Investigation and Analysis of Winter Classroom Thermal Environment In Chongqing

Jing Liu
Postgraduate
Chongqing, China
Jimlau_@163.com

Baizhan Li
Ph.D
Professor
Chongqing, China
Baizhanli@cqu.edu.cn

Runming Yao
Ph.D
Senior researcher
Cambridge, UK
ry207@cam.ac.uk

Abstract: The classrooms in Chongqing are taken as a study subject in this paper. Measurements of the indoor thermal environmental parameters, e.g., indoor dry/wet bulb temperature, and air velocity, were taken. Combined with the questionnaire, which included the thermal sense value of the occupants, the winter classroom thermal environment was evaluated. Measures for improving the classroom indoor thermal environmental quality were also given. The lower limit air temperature of the non-air conditioned classrooms in winter was determined to be 14.04℃, corresponding to an acceptable thermal environment by up to 80% of the occupants.

Key words: classroom, thermal comfort, thermal sensation, thermal environment

1. BACKGROUND

Under the series of policies which promote the education development, the country's investment in education and science research is increased year by year. Colleges and universities are undoubtedly the pioneers in the campaign, which shoulder the important task of training complex talents. However, it seems we overlook a question that, with the environment pollution deteriorating and city heat island effect increased, whether the present thermal environment in classroom is fit for the students' studying?

With the country economy and people's standard living increased, public's concern about buildings' thermal environment has reached a new level. However, now in our country the researches about this subject are mainly on office buildings and residential buildings. As for the classrooms with high population density in colleges and universities, people take little attention about them. Classrooms are the most important places for the college students to learn, and the classroom thermal environment conditions have effects on the college students' health and studying efficacy directly. Thus, with the above questions and for finding out the thermal environment and thermal comfort conditions of classroom in Chongqing, the author carry out the field study of the indoor thermal environment in Chongqing University during Dec, 2005 and Jan 2006.

2. METHODOLOGY

2.1 Questionnaire

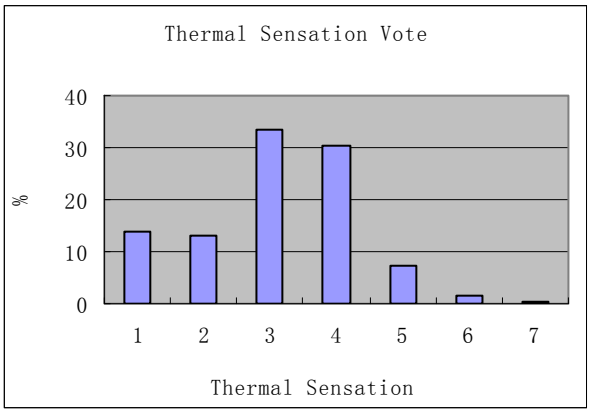
Respondents would have a questionnaire investigation about indoor thermal comfort, expressing their subjective sensation of indoor environment. The main contents of the questionnaire include: background of personnel, thermal sensation, humid sensation, airflow sensation and overall clothes situation.

2.2 Thermal environment parameters measurement

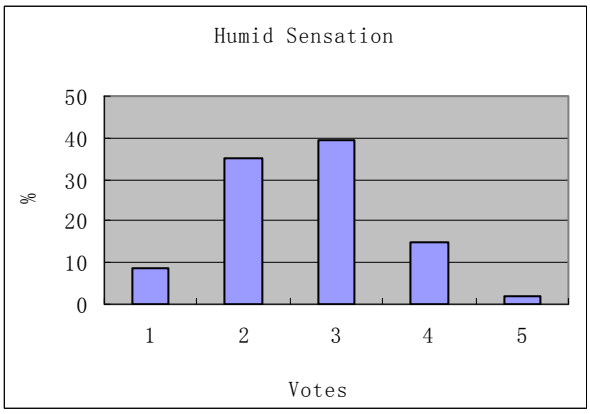
Indoor environmental parameters of the measurement including: dry bulb temperature, wet bulb temperature, air velocity and so on. Apparatus include: dry-wet bulb thermometer and hot-wire anemometer. Because the respondents keep sitting posture in classroom, we choose points of 0.1m, 0.6m and 1.1m of vertical height as air velocity and temperature test points of feet, wrist and neck, and measurement period of each point is more than minutes, and then to have average value.

