Faculty of Engineering

Development of Adaptive Thermal Comfort Models for Residential Buildings in Sarawak Urban Areas

John Tin Yuan En

Doctor of Philosophy
2018

UNIVERSITI MALAYSIA SARAWAK

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Development of Adaptive Thermal Comfort Models for Residential Buildings in Sarawak Urban Areas

John Tin Yuan En

A thesis submitted

In fulfillment of the requirements for the degree of Doctor of Philosophy

(Electrical and Electronics Engineering)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2018

DECLARATION

I, John Tin Yuan En (11011558) from Faculty of Engineering UNIMAS hereby declare that the work entitled, Development of Adaptive Thermal Comfort Models for Residential Buildings in Sarawak Urban Areas is my original work. I have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for me by another person. The thesis has not been accepted for any degree and is not concurrently submitted in candidature for any other degree.

_____

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ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to my supervisor, Assoc. Prof. Dr Wan Azlan Bin Wan Zainal Abidin for his guidance and advices throughout the entire process of my research work. Furthermore, I would like to take this opportunity to thank my co-supervisors, Assoc. Prof. Dr Azhaili Baharun and Assoc. Prof. Dr Thelaha Masri for their attentions and assistance throughout this study.

Special thanks are due to my beloved parents, family members, coursemates and friends who inspired, supported and encouraged me in my study. Their support is significant to me in completing my thesis.

ABSTRACT

Energy consumption of building sectors has increased rapidly due to the improved living standard and the rise of resident's expectations on thermal comfort. Mechanical ventilations especially air conditioning system is essential for hot and humid countries to achieve their ideal indoor comfort condition. However, such cooling system consumes a huge amount of electricity which is in contradiction with the concept of energy conservation. Thermal comfort assessment is one of the methods to overcome this issue. It evaluates the thermal perception of the occupants and consecutively facilitates the efficient usage of mechanical ventilation systems and attains the purpose of saving the energy. Steady state model and adaptive model are the two main approaches to evaluate thermal comfort. Fanger's Predicted Mean Vote (PMV) model is a prevalent example of steady state model where environmental and personal factors are comprised. On the other hand, adaptive model involves comfort temperature and outdoor temperature to predict the thermal comfort of the indoor environment. Several research studies have indicated that PMV model is not applicable on tropical buildings as it often overestimates the actual thermal sensation of the occupants. Conversely, adaptive model is found to be expressing occupants' thermal perception competently. In this study, thermal comfort analysis was carried out on the free running residential buildings in Sarawak which were naturally ventilated with minimal usage of mechanical ventilation systems. Physical measurements and subjective assessments were performed to evaluate the thermal responses of 287 residents based on ASHRAE scale, Bedford scale, thermal acceptability scale and thermal preference scale. PMV model was also used to predict the thermal sensation of the residents. Bedford scale showed the highest percentage of acceptable votes followed by

ASHRAE scale, thermal acceptability scale and thermal preference scale. The comfort temperatures of the study were obtained from ASHRAE scale, Bedford scale and PMV model which were found to be 27.5 ℃, 28.1 ℃ and 26.2 ℃ respectively. The adaptive thermal comfort models were proposed based on the responses of residents on ASHRAE scale and Bedford scale. According to actual percentage dissatisfied which fulfilled 80% satisfaction, the upper and lower limit of the model for indoor operative temperature, relative humidity and air velocity were from 27.3 ℃ to 29.6 ℃, 74.0% to 92.0 % and 0.18 ms^{-1} to 0.66 ms^{-1} respectively.

Keywords: Thermal comfort; residential buildings; adaptive model; comfort temperature; ASHRAE scale; Bedford scale

Perekaan Model Keselesaan Terma Adaptif untuk Bangunan Kediaman di Kawasan Bandar Sarawak

ABSTRAK

Penggunaan tenaga dalam sektor bangunan telah meningkat dengan drastik disebabkan oleh taraf kehidupan dan permintaan penduduk yang semakin meningkat terhadap keselesaan terma. Pengudaraan mekanikal terutamanya sistem penyaman udara memainkan peranan yang penting untuk negara-negara yang mengalami iklim panas dan lembap demi mencapai keselesaan terma yang memuaskam. Walaubagaimanapun, sistem penyejukan tersebut memerlukan pengunaan elektrik yang besar dan fenomena ini adalah bertentangan dengan konsep pemuliharaan tenaga. Penilaian keselesaan terma merupakan salah satu cara penyelesaian untuk mengatasi masalah tersebut. Cara ini menilai persepsi terma penduduk-penduduk kediaman untuk memastikan penggunaan pengalihudaraan mekanikal secara berkesan dan stereusnya mencapai tujuan penjimatan tenaga. Model keadaan mantap dan model penyesuaian adalah dua pendekatan utama untuk menilai keselesaan terma. Model Fanger Predicted Mean Vote (PMV) ialah salah satu contoh model keadaan mantap yang melibatkan faktor persekitaran dan faktor manusia. Sebaliknya, model penyesuaian melibatkan suhu selesa dan suhu persekitaran luar untuk meramalkan keselesaan terma dalam persekitaran yang tertutup. Beberapa kajian penyelidikan telah menunjukkan bahawa model PMV tidak sesuai untuk digunakan di atas bangunan - bangunan yang beriklim tropika kerana ia sering meremehkan sensasi haba yang dialami oleh para penghuni. Model adaptif pula dikesan dapat menyampaikan persepsi terma penghuni dengan lebih tepat. Dalam penyelidikan ini, kawasan-kawasan perumahan Sarawak yang menggunakan sistem pengudaraan semula jadi dan sistem

pengudaraan mekanikal telah disiasat dari segi keselesaan terma. Tindak balas terma daripada 287 penduduk tempatan telah dianalisis melalui pengukuran fizikal persekitaran dan penilaian subjek berdasarkan soal-soal penyelidikan dengan menggunakan skala ASHRAE, skala Bedford, skala penerimaan terma dan skala kegemaran terma. Model PMV juga digunakan untuk meramalkan reaksi penduduk-penduduk terhadap keadaan persekitran mereka. Skala Bedford memaparkan peratusan penerimaan yang tertinggi diikuti oleh skala ASHRAE, skala penerimaan terma dan skala kegemaran terma. Suhu selesa yang diperolehi daripada skala ASHRAE, skala Bedford dan model PMV masing-masing adalah 27.5 ℃, 28.1 ℃ dan 26.2 ℃. Model-model keselesaan terma adaptif ini adalah dibina berdasarkan maklumat-maklumat yang dibekalkan oleh para penduduk melalui skala ASHRAE dan skala Bedford. Untuk memastikan model-model yang dibina ini memenuhi kepuasan para penduduk sebanyak 80%, had batasan untuk model ini dari segi suhu, tahap kelembapan dan halaju udara adalah dari 27.3 ℃ hingga 29.6 ℃, 74.0% hingga 92.0% dan 0.18 ms^{-1} *hingga 0.66* ms^{-1}.

Kata kunci: *Keselesaan terma; kawasan perumahan; model adaptif; suhu selesa; skala ASHRAE; skala Bedford*

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