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Experimental Study on Human Thermal Comfort in Classroom Environment

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Abstract

This study aims to find out the relationship between human overall satisfaction and indoor air quality, so as to evaluate the thermal comfort of human body under the combined action of various factors. This study adopts the research method of combining objective measurement with subjective questionnaire. In terms of objective measurement, the main test parameters include indoor temperature, wind speed, relative humidity, carbon dioxide concentration, outdoor temperature and outdoor relative humidity. The test instrument adopts hand-held multifunctional anemometer and indoor thermal environment and air quality tester. Through the analysis of the measured data and the questionnaire survey, it is found that the indoor thermal environment of the classroom in November is basically comfortable, and it will be slightly cold on low temperature days. The subjective voting TSV is consistent with the predicted PMV, but the value is relatively low, which is mainly caused by the non-artificial air conditioning environment, human subjective expectation and adaptability.

Keywords

Thermal Comfort; Temperature; Indoor Air Quality.

1. Introduction

People spend most of their lives indoors. The indoor environmental quality is mainly determined by several factors such as heat, sound, light and air quality, which is closely related to people ' s production and life. Since the 20th century, the rapid development of various indoor environment control technologies represented by air conditioning has enabled human beings to gradually master the adjustment means of the above environmental factors, which provides the possibility for creating a comfortable indoor environment. In the fields of heat, sound, light and air quality, many scholars have done a lot of research and exploration. However, with the increasing occurrence of morbid architectural syndrome in modern architecture, researchers have realized that people ' s discomfort in architecture is often not affected by a single factor, but a combination of various factors on human physiology and psychology. It is difficult to solve the problems caused by sick building syndrome only by studying single factors such as thermal environment and air quality. Therefore, some scholars put forward the indoor air quality is a certain time and a certain area of the air contained in the test. It is an important indicator for indicating environmental health and habitability. The main standards include oxygen content, formaldehyde content, water vapor content, particulate matter and so on. It is a set of comprehensive data that can fully reflect the air condition of the place. Classroom is an important place for teachers and students ' teaching activities. The teaching activities of teachers and students on campus are mostly completed in the classroom. A good indoor environment is a necessary condition to ensure students ' learning efficiency and health. With the continuous improvement of people ' s living standards, people ' s attention to indoor thermal environment and healthy air quality is also growing. Therefore, the investigation and analysis of classroom indoor environment is of great significance. At the same time, indoor air quality is not only related to the comfort and health of building users, but also further affects their work and learning efficiency. Relevant articles show that if the indoor environment quality is improved, the work efficiency of personnel can be increased by 15 % to 20 %. Therefore, it is very important to study the indoor environmental quality of public buildings and its evaluation method. In this study, the relationship between the overall satisfaction of human body and indoor air quality and the thermal comfort of human body under the combined action of various factors were further explored through the air quality satisfaction questionnaire and the questionnaire survey of indoor personnel.

2. Research Data

2.1 Basic Information of Investigation Sites

The site for the investigation was selected at the No. 11 Teaching Building of North China Electric Power University. The survey site belongs to a cold area and the design requirements are to first meet the winter insulation requirements and some areas take into account the heat protection requirements. The average high temperature at the survey site in November 2021 is 16°C. The average low temperature is 4°C. The extreme high temperature is 18°C and the extreme low temperature is 4°C. This study uses the November temperature change curve of previous years to roughly analyze the trend of November temperature change.

