UNIVERSITI PUTRA MALAYSIA

INDOOR ENVIRONMENTAL QUALITY AND ENERGY COST SAVING PREDICTION MODEL FOR RADIANTLY COOLED SLAB TROPICAL BUILDINGS

KWONG QI JIE

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DOCTOR OF PHILOSOPHY
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KWONG QI JIE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

This thesis is dedicated to my beloved parents for instilling in me the importance of hard work, perseverance and higher education and to my fiancé who has provided me with words of encouragement throughout my candidature.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

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Chairman : Nor Mariah Adam, PhD
Faculty : Engineering

The building sector is one of the major energy users. This has made efficient energy utilisation in buildings a necessity in conserving the fast-depleting resources and to achieve reduction in energy cost. Efficient use of energy consuming devices such as air-conditioning and artificial lighting systems in buildings is therefore essential for energy efficiency improvement.

This research aims to evaluate the indoor environmental quality (IEQ) of a Malaysian building that was cooled via a combination of radiant and convective systems and to compare the energy performance of this apparatus to a conventionally designed all-air system. Field assessments which consisted of physical and subjective (questionnaire) assessments were conducted to measure the current IEQ levels as well as to identify the occupants' perception on their immediate surroundings. The energy management system was used to gather energy consumption data of the building under study.

The outcomes demonstrated that the measured IEQ parameters were within acceptable ranges except for the air velocity profile. From the subjective measurement, 83.3% of the occupants were satisfied with their thermal environment and 59.5% of the votes were placed within the three central categories of the thermal sensation scale. Besides, each environmental comfort factor exerted different level of impact towards the occupants' work productivity. Natural daylight was found to be sufficient in providing a visually comfortable environment to occupants during peak working hours, while occupants were generally more tolerant towards the acoustical condition. The air quality was perceived as acceptable for 92% of the occupants, which was consistent with the measured air contaminants' levels. The operative temperature was calculated by using the measured air temperature and mean radiant temperature and a neutral operative temperature of 25.4 °C was

obtained. An adaptive coefficient of -1.1262 was subsequently calculated which showed the level of thermal adaptation among the occupants. Besides, it was found that the combined radiant-convective system was able to reduce the energy cost for air-conditioning of interior spaces by 42.5%. A simple payback period of 5.3 years was calculated by considering all the associated costs. The outcomes of this study also suggested that more energy savings without compromising human comfort can be obtained by raising the thermostat setting to 2 °C higher than the conventional setting and the use of natural daylight during working hours. Further studies on evaluating the IEQ conditions of other tropical buildings that are using radiant cooling systems and application of automatic window shades for daylight control were suggested.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KUALITI PERSEKITARAN DALAMAN DAN MODEL PENYANGKAAN PENJIMATAN KOS TENAGA UNTUK BANGUNAN TROPIKAL DILENGKAPI DENGAN SISTEM PENYEJUKAN RADIANT

Oleh

KWONG QI JIE

Jun 2014

Pengerusi : Nor Mariah Adam, PhD
Fakulti : Kejuruteraan

Sektor bangunan merupakan salah satu pengguna tenaga terbesar, maka kecekapan penggunaan tenaga ialah amalan yang amat penting dalam sektor tersebut. Sistem penyaman udara dan lampu elektrik merupakan pengguna tenaga utama dalam bangunan komersial. Jadi, sistem-sistem sebegini mesti digunakan secara efisyen demi mengelakkan pembaziran tenaga.

Kajian ini bertujuan untuk mengkaji kualiti persekitaran dalaman (KPD) dalam sebuah bangunan Malaysia yang dilengkapi dengan kombinasi sistem penyejukan secara radiant dan konvektif dan membandingkan prestasi penggunaan tenaga sistem ini dengan sistem penyaman udara konvensional. Kajian lapangan yang meliputi pengukuran objektif dan penilaian subjektif telah dijalankan untuk mengkaji tahap KPD dalam bangunan tersebut serta mengenalpasti persepsi pengguna mengenai keadaan persekitaran. Selain itu, sistem pengurusan tenaga telah digunakan untuk mengumpul data-data penggunaan tenaga dalam bangunan itu.

