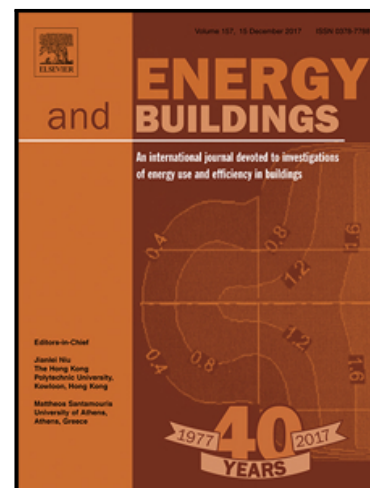


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Adaptive Thermal Comfort in the different buildings of Darjeeling Hills in eastern India – effect of difference in elevation

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ABSTRACT Thermal comfort standards are required to provide comfortable indoor condition which has a positive effect on the occupant. However, the Predicted Mean Vote – Percentage People Dissatisfied (PMV-PPD) model which is used to determine the indoor comfort in most of the international standards fails often, especially in naturally ventilated buildings. Several field studies were conducted elsewhere to determine the comfort condition, but very few are reported for the cold and cloudy type of climate and in hilly region. In this paper, the results of field studies conducted in 10 buildings of different types located in varying elevation are presented. A total of 2608 responses of thermal comfort were collected from 436 subjects between January and December, 2015. The mean clothing insulation of the subjects were found to increase with the increase in the elevation of the location and this difference was statistically significant, $t = -94.05$ ($df = 2607$, $p < 0.001$). The yearly mean clothing insulation in S0135 was 0.640 clo, K1420 was 0.722 clo, M1640 was 0.947 clo, S1950 was 1.055 clo and T2565 was 0.907 clo respectively. Whereas, the mean comfort temperature decreased with the elevation of the location and this difference was also statistically significant, $t = -92.34$ ($df = 2607$, $p < 0.001$). The yearly mean comfort temperature for the location S0135 was 28.37 °C, K1420 was 20.59 °C, M 1640 was 20.07 °C, S1950 was 19.72 °C and T2565 was 17.35 °C, respectively, where the digits in the locations (i.e. 0135 in S0135, 1420 in K1420, 1640 in M1640, 1950 in S1950 and 2565 in T2565) represents the elevation of the location under study in meters above mean sea level. A relation of the indoor comfort temperature with the outdoor environmental conditions and with the elevation of the location under study is obtained.

Keywords – Elevation; Predicted Mean Vote; Clothing Insulation; Comfort Temperature

1. INTRODUCTION

Comfortable indoor conditions are preferred by human beings, which not only improve their productivity but also their health and satisfaction [1]. In an air conditioned (AC) building mechanical and thermal measures are employed to achieve this comfortable conditions in indoors, which is rather energy intensive [1]. In contrast, naturally ventilated (NV) buildings use simple measures like windows and fans to provide comfort without any HVAC devices, thus consume lesser energy throughout its lifetime, which attracts designers, architects and building owners [2]. However, defining the proper comfort conditions and its prediction inside the building prior to the design and actual construction of the building, is important, else if the building fails to provide the desired comfort later, it can result in the retrofication with HVAC devices, which may be counterproductive energy wise [1].

Thermal comfort is defined by the ASHRAE Standard 55 [3] as “that condition of mind which expresses satisfaction with the thermal environment.” The laboratory based ‘steady state’ model of thermal comfort, known as the Predicted Mean Vote (PMV-PPD model) proposed by Fanger [4] were the basis for the internationally accepted thermal comfort standards like ASHRAE 55 [3] and ISO 7730 [5]. This model do not however include the various adaptive opportunities that the indoor occupants may undertake to make themselves more comfortable, thus frequently either overestimates or underestimates the thermal comfort in warm or cool conditions, respectively [6]. This prompted thermal comfort researchers to conduct several survey based field

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