Research on Thermal Environment of University Classrooms in Severe Cold Areas Based on Different Seating Rate

Meng Huang¹,²,³, Guoqiang Zhang¹,²,³
¹School of Architecture, Harbin Institute of Technology, Harbin 150001, China
²Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, Harbin 150001, China
³Heilongjiang Cold Region Architectural Science Key Laboratory, Harbin 150001, China
*Corresponding author’s e-mail: 408225103@qq.com

Abstract. College classrooms are the main place for teachers' teaching and student learning. The quality of the thermal environment in the classroom is directly related to the students' physical and mental health and learning efficiency[1]. In the cold regions, the classrooms of colleges and universities are often closed, and the seating rate is generally high. Through the on-site actual measurement of the classroom of the School of Architecture of Harbin Institute of Technology, this paper compares and analyzes the changes of thermal environment in the classroom under the three typical seating rates of 0.2, 0.5 and 1.0. The results showed that in the closed classroom, there is a positive correlation between the seating rate and the indoor air temperature and humidity. The high heat dissipation rate of the human body has a significant effect on the indoor air temperature and humidity. When the seating rate is 0.2-0.5, the temperature rise is more obvious. At a seating rate of 0 and 1.0, the highest indoor air temperature is located in the southeast corner of the classroom and the highest relative humidity is located in the southwest corner of the classroom.

1. Introduction
With the continuous improvement of people's living standards, people's requirements for indoor thermal environment are getting higher and higher. In recent years, China's colleges and universities have developed rapidly, and the indoor thermal environment of college classrooms has received more and more attention from all walks of life. The research mainly focuses on the influence of the body volume, orientation, and external protective structure of the classroom [2] The impact of the seating rate on the thermal environment during teaching is relatively small.

Studies have shown that adult males (body weight 60kg) have an average cooling power of 108W in classrooms and 85W in adult women (45kg) [3], Hu Tianle et al found that the difference in seating rate will affect the relative humidity and carbon dioxide concentration in the self-study room [4]. In the winter, Wan Hao conducted a survey on a scientific research building of Tongji University, and made an objective evaluation of the indoor thermal environment in the classroom in winter, and proposed corresponding improvement strategies [5]. In the summer, Qiu Jing conducted a survey on public classrooms in colleges and universities. He studied the classrooms with full seating rate and 0.5 seating rate, and found that the indoor and outdoor temperature differences in classrooms were...
significantly different under different seating rate [6]. Paola Ricciardi conducted a measuring and questionnaire survey of the indoor thermal environment of different types of classrooms in the University of Pavia, Italy, and conducted subjective and objective evaluations [7] Wang Haijun studied the temperature and humidity of different floors, orientations, and different classrooms in the same classroom [8].

2. Research methods

Firstly, the classroom number arrangement and semester course arrangement of Harbin Institute of Technology were investigated. It was found that the classroom with a seating rate of 1.0 accounted for 40%, the classroom with a seating rate of 0.5 accounted for 30%, and the seating rate of 0.2 accounted for 15%. 80% of the classroom seating rate is 0.5 or above. It can be seen that in the curriculum arrangement, the utilization rate of the classroom is relatively high, and 1.0, 0.5, and 0.2 are studied and analyzed as three typical seating rates, and the classrooms in the idle (0 seating rate) classroom are analyzed.

The measuring sites were selected in the classrooms of 520, 522, 524, and 526 in Zhengxin Building of Harbin Institute of Technology. All four classrooms were oriented in the north and the specifications were the same; the length was 13.5m wide and 9m, and there were 70 seats. The two diagonals of the room are taken as the positioning lines, and the points at the intersection of the diagonal and the three equal points are arranged to ensure that the points are even and reasonable, and the measuring results are scientific and accurate as shown in Figure 1.

![Figure 1. Schematic diagram of measuring points](image)

The measuring date is March 8, 2018, the outdoor temperature of the day is -7~-17℃, and the measuring time is 7:00-17:00. A total of 120 students were invited to participate in this measuring, and at 10:00-11:50 sit in each classroom to simulate the normal class situation (10:00-10:50 for the first quarter, 10:50-11:00 for the break, 11:00-11:50 for the second quarter). 522 classrooms filled with 70 people, the seating rate is 1.0; 524 classrooms are evenly distributed 34 people, the seating rate is 0.5; 526 classrooms are evenly distributed 16 people, the seating rate is 0.2; and 520 classrooms all day no one enters the seating rate is 0.

