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Traditional and Intelligent Buildings – Perceptions of Thermal Comfort

KRAWCZYK Natalia[1,a] *

[1]Faculty of Environmental, Geomatic and Energy Engineering, Kielce University of Technology, Poland

[a]nkrawczyk@tu.kielce.pl

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Abstract. The article presents the perception of thermal comfort in two buildings, intelligent and traditional. 32 people aged 18 to 22 and one women aged 52 participated in the study. Two indicators were analyzed, PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied). The analysis consisted in comparing the actual feelings of the respondents with the results based on Fanger's model. The assessment of air humidity and thermal preferences are also shown.

Introduction

Thermal comfort is a state in which we are neither too cold nor too warm. It is difficult to choose the right parameters in a room because one person may be too warm and for another, it may be too cold in the same air parameters and in the same room. Everyone's perception of our surroundings is different. This is only a subjective judgment. The perception of thermal comfort is influenced by air temperature, relative humidity, carbon dioxide concentration, air speed, light intensity, seasons of the year, noise, etc. Each of these factors may affect our well-being or discomfort. The consequence of not ensuring thermal comfort may also be, for example, a headache, which makes us feel less productive. The assessment of thermal comfort is a very important issue. It helps us determine the parameters in which a person feels indifferent. For modern construction, it is assumed that the requirements for controlling the parameters of the internal environment with the use of BMS (Building Management System) systems will meet the highest requirements compared to traditional construction.

In the 1970s, O. Fanger, on the basis of the applicable standards: ISO 7730 [1] together with PN-EN 16798-1: 2019 [2], developed two indicators, PMV (Predicted Mean Vote) and PPD denoting the predicted number of dissatisfied people (Percentage of Dissatisfied People). The PMV index is expressed on a seven-point scale, where "-3" means cold and "+3" hot.

Currently, many researchers are involved in research on thermal comfort in school buildings, homes, universities, and offices, and less in intelligent buildings. The research on thermal comfort in intelligent buildings was carried out by Krawczyk and Krakowiak [3], who compared the results of an intelligent building with a traditional building. The research shows a difference between the PMV index and the actual results from the questionnaires. Their results showed that PMV in summer was below zero, and vice versa in winter. Homoda et al. [4] found that not only temperature is an important factor influencing thermal comfort. Relative humidity should also be taken into account. The research on thermal comfort in schools was carried out by Jindal [5] on 130 students. He examined the thermal environment and students' perceptions, finding that students feel best at temperatures ranging from 15.5 to 33.7°C. The authors [6, 7] dealt with research on intelligent buildings. It has to be mentioned that thermal sensations depend not only

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on the air temperature but also on a number of factors for example individual preferences, and heat transfer issues [8-11]. It may be evaluated by a time-consuming FEM analysis or, alternatively, by a surrogate model derived from DOE methods [12, 13] and a non-parametric approach [14, 15].

Air-conditioning and heating devices significantly affect the conditions in the room, therefore the designed air-conditioning and heating systems should provide appropriate parameters, depending on the purpose of the room.

Material and Method

In this study, a study was carried out for two buildings, a school building and an intelligent building of Energis of the Kielce University of Technology. The results for the first building were taken from the article [3]. However, for the second building, research was carried out in January 2022. Air temperature, relative air humidity and air velocity for the traditional building are 27.7°C, 47.60% and 0.05 m/s [3], while for the intelligent one: 25.1°C, 29.72% and 0.09 m/s.

The school building has no ventilation in the classrooms. On the other hand, the building of the Kielce University of Technology has mechanical ventilation. The intelligent building houses 22 lecture halls, laboratories, and rooms for lecturers and other employees. It is equipped with solar collectors, heat pumps, and photovoltaic cells, which are placed on the roof of the building. Thanks to photovoltaic panels and solar collectors, the building uses solar energy to heat water and generate electricity to illuminate the building. The school building is shown in Fig. 1 below, and the building of the Kielce University of Technology is shown in Fig. 2.

Fig. 1. Photo of the school building.

Fig. 2. Photo of the Energis building.

The school building was built in 1903, and the supply of fresh air is possible only through doors and windows. The Energis building, on the other hand, was built in 2012 and was designed with sustainable development in mind.

The study was conducted using two methods. The first method was to measure the microclimate parameters with a Testo 400 gauge. It was placed at the level of the thermal center of gravity. Air temperature, black sphere temperature, air velocity, mean radiation temperature, relative humidity, and carbon dioxide concentration were measured. The values were read after the measurements stabilized for 15 minutes. The second method consisted in completing the questionnaires on thermal impressions of the microclimate. This allowed for the assessment of thermal comfort in the room in which they stayed. In addition, the survey contained a question about clothing, thanks to which the average level of insulation of the garment was determined. The thermal resistance of the office chair was added to the value of thermal resistance, which is 0.1 clo. The total value of the thermal resistance for the first room was 0.62 clo, and for the second - 0.73 clo. At the end of the questionnaire, there was a record with data on the age, sex, weight, and height of the respondents. 32 people aged 18 to 22 and one women aged 52 participated in the buildings in question.

