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Microclimatic conditions in office spaces

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Microclimatic conditions in office spaces

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Abstract. The microclimate of interiors is the set of all the physical and chemical parameters of the rooms influencing the human body and the building. From the time of the introduction of installation systems into the construction industry, shaping the internal microclimate of the building has become on the one hand an easier task, but on the other hand it requires due diligence and professional knowledge of the design of the internal conditions of particular rooms. Modern solutions enable people to interfere in a building object in order to ensure the right temperature, damp proofing, appropriate lighting, etc. This article presents the methods of assessing the rooms in terms of thermal comfort. The Predicted Mean Vote (PMV) and Predicted Percentage Dissatisfied (PPD) indicators were determined in an analytical way for selected office spaces and the analysis of factors affecting conditions in particular rooms was carried out. The article contains the comparison of the results obtained from the observation with the recommendations contained in the legal regulations and, in particular in the Regulation of the Minister of Labour and Social Policy of 26th September 1997 on general provisions concerning industrial safety.

1. Introduction

In connection with the trend of lengthening the time spending in closed spaces yet aiming to reduce the energy demand, it is necessary to shape adequate internal environment of rooms. The issues of the microclimate of an interior and the thermal comfort of people staying in buildings have become the subject of many studies [1] [2]. The term of the microclimate of interiors is defined as the set of all physical and chemical parameters of a particular room influencing the human body and the building. The main parameters of the microclimate include: air temperature, the average surface temperature of barriers, air movement velocity, relative air humidity. The set of non-thermal factors are: air pollution, air ionization, noise level, lighting, etc. These factors have a negative impact on the physical and mental state as well as the health of a human being. Since the introduction of installation systems into the construction industry, shaping the internal microclimate of rooms has become an easier task to do, yet it generates some problems to which special attention should be paid. Therefore, it is important to control the working environment. Providing employees with appropriate conditions affects their physical and mental state, concentration, reduces accidents and occupational diseases, and also improves the productivity and quality of service [3].

Ensuring appropriate internal environment is one of the factors that enables to maintain the efficiency of the human body in terms of thermal balance. The process of thermoregulation depends on the values of the physical parameters that characterize the microclimate of internal environment and their variation in time [4]. The author of the cited publication, on the basis of the literature, refers to the heat balance equation that describes the heat exchange between a man and the surrounding environment (1):

$$M = W + R + C + E + RES + \Delta S \quad (1)$$

where:
M - power flux density of metabolic heat production, W/m^2
W - power flux density intended for mechanical work, W/m^2
R + C - power flux density lost as a result of convection and radiation, W/m^2
E - power flux density lost as a result of sweat evaporation, W/m^2
RES - power flux density lost as a result of breathing, convection and vaporization, W/m^2
ΔS - heat accumulation, W/m^2.

The desired state is the state of thermal equilibrium, in which the metabolic heat generated in this state, is automatically dispersed without the process of thermoregulation. Such conditions are regarded as neutral environment for a human being. Thermal and humidity parameters influencing the process of shaping the neutral environment, also affect the feeling of thermal comfort, defined as a condition in which a person feels neither hot nor cold [5]. The concept of thermal comfort has become the topic of a lot of research work, in which we can find three approaches to this concept [6].]. The first way is constructing physical models of a human being by means of dummies that stimulate biochemical metabolism. The second way of identifying the concept of thermal comfort is called psychological. This method involves obtaining the answers to the questions, which are asked people staying in rooms. The last way of analysing is the thermophysiological approach, in which research methods are based on colorimetry.

Apart from the trends in the research mentioned above, it is necessary to pay attention to basic indexes used to analyse the thermal comfort in a particular room proposed by Fanger [7]. The first one is the PMV index (Predictive Mean Vote) that is used to determine the degree of discomfort. The PMV index determines the expected average assessment in accordance with Fanger's seven-stage psychophysical scale of thermal sensations [7] (Table 1).

Table 1. Scale of the PMV index [5]

PMV	3	2	1	0	-1	-2	-3
Feeling	very hot	hot	slightly warm	comfortable	slightly cool	cool	very cold

The PMV parameter can be determined provided that [8]:

- the temperature of air in the room is: 10 – 30^{0}C ,
- the average radiant temperature of the barriers in the room is: 10 - 40 ^{0}C,
- the air velocity in the room is: 0 - 1m/s,
- the partial pressure of water vapour in the room is: 0 - 2700 Pa,
- the energetic expenditure of people staying in the room is: 46,6 - 232,8 W/m^2,
- the thermal clothing insulation is: 0 - 2 clo.

The second indicator of assessing the thermal comfort is the PPD (Predicted Percentage of Dissatisfied) index, which predicts the number of dissatisfied people. It determines the percentage of people staying in the particular environment who feel the lack of the thermal comfort. The minimum value of the PPD index is 5% because it is impossible to fit the thermal parameters of the room in such a way to make the people, staying in the room, feel the thermal comfort. The PMV and PPD indexes help to assess the prevailing conditions in the room.

