EVALUATION OF THERMAL COMFORT IN MODERN SMALL UNIVERSITY LECTURE HALL IN RELATION TO AIR CONDITIONING SYSTEM

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ABSTRACT

The paper is focused on the evaluation of thermal comfort in modern small university lecture hall in relation to air conditioning system. Providing the optimal parameters of the thermal comfort in the interiors of a university is immensely important for the students. Meeting these parameters is inevitable not only from physiological point of view but also to achieve the desirable students' performance. Parameters of the thermal comfort are also influenced by air conditioning system in small university lecture hall. Correct design of air conditioning system parameters is very important. Experimental measurements of thermal comfort were carried out in the winter season in the small lecture hall of Vienna University of Economics and Business. The device Testo 480 was used for the measurements. Gained values of air temperature, air relative humidity, air velocity, globe temperature, indexes PMV and PPD are presented in the charts. Modern air conditioning system of the small university lecture hall was evaluated on the basis of thermal comfort parameters. Conclusion of this paper states the principles of how to design modern air conditioning systems in the small new university lecture halls.

1. INTRODUCTION

Modern world universities have also air conditioning system or mechanical ventilation system in small university lecture halls. In Slovakia, small university lecture halls have neither air conditioning system nor mechanical ventilation system. New universities as well as existing old universities in Slovakia have small university lecture halls only with natural ventilation. Missing air conditioning system or mechanical ventilation system is a disadvantage of small university lecture halls regarding thermal comfort and CO₂ concentration. Therefore, it is important to equip small university lecture halls in the new modern universities with air conditioning system or mechanical ventilation system. When planning reconstruction of an existing old small university lecture hall, air conditioning system or mechanical ventilation system should be considered.

Ensuring thermal comfort in the small university lecture hall is very important because students spend the majority of their time in university buildings in the small university lecture halls. Thermal comfort in the small university lecture hall is defined as the state of mind that expresses satisfaction with the surrounding environment. The fundamental quantities for the evaluation of the thermal comfort are internal air temperature, operative temperature, globe temperature, air relative humidity and air velocity [1]. Then the thermal comfort is evaluated with index PMV (Predicted mean vote) and index PPD (Predicted percentage dissatisfied) [2], [3]. Not fulfilling the parameters of the thermal comfort in the small university lecture hall contributes to dissatisfaction and the high sickness rate of students, especially in the winter [4], [5]. There is no teaching process happening during summer season and thus the focus of the research was on the winter season [6], [7].

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https://doi.org/10.2478/9788395669699-006
Thermal comfort in small university lecture halls with air conditioning system or mechanical ventilation system is influenced by the position of supply air and extract air, direction of airflow and air velocity [8]. Big disruption of the thermal comfort and formation of local thermal discomfort is induced by incorrectly designed position of supply air and extract air or excessive air velocity [9].

When the parameters and air elements of air conditioning system or mechanical ventilation system are incorrectly designed then the local thermal discomfort emerges. The incorrect operation of ventilation system might also contribute to its creation. Local thermal discomfort (the thermal dissatisfaction) can also be caused by unwanted cooling or heating of one particular part of the body [10]. The most common cause of the local thermal discomfort is the draught but local discomfort can also be caused by an abnormally high vertical temperature difference between head and ankles, by too warm or too cool floor, or by too high radiant temperature asymmetry. People are most sensitive to radiant asymmetry caused by a warm ceiling, a cool wall (windows, glazed facade), a cool ceiling or by a warm wall. Incorrect position, incorrect distance of supply air and extract air from the floor, and the incorrect velocity of the air flow usually causes also the feeling of draught which is one of the most serious cause of the emergence of local thermal discomfort.