Results and Discussion

The same number of people took part in both rooms. In the first room, the subjects were 17 to 18 years old and one woman was 52 years old, and in the second room, they were from 20 to 22 years old. The respondents were asked about their thermal feelings, which are included on a seven-point scale: "-3" - too cold, "-2" - too cool, "-1" - pleasantly cool, "0" - comfortable, "1" - pleasantly warm, "2" - too warm, "3" - too hot. Fig. 3 below shows the frequency of the answers given on the subject of thermal impressions.

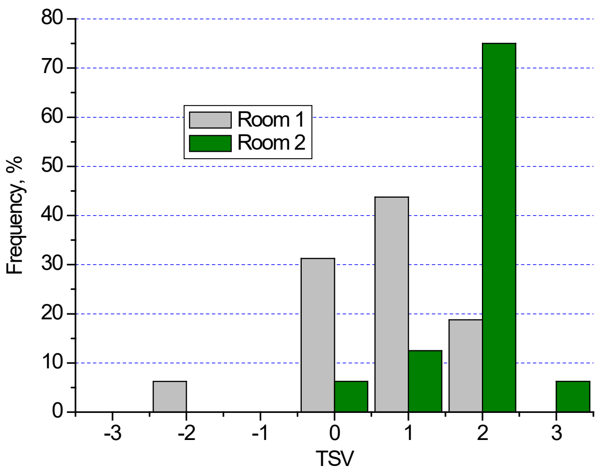

Fig. 3. Frequency of responses regarding thermal sensations vote (TSV).

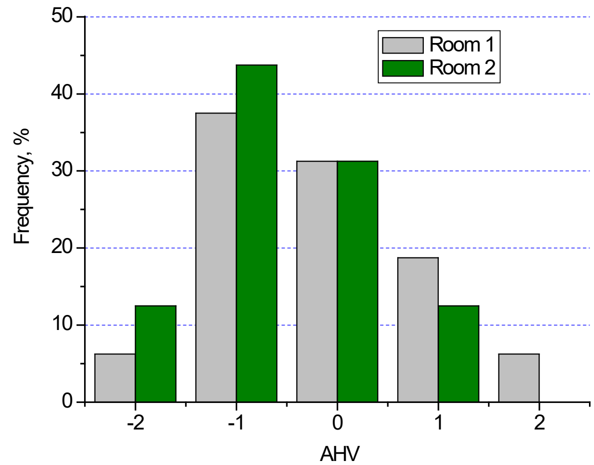

Fig. 4. Frequency of responses regarding air humidity vote (AHV).

In the figure above, the results for a traditional building are marked in gray, and the results for an intelligent building are green. It can be noticed that for a traditional building, students most often chose the answer "pleasantly warm", which amounted to 43.75%. They then chose the answer "comfortable" - 31.25%. Consecutively "too warm" - 18.75%, while the least chosen answer by students was "too cool" (6.25%). For the Energis building it looks like this: the most common answer was "too warm" (75%), then "pleasantly warm" (12.50%), and the options "comfortable" and "too hot" had the same number of answers - 6,25%. Looking at all the answers, it was found that the respondents did not feel well in the rooms they studied. For both buildings, the percentage of choosing the answer -3, -2, + 2, + 3 was greater than 10.00% and amounted to 25% for a traditional building, and 81% for an intelligent building. The respondents were also asked about the assessment of indoor humidity. In the questionnaire, when asked about the assessment of air humidity, there were the following answers: "-2" - too dry, "-1" - fairly dry, "0" - pleasantly, "1" - quite damp, "2" - too humid. The graph for the assessment of air humidity is presented in Fig. 4. The most frequently chosen answer for both rooms was the answer "fairly dry". It was 37.50% for the first room and 43.75% for the second room. The second most frequently chosen answer was "pleasantly". For both buildings, it accounts for 31.25% of all the answers provided. The respondents chose the next answer, it is "quite damp". It is 18.75% for the first room and 12.50% for the second. The options "too dry" and "too humid" are 6.25% each for the first room. For the second room, the answer "too dry" is 12.50%. It can be concluded that the respondents assessed the humidity in the examined rooms in a similar way. Fig. 5 shows respondents' preferences for humidity.

Respondents had a choice of individual answers: "-1" - drier, "0" - no change, "1" - more humid. It can be seen from the chart above that the respondents would like their indoor air to be more humid. It looks like this. For room 1 "no change" and "more humid" are at the same level, they constitute 43.75%. When asked about their preferences regarding humidity, the respondents also selected the "more dry" option, which is 12.50%. When assessing the air humidity for the second room, more than half of the respondents (56.25%) considered the prevailing conditions "pleasantly". 43.75% of the respondents chose the answer "no change".

From this chart, it can be seen that the respondents want changes in indoor air humidity. The comparison between the TSV obtained from the questionnaires and the PMV calculated from the Fanger model is presented in Fig. 6.