2. Methodology

The observations were carried out in the rooms located in a 3.1. building, at the University of Science and Technology in Bydgoszcz, al. Kaliskiego 7. This is a one- and two-storey building, partly built with a basement. It was constructed in accordance with panel building (SBO) industrialized technology in the eighties last century. The building has mainly a frame construction (columns, beams, etc.), partially, the bearing elements are solid ferroconcrete walls that are not thermally insulated. Some rooms in the building have old woodwork and some – new PVC windows. There are two, large auditoriums, several smaller lecture halls, administrative areas, research laboratories (labs) and halls. . The supporting structure of the roof consists of steel, openwork beams with the span of 12.0 and 15.0 m, and spaced every 3.0 m. The building is provided with heating from the city's heating network, there are no thermostatic valves installed. Before the thermal modernization, the building is characterized by low heat insulation of external wall barriers and high energy consumption for heating purposes. The heat-transfer coefficients for the external walls are about 1.5 W/m^2K and for the old window sets are about 2.6 W/m^2K, while for the new ones, are about 1.5 W/m^2K. In order to evaluate the thermal environment of the administrative areas, 6 office spaces were selected with a similar surface of about 17 m^2 and with the gravity ventilation system. One person has their place of work in each of those rooms. The measurements were taken in 2 rooms located at the southern side and in 4 rooms with the windows faced north. In the rooms faced north, there are new PVC windows fitted and in the rooms faced south, there are old, wooden windows. The windows and the door were closed, the lighting and one computer were on. The measurement of the parameters of the air inside the rooms is taken three times a day. The first measurement was taken at about 8.00 a.m., next – at about 12.00 a.m. and the last – at 3.00 p.m. Two test days were chosen: 12th May, 2017 with an average temperature of the external air of 19.5°C, and 11th June, 2017 with an average temperature of the external air of 25.2°C. According to PN-EN ISO 7730:2006 standard [9], in order to assess the thermal comfort of the rooms, the following measurements and calculations were taken:

- the assessment of general work conditions was based on the interview with a person who was working in a particular room. The parameters of the internal microclimate in the room were measured, i.e.: relative air velocity, relative humidity, ambient air temperature, air humidity.
- On the basis of collected data and accepted values of the factors:
  - metabolic energy production - 70 W/m^2,
  - basic clothing insulation -1 clo
  - air velocity in the area occupied by the people - 0.1 m/s,
  - radiant temperature is the same as the temperature of the internal air, the PMV and PPD indexes were determined.
- The calculated PMV and PPD indexes were compared with reference values included in the [8] standard and the modernisation of the rooms was proposed in order to improve the thermal comfort.

The PN-EN 15251:2012 standard [10] introduces the classification of rooms and gives the recommended values of the PPD and PMV indexes for each category. . The office spaces, which were tested, are classified as the 3rd category because they are in the existing building. . It is recommended that for the 3rd category the value of the PPD index should be lower than 15%, which corresponds to the value of the PMV index from –0.7 to +0.7.

The devices which were used to measure the parameters have the certificates of conformity and calibration. The humidity and temperature of the air were measured by means of the hytherograph (Figure 1) and the test measurement of the air velocity was taken by means of the anemometer TA 430 (Figure 2).

Figure 1. Hytherograph C3120.

Figure 2. Airflow anemometr TA430.

3. Results

The obtained results of the measurements allowed us to calculate the PMV and PPD indexes. The calculations were made on PMV 2008 ver 1.0, Ingvar Holmer calculator, which is available on the following website: http://www.eat.lth.se. According to the author of the programme, the calculations are based on an English version of the PN-EN ISO 7730:2006 standard [9]. The table below shows (Table 2.) the comparison of the results of the indicators from two test days, for 6 selected office spaces. The measurement was taken in each room three times at: 8.00 a.m., 12.00 a.m. and 3.00 p.m.

Table 2. Results of calculating operative temperature, PMV and PPD

12.05.2017	**PMV**	**PPD**	11.06.2017	**PMV**	**PPD**
room 1	-0,61	12,70	room 1	0,27	6,50
	-0,34	7,30		0,83	19,40
	-0,06	5,10		0,79	18,10
room 2	-0,65	13,90	room 2	0,60	12,60
	-0,28	6,60		0,59	12,30
	-0,17	5,60		0,87	20,90
room 3	-0,67	14,30	room 3	0,20	5,90
	-0,11	5,30		0,67	14,60
	-0,01	5,00		0,81	18,80
room 4	-0,17	5,60	room 4	-0,04	5,00
	-0,02	5,00		0,32	7,10
	0,03	5,00		0,44	9,10
room 5	-0,21	5,90	room 5	0,27	6,50
	0,05	5,00		0,49	10,00
	0,12	5,30		0,40	8,40
room 6	-0,18	5,70	room 6	-0,47	9,60
	-0,04	5,00		0,60	12,70
	0,16	5,50		0,56	11,50

As tested office spaces are classified as the 3rd category, the value of the PPD index should be lower than 15% and the values of the PMV should range from –0.7 to +0.7. The graphs below show the relationship between predicted evaluation of the average PMV and predicted number of people who will feel the lack of the thermal comfort (PPD) in particular rooms for the selected test days: 12.05.2017 (Figure 3.), 11.06.2017 (Figure 4.), for the selected hour: 12.00 a.m.

