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Indoor thermal environment evaluations and parametric analyses in naturally ventilated buildings in dry season using a field survey and PMVe-PPDe model

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ABSTRACT

The PMV model predicts thermal sensation well in HVAC buildings while it predicts a warmer thermal sensation than the occupants actually feel in naturally ventilated buildings. For using PMV model to predict thermal sensation well in a naturally ventilated building, the extended PMV model (PMVe) including an expectancy factor (e) and PMV was proposed by Fanger. Besides, calculations of PMV are too complex to be applied in practice. To obtain simple and applicable correlations, taking Qujing of Yunnan province, China, as example, a dry season (6-month) field measurement was conducted in a naturally ventilated residential room. Based on the collected data, PMVe values were calculated by using Newton's iterative method. It is shown that the PMVe values approximately vary from −1.3 to 0.20 and the indoor thermal environment is somewhat discomfortable on some cloudy or rainy days. Parameters relationships and indoor air temperature gradients (vertical and horizontal) were also studied by using linear regression technique and quadratic polynomial fit technique. Numerous correlations with high relativities have been developed. It is convenient to use these results to evaluate the indoor thermal environment in naturally ventilated buildings under similar climatic conditions.

1. Introduction

Based on the relevant statistics, people spend 80% of their lifetime indoors [1], and in industrialized countries the percentage is over 90% [2]. It is commonly accepted that the poor indoor comfort has detrimental effects on people's productivity and health [3,4]. For example, it was found that the productivity will be increased by 15% when office workers are satisfied with their environments [5]. In order to improve their indoor thermal environment, people start to equip their houses and offices with heating systems in winter and with air-conditioning systems for the summer conditions. This leads to tremendous amount of energy required for improving indoor thermal environment. Building energy consumption accounts for about 40% of the total energy consumption in the EU member states [6], 26.7% in Argentina [7] and 27.5% in China in 2001 [8].

With the ever growing awareness for a need to reduce building energy use and to improve indoor thermal environment, it becomes increasingly important to seek ways to control and assess the indoor thermal environment. To actualize this objective, extensive studies on indoor thermal environments have been carried out at home and abroad by using field surveys [9–11] and theoretical analyses [12–14]. A large number of thermal comfort indices have been set up for the analysis of indoor climates [15]. But only a few of them have been used to evaluate the ability of an existing room climate to create satisfactory thermal conditions for occupants. The most common and best understood one is Fanger's Predicted Mean Vote – Predicted Percentage of Dissatisfied (PMV-PPD) [13]. While the PMV model predicts thermal sensation well in buildings with HVAC systems, field studies in warm climates in buildings without air-conditioning have shown that it predicts a warmer thermal sensation than the occupants actually feel [16–18]. For such naturally ventilated buildings an adaptive model has been proposed [19]. This model is a regression equation that relates the neutral temperature indoors to the monthly average temperature outdoors [11,19–22]. The only variable is thus the average monthly outdoor temperature, which at its highest may have an indirect impact on the human heat balance. An obvious weakness of the adaptive model is that it does not include human clothing or activity or the four classical thermal parameters that have a well-known impact on the human heat balance and therefore on the thermal sensation. In contrast, the PMV model includes four environmental factors (air temperature, mean radiant temperature, relative humidity and relative air speed) and two personal factors (activity and clothing). This model, internationally standardized by the ISO 7730, shows the quantitative values of the

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