2. ANALYSIS OF AIR CONDITIONING SYSTEM IN MODERN SMALL UNIVERSITY LECTURE HALL

Modern prestigious universities put a big emphasis on the quality of indoor climate not only in large university lecture halls but also in small university lecture halls; even in the smallest lecture rooms. Large and small university lecture halls use high-quality air conditioning system and the smallest lecture rooms use mechanical ventilation system. Thus, they do not rely on natural ventilation in any space for students. From the thermal comfort perspective, the quality of air conditioning system in small university lecture halls also depends on the correct air distribution system [10]. Students have to feel thermal comfort; pleasantly warm without the feeling of draught. Therefore, besides the air temperature and air velocity in air vents, the position of supply air and extract air in small university lecture hall is very important [11]. The most modern and suitable solution is the air distribution from the bottom towards the top, which must be considered already in architectural design of the interior of small university lecture hall. It is necessary to design interior in such a way that air conditioning system can work effectively. During air distribution, air velocity in vents for supply air can be very low and thus a sitting student does not have a feeling of draught. In small university lecture halls, the following air distributions are unsuitable: from the top towards the bottom and from the front to the back wall. These unsuitable air distributions in small university lecture halls cause a high air velocity in the parts of students’ seating which causes the feeling of draught, dissatisfaction and worse concentration during the lecture.

Modern new small university lecture halls were chosen for scientific analysis. Air distribution systems were analyzed in detail. Existing modern new small university lecture halls were closely analyzed in terms of placement of vents for supply air. The most used system was air distribution from the bottom to the top; therefore, this type of air distribution was analyzed. Often, the vents for supply air were placed directly into the floor but the most progressive solution is the one where the vents for supply air are located in the stepped floor which is built because of stepped seating. From all of the analyzed modern new small university lecture halls, the one at Vienna University of Economics and Business was chosen for the research of thermal comfort in relation to air conditioning system, Figure 1. Floor shape of small university lecture hall is stepped. Architectural solution sticks to the simple and clear outline which is contrasted by bright orange color of seating for students, Figure 2. The position of rectangular continuous vents for supply air in the stepped floor in small university lecture hall is shown in Figure 3. Architectural design of small university lecture hall is harmonized with shape, position and location of vents for supply air. Neat and simple shape of the small hall is in accordance with simple shape of vents for supply air in stepped floor. Unobtrusive and modern vents for supply air does not disturb
architectonic appearance of the interior. Suppressed design of vents for supply air contrasts with bold orange color of seats. Vents for extract air are placed in ceiling.

Figure 1. Researched small university lecture hall in Vienna University of Economics and Business

Figure 2. Vents for supply air in the stepped floor of researched small university lecture hall

3. METHODOLOGY OF EXPERIMENTAL MEASUREMENTS IN MODERN SMALL UNIVERSITY LECTURE HALL

Experimental measurements were carried out in the small university lecture hall – Figure 1, Figure 2 at the Vienna University of Economics and Business in the end of March. The aim of the measurements was to record the parameters of the thermal comfort: air temperature, air relative humidity, air velocity, index PMV and index PPD.

The measurements were carried out in the small university lecture hall in four standpoints – A, B, C, D in the height of 1.1 m above the floor level, and in two standpoints – E, F in the height of 0.1 m above the floor level, Figure 3. Standpoint A was in the next-to-last row of students’ seating on the right side (next to indoor wall) in the height of 1.1 m above the floor level, Figure 4a. Standpoint B was in the fifth row of students’ seating on the right side (next to indoor wall) in the height of 1.1 m above the floor level, Figure 4b. Standpoint C was in the fifth row of students’ seating on the left side (next to external wall) in the height of 1.1 m above the floor level, Figure 4c. Standpoint D was in the next-to-last row of students’ seating on the left side (next to external wall) in the height of 1.1 m above the floor level, Figure 5a. Standpoint E was in the next-to-last row of students’ seating on the right side (next to indoor wall) in the height of 0.1 m above the floor level, Figure 5b. This means that standpoint E is on the same place as standpoint A; only the height above the floor level is different. Standpoint F was in the next-to-last row of students’ seating on the left side
(next to external wall) in the height of 0.1 m above the floor level, Figure 5c. This also means that standpoint F is on the same place as standpoint D; only the height above the floor level is different. All of the measurements took place during the lectures with full capacity of small university lecture hall; therefore, it was not possible to do the measurements in the center of the hall.