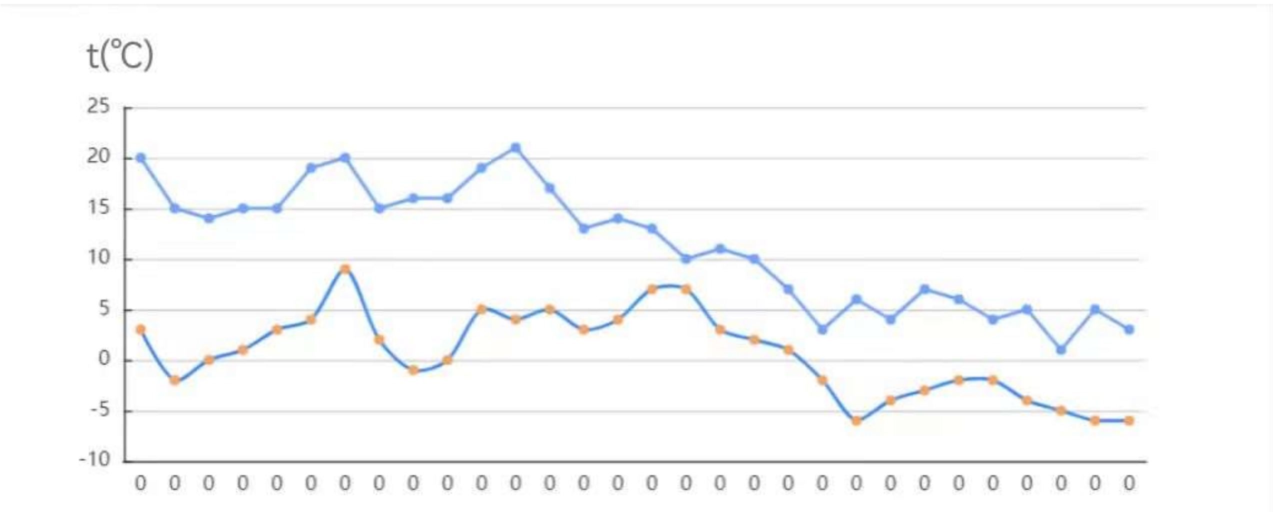

Fig. 1 Changes in the maximum and minimum temperatures in November

It can be seen from the analysis in the figure that the average low temperature of the survey site in November 2020 was 0°C. The average high temperature was 11°C and the average temperature was between 3 and 15°C. The temperature in this month was not stable enough. As can be seen from the figure, the lowest temperature this month is only -6 °C, the highest temperature is as high as 22 °C, the smallest daily temperature difference is only 3 °C, and the largest daily temperature difference is as high as 18 °C. The number of heating and cooling is relatively frequent. The survey was conducted on November 16 and 18 respectively. This article refers to the 16th as the colder day and the 18th as the hotter day. The object of this survey is the classroom of No. 11 Teaching Building of the Second Campus of North China Electric Power University in Baoding City. The room is 10.5m long and 8m wide. There are four windows on one side. The windows are 2 m high and 1.5m wide. Since there is heating in the classroom, the average indoor temperature is maintained at 16-18°C.

2.2 Objective Measurement

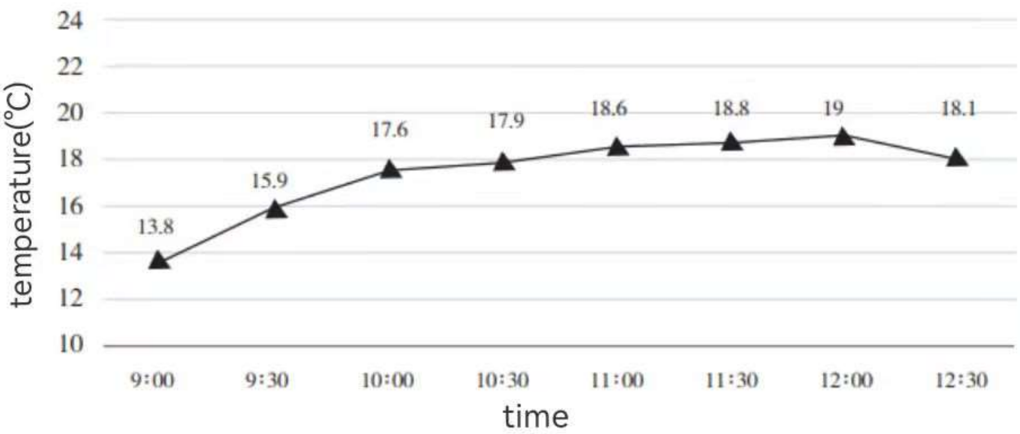

Fig. 2 Indoor temperature change

The classroom time for this survey is from 9:15 to 12:00, and the measurement starts at 9:00 and ends at 12:30. From the indoor time-temperature change chart, it can be seen that the room temperature is low before class, high during get out of class, and decreased after class. The room temperature was raised by 5.2°C. Indicates the presence of personnel and the heat from instructional activities that may have increased room temperature in the classroom. Observing its change law, the temperature rises rapidly in the first 1 h, and then slows down.

