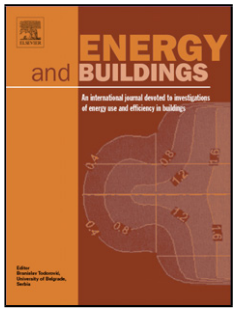

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PII: S0378-7788(17)31988-6
DOI: https://doi.org/10.1016/j.enbuild.2017.12.026
Reference: ENB 8219

To appear in: *ENB*

Received date: 9-6-2017
Revised date: 7-12-2017
Accepted date: 13-12-2017

Please cite this article as: Samar Thapa, Ajay Kr.Bansal, Goutam Kr.Panda, Thermal Comfort in naturally ventilated office buildings in cold and cloudy climate of Darjeeling, India – An adaptive approach, Energy and Buildings https://doi.org/10.1016/j.enbuild.2017.12.026

Thermal Comfort in naturally ventilated office buildings in cold and cloudy climate of Darjeeling, India – an adaptive approach

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ABSTRACT Thermal comfort standards are essential to determine a good indoor climate as well as to optimize energy use inside a building. The Predicted Mean Vote (PMV) model is used to determine the indoor comfort limits in a conditioned building. However, PMV model often exaggerates thermal sensation, as it does not include adaptation undertaken by the subjects in the real environment. These adaptive effects depend upon factors like local climatic condition, ethnicity, culture, etc. In this paper the results of adaptive thermal comfort based field studies conducted in 3 naturally ventilated office buildings of cold and cloudy climate in north east India are presented. The variation in thermal sensation, thermal preference, clothing insulation, neutral temperatures and other behavioral adaptive measures undertaken by the subjects like taking hot and cold beverages, number of showers in order to feel comfortable are discussed. The comfortable thermal sensation votes are plotted on the psychometric chart and a comparison with the comfort zone prescribed by ASHRAE is made. The subjects were found to be comfortable in cooler temperature than that prescribed in the standard, and thereby a modification in the comfort zone, which reflects the adaptive action of the subjects for the region is proposed.

Keywords – Clothing Insulation; Thermal Sensation; Psychometric Chart; Comfort Zone

1. INTRODUCTION

Occupants spend a large portion of their time in indoor environment. As per the survey conducted by the University of Maryland in early nineties, an average person spends about 87% of his time inside a building. Due to this long time spent indoors, it is essential that the conditions inside these buildings remain comfortable, both thermally and visually. Hence, in a conditioned building, HVAC measures are applied in order to heat, cool or ventilate the building. However, it is energy consumptive. This necessitates the proper definition of comfort conditions inside a building not only to provide comfort but also to save energy. The Predicted Mean Vote – Percentage Predicted Dissatisfied (PMV – PPD) model developed by PO Fanger [1] in the early seventies which is mathematically robust and reproducible, is used to determine the indoor comfort limits in a conditioned building. However, lately there has been realization by the research community that the climate chamber based PMV-PPD model [1] often exaggerates the thermal sensation and leads to either overestimation or underestimation of comfort condition in warm and cool climate, respectively [2]. This is because, in the real environment, subjects undergo adaptation and utilize several available measures and make the conditions more comfortable for them.

As per the adaptive principle, "if a change occurs so as to produce discomfort, occupants react in ways which tend to restore their comfort" [3]. Several field survey studies have been conducted, since then throughout the world in order to understand the adaptation undertaken by the subjects [4 - 8], as a result de Dear and Brager [9] provided with the revisions in the ASHRAE Standard 55 - 2013[10] for naturally ventilated (NV) buildings. In fact, NV buildings are of much interest to architects, engineers and even building owners because of their relatively lesser energy requirement during their running in comparison to air conditioned (AC) buildings. They rely on natural measures like windows, fans, etc for providing comfort. However, improperly designed NV buildings may not provide adequate comfort and may lead to the later retrofication with HVAC utilities which can become counterproductive energy wise [11].

1.1 Thermal Comfort: Indian Scenario

Building sector is responsible for around 35 % of the energy consumption in India and this rate is growing annually at 8% [12]. Around 73% of the energy consumed in the building sector is utilized for running the buildings [13], which include providing comfortable condition beside other uses like lighting, ventilating, etc. The National Building Code (NBC) of India [14] prescribes a two narrow range of temperature, 23 °C – 26 °C for summers and 21° - 23 °C for winters, irrespective of the wide variation in the geography, climatic, ethnic and cultural diversity in its huge population. However, recent field studies in Indian buildings by Mishra and Ramgopal [11] and Indraganti et al. [15] in hot and humid climates and by Dhaka et al. [16] in composite climate reveal that Indian subjects exhibit comfort temperature much wider than that prescribed by the NBC [14]. Manu et al. [17] had proposed the Indian Model of Adaptive Comfort