During the measuring, the classroom was normally heated, the windows were closed in the measuring, and the curtains were fully unfolded; except for the classroom, the classroom doors were closed; the measuring mainly considered the influence of air temperature and relative humidity on the indoor thermal environment of the classroom. The BES-02 temperature and humidity collection recorder collects and records data such as air temperature and relative humidity. The technical parameters of the instrument are shown in Table 1. The instrument was subjected to multiple calibration before the measuring, and the BES-02 temperature and humidity acquisition recorder was placed in a radiation shield and fixed on a tripod. The measuring height is 1.1m, corresponding to the height of the human face in the sitting position, and the measuring recording interval is 5min. To ensure the accuracy of the measuring results, the temperature and humidity measuring results of each classroom take the average value of each measurement point.
Table 1. Instrument technical parameter table

| Name and model | Range          | Accuracy | Sampling period |
|----------------|----------------|----------|-----------------|
| BES-02 temperature and humidity collection recorder | Temperature: -30 to 50°C | ±0.5℃ | 10 s to 24 h |
|                | Relative humidity: 0~99%RH | ±3%RH    | 10 s to 24 h   |

3. Research results and analysis

3.1. Influence of different seating rate on indoor temperature and humidity

According to the average temperature value and the average humidity value of each measuring point in the three classrooms, a comparative analysis is performed, and line charts are shown in FIG. 2 to FIG. 4.

Figure 2. T/RH changes of 0.2 seating rate

Figure 3. T/RH changes of 0.5 seating rate

Figure 4. T/RH changes of 1.0 seating rate

The seating rate of 522 classroom is 1.0; the temperature and humidity measuring results are shown in Figure 2. From 10:00 to 10:50, the air temperature rises from 22.5℃ to 24.6℃, which is 2.1℃. The relative humidity rises from 24.6%RH to 30.2%RH, a total increase of 5.6%RH; during 11:00-11:50, the air temperature increased from 24.7℃ to 25.2℃, increased by 0.5℃; relative humidity increased from 30.6%RH to 32.6%RH, increased by 2%.

The seating rate of the 524 classroom is 0.5, and the temperature and humidity measuring results are shown in Figure 3: 10:00-10:50, the indoor temperature is raised from 22.4℃ to 24.0℃, which is increased by 1.6℃; the relative humidity is increased from 20.8%RH to 24.3%RH, increased to 3.5%RH; during 11:00-11:50, the temperature increased from 23.9℃ to 24.3℃, increased by 0.4℃; relative humidity increased from 24.4%RH to 25.1%RH, increased by 0.7%RH.

The seating rate of 526 classroom is 0.2, the temperature and humidity change is shown in Figure 4: 10:00-10:50, the indoor temperature rises from 21.7℃ to 22.3℃, and rises by 0.6℃; the relative humidity rises from 21.4%RH to 22.3%RH, increased by 0.9%RH; 11:00-11:50, the temperature increased from 22.3℃ to 22.5℃, increased by 0.2℃; relative humidity increased from 22.3%RH to 22.6%RH, increased by 0.4%RH.

From the measuring results, it can be found that during the second lesson, the increase in temperature and humidity of the classrooms with different seating rates is lower than that of the first class. The main reason is the air flow caused by the open doors during the break, and the movement of people; And the greater the seating rate, the more obvious the incremental decrease. At the end of the
course, the temperature in the classroom will take some time to return to normal room temperature. If another class is scheduled, the temperature in the classroom will continue to rise, causing the room temperature to be too high.

![Figure 5. Comparison of temperature and humidity increments of different seating rates](image)

The temperature and humidity increments of three different seating rate classrooms are analyzed. The line chart is shown in Figure 5. The temperature and humidity increment of 1.0 seating rate is 2.6°C, 7.6%RH, and the 0.5 seating rate is 1.8°C, 4.2%. RH, 0.2 seating rate is 0.8°C, 1.3%RH. It can be seen from the line chart that the temperature and humidity changes at the seating rate of 0.2 to 0.5 are more pronounced than when the seating rate is 0.5 to 1.0.

### 3.2. Temperature and humidity distribution in the classroom

![Figure 6. Temperature and humidity distribution of 0 seating rate](image)

![Figure 7. Temperature and humidity distribution of 1.0 seating rate](image)

Comparing and analyzing the temperature and humidity changes of each measuring point in the classroom of 0 seating rate and the seating rate of 1.0, and line charts are shown in Figures 5 and 6.

