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Thermal Comfort and Thermal Adaptation between Residential and Office Buildings in Severe Cold Area of China

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Abstract

Harbin is located in Chinese severe cold area. Local people stay indoors by most of time in winter. The occupants' behavioural regulation was greatly different between residents and office staffs, which might lead to the differences of human thermal responses. A field study was conducted in residential and office buildings from September 2013 to May 2014. The thermal environmental parameters were continuously measured and 1050 subjective questionnaires were collected. The results show that the occupants' behavioural thermal regulation was different between residents and office staffs periodically. There were deviations between indoor air temperature and neutral temperature. The subjects in office buildings expected more to lower the indoor air temperature in winter. The local occupants had adaptation to both cold climate and indoor environment. The strategy of maintaining indoor temperature was suggested according to the different building functions to save energy and keep comfortable.

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Keywords: Thermal comfort; Thermal adaptation; Field study; Residential building; Office building

1. Introduction

In view of increasing concerns about climate change and building energy conservation, more and more researchers paid more attention on occupants' behavioural adaptation and thermal comfort conditions [1]. And the legitimacy of the adaptive comfort model has been worldwide recognized, and it has been adopted by ISO 7730 [2]

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and specified by ASHRAE Standard 55 [3]. The adaptive comfort model emphasizes the role occupants play in dominating their own thermal comfort compared with PMV model [4]. Based on the presumption, people can actively adapt themselves to their thermal conditions rather than merely accepting it passively. Besides, the research on human thermal adaption should be carried out by and large in different climate zone, different nations and different thermal history respectively. Brager and De Dear proposed the human thermal adaption by three concepts: physiological acclimatization, behavioural adjustment, and psychological habituation or expectation [5]. They also indicated that behavioural adjustment and psychological expectation had more influence on thermal adaptation in buildings compared to the slower process of acclimatization. And, the current research on occupants' behavioural and psychological adaptation was mainly developed through the field investigation.

Harbin is located in the severe cold area of China with a long and cold winter, and the centralized heating period lasts for 6 months. The indoor design heating temperature is 18℃ during the heating period according to Chinese standard. However, the real indoor temperatures are generally higher than 24℃ in variety of buildings, also going beyond the upper limits in ASHRAE 55 (2013) and ISO 7730 (2005). The energy consumption for space heating accounts for a huge proportion of the total building energy consumption in the city.

Wang et al. [6-8] carried out a series of field study on occupants' thermal comfort and thermal adaptation in Harbin. They concluded that local occupants had thermal adaptation to the cold climate. The thermal neutral temperature of local occupants was lower in winter versus in autumn. However, the local occupants always stay indoors in winter, thus, what kinds of thermal regulation will the occupants present during the space heating period? Oseland [9] found that there were significant differences for the perceived warmth of the same group of people in the same clothing and conducting the same activity, at the office, at home, and in a climate chamber. Nevertheless, what kinds of thermal responses will the occupants have in their real life including their thermal perception and thermal behaviours? In allusion to these problems, a field study was conducted in winter and transitional seasons in which 44 volunteer subjects were tracking surveyed in their residential rooms or work offices. Through this study, the periodic thermal responses of the occupants in buildings of different functions were presented, and some suggestions were proposed to maintain thermal comfort and save energy.

Nomenclature

PMV	Predicted mean vote
PMV'	Predicted mean vote after standardization
TSV	Thermal sensation vote
TSV'	Thermal sensation vote after standardization

2. Methods

The field study was conducted in residential and office buildings from September 2013 to May 2014 which included the whole space heating period and two transitional seasons (late autumn, early spring). The space heating started on October 20, 2013, stopped on April 20, 2014. The outside air temperature started going below -10℃ on November 22, 2013 and going above -10℃ on March 2, 2014 in winter as shown in Fig. 1. In order to research the variation of occupants' thermal responses as the climate changes, the whole space heating period is divided into three phases, the early-heating period from October 20 ~ November 22, 2013 (34 days), mid-heating period from November 23, 2013 ~ March 2, 2014 (100 days) and a late-heating period from March 2 ~ April 20, 2014 (49 days).