Microclimatic Conditions in Office Spaces - Case Study

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Abstract. A modern man stays in closed rooms for most of the day. That is why, the indoor environment should have a beneficial effect on people’s health and well-being. The conditions in the room are called the microclimate of the interior. It is the set of all physical and chemical parameters of rooms affecting the human body and building. The values of these parameters are influenced by the structure of the building and installations such as heating, ventilation and lighting. Since the introduction of installation systems into the construction industry, shaping the internal microclimate of the building has become easier 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. The office space is located in a building that will be thermo-modernized. Currently, spaces have various technical solutions in the field of window frames, installed radiators and installed lighting fittings. 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 analytically for selected office spaces in different seasons. The article also presents the comparison of the results obtained from the observations with the recommendations contained in the legal regulations together with the analysis of the applied technical solutions of the central heating installation.

1. Introduction

The question of the microclimate of an interior has become the core of people’s interest since they started to spend most of the day in closed spaces. According to the majority of people, activities such as working, staying at home or leisure time should be performed in customized spaces in terms of construction and proper inner conditions. The issues of the microclimate of an interior and the thermal comfort of people staying in buildings have become the subject of many studies. 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 diverse influence on a human body. On one hand, they facilitate keeping the thermal stability and balance of an organism, but on the other hand, they may have a negative effect on the health and comfort of persons staying in the rooms. Architects are tasked with finding a compromise that will provide people with comfortable conditions. Ensuring appropriate conditions for workers has become an important issue because it influences their well-being, concentration, limits accidents and job-related illnesses, moreover, it improves labour efficiency and the quality of service [1].

The installations inside the room, especially heating and ventilation, should be carefully designed because this enables us to gain required parameters. The aim of a heating installation is to raise the
temperature during colder seasons in order to guarantee the thermal comfort, in other words, the state in which a person feels neither warm nor cold [2].

Regardless of the kind of a heating installation, it is essential to include comfort, safety and economical concerns while designing such an installation. It should be customized to a user’s needs, failure-free, and in case of any failure or fault, it should be easy and safe to fix the problem.

Basic elements of a heating installation are: a heat source, pipes, fittings, devices and heat receivers, especially the heaters and radiators. A primary classification criterion for heaters is: the kind of energy carrier and the way of transferring the heat to the room [3]. Because of shaping the microclimate inside the room, a quite important is the way of transferring the heat and it may be done by convection or radiation. The kind of heaters in the room directly influences the conditions in the room. This article attempts to evaluate the inner microclimate of chosen office spaces, in which different heaters are installed. Presented research results are the part of research cycle carried out before thermal modernization of the building. The analysis of obtained results is based on determining the indexes used to analyse the thermal comfort in a particular room proposed by Fanger [4].

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 [4] (Table 1).

| 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 [5]:
- the temperature of air in the room is: 10 – 30°C,
- the average radiant temperature of the barriers in the room is: 10 – 40°C,
- the air velocity in the room is: 0 - 1 m/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/m²,
- 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.

The PN-EN 15251:2012 standard [6] 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.

2. Methodology

The measurements of the air parameters used to calculate the values of the PPD and PMV indexes were taken in the spaces 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, where partially the bearing elements are solid ferroconcrete walls that are not thermo-modernized. Some rooms in the building have old woodwork and some – new PVC windows. There are rooms and spaces of different use, for example: lecture
halls, office spaces, administrative areas. 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 different heaters and radiators installed in the spaces but there are no thermostatic valves installed. The central heating installation is regulated by the thermal centre. The external wall barriers are marked with low heat insulation and the same, the building generates high energy consumption for heating purposes. The heat-transfer coefficients for the external walls are about 1.5 W/(m²K) and for the old window sets are about 2.6 W/(m²K), while for the new ones, are about 1.5 W/(m²K). In order to evaluate the thermal environment of the administrative areas, 6 office spaces were selected with a similar surface of about 17 m² 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. In the rooms face north, there are cast iron radiator located under the windows (Figure 1), and in other two rooms, there are radiators made of FAVIERA tubular steel (Figure 2).

During the measurements of the air parameters, the windows and doors inside were closed, the lightening was on and one computer was working. The measurement was taken three times each day. The first measurement was taken at about 8.00 a.m., next at 12.00 and the last – at 3.00 p.m. Three measurement days were chosen in the heating season: 21st November 2017, with an average temperature of the external air of 2.3°C, 18th December 2017, with an average temperature of the external air of -1.9°C and 15th January 2017, with an average temperature of the external air of -2.6°C. According to PN-EN ISO 7730:2006 standard [7], 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/m²,
  - 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 [7] standard and the possibility of modernization was discussed in order to improve the thermal comfort of tested rooms.

The measurement of the humidity and the air temperature was taken by means of Comet thermo-hygrometer C3120 and the test measurement of the air velocity was taken by means of Airflow anemometer TA 430. The mentioned devices have the certificates of conformity and calibration.