3. FIELD STUDY RESULTS

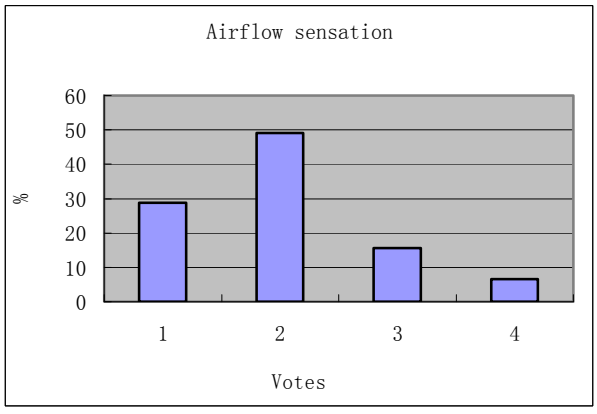
Statistics of questionnaire result is shown in Fig 1.



1-Cold; 2-Cool; 3-Slight cool; 4-Just right; 5-Slight warm; 7-Warm



1-Damp; 2-Slightdamp; 3-Just right; 4-Slight dry; 5-Dry



1-Stuffy; 2- Just right; 3-Comfortable draft; 4-Discomfortable draft

Fig 1 Statistic summary of questionnaire

It can be seen that because there are no air conditioning and heating system in classroom, only 30.35% of respondents consider the indoor temperature is moderate, and as much as 60.57% of respondents choose “slight cool” and “cold”. In aspect of humidity, more than 40% of respondents regard it as “slight humid” to “humid”. It is determined by climate characteristic of cold and humid in winter in Chongqing. Respondents who consider air velocity is moderate account 49.04%, and 28.85% of them choose “stuffy” without enough airflow. It is closely in relation with the situation of windows closed to maintain indoor temperature. The average clothing insulation values is 1.42clo.

In the aspect of field measurement, the average value of indoor air temperature, air velocity and relative humidity are: 13.43℃, 0.03m/s and 84.28% respectively. The temperature value is not in ASHRAE winter thermal comfort zone. Values of air velocity and relative humidity could not be satisfied by most respondents. It reflects that the bad ventilation and damp is the general problems in winter classroom.

4. DISCUSSION

4.1 Comparison of PMV and AMV

PMV is an environmental index based on Fanger’s thermal comfort equation. This index is not an equivalent value but a mean vote values determined by ASHRAE thermal sensation classification[1]. It is predicted mean vote based on thermal comfort equation, and AMV is actual mean vote to real thermal environment.

Input the parameters of air temperature, air velocity, relative humidity and metabolism rate to PMV program (suppose that the mean radiant temperature equals to indoor air temperature), we could draw the fig.2 from the values. It can be seen that PMV values is general lower than AMV’s, and it can be explained from physiology, psychology and behavior adaptation. In physiology aspect, respondents are young people of about 20, and they have strong adaptability. This is an organism response which formed from long time living in the cruel thermal environment[2]. In psychology aspect, respondents have accepted the fact that there is no air conditioning and heating system in classroom, their psychological expected values would changes correspondingly. In behavior aspect, respondents adopt some measures to change

body heat balance. These measures including increase clothe, drink hot drinking, use portable heater and so on. So, the three aspects above are main reasons for the difference between PMV and AMV.

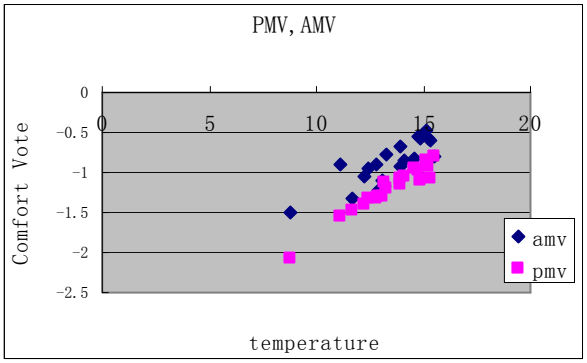


Fig. 2 PMV, AMV vary with indoor air temperature

4.2 Acceptable temperature range

PMV and AMV to have a linear regression with t_a , fig.3. Linear regression equation of PMV and AMV are : PMV = $0.1943t_a$-3.8443 (R^2=0.9649), AMV=$0.1672t_a$-3.197 (R^2=0.7591) respectively. From the two equations it can obtain neutral temperature of PMV is 19.79 ℃ and neutral temperature of AMV is 19.12℃. The difference of them is 0.87℃. It also explained that respondents have adaptation in physiology, psychology and behavior aspects who long time living in the cruel thermal environment.