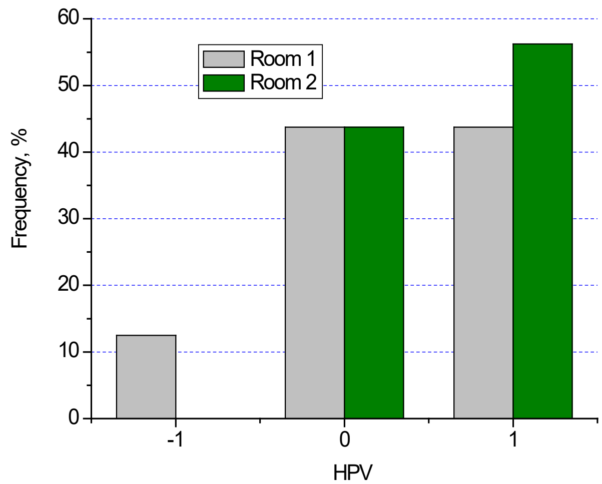

Fig. 5. Frequency of responses regarding the humidity preferences vote (HPV).

Figure 6 shows the gray color of the PMV results calculated on the basis of the Fanger model, while the green color represents the TSV obtained from the questionnaires. It can be seen that for the traditional building (Room 1) and the intelligent building (Room 2), the PMV and TSV values do not coincide. The adopted range of thermal comfort ranges from -0.5 to +0.5. Taking the answers obtained from the questionnaires, both buildings mix in this respect, but looking at the calculated results, they do not fit anymore. PMV for the first room is 0.16 and for the second room -0.1. On the other hand, the TSV is outside the scope of the ISO 7730 standard. The TSV for the traditional one is 0.69, and for the intelligent one is 1.81. Such a discrepancy between these indicators may depend on many factors that were not included in Fanger's model. Figure 7 below presents the thermal sensations of dissatisfied people in the examined rooms.

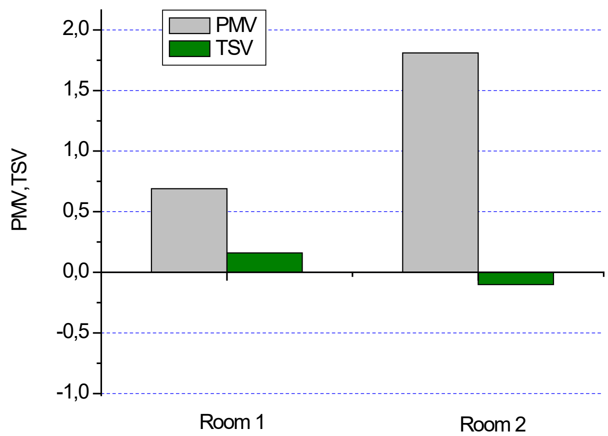

Fig. 6. A comparison of PMV calculated on the basis of the Fanger model and TSV obtained using questionnaires for both the buildings.

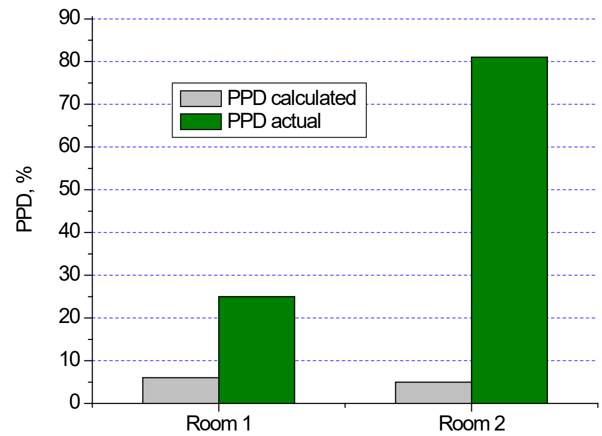

Fig. 7. Comparison of actual survey results with calculated results for PPD.

The above figure presents the results concerning the percentage of people dissatisfied with the prevailing indoor conditions. The results calculated on the basis of the Fanger model are marked in grey, and the results from the questionnaires are marked in green. The PPD is in no way overlapping with each other. For building 1, PPD was calculated at 6%, and 25% from the questionnaires. For building 2, the PPD z calculated on the basis of the Fanger model is equal to 5%, and on the basis of the surveys, it is equal to 81%. Hence the conclusion that the actual PPD results are much higher than those calculated on the basis of the Fanger model.

Conclusions

The measurement results of the microclimate parameter from the Testo 400 measuring device were compared with the actual results based on the questionnaires. The research for the traditional building was carried out in summer, and for the intelligent building in winter. Overall, the study confirmed that the TSV results (based on the questionnaires) were not consistent with the PMV results (calculated using the Fanger model). Therefore, the best solution is to modify the Fanger model. This discrepancy may result from other parameters that are not included in the model but have an impact on people's feelings and their responses to the surveys. Differences can also be seen in the PPD indicator. According to the ISO 7730 standard, the PPD ratio should not exceed 10%. Unfortunately, for a traditional and intelligent room, the percentage of dissatisfied people exceeded 10%. This proves that the Fanger model needs to be modified. Additionally, the survey showed that respondents prefer higher relative humidity. Therefore, it is necessary to take care of the thermal conditions of people staying in educational rooms.

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