many cases balconies were closed with glazing constructions. Based on conducted simulations authors analyzed the microclimate conditions in different apartments, with different orientation of balconies. Different simulation steps were analyzed which allowed an evaluation of the influence of different windows, loggia glazing framings and night cooling on microclimate in different apartments.

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Keywords: large panel building; thermal comfort of the panel buildings; PMV (Predicted Mean Vote); balcony framings; loggia

1. Description of problem

Overheating problems in large panel buildings are very common and seem to be very important from the

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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.

The most important aspect is the improvement of the building energy certificate of those buildings. It is connected with the thermal modernization of the building envelope. Grudzinska [1] describes the influence of the balcony envelope on the possibility of energy savings in adjacent living space. Usage of glazing framing around the balcony can reduce the energy demand in adjacent rooms up to 22%. It is caused by increased solar gains.

This article examines the influence of window solar heat gain coefficient, loggia framings and night cooling on microclimate conditions in separate flats.

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; environmental parameters (air temperature, average radiation temperature, air flow speed and relative humidity). These factors make up what is known as the 'human thermal environment'. Evaluation of thermal comfort is based on the PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) indexes [2].

International standard PN-EN ISO 7730, 'Ergonomics of the thermal environment. Analytical determination and interpretation of thermal comfort using a calculation of the PMV and PPD indices and local thermal comfort criteria' uses Fanger's method to estimate thermal comfort. The Predicted Mean Vote (PMV) model stands among the most recognized thermal comfort models. It was developed using principles of heat balance and experimental data collected in a controlled climate chamber under steady state conditions. Fanger's 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. Also, psychological parameters such as individual expectations may affect thermal comfort. The thermal sensation 7 level scale with values between -3 and 3 describes the thermal sensation between 'hot' and 'cold'.

Occupants can control their thermal environment by means of clothing, operable windows, fans, heaters, internal and external sun shades.

3. Description of analyzed building

The simulations were conducted for the W70 panel dwelling building, built in 1974. Plan area 21.5 m x 13.2 m; usage building area – 2279 m^2, 25 m high with 11 levels. Basement below entire building, flat roof. Picture and visualization of the building are presented in Figure 1.

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 plaster at both sides: U=0.20 [W/m^2K]. Triple glazing windows: U =1.1 [W/m^2K] to keep current national requirements.

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

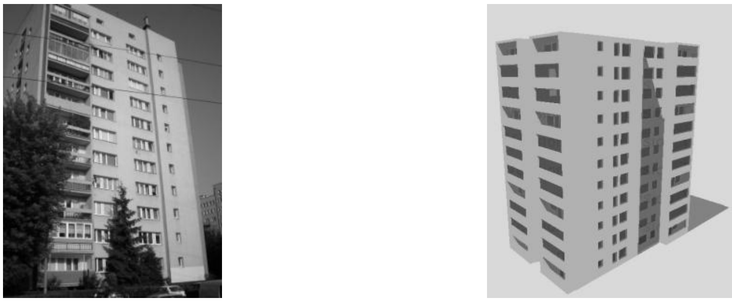

Fig. 1. West building elevation and visualization of the analyzed building.

The simulations were 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.

4. Simulation settings

The main aim of simulations was to determine the temperature and PMV index of particular flats with windows at different elevations during the summer months. The period of time between 15th of May and 15th of September was taken into consideration because at this time in Poland, there is a risk of overheating.

Every single flat is a separate thermal comfort zone. Orientations of the flats are as follows: flat number 1 (F1) – east and south with the balcony at south side, flat number 2 (F2)– west and south with balcony at south, flat number 3 (F3) – west and north – balcony at west, flat number 4 (F4)– east and north – balcony at east side.

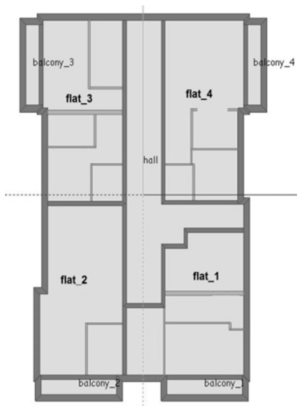

Fig. 2. Typical zones' visualization at every building level.

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; on the weekends and 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/hour for kitchen and 50 m^3/hour for bathroom [3].

5. Test results

Eight different simulation steps were analyzed. Data for different flats located at four different levels were compared.

I. All windows and loggia glazing with **SHGC=0.63** and U=1.1W/m^{2}K
1. All windows in the building without loggia framing
2. All balconies closed with loggia framing
3. Balcony framing opened during the night, windows closed
4. Both loggia and building windows opened during the night until the internal temperature drops to 18°C

II. All windows and loggia glazing with **SHGC=0.42** and U=1.1W/m^{2}K
1. All windows in the building without loggia framing
2. All balconies closed with loggia framing
3. Balcony framing opened during the night, windows closed
4. Both loggia and building windows opened during the night until the internal temperature drops to 18°C

Balconies were modelled with solid walls on both sides, solid front wall 105 cm high and window framing up to the next floor balcony (see figure 3).