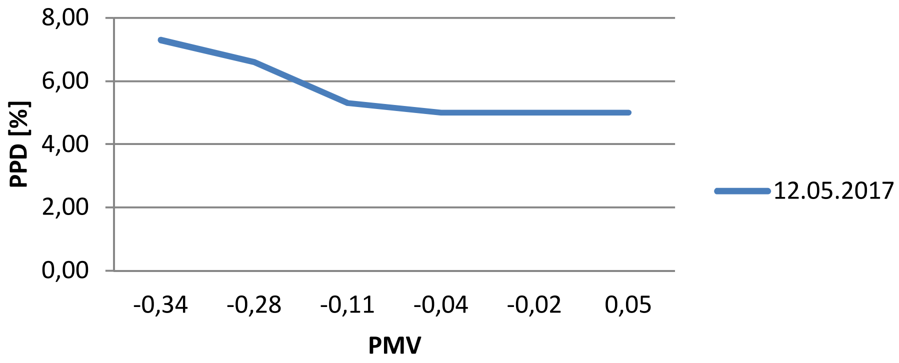

Figure 3. PMV and PPD in office space, date: 12.05.2017

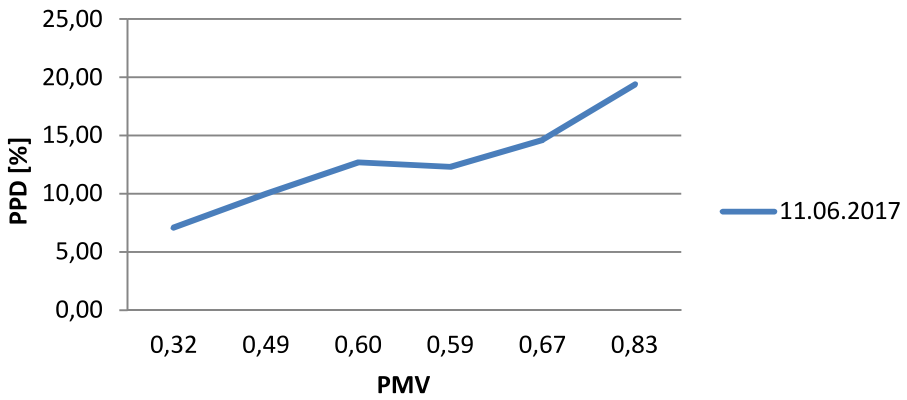

Figure 4. PMV and PPD in office space, date: 11.06.2017

The graphs with the values of the PMV and PPD indexes show that the percentage of people dissatisfied with the prevailing conditions in the room is increasing along with the rise of the external air temperature. On the day when the temperature did not exceed 20^0C, the number of dissatisfied people did not exceed 8%, however, if the temperature was 25^0C, this number increased to about 20% in the chosen rooms.

4. Conclusion

The studies, which were conducted, are partial studies of the selected office spaces in the building, which is planned for thermal modernisation. The building does not meet the regulations in force connected with the insulation of the barriers. The lack of proper insulation of the external wall barriers, old windows and the location of the rooms influence the microclimate of the interior.

On the basis of the measurements, which were taken, it can be stated that:

- The value of the PMV coefficient in 92% fits into the range of conditions, which correspond to the 3^{rd} category from -0.7 to +0.7.
- The calculated values of the PPD index show that 11% of the received results indicate uncomfortable conditions inside the room.
- Uncomfortable internal conditions appeared on a warmer day in the rooms faced south with old windows. The rise of the temperature inside the rooms caused by insolation created adverse internal conditions.

The research that was carried out indicates moderate working conditions in the selected office spaces. The building does not meet the insulation requirements, that is why it reacts to changing external weather conditions very quickly. The building has the gravity ventilation system, which sometimes does not work correctly and that is why the heat gain is not removed from the building efficiently. Due to the fact that there is little research done on this topic, it is difficult to talk about a comprehensive view of the conditions of the internal microclimate of the rooms. In the future, the research is planned to be carried out in different seasons of the year, and also, after the thermal modernisation of the building, it will be checked how the change of the lamination of the external wall barriers and woodwork will influence the microclimate of the interior. On the basis of the publication [11], it can be assumed that after the thermal modernisation, the thermal comfort of the workers will improve.

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