ENHANCING THE THERMAL PERFORMANCE OF COURTYARD OFFICE BUILDING IN HOT-HUMID CLIMATE: A CASE STUDY OF DEVELOPMENT DEPARTMENT BUILDING UNIMAP

by

ESRA'A SHEHADEH HUSSEIN ABBAAS
(1532011867)

A thesis submitted in fulfillment of the requirements for the degree of Master of Science in Building Engineering

School of Environmental Engineering
UNIVERSITI MALAYSIA PERLIS

2018

UNIVERSITI MALAYSIA PERLIS

DECLARATION OF THESIS

Author's Full Name	:	ESRA'A SHEHADEH HUSSEIN ABBAAS
Title	:	ENHANCING THE THERMAL PERFORMANCE OF COURTYARD OFFICE BUILDING IN HOT-HUMID CLIMATE: A CASE STUDY OF DEVELOPMENT DEPARTMENT BUILDING UNIMAP
Date of Birth	:	01 FEBRUARY 1991
Academic Session	:	2017/2018

I hereby declare that this thesis becomes the property of Universiti Malaysia Perlis (UniMAP) and to be placed at the library of UniMAP. This thesis is classified as:

☐	**CONFIDENTIAL**	(Contains confidential information under the Official Secret Act 1997)*
☐	**RESTRICTED**	(Contains restricted information as specified by the organization where research was done)*
☑	**OPEN ACCESS**	I agree that my thesis to be published as online open access (Full Text)

I, the author, give permission to reproduce this thesis in whole or in part for the purpose of research or academic exchange only (except during the period of _____ years, if so requested above).

	Certified by:
SIGNATURE	**SIGNATURE OF SUPERVISOR**
M913680	IR. DR. MOHAMMAD ARKAM BIN CHE MUNAAIM
(NEW IC NO. /PASSPORT NO.)	**NAME OF SUPERVISOR**
Date: 01 February 2018	Date: 01 February 2018

NOTES : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with the period and reasons for confidentiality or restriction. Replace thesis with dissertation (MSc by Mixed Mode) or with report (coursework)

ACKNOWLEDGMENT

My only Acknowledgment goes to my beloved husband Ala'eddin for his continuous and massive support along the journey of my master research and thesis writing. I appreciate his teaching me how to think logically and to handle every single issue facing me during my research. Thank you for guiding me how to be a good warrior to achieve my ambitious and for being side by side with me to make my target completely accomplished.

DEDICATION

I would like to dedicate this thesis to:

My dear mother and father who were always there to provide support and encouragement from my childhood to believe in myself and select my own track of science that I like, I love you both.

My beloved husband, my greatest blessing from Allah, for his patience with love and inspiration along my study time.

My sister for being my best friend, soul mate and the best part of me.

My brothers for being great brothers.

My daughters for stealing my heart.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating Ventilating and Air-conditioning
HVAC	Heating, Ventilation, and Air Conditioning
RH	Relative Humidity
PMV	Predicted Mean Vote
PPD	Predicted Percentage of Dissatisfied
GBI	Green Building Index
MS	Malaysian Standard

Menambahbaik prestasi terma di laman bangunan pejabat dalam kawasan beriklim panas dan lembab: Kajian Kes Bangunan Jabatan Pembangunan UniMAP