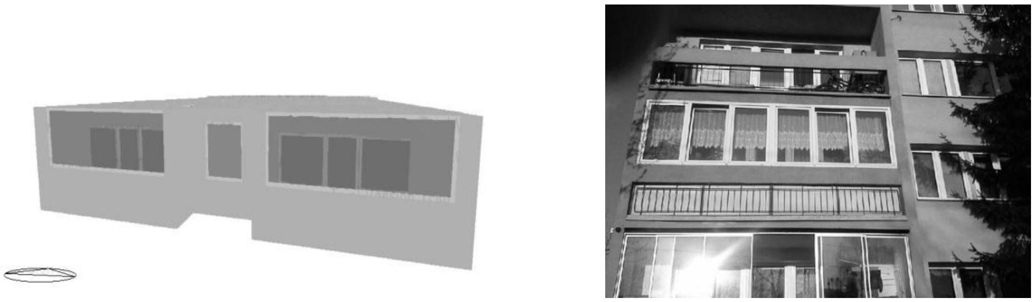

Fig. 3. Model visualization of balcony loggia framing at south elevation of building.

In the six simulation steps there is an assumption that all building windows are closed for the entire day. It affects the internal temperatures significantly. All simulation results in those six steps, have shown that during some days between 15th of May and 15th of September the average interior air temperatures of different dwellings exceed 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.

Simulation steps #4 and #8 assume night cooling of the flats which was modelled as additional ventilation rate but describes the cooling of the flats by opening the windows.

Night cooling was modelled as 5 air ventilation exchanges of the flat volume between 8 p.m. and 6 a.m. but temperature inside cannot drop below 18°C.

5.1. Influence of SHGC parameters on microclimate of interiors

SHGC solar heat gain coefficient, description of windows used in the United States, refers to the solar energy transmittance of the glass. In Europe g value describes the same parameters of the glazing. Both values range from 0 to 1, and the lower value the lower solar gains can be obtained. Solar heat gain coefficient values are calculated using the sum of the primary solar transmittance and the secondary transmittance. Primary transmittance is the fraction of solar radiation that directly enters a building through a window compared to the total solar insulation, the amount of radiation that the window receives. The secondary transmittance is the fraction of inwardly flowing solar energy absorbed in the window (or shading device) again compared to the total solar insulation.

Usually the choice of windows in the building is determined by the U value, to minimize the heat losses. Unfortunately with a lower U value usually the SHGC parameter is also lower.

Two simulation steps #1 and #5 have shown this significant influence. In the case of #1 SHGC=0.63, in the case of #5 SHGC=0.42, the U value in both cases is the same U=1.1 W/m^{2}K which means that energy losses in both cases would be the same. In the case of windows with higher SHGC value due to the higher solar gains the operative temperature, on all levels, for most of the time is significantly higher than 25°C. Figures 4a and 4b present the number of discomfort hours for all four flats at the third floor. The daily maximum interior temperature is 37.5°C (flat F2) and the PMV value is above 3.5. The number of discomfort hours, with the temperature above 25°C for flat number #2, in the assumed period of time is 2549. Those negative flat conditions continue almost for the entire day and do not change significantly during the night.

In the case of windows with a lower SHGC= 0.42, the number of discomfort hours is about 17% lower and equal to 2121 for flat F2. Maximum interior temperature is 34.90°C. The number of hours with the temperature above 32 decreased significantly from 571 to 191.

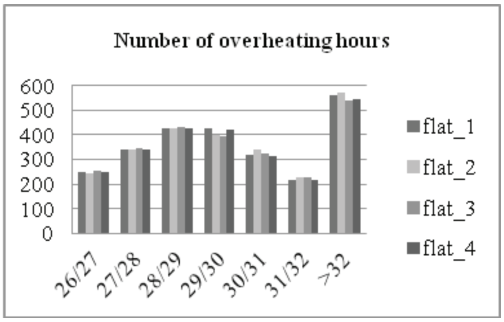

Fig. 4a. Number of overheating hours for four flats at the third floor – windows with SHGC=0.63.

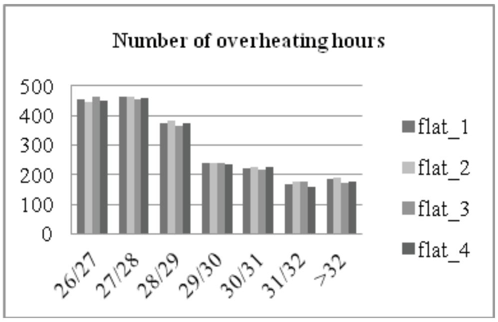

Fig. 4b. Number of overheating hours for four flats at the third floor – windows with SHGC=0.42.

