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An Energy Efficiency Assessment of the Thermal Comfort in an Office building

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Abstract

People spend about 90% of their time indoors, so a comfort indoor thermal environment is essential for the satisfaction, productivity and well-being of the building occupants. Assessment of the indoor thermal comfort is the key point for building HVAC system design and operation to provide a comfort indoor environment to building occupants. Predicted Mean Vote (PMV) model is the most widely used tool for the indoor thermal comfort assessment. In this study, the application of the PMV model in Qatar with dry, subtropical desert climate is evaluated. An experiment was conducted in an office building in Doha, Qatar to reveal the occupant perception of indoor thermal comfort. Using collected data, the PMV indexes were calculated using Fanger's theory and compared with the Actual Thermal Sensation (ATS) of the occupants to assess the applicability of the PMV model to predict the indoor thermal comfort in air conditioned buildings in the climate zone of Qatar. The corresponding occupants' satisfaction level with the indoor thermal comfort and their adaptive behavior were also assessed.

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Keywords: Thermal comfort; PMV; Occupant bahavior; Building enery efficiency

1. Introduction

Indoor thermal comfort is the most important factor that determines the overall indoor environment quality which is the major concern of building occupants due to their long time stay indoors [1]. Building occupants' perception of indoor thermal comfort normally refers to their feelings of room comfort, for example, the room is hot, cold or neutral etc. and is not a direct sensation of indoor air temperature. Due to the essential role that building occupants play in the building operation and further more in the building energy efficiency enhancement, the assessment of their indoor thermal comfort is quite important for not only building design and operation, but also for building energy efficiency improvement. Predicted Mean Vote (PMV) model which was first developed by Fanger [2] is the most widely accepted tool for the indoor thermal comfort assessment and was adopted by international standards such as ISO 7730 [3] and the ASHRAE Standard 55–92 [4] to evaluate the indoor thermal comfort conditions. In previous studies, this model has been evaluated and validated using data collected from different climate zones and different building types. Although the strength of PMV model has been proved by many studies, it was found that the PMV model didn't perform very well for assessment of the indoor thermal comfort in naturally ventilated buildings. Therefore, the adaptive model [5] was adopted by AHRAE Standard called Adaptive Comfort Standard (ACS) as an extension tool of PMV method for the thermal comfort evaluation in naturally ventilated buildings [6]. Despite that a lot of studies validated the application of PMV model in air conditioned buildings, some recent studies indicate that there are discrepancies between the

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PMV model prediction and the Actual Mean Vote (AMV) of the building occupants while evaluating the indoor thermal comfort in air conditioned buildings [7-11].

In this study, the application of the PMV model in Qatar with dry, subtropical desert climate is evaluated. An experiment was conducted in an office building served with a central VAV air conditioning system in Doha, Qatar to reveal the occupant perception of indoor thermal comfort. The occupants' adaptive behavior were also examined in this study.

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Nomenclature

PMV	Predicted Mean Vote
T_a	Room air temperature
T_{mra}	Mean radiant temperature
RH	Relative humidity of room air
V_a	Air velocity
MR	Metabolic rate
CL	Clothing level

2. Methodology

2.1. Experiment Facility

The chosen building for this study is an office building located in College of North Atlantic, Qatar numbered as building 7. It is a two story office building with gross area of about 3,184 m^2. Each floor can be divided into East and West Zones. The experiment was conducted in the West zone of the ground floor with a gross area of about 657 m^2. There are total 22 personal offices, 1 staff lounge and 1 equipment room in this experimental zone, which is served by three AHUs. Chilled water is provided by the campus central plant and no heating device is in use. The floor plan is shown in Fig. 1. Each office is served by one VAV terminal box controlled with local thermostat. Except office 7110a and 7110b, each office is occupied by one university instructor and 14 of the total 20 occupants agreed to participate in the study.

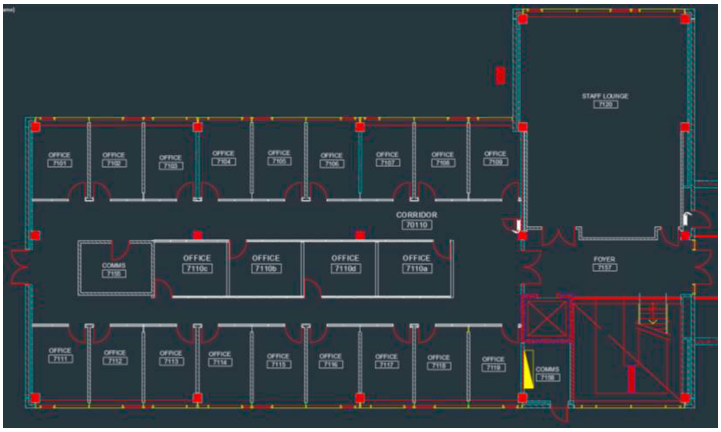

Fig. 1. Experiment zone floor plan.

2.2. Data Collection

The PMV index should be calculated using 6 inputs according to Fanger's theory. As shown in Equation 1, air temperature, mean radiant temperature, relative humidity, air velocity, metabolic rate and clothing level are the six factors that determine the PMV index. The former first 4 inputs are measureable parameters which can be obtained through sensors and the latter 2 inputs need evaluation through subjective studies like survey feedbacks from the occupants.

$$\text{PMV} = f\left(T_a, T_{mra}, RH, V_a, MR, CL\right) \quad (1)$$

The indoor thermal conditions like temperatures and relative humilities and indoor air velocities are monitored using sensors and recorded in the data acquisition system at 15 min intervals. However, due to the experiment conduction limitation, we didn't get a chance to measure the mean radiant temperature in each office room. Considering the big thermal mass of the building,