In the classroom of 0 seating rate, the temperature and humidity trends of each measuring points in the classroom are basically the same, and the temperature at the point 4 in the northwest corner is significantly higher than other points. The average temperature is 21.6°C, and the temperature of the measuring points 1, 2, 3, and 5. The difference is not large, and the average values are 21.2°C, 21.3°C, 21.2°C, and 21.3°C, respectively. The relative humidity and humidity of each measuring point are
quite different. The relative humidity of the measuring point 1 in the northeast corner of the classroom is the highest, the average is 25.1%RH; the lowest relative humidity of the measuring points 3 and 4 is 17.9%RH; 5 The average relative humidity was 23.6%RH and 21.2%RH, respectively.

In the classroom of 1.0 seating rate, the temperature and humidity trends of each measuring point are basically the same, in which the temperature of measuring point 4 is the highest, the average temperature is 23.5℃; the temperature of the other four measuring points is similar, the average temperature of measuring points 1, 2, 3 is 23.1℃, point 5 is 23.2℃. The relative humidity measuring results of each measuring point show that the relative humidity of measuring point 1 is the highest, the average value is 31.2%RH, and the lowest average value of measuring point 4 is 24.5%. The average values of the other measuring points 2, 3, and 5 were 29.5%RH, 25.8%RH, and 27.8%RH, respectively.

Based on the above measuring results, it can be found that when the seating rate is 0 and 1.0, the northwest corner of the classroom has the highest average temperature and the lowest average relative humidity; the northeast corner of the classroom has the lowest average temperature and the highest average relative humidity.

4. Conclusion
In this paper, the indoor air temperature and relative humidity of the classrooms of Harbin Institute of Technology were tested on site, and the temperature and humidity changes in the classrooms of 0.2, 0.5, and 1.0 were compared and analyzed. Through the above experimental data analysis, the following conclusions are drawn:

(1) In the closed classroom, the seating rate has a positive correlation with the indoor temperature and humidity. The temperature and humidity changes at the seating rate of 0.2 to 0.5 are more pronounced than when the seating rate is 0.5 to 1.0.

(2) During the test, the indoor temperature and humidity increments of the three seating rate classrooms during the second lesson were significantly lower than the first lesson, which proved that the inter-class ventilation had a significant impact on the indoor temperature and humidity rises, and the greater the seating rate, the more obvious the impact.

(3) When the seating rate is 0 and 1.0, the northwest corner of the classroom has the highest average temperature and the lowest average relative humidity; the northeast corner of the classroom has the lowest average temperature and the highest average relative humidity.

References
[1] Yang Xiaomin. (2013) Measurement and evaluation of classroom environment quality in colleges and universities. Nanhua University.
[2] Wang Hongguang. (2005) Research on indoor thermal environment of college classrooms in Xi'an area. Xi'an University of Architecture and Technology.
[3] Wang Zhengli, Sun Dongliang, Zhang Jiaxi. (2008) Analysis of human body heat dissipation in air-conditioned rooms based on biochemical principles. Building Thermal Ventilation and Air Conditioning. 27: 56-58.
[4] Hu Tianle, Cao Bin, Zhu Yingxin. (2015) Effect of Self-study Classroom Rate in Beijing on Indoor Thermal Environment in Heating Season. HVAC, 8: 98-101.
[5] Wan Wei, Song Dejun. (2007) Winter Indoor Thermal Environment Assessment and Architectural Design Strategy Analysis of Shanghai Campus Buildings. Journal of Building Science, 23: 48-52.
[6] Qiu Jing, Ling Qiang. (2014) A Study on the Summer Thermal Environment of Public Classrooms in Wuhan Universities. Huazhong Building, 5: 32-35.
[7] Ricciardi P, Buratti C. (2017) Environmental quality of university classrooms: Subjective and objective evaluation of the thermal, acoustic and lighting comfort conditions. Building and Environment, S0360132317304882.
[8] Wang Haizhen, Chen Xue, Song Junjie. (2016) Indoor Temperature and Humidity measuring and
Comfort Evaluation of University Classroom——Taking the School of Architecture of Suzhou University as an Example. Global Human Geography, 2: 260-262.

[9] Huo Xiaoping, Ge Cuiyu. (2005) Measuring and Analysis of Indoor Thermal Environment in Buildings. Journal of Building Science and Engineering, 22: 75-78