ABSTRAK

Laman (Courtyard) merupakan satu pilihan bagi tujuan penyejukan semulajadi memandangkan keupayaannya mencipta satu iklim berasingan antara dalam dan luar bangunan. Ini dicapai dengan mencipta perbezaan suhu di antara kawasan dalaman dan luaran. Keberkesanan menggunakan laman bagi tujuan pengudaraan di kawasan beriklim panas dan lembab bagi sesebuah bangunan masih dipertikaikan kerana kajian yang minima dilaporkan di Malaysia. Objektif kajian ini ialah untuk melaksanakan simulasi EnergyPlus bagi menerokai kesan kehadiran laman di bangunan pejabat setingkat melalui menyelidikan pengudaraan semulajadi, glazing tingkap dan teduhan bidai tingkap dari segi kesan haba pada 21 April dan 21 Oktober yang mewakili musim kemarau dan musim hujan di Malaysia. Bangunan Jabatan Pembangunan di Kampus Pauh Putra Universiti Malaysia Perlis (UniMAP) diambil sebagai lokasi Kajian Kes. Keputusan menunjukkan pengudaraan tetingkat adalah cara berkesan untuk mengurangkan suhu udara dalaman kerana keupayaannya memindahkan udara panas di dalam bangunan dengan udara yang lebih sejuk di laman. Sebaliknya, pengudaraan silang mempunyai kesan mengurangkan kelembapan relatif dalam bangunan kerana aliran udara boleh meneutralkan kelembapan di ruang dalaman. Nilai PMV yang tinggi dengan pengudaraan tetingkat di mana ia berkesan untuk meningkatkan keselesaan terma. Teduhan venetian mengurangkan suhu dalaman dan penggunaan bidai luar adalah lebih berkesan kerana ia menghalang radiasi suria. Disamping itu, bidai luar menyebabkan peningkatan kelembapan relatif di dalam bangunan berbanding ketiadaan teduhan tingkap kerana pengurangan suhu. Secara am, teduhan tingkap menjelaskan penambahbaikan nilai PMV dan bidai luar paling berkesan dalam menambahbaik nilai PMV semasa musim hujan tetapi tidak memberi kesan ketara pada musim kemarau. Pengunaan tingkap kaca dua dan tiga lapisan pada hari-hari tersebut mengurangkan suhu dalaman sebaliknya meningkatkan kelembapan dalaman berbanding dengan kegunaan tingkap kaca satu lapisan. Nilai PMV untuk kesan pemasangan tingkap kaca menunjukkan tingkap kaca pelbagai lapisan akan meningkatkan haba untuk penghuni tetapi ia masih dalam toleransi keselesaan haba. Akhirnya, diperhatikan bahawa pengudaraan adalah faktor yang paling berkesan dalam mengurangkan suhu dan kelembapan relatif seterusnya meningkatkan kelesaan terma bagi bangunan dengan laman di persekitaran panas lembab dalam parameter yang dikaji. Kajian ini menyumbang kepada kelestarian senibina di mana penggunaan laman di persekitaran panas lembab khususnya di Malaysia kerana keberkesannya meningkatkan prestasi terma yang membantu keselesaan terma hampir dengan nilai yang diperlukan.

Enhancing the Thermal Performance of Courtyard Office Building in Hot-Humid Climate: A Case Study of Development Department Building UniMAP

ABSTRACT

Courtyard is considered a natural alternative for cooling since it has high ability to create a local climate within a building that is nicer than the outside which leads to create temperature difference between indoor and outdoor. The efficiency of courtyard in hot-humid climate still questionable due there are minimal research reported especially in Malaysia. The objective of this research is to perform a simulation study using EnergyPlus simulator to explore the influence of the presence of a courtyard in a single storey office building via investigating the impact of natural ventilation, window glazing and window blind shading on the thermal performance of the building on 21 April and 21 October that representing the dry season and wet season days in Malaysia. The Development Department building at University Malaysia Perlis (UniMAP) that is located in Pauh Putra Campus has been taken as a case study. The results show that the stack ventilation is the most effective way to reduce the indoor air temperature due to its high ability on exchanging the indoor warm air with the cooler one in the courtyard. In contrary, the cross ventilation has the greatest impact on reducing the relative humidity within the building since it is capable to dilute the moist concentration in the interior spaces as a result of airflow. The best PMV values for ventilation effect is obtained for stack ventilation, indicating its effectiveness in enhancing the thermal comfort of the building. Moreover, venetian blind shading is capable to reduce the indoor air temperature for the building and using external blind is more effective due to its impact on blocking sun radiation. Additionally, the external venetian blind causes to increase the relative humidity within the building compared to no window shading case due to the reduction of air temperature. Generally, window shading reveals an enhancement on PMV values and the external blind has the most effective where it is capable to shift PMV values within comfortable level during wet season, but it does not much impact on the thermal sensation level during dry season. Using double and triple glazing windows able to reduces the indoor air temperature and in contrary, relatively increases the humidity within the building compared to using single glazing window. The PMV values of glazing effect revealed that using multi-layered glazing window slightly enhances the thermal sensation for occupants but it is not able to reduce the uncomfortable hours on both design days. Finally, it can be observed that the ventilation is the most effective factor on reducing the air temperature and relative humidity, as well as to enhance the thermal comfort level for courtyard buildings in hot-humid climate among the other studied parameters. This work contributes to sustainable architecture where courtyard application concept is used in hot-humid climate specifically for Malaysia due to its effective ability to enhance the thermal performance and help in improving the thermal comfort level near to the desired values.