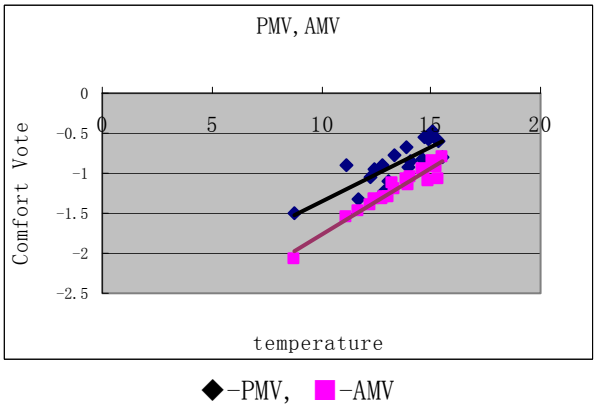


Fig. 3 PMV, AMV linear regression

Two methods of determining the acceptable rate of thermal environment are direct method and indirect method[3]. The acceptable thermal environment definition in ASHRAE is “an environment that at least 80% of the occupants would find thermally acceptable[4]”. On basis of PMV-PPD index in ISO7730[5], we obtain acceptable temperature range (14.04℃, 24.2℃), and the minimum value is close to indoor average temperature 13.43℃.

4.3 Gradient of PMV, AMV linear regression equation

We can see from the PMV, AMV linear regression equation, and air temperature t_a as independent variable, that the gradient is 0.1943/℃ and 0.1672/℃, respectively. The gradient reflects the sensitivity of the respondents’ thermal sensation to indoor air temperature t_a. That is to say, the indoor air temperature changes 5.15℃, the Predicted Mean Vote (PMV) will change one unit correspondingly. The same, the Actual Mean Vote (AMV) will change one unit with the the indoor air temperature changes 5.98℃. Therefore, the respondents’ indoor air temperature sensitivity under the PMV model is more sensitive than AMV’s, which prove the respondents’ adaptability.

4.4 Relationships between the PMV, AMV and outdoor air temperature t_{out}

Fig.4 shows the linear regression of PMV, AMV to outdoor air temperature t_{out}. The linear regression equation of PMV to outdoor air temperature t_{out} is PMV=$0.1567t_{out}$-2.6063 (R^2=0.6635), with the t_{neu}=16.63℃. The linear regression equation of AMV to outdoor air temperature t_{out} and its neutral temperature t_{neu} are AMV=$0.12t_{out}$-1.9589 (R^2=0.8408), t_{neu}=16.32℃, respectively. AMV’s t_{neu} is lower 0.31℃ than the PMV’s, which proves the respondents’ adaptability again. During the measurement, the average outdoor air temperature t_{ou} is 8.95℃, much lower than the neutral temperature t_{neu}. In order to offsetting the discomfort of the thermal environment without air-conditioning and heating system, respondents mainly adopt the way of behavioral adaptability.

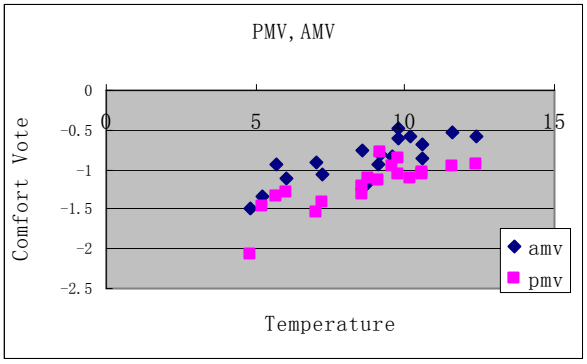


Fig.4 PMV, AMV vary with outdoor air temperature

5. MEASUREMENTS OF IMPROVING CLASSROOM THERMALENVIRONMENT

Because of the high population density, no heating system and air-conditioning in the classroom, we should improve the classroom thermal comfort as following:

(1) The cooling load of building with east-west orientation is higher 20% than south-north orientation building in Chongqing[6]. It is advisable to arrange teaching activities in the east-west orientation classroom in winter;

(2) Make sure the reasonable area ratio of window to wall. Adopting the window with double window frame and double glass, well thermal insulation performance will be got. The airtightness of windows should be noticed;

(3) Over all heat transfer coefficient of building envelope and thermal inertia index should accord with the relative standards, which is not only beneficial to thermal insulation performance, but also contribute to the energy saving.

6. CONCLUSION

(1)60.57% of respondents choose “slight cool” and “cold” in thermal sensation vote, which explained that the thermal environment of winter classroom is general cold and humid.

(2)There is difference between PMV and AMV, which is the synthetic result of physiological adaptation, psychological adaptation and behavioral adaptation.

(3)Linear regression equation of PMV and AMV are : PMV = $0.1943t_a$-3.8443 (R^2=0.9649), AMV=$0.1672t_a$-3.197 (R^2=0.7591) respectively, and neutral temperature of PMV is 19.79℃, 19.12℃ is AMV’s. The difference of them is 0.68℃. This is also a performance of adaptation.

(4)Acceptable indoor temperature range is 14.04℃,-24.2℃ in winter classroom.With the indoor air temperature changes 5.15℃, PMV will change a unit correspondingly; as to AMV, the value is 5.98℃.

(5)AMV=0, the outdoor air temperature is 16.32℃,;while PMV=0, outdoor air temperature is 16.63℃.

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