Figure 3. Ground-plan of small university lecture hall with standpoints

Figure 4. Measurements in standpoint A, B and C in the height of 1.1 m above the floor level

Figure 5. Measurements in standpoint D in the height of 1.1 m above the floor level, in standpoint E and F in the height of 0.1 m above the floor level
The parameters of the thermal comfort were recorded with the device Testo 480. Input data in measurements were metabolic rate 1.0 met and clothing insulate 1.0 clo. Twenty measurements with time delay (one by one) were carried out in each standpoint. Statistical mean was calculated from measured values. Measurements were carried out one by one in individual standpoints. Outdoor air temperature and air relative humidity were measured and recorded by the separate device. Outdoor air temperature increased from value 21.3 °C to value 21.9 °C. Outdoor air relative humidity decreased from the value 43.1 % to the value 43.9 %.

4. RESULTS AND ANALYSIS OF MEASUREMENTS

Figure 6 shows the values of air temperature in the height of 1.1 m and 0.1 m above the floor level in all standpoints. In all standpoints, the air temperature was optimal. Among the standpoints A, B, C, D was minimal difference. The biggest air temperature was in standpoint B which is located in the room center near indoor wall. In standpoints A, B, air temperature was just slightly bigger than in standpoints C, D. External wall has northeast orientation and is very well insulated. Area of good quality windows is optimized. Values of air temperature in standpoints E, F were slightly smaller compared to others which means that also values in the height of 0.1 m above the floor level are satisfactory. These results definitely showed optimal provision of thermal comfort, usage suitability of air conditioning system, correct air distribution system and correct placement position of vents for supply air in the stepped floor.

![Image of air temperature graph](image1)

Figure 6. Values of air temperature in all standpoints

The values of air velocity in the height of 1.1 m and 0.1 m above the floor level in all standpoints were in range of values 0.00 and 0.02 m.s\(^{-1}\), which means satisfactory values. It confirms the suitability of air conditioning system with vents for supply air in the stepped floor.

Figure 7 shows the values of air relative humidity in the height of 1.1 m and 0.1 m above the floor level in all standpoints. The values of air relative humidity were acceptable; to achieve optimal values, it would be needed to slightly moisture the air.

![Image of air relative humidity graph](image2)

Figure 7. Values of air relative humidity in all standpoints
Figure 8 shows the values of index PMV in the height of 1.1 m and 0.1 m above the floor level in all standpoints. In all standpoints, the value of index PMV was optimal and balanced. Values in standpoints C, D, F were only slightly lower but the index PMV was still reaching optimal values. Values of index PPD reached maximal value of 6.3 which is optimal. Results showed the suitability of use of air conditioning system and the correct location of the placement of vents for supply air in the stepped floor.

5. CONCLUSIONS

The evaluation of thermal comfort in modern small university lecture hall definitely showed the need and correctness of application of air conditioning system. For students’ well-being, it is very important to ensure optimal values of thermal comfort parameters in the height of 1.1 m and 0.1 m above the floor level. Furthermore, the experiments confirmed the suitability of air distribution system from the bottom towards the top. Both the scientific analysis and the measurement results showed that it is the most suitable to use vents for supply air in the stepped floor. Airflow from these vents for supply air is uniform and can ensure optimal thermal comfort parameters. Hot, pleasant air with low velocity flows around the students’ legs and thus unpleasant feelings and local thermal discomfort do not arise. Researched modern new small university lecture hall at Vienna University of Economics and Business is a suitable example of good cooperation between HVAC designer and architect.

REFERENCES