CHAPTER 1

INTRODUCTION

1.1 Research Background

The increment in human activities and industrial revolution leads to sharp changes in the ecosystem and accordingly in climate due to the incredibly increase in earth temperature, which in turn causes global warming phenomena. The continue increases in global warming and energy consumption required to apply sustainable concepts in order to reduce their effect in daily life. Applying sustainable concepts in buildings considered one of main approaches to maintain energy consumption (Cho & Mohammadazadeh, 2013).

Sustainable architecture is a term describes the science and style of buildings that are designed and constructed according to environmentally friendly concepts. In other words, sustainable architecture is about minimizing the harm environmental impact of buildings by enhancing efficiency and moderation the use of resources consumed in the building's construction. The aim of sustainability, or ecological design, is to ensure that the activities and decisions we are making these days in construction do not restrain the opportunities of coming generations of having better life (Sirija & Arch, 2013).

Transitional spaces such as atrium, balcony, patio and courtyard are potentially and traditionally efficient ways to moderate indoor climate of building with the free sources available from nature. These kinds of spaces are recently being considered from the thermal comfort point of view (Samadi, 2014; Taleghani, Tenpierik & Dobbelsteen, 2012). In addition, many researchers reported that transitional spaces have large

implications to occupants' experience and building energy consumption (Hui & Jiang, 2014).

There are many reports reveals that using internal courtyards help the air to flow within the interior spaces of the building and also help get rid of the hot air inside the building. Observance the opening to be narrow and directed to prevailing winds side. Making sun-breakers help to get enough shades and help to make of a difference in temperatures lead to disturbance of air which helps air movement thus enhance the thermal comfort within the building (Moosavi, Mahyuddin, Abd Ghafar, & Ismail, 2014).

The significant of courtyard in buildings is to create a comfort local climate that is isolated from the outdoor since the courtyard is shaded and less sun radiation reaches to it. The existence of courtyard in a building effectively produces shading and isolates the indoor area from radiation during daytime. However, during daytime the cool air in courtyard resultant shading creates air ventilation due to the air density difference. Beside that the air ventilation during night occurs due to the exchange of warm air inside the rooms adjacent to the courtyard with the outdoor cold air through the openings.

In order to obtain high thermal comfort for courtyard building many parameters should be taken into consideration such as the shape, orientation, dimension, and height of the courtyard. In hot-humid areas, not all these parameters have effectively impact on the thermal performance in a building with a courtyard compared to other climates. Therefore, more parameters such as natural ventilation, window shading and window glazing should be considered to enhance the thermal performance of the courtyard buildings in hot-humid environment.

Hot humid climate exists at latitude between -15° and +15° around the equator to include many areas such as northern Australia, mid and south America and large part of Africa. The average temperature during the year in these areas is 27 °C and varies in the

range of 1-3 °C from a month to another and the relative humidity within the range of 70% - 90% (Djamila, Chu & Kumaresan, 2014). Thus this climate affects negatively on the workability and productivity of the residents, therefore, it is necessary to improve the thermal comfort of the buildings in these area to enhance the productivity of people which in turn contributes to the economic development for the countries located in this kind of climate.

The building should be designed in a shape that enable it to be located within or close to the thermal comfort zone, which can be achieved by reducing the number of the openings within the building, using smaller openings to minimize the gain heat from the surrounding environment, using insulating materials within the external walls to decrease the influence of the external humidity and hotness and avoiding to use thick concrete structures due to their high thermal conductivity. The thermal comfort for buildings within these regions can be accomplished by considering a design in which the building is enclosed with a minimum interaction with the external environment which enable maximum shading and natural ventilation that help to obtain a low temperature internal air (Ghaffarianhoseini, Berardi & Ghaffarianhoseini, 2015).

Courtyard had been used as a part of buildings in different countries located in hot humid areas such as China and India (Chan & Xiong, 2005), however, it still not common in Malaysia. In this research, a simulation study to investigate the effect of presence of a central courtyard in an office building in Malaysia on its thermal performance. The effect of natural ventilation through windows, window venetian blind shading and window glazing on office building in hot-humid climate will be deeply explored.

1.2 Problem Statement

Many solutions have been proposed to improve the thermal comfort of buildings in hot-humid areas. Among of them, introducing courtyard to buildings enhances the thermal performance for the building's interior due to its impact on the passive cooling (Toe, 2013). Courtyard is considered a natural alternative for cooling since it makes the local climate nicer than the outside one, that leads to create temperature difference between internal zone and outdoor areas.