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 [7]. 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 |
|--------------------|-----------------|-----------------|-----------------|-----------------|
| 21.11.2017          | PMV  | PPD  | 18.12.2018          | PMV  | PPD  | 15.01.201          | PMV  | PPD  |
| room 1              | -0.42| 8.70 | room 1              | -0.02| 5.00 | room 1              | -0.25| 6.30 |
|                     | -0.38| 8.10 |                   | 0.13 | 5.30 |                   | 0.04 | 5.00 |
|                     | -0.30| 6.90 |                   | 0.02 | 5.00 |                   | -0.05| 5.10 |
| room 2              | -0.47| 9.60 | room 2              | -0.13| 5.40 | room 2              | -0.31| 7.00 |
|                     | -0.43| 8.80 |                   | -0.06| 5.10 |                   | -0.15| 5.40 |
|                     | -0.34| 7.40 |                   | 0.04 | 5.00 |                   | -0.19| 5.70 |
| room 3              | -0.31| 7.00 | room 3              | -0.23| 6.10 | room 3              | -0.31| 6.90 |
|                     | -0.24| 6.20 |                   | -0.12| 5.30 |                   | -0.26| 6.40 |
|                     | -0.20| 5.80 |                   | -0.10| 5.20 |                   | -0.24| 6.20 |
| room 4              | -0.32| 7.20 | room 4              | -0.08| 5.10 | room 4              | -0.16| 5.50 |
|                     | -0.28| 6.60 |                   | -0.08| 5.10 |                   | -0.17| 5.60 |
|                     | -0.25| 6.30 |                   | -0.11| 5.30 |                   | -0.24| 6.20 |
| room 5              | -0.48| 9.80 | room 5              | -0.40| 8.40 | room 5              | -0.16| 12.70 |
|                     | -0.46| 9.40 |                   | -0.43| 8.90 |                   | -0.57| 11.80 |
|                     | -0.43| 8.90 |                   | -0.41| 8.50 |                   | -0.46| 9.40 |
| room 6              | -0.54| 10.90| room 6              | -0.38| 8.00 | room 6              | -0.55| 11.40 |
|                     | -0.47| 9.50 |                   | -0.41| 8.50 |                   | -0.42| 8.70 |
|                     | -0.42| 8.70 |                   | -0.43| 8.90 |                   | -0.33| 7.30 |

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: 21.12.2017 (Figure 3.), 18.12.2017 (Figure 4.), 15.01.2018 (Figure 5), for the selected hour: 12.00 a.m.
Figure 3. PMV and PPD in office space date 21.11.2017

Figure 4. PMV and PPD in office space date 18.12.2017

Figure 5. PMV and PPD in office space date 15.01.2017

In the graphs presenting the values of PMV and PPD indicators one can notice the dependence that the problem is posed by two rooms on the southern side. The percentage of people dissatisfied with the conditions in the room increases with the decrease of the outside air temperature.

4. Conclusion

The research presented in the article is the element of complex research on the internal microclimate of the rooms located at the University of Science and Technology in Bydgoszcz, in a building that is going to be thermo-modernised. The thermal modernisation will include the insulation of the external wall barriers, the replacement of woodwork and the modernisation of the central heating installation. At present, the building does not meet the obligatory requirements connected with barrier insulation, which influences the energy consumption of the building object and the conditions inside the rooms. On the basis of the measurements, which were taken, it can be stated that:
• The value of the PMV coefficient in 100% fits into the range of conditions, which correspond to the 3rd category from -0.7 to +0.7.

• Uncomfortable internal conditions appeared on a warmer day in the rooms faced south with old windows and radiators made of FAVIERA tubular steel. This heating system does not work well in office rooms, it is not very efficient, which causes a feeling of cold in people staying in the room.

The analysis of obtained results indicates moderate or unsatisfying work conditions in chosen office spaces. The building does not meet the insulating requirements and has different heat receivers which cause variable internal conditions depend on atmospheric conditions. The solution with the use of Faviera heaters in an office space results in thermal discomfort of people staying inside. The research results presented in the article are the fragment of research cycle carrying out to determine the conditions in the rooms in a chosen building. After the thermal modernisation of the building object, the test measurements are planned to be taken in order to determine the impact of the implemented changes on the internal environment. On the basis of the publication [8], it can be assumed that after the thermal modernisation, the thermal comfort of the workers will improve.

References
[1] Chojnacka A and Sudol-Szopińska I 2007 Thermal comfort in office areas in terms of standards (Work Safety vol 6) pp 16-19
[2] Recknagel, Sprenger, Honmann, Schramek, Guide Heating and Air-conditioning, EWFE, Gdańsk 2008
[3] Koczyk H., Practical heating. Designing, assembly, operation, SYSTHERM SERWIS, Poznań 2006
[4] Fanger P O 1974 Thermal Comfort (Warsaw: Arkady)
[5] Hendiger J Ziętek P and Chludzińska M 2013 Ventilation and air conditioning. Design aids (Warsaw: Venture Industries)
[6] PN-EN 15251:2012 Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics
[7] PN-EN ISO 7730:2006 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
[8] Shaharon M N and Jalaludin J 2012 Thermal Comfort Assessment-A Study Toward Workers’ Satisfaction in a Low Energy Office Building, American Journal of Applied Sciences vol 9. pp 1037-1045