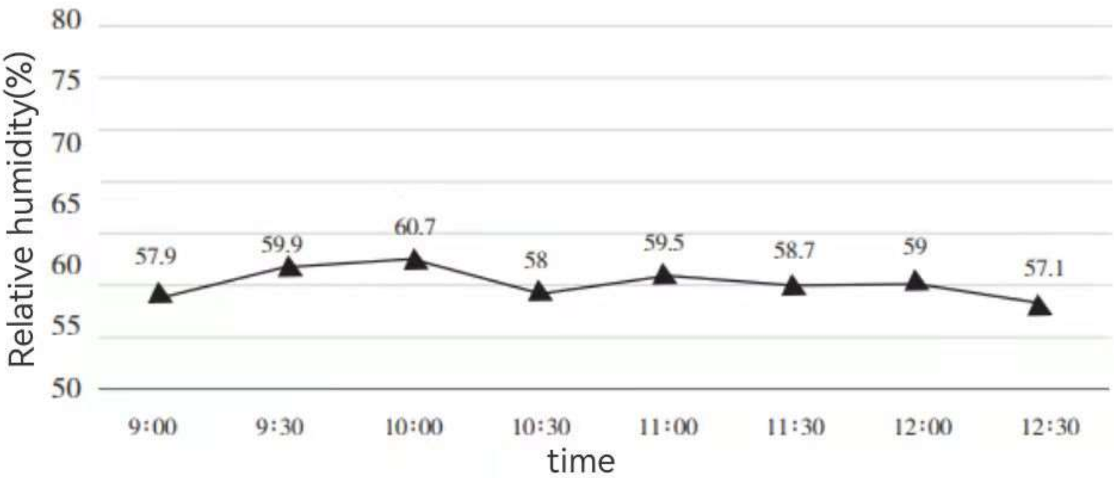

Fig. 3 Indoor relative humidity change

Indoor relative humidity did not change significantly as students entered the classroom and studied. However, compared with the measured value of outdoor relative humidity, the measured indoor humidity is about 20 % higher than the outdoor humidity. In addition, the indoor wind speed is kept at about 0.1 m/s.

2.3 Questionnaire

The main items of the questionnaire in this research include activities, thermal sensation voting TSV and thermal environment satisfaction. Among them, the activities of the surveyed persons are mainly sitting posture learning (filling in the form), and their activity metabolic rate is 1.2 met; in terms of the thermal resistance of clothing, the surveyed students use the formula to calculate the thermal resistance value of the clothing with typical clothing, and after taking the average value The estimated thermal resistance of the clothing condition of the respondents was 1.0 clo.

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$$Icl=0.82\sum I\ cli+0.161$$

The thermal sensation voting TSV situation is shown in the figure respectively. Among them, 24 people on colder days chose -1 accounting for 41.37% and 33 people on warmer days chose 0 accounting for 56.89%.

