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Thermal comfort assessment and characteristics of occupant's behaviour in naturally ventilated buildings in composite climate of India

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ABSTRACT

Energy consumption in Indian building sector is increasing at high rate. The National Building Code of India specifies a narrow comfort temperature range between 21 °C and 26 °C for all types of buildings and for all seasons. A thermal comfort field study was conducted in 32 naturally ventilated buildings, collecting a total of 2610 samples spread over a total period of four years, covering multiple seasons, age groups, clothing types and building types. Questionnaires were administered to building occupants to record sensations and preferences for air temperature, relative humidity and air velocity on ASHRAE seven point and five point scales. The objective of the study was to evaluate thermal comfort of occupants and study the methods of thermal adaptation such as adjusting clothing, window opening, and use of air circulation fans. Griffith's method was used to determine thermal neutrality. The comfort temperature for summer and winter season was found to be 30.6 °C and 25.2 °C, respectively. Preferred clothing level for summer was found to be 0.30 clo, whereas in winter it was 0.80 clo. Preferred air velocity was observed as 0.62 m/s in summer season and 0.27 m/s in winter. Controlling air velocity has been found to be preferred method of thermal adaptation over adjusting clothing and window opening.

Introduction

The internationally accepted standard for defining thermal comfort conditions (American Society of Heating, Refrigerating and Air-conditioning Engineers Inc., 2013; ISO 7730, 2005), is based on Fanger's heat balance model of the human body. This heat balance model, also called PMV (Predicted Mean Vote) / PPD (Percentage People Dissatisfied) model, is among the most widely accepted models for building thermal design and determination of thermal comfort conditions especially in air conditioned spaces. The evidence of critical role played by psychological, physiological and socio-cultural aspects of adaptation in defining comfort standards has led researchers to question the universal applicability of uniform comfort conditions suggested by these standards (Brager and de Dear, 1998; Humphreys and Nicol, 1998; Yao et al., 2009; Nicol, 2004).

An alternative to the PMV/PDD model is the adaptive model, which is based on the results of field studies conducted since 1960s (Auliciems, 1981; Nicol et al., 2012). According to the adaptive hypothesis, contextual factors and past thermal history modify the occupant's thermal expectations and preferences. Currently, the adaptive model is widely accepted as efficient tool in predicting indoor comfort conditions for naturally ventilated buildings (American Society of Heating, Refrigerating and Air-conditioning Engineers Inc., 2013; Brager and de Dear, 1998; Cândido et al., 2011).

The National Building Code of India of 2005 (Bureau of Indian Standards (BIS), 2007) defines two indoor temperature ranges, for summer 23 °C–26 °C and winter 21 °C–23 °C. These are supposed to be applicable for conditioned as well as naturally ventilated buildings.

Sharma and Ali (Sharaf\at and Sharma, 1986) carried out thermal comfort study in tropical climate of India and reported high comfort temperature range (25 °C–30 °C).

Indraganti (2010a) carried out thermal comfort field study in naturally ventilated apartment and found a neutral temperature of 29.2 °C for studied subjects in summer season.

Singh et al. (2010) carried out a field study for vernacular architecture of North-Eastern India for three climatic zones and demonstrated seasonal and regional differences in neutral temperature.

Dhaka et al. (2015) carried out a thermal comfort study for naturally ventilated buildings in composite climate of Jaipur and found a neutral temperature of 27.2 °C for all seasons. This study was conducted mainly with young subjects. Differences in age were not considered. Moreover this study did not include analysis of occupant behaviour and adaptation.

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It has been found that most of the studies conducted in India so far had carried out data collection from one particular building type, including study conducted by Sharma and Ali (Sharafat and Sharma, 1986), Indraganti (2010a) and Singh et al. (2010). Even the recent work for project IMAC (Indian model for adaptive thermal comfort) (Manu et al., 2016), only included office buildings, and is carried out with very limited surveys from four months of the year.

Research on adaptive comfort, specifically in warm to hot climates, has revealed that occupants in naturally ventilated buildings are more tolerant towards high fluctuations encountered in indoor environmental conditions (Sharafat and Sharma, 1986; Nicol, 1974; Wong and Feriadi, 2004).

In a naturally ventilated building, occupants use several adaptive opportunities and controls such as operable windows, doors, blinds, curtains, fans & fan regulator for adjustment of air velocity to make themselves comfortable in the changing thermal environment. Uses of these adaptive controls are also affected by seasonal and climatic variations in indoor conditions (Brager et al., 2004; Indraganti, 2010b; Rijal et al., 2007, 2008).