5.2. Influence of loggia framings on microclimate conditions

The overheating problems are closely related with the orientation of glazing and the worst thermal conditions are usually observed in rooms with windows oriented to the west. It is connected with the angle of solar radiation. In the analyzed building, the windows located at the south elevation are shaded by the balconies at higher levels which lessen the solar gains.

Table 1 presents the number of overheating hours and the number of hours with internal temperature above 30°C in two flats (F2 with windows at south and west and F3 with windows and balcony framing at west and north) at ground and third floors, for eight different simulation steps.

Table 1. Number of overheating hours and with temperature above 30°C for different flats at ground floor and at the third floor.

	Simulation steps							
	All windows and loggia glazing SHGC=0.63				All windows and loggia glazing SHGC=0.42			
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Ground floor – flat number 2								
Number of overheating hours (above 25°C)	2375	1977	1856	320	2086	1079	996	96.5
Number of hours with temp above 30°C	854	468	410	4.5	560	74	65	0
Ground floor – flat number 3								
Number of overheating hours (above 25°C)	2325	1933	1819	292	1814	1055	972	88
Number of hours with temp above 30°C	788	438	384	5	370	70.5	61	0
Third floor– flat number 2								
Number of overheating hours (above 25°C)	2549	2342	2278	429	2121	1534	1455	179.5
Number of hours with temp above 30°C	1137	783	722	25	591	245	215	0
Third floor– flat number 3								
Number of overheating hours (above 25°C)	2524	2322	2260	409	2085	1520	1441	172
Number of hours with temp above 30°C	1092	765	705	22	560	239	210	0

Steps 2 and 5 show the balcony glazing framing reduces the number of overheating hours inside the flats. In case of loggia glazing with SGHC=0.42 this reduction is significant, for the flat at the third floor it is about 25%. Maximum temperatures inside the flats are also lower however temperatures in loggias are much higher. Table 2 presents maximum temperatures in the flats and corresponding temperatures in loggias. In the most unfavourable cases for flats with balconies at the west elevation, SGHC=0.63, the temperature inside the balcony framing is around 43°C and the PMV factor is equal to 7.66. Again the use of loggia glazing with lower with SGHC=0.42 reduces the temperatures inside the balconies to around 37°C, for the same flats. The PMV factor decreases to 4.64.

Table 2. Maximum temperatures in analyzed flats and corresponding temperatures inside balcony framing.

	Simulation steps							
	SHGC=0.63				SHGC=0.42			
	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6	Step 7	Step 8
Ground floor – flat number 2								
Maximum temperature in the flat	36.53	**32.03**	34.60	31.16	34.31	**32.03**	31.84	30.69
Corresponding temperature on the balcony	-	**36.75**	35.96	32.99	-	**32.05**	31.79	30.53
Ground floor – flat number 3								
Maximum temperature in the flat	36.73	**32.07**	34.72	31.18	34.57	**32.08**	31.89	31.13
Corresponding temperature on the balcony	-	**43.51**	42.95	40.44	-	**37.48**	36.79	35.16
Third floor– flat number 2								
Maximum temperature in the flat	37.47	**33.10**	35.90	31.88	34.89	**33.09**	32.96	31.92
Corresponding temperature on the balcony	-	**37.41**	36.82	33.04	-	**35.95**	32.48	31.52
Third floor– flat number 3								
Maximum temperature in the flat	37.51	**33.14**	35.93	31.84	34.99	**33.14**	33.00	31.94
Corresponding temperature on the balcony	-	**42.61**	41.98	38.11	-	**36.76**	36.22	35.26

Night cooling of just the balcony framing only slightly affects the internal temperature conditions (simulation steps 3 and 7).

Night cooling of the flats gives the most significant effects. This process however is difficult to be modelled as it's hard to predict how many hours during the night windows are opened. What is more, on the ground level there may be problems with opening the windows due to safety reasons.

Simulation steps #4 and #8 assume night cooling of the flats which was modelled as an additional ventilation rate but describes the cooling of the flats by opening the windows. Night cooling was modelled as 5 air ventilation exchanges of the flat volume between 8 p.m. and 6 a.m. but the temperature inside cannot drop below 18°C. Loggia framings are opened at the same time as windows.

In the case of all flats, the number of discomfort hours decreased more than 80%, compared to the assumption when windows and loggias are closed (steps 2 and 6). Temperatures above 30°C were almost entirely eliminated.

6. Conclusions

The results of the conducted analysis show that the overheating problem appears 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. To reduce high temperatures inside the flats; windows with solar heat gain coefficients as low as possible should be used. It should be taken into consideration in the process of thermal modernization of large panel buildings. Loggia framings reduce the internal thermal conditions however they make use of balcony space impossible due to such high internal temperatures. The most favorable conditions are observed with night cooling of the flats. Modeling of this process is however very complicated and requires extensive analysis which will be the subject of future simulations.

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