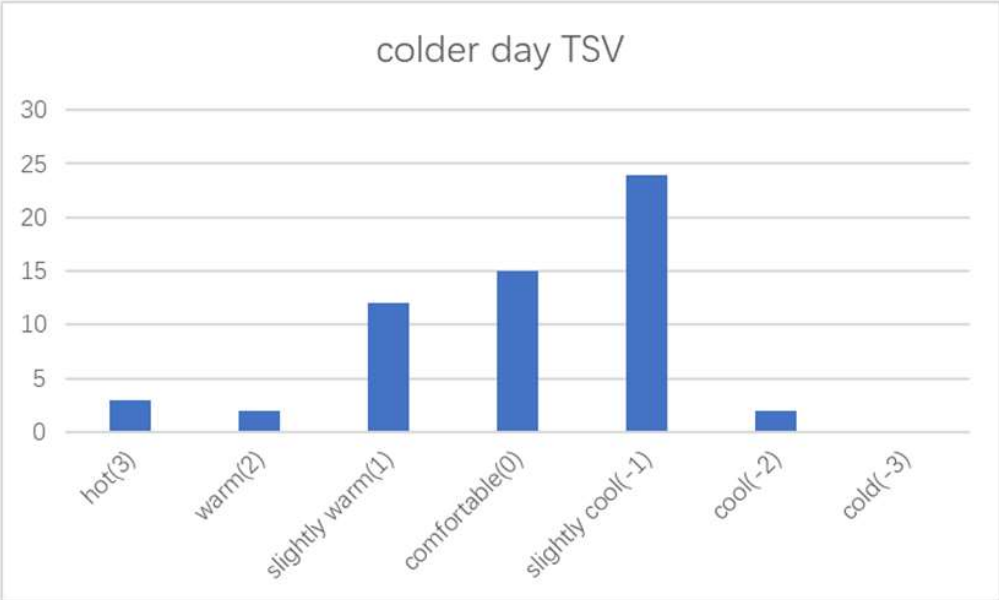

Fig. 4 Colder day TSV voting results

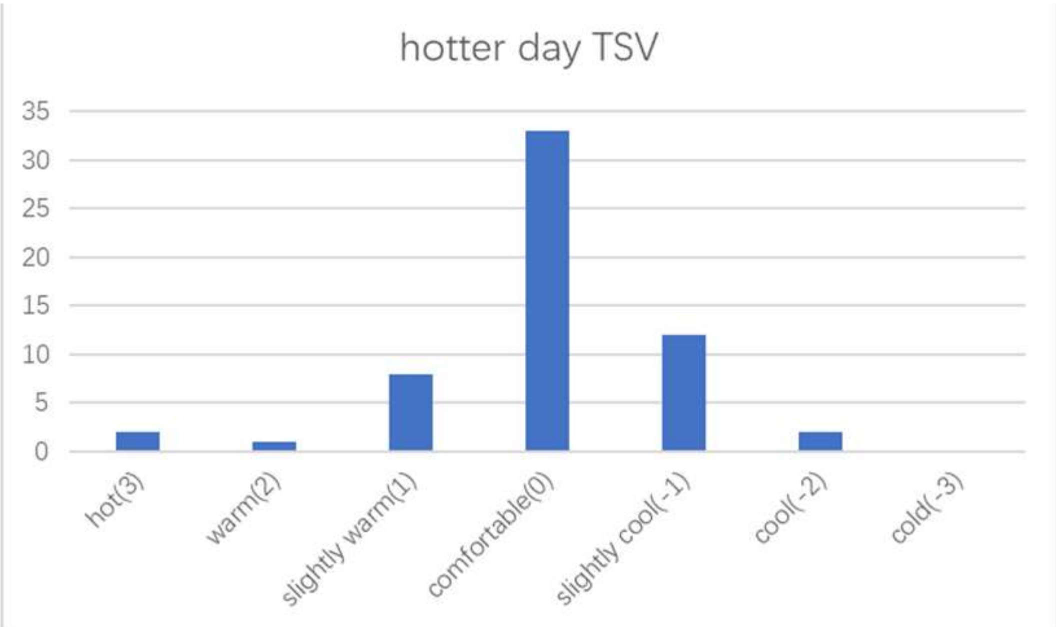

Fig. 5 Hotter day TSV voting results

3. Thermal Comfort Analysis

Using the PMV calculation tool, the objective test data, the metabolic rate of personnel activity and the thermal resistance parameters of clothing were input to calculate the expected average thermal sensation index PMV value when the questionnaire was conducted, which was -0.55 on cooler days and 0.4 on warmer days. Referring to the ASHRAE55 standard, PMV slightly exceeds or falls below thermal comfort by 0.5 on cooler days, indicating that the thermal environment of the classroom basically meets the comfort requirements.

Comparing the thermal sensation voting TSV value of the questionnaire with the calculated PMV value, the thermal sensation of the tested persons is consistent with the objective analysis. However, the votes on colder days have the largest proportion of -1, and the measured and calculated value is -0.55. The TSV value with the highest proportion of voting will be about 0.4 lower than the calculated PMV value. According to "Analysis, Regulation and Interpretation of Thermal Comfort by Calculating PMV and PPD Index and Local Thermal Comfort Criteria" and according to the formula, the PMV value calculated according to the questionnaire is brought in.

$$PPD=100-95\times\exp(-0.03353\times PMV4-0.2179\times PMV2)$$

The predicted dissatisfaction rate PPD values for colder days and hotter days were calculated to be 12.7% and 9.1%, respectively. Compared with the proportion of respondents who were dissatisfied with the questionnaire (27.3% on colder days and 12.6% on hotter days), the dissatisfaction rate of the calculated value was lower than that of the vote.

To sum up, the thermal environment indicators of the two tests in this classroom basically meet the requirements of thermal comfort. The proportion of people who feel slightly cold on colder days is higher and the actual feeling of people will be colder than that predicted by PMV. The main reason is that the calculation method of PMV is suitable for steady-state thermal environment, but not fully applicable in non-artificially regulated environment. It needs to be combined with human physiological, psychological and behavioral adaptation, and can be directly used for thermal comfort prediction after further revision.

