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Analysis on Human Adaptive Levels in Different Kinds of Indoor Thermal Environment

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Abstract

To reveal the law of human adaptive level changing along with indoor temperature and humidity in naturally ventilated buildings, an approach of field survey of thermal comfort has been carried out in an university of Guangzhou for about a year, and adaptive coefficient (λ) proposed in adaptive PMV model (aPMV) has been used to calculate the level of adaptation in different combination of indoor temperature and humidity. The results show that, the effects of different combinations of indoor temperature and humidity on human adaptive level vary from each other obviously, the level of adaptation in cool and dry environment (CDE) and comfortable environment (CE, PMV<0) was low, but it is high in hot and humid environment (HHE) and CE (PMV>0) .The adaptive coefficient (λ) are 0.64 (HHE), -0.06(CE, PMV<0), 1.07(CE, PMV>0) and -0.37 (CHE), respectively.

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Keywords: indoor thermal environment; adaptive coefficient (λ); adaptive PMV model; thermal sensation

1. Introduction

Thermal comfort is an important aspect of residential buildings other than the usual safety and security aspects [1]. With strong desire of more comfortable indoor thermal environment, the research of thermal comfort evaluation indices has been brought to more and more scholars. Two kinds of approach exist in contemporary thermal comfort research: they are heat balance models based on laboratory studies and adaptive models based on field studies. As is known to all, the PMV-PPD method put forward by Fanger was established by using steady-state heat balance

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method in artificial climate chamber, which was considered to ignore the psychological dimensions of adaptation, social and cultural aspects of an occupant, which are otherwise so prominent in any naturally ventilated buildings. Lately, it was found that the results obtained by this method worked fairly well for conditioned buildings and deviated widely when applied to naturally ventilated buildings [2, 3, 4]. The adaptive thermal comfort model [5] put forward by ASHRAE RP-884 project [6] pointed out that thermal comfort is affected by the psychology, physiology and behavior, it well explains the deviation. So there is a great need to carry out an in-depth study on the adaptive model both theoretically and practically. It is to be hoped that the adaptive model can be based on a theory which has been successfully tested against wide-ranging empirical results. de Dear claimed that the adaptive and heat balance approaches to modeling thermal comfort are complementary rather than contradictory[5]. Therefore some attempts have been made in order to correct the PMV model in the built environment. Fanger and Toftum proposed an extended PMV model which incorporated an 'expectancy factor, e', the main factor explaining why PMV overestimates the thermal sensation of occupants in free-running buildings in a warm climate [7]. Yao et al. established the 'adaptive predicted mean vote' (aPMV) model by using 'the black box' method [8]. Then the least square method [9] has been used to derive the adaptive coefficient in the thermal comfort adaptive model and established the 'corrected predicted mean vote' (cPMV) model in different climate zones and seasons by [10]. Zheng et al. used the aPMV model to find out the difference of human adaptive thermal comfort before heating period and after heating period [11].The aPMV and cPMV model are both using adaptive coefficient to quantify the adaptive level of human.

Most of the residential buildings in hot summer and warm winter zone in China are naturally ventilated buildings. Zhang et al.[12] pointed out that physiological and psychological adaptation can obviously change the range of acceptable temperature in this area. Due to the characteristics of this climate, indoor temperature and relative humidity are considered to be the two of the factors that influent human's thermal sensation most. Therefore, this paper researched the law of human adaptive level changing along with indoor temperature and humidity in naturally ventilated buildings by using aPMV model which has already been applied in "*Evaluation standard for indoor thermal environment in civil buildings (GB/T 2012)*" and the results may revise and improve the standard.

2. Methodology

A field study had been conducted in naturally ventilated buildings in Guangzhou of China from May 2008 and lasted for a whole year. The study simultaneously included subjective survey and environmental data monitoring, which were taken among 30 healthy college students (15 males, 15 females) who had already lived there for a long time. The 30 students would do the survey for a whole year in order to weaken the individual differences. The research sites were selected in subjects' main daily experience buildings, thermal environment physical measurement was in accordance with the international standard.

Indoor and outdoor environment parameters (indoor and outdoor air temperature, relative humidity, velocity and black globe temperature) had been tested. Subjective questionnaire includes respondents' clothes, activity rate, thermal sensation, humidity sensation vote, airflow sensation vote and so on.

3. Results and analysis

3.1. Thermal sensation

According to *Design code for heating ventilation and air conditioning of civil buildings GB 50736-2012*, the comfort indoor temperature range is 18-28°C and relative humidity range is 30-70%. In this paper, we define the environment with the temperature higher than 28°C and relative humidity higher than 70% as HHE, and in turn define the environment with the temperature lower than 18°C and relative humidity lower than 30% as CDE. According to the collected data from Guangzhou, the indoor environment can be divided into three conditions to be analyzed, which are CDE, HHE and CE.

The ASHRAE seven-point thermal sensation scale (-3, -2, -1, 0, 1, 2, 3) was used in the survey to help respondents express their own thermal sensation. The mean thermal sensation (MTS) and PMV were then regressed