Most of the current research in other countries is aiming at the prediction of occupant behaviour and use of various controls; simultaneously developing algorithms of occupant's controls. Algorithms developed through such studies can be utilized for simulation of buildings (Nicol and Humphreys, 2004). However, a very few studies have been reported for the use of various behavioural controls in residential and educational environments from Indian building sector in recent years (Dhaka et al., 2013; Indraganti, 2010c).

The present study was conducted to find out the range of neutral temperature specific to naturally ventilated buildings in composite climate and occupants' behaviour in the context of control strategies. This paper summarizes a thermal comfort field study conducted in 32 naturally ventilated buildings in composite climate zone of India.

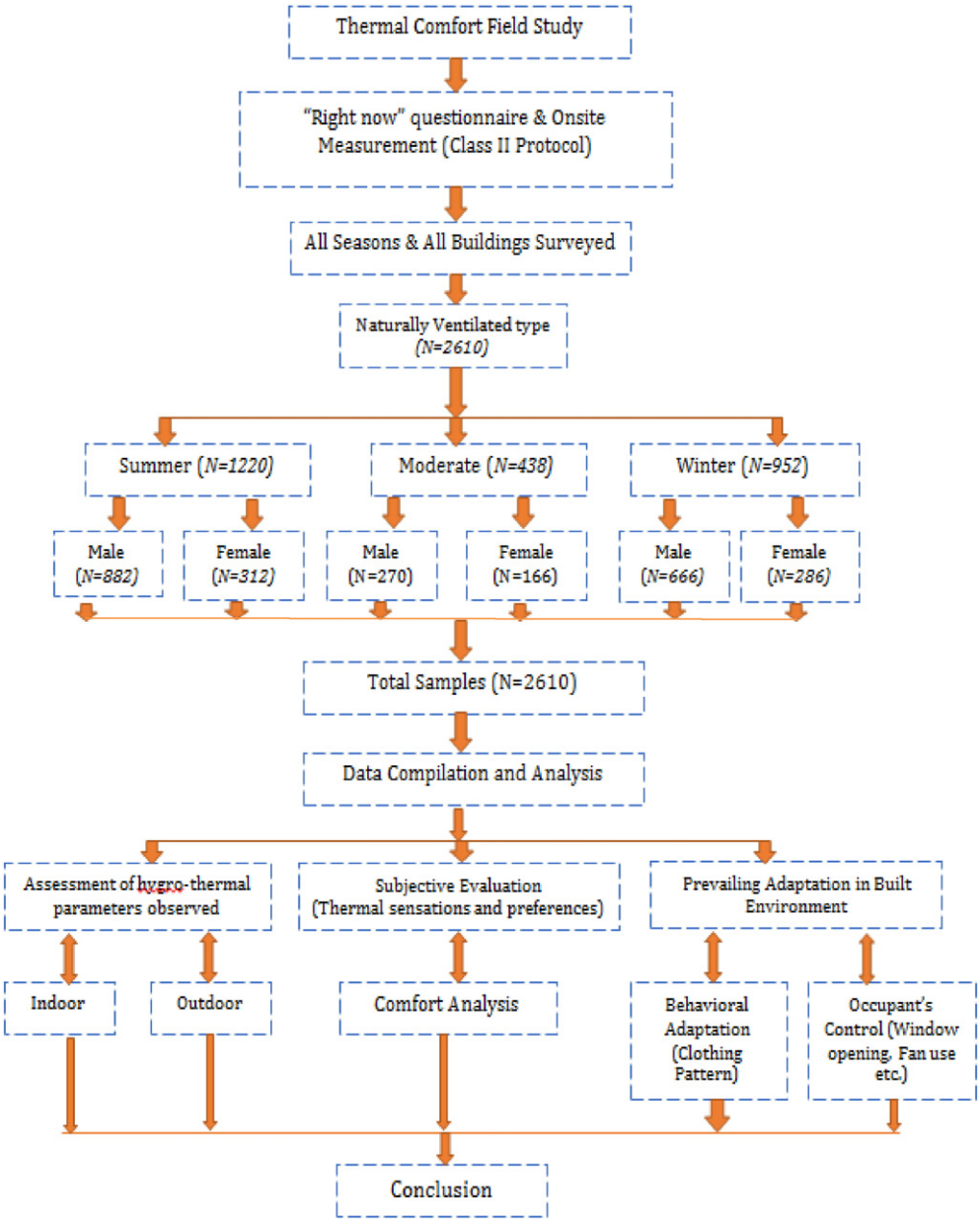

Fig. 1. Methodology of the study.