4. Conclusion

According to the measured data and questionnaire analysis, the indoor thermal environment of the research classrooms in November is basically comfortable, but it will be slightly colder on days when the temperature is relatively low. The subjective vote TSV of people is consistent with the predicted value PMV, but the value is relatively low. This is mainly caused by factors such as the non-artificial air conditioning environment of the classroom and people's subjective expectations and adaptability.

Thermal sensation is a person's subjective description of whether the surrounding environment is "cold" or "hot". In fact, people cannot directly feel the temperature of the environment, but can only feel the temperature of the nerve endings located under the surface of their skin. Thermal comfort is a combination of the human body's own thermal balance and the perceived environmental conditions to obtain a feeling of comfort. The feeling of comfort is physical and psychological. In addition to the factors in thermal sensation, the factors that affect thermal comfort include air humidity, vertical temperature difference, wind blowing, radiation non-uniformity, and other factors. Therefore, there is a separation phenomenon between thermal comfort and thermal sensation.

Thermal comfort cannot exist in a fixed environment for a long time, it is a dynamic process. Thermal comfort can be achieved in a steady state environment, and thermal comfort can also be achieved in a dynamic environment, which varies with the environment. Moreover, due to the differences between individuals and the different adaptability to various environments, different evaluations of the same environment are produced. People have different thermal sensations and thermal comforts in the same environment, which are largely produced by the thermal adaptability of the human body.

With the improvement of living standards, people have higher and higher requirements for thermal comfort in the indoor thermal environment, and the operating energy consumption of HVAC systems also increases. Studies have shown that the lower the outdoor temperature, the better the adaptation of people to the cold environment. The stronger the sex, the worse the adaptability to the hot environment. Therefore, it is not suitable to maintain the indoor temperature too high in winter, which is not comfortable and wastes energy.

With the development of green buildings, healthy buildings, ecological buildings, ultra-low energy consumption buildings and other fields in China, the aging society and the continuous improvement of the energy consumption level of urban life, the problem of thermal comfort measurement and evaluation suitable for national conditions has increasingly caused people's attention. In the past, heating methods often only focus on indoor temperature. Judging from the temperature index alone, the indoor temperature of buildings across the country is still uncomfortable, and many in the south rely on their own functions to resist freezing.

In my country's existing standards and norms, temperature and humidity are generally used as indicators to measure indoor thermal comfort. The evaluation methods are limited, and the influence of various thermal environmental factors and adaptability factors on indoor thermal comfort is not fully considered. The research on human factors and physical factors has become more and more in-depth, especially the research on physiological heat response, physiological regulation and physiological adaptation mechanism, so that my country's thermal comfort research team gradually incorporates physiological parameters into the research scope.

The PMV indicator reflects the statistical evaluation value in a steady-state uniform thermal environment and does not represent a specific individual. The local climate, living habits, customs and other long-term adaptation, thermal experience, thermal expectations, response to the thermal environment (different thickness of subcutaneous fat), and individual physique are different, and each person's thermal comfort needs are different. Everyone has their own preferred comfort temperature, which varies with activity, clothing, diet, and mood. In order to meet the thermal comfort requirements of most people, it is mainly based on the design standards for heating, air conditioning, and building indoor thermal environment parameters, such as ASHRAE 55 and ISO 7730, but these parameters are limited to a small range.

Neglecting the human body's ability to adapt to the environment, ignoring the building's own environmental regulation, and relying too much on HVAC to create a "steady-state comfortable environment" will not only bring about environmental pollution and energy waste, but more importantly, the decline of the human body's physiological regulation. It is also not good for human health. The dynamic thermal environment is an objective law that conforms to the thermal sensation of the human body. It is an inevitable trend to create a healthy, comfortable, low-energy-consumption, and low-emission dynamic building indoor thermal environment based on people.

With the continuous improvement of people's living standards, the state advocates the creation of green buildings and healthy buildings in a new era. In addition to considering the organization of natural ventilation in architectural design, designers also need to understand and use new technologies such as heat recovery fresh air systems and solar fresh air systems. Improve air quality while focusing on energy conservation to create a sustainable and comfortable indoor environment.

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