Keputusan yang diperolehi menunjukkan bahawa tahap-tahap parameter KPD adalah dalam julat yang boleh diterima kecuali profil halaju udara. 83.3% daripada jumlah pengguna amat berpuas hati dengan keadaan termal di tempat kerja mereka dan 59.5% daripada undian telah diletakkan dalam tiga kategori pusat untuk skala sensasi termal. Selain itu, setiap faktor keselesaan persekitaran mempengaruhi pretasi kerja pengguna bangunan dalam tahap yang berlainan. Pancaran cahaya semulajadi adalah mencukupi untuk mewujudkan suasana yang selesa untuk pengguna pada waktu bekerja manakala tahap kuasa bunyi pula kurang memberikan kesan atas prestasi kerja. 92% daripada jumlah pengguna berpendapat bahawa kualti udara dalam bangunan tersebut adalah memuaskan kerana tahap pencemaran udara yang disukat adalah amat rendah. Suhu operatif telah dikira dengan menggunakan suhu udara dan purata suhu radiant dan suhu keneutralan dalam bangunan tersebut

ialah 25.4 °C. Dengan menggunakan hasil kajian yang diperolehi, satu adaptif pekali suaian sebanyak -1.1262 telah diperolehi dan ini menunjukkan tahap adaptif termal bagi pengguna bangunan tesebut. Di samping itu, sistem penyejukan secara radiant dapat mengurangkan penggunaan tenaga sebanyak 42.5%. Tempoh bayaran balik untuk pemasangan sistem radiant tersebut adalah 5.3 tahun dengan mengambil kira kesemua kos yang terbabit. Hasil kajian ini telah membuktikan bahawa suhu udara dalam bangunan yang dikaji boleh ditingkatkan sebanyak 2 °C lagi dan pancaran cahaya semula jadi dapat digunakan pada waktu bekerja untuk menjimatkan kos penggunaan elektrik. Untuk kajian selanjutnya, keadaan KPD dalam bangunan tropika yang lain yang turut menggunakan sistem penyejukan secara radiant dan kesesuaian menggunakan bidai automatik untuk mengawal tahap pancaran cahaya adalah dicadangkan.

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Kwong Qi Jie
June 2014

I certify that an Examination Committee has met on 17 June 2014 to conduct the final examination of **Kwong Qi Jie** on his Doctor of Philosophy thesis entitled "Indoor environmental quality and energy cost saving prediction model for radiantly cooled slab tropical buildings" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the candidate be awarded the degree of Doctor of Philosophy.

Members of the Thesis Examination Committee are as follows:

Mohd Khairol Anuar bin Mohd Ariffin, PhD, PEng
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Mohd Zainal Abidin bin Ab. Kadir, PhD, PEng
Professor
Faculty of Engineering
Uniersiti Putra Malaysia
(Internal Examiner)

Luqman Chuah Abdullah, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Jan L M Hensen, PhD
Professor
Department of Built Environment
Eindhoven University of Technology
Netherlands
(External Examiner)

_____

NORITAH OMAR, PhD
Professor/ Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

Nor Mariah Adam, PhD
Associate Professor
Institute of Advanced Technology
Universiti Putra Malaysia
(Chairman)

Barkawi Sahari, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Nuraini Abdul Aziz, PhD
Senior Lecturer,
Faculty of Engineering
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

Declaration by Graduate Student

I hereby confirm that:

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Declaration by Members of Supervisory Committee

This is to confirm that:

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Signature: _____
Name of Chairman of Supervisory Committee: Assoc. Prof. Ir. Dr. Nor Mariah Adam

Signature: _____
Name of Member of Supervisory Committee: Prof. Ir. Dr. Barkawi Sahari

Signature: _____
Name of Member of Supervisory Committee: Dr. Nuraini Abdul Aziz

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