The literature shows that improving the performance of courtyard in buildings within hot-humid areas is still argued topic. In addition, it is found that there are very minimal studies reported the interior courtyard as an architecture element for buildings in Malaysia (Ghaffarianhoseini et al., 2015; Toe, 2013; Zakaria & Ismail, 2012). In which the courtyard is discussed for existing buildings to evaluate its impact on the interior air temperature of these buildings. However, these studies do not report any improvement on courtyard conditions or investigate how to enhance the thermal performance of these buildings. Additionally, there are lack of studies investigate the impact of natural ventilation, window shading and window glazing on the thermal performance of courtyard buildings in hot-humid climate. The effect of these parameters on thermal comfort of buildings in hot-humid climate are highly important to be understood.

1.3 Research Questions

Based on problem statement, understanding the influence of existing courtyard in a building located in hot-humid area in terms of its impact on the thermal performance and thermal comfort leads to the following questions:

1. How central courtyard is able to create temperature gradient between the outer side and inner side of a building in hot-humid climate?
2. What is the impact of the natural ventilation through the windows of courtyard building on the thermal performance of the interior areas of the building in hot-humid climate?
3. Will the position of the window venetian blind shading effect on the thermal performance of the courtyard building in hot-humid climate?
4. Does the window glazing for courtyard building influences the thermal performance of the building in hot-humid climate?

1.4 Research Objectives

This study aims to investigate the effect of the courtyard within the Development Department building at University Malaysia Perlis in Pauh Putra campus and to improve its conditions on the thermal performance and thermal comfort for the building. In this research, the thermal performance is studied based on the indoor air temperature and relative humidity within the building. However, the thermal comfort is evaluated based on the predict mean value (PMV) according to Fanger's model. The objectives of this research can be summarized as follow:

1. To evaluate the impact of a central courtyard on creating temperature gradient between the outer side and inner side of a building in hot-humid climate
2. To investigate the impact of the natural ventilation of the courtyard on the thermal performance and thermal comfort of the building.
3. To study the window venetian blind shading effect on the thermal performance and thermal comfort of the building.

4. To explore the glazing effect for the windows on the thermal performance and thermal comfort of the building.

1.5 Scope of Research

This research will focus on designing a three dimensional model for the Development Department building using OpenStudio SketchUp Plug-in software to be simulated via EnergyPlus simulation software. Two main parameters, particularly the air temperature and relative humidity, will be studied hourly to evaluate the thermal performance within the building. Then these parameters in additional to air velocity and mean radiant temperature parameters are going to be used to appraise the thermal comfort based on the predict mean value (PMV) according to Fanger's model.

In order to achieve all research objectives, different models will be created to explore the influence of courtyard on creating temperature gradient between the outer and inner sides of the building, and to investigate the impact of natural ventilation, window shading and window glazing on the thermal performance and thermal comfort of the building. These models will be simulated for two design days namely, 21 April and 21 October. However, all the studied parameters can be measured at any date through the year but this study focus on these two design days since they are extremes date in Malaysia and representing the dry season and wet season according to 2009 ASHRAE handbook.

1.6 Thesis Overview

Chapter 1 describes a research background about the courtyard building and the advantages of using courtyard as an architecture element to enhance the thermal comfort in a building. The research gap of using courtyard in buildings located within hot-humid climate and the objectives of this research work are also presented.

Chapter 2 presents a literature review about courtyard and the development concept of using courtyard in different civilizations in addition to discussing cases of using courtyard in Malaysia and office buildings. The function of courtyard as passive cooling component in buildings in different climate regions is also explained. Moreover, concepts such as thermal performance and thermal comfort are elaborated in details to have good understanding for building in a presence of courtyard thermally.

Chapter 3 describes the case study which is the Development Department building in University Malaysia Perlis at Pauh Putra campus, the procedures of modelling and simulation the building as well as the parameters that have been used and conditions of each experiment.

Chapter 4 discusses the results of the influence of natural ventilation, glazing system and window blind shading on the indoor air temperature, relative humidity and thermal comfort for the Development Department building on two design days representing the dry and wet seasons.

Chapter 5 summarizes the investigation of the impact of natural ventilation, glazing system and window blind shading on the thermal performance and thermal comfort for the Development Department building in addition to suggestion future work that may be taken in consideration by researcher interested in this field to improve the performance of courtyard